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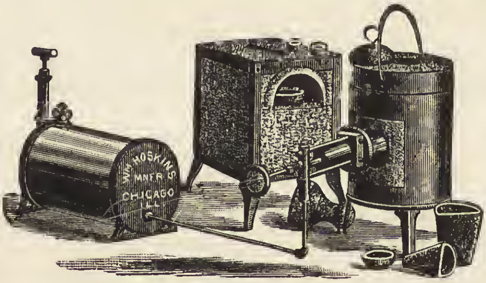

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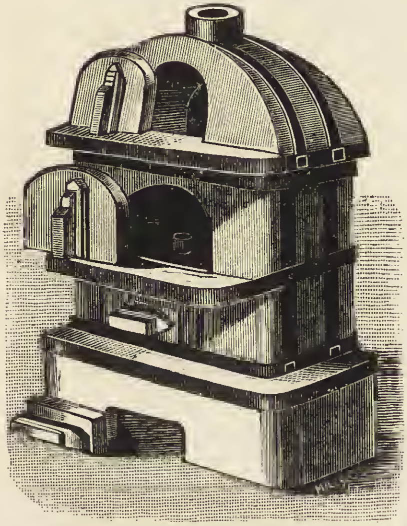

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"This volume is a result of the development of the annual statistical numbers of the *Engineering and Mining Journal*, and owes its existence to the appreciation with which these statistics have been received by business men, by experts, and by others interested in the mineral industry throughout the world.

"The modern newspaper has made promptness in furnishing information not only familiar but indispensable to the man of affairs, and accurate and timely statistics have now become absolutely necessary for the intelligent direction of industry, trade, and legislation. The collection of such statistics in an industry which extends over the face of the entire globe is, however, a work so vast and difficult that it has hitherto been considered impossible except through the unlimited resources of governments; and as the machinery of government is not adapted to the rapid attainment of results, the statistics of the mineral industry have been so tardily collected and published in all countries that their value has been greatly impaired. . . . For many years the *Engineering and Mining Journal*, as the leading representative of this great industry, has accumulated vast stores of statistical information relating to it, and has greatly improved the machinery for the collection of statistics. . . .

"The universal appreciation of the work done by the *Engineering and Mining Journal* called for its extension, and consequently in this initial volume there are given, for the first time, the statistics of substantially all the minerals and metals produced in the United States and in many other countries for the full year 1892, and often from the earliest times. This series of annual volumes it is intended shall, in due time, cover the entire mineral industry of the world, giving its statistics, its technology, and its trade, each succeeding volume not repeating the data given in previous issues, but supplementing them, and carrying forward the current history of the industry almost to the day of publication. Unaided by any governmental powers to enforce the making of returns, we have relied for success solely upon personal courtesy and confidence and upon the intelligent appreciation of the value of the work to the industry at large, and this great volume is the monument we have erected to the courtesy of those whose prompt and willing co-operation has alone rendered its success possible. Long experience in this kind of work has fully demonstrated the fact that men are in general more willing to give important and correct information to the private individual who can be held responsible for its proper use than to the more or less impersonal 'government.' It is indeed extremely rare that any producer neglects or refuses to give full, truthful, and satisfactory replies to our requests for information. . . .

"Accuracy should always be the first care of the statistician, but it is scarcely less important to the business man that the information should be promptly furnished. Belated statistics are ancient history, of little practical value in the active affairs of an industry, or as a guide for legislation affecting it. . . . Subjects which are uppermost in the business world naturally demand the greatest attention in this industrial work. . . .

"Much attention has been devoted to the subject of cost of production. The itemization of cost is the first essential step in securing economy in producing any article, and the history of every country and of every industry has shown that prosperity, whether national, industrial, or individual, is, in a general way, inversely proportional to the cost of supplying the rest of the world with what one produces. The great economies which command the markets for products are due, not to reductions in wages, but to increased knowledge and intelligence, and are accompanied by higher remuneration and a betterment of the condition of those engaged in the industry. . . .

"It is the object of the *Engineering and Mining Journal* to give in detail, and of this supplemental volume of the *Journal* to summarize, the facts which show how such results are accomplished; to photograph, as it were, from time to time, the condition of the several departments of the mineral industry in various parts of the world, placing within the reach of all the information that intelligence can apply to the reduction of cost in producing and marketing the useful minerals and metals and in promoting the welfare of those engaged in this industry. In every country this information will enable those who legislate for and those who administer this industry to do so with an intelligent appreciation of the conditions affecting it in its every department, and, widely disseminated, will promote the national prosperity.

"It is with the very greatest regret that we have been obliged in this work to use other than the metric system of weights and measures, which are now legalized in nearly every civilized country and should be universally adopted. The necessity of conforming to custom and popular prejudice in a work so expensive as this explains the use here of that nightmare of weights and measures which, as a relic of barbarism, survives and is used in all English-speaking countries as 'the English system.' We have, however, where possible, reduced the number of varieties of measures as used in the publications of the United States Government. All foreign statistics are given in this work in metric weights, and the United States products are given in the metric system as well as in the customary weights. . . .

"The advertising pages of this book will well repay the careful perusal and study of every reader who wishes to be well informed upon the present condition of the mineral industry. They give an admirable and practical insight into the present state of the mining and metallurgical arts, for in them nearly every manufacturer or dealer of note in this country advertises the machines, appliances, and processes which are now in vogue, or which it is sought to introduce, while the names and qualifications of the most eminent members of the engineering professions indicate the importance and directions of modern mining and metallurgy. These advertising pages are no less important to those who desire a clear knowledge of the means by which this country has come to be far the most important producer of minerals and metals, than to him who wishes to know where to get that full and reliable information concerning the values of properties, machinery, processes, and products which should precede the investment of capital."

Had any doubt existed as to the utility and even absolute need of such a work as this, it would have been quickly dispelled by the prompt and enthusiastic recognition of its value and the unstinted and unanimous words of praise which welcomed in every part of the world the first volume of THE MINERAL INDUSTRY, ITS STATISTICS, TECHNOLOGY AND TRADE. It is not too much to say that probably no other technical book was ever so universally praised, as is shown in the brief extracts given on another page from some of the thousands of letters received, and doubtless never before was a technical book sold in so large numbers within so short a time. These results are extremely gratifying not alone from a business standpoint, but chiefly because they constitute a flattering evidence of the value of the work as a whole, and of the ability of the many specialists who contributed to its pages.

This success has increased the obligation we are under to the great captains of the industry throughout the world who have, with uniform courtesy and unlimited confidence, furnished the data which alone have permitted the compilation and prompt publication of these valuable statistical volumes.

From the very first the amount of useful material grew so rapidly with the plans for the work that it quickly became evident that the book must become larger and more costly than anticipated. The original object has, however, been kept in view of placing it within the reach of all.

The importance of collecting in this volume, as far as possible, the existing statistics of production, imports, exports, and consumption of the various minerals and metals in every country, and the large space devoted to this and to the description of the best existing practice in the chief departments of metallurgy and chemical technology, have crowded over into the current issues of the *Engineering and Mining Journal* and into succeeding volumes of this book much valuable information, and retarded the issue of this book beyond the date at which it is expected future volumes will appear.

The data collected in these two volumes present already a good foundation on which to commence an intelligent study of the industry and of the conditions which affect it, and we earnestly invite the co-operation in this work of all who possess further facts which may be of use in it.

This introduction may be appropriately ended with the following closing paragraph of the preface to the first volume:

"No one can appreciate more fully than the statistician himself the limits and shortcomings which are inseparable from all statistical work of this character. As further facts come to light and a higher degree of accuracy rewards our continuous efforts to render these volumes trustworthy, corrections will be made in the statistics should errors of importance be found. He is but a dishonest statistician who retains known important erroneous statements in order that the public, in its ignorance, may believe, from the absence of corrections, that his figures are accurate. Readers of this book are therefore earnestly requested to notify its editor of any errors or omissions which may be found in it, in order that corrections may be made in subsequent volumes, and suggestions which may render future volumes more valuable will be gratefully received."

RICHARD P. ROTHWELL.

NEW YORK, April, 1894.

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25.4000	0.304801	0.914402	1.60935	= 1 =	3.70	29.57	0.94636	3.78544	16.387	0.02832	0.765	0.35242
50.8001	0.609601	1.828804	3.21869	= 2 =	7.39	59.15	1.89272	7.57088	32.774	0.05663	1.529	0.70485
76.2001	0.914402	2.743205	4.82804	= 3 =	11.09	88.72	2.83908	11.35632	49.161	0.08495	2.294	1.05727
101.6002	1.219202	3.657607	6.43739	= 4 =	14.79	118.30	3.78544	15.14176	65.549	0.11327	3.058	1.40969
127.0002	1.524003	4.572009	8.04674	= 5 =	18.48	147.87	4.73180	18.92720	81.936	0.14158	3.823	1.76212
152.4003	1.828804	5.486411	9.65608	= 6 =	22.18	177.44	5.67816	22.71264	98.323	0.16990	4.587	2.11454
177.8003	2.133604	6.400813	11.26543	= 7 =	25.88	207.02	6.62452	26.49808	114.710	0.19822	5.352	2.46696
203.8004	2.438405	7.315215	12.87478	= 8 =	29.57	236.59	7.57088	30.28352	131.097	0.22654	6.116	2.81938
228.6004	2.743205	8.229616	14.48412	= 9 =	33.28	266.16	8.51724	34.06896	147.484	0.25485	6.881	3.17181

SQUARE.					WEIGHT.			
Square Inches to Square Centimeters.	Square Feet to Square Decimeters.	Square Yards to Square Meters.	Acres to Hectaers.		Grains to Milligrams.	Avoirdupois Ounces to Grams.	Avoirdupois Pounds to Kilograms.	Troy Ounces to Grams.
6.452	9.290	0.836	0.4047	= 1 =	64.7989	28.3495	0.45359	31.10348
12.903	18.581	1.672	0.8094	= 2 =	129.5978	56.6991	0.90719	62.20696
19.355	27.871	2.508	1.2141	= 3 =	194.3968	85.0486	1.36078	93.31044
25.807	37.161	3.344	1.6187	= 4 =	259.1957	113.3981	1.81437	124.41392
32.258	46.452	4.181	2.0234	= 5 =	323.9946	141.7476	2.26796	155.51740
38.710	55.742	5.017	2.4281	= 6 =	388.7935	170.0972	2.72156	186.62089
45.161	65.032	5.853	2.8328	= 7 =	453.5924	198.4467	3.17515	217.72437
51.613	74.323	6.689	3.2375	= 8 =	518.3914	226.7962	3.62874	248.82785
58.065	83.613	7.525	3.6422	= 9 =	583.1903	255.1457	4.08233	279.93133

1 chain = 20.1169 meters.
1 square mile = 259 hectaers.
1 fathom = 1.829 meters.
1 nautical mile = 1853.27 meters.
1 foot=0.304801 meter, 9.4840158 log.
1 avoir. pound = 453.5924277 gram.
15432.35639 grains = 1 kilogram.

TABLES FOR CONVERTING METRIC TO UNITED STATES WEIGHTS AND MEASURES.

LINEAR.					CAPACITY.							
Meters to Inches.	Meters to Feet.	Meters to Yards.	Kilometers to Miles.		Milliliters or Cubic Centiliters to Fluid Drams.	Centiliters to Fluid Ounces.	Liters to Quarts.	Dekaliters to Gallons.	Hektoliters to Bushels.	Cubic Centimeters to Cubic Inches.	Cubic Meters to Cubic Feet.	Cubic Merets to Cubic Yards.
39.3700	3.28083	1.093611	0.62137	= 1 =	0.27	0.338	1.0567	2.6417	2.8375	0.0610	35.314	1.308
78.7400	6.56167	2.187222	1.24274	= 2 =	0.54	0.676	2.1134	5.2834	5.6750	0.1220	70.629	2.616
118.1100	9.84250	3.280833	1.86411	= 3 =	0.81	1.014	3.1700	7.9251	8.5125	0.1831	105.943	3.924
157.4800	13.12333	4.374444	2.48548	= 4 =	1.08	1.352	4.2267	10.5668	11.3500	0.2441	141.258	5.232
196.8500	16.40417	5.468056	3.10685	= 5 =	1.35	1.691	5.2834	13.2085	14.1875	0.3051	176.572	6.540
236.2200	19.68500	6.561667	3.72822	= 6 =	1.62	2.029	6.3401	15.8502	17.0250	0.3661	211.887	7.848
275.5900	22.96583	7.655278	4.34959	= 7 =	1.89	2.368	7.3968	18.4919	19.8625	0.4272	247.201	9.156
314.9600	26.24667	8.748889	4.97096	= 8 =	2.16	2.706	8.4534	21.1336	22.7000	0.4882	282.516	10.464
354.3300	29.52750	9.842500	5.59233	= 9 =	2.43	3.043	9.5101	23.7753	25.5375	0.5492	317.830	11.771

SQUARE.					WEIGHT.			
Square Centimeters to Square Inches.	Square Meters to Square Feet.	Square Meters to Square Yards.	Hectares to Acres.		Kilograms to Grains.	Hectograms to Ounces Avoirdupois.	Kilograms to Pounds Avoirdupois.	Grams to Ounces Troy.
0.1550	10.764	1.196	2.471	= 1 =	15432.36	3.5274	2.20462	0.03215
0.3100	21.528	2.392	4.942	= 2 =	30864.71	7.0548	4.40924	0.06430
0.4650	32.292	3.588	7.413	= 3 =	46297.07	10.5822	6.61386	0.09645
0.6200	43.055	4.784	9.884	= 4 =	61729.43	14.1096	8.81849	0.12860
0.7750	53.819	5.980	12.355	= 5 =	77161.78	17.6370	11.02311	0.16075
0.9350	64.583	7.176	14.826	= 6 =	92594.14	21.1644	13.22773	0.19290
1.0850	75.347	8.372	17.297	= 7 =	108026.49	24.6918	15.43235	0.22505
1.2400	86.111	9.568	19.768	= 8 =	123458.85	28.2192	17.63697	0.25721
1.3950	96.874	10.764	22.2	= 9 =	138891.21	31.7466	19.84159	0.28936

The only material standard of customary length authorized by the U. S. Government is the Troughton scale, whose length at 59°.62 Fahr. conforms to the British standard. The yard in use in the United States is therefore equal to the British yard.

The only authorized material standard of customary weight is the Troy pound of the Mint. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from the British standard Troy pound of 1758 by direct comparison. The British avoirdupois pound was also derived from the latter, and contains 7000 grains Troy.

The grain Troy is therefore the same as the grain avoirdupois, and the pound avoirdupois in use in the United States is equal to the British pound avoirdupois.

The British gallon = 4.54346 liters.
The British bushel = 36.3477 liters.

By the concurrent action of the principal Governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilograms were prepared, from the other a definite number of meter bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot to the different Governments and are called National prototype standards.

The metric system was legalized in the United States in 1866.

The International Standard Meter is derived from the Mètre des Archives, and its length is defined by the distance between two lines at 0° Centigrade, on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogram is a mass of platinum-iridium deposited at the same place, and its weight *in vacuo* is the same as that of the Kilogramme des Archives.

The liter is equal to a cubic decimeter of water, and it is measured by the quantity of distilled water which, at its maximum density, will counterpoise the standard kilogram in a vacuum, the volume of such a quantity of water being, as nearly as has been ascertained, equal to a cubic decimeter.

Long ton: 2240 lbs. avoirdupois = 1016 kilo.
Short ton: 2000 " " = 907.2 "
Pound avoirdupois = 453.6 grams.
Flask of mercury = 76½ lbs. avoir. = 34.700 kilo.
Troy ounce = 31.104 grams.
Gallon = 3.785 litres.

Barrel of petroleum = 42 gal. = 1.59 hec.
" " salt = 280 lbs. = 127 kilo.
" " lime = 200 " = 90.720 "
" " natural cement = 300 = 136.080 "
" " Portland cement = 400 " = 181.440 "
Gold coining value per oz. c. $20.6718 = $0.6646 per gram.
Silver " " " " c. $1.2929 = $0.04157 " "

OFFICIAL UNITED STATES VALUES OF FOREIGN COINS, APRIL 1, 1894.

Country.	Standard.	Unit.	Value in U.S. Gold.	Coins.
			cts.	
Argentina	Both	Peso	96.5	Gold: argentine ($4.824) and ½ argentine. Silver: peso and divisions.
Austria-Hungary	Gold	Crown	20.3	Gold: former system—4 florins ($1.929), 8 florins ($3.858), ducat ($2.287), and 4 ducats ($9.158). Silver: 1 and 2 florins. Present system—Gold: 20 crowns ($4.052) and 10 crowns ($2.026).
Belgium	Both	Franc	19.3	Gold: 10 and 20 francs. Silver: 5 francs.
Bolivia	Silver	Boliviano	46.3	Silver: boliviano and divisions.
Brazil	Gold	Milreis	54.6	Gold: 5, 10, and 20 milreis. Silver: ½, 1, and 2 milreis.
Canada	Gold	Dollar	100	
Central America:				
Costa Rica Guatemala Honduras Nicaragua Salvador	Silver	Peso	46.5	Silver: peso and divisions.
Chile	Both	Peso	91.2	Gold: escudo ($1.824), doubloon ($4.561), and condor ($9.123). Silver: peso and divisions.
China	Silver	Tael ‡	68.6 76.5	
Colombia	Silver	Peso	46.5	Gold: condor ($9 647) and double-condor. Silver: peso.
Cuba	Both	Peso	92.6	Gold: doubloon ($5.017). Silver: peso.
Denmark	Gold	Crown	26.8	Gold: 10 and 20 crowns.
Ecuador	Silver	Sucre	46.5	Gold: condor ($9.647) and double-condor. Silver: sucre & divisions.
Egypt	Gold	Pound	494.3	Gold: pound (100 piasters), 5, 10, 20, and 50 piasters. Silver: 1, 2, 5, 10, and 20 piasters.
Finland	Gold	Mark	19.3	Gold: 20 marks ($3.859), 10 marks ($1.93).
France	Both	Franc	19.3	Gold: 5, 10, 20, 50, and 100 francs. Silver: 5 francs.
German Empire	Gold	Mark	23.8	Gold: 5, 10, and 20 marks.
Great Britain	Gold	Pound	486.65	Gold: sovereign (pound sterling) and ½ sovereign.
Greece	Both	Drachma	19.3	Gold: 5, 10, 20, 50, and 100 drachmas. Silver: 5 drachmas.
Haiti	Both	Gourde	96.5	Silver: gourde.
India	Silver	Rupee	22.1	Gold: mohur ($7.105). Silver: rupee and divisions.
Italy	Both	Lira	19.3	Gold: 5, 10, 20, 50, and 100 lire. Silver: 5 lire.
Japan	Both*	Yen	99.7 50.1	Gold: 1, 2, 5, 10, and 20 yen. Silver: yen.
Liberia	Gold	Dollar	100	
Mexico	Silver	Dollar	50.5	Gold: dollar ($0.983), 2½, 5, 10, and 20 dollars. Silver: dollar (or peso) and divisions.
Netherlands	Both	Florin	40.2	Gold: 10 florins. Silver: ½, 1, and 2½ florins.
Newfoundland	Gold	Dollar	101.4	Gold: 2 dollars ($2.027).
Norway	Gold	Crown	26.8	Gold: 10 and 20 crowns.
Peru	Silver	Sol	46.5	Silver: sol and divisions.
Portugal	Gold	Milreis	108	Gold: 1, 2, 5, and 10 milreis.
Russia	Silver	Ruble ‖	77.2 37.2	Gold: imperial ($7.718) and ½ imperial† ($3.86). Silver: ¼, ½, and 1 ruble.
Spain	Both	Peseta	19.3	Gold: 25 pesetas. Silver: 5 pesetas.
Sweden	Gold	Crown	26.8	Gold: 10 and 20 crowns.
Switzerland	Both	Franc	19.3	Gold: 5, 10, 20, 50, and 100 francs. Silver: 5 francs.
Tripoli	Silver	Mahbub §	41.9	
Turkey	Gold	Piaster	04.4	Gold: 25, 50, 100, 250, and 500 piasters.
Venezuela	Both	Bolivar	19.3	Gold: 5, 10, 20, 50, and 100 bolivars. Silver: 5 bolivars.

* Gold the nominal standard. Silver practically the standard. † Coined since January 1, 1886. Old half-imperial = $3.986. ‡ Shanghai and Haikwan (Customs). § Of 20 piasters. ‖ Silver the nominal standard. Paper the actual currency, the depreciation of which is measured by the gold standard.

RICHARD P. ROTHWELL.

CONTRIBUTORS.

It would require a book to contain the names of the many thousands who have, by contributing statistical or other valuable information, aided in the preparation of this volume; it is therefore impossible to do more than express sincere appreciation of and gratitude for the courtesy and assistance each has extended. As a further recognition of the special services of those who have contributed articles to these pages and that the readers of the book may appreciate the authoritative character of the information here given, it affords us very great pleasure to give the following brief biographical sketches of the chief contributors and excellent portraits of a number of them. These are arranged in alphabetical order, as are the general articles in the body of the work.

Acheson, Edward G., born in 1856, served four years on an engineer corps engaged in railroad construction, and then accepted a position with the United Pipe Lines Company. In 1880 he held a position with the distinguished electrician T. A. Edison, at Menlo Park, N. J. The following year he was sent to Europe as assistant engineer, and constructed the first incandescent light plants in Holland and Italy. Returning to the United States in 1884, he spent two years in experimental work, and then became electrician to the Standard Underground Cable Company of Pittsburg. In 1890 he organized the Monongahela Electric Light Company and became its president. During the following year some experiments led to the production of carborundum, and the Carborundum Company was organized with Mr. Acheson as its president. Mr. Acheson has contributed many valuable papers to technical literature and wrote for this volume the article on carborundum.

Adams, William H., was born in Michigan in 1843. At the close of the war he went to Canada and took charge of the Hartford copper mine and smelting works in the Capelton district, Quebec. In 1883 he took charge of the Arminius mine in Louisa County, Virginia, and has devoted his attention chiefly to perfecting furnaces for roasting pyrites and apparatus used in acid making and copper extraction, on which subjects he is eminent authority, having constructed and managed the first four works erected in America for these purposes. Mr. Adams is a well-known contributor to the transactions of the various engineering societies of which he is a member, and to the *Engineering and Mining Journal.* Mr. Adams has contributed to the second volume, as to the first of this work, the article on pyrites.

Blue, Archibald, was born in 1840 in Oxford, Ontario, Canada. After engaging for some years as a teacher, he entered the field of journalism, which he followed for nearly fourteen years. In 1881 he was appointed to organize and take charge of a Bureau of Industrial Statistics in connection with the Department of Agriculture, and in 1884 was made deputy head of the department. During 1889–90 he served as member and secretary of the Royal Commission appointed to inquire into and report upon the mineral resources of Ontario, and in 1891 resigned his office to become Director of the Bureau of Mines of Ontario, with his offices in Toronto. Mr. Blue has contributed valuable statistics of Ontario to this volume.

Botella y Hornos, Federico, recently Inspector-General of the Mining Corps and at present Chief of the Bureau of Mining Statistics at Madrid, Spain, is a mining engineer of high reputation in Spain. He is a member of the Academy of Sciences and author of several papers and other works on technical subjects. Señor Botella y Hornos has very kindly furnished the latest statistics of the mineral production of Spain.

Bryan, L. W., born in 1853, in Luzerne County, Pennsylvania. In 1876 Mr. Bryan went to Arkansas, and has since been prominently identified with the development of the coal industry in that and other States. He opened the Onita mines near Russellville, then the Coal Hill and Spadra. In 1886 he laid out and purchased the Jenny Lind coal field for Mr. Jay Gould. The following year he became superintendent for the Texas Coal Company, and remained with it until appointed United States Mine Inspector for Indian Territory. Mr. Bryan's duties have led him into the coal fields of Iowa, Missouri, and Kansas, where he has purchased and developed many valuable mines and also in the coal fields of Arkansas and Indian Territory.

Campbell, H. H., metallurgist, who contributes to this volume the article on the work of the open-hearth steel furnaces at Steelton, has been for over fifteen years connected with the Pennsylvania Steel Company, and has had charge of the open-hearth plant of that company, which was, in fact, built up under his direction. To him is due the credit of designing and operating the first large open-hearth furnaces in this country; he is also the inventor of many improvements of value, and had a large share in planning the works of the Maryland Steel Company at Sparrow's Point, near Baltimore. Mr. Campbell is a well-known contributor to technical literature; among these articles is an exhaustive paper on the "Open-Hearth Process," read at the Engineering Congress in Chicago last year.

De Kalb, Courtenay, born in Virginia in 1861 and educated as a mining engineer at the Columbia School of Mines, New York. He has traveled much in Central and South America and has examined and studied mines in those countries. Mr. De Kalb has been a frequent contributor to the technical periodicals on mining and transportation in South America. He has contributed to the present volume the articles on Bolivia and Peru.

Dick, Alexander, mining engineer and English Government certificated colliery manager. Born near Glasgow, Scotland. Studied mining engineering in the office of Young's Paraffine Light and Mineral Oil Company at Addiewell Mines, Midlothian, Scotland. For a number of years Mr. Dick was professionally engaged in the management of coal mines, and later was principal of the Correspondence School of Mines at Scranton. Since 1891 he has been occupied in journalistic work and has assisted in compiling and editing the statistics of coal for this volume. Mr. Dick is the patentee of the Dick Porthole Safety Lamp, and has recently become editor of the *Canadian Colliery Guardian* of Halifax, N. S.

Donald, J. T., M. A., Professor of Chemistry, Medical Faculty, Bishops College, graduated from McGill College, Montreal, Canada, in 1878, and during the following two years took a post-graduate course in chemistry. After spending some time in Europe, examining its mines and industries, he returned to Canada, and has since taken an active part in the development of the mineral industry of that Dominion. His laboratory in Montreal is a well-known institution.

Eder, Henry James, mining engineer, was born in Palmira, Cauca, Republic of Colombia. Educated in England, and studied mechanical engineering at Finsbury Technical College, City and Guilds of London Institute, and civil and mining engineering at the Écoles des Mines, Arts et Manufactures, attachées à l'Université de Liége, Belgium, and at the Royal Prussian School of Mines at Clausthal, Hartz. He has visited professionally the chief mining districts of Germany, Austria, Hungary, England, and Belgium, and the Western States of this country. Mr. Eder contributed to the first volume of The Mineral Industry, and his wide acquaintance with the important mining districts, combined with his knowledge of foreign mines and languages, have enabled him to give valuable assistance on the editorial staff of the present volume.

Engelhardt, Dr. F. E., was born in 1835 in Hanover, Germany, and took preliminary studies at the gymnasium in Hildesheim. Studied at the University of Göttingen from 1854 to 1857, when he came to America. During the last year in Göttingen he acted as an assistant to Prof. F. Wohler. In the United States he has been an assistant in chemistry in Amherst College, Mass.; in Columbia College, New York; Professor of Chemistry in St. Francis Xavier's College, New

SOME OF THE CONTRIBUTORS TO THE MINERAL INDUSTRY.

EDWARD G. ACHESON.

WILLIAM H. ADAMS.

ARCHIBALD BLUE.

L. W. BRYAN.

J. T. DONALD.

HENRY JAMES EDER.

F. E. ENGELHARDT.

Harzé, Emile, born in 1835 at Liége, Belgium; studied at the Ecole des Mines attached to the university of his native place. In 1858 he entered the State Mining Corps and successively occupied important Government positions at Mons and Liége, and in 1879 was made Director-General of the Central Administration at Brussels. In 1890 he was one of the Belgian representatives at the Berlin Labor Conference. Mr. Harzé is a member of numerous technical and scientific societies and is on the committees of a number of commissions, among them the *Conseil Supérieur du Travail.* He has published a great number of valuable monographs and is one of the highest authorities in Europe on mine ventilation, statistics, and questions affecting labor. To the present volume Mr. Harzé has contributed notes on Belgian coal mining and the statistics of the Belgium industry.

Hobart, Frederick, A. B. and A. M. of the College of the City of New York. Mr. Hobart has been connected with the Jersey City Locomotive Works; Bullock Machine Company, Jersey City; Wrigley Machine Works, Newark, N. J.; Grant Locomotive Works, Paterson, N. J.; has been assistant editor of the *Railroad Gazette*, associate editor *Railroad and Engineering Journal*, assistant editor *Engineering and Mining Journal*, a contributor to various technical periodicals, and is the translator of *Notes on Steam Hammers* and *Economies in the Combustion of Fuel.* Mr. Hobart has contributed to this second volume, as also to the first, of The Mineral Industry its copious index. The preparation of this is a very important and useful contribution and one in which he has shown unusual skill and care.

Hoepfner, Dr. C., born in 1857, at Friedrichslohra, Central Prussia. After a collegiate education he studied chemistry, geology, and mineralogy at Berlin. In 1881 he took degree of Ph.D., and in the following year went to Southwest Africa with the intention of establishing a German mining colony. After remaining there for some time Dr. Hoepfner returned to Germany and became manager of the chemical department of Siemens & Halske of Berlin. Recently he came to America, where he expects to remain. Dr. Hoepfner is devoting his attention to electrical processes for the extraction and refining of metals and the production of chemicals.

Holibaugh, J. R., mining engineer of Joplin, Mo., who is exceptionally familiar with the zinc-lead industry of Missouri and Kansas, has furnished much very valuable information which appears in the articles in this volume devoted to that industry.

Hopkins, T. C., born in 1861, in Pennsylvania. In 1883 he entered De Pauw University at Greencastle, Ind., graduated in 1887, and took the degree of M. S. in 1890. For some time he had charge of the department of chemistry at this university. During 1889–90 Mr. Hopkins was assistant on the Geological Survey of Arkansas. In 1893 he was engaged as instructor in geology in the mining department at the State College, Pennsylvania. His published writings consist of valuable contributions to the Geological Survey Reports of Arkansas and papers read before various technical and scientific societies. To the present volume Mr. Hopkins has contributed articles on limestone, marble, and lime.

Howard, J. W., born in 1860, at West Point, N. Y. Educated at Phillips Academy, Andover. He was engaged with the West Shore Railroad in construction work for some time and followed this with study abroad and a year's practical construction work in Nebraska; he then entered the Polytechnic Institute at Troy, N. Y., where he studied civil engineering and graduated. Mr. Howard has given special attention to the study of asphalt and the uses of this material and its compounds in engineering work, and has contributed to the present volume a very valuable article on this subject.

Ingall, Elfric Drew, born in 1858, at Greenhithe, Kent, England. Studied at the Royal School of Mines, London, and afterward in the mining districts of Cornwall and Wales. In 1880 he was sent to Canada to examine mining properties on Lake Superior, and afterward became manager of a company there. He subsequently spent some time in Wyoming studying copper deposits, after which he joined the Canadian Geological Survey and has remained its mining engineer in charge of the division of mineral statistics and mines since 1884. Mr. Ingall's work on the silver-bearing veins of the Thunder Bay district, the apatite deposits of Quebec, and the mineral developments around the Canadian shores of Lake Superior, are well known, and with them the valuable data published each year by his division of the survey.

SOME OF THE CONTRIBUTORS TO THE MINERAL INDUSTRY.

H. O. HOFMAN.

T. C. HOPKINS.

DON FEDERICO DE BOTELLA Y HORNOS.

J. W. HOWARD.

HENRY MARION HOWE.

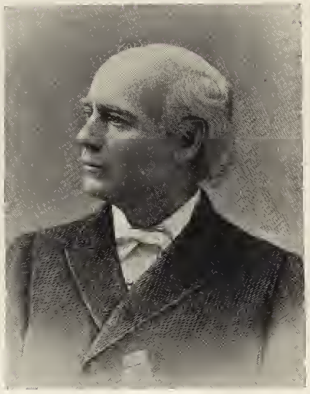
ELFRIC DREW INGALL.

WALTER RENTON INGALLS.

SOME OF THE CONTRIBUTORS TO THE MINERAL INDUSTRY.

CHARLES J. NORWOOD.

ROMAN ORIOL.



EDWARD ORTON.

R. A. F. PENROSE, JR.

EDWARD DYER PETERS, JR.

ROBERT H. RICHARDS.

THOMAS ARTHUR RICKARD.

INGALLS, WALTER RENTON, mining engineer, graduate from the Massachusetts Institute of Technology, on leaving which he engaged in professional work in Colorado and other Western States. Mr. Ingalls in 1890, 1891, and until early in 1892 was assistant editor of the *Engineering and Mining Journal.* He then accepted a temporary engagement at mines in Mexico, and returning to New York assisted in the compilation of the first volume of THE MINERAL INDUSTRY. On its completion he visited the chief mining districts in Europe, spending the greater part of 1893 in the work, more especially in a study of the present practice in zinc metallurgy. The result of this labor is given in the excellent article on "Zinc" and in other contributions which Mr. Ingalls has made to the present volume. Mr. Ingalls has contributed also much valuable assistance in the general preparation of this work.

KEMP, JAMES FURMAN, entered Amherst College in 1877 and graduated (A.B.) in 1881; graduated from Columbia College as mining engineer in 1884; was private assistant to Prof. J. S. Newberry in 1884–85; instructor in geology, Cornell University, 1886–88; assistant professor of geology and mineralogy, 1888–91; adjunct professor of geology, Columbia College, 1891–92; and professor of geology in 1892. Professor Kemp has written much on subjects connected with economic geology and petrography, his most important work being *The Ore Deposits of the United States,* published by the Scientific Publishing Company, a work which has attracted world-wide comment and commendation. He is at present especially engaged on the geology of the Adirondacks under the New York State Geologist, Prof. James Hall. Professor Kemp is a prominent member of many scientific societies. He has contributed to this volume an article on "Sulphur" and one on the "Development of Theories of the Origin of Ores."

LEDOUX, ALBERT R., was born in 1852 in Kentucky. In 1870 he entered the Columbia School of Mines and afterward went to Berlin University. After two years in Hoffmann's laboratory spent in original research he went to Göttingen, where he graduated in 1875, receiving the degrees of M. A. and Ph. D. Returning to New York, he entered a laboratory and was called from this to become the North Carolina State Chemist. In 1880 he and Dr. P. de P. Ricketts opened a laboratory in New York. In 1885 the firm of Ledoux & Co. was organized, composed of the brothers Dr. A. R. and Augustus D. Ledoux. Dr. Ledoux is the president of this corporation, and as such is chemist to the New York Produce Exchange and the Linseed Association and analyst of the National Lead Company and many large manufacturing and business concerns. He is a well-known contributor to technical literature. To the present volume Dr. Ledoux has contributed an interesting article on "Copper Resources of Montana."

LEFEVRE, EDWIN, born in Colon, Republic of Colombia, in 1870. Studied mining engineering at Lehigh University, Bethlehem, Pa. He has been engaged in journalism for several years, and has contributed to numerous newspapers and literary periodicals in the United States and South America. Since 1890 he has been a member of the editorial staff of the *Engineering and Mining Journal.* Mr. Lefevre has contributed articles upon the commercial department of the industry, the metal and mining stock markets, with which his duties on the *Engineering and Mining Journal* have rendered him very familiar.

LUNGE, GEORGE, PH.D., born in 1839, at Breslau, Silesia, Prussia. Studied at the University of Breslau, where he received the degrees of M. A. and Ph. D., and then at Heidelberg under Bunson & Kirchhoff. In 1884 he went to Great Britain, where he became connected with the coal tar and ammonia industry. A few years later Dr. Lunge took an opportunity to connect himself with the sulphuric acid and akali industry. In 1876 he left England to accept the post made vacant by the death of Emil Kopp at the Swiss Federal Polytechnic School at Zurich, where he is now professor of technological chemistry and dean of the faculty of chemistry. Dr. Lunge has contributed to technical literature some of its most important works. His *Coal Tar and Ammonia, The Manufacture of Sulphuric Acid and Alkali,* and *The Alkali-maker's Hand-book* have each passed through several editions and are standard works on these subjects. Besides these, he is a contributor to the *Engineering and Mining Journal,* has published numerous articles upon various subjects of technical chemistry in this and other periodicals, and is, in that important branch of industry, one of the highest and most widely quoted authorities. Dr. Lunge has contributed to this volume a sketch of the progress made in Europe in 1893 in the chemical industry.

McCalley, Henry, Assistant State Geologist of Alabama. Graduated from the University of Virginia in 1875 with degrees of Civil and Mining Engineer. In 1878 was made assistant professor of chemistry in the University of Alabama, and in 1883 appointed Assistant State Geologist and Chemist to the Survey. Mr. McCalley has made many special analyses of the soils and minerals of Alabama and has done much toward aiding the rapid development of that State's resources. His articles on economic geology and the resources of Alabama have appeared in many technical periodicals and the proceedings of the societies of which he is a member.

Memminger, C. Gustavus, mining engineer, born in 1864, at Charleston, S. C. Graduated from the University of Virginia in 1886, and began professional work in the phosphate industry of South Carolina. Shortly afterward he went to Colorado, and on his return to the South took an active part in its mining development. When the Florida phosphate beds were opened, Mr. Memminger went to that State, where his previous knowledge of phosphate mining enabled him to take a prominent part in bringing the industry to its present state of development. He has contributed to this volume a valuable article on phosphates and fertilizers, and is a regular contributor to the *Engineering and Mining Journal* on the same subjects.

Merrill, George P., Curator of Geology in the United States National Museum (the Smithsonian Institute), at Washington, and Professor of Geology and Mineralogy in the Corcoran Scientific School of the same city. Mr. Merrill has written many papers on scientific and technical subjects, and is widely known to the industrial world through his work on *Stones for Building and Decoration.* To the present volume he has contributed valuable articles on "Lithographic Stone and Onyx."

Norwood, Charles J., State Inspector of Mines in Kentucky, and Curator of the Geological Department of that State. Mr. Norwood was at one time assistant on the Missouri Geological Survey, and afterward assistant on the Kentucky Geological Survey under Prof. N. S. Shaler. From 1877 to 1881 he was also Norton Professor of Natural Science in Bethel College, Russellville, Ky. For some years he was professionally engaged in various Southern and Western States, and in 1884 was appointed State Inspector of Mines for Kentucky, where he is now serving his third term. Mr. Norwood is one of the most efficient officials in this country whose duties are especially connected with the mineral industry. He has given valuable assistance in collecting promptly the coal statistics of Kentucky, and in furnishing information concerning the fluorspar and other useful minerals of the State.

Oriol, Roman, mining engineer, editor of the *Revista Minera Metalurgica y de Ingenieria,* Knight of the Order of Charles III. of Spain. Born in Barcelona in 1847, graduated from the Madrid School of Mines in 1870, and entered the National Corps of Mining Engineers the same year. After nearly ten years of professional work in developing the mineral resources of Spain, Señor Oriol was appointed professor of mining, mining economy, and laws at the Madrid School of Mines. In 1883 he assumed the management of the *Revista Minera Metalurgica y de Ingenieria,* which he has developed into the most influential and widely circulated industrial and scientific periodical in Spain. He is the author of *Carbones Minerales de España,* and compiler of the *Annario de las Minas y Fabricas Metalurgicas de España.* Señor Oriol has contributed to this volume of The Mineral Industry a valuable paper on Spain.

Orton, Edward, State Geologist of Ohio and professor of geology in Ohio State University. Born in Delaware County, New York, in 1829. Graduated at Hamilton College, Clinton, N. Y., in 1848. From 1856 to 1859 Mr. Orton was professor of natural science in the State Normal School at Albany, and from 1865 to 1873 professor of geology at Antioch College, Ohio. In 1869 he was appointed Assistant Geologist of Ohio, and in 1883 was made Chief Geologist. Under his administration the Survey has published many valuable reports which have been of great benefit to the development of the State mineral resources. Professor Orton is widely known, both as an able geologist and as a man of great scientific attainments. He has contributed to this volume an article on the clay industry of Ohio.

Page, Thomas M., President of the Page & Krause Manufacturing and Mining Company. Born in St. Louis, and after serving in the civil war began work at the Washington Foundry, St. Louis, in 1866. In 1872 he entered the employ of the Page & Krause Company, of which

SOME OF THE CONTRIBUTORS TO THE MINERAL INDUSTRY.


JAMES FURMAN KEMP.


ALBERT R. LEDOUX.


GEORGE LUNGE.


HENRY MC CALLEY.


C. GUSTAVUS MEMMINGER.


GEORGE P. MERRILL.


S. B. NEWBERRY.

he is now the president. Mr. Page is well known in connection with the barytes industry, in the development of which he has taken a prominent part, and he has contributed to this volume much valuable information on this subject.

PELLATI, N., mining engineer, Rome, Italy, is a distinguished mining engineer who holds the position of Inspector-General of the mines of the Kingdom of Italy. Mr. Pellati has contributed the mineral statistics of Italy, and has taken a warm interest in the success of this book.

PENROSE, R. A. F., JR., E. M., PH. D. Born in 1863. Graduated from Harvard College in 1884, and was assistant on the United States Geological Survey until 1886. From this year until 1888 Dr. Penrose superintended some of the apatite mines in Canada, and in the latter year became Assistant State Geologist of Texas. In the latter part of 1889 he became connected with the Survey of Arkansas and remained there until 1892, when he was appointed assistant professor of economic geology at the University of Chicago. Dr. Penrose has contributed many papers to the geological reports of the United States and various States, and is also a well-known contributor to the columns of the *Engineering and Mining Journal.* In the present volume he has sketched the progress in the manganese industry during the year 1893, in continuation of his valuable article on this subject in the first volume of this work.

PETERS, EDWARD DYER, JR., M. D., mining engineer and metallurgist, and the well-known author of that admirable work, *American Methods of Copper Smelting.* Dr. Peters was born in 1849, at Dorchester, Mass., and, after receiving his preliminary training in this country, studied four years at the School of Mines in Freiburg, Saxony. After spending five years in Colorado he studied medicine, but later returned to his metallurgical work, and has since been engaged successively by the Orford Copper Company, the Canadian Copper Company in Ontario, the Calumet and Hecla in Michigan, and the Parrott in Montana. During the past year he has been engaged in examining the copper mines of Tasmania, and for the past six months has been engaged in examining nearly all the copper mines and works in Europe. Dr. Peters is, therefore, exceptionally well qualified to prepare the article on "Improvements in the Metallurgy of Copper," which he has contributed to this volume of THE MINERAL INDUSTRY.

PRESTON, ROBERT E., Director of the United States Mint, has courteously furnished us with much information concerning the distribution, production, coinage, etc., of the precious metals. Mr. Preston entered the Government service in 1856 as a clerk in the office of the First Auditor of the Treasury. When the present organization of the Mint Bureau was completed in 1873 he was transferred to that bureau and appointed examiner. Shortly afterward he was placed in charge of the statistical work and retained that position until September last, when he succeeded Mr. E. O. Leech as Director of the Mint. We are under many obligations to Mr. Preston for his courteous assistance in this work.

RANDOL, J. B., has long been our highest authority on quicksilver trade statistics. He has contributed the article and the statistical matter relating to "Quicksilver" in this volume. For many years and until recently Mr. Randol was manager of the New Almaden Quicksilver Mining Company of California. Since his retirement from that position he has been engaged in conducting operations on his own account.

RICHARDS, JOSEPH WILLIAM, professor at Lehigh University, Bethlehem, Penn. He was born in Birmingham, England, thirty years ago, but came to this country with his parents when a boy. He was educated at the Philadelphia High School and Lehigh University, where he received the degree of Doctor of Philosophy. For several years he has devoted his attention to the study of aluminum and has written an exhaustive treatise on that metal, besides preparing for the technical periodicals papers on the same subject. In connection with his father he has also done much practical work in investigating the metal and its alloys, one of the best known of which is the "Richards bronze." Dr. Richards prepared for this work the article on "Aluminum," on which subject he is one of the highest authorities living.

RICHARDS, ROBERT HALLOWELL, Professor of Mining and Metallurgy at the Massachusetts Institute of Technology; Past President American Institute of Mining Engineers. Born in 1844, at Gardiner, Me. In 1868 he graduated in the first class from the Institute of Technology and became assistant in chemistry in the Institute, passing successively to the posts of instructor, assistant professor of chemistry, professor of mineralogy and assaying, professor of mining engineering, and in 1884 to his present professorship of mining and metallurgy. Under his administration the school's mining and metallurgical laboratory has been developed to a high state of excellence. Professor Richards has also been actively engaged in professional work, and has been a prominent contributor of valuable papers to the technical press and various scientific societies. He has contributed to this volume an article on ore dressing.

RICKARD, THOMAS ARTHUR, E. M. Born in 1864, at San Terenzo, Italy. Educated in Russia and England, graduating at the Royal School of Mines, London, in 1885. Since then has been engaged professionally in Colorado and various Western States, and in Australia and New Zealand. Mr. Rickard is located as a consulting mining engineer in Denver, and his name is well known in connection with many important mining enterprises in the West. He is a member of various scientific societies and a well-known contributor to the literature of his profession. He has contributed to this volume a timely article on the gold resources of Colorado.

RIES, HEINRICH, Ph. B., geologist, studied in various countries in Europe and afterward entered Columbia College School of Mines, New York City. After graduating he engaged in professional work and was appointed Assistant Geologist on the New York State Geological Survey. While holding this position he studied the clays of New York State and contributed much valuable data on this subject. During the World's Fair Mr. Ries was Assistant Director of the New York scientific exhibit, and is now a Fellow in Mineralogy at Columbia College. He has contributed to this volume a valuable article on the clay industry.

THOMAS, WILLIAM, F. G. S., Associate Member Institution of Civil Engineers, London, born at Camborne, Cornwall, in 1857. He became Secretary of the Mining Association and Institute of Cornwall in 1886. He has been the lecturer on mining and ore dressing and instructor in mine surveying at the Camborne School of Mines since its establishment in 1887. In 1893 he was a member of the Mines and Metallurgy Committee of the Royal Commission for the Chicago Exhibition. He is a member of the Geologists' Association, the South Staffordshire and East Worcestershire Institute of Mining Engineers, the Federated Institution of Mining Engineers, and the Society of Arts, and is one of the Council of the Institution of Mines and Metallurgy. During the past year Mr. Thomas and Mr. J. C. Burrow of Camborne have been experimenting extensively in connection with underground photography in the Cornish mines, and have succeeded in obtaining, by means of combined oxyhydrogen limelights and magnesium flashlights, a very remarkable series of underground photographs which will be reproduced in the *Engineering and Mining Journal.* To this second volume of THE MINERAL INDUSTRY Mr. Thomas has contributed a valuable article on "Arsenic."

SAN ROMAN, FRANCISCO J., is a distinguished Chilean engineer, who has had charge of important works. The surveys from which the new topographical maps of Chile have been made were carried out under his direction. Señor San Roman was Commissioner from Chile to the Columbian Exposition, and after his work there was completed he remained in this country for a time in charge of the interests of the Mining Exposition to be held this year in Santiago. Señor San Roman assisted us materially in obtaining the statistics for Chile, and furnished a valuable contribution on Chilean mineral deposits.

SAUNDERS, WILLIAM L., was born at Columbus, Ga., in 1856, and is the son of Rev. Dr. Saunders of Virginia, who was nephew of Robert Saunders, the celebrated professor of mathematics who became president of William and Mary College, at Williamsburg, Va. He was brought up in Florida, and educated by his father. He went to Philadelphia in 1872 and entered the scientific department of the University of Pennsylvania, graduating as civil engineer in 1876. Mr. Saunders began his professional life as civil engineer in charge of hydrographic work, such as building ship channels, dock building, and general hydrographic construction. While excavating ship channels he introduced improvements in machinery for blasting rock under water, and was the first to introduce a water jet following a drill bit into the hole. He was engaged as engineer for the Ingersoll Rock Drill Company in 1882, and conducted experiments in marble quarries in Vermont. While there he designed and patented the channeling and gadding machines now largely used in quarries, known as the Ingersoll channelers and Ingersoll gadders. He also designed the first commercially successful direct-acting channeling machine.

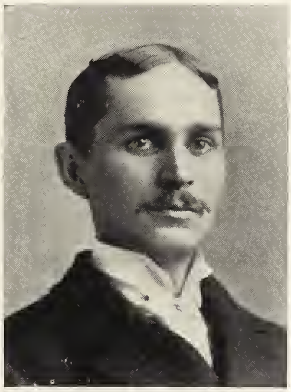
SOME OF THE CONTRIBUTORS TO THE MINERAL INDUSTRY.

HEINRICH RIES.

WILLIAM L. SAUNDERS.

JOHN STANTON.

WILLIAM THOMAS.



TITUS ULKE.

M. E. WADSWORTH.

SOPHIA BRAEUNLICH.

He is a member of the American Society of Mining Engineers, the American Society of Mechanical Engineers, and the American Society of Civil Engineers. Mr. Saunders has contributed to the present volume the article on "Improvements in Stone Quarrying."

SMOCK, JOHN C., State Geologist of New Jersey, has long been connected with the Geological Survey of New Jersey. Mr. Smock has written for this volume the article on "Marls," a subject with which he is thoroughly conversant. The admirable work done by the Geological Survey of New Jersey is well known, and much of its excellence is due to Professor Smock's care, both while he was assistant to the late Professor Cook, and since that gentleman's death, as Chief of the Survey.

STANTON, JOHN, Secretary and Treasurer of the Atlantic, the Allouez, and the Central and the Wolverine Copper Mining Companies of Michigan, whose affairs he has conducted with great ability and with marked success. Mr. Stanton has for the past two years acted as statistician for the great copper producers in their monthly exchange of statistics with the European producers.

ULKE, TITUS, Met. E., born in 1866, at Washington, D. C. In 1889 he graduated from the Royal School of Mines at Freiberg, Saxony, as metallurgical engineer. After spending some time in visiting the various mines and metallurgical works of Europe, Mr. Ulke returned to this country and was engaged as chemist to the Harney Peak Tin Company in South Dakota. In 1891 he became assayer for the United Smelting Company, and afterward was engaged by the Anaconda Mining Company as chemist at its electrolytic copper refining works. In 1893 Mr. Ulke acted as metallurgist to the Mines and Mining Department of the Chicago Columbian Fair, and has contributed articles on copper concentration and electrolytic refining to this volume.

VAN ESVELD, W. C., of Surinam, Dutch Guiana, Chief Director of the Surinaamsche Bank, and in that capacity has a wide acquaintance with the business of Dutch and British Guiana. He has courteously furnished the statistics of the gold production of British and Dutch Guiana, which, in the present volume, are given for the first time with any approach to completeness.

VON ERNST, CARL, RITTER, Superior Counselor of Mines, Counselor of Regency, Counselor of Commerce, Director of the Commercial Affairs of the Austrian Government's Mines. Born Oct. 1, 1833, at Zara, Dalmatia, Austria; studied in the Technical Academy at Prague (Bohemia) and in the Mining Academy at Schemnitz (Hungary), and in 1855 entered the Government service; was engaged in the State's service at Venice, Lombardy, and Vienna, and appointed by the Government to travel over the mining districts of Italy and of the island of Sardinia. In 1874 he became director of the commercial affairs of the Austrian Government's mines. In 1881, in company with Professor Höfer at Leoben (Styria), he engaged in editing the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, and some years later the publication of the annals of the Mining Academy at Leoben (Styria), Przibram (Bohemia), and Schemnitz (Hungary). Ritter von Ernst is one of the most eminent statisticians in Europe; he has contributed to this volume of THE MINERAL INDUSTRY the statistics and other valuable information of the mining industry of Austria-Hungary and of Bosnia.

WALDO, CLARENCE A., Professor of Mathematics, De Pauw University, Greencastle, Ind.; for eight years previously Professor of Mathematics at Rose Polytechnic Institute, Terre Haute, Ind.; in 1893 Secretary of the Mathematical Section of the American Association for the Advancement of Science; Secretary of the Indiana Academy of Sciences; Ex-President of the Indiana College Association. He has for years devoted himself especially to mineralogy, and particularly to the materials and processes of the talc industry, upon which he is a high authority. Mr. Waldo has contributed articles on talc and soapstone to this volume.

WALKER, EDWARD, London representative of the *Engineering and Mining Journal* and the Scientific Publishing Company. Born in 1865 and educated at Owens College, Manchester, England, where he took the deegrees of B. Sc. and M. Sc., in 1886 and 1889, respectively. Mr. Walker has served on the editorial staff of *Industries*, London, and the *Engineering and Mining Journal*, New York, and now practices as a consulting engineer chiefly in connection with law cases and patents, and is the accredited representative in charge of the London offices of the *Engineering and Mining Journal* and the Scientific Publishing Company. Mr. Walker has contributed to this volume much information concerning the mining stocks dealt in in London.

WALLACE, J., author of the article on "Ozokerite" in this volume, was born in North Carolina, his father, David Wallace, being a member of the widely known botanical house of Wallace Brothers at Statesville. Mr. Wallace early turned his attention to the study of geology and mineralogy. In 1883 he visited Utah, where he located in the following year the deposits of ozokerite which he still controls. On his return from Utah he took part in the discovery of the Colorado oil fields, and later organized the Colorado Oil Company. For some time past he has been First Vice-President of the United Oil Company, which now controls the Colorado oil wells, and has successfully managed the affairs of that corporation. Mr. Wallace has studied the subject of ozokerite thoroughly, and at his own expense some years ago went to Europe to study the deposits of Galicia, which now furnish most of the supply.

We are indebted to the following gentlemen, inspectors of coal mines in the various States, for material assistance in securing returns of the coal output, thus enabling us to compile the statistics of coal production at an earlier date than they have ever before been presented in complete form: Mr. JAMES D. HILLHOUSE, JR., of Alabama; Mr. HARRY MCMULLEN of Arkansas; Mr. D. J. REED of Colorado; Messrs. JOHN G. MASSIE, THOMAS HUDSON, JAMES FREER, WALEON RUTLEDGE, and QUINTIN CLARK of Illinois; Mr. LUKE W. BRYAN of Indian Territory; Mr. M. G. THOMAS of Iowa; Mr. C. J. NORWOOD of Kentucky; Mr. FRANK J. MCMAHON of Maryland; Mr. GEORGE W. HILL of Michigan; Mr. CHARLES EVANS of Missouri; Messrs. G. C. SWALLOW and C. S. SHOEMAKER of Montana; Mr. R. M. HASELTINE of Ohio; Mr. W. H. HAMPTON of Oregon; Messrs. CHARLES CONNOR, JAMES BLICK, J. T. EVANS, BERNARD CALLAGHAN, THOMAS K. ADAMS, WILLIAM JENKINS, HENRY LOUTTIT, JAMES N. PATTERSON, D. H. THOMAS, and ROGER HAMPTON of Pennsylvania; Mr. J. W. LLOYD of Tennessee; Mr. ROBERT FORRESTER of Utah; Mr. E. MORGAN of Washington; Messrs. D. M. HARR and M. F. SPRUCE of West Virginia; Mr. DAVID G. THOMAS of Wyoming.

We are under obligations to each of the following gentlemen for valuable assistance in this work: A. CORDELLA, Director-General Société des Usines du Laurium, Athens; PERCIE H. COWARD, San Francisco, Cal.; GEORGE H. HARRIS, Fair Haven, Vt.; AUGUSTO DA F. MONTERIO, Chief of Department of Mines and Industry, Portugal; G. JAMES MORRISON, Shanghai, China; T. M. PAGE, President Page & Krause Mining and Manufacturing Company, St. Louis, Mo.; E. BERTRAM PIKE of the Pike Manufacturing Company, Pike Station, N. H.; W. R. SHIELDS, Columbus, Ohio; CHUJI TAKAHASHI, Director of the Mining Bureau, Tokio, Japan; ROBERT M. THOMPSON, President Orford Copper Company, New York City; DR. H. VOLTZ, Secretary-General of the Oberschlesischen Berg- und Hüttenmännischen Verein, Kattowitz, Oberschlesien, Germany; J. B. WILBUR, Secretary American Legation, Lisbon, Portugal.

That most important department of this work, its business and financial administration, has been under the control of Mrs. SOPHIA BRAEUNLICH, treasurer and business manager of the Scientific Publishing Company and of the *Engineering and Mining Journal*, and who was for many years on the staff of that paper. To her remarkable business ability is due in no small degree the success which has crowned this undertaking.

MATTOON, CHARLES F., the skillful and experienced reader, has had charge of the proofreading of this, as of the first volume of this work.

ABRASIVES.

Corundum and Emery.

Corundum, which occurs in all colors from white or transparent through red, yellow, green, brown, and almost black, stands second only to the diamond in the scale of hardness; is almost infusible, has a sp. gr. of 4.2, and when pure consists of oxide of aluminum containing 53.2% metallic aluminum. In the arts three varieties are recognized: (1) Sapphire, including the valuable transparent and translucent gems such as the ruby, topaz, and emery; (2) corundum, or adamantine spar, embracing the opaque varieties used as polishing material; and (3) emery, a dark granular variety of corundum containing a considerable percentage of iron.

Both corundum and emery occur associated with crystalline limestone or dolomite gneiss, granite, mica, and chloritic slate, serpentine, and olivine rocks. In the United States they are found in certain strata along the line of the Appalachian range from Chester, Mass., to northern Georgia, and in the West at Salida, Colo., and some other points. The Salida deposits have been opened quite recently and promise to be an important producer. The corundum occurs in hornblendic gneiss in a fairly well defined vein, varying from 6 ft. to possibly 30 ft. in width, and lying almost perpendicular.

The principal use of both corundum and emery is in the manufacture of abrasive wheels, though considerable quantities are used in the form of powder. All of the corundum consumed in the United States is of domestic production, but the greater part of the emery used is imported from Asia Minor. The imports and exports of the United States will be found in another part of this volume.

PRODUCTION OF CORUNDUM IN THE UNITED STATES.

Year.	Tons, 2000 lbs.	Value.	Year.	Tons, 2000 lbs.	Value.	Year.	Tons, 2000 lbs.	Value.
1881	500	$80,000	1886	645	$116,190	1891	2,265	$90,230
1882	500	80,000	1887	600	108,000	1892	1,504	139,944
1883	550	100,000	1888	589	91,620	1893	1,747	140,589
1884	600	108,000	1889	2,245	105,567			
1885	600	108,000	1890	1,970	89,395	Total	14,215	$1,357,535

INFUSORIAL EARTH AND TRIPOLI.

Infusorial or diatomaceous earth, also called earthy tripoli or fossil flour, is found in the United States at numerous places. Among others may be mentioned Newton County, Missouri, Dunkirk, Md., Framingham, Mass., and points in Kansas, Connecticut, Rhode Island, and Virginia. In California and Nevada also there are said to be deposits of much extent, which are still undeveloped, however, on account of their remoteness from market.

The deposit of infusorial earth on the Patuxent River, near Dunkirk, in Calvert County, Maryland, is said to be 7 ft. thick; it rests upon greensand marl and is overlaid by sand, gravel, and clay. There is another bed of the mineral at Pope's Creek, in the same vicinity, which was formerly productive but has not been worked for the last three or four years.

At Framingham, Mass., the tripoli bed is found in low, marshy land, overlying lignite. To prepare it for market, the product is calcined at a white heat. The valuable deposit in Newton County, Missouri, although discovered about 1870, was not worked until 1887, when a plant was erected for reducing the rock to a fine powder for mechanical purposes and for sawing, turning, and shaping the mineral in various forms for water filters. The deposit of tripoli is overlaid with 3 to 4 ft. of loose earth, and in thickness ranges from 5 to 10 ft. It underlies, it is claimed, from 80 to 100 acres, and contains 98% silica. The mineral is very compact, but sufficiently porous to make an excellent water filter. It is free from iron and coarse sand or grit, and when ground for polishing purposes makes an exceedingly fine powder. The grain is sharp and cutting, and yet fine enough not to scratch metal surfaces in polishing. The ground material is also used to a considerable extent in the manufacture of soap.

The production of infusorial earth in the United States in 1893 is estimated at 1709 short tons, valued at $46,800, as against 1323 tons, valued at $41,950, in 1892.

Part of the infusorial earth produced in the United States is used for making protective coating for boilers, only the better grades being employed for polishing material. None of the American product has ever been used as an absorbent of nitroglycerine in the manufacture of dynamite, it being considered inferior to the German earth for this purpose. Not much infusorial earth of any kind is used in making dynamite, however, at the present time, wood pulp and other cheaper substances having taken its place. Analyses of infusorial earth from various localities in the United States are given in the following table, taken from the Report of the Eleventh Census on the Mineral Industries of the United States:

	From Pope's Creek, Maryland. (*a*)	From Morris County, New Jersey.	From Near Richmond, Virginia. (*b*)	From Storey County, Nevada.(*c*)
Moisture	3.47%	....	8.37%	....
Silica	81.53	80.66%	75.86	81.08%
Alumina	3.43	3.84	9.88	....
Protoxide of iron	3.33	....	....	....
Lime	2.61	0.58	0.29	....
Ferric oxide	....	....	2.92	....
Magnesia, soda, potash, sulphur, and organic matter	5.63	....	1.63	....
Loss on ignition	....	14.01	....	....
Water at red heat	....	....	....	18.44
Loss	....	....	....	0.48
Total	100.00	99.09	....	100.00

(*a*) Analysis by P. de P. Ricketts. (*b*) J. M. Cabell. (*c*) W. Habirshaw.

CARBORUNDUM.

By E. G. Acheson.

THE fact that carbon and silicon would unite to form a stable, definite chemical compound was discovered by me in the early summer of 1890, as a natural result following my invention, in the previous March, of the new substance known as "carborundum." This latter was the direct outcome of experiments having as their object the production of an abrasive material, and was first made by subjecting a mixture of fine carbon and clay to the intense heat produced by an electric current. It was supposed that the crystals resulting from this process were composed of carbon and alumina, and the name carborundum was therefore given to the new substance. Analysis, however, showed the supposition to be erroneous, the component parts proving to be carbon and silicon, under the fomula SiC.*

In June, 1890, the Carborundum Company was organized for the purpose of manufacturing carborundum, and to this concern my patent, covering the new material, was sold. Active work was at once undertaken for the perfection of the processes and the working of the crude material into marketable forms.

Efforts made to introduce carborundum powder into the diamond cutting and lapidary trades were not productive of any considerable success, it being found that while carborundum was capable of abrading a diamond, it was brittle, and would not resist crushing to the extent that diamond would, thereby proving to be inefficient.

While the lapidary trade to the Carborundum Company would be commercially insignificant,—with its finest powder selling at $4 per lb., and a workman using but three to five karats per week,—the successful manufacture of a substitute for bort and diamond powder is of very great importance to the dealers in these materials. Tests made in the exhibit of Messrs. Tiffany & Co., in the Mines Building at the World's Columbian Exposition, under the supervision of Mr. George F. Kunz, are stated to have produced results of a negative character, and contradictory to those obtained by several diamond-cutting firms in New York; hence the question of the hardness of carborundum remains undetermined —a fit subject for ex-parte evidence.

The history of the invention and early manufacture of carborundum has already been fully described,† and my present intention is to refer only to the developments made during the past year.

It is now impossible to learn the exact amount of carborundum produced prior to 1893, but I would place it at about 1000 lbs., while the value of that sold, in all forms, was only $721. The details of making vitrified wheels were fairly well in hand, and the company was prepared to make an effort to introduce small wheels and points into the dental trade. The Westinghouse Electric and Manufacturing Company had already adopted carborundum wheels, one-half inch diameter by one-half inch in thickness, for grinding the joints of their "stopper lamps."

During the first week of January, 1893, 12,000 wheels, one-half inch in diameter by one-sixteenth of an inch thick, were mailed to the same number of dentists, with a request that they would try the sample in either a wet or a dry

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* "On Carborundum," by Dr. Otto Muhlhaeuser, *Jour. Amer. Chem. Soc.*, Vol. XV., No. 7, July, 1893.

† "Carborundum: Its History, Manufacture, and Uses," by E. G. Acheson, *Journal of the Franklin Institute*, September and October, 1893.

state. This resulted in the sale to dentists, during the year, of about 200,000 wheels and points of various sizes and forms, valued at over $23,000. The Westinghouse Electric and Manufacturing Company continued the use of wheels for stopper grinding, its orders for the year aggregating over 64,000 wheels—a truly excellent testimonial of the value of carborundum for glass grinding.

During the year considerable attention was devoted to the introduction of carborundum wheels into the machine, tool, cutlery, watch, glass, optical, and other trades, with more or less success. A serious mistake was made, however, in the first half of the year, by placing on the market wheels that had not been turned or trued up, resulting, in some cases, in very adverse criticisms on the value of carborundum; in many instances, both wheels and material were condemned without trial. In June the company endeavored to recover this lost ground by turning up all wheels over three inches in diameter; since then their use has been much more rapidly extended, and they are now to be found at work in watch factories, optical works, glass works, bicycle works, gun works, machine shops, sawmills, car shops, foundries, tool factories, and many other places. With few exceptions they give great satisfaction, as is evident from statements made and the continual repetition of orders from those who are now considered old customers.

Considerable difficulty has been encountered in the proper selection of wheels, in hardness and size of grain, for given kinds of work. These are points that nothing short of experience will teach, and they are now possessed by the emery wheel manufacturers as a result of continued and careful study through many years.

The present prices of carborundum wheels for machine work are from two to six times those of similar wheels of emery, depending upon the discount quoted by the emery dealer. This high price, or rather great difference in the prices, constitutes a barrier to the rapid and general use of the carborundum wheel, as the first cost is frequently the controlling factor.

The small capacity of the company's plant has also seriously interfered with the more extended introduction of wheels, as many orders have been refused, owing to the large size of the wheels required. Still another impediment has been the failure to produce the grains or crystals of carborundum of the larger sizes found desirable for some classes of work. That these difficulties will in time be overcome there can be no doubt, if we are to judge from what was accomplished during the last year. Increased plant capacity will result in decreased cost, and at one ton per day the price of wheels might easily be halved. The possibility of filling all orders, however large, is, of course, subject only to the amount produced, and, like the price, is to be met by increased plant. In the past year the sizes of the crystals or grains have been increased from a No. 80 to a No. 30 mesh, as a result of the increased size of the carborundum furnace, and it has now been demonstrated that the question of increasing the size of the grain is also to be met by increased plant capacity.

During the year the capacity of the works of the Carborundum Company was increased from 25 lbs. to 225 lbs. per day of twenty-four hours. Owing to several accidents to machinery, and the intervention of experimental work, this possible output was very materially reduced, the total amount manufactured being but 15,200 lbs.

ALUM.

ALUM is found native at several places in the United States, but nowhere have the deposits yet become of commercial importance, either because of their remoteness from markets, or because of their limited extent. Native alum occurs chiefly in the form of an efflorescence on clayey rocks, and as alum-bearing clay and shale, which are used abroad as commercial sources of the substance, but not in this country, though such clays exist in New Jersey, Indiana, Alabama, Georgia, and many other of the Eastern, Southern, and Central States. Native alum occurs in California, Arizona, Utah, Nevada, New Mexico, and other Rocky Mountain States. There is said to be a very large deposit of impure mineral on the Gila River in Socorro County, New Mexico, about two miles below the fork of the Little Gila, but it is too far away to be of importance under present conditions. During the past year a deposit, which is said to contain 72% soda-alum, is reported to have been discovered in the Indian Springs district, Lion County, Nevada.

The alum of commerce is made from alum shales, bauxite, and cryolite, the last two minerals being the only kind of raw material used in the United States. Alum is made from cryolite only by the Pennsylvania Salt Manufacturing Company; all the other producers use bauxite, which is derived in part from the Georgia-Alabama banks, and in part from Ireland. (See article on "Bauxite.") The foreign mineral is gradually being displaced by the American, however, notwithstanding the low price at which it can be delivered on the Atlantic coast, being brought across the ocean at ballast rates. (See articles on "Bauxite" and "Cryolite.")

Potash-alum ($K_2SO_4 + Al_2(SO_4)_3 + 24H_2O$) contains 9.95% potassium, 10.83% alumina, 33.71% sulphuric acid, and 45.51% water. It crystallizes readily in regular octahedra, loses three-fourths of its water when heated to 60° C., and melts at 92° C. in its water of crystallization, forming a colorless liquid. Potash-alum is very soluble in water, 100 parts of the latter at 40° C. taking up 31.2 parts of the salt, and 100° C., 360 parts. The solution has a strong acid reaction.

Ammonia-alum [$(NH_4)_2SO_4 + Al_2(SO_4)_3 + 24H_2O$] contains 3.89% ammonia, 11.9% alumina, 35.1% sulphuric acid, and 48.11% water. When strongly heated this salt is decomposed, ammonium sulphate, water, and sulphuric acid being driven off, and alumina remaining. Ammonia-alum is soluble to about the same degree as potash-alum in water at 20° C. and 40° C., but the water at 100° C. will take up 422 parts of it.

Soda-alum $[Na_2SO_4 + Al_2(SO_4)_3 + 24H_2O]$ contains 6.8% soda, 11.2% alumina, 34.9% sulphuric acid, and 47.1% water.

Aluminum sulphate $[Al_2(SO_4)_3 + 18H_2O]$ is largely prepared, being sold in the trade under the name of concentrated, or cake, alum. It is a white, somewhat transparent substance, which may be cut with a knife, and is readily soluble in water. When pure it contains 18.78% alumina, 38.27% sulphuric acid, and 42.95% water, but the commercial product varies somewhat from this standard.

The method of manufacturing alum, whether from alum shale, bauxite, or cryolite, is very simple, depending upon the formation of sulphate of aluminum, which can be dissolved in water. In the case of raw material in which the aluminum is already present in the form of sulphate, like some of the alum shales, lixiviation with water is the first step in the process. Bauxite, which contains hydrous oxide of alumina, is treated with sulphuric acid to form sulphate. In making alum from cryolite the hydrate of aluminum, which is precipitated in carbonating the solution of aluminate to sodium, is treated with sulphuric acid like the natural hydrate of aluminum in bauxite. To the solution of aluminum sulphate is added a sodium, potassium, or ammonium salt, according to the kind of alum to be made. Alum is thereby precipitated as a crystalline powder or so-called flour or alum, which is washed with cold water and redissolved in boiling water. The hot solution is run into vats, where pure alum is crystallized out.

The following concerns in the United States are engaged in the manufacture of alum and sulphate of aluminum : Bayonne Chemical Works, Bayonne, N. J.; Buffalo Chemical Works, Buffalo, N. Y.; Harrison Bros. & Co., Philadelphia; Martin Kalbfleisch's Sons Co., New York; Merrimac Chemical Company, Boston; Nichols Chemical Company, New York; Pennsylvania Salt Manufacturing Company, Natrona, Penn.; Powers & Weightman, Philadelphia; United States Chemical Company, Camden, N. J. The total production of alum in the United States in 1893 was between 40,000 and 55,000 tons. The value of alum ranges from 75c. to $2 per 100 lbs.

Alum and aluminum salts are very extensively applied in the arts. Alum is used as a mordant in dyeing (except when the tar colors are employed), in the preparation of the lake colors, in the manufacture of paper, in tanning leather, and in clarifying turbid water (in which the alum combines with the suspended alumina, forming an insoluble basic alum, which drags down organic and other impurities). Aluminate of sodium is used in dyeing and calico printing, and the saponification of fats in the manufacture of stearine candles, an alumina soap being formed, which is decomposed by acetic acid into aluminum acetate and free fatty acid.

ALUMINUM.*

By Joseph W. Richards.

During 1893 no new process of producing aluminum was put into practical operation. The year was characterized by improvements in the present electrical processes, which, together with increased output, put the industry on a much firmer basis than it has ever had before. It was a year of healthy growth along fixed lines. The estimated amount manufactured during 1892 in all countries was 500 metric tons; during 1893 this amount was more than doubled. The ruling price abroad was $1.25 per kilo (57c. per lb.); in the United States, 75c. to 80c. per lb. (The present tariff on aluminum in ingots is 15c. per lb.)

The beginning of the year brought to an end the lawsuit of the Pittsburg Reduction Company, owner of the Hall process patents, *versus* the Cowles Electric Smelting and Aluminum Company, for infringement. Some of the ablest expert talent was engaged on each side. The court decided that Hall's patents cover the electrolysis of a fused bath of cryolite in which alumina has been dissolved, that the method of heating the bath, whether externally or by the internal heating by the current, is not an essential feature of his process, and that none of the references to prior processes quoted by the defendant disclosed the principle of Hall's process. Since February last the Pittsburg Company has been the only producer of pure aluminum in this country.

The usual number of new companies to work new processes, with capital stock of from $1,000,000 to $10,000,000, some bona fide and some otherwise, were projected during the year. One or two were exposed as humbugs by the *Engineering and Mining Journal.*

Great advances were made in working, alloying, and utilizing aluminum, which are mentioned in detail farther on. The demand was continually ahead of the supply, so that it happened frequently that very promising uses for the metal were temporarily abandoned because of the difficulty of getting a supply. This phase of the question is being rapidly met by the manufacturers, the Pittsburg Reduction Company now producing nearly a ton of metal a day, against a quarter of a ton at the beginning of 1893, and it has closed a contract with the Niagara Falls Power Company for 6500 electrical horse-power, with which it will manufacture, inside of a year, 8000 lbs. a day. Part of this new plant is expected to be in operation by March, 1894.

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* Professor Joseph W. Richards, the author of this article, prefers the word "aluminium" to "aluminum," but the necessity for uniformity in this work has led to the use of the shorter name. The use of either may be defended by high authority.—Ed. The Mineral Industry.

Abroad, the Swiss works at Neuhausen have already enlarged their plant to 4000 horse-power, and have been producing 5000 lbs. a day since March, 1893, while almost all the other European plants have been enlarged. A French company to work the Hall process has also been formed, and promises to get into operation in 1894.

The aluminum industry thus presents at this stage the interesting spectacle of the manufacturers trying to keep pace with the demand, with the latter yet in the lead. But as the supply increases, costs are less, and the metal is sold cheaper. During 1892 aluminum was temporarily sold at 50c. per lb., but this was the result of trade rivalry, and was about the cost of production. On Jan. 1, 1894, the Swiss makers began to sell permanently at 5f. per kilo, or 45c. per lb. Large production has rendered this low figure possible, and the president of the Pittsburg Company states that when producing on an equally large scale it will be able to sell at a correspondingly low figure.

At the World's Columbian Exposition the only manufacturers represented were the Pittsburg Reduction Company. The exhibit was very complete, including a model of an extraction pot, samples of all the materials used in the process, aluminum in ingots, rods, sheet, wire, leaf, etc., and worked up into culinary utensils, medals, etc. In addition to this, there were exhibits of various aluminum articles by two local dealers in aluminum; also a metallurgical collection, illustrated by diagrams, with historical specimens, loaned by the writer. It is to be regretted that the foreign makers were not represented in the metallurgical section.

Raw Materials.—Bauxite and cryolite are now the staple minerals of the aluminum industry. Abroad, no new developments in the bauxite deposits are reported; in the United States, the Alabama and Georgia deposits are being extensively mined. The Georgia Bauxite Company exhibited splendid masses of ore at the Columbian Exposition. The Solvay Process Company of Syracuse, N. Y., put up a plant in 1892 for making alumina from bauxite, with a capacity of 20 tons per day. It is to be hoped that this enterprising firm will make alumina of such purity and at such a price as will make our country independent of Germany in this matter.

The Congo Coal Company of Congo, Ohio, while sinking a shaft, found a mineral in a stratum 25 ft. thick, which appears to be a mixture of aluminum silicate and sulphate, from which the sulphate could be extracted by leaching. Dr. Lisle of Springfield, Ohio, sends me the following analysis: Alumina, 50.16%; silica, 28.98%; lime, 0.46%; sulphuric acid, 16.21%; water, 4.28%; total—100.09. A thick vein of such material would seem to promise a cheap source of pure alumina.

Physical and Chemical Properties.—Professor Dewar has measured the electrical resistance of aluminum at low temperatures, and finds that it varies directly as the absolute temperature. Its electrical resistance compared with that of copper is 100 to 60.7. Moissan finds that aluminum volatilizes easily in the electric arc. The latent heat of fusion has been determined by Pionchon as 80 calories; by Richards as 100 calories. Aluminum castings shrink two per cent. in setting, which is diminished by adding a small percentage of copper. If overheated, molten aluminum absorbs gas, and castings are apt to contain blow-holes. Coehn remedies this by using a little sodium in the crucible, adding just enough to form a film over the molten metal. The ductility of aluminum allows it to be treated by the Mannesmann process of cold rolling.

A. Arche has published experiments on the resistance of aluminum to chemical corrosion. Best quality aluminum placed in a five per cent. solution of acetic acid corroded most when cast, and least when hammered. The acetic acid solution, red wine, tea, rum, water, preserve, two per cent. tartaric acid solution, and white wine acted inappreciably on the metal. A one-half per cent. solution of soda lye and a one per cent. solution of common salt acted slightly in twelve days, the metal exposed losing in that time 0.08% and 0.18% of its weight, respectively. In every case aluminum was less acted on than tin or copper, the metals usually used in cooking utensils.

It has been found that the strength of aluminum can be enormously increased by suitable working. The Pittsburg Reduction Company has put up its rolling mill, and is rolling aluminum angles and shapes for light structural work, such as torpedo boats. It finds that by careful cold rolling the tensile strength can be raised to 40,000 or 50,000 lbs. per sq. in., with an elastic limit as high as 25,000 lbs. This is obtained in pure aluminum, but the light alloys, containing small amounts of hardening metal, can be similarly improved.

Methods of Reduction.—As far as the processes now in actual operation are concerned, all the improvements which have been made are kept as secret as possible, so that metallurgical curiosity must remain unsatisfied. Dr. Kiliani, at Neuhausen, is under contract not to publish in any way any improvements he makes, and all the other makers adopt the same policy "for business reasons." The real reason for this secrecy is that they are all using the same fundamental process of electrolyzing a fused fluoride bath containing alumina, and therefore they all stand on the same footing except in regard to little details, all improvements in which give the one making them his only advantage over competitors, and therefore necessitates that they be kept secret.

The Grabau Aluminum Werke, at Trotha, Germany, are yet in the experimental stage, but are working in a different line from the above makers. Herr Grabau's starting-point is kaolin, which can be obtained of great purity cheaper than perhaps any other aluminum ore. His idea is to dissolve out the alumina with sulphuric acid, and by using fluorspar convert the aluminum sulphate into aluminum fluoride. He claims to be able to make this salt of greater purity than commercial alumina, and at a considerably lower price. This fluoride is then to be reduced either by a deficiency of sodium, forming cryolite as a by-product, or by fluxing with sodium carbonate and electrolyzing, producing cryolite again as a by-product, according to the reaction:

$$4Al_2F_6 + 6Na_2CO_3 + 3C = 4Al + 2(Al_2F_66NaF) + 9CO_2.$$

Grabau also claims to be able to make an aluminum oxyfluoride, Al_2OF_4, instead of Al_2F_6, and the electrolysis of this compound in a fused cryolite bath is likewise proposed. A slab of aluminum sent by Herr Grabau to the writer for exhibition at Chicago was thus made from kaolin, and was of the very best quality.

Light Aluminum Alloys.—Good progress has been made in the line of hard alloys for light castings. These alloys are generally made with 3% to 5% of copper and 10% to 20% of zinc. This metal is almost as hard and rigid as cast iron, and is an excellent material for such castings as bicycle frames, window frames, etc. An alloy with 3% of German silver was first made by the writer. It is about twice as strong as ordinary aluminum and is as elastic as steel. For scale beams, the alloy with 3% of silver and 2% of pure copper is found best adapted. After casting, the piece is subjected to heavy pressure, which slightly diminishes its section but leaves it very hard and springy. Aluminum alloyed with manganese was shown in tubes at the Columbian Exposition, but the proportion of manganese was not stated. The metal was very rigid. Mr. Charles F. Whitney of Newton, Mass., has patented the alloy of aluminum 76%, with 12% or less of both manganese and tungsten. Tests made in Germany show that aluminum with 2.7% and 6% of copper had the following properties:

	2.7 Per Cent. Copper.		6 Per Cent. Copper.	
	Tensile Strength, Lbs. per Square Inch.	Elongation, Per Cent.	Tensile Strength, Lbs. per Square Inch.	Elongation, Per Cent.
Cast	23,000	13.5	17,000	5
Cold rolled	43,000	3	47,000	10
Annealed and rolled	28,500	19.5	28,500	12

Aluminum in Iron and Steel.—Among the makers of steel castings the use of aluminum is universal. It is also used by the majority of open-hearth and Bessemer steel producers. The material is usually the second quality aluminum, averaging 96% pure, which can be bought at about four-fifths the price of the purest metal. The use of ready-made ferro-aluminum is decreasing, because of the unknown impurities which the iron alloy might introduce. The latest practice in Europe is to drop the aluminum into the pouring gate of the flask or mold. It is said that the aluminum diffuses itself with such rapidity through molten iron that even when thus given the chance to act only between the pouring and the setting of the metal, it acts perfectly. In Friedenshütte sound steel castings are obtained using only 0.004% of aluminum dropped into the flasks, whereas a much larger quantity put into the ladle was ineffective. A Swedish works making Bessemer steel finds 0.02% of aluminum sufficient if used in the molds, and another making Martin steel finds 0.01% ample if it is dropped into the flasks. Low carbon metal requires more aluminum than high carbon, Bessemer metal more than Martin steel, and more is required when the aluminum is added in the ladle than when dropped into the flasks. In casting 900-lb. ingots of 0.15% carbon steel, a zone of blow-holes was seen about one inch from the sides. Using 0.02% of aluminum in the same metal, superficial blow-holes appeared in such quantities as to make the ingot unsalable; but with 0.04% of aluminum the ingot was free from blow-holes and almost faultless. Care must be taken not to add more than is just sufficient to make the metal fluid and sound, as an excess tends to make carbon separate out as graphite, and causes great shrinkage. Frequently a little less aluminum is added than is necessary to remove all the blow-holes, so regulating the addition that the metal neither rises nor shrinks in the mold, risking rather a few blow-holes in the ingot than a shrinkage cavity.

Aluminum in Copper.—If a little aluminum is added to the bath of molten copper ready for pouring it reduces immediately any protoxide remaining in it, stops the evolution of gas, and the metal becomes more fluid and dense and malleable after casting.

Aluminum in Zinc.—In 1890 Mr. Joseph Richards of Philadelphia, the writer's father, discovered that a minute amount of aluminum added to molten zinc rendered it much more fluid and protected it against oxidation. The increase of fluidity is doubtless due to the removal of dissolved zinc oxide. This observation was made the subject of two patents, one for the use of aluminum in the refining or liquation of galvanizer's dross (zinc hard with iron), the other for the use of aluminum in the galvanizing bath. In the refining process the dross is melted at a high temperature and then cooled slowly, when rich alloys of zinc and iron sink and purer zinc can be bailed from the surface. The addition of 0.005% of aluminum noticeably thins the bath, facilitates the separation, and lessens the amount of skimmings due to oxidation. In the galvanizing process the addition of 0.01% of aluminum makes the bath more fluid, less skimmings are formed, and the coating is thinner, more uniform, more brilliant, and holds its luster longer. The Delaware Metal Refinery of Philadelphia owns the patents on this use of aluminum in the galvanizing bath.

Over three years ago it was discovered that zinc thus refined with aluminum was superior to any other brand of zinc for desilverizing bullion. Since then thousands of tons have been sold to desilverizers in the East for that purpose, an extra hundredth of a per cent of aluminum being put into the zinc intended for that use. Recently the same fact has been patented in Germany, and has attracted considerable attention as the Rössler-Edelman process. In the latter zinc with up to 0.5% of aluminum has been used, and has been found to have very important advantages over ordinary zinc. Instead of four to six operations in desilverizing, only one is now necessary, and the scums are almost entirely free from oxide, and thus much easier to work. The Germans have carried this idea further than has been done on this side of the Atlantic, but to our metallurgists belongs the credit of first perceiving the advantages of aluminum-zinc in the desilverization of base-bullion.

Electro-deposition of Aluminum.—The Tacony Metal Company, Philadelphia, Mr. Darling, superintendent, is electro-depositing aluminum on the iron columns of the tower of the new City Hall. The columns are first given a thick electric coating of copper, and then the aluminum is deposited. The tank used for the latter operation contains a total anode surface of 300 sq. ft.; the total current is 2500 ampères by 8 to 10 volts, which gives 8 ampères per sq. ft. of anode surface. One of the columns plated has a surface of about 150 sq. ft., which gives a current density at the cathode of about 16 ampères per sq. ft. The aluminum anodes used are made by the Pittsburg Reduction Company. It is stated that with this density of current, and a solution which has very little chemical action on aluminum, the process is without any special difficulty, but the chemical composition and degree of concentration of the electrolyte used are kept secret. On a column seen by the writer the aluminum coating was about a quarter of an inch thick, and was continuous, but quite rough. For architectural work, iron thus coated may find extensive use.

Soldering Aluminum.—No fewer than eight patents were taken out in 1893 for aluminum soldering processes. It is no exaggeration to say that, outside of silver solder, practically the only solder being used on aluminum is that of Mr. Joseph Richards of Philadelphia. Over $200 worth of this was sold in 1893, in Germany, England, and the United States, and it is evident that such an amount will solder about all the aluminum work which is being done. The solder consists of aluminum, zinc, tin, and phosphorus, and has been lately improved in its proportions, so that it gives, with reasonable care, entirely satisfactory results.

Uses of Aluminum.—We can scarcely enumerate the new uses to which aluminum has been applied. First in importance is the manufacture of culinary utensils. The Illinois Pure Aluminum Company of Lemont, Ill., started early in the year to put a line of this ware on the market. It has been hampered chiefly by lack of material to work with. The plant employs twenty hands, and can use a ton of aluminum a week. Speaking from actual experience with aluminum cooking utensils, they can hardly be too highly praised and recommended. The most expert cooks and chefs give them unqualified praise. They are practically indestructible. The Illinois firm now makes a line of over twenty articles for cooking, and the price is about the same as for copper or agate ware. America has certainly taken the lead in this utilization of aluminum, which will become, in the writer's opinion, the most extensive application of the pure metal that will ever develop.

We have only space to barely enumerate the other new uses. Sanitary pails for prisons, horseshoes with steel toe, teething plates for infants, photographic cameras, microscopes, jewelers' eyeglasses, artificial limbs and noses, bicycles, sulkies, stirrups, bitts, spurs, slate-pencils, sextants, transits, cages in coal mines, elevators and grill work around elevator shafts, lithographic plates, pocket scales, pocket levels, hot-air ovens, water baths, pincers, rings, tripods, sand baths for chemical use, evaporating pans and stills in chemical works and breweries, heating and cooling coils, brushes, walking sticks, umbrella frames, billiard cues, etc.

Mr. W. S. Cooper of Philadelphia casts solid aluminum bath tubs, 6 ft. long, 2 ft. wide, 2 ft. deep, $\frac{3}{8}$ in. thick, weighing 140 lbs. This feat is worthy of special mention because such a casting would be difficult to make in any metal, even cast iron, and is, in fact, the finest casting in aluminum which I have seen.

We must not omit mentioning the five aluminum launches and yachts so far made by Escher, Wyss & Co. of Zurich. One is 43 ft. long, weighs 3000 lbs., and cost only $4000. The Messrs. Herreshoff are building a yatch whose deck and upper works will be entirely of aluminum, while a torpedo boat is being constructed by Yarrow & Co. on the Thames, England, entirely of aluminum.

It is the writer's opinion that the time has come when our cents should be coined of aluminum. The advantages of light, clean aluminum over heavy, poisonous copper are self-evident.

The statistics of production and imports of aluminum are given in the general Uuited States tables at end of volume.

ANTIMONY.

Antimony is a metal of silver-white color, with a yellowish cast. It has a strong metallic luster and a crystalline texture. Its sp. gr. is 6.712, and it melts at 430° C. It is harder than copper, is not extensible, is very brittle, and can be easily pulverized. The metal of commerce usually contains arsenic, iron, copper, sulphur, and gold, that smelted from Portuguese ores having on an average 2.5 oz. gold per ton.* Antimony comes into the market in the form of conical ingots, known as "star antimony," this term referring to that stellated crystalline surface which is preferred in the trade, and which is produced by allowing the metal to cool slowly beneath a layer of slag of special composition.

Ores of Antimony.

The common ores of antimony are stibnite, Sb_2S_3 (called also antimony glance), which when pure contains 71.8% antimony and 28.2% sulphur ; senarmontite, Sb_2O_3, or oxide of antimony ; and kermesite, or red antimony, which is a mixture of oxide and sulphide, being represented by the formula $2Sb_2S_3 + Sb_2O_3$. By far the most important of the ores is the sulphide, stibnite. This is a crystalline mineral of a shiny steel-gray color, so soft that it can be readily cut with a knife, and so fusible that it melts in the flame of a candle. These properties easily establish its identity. It crystallizes usually in aggregates of needles and bladed crystals, which serve at once to distinguish it from galena and other minerals. When heated on charcoal before the blow-pipe, dense white fumes of oxide of antimony are given off. The natural oxide of antimony, senarmontite, is a dense, heavy, white mineral which has been found at one place in Sonora near the Arizona line. Antimonial ochers occur in various parts of the world, notably in Algeria, Asia Minor, and Borneo, forming ores which are second in importance to the sulphide. Red antimony, or kermesite, is mined in Italy.

According to W. L. Watts, in the Eleventh Report of the State Mineralogist of California, which has recently been published, a ledge of "quartzite and porphyritic rock" containing native antimony has been discovered on Erskine Creek, four miles south of Hot Springs, in Kern County. Two tons of metal were taken from a shaft 30 ft. deep and 1.5 ton from a cut 8 ft. deep. The

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* E. A. Smith, *Journal of the Society of Chemical Industry*, April 29, 1893, p. 216.

native antimony was found in nodular masses, coated with oxide of antimony and clay, which varied in weight from one ounce to 300 lbs. The two openings from which ore was obtained were about 1,000 ft. apart, on the same ledge. There are many veins carrying sulphide of antimony in the neighborhood of this ledge, particularly in a southerly direction therefrom, and numerous claims have been located, but are at present awaiting capital for development.

OCCURRENCE OF ANTIMONY ORES.

United States.—Antimony ore, chiefly stibnite, is found in the United States at numerous localities, especially in the Rocky Mountains and on the Pacific coast, but owing to remoteness from shipping points many of them are not workable under present conditions. Among the places where the mineral is known to exist should be mentioned the neighborhood of Coyote Creek, Iron County, Utah, where the veins are said to be extensive. It is reported that a mine was worked there some ten or twelve years ago, but the enterprise was unsuccessful on account of the high cost of shipping the ore. The next antimony mines opened in the United States were in California, where the mineral has been found in promising veins at Panamint, Inyo County ; in San Emigdio Cañon, Kern County ; and at the Alta mine, San Benito County, which has been worked from time to time. All the antimony produced in the United States previous to 1888, of which there is record, was derived from this State, the maximum output being made in 1887, when 75 tons of metal, representing probably 300 tons of ore, were turned out. The production of antimony in California ceased in 1888, however, and in 1889 the only States producing it were Arkansas and Nevada, the former yielding 65 tons and the latter 200 tons of ore. The antimony mined in Arkansas came from the property of the United States Antimony Company, at Antimony, Howard County. In 1890 the production of ore in Nevada amounted to 310 tons, of which 250 tons were smelted in San Francisco ; the Arkansas mines produced 81.5 tons, and mines in the neighborhood of Thompson Falls, in Montana, also the property of the United States Antimony Company, produced 29.5 tons. The Arkansas and Montana ore was smelted in Philadelphia. The following year, 1891, witnessed a great development in the antimony mining industry of the United States, although neither the Arkansas nor Montana mines were worked. A promising property on Big Creek, near Austin, Nev., was taken over in the early part of the year by an English company, the Big Creek Mining Company, Limited, which immediately began its exploitation energetically. The shipments made by this company during the year amounted to 700 tons, averaging 65% antimony, which realized £28 per ton in Liverpool. The company derived a good profit from the business, paying dividends amounting to $25,000 for the year. The Thies-Hutchins mines (now known as the Sutherland mines) at Black Knob, 15 miles from Lovelock's, in Humboldt County, were also operated during the year, and produced about 400 tons of ore, which it was reported averaged 33⅓% antimony, but no shipments were made, it being proposed to reduce the ore at the mines, for which purpose a furnace was subsequently erected ; this did not prove successful, however, and was never run except experimentally. A small quantity of Arkansas ore carried over from 1890 was smelted in Philadelphia in 1891, the yield being 2578 lbs. of metal. The producers in 1892 were the same as in 1891, the Big Creek Mining Company, Limited, shipping 600 tons of ore, averaging 60% antimony, while the Sutherland or Thies-Hutchins mines shipped 200 tons of ore, averaging 55%. A small amount of ore, possibly 20 tons, was produced in California during the year.

The production of antimony ore in the United States in 1893 was smaller than in the previous year, the producing mines having been idle for part of the time on account of the low prices quoted for ore. The total production of antimony ore in Nevada was only 350 tons, most of which came from the Sutherland mine and from the Bernice district (Churchill County). A few tons also were shipped from Mill City, in Churchill County. The Big Creek mines did not produce much, the company preferring to wait for better prices. In California, however, there was a larger production than in 1892, Messrs. Millar, Brooker & Co. having operated under lease a mine at Hollister, in San Benito County, which produced about 250 tons of ore, yielding 100 tons of refined metal. At the present time the Big Creek and Sutherland mines are closed down. Some promising discoveries of antimony were made during the year in South Dakota and Utah, but with the present high cost of transportation and low prices for the metal these deposits cannot be developed.

Other Countries.—In Europe, Portugal and the countries adjoining the Mediterranean are the principal producers of antimony ore. The most important mines (Gondomar, Lixa, etc.) of Portugal are situated near Oporto. Their ores are frequently gold-bearing. There are no recent mineral statistics published for this country, and it is therefore impossible to state its present production of antimony ore. The output in 1881 was 880 metric tons, in 1885 it was 2060, and in 1889, 1509 tons. The average since that time has been probably about 2000 tons per annum. Spain produces a few hundred tons of ore each year, chiefly from the Salamea de la Serena, in the province of Badajoz. In Italy, kermesite, or red antimony ($2Sb_2S_3$, Sb_2O_3), is mined in Tuscany, near the town of Pereta. Extensive deposits are said to occur at Allchar, in Macedonia, and near Podrynia, in Servia. The mines of Germany are no longer productive, their output having fallen from 189 tons in 1878 to 5 tons in 1885, since which time it has not exceeded 2 tons per annum. The production of the United Kingdom also has become insignificant. Austria and Hungary produce together about 1000 tons of ore per annum, the chief mines of the former country being situated on the Moldau River, in Bohemia, and in Styria, while those of Hungary are at Magurka and Kremnitz, the stibnite of the latter place being auriferous. France has become the largest producer of antimony in the world since 1889, her present output exceeding 5000 tons per annum. The French mineral is derived chiefly from Corsica and Auvergne (Puy-de-Dôme, Cantal, and Haute-Loire), while small amounts are also turned out from the other departments, including L'Ardèche, La Corrèze, Le Gard, La Lozère, and La Vendée. Algeria formerly made a considerable output, chiefly from the mine Haminat, which produced a rich oxidized ore, but work there was suspended in 1884 on account of legal difficulties. Antimony ore is also found at Sousa, in Algeria. Important deposits of antimony ore occur in Asia Minor (whence it is exported through the port of Smyrna), in Servia, and in Macedonia. The exports from the last mentioned country were 425 tons in 1892, against 210 tons in 1891.

PRODUCTION OF ANTIMONY ORE.* (IN METRIC TONS.)

Year.	Austria.	Canada.	France.	Hungary. (*a*)	Italy.	Japan.	Macedonia.	N. S. Wales. (*b*)	New Zealand.	Queensland.	Spain.	United States.	Victoria.
1880	202	41	1,781	583	540	......	....	....	61	... .	11	....	......
1881	187	34	2,089	767	600	394	....	....	2	361	14	....	......
1882	509	328	1,359	734	1,450	2,504	....	....	30	255	30	....	.....
1883	495	168	1,059	613	2,027	2,407	....	382	31	535	45	....	......
1884	306	491	658	490	1,714	1,492	....	441	......	760	1,095	....	192
1885	180	770	536	687	2,887	2.686	....	298	677	71	150	....	......
1886	393	675	247	191	1,738	2,416	....	277	63	112	8	......	......
1887	391	584	341	238	848	1,566	....	171	136	....	322	......	......
1888	353	345	789	198	507	1 484	....	193	382	....	440	... ..	......
1889	343	55	2,229	174	563	1,944	353	225	501	59	456	240	4.6
1890	770	27	4,962	224	891	3,224	364	1,043	523	175	*c*824	327	132
1891	333	10	5,316	......	782	2.286*c*	210	930	421	220	*c*856	635	67
1892	97	.. .	5,000*e*	853	621	2,500*e*	425	740	370	26	*c*563	744	299
1893	......	.	.. .	......			. ...	. ..	....	....	....	......	......

* Borneo and Portugal produce large quantities of ore, but no continuous returns can be obtained. Borneo produced in 1881, 1882, 1883, respectively, 1886, 1870, and 1383 tons. Portugal in 1881, 1885, and 1889, respectively, 880, 2060, and 1509 tons. In 1892, 286 tons were exported from Peru. (*a*) Does not represent the total production, as most of the ore smelted is not included. (*b*) Ore and metal. (*c*) Fiscal year. (*d*) P vious to 1884 the total production was 11,183 tons.

A few hundred tons of antimony ore were formerly produced annually in New Brunswick and Nova Scotia, Canada, but these mines are no longer worked. Borneo and Japan are large producers, the shipments of liquated sulphide from the two countries amounting to between 3000 and 4000 tons per annum. The most important mines in Japan are found on the islands of Amakusa and Shikoku, while in Borneo the principal mine is at Bidi, in Sarawak. Antimony is also mined to a small extent in the Punjab (British India), and at Ackoï, in Tonquin. The output of antimony in Australia is very irregular. The ores of these colonies are frequently gold-bearing, and their production will doubtless increase very largely when some satisfactory process for their treatment is devised.

Preparation of Antimony Ore.

Low-grade stibnite ores are often concentrated by liquation before shipment to market, which is easily accomplished through the ready fusibility of the mineral. The process is best carried out on the system used at Ramée, in La Vendée, where the ore is placed on the sloping hearth of a reverberatory furnace, the molten sulphide draining out of the ore and flowing to the lowest point of the hearth, whence it runs through a channel to a pot placed outside the furnace. The concentration of antimony sulphide ores by liquation is a wasteful process, and it has been frequently proposed to substitute mechanical dressing for it. The latter operation is attended with difficulty, however, on account of the character of the ore. The mineral, which is very brittle, is usually disseminated in fine, needle-like crystals in a hard quartzose gangue, so that in crushing it is concentrated in the fines, which, of course, are the hardest to dress. Moreover, the needle-like crystals into which the mineral breaks make it difficult to size the crushed ore properly by screens. The mechanical dressing of antimony ores has been neglected on account of these circumstances.

Market for Antimony Ore.

The market for antimony ore is governed by the London quotations for the metal or regulus. The natural sulphide is the principal mineral, having replaced to a great extent the liquated sulphide, or crude antimony, which was formerly a common product, especially from the very distant producers of Japan and Borneo.

Natural sulphides with 50% antimony and over are considered to be first-class ore. The second class consists of ore containing between 30% and 50%. An ore with less than 30% is considered very poor, and is not easily sold. Oxidized ores, generally less rich than the sulphide ores, and more costly and difficult to reduce when they are treated alone, bring lower prices. The value of an ore is also affected by the impurities which it may contain, arsenic and lead, even in a very small proportion, reducing it considerably, while pyrites is also harmful, although less so.

During the past five or six years the amount of oxidized ores brought to market has much increased, a large quantity of ore with 35% to 40% antimony having been shipped from Smyrna. Antimony ores are sometimes sold in England directly to the smelters, but they are usually disposed of through brokers. The ore is paid for according to its metal contents determined by a fire assay, which is analogous to the method of smelting employed. The ordinary terms of sale are as follows: Payment 14 days after the arrival of the mineral at the works; "good weight" of 12 lbs. per long ton, or 5.3 kilograms per metric ton; 2.5% discount for cash. The smelter also deducts for sampling and weighing the ore, etc., a sum which is usually about 30c. per ton. The price paid for the ore is, of course, based on its grade and the value of the metal at the time. With regulus at £38 to £38 10s. per long ton (2240 lbs.), as at present, ore assaying 50% antimony is worth £10 10s. and £11 per ton in London. The range of variation in the price paid for ore is illustrated by the terms of a contract made in 1887 between the New Zealand Antimony Company and Messrs. Cookson & Co. for a period of five years.* The price schedule was fixed thus: £10 per ton for 50% ore, with an increase of 4s. for each unit over 50, this price corresponding to a quotation of £34 per ton for regulus. For each increase of 10s. per ton in the value of regulus over £34 the price of a ton of ore was to be increased 2½s., and for each decline of 10s. in the value of regulus below £34 per ton the price of the ore was to be 5s. per ton less. When the price of regulus fell to £30 per ton, therefore, 50% ore brought only £8 per ton. A rise in the price of regulus to £40 made the ore worth £11 10s. With regulus at £50, ore brought £14; at £60 for regulus, £16 10s.; at £70 for regulus, £19; and at £80 for regulus, which was the maximum reached in the latter half of December, 1889, the value of 50% ore was £21 10s. per ton.

The French smelters, whose business has hitherto been less important than that of the English, have purchased ores in a less systematic manner, their offers being governed by purely local circumstances and their immediate needs rather than by the general condition of the market. Since 1889, however, notable progress has been made in the establishment of the business on a more stable basis, and regular scales like those used in England have been adopted.

Various formulas have been devised for arriving at the value of antimony ore. One in common use is the following:

$$p = \frac{t}{100}\left(1 - \frac{1}{a}\right)(c - f).$$

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* *London Mining Journal,* Dec. 10, 1887.

In this formula p represents the value of 1000 kilograms, or one metric ton of mineral; $\frac{t}{100}$ is the tenor of the ore determined by fire assay; $\frac{1}{a}$ is the loss in smelting, a being a number greater than unity; c is the value of regulus in francs per metric ton; f is the cost of smelting and the profit of the smelter per ton of regulus. The loss in smelting may be calculated as 10% of the metallic tenor of the ore, and the cost of smelting at 350 to 500f. per ton of metal produced, varying according to local circumstances. This formula is, of course, applicable to calculating the value of antimony ore in either English or American money by substituting the equivalent of francs, remembering always that the result arrived at is for a metric ton of mineral. In the case of English smelters the value of f should be calculated at £14 to £18. In calculating the loss the following schedule would be very advantageous to the smelter: Nine per cent. of the dry assay for ores with 55% Sb or more; 10% for 50 to 55; 11% for 45 to 50; 15% for 40 to 45; 18% for 35 to 40; and 20% for ores assaying less than 35% antimony.

ANTIMONY SMELTING.

The principal centers of the antimony smelting industry are in England and France. The chief concerns engaged in the business in the former country are Messrs. Cookson & Co., of Newcastle-on-Tyne; Hallett & Fry, Johnson, Matthey & Co., Limited, and Pontifex & Wood, all of London. The brand of the first mentioned firm is considered superior to the others, and its products bring a higher price. It is claimed, however, that this metal is in no way superior to the best of the French product. The antimony smelting industry in France is of long standing, there being smelters at Clermont, Riom, Orléans, and Limoges at the beginning of the century. At the present time, however, there are only three works of importance in operation, viz.: that of MM. E. Beau at Alais (Gard), and those of Emanuel Chatillon and V. Giraud at Brioude (Haute-Loire). The works at Alais treat ores imported from Corsica, Italy, and Algeria by the method of precipitation by iron. The works at Brioude treat French ores especially, either by the iron method or by roasting and reduction of the oxide.

Most of the ore produced in Australia is shipped to England for reduction. New South Wales, however, exports a small amount of metal, which is produced chiefly in the Hillsgrove district, where there are a few furnaces in operation.

There are two important producers of antimony in Bohemia, who treat ores mined in that kingdom and also ores brought from Hungary. These are the Mileschauer Berg- und Hüttenwerks-Actiengesellschaft, operating at Schönberg and Proutkovitz, and Herr Emil Pollak, at Příčov. The production of metal in Austria amounts to about 200 tons per annum, while from 250 to 350 tons per annum are turned out in Hungary. A part of the antimony ore produced in Italy is smelted at a works in Florence, which is the only one in the kingdom. Its production is small, amounting to only about 200 metric tons per annum.

Antimony ore mined in New Brunswick was formerly smelted at the works of the Brunswick Antimony Company, near Boston, Mass. These have been idle for several years, however, owing to the failure of the company to secure sufficient supplies of ore. The United States Antimony Company, which controls mines in Arkansas and Montana, has small smelting works in Philadelphia, but they have been idle since 1890 on account of the cost of bringing ore from the mines with the present transportation facilities. The only antimony smelting works now in operation in the United States are those of the Mathison Smelting Company and Millar, Brooker & Co., at San Francisco, which draw ores from the Pacific States and Territories, chiefly from California and Nevada. The capacity of these works is about 700 tons of refined metal per annum.

METALLURGY OF ANTIMONY.

Antimony ores are usually smelted by the roast-reduction process, or by precipitation by iron. In the former the sulphide is roasted oxidizingly in reverberatory furnaces, the desulphurized product being then reduced with charcoal in crucibles. Oxidized ores may be reduced directly in the same manner. In precipitation by iron the sulphide ore is melted with wrought-iron scrap (old tin plate is often used for this purpose), calcined salt-cake, and charcoal. The sulphide of antimony is decomposed by the iron with the formation of metallic antimony and sulphide of iron; the metal obtained is remelted with soda two or three times in order to eliminate the arsenic and other impurities. Crude antimony is also purified by melting with antimony oxide, which oxidizes the iron and sulphur contained in the metal, being itself reduced in the same proportion. A full description of the English process of antimony smelting is to be found in THE MINERAL INDUSTRY, Vol. I. (1892), p. 23.

Mons. P. L. Burthe, in a paper on "The Sale of Antimony Ore," in *Annales des Mines*, August, 1892, pp. 163–191, from which much data concerning the antimony industry in this article are taken, makes the following statement of the cost of producing antimony in a French smeltery, working on 50% ore six days per week with three furnaces, and producing at least two tons of refined regulus per week: Labor, smelters, refiners, etc., 75.87f.; crucibles, 27.36f.; coke, 34.83f.; castings, 31.10f.; old iron, 41.05f.; cleaning ingots, etc., 18.66f.; repairs to furnaces, 6.02f.; molds and tools, 6.40f.; weighing and cost of shipment, 4.77f.; transportation by wagon and various expenses, 2.40f.—total, 248.53f.

Several wet processes for the treatment of low-grade antimony ores, especially those which are gold-bearing, like the Australian and Portuguese, have been devised recently, the more important of them being electrolytic. The following summary includes most of those which have been described in the technical periodicals of the past two or three years, none of them having come yet into practical use on a large scale:

a. Smith & Hargreaves dissolve the sulphide of antimony in hot chlorhydric acid and precipitate the antimony by iron or zinc. According to other methods, basic chloride of antimony is precipitated from the chlorhydric acid solution by water or by electrolysis.

b. Lyte roasts antimony-bearing lead, silver, and copper ores chloridizingly, condenses the antimony vapor in a solution of salt, and precipitates the metal from the solution by iron or zinc. This process requires complicated condensation apparatus.

c. Borchers leaches the ore with a solution of sodium sulphide and precipitates the antimony electrolytically.

d. Sanderson electrolyzes plates of gold-bearing antimony in a solution of antimony oxide with sodium chloride, whereby the antimony at the cathode is dissolved and is then precipitated in small scales, while the gold is separated.

e. Kipp dissolves the ore in a solution of an iron salt, preferably a haloid salt, according to the following reaction:

$$2Fc_2Cl_6 + Sb_2S_3 = 2Fe_2Cl_4 + Sb_2Cl_4 + S_3.$$

The solution is then electrolyzed, whereby metallic antimony is precipitated.*

USES.

Antimony is used chiefly in the form of alloys with other metals, an admixture of antimony in general rendering metals more lustrous, hard, and brittle. For instance, the alloy of antimony and lead containing 86.5% lead and 13.5% antimony is four times as hard as pure lead, while that containing 64.14% antimony is 11.7 times as hard as lead. This property is made use of in type metal, which is an alloy of lead, antimony, and bismuth, containing from 17% to 20% antimony. Other important alloys of which antimony forms a part are britannia metal (10% antimony and 90% tin), pewter (89.3% tin, 7.1% antimony, 1.8% copper, and 1.8% bismuth), and argentine (85.5% tin and 14.5% antimony), which is sometimes used for tableware. Antimony also forms a part of anti-friction metals employed for machinery.

A new series of alloys of antimony has been discovered and described during the past year.† These are alloys of antimony and aluminum, with which, in opposition to the general belief, it has been found that antimony combines in all proportions and at a comparatively low temperature. Aluminum-antimony alloy containing less than five per cent. antimony is greatly superior to aluminum in hardness, tenacity, and elasticity, and is at the same time very malleable. It is not so white as pure aluminum, but gives a much clearer and more silvery note when struck, and resists atmospheric corrosion better. If the percentage of antimony be raised, the hardness increases, but tenacity and elasticity diminish, and when the proportion of antimony exceeds 10%, the alloy crystallizes in brilliant laminæ. The melting point and the ease with which moist air acts on the alloy increase with the percentage of antimony present, and attain a maximum when its composition is: Aluminum, 18.37%; antimony, 81.63%. This alloy appears to be a true aluminum antimonide, corresponding to the formula $Al_2\ Sb_2$. It forms a gray mass possessing an iridescent luster, and showing a grayish-black crystalline fracture on breaking. Its melting point appears to exceed that of soft steel, a remarkable fact considering the comparatively low fusing points of its components. The alloy is not attacked by dry air at ordinary temperatures. At high temperatures antimony slowly volatilizes, and in presence of air the aluminum is oxidized. Under the influence of moist air or water,

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* Hering, *Dingler's Polytechnische Journal*, 1892, 286, p. 287.

† D. A. Roche, *Moniteur Scientifique*, 1893, pp. 269, 270.

especially at more elevated temperatures, the alloy gradually crumbles to a black powder, and antimony hydride is given off. Caustic alkalies and hydrochloric acid attack the alloy with great energy. If the percentage of antimony be increased still further, the fusing point and corrodibility of the alloy again rapidly diminish.

According to M. Roche, from whose paper these data are taken, aluminum-antimony alloys readily combine with other metals forming complex alloys, some of which are claimed to be susceptible of important industrial applications. For instance, aluminum-nickel-antimony or aluminum-tungsten-antimony alloys are remarkable for their great hardness, tenacity, and elasticity; the silver alloys, with or without the addition of nickel or copper, take a very high polish; the alloys with iron, and especially steel, with or without nickel, chromium, etc., possess an extremely fine grain absolutely free from flaws, and are extremely hard and tenacious.

PRODUCTION.

The production of antimony ore and metal in the United States is given in the following table. It will be noted that the figures for the years 1891 and 1892 differ from those given in THE MINERAL INDUSTRY, Vol. I., p. 27. This is due to a different method of compilation. The figures in the column "Metal" of the following table give the production of star antimony at American smelting works, while the statistics for 1891 and 1892 in the previous volume of THE MINERAL INDUSTRY gave the total amount of antimony contained in ore produced in the United States, which was estimated from the average grade of the shipments from the mines, of which a part was exported to England. The total amount of antimony contained in the ore produced in the United States in 1891 was 910,000 lbs.; in 1892, 956,000 lbs.; and in 1893, 600,000 lbs.

UNITED STATES: PRODUCTION AND IMPORTS OF ANTIMONY ORE AND METAL.

Year.	Metal.				Ore.			
	Production.		Imports.		Production.		Imports.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1880	100,000	$10,000	2,019,389	$265,773	....	....	25,150	$2,349
1881	100,000	10,000	1,808,945	253,054	....	....	841,730	18,199
1882	120,000	12,000	2,525.838	294,234	....	....	1,114,699	18,019
1883	120,000	12,000	3,064,050	286,892	....	....	697,244	11,254
1884	120,000	12,000	1.779,337	150,435	....	....	231,360	6,489
1885	100,000	10,000	2,579,840	207,215	....	....	215,913	7,497
1886	70,000	7,000	2,997,985	202,563	....	....	218,366	9,761
1887	150,000	15,000	2,553,284	169,747	....	....	362,761	8,785
1888	200,000	20.000	2,814,041	248,015	....	....	68,040	2,178
1889	230,000	28,000	2,676,130	304,711	530,000	$15,900	146,309	5,568
1890	258,000	40,756	3,315.659	411,960	720,000	21,600	611,140	29,878
1891	556,000	47,007	3,258,701	388,850	1,400,000	45,500	1,433,531	36,232
1892	400,000	36,000	3,950,864	392,761	1,700,000	51,000	192,344	7,338
1893	700,000	63,000	....	....	1,700,000	41.000	116.495	4,753

The statistics of the production of metal in the above table for the years previous to 1892 are from THE MINERAL INDUSTRY, Vol. I; those for 1892 and 1893 are from direct returns from the producers. The statistics of the production of ore for 1889 and 1890 are from the *Mineral Resources of the United States*; those for subsequent years are from direct returns from the producers.

A large amount of antimony enters the market in the form of hard lead, or lead bullion, containing from 15% to 20% antimony, which is not reckoned in the production of antimony proper. This product is turned out in considerable quantity by all of the lead-refining works. Thus in the United States the production of hard or antimonial lead in 1890 was 4896 tons of 2000 lbs., while in 1891, 1892 and 1893 it was 5105 tons, 5805 tons and 5283 tons respectively,* the antimony contents of the same years being estimated at 832 tons, 868 tons, 987 tons and 898 tons respectively. This is not included in the figures of the production of antimony in the United States in the preceding table.

The production of antimony regulus in the United States has been increasing to such an extent during the past three years that there is promise that it will become an important branch of the metallurgical industry in the United States. The falling off in the output in 1893 was due entirely to the prevailing financial depression, and a revival in business will doubtless be followed by an increase in the production of antimony. The Mathison Smelting Company (formerly Star & Mathison) of San Francisco, which has been engaged in antimony smelting for twenty years, now proposes to erect works in the East, probably in New York. This company produces the U. S. brand of regulus, which ranks among the standard brands of the metal, analyses showing from 99.65% to 99.85% antimony.

The Idaho Antimony Company of Kingston, Idaho, started its newly erected dressing works in 1893, and experimented with its smelting furnace, but the latter did not prove satisfactory, and in the Autumn work at the mines was suspended for the winter months. About 250 tons of ore assaying 30 per cent. antimony, and valued at $20 per ton, were taken out of the mine in the course of development work, but none was shipped or sold; the production in the previous year was about 50 tons, also valued at $20 per ton

AMERICAN ANTIMONY MARKET IN 1893.

At the beginning of the year Cookson's was selling for 11@11¼c. per lb., L.X. for 10½c., and Hallett's for 10¼c., while at the close the respective figures were 9¾@10c., 9½c., and 9c., making the decline from 1 to 1¼c. per lb. Prices commenced to decline very early in the year, but did not go down rapidly, as the consumption was good; but later on, when that fell off and in fact almost ceased, the pressure upon the market from English producers quickly caused a drop to a lower level, at which contracts were entered into by many. However, although holdings here at the close of the year are very moderate, the market shows no signs of improving.

Contrary to expectations, the American production made no progress, and the supplies received occasionally from California continue to be very small; indeed, there is little encouragement now offered because of the proposition to do away entirely with the duty of ¾c. per lb. on imported regulus. The importations in 1893 were mostly of Cookson's and Hallett's, the figures for L.X. showing a great falling off, while the quantities of Japanese and Italian antimony were very small.

AVERAGE MONTHLY PRICES OF ANTIMONY IN NEW YORK, IN CENTS PER POUND.

		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1891	Cookson's	.19	.18	.17½	.17⅛	.16	.14½	.13⅝	.12	.11⅝	.13¼	.16	.16¼	.15½
	Hallett's	.16½	.16¾	.16	.15½	.14¾	.13	.12	.10⅝	.10	.11	.12¼	.12¼	.13½
	L. X.	.17⅛	.17	.16¾	.16	.15⅛	.13⅝	.12½	.11⅜	.10⅝	.12	.15¼	.15⅛	.14⅜
1892	Cookson's	.15⅞	.15	.14$\frac{9}{10}$	.15	.15⅛	.14⅖	.14⅕	.13½	.11½	.11⅘	.12	.11½	.13¾
	Hallett's	.14⅖	.11	.10$\frac{9}{10}$	.11	.11½	.11¼	.11	.10¾	.10½	.10½	.10⅝	.10¾	.12⅒
	L. X.	.12⅛	.12⅛	.12½	.12½	.13	.12¾	.12½	.11⅞	.11¼	.11⅕	.11$\frac{3}{16}$	.10⅘	.12
1893	Cookson's	.11	.10¾	.10¾	.10¾	.10⅛	.10½	.10½	.10¼	.10$\frac{3}{10}$	.10¼	.10	.10¼	.10½
	Hallett's	.10¼	.10⅜	.10	.10	.10	.9$\frac{9}{10}$	.9⅞	.9¾	.9⅗	.9¾	.9½	.9¼	.9⅞
	L. X.	.10½	.10⅝	.10⅜	.10¼	.10⅜	.10	.10⅛	.10	.10	.10	.10	.10	.10⅕

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* THE MINERAL INDUSTRY, Vol. I.

The London Antimony Market in 1893.

Antimony opened in January at £42 10s.@£43, and declined during the month to £41 10s. In February there was a fair Continental demand, leading to considerable sales at £40 10s. One of the largest English producers having sold the greater part of his output for three months ahead, a firmer tone became apparent and the value increased 20s. per ton during March. April passed off without any quotable change, but May brought a considerable decline, and, smelters meeting the market more freely than for some time past, £38 10s. was at length recorded. The next two months developed no new feature deserving of special mention, and August was marked only by still greater dullness and a fall to £38. Between this and £38 10s. the value rose until November, when £37 10s. was reached. We close at this figure, which is less than half the value ruling early in 1890, when the first rise of 1889 reached its climax.

VALUE OF ANTIMONY REGULUS IN LONDON.

Year.	Low.	High.
1875	£50	£59
1876	55	69
1877	48	50
1878	48	50
1879	50	70
1880	£60	£75
1881	55	60
1882	42	55
1883	36	40
1884	40	45
1885	£35	£39
1886	29½	35
1887	30	40
1888	39	50
1889	45	75
1890	£70	£76
1891	40	72
1892	43	52
1893	37	43

Antimony Mining and Smelting in Japan.

The most important antimony mine in Japan is at Ichinokawa, in Ojoinmura, Nii-gori, Iyo Province, Ehime Prefecture, on the island of Shikoku. It is a little more than two miles from the town of Saijo and three miles from the seacoast. The mine is said to have been discovered eleven centuries ago, but there are no records of early operations in it. At present it is worked by Kawabata Kumasuke and fifty-eight other persons as a private concern.

The country rock of the district in which this mine is situated is graphitic sericite schist belonging to the Archæan. The ore deposits occur in the form of veins, of which there are three principal ones. Two of them, the Tsurubi and Kamebi, are parallel to each other, striking east and west, and dipping south at an angle of about 75°. They often unite, in which case they are very wide and rich. The third principal vein, known as the Yokobi, also strikes east and west and dips south, but at a moderate angle, never more than 38° and sometimes only 10°. It is thought that the Yokobi vein intersects the Tsurubi and Kamebi veins at a greater depth than has yet been explored. These veins vary from one inch to three feet in width. There are also many other workable veins in the district.

All the veins are worked by shafts and levels, the former being from 50 to 150 ft. deep, and the latter from 300 to 2000 ft. long. The cost of mining averages 5.877 *yen* ($5.88) per 100 *kin* (60 kilos) of ore.

The ore, which is stibnite of high grade, is smelted at works on the sea-coast at Sanchoba, three miles from the Ichinokawa mine, and only half a mile from Saijo. The method of smelting employed is very simple. A crucible with a small hole bored through its bottom is set upon another crucible. The upper one is filled with powdered ore covered and heated from below, coal being used as fuel. The sulphide of antimony in the ore is melted and drains away from the gangue into the lower crucible, whence it is ladled into molds. The monthly production of ore averages 200,000 lbs., and that of antimony sulphide from 150,000 to 160,000 lbs. The sulphide of antimony is reduced to metal and shipped in boxes to Osaka and Kobe, which are the principal markets for the product, both being within 200 miles of the mines. The cost of smelting is 0.385 *yen* (38½c.) per 100 *kin* of antimony sulphide, and 2.5 *yen* ($2.50) per 100 *kin* of refined antimony.*

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* Wada Tsunashiro, *The Mining Industry of Japan*, 1893, p. 223.

ARSENIC.

By William Thomas.

Occurrence.—Arsenic is a widely diffused element, although it does not occur in many localities in commercially payable quantities. It has sometimes been found native on a small scale, for example at Nagyag, in Transylvania, where the occurrence of metallic arsenic on the lower faces only of crystals of dialogite has been used as evidence in favor of the sublimation theory.* Arsenic occurs in combination with sulphur in realgar (As_2S_2) and in orpiment (As_2S_3). It is frequently found in combination with nickel or cobalt, and still more frequently as a metallic arsenide combined with sulphides of nickel, cobalt, silver, copper, or other metals, particularly with iron in the well-known mineral mispickel, or arsenical pyrites. Arsenic also forms a series of arseniates with nickel, cobalt, iron, copper, lead, and the alkaline earths. These are not of much commercial value, but some of the iron and copper arseniates, especially the latter, found in the old copper mines of Cornwall are treasured to-day in the best mineral collections as unique. The olivenites, liroconites, etc., from old Wheal Gorland and Unity mines in Cornwall, a splendid collection of which may be seen in the Robert Hunt Museum of the Mining Association and Institute of Cornwall, are highly valued by mineralogical connoisseurs.

Sources.—Attempts to produce arsenic of late years outside of Cornwall and Devon have generally failed after a short trial. For many years certain quantities have been produced in Germany and Austrian Silesia, but the bulk of the production has been, as at the present time, from the mines of Cornwall and Devon. The sources whence arsenic is derived in the two counties are:

1. As a side-product in the treatment of the ores from (*a*) tin mines, (*b*) mines where tin and copper ores are associated, and (*c*) mines where tin and copper and wolfram ores are associated.
2. Arsenic is produced from waste heaps in some exhausted copper mines treated for the arsenic they contain.
3. Some mines are worked solely for arsenical pyrites which is sold, concentrated but not roasted, to the arsenic refiners.
4. Some mines are worked for arsenical pyrites which is concentrated and manufactured into commercial white arsenic on the mine.

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* Phillips, *Ore Deposits*, p. 81.

A description of the method adopted in a few selected cases will best illustrate arsenic mining and production at the present time.

Levant Mine, St. Just, Cornwall.—This is one of the mines near the Land's End, and is attractive to tourists on account of its being situated on the precipitous Cornish cliffs, and for its workings, extending several hundred fathoms under the Atlantic. The mine is well equipped, and its dressing-floors are among the best laid out in Cornwall. The lodestuff, on its arrival at the surface, is tipped over a screen of iron bars which separates "rocks" from "smalls." The latter are conveyed by inclined tramway at once to the stamps, and the former are hand selected, one portion being sold as copper ore and the remainder sent to the stamps as tin-stuff. The vein-stuff is an intimate mixture of tinstone with yellow and other ores of copper, and sulphurous and arsenical mundic, with the usual gangue of the district. The tin concentrates from the stamps dressing-floors are treated in four Brunton's calciners, the fumes from which are conducted through an extensive series of zigzag flues into a large depositing chamber, the roof of which is supported on pillars, and thence through further flues into the stack. The arsenic, deposited as As_2O_3 with the flue dust in zigzags and the chamber, is sold as crude arsenic to the arsenic refiners, the monthly produce of this mine being from 15 to 20 tons, worth about £6 per ton.

Devon Consols, Tavistock, Devon.—Mining operations were commenced here in 1844. As a copper mine Devon Consols was a great success, over £1,000,000 having been divided in profits within twenty years. Hoping from the presence of occasional tinstones that tin might be found underneath the copper, as in several of the leading Cornish mines, the executive put down one of the main shafts to the 300-fathom level, but up to the present time tin has not been discovered in payable quantities. The lode has, however, always yielded arsenical mundic in abundance, and it has been ascertained that immense heaps of waste or deads at surface from the old copper lodes will produce two or three per cent., or even more, of As_2O_3. Consequently a portion of the old copper plant has been fitted up to treat this waste material for arsenic. Tram roads have been laid down to convey the stuff to a set of 3 ft. 6 in. diameter Cornish crushing rolls, by means of which it is crushed wet through 12-mm. (about ½-in.) holes. The crushed stuff is separated into three classes, which, after concentration by jigging, run respectively about 25, 30, and 35% arsenious anhydride. A classifier separates the fine stuff, which is afterward buddled, making a fourth and lower class of concentrate. These concentrates are treated in Oxland's revolving cylinder calciner or in flat furnaces, the crude arsenic being deposited in the flues and chambers in the usual way and afterward refined.

Gawton Mine, Tavistock.—No better example of an arsenic mine exists in the two counties than Gawton. The set is situated on the Devonshire side of the river Tamar, about five miles from Tavistock, the river separating Gawton rights from those of Okel Tor mine, which formerly worked the same lode for arsenical pyrites, but has now suspended operations. The engine shaft, in low-lying ground close by the river's edge, has been sunk to the 105-fathom level vertically, and thence to the 117 on the course of the lode. The strata under the river Tamar are so impervious to water that the average rate of the Cornish pumping engine is only two strokes per minute. The lode varies considerably in width, in one place being 40 ft. wide, and it sometimes yields 20 to 30 tons of arsenical pyrites per fathom. The arsenical pyrites is often associated with a little copper pyrites. This class of ore is selected and sold for copper after it has been separately roasted for arsenic. The present output of the mine, which is limited, pending extensive additions and improvements now being made to the plant, is from 800 to 900 tons per month, averaging 10½% arsenious anhydride, As_2O_3. The ore containing copper of value is selected, the remainder is put through a Blake stonebreaker indiscriminately, and crushed by a set of Cornish rolls through a 12-mm. screen. Then it is roasted in flat furnaces or in Oxland's calciner. This is, however, a temporary arrangement only. As soon as the plant now approaching completion is in operation, all the produce of the mine will be conveyed by means of an inclined tramway to the top of the hill. Here a stonebreaker and set of Cornish rolls will crush the stuff to about ¼-in. size, and a set of jiggers will produce three separate classes of concentrates, as at Devon Consols, so that the average percentage of the stuff before roasting will be about 30% arsenious anhydride, instead of 10½%, as now, a difference the economical advantages of which are obvious.

Roasting of the Ores.—The roasting of arsenical ores in Cornwall and Devon is performed by means of (*a*) flat furnaces, (*b*) Oxland's calciner, (*c*) and Brunton's calciner.

(*a*) *Flat Furnaces.*—These are usually constructed in pairs, a parting brick wall 1 ft. 6 in. thick longitudinally separating the two single furnaces. The external dimensions of the double furnace are 24 ft. by 16 ft., so that, allowing for the parting wall of 1 ft. 6 in., and two external walls of 9 ft. each, the single furnace is 6 ft. 6 in. wide internally. The arch commences at 7 ft. above the bed and springs 9 ft.; thus giving a maximum height of roof over the bed of 1 ft. 4 in. The fire is 4 ft. by 2 ft., and is separated from the bed by a bridge of brickwork raised 9 in. This leaves the interior length of the bed about 20 ft. There are five or six rabbling holes to each furnace, through which the ore is worked by hand gradually from the back to the fire end. The feed is through a hopper at the back, and the discharge immediately behind the fire-bridge. Each double furnace will treat effectively from 8 to 10 tons of ore per day of twenty-four hours, and will consume 3 cwt. of coal per ton of stuff roasted. Six men are required for each double furnace, working two at a time in eight-hour shifts. These men are, in most cases, paid by the ton, the price ranging from 3s. to 3s. 6d. per ton of ore, a rate which enables them to earn from 4s. to 5s. per day. Samples of the roasted ore are systematically assayed. For any arsenic found in the sample above the fixed minimum permitted, the men are subjected to a reduction of rate. This insures good work being done.

(*b*) *Oxland's Calciner.*—A shell of an ordinary Cornish boiler 24 to 30 ft. in length and 5 to 6 ft. in diameter may easily be converted into an Oxland calciner by lining the shell with fire brick and inserting old iron plates at intervals between the rows of fire brick so as to project a little way toward the center, and so facilitate the tumbling of the stuff when the tube is slowly revolved. The axis is slightly inclined, so that by feeding through the elevated end of the tube the material finds its way down the tube toward the fire end, and is discharged behind the fire, as in the case of the flat furnace. An Oxland calciner will heat from 20 to 25 tons of 15% ore per day of twenty-four hours, and will consume from 10 to 20 lbs. of coal per ton of ore treated. The quantity of ore treated, as well as the amount of coal required per ton, naturally varies with the quality of the ore. In roasting 20 to 30% ore the sulphur is present in such quantities that only a small amount of coal is required. Three men and three boys are required to operate the calciner, working one man and one boy together in eight-hour shifts. The contract price usually paid for the labor in running the Oxland calciner is 10d. to 1s. per ton of ore treated.

(*c*) *The Brunton Calciner.*—This consists of a convex circular bed 15 or 16 ft. in diameter, paved with fire brick and revolved horizontally from five to ten revolutions per hour, the speed depending upon the character of ore to be treated. Two fires are placed side by side, so that the current of hot air conveying the products of the combustion of the coal from the fires may be directed diametrically across the revolving bed. From iron girders, built in the fire-brick arch which is turned over the bed, fixed cast-iron plates, locally known as "flukes," are suspended to within a short distance of the bed. These are fixed at an angle of about 45° to the radius of the bed, so that as the bed in its revolution brings the hot ore against the fluke, the latter plows the ore outward. The feed being from a hopper at the center, this continual plowing results in turning the ore over and over outward till it falls over the perimeter of the bed underneath which it is discharged. The speed of the bed regulates the rate of delivery. For average arsenical ores each Brunton's calciner will turn out four to five tons per day of twenty-four hours. Each calciner requires one man working 12-hour shifts, or two men in all, who are paid about 2s. per ton of ore treated. The coal consumed averages 1½ to 2 cwt. per ton of ore.

Something may be said for and against each class of furnace. The flat furnace is easily and cheaply constructed and repairs are of a simple and inexpensive nature. A uniform temperature is easily maintained, and the operation is well performed. On the other hand, the labor and fuel are higher than the Oxland or Brunton. The Oxland is faster and is cheaper by the ton both in labor and in fuel, but repairs are more costly; wear and tear are appreciably more; the tube requires two or three horse-power to drive it, and it is more difficult to maintain a uniform temperature and an even draught. Further, the force of the draught is often such that a greater than the average amount of fine, solid matter goes off with the fumes and gases into the flue, where it is deposited as flue dust with the arsenious anhydride. The Brunton calciner undoubtedly does the most uniform work, but it is slow. It requires scarcely any looking after. As a rule, the selected or better class ores are treated in the Brunton. For example, those portions containing copper ores are usually treated in the Brunton calciner, and the roasted stuff discharged is sold to the copper smelters for copper. At Drakewalls, and a few other tin mines, the vein-stuff is crushed to about one-half inch size, roasted on Brunton's calciners, and then stamped and dressed in the ordinary way for tin. This, however, is not usual in tin mines. The general practice is to stamp the tin-stuff (which as it is raised averages about 2% tin oxide) sufficiently fine to pass through a No. 36 (Cornish gauge) grate, and concentrate it up to about 15% or 20% tin oxide before roasting.

In some of the mines the waste from the furnaces forms an interesting, but at present unsolved, problem. Very little practical attention has been bestowed upon the treatment of this waste, although it has formed a subject for much discussion. There is quite a variety of substances in some of the waste. Invariably there is from 1% to 2% of copper and a few pounds of tin to the ton. These are often accompanied by from 2 to 5 oz. of silver per ton and traces of nickel and cobalt. Unfortunately, there is too little of either metal to make one keen on experiments; and equally unfortunate, owing to the various means of roasting practiced and the unequal temperature observed, the same pile contains both soluble and insoluble salts of the same metal. Before any serious attention can be given to the waste from the arsenic furnaces, greater care must be taken in roasting and a more uniform system of roasting adopted. The operation has, in the past, been conducted with a view to getting out as much arsenic as possible at a minimum cost, regardless of other matters; and even to this end ways and means have not, perhaps, been very carefully thought out. Arsenic may be easily volatilized at a comparatively low temperature, and if lower but more uniform temperatures were observed, and a liberal supply of hot air, apart altogether from the fire, were introduced directly upon the bed, the writer is strongly of the opinion that (1) a profitably workable waste would result, (2) the arsenic would be oxidized at a smaller expenditure of fuel than now, and (3) the output of the Brunton furnace would be from 50% to 100% more than at present.

Prof. W. P. Blake, at the Montreal meeting of the American Institute of Mining Engineers, in February, 1893, read a paper on his modification of the Brunton furnace, designed especially for the oxidization of sulphur and arsenic in pyritic ores. The principal new feature in the Blake furnace is the introduction of superheated air upon the charge without contact with the fuel, "giving an atmosphere of great oxidizing power and causing the rapid combustion of the sulphur vapor as formed and its removal as sulphurous acid." Existing Brunton furnaces in Cornwall and Devon might easily be modified in this direction and for a small outlay.

The Flues.—The flues in which the crude arsenic or soot is deposited are generally so arranged that, within 100 to 200 ft. of the furnace, the fumes may enter an extensive series of zigzag chambers built of masonry or brickwork. These are usually from 5 ft. to 5 ft. 6 in. high by 3 to 4 ft. wide, and they extend in some cases over 1000 ft. in length. From the zigzig chambers a further length of some hundreds of feet leads to a stack or chimney 60 to 120 ft. in height, through which the gases, etc., make their exit into the air. At Gawton the series of flues through which the products from the furnaces are conveyed makes in all a distance of nearly a mile.

Refining.—The crude arsenic deposited in the flues often contains over 70% arsenious anhydride if the roasting has been carefully performed. The foreign matter, flue dust, etc., is removed by refining; that is, practically by repeating the roasting. The most recently erected arsenic refinery, and by far the best in existence, is that at Gawton. The crude arsenic is trammed from the flues into a dustroom, well sealed, from which it is fed into two pairs of flat furnaces, the construction of which is similar in principle to that of the flat furnaces already described. There are a few small points of difference in detail. The external dimensions of each pair are about 16 by 16 ft.; the maximum height of center of arch over the bed is 1 ft. 6 in., instead of 1 ft. 4 in.; and there are only three rabbling holes to each single furnace. The fuel is a mixture of about equal portions of coke and anthracite, instead of coal. Flat furnaces are invariably used in the refineries. From the furnace the fumes are led through a brickwork hot flue about 100 ft. in length. In this practically nothing deposits except the fine flue dust. The hot flue communicates with a set of twelve zigzag chambers (kitchens), in which the arsenious anhydride in its pure state deposits. These chambers, of substantial brickwork, are built in duplicate, so that by opening or closing an iron door or damper the current may be turned into either set while the other is being cleared. Each chamber in the set of zigzags measures in plan 14 ft. long by 4 ft. wide, and is 7 ft. high. The set of twelve chambers enables the fumes to be conveyed 168 ft. throughout. On leaving these chambers the fumes are conducted direct into the main flue, which receives the current from the roasting furnaces, so that in the rare case of arsenic finding its way beyond the confines of the kitchens, it is sure to be redeposited in the main flues

A peep inside the refinery chambers as the plate-iron doors are being removed preliminary to the clean-up is a grand sight. In the one or two compartments adjoining the hot-flue there is not much arsenic in bulk, but a somewhat spare crop of magnificent crystals covers the interior. On getting into compartments No. 3, 4, and 5, and up to No. 8 or 10, a thick mass of intertwined crystal covers the floor sometimes for two or three feet, or more, in height, while all around the roof and sides of the chambers clusters of brilliant white crystals of arsenious anhydride abound. The chambers are cleared and the contents removed by tram wagon to the grinding room, where the whole of the arsenic is put through an ordinary flour mill, hot or warm, just as it is removed from the kitchens. It falls from the mill into a hopper underneath, whence it is fed directly into barrels, a pair of barrels being filled at the same time on a stand, to which is given an automatic shaking motion to facilitate packing. In this state the white arsenic is ready for sale.

The largest producers have their own cooperage and make their own barrels. Staves and ends, of birch, half an inch in thickness, are imported from Norway, sawn to pattern, and barrels measuring 32 in. high by 16½ in. diameter (the standard size), to contain about 3¾ cwts. of arsenious anhydride, can be made for about 2s. each on the works, inclusive of labor, wood, and iron hoops.

Refining is performed by (*a*) those who control, directly or indirectly, the output of arsenical pyrites from mines that are worked for that ore, and (*b*) those who buy bargains of crude arsenic from mines selling such as a side-product. There are four companies of the (*a*) class at present at work and five of the (*b*) class. Six are in Cornwall, two in Devon, and one in Glamorganshire.

Uses.—Arsenical compounds have acquired notoriety from the circumstance that murderers and suicides have so often successfully resorted to the use of them for the accomplishment of their designs. The terribly poisonous character of many arsenical compounds having so markedly demonstrated itself, it is reasonable to infer that not only the general public, but scientific and medical circles, have become accustomed to avoid as much as possible such dangerous substances and unconsciously to overlook some of the good qualities which arsenic undoubtedly possesses. The general public knows very little of the sources of arsenic supply, of the manufacture of arsenical compounds, or of the properties of the products of the manufacture.

Arsenic forms a series of colors which are extensively—perhaps, in some directions, too extensively—used. Scheele's green is an arsenite of copper, and Schweinfurt green, or imperial green, is an aceto-arsenite of the same metal. Arsenite of potash is used in making mineral green. Yellows, reds, and grays may also be formed by chemical combinations of other elements with arsenic. A considerable amount of the green used to color wall papers was at one time an arsenical green, and probably some wall papers still carry appreciable amounts of arsenic, though to a smaller extent than formerly.

Medicinally arsenic has many good qualities. *Liquor arsenicalis* (arsenate of potash) is employed beneficially in some intermittent fevers, and occasionally in rheumatism and some nervous affections. Even the extremely poisonous anhydride, As_2O_3, is known to be a valuable tonic, and many persons acquire a liking for frequent minute doses of this form of arsenic, from which they derive benefit.

Advantage is taken of the solubility of arsenious anhydride in water to apply its use in different ways. Ten parts of hot water, or thirty parts of cold, dissolve one part of the anhydride. A saturated solution of arsenious anhydride is a good wood preserver and a preventive of "dry" and other rots. In the Cornish mines this arsenious anhydride solution is often used to preserve timber, both underground and at the surface. Carpenters and builders also use it for paying over joists, etc., in new houses. In agriculture arsenic has many uses. Hundreds of tons of white arsenic yearly go to the making of sheep-wash. In the west of England many farmers have found that by dissolving white arsenic in water and placing the solution a few inches deep in a wooden trough about 20 ft. long by 1 ft. 6 in. wide, foot-rot in sheep may be beneficially treated, the sheep being compelled to walk through the solution a few times, and then driven onto dry ground for a short time so that the solution may dry on the feet. Enormous quantities of arsenic have been used in making Paris green with which to kill the Colorado beetle, so destructive to potatoes. The miners in the mining districts of Cornwall and Devon, many of whom have their own potato plots, invariably get their healthiest crops of potatoes in the immediate vicinity of an arsenic stack, owing to the fact that arsenic checks the potato disease or blight. Considerable quantities of arsenic were sent across certain mountainous tracts of country in South America on mule-back and were used for dressing hides of leather prior to export. The arsenic effectually prevents attack from insects on the leather. Arsenic is used in calico printing (white arsenic) as a conveyor or fixer, or both, of aniline colors. It does not enter into the color, but is quite washed out of the calico during the process and goes to waste. Some ten years ago experiments were made to save this waste, but arsenic was so cheap it was not worth recovering under the circumstances. Small quantities of arsenic are used in the manufacture of some varieties of glass, and in mixing with lead for making shot. Arsenic does not, however, make useful mixtures with the metals generally. It usually renders a metal harsh and brittle, as is sometimes seen in the case of tin when a badly roasted parcel of tin ore is taken to the smelters, and a few thousandths of one per cent. of arsenic is sufficient to render gold brittle. From the foregoing remarks it will be seen that arsenious anhydride is the principal form of commercial arsenic. At the present time in Cornwall and Devon other forms are rarely prepared. The bulk of the arsenic is consumed as arsenious anhydride, and where other forms are required, as in the manufacture of colors or the preparation of medicines, those forms are mostly prepared by the parties principally concerned in their application.

It has sometimes been stated that the men employed in the arsenic industry are often subject to blood poisoning and other evils, but this is an exaggeration. Naturally some of the operations can only be conducted by skilled workmen thoroughly acquainted with their work, men who know what precautious have to be taken. Great care is necessary in cleaning out the chambers, in grinding the white arsenic, and in filling the barrels—in fact, in all work where dust may be made to rise. The nostrils are kept plugged with cotton wool in the dusty operations, and the limbs are bandaged or wrapped round in cleaning out the flues. It is a most unusual thing to find employees suffering in any way from arsenical poisoning.

Cost of Production.—That portion of the arsenic production which comes as a side-product from the tin mines may be described as being produced in an accidental way, and it is not easy to place costs against the arsenic from this source. In the absence of arsenical pyrites it is necessary to roast the tin ore. Consequently, in any case the costs of the roasting are incurred. The cost of arsenical pyrites on many of the Cornish lodes is very irregular. At Drakewalls mine, for example, tin has been raised for three or four centuries from a series of veins which may be classed as a stockwork. Near the deepest portion of the present workings, and in the proximity of a large and well-defined vein, arsenical pyrites has been abundant for 20 or 30 fathoms' sinking. There had never been much arsenic before in association with Drakewalls tin, and there are now indications of a falling off again. At the Levant mine the returns of arsenic vary considerably; but, as elsewhere, the process of roasting goes on continually. If much arsenic is present, it forms an asset of some value. If little arsenic be present, that little must be separated from the tin by roasting, or the tin sales will not realize a proper price. A few years ago the crude arsenic obtained in this accidental way by the mines was purchased at a low figure by the refiners, who made a large profit in refining. Of late years, however, there has been such competition among refiners that the prices paid by them for crude arsenic to the mines have advanced so as to leave very little profit at the present time. The principal arsenic producer, Devon Consols, has, during the year 1893, paid satisfactory dividends, notwithstanding the fact that arsenic has been rather low in price of late. (The present price of white arsenic is about £10 per ton, f. o. b.)

The mines worked for arsenical pyrites are at present enabled to obtain a small profit by selling their ores at prices ranging from 15s. to 18s. per ton. It may be concluded that, apart altogether from the arsenic which comes as a side-product from the tin mines, at the present time arsenical pyrites running about 25% to 30% arsenious anhydride is being raised for 12s. 6d. to 15s. per ton by the mines worked for that ore alone, and white arsenic is being produced at a cost of about £9 per ton by the principal producers.

Statistics.—It is not easy to obtain full and reliable statistics. The following table gives the quantity of "arsenic, crude and refined," and of arsenical pyrites, raised in the United Kingdom for the period stated. The only arsenic-producing counties were Cornwall and Devon.

ARSENIC PRODUCTION OF THE UNITED KINGDOM. (IN TONS OF 2240 LBS.)

Crude and Refined Arsenic.					Arsenical Pyrites.	
Year.	Tons.	Year.	Tons.	Value.	Tons.	Value at Mine.
1872	5,271	1884	7,905	£57,841		
1873	5,187	1885	10,040	58,430		
1874	4,219	1886	5,927	32,802	4,918	£7,749
1875	3.783	1887	4,618	32,458	4,364	3,205
1876	4,091	1888	4,624	35,197	5,325	4.240
1877	4,111	1889	4.758	38,260	7,688	7,317
1878	4,464	1890	7,276	60,727	5,114	4,414
1879	4,400	1891	6,048	58,593	5,095	4,370
1880	4,350	1892	5,114	43,686	4,497	4,988
1881	5,150	1893	5,120	44,000	.....	......
1882	5,972					
1883	7,000					

During the year 1893 the only mines in Cornwall which produced arsenic in appreciable quantities were Botallack, Levant, East Pool, South Crofty, Tincroft, Wheal Agar, Callington United, Danescombe, and Drakewalls. These together have produced in the year about 2500 tons of crude and refined arsenic. In Devonshire, Devon Great Consols has been selling about 200 tons of refined arsenic per month in 1893. Gawton is the only other Devon arsenic mine at present yielding arsenic in appreciable quantities, and owing to the important improvements being carried on in the construction of plant and furnaces, the sales have not been so extensive in 1893 as they will be in 1894. The present output at Gawton has already been stated. Taking the two counties together the returns for 1893 are just the same as for 1892. The increase, if any, is a very small one.

In the above excellent paper Mr. Thomas gives with satisfactory fullness the present practice in English arsenic works. The editor has, however, thought it might prove useful to give a few notes from his own experience in the roasting of arsenic ores and the condensation of arsenic fumes under conditions differing widely from those obtaining in Cornwall.

The Canada Consolidated Gold Mining Company, at Deloro, Ontario, about twelve years ago opened a mine and built works for the treatment of gold-bearing mispickel ores of extreme purity, containing about 42% arsenic and 20% sulphur. The gangue is quartz and a little calcspar. The ore was worked exclusively for the gold, of which the mispickel concentrates contain on an average about $75 to the ton. and the arsenic was purely a by-product. In fact, very little of it was refined until after the mine was closed, which event occurred through conditions altogether outside of the value of the ore or its quantity. The ore as milled contained probably an average of 20% mispickel, was crushed dry in Blake crushers and steel rolls, sized dry in revolving screens, and concentrated in water jigs. The works had not been provided with slime concentrators. The ore too fine for jigging was mixed with the concentrates and went to the roasters, and thence to the chlorinating barrels, where the gold was extracted to fully 92% on an average. With this operation we have nothing to do here.

The roasting was carried on in two revolving cylinders which originally were of the Oxland type, lined with firebrick and with firebrick shelves running longitudinally, but experience led to very important improvements, which consisted in substituting for the shelves tile diaphragms 12 in. wide, which met in the center of the cylinder and divided it up longitudinally into four compartments. In the upper end of the cylinder these tile diaphragms were continuous, so that the ore was divided into four equal parts and rolled around in each compartment as it passed from the upper to the lower end of the furnace. When about half the length of the cylinder was reached the several tiles forming the diaphragms were separated by an inch space, so that as the cylinder revolved the ore sifted down from one compartment to another across the current of air passing up the furnace from the fireplace. This formed an ideal roasting furnace, the capacity of which depended solely upon the amount of air which was passed through it, and this air was furnished by a suction fan, placed near the chimney, and was therefore completely under the control of the furnace man. The tiles remained perfectly clean.

This first furnace was about 30 ft. in length and 5 ft. 6 in. in diameter, and from it the ore ran directly through a pipe into a second cylinder, placed lower down, and which was 60 ft. in length and 6½ ft. diameter, and had an independent fireplace and an independent chimney. As the arsenic was nearly all expelled in the first cylinder, the second required only small dust chambers and no condensing chambers. An abundant draft for this cylinder was obtained by the natural draft of the chimney. This cylinder was also divided longitudinally into four compartments. In each furnace the diaphragms commenced only at a distance of three or four feet from the upper end of the cylinder. The space between them and the end of the cylinder was provided with the usual brick shelves, but placed in a spiral, so that they made the upper end of the furnace a screw. When the ore was charged into it, no matter how rapidly, these spiral shelves caught it and worked it back into the cylinder, so that it never fed out over the upper end as it otherwise would have done. This simple device will be fully appreciated by the practical metallurgist, as will also the arrangement of a cylinder into longitudinal compartments; for that was fully demonstrated to more than double the capacity of the furnace with shelves, and it reduced the consumption of fuel by fully one-half. As much as 48 tons of ore have been roasted in twenty-four hours in this plant, with a total working force on each 12-hour shift of one feeder, one fireman, and, during the day shift, one man on the cooling floor.

There is no patent on either of these improvements, or to the use of a suction fan to create the draft, and they are therefore open to the whole profession. They were devised and introduced by the writer.

The fumes from the arsenic furnace passed first into a large and high dust chamber, placed above and at the end of the upper cylinder. Into this dust chamber the raw ore was run through a pipe passing through the side near the top of the chamber, the sides and bottom of which were inclined at steep angles so that both the dust and the raw ore would slide down into the cylinder itself. A lip or apron of boiler plate built into the brickwork of the chamber projected three or four inches into the cylinder, and the ore, together with the dust, was carried back into this far enough to be caught by the spiral shelves and worked in. There was no difficulty experienced in this arrangement, and as it dispensed altogether with the usual feed pipe entering the upper end of the roasting cylinder, it was a great improvement. The dust chamber was very large, so that the velocity of the gases in it would allow the dust to settle quite thoroughly, while it was so hot that none of the fumes condensed there. The gases rose to a height of perhaps 10 or 12 ft., passed over a bridge wall the entire width of the dust chamber, about 12 ft., and entered the first condensing chamber through the top.

The condensing chambers were built on arches. The sides near the bottom were inclined so as to allow the condensed arsenic to run down into the trough forming the bottom of the chamber, and a hole covered with an iron plate was left in the bottom. The partitions between the condensing chambers in the latest design ran up to within a short distance of the top, and the gases flowed over this wall from one chamber to the other across the entire width of the chambers (about 12 ft.). As first built the condensing chambers were divided with a hanging wall across the center with a port near the top at the end of the chamber so that the gases made a vertical and a horizontal zigzag in passing through the chambers. It was quickly found that this was a very bad arrangement, and the hanging walls were cut away, making only a zigzag horizontally for the gases. This was better, but experience amply demonstrated that the ideal condensing chambers are simply comparatively shallow, very wide chambers, with the gases running in an even stream right under the roof or cover, the chamber itself being a dead space in which the condensed fumes collect, and as the sides of the chamber are inclined it is very easy to empty them into a truck or car which is pushed in under the arches on which the chambers stand, a sheet-iron door closing the archway and preventing any escape of arsenic dust. There is no handling or contact of the men with the arsenic while emptying the chambers. No dust comes out in the room, since the fan creates a draft in at the door, even when the chambers are cold.

The first few chambers can be made with heavy walls and brick arch roofs, so that the high temperature is retained in them to prevent the condensation of the arsenic until after the dust is all separated from the fumes. Beyond that point, with the ore of which I am speaking, the quicker the condensation was effected the better. The ore contained no volatile substances except arsenic and sulphur; and the crude arsenious oxide was of very remarkable purity, containing 97.6% As_2O_3. It was therefore found an advantage to use iron plate tops to the chambers, and to make the walls of the chambers as thin as possible and put air spaces in them. In fact, the experience was sufficient to show that sheet iron would have been better than brick for the sides as well as tops of the chambers. It did not rust when properly prepared, and the condensation of the arsenic would have been much hastened. With a pure ore like this, the quick condensation has an additional advantage in that it precipitates the arsenic as an impalpable powder, finer than it can ever be ground in any mill, and thus saves the grinding which is necessary with the coarsely crystallized arsenic of the Cornish works. If the dust chambers be large enough and gas fuel be used, it is in the highest degree probable that white arsenic can be made at the first operation continuously, as it was occasionally in these works. The crude fumes were of a very light gray color at the darkest, and occasionally were pure white. It is easily seen that with sheet iron chambers of the proper form a comparatively small number would be required and the whole operation would be greatly simplified and its cost reduced.

The draft for the furnace was provided by a Guibal centrifugal fan, eight feet diameter. The fumes were drawn in at the center of this fan and delivered into the flue leading to the chimney, which did not then require to be high, since it contributed nothing to the draft. The air supply of the furnace was completely under control with the fan.

The crude arsenic was refined to the extent of several hundred tons in an ordinary reverberatory furnace of the same dimensions as some of those described in Mr. Thomas's paper. The arsenic itself was of extraordinary purity.

Probably the most important use that has ever been found for arsenic is as a vermicide in agriculture. On the contrary, the absence of worms allowed the plants to grow much better than usual, and the crops were excellent both the first and the second year, and, I believe, in subsequent years.

These very valuable experiments in agriculture were made by Mr. William H. Stevens of Detroit, Mich., who was interested in the Deloro works and for several years tested arsenic on his farms near Detroit. More than a thousand acres of land were treated by him with uniform success.

The common crude arsenic from the condensing chambers was employed in barnyard compost or in superphosphates or other fertilizer. Experiments with quantities up to 900 lbs. of white arsenic to the acre showed no injurious effect upon the plants. If put upon the leaves of plants it killed them, but in one case an army of locusts was destroyed by sprinkling the dry arsenic on the grass and plants in front of it. This use of arsenic in agriculture appears to be of incalculable importance, for it is estimated that a very large proportion of all the crops in every country is destroyed each year by worms. If this use of arsenic should be generally adopted the supplies now manufactured in the world, amounting to between 8000 and 9000 tons, would be wholly insufficient.

Arsenic is very injurious to most animals. Cows and horses are easily poisoned by it, but hogs are not affected. In fact, in the disease known as hog cholera arsenic administered in milk, or otherwise, is said to be an absolute specific.

The simplest and best antidote for arsenic poisoning, and the one in use at the Canadian works referred to, is freshly precipitated hydrated oxide of iron. This precipitate can be kept for some time under water in bottles, and a spoonful of it may be taken without the least inconvenience by any one who has been poisoned by arsenic. It is an immediate and absolute antidote. Arsenic sores may be washed with this oxide of iron. It is an antidote also effective with animals. This oxide of iron is prepared as follows :

Take Sulphate of iron (crystals)	280	parts
Sulphuric acid	100	"
Nitric acid	35	"
Water	500	"

Dissolve the sulphate of iron in the water and sulphuric acid ; add nitric acid, very gradually toward the last of the operation, until the liquid shows a clear red color, keeping the solution hot. Use a capacious vessel. Precipitate with ammonia until all the iron is precipitated ; then filter and wash the filtrate well with water.

ASBESTOS.

By J. T. Donald.

The term asbestos was originally applied to the fibrous variety of the mineral hornblende, which is an anhydrous or nearly anhydrous silicate of alumina, lime, magnesia, and iron. As the physical structure of a mineral is much more evident than its chemical composition, it is not a matter for surprise that the name asbestos came to be applied to fibrous forms of other minerals, and especially to chrysotile, the fibrous form of serpentine. At the present time fibrous hornblende is of but very slight economic value, while on the other hand fibrous serpentine or chrysolite, under the name of asbestos, has become an article of great economic importance, and is regarded as typical asbestos, and any fibrous mineral lacking the flexibility and silkiness of fiber that are characteristic of chrysolite is pronounced bastard asbestos, even though such be the mineral to which the name was first applied and to which by the mineralogist it is still restricted.

The composition of serpentine and of Canadian and Italian asbestos is shown by the following analyses. The last two were obtained by the writer, that of serpentine is taken from Dana's *System of Mineralogy.*

	Serpentine.	Asbestos.	
		Canadian.	Italian.
Silica	40.71%	40.57%	40.30%
Magnesia	41.48	41.50	43.37
Ferrous oxide	2.43	2.81	.87
Alumina	2.39	.90	2.27
Water	12.61	13.55	13.72
	99.62	99.33	100.53

It is important to note that the water in these analyses is not moisture which may be driven off by exposure to a temperature of 100° C., but is chemically combined water, and on its presence the value of the asbestos largely depends.

Inasmuch as asbestos is fibrous serpentine, every deposit of the latter is a possible asbestos mining ground; and there are very few exposures of serpentine rock that do not display more or less of the fibrous variety. Consequently reports of the occurrence of asbestos are very numerous. The high prices obtained in 1890 and 1891 led to a widespread search for this mineral, but small areas in only two countries, Italy and Canada, can be considered as of any importance as producers of it. The Italian mineral was first in the field and was practically the sole source of supply until the opening of the first Canadian mine in 1878.

Asbestos goods were made in a small way and as curiosities centuries ago, but the asbestos industry proper has not been carried on for more than twenty-five years. The gradual use of steam at increasingly higher pressure showed the weakness of the old forms of packing for joints and glands, and led to the adoption of asbestos, which was found to be well adapted for this purpose. In 1879, coincident with the beginning of asbestos mining in Canada, a company was formed which succeeded in bringing under one management the numerous small mines of the Italian district and the manufacture of their product. It is not surprising, therefore, that the Canadian mineral—which at first was poorly dressed—found no favor with this sole consumer of crude asbestos and was with difficulty marketed the first year, though it amounted to only 50 tons. It, however, soon made for itself a place and a reputation, and the Italian monopoly has even acquired a mine in Canada and works it vigorously; while companies in Italy engaged in the manufacture of asbestos goods now draw their supplies in part from Canada, which now supplies about 85% of the world's consumption.

The superiority of the Canadian mineral over the Italian is due, not to difference in composition, but to the great ease with which its fibers can be separated. The Italian mineral has to undergo tedious processes to insure the separation of the fibers, though since it yields much longer fibers than the Canadian, there will always be a certain demand for it for special purposes.

Asbestos occurs in veins in certain serpentines; the productive area in Canada is confined to a very small portion of the belt of serpentine rock which extends, though with frequent breaks, northeastward from the Vermont boundary to some distance beyond the Chaudière River.

This belt of serpentine forms a part of what was known to Logan and the earlier Canadian geologists as the Quebec Group, and is now considered as of Cambrian or pre-Cambrian age. Although good workings occur elsewhere, the great majority of the mines are along the line of the Quebec Central Railway, which runs from Levis, opposite Quebec, to Sherbrooke, and cluster around Thetford and Black Lake stations. The asbestos forms irregular veins in the serpentine, varying from mere threads to four or six inches in width and occasionally even more, although the greater part of the highest grade is the yield of veins that do not exceed one and a half to two inches in width. The fiber always lies at right angles to the walls of the vein, unless thrown otherwise as a result of faults.

The normal color of the asbestos in the vein is white, greenish, or yellowish, but near the surface, and where the rock is shattered, the mineral is frequently discolored by oxide of iron; moreover, the veins themselves are frequently traversed by bands of foreign matter, such as compact and sometimes coarsely fibrous, foliated, and slaty serpentine, and magnetic and chromic iron, which lessen their value, since they cut up the fiber, and must be removed from the mineral at considerable cost. The asbestos of the Thetford mines generally contains much less of such foreign matter than does that of the Black Lake district, and brings rather higher prices.

In considering the genesis of asbestos, we must consider the fibers as crystals. The asbestos bears to the serpentine the same relation that veins of calcite and crystalline quartz bear to the beds of limestone and quartz rock in which they occur. In all three cases water containing certain of nature's solvents has percolated through the beds, taking up into solution portions of the same, and redepositing them in crevices, in masses of crystals. Thus in asbestos veins we find magnetic iron, not disseminated as in the parent serpentine, but concentrated toward the middle of the vein.

Asbestos has a lower specific gravity than serpentine, and, as a rule, contains a higher percentage of water, the average of five samples of Canadian serpentine being 13.49%, while four samples of asbestos gave 14.25%. Serpentine is generally regarded as an alteration product of some form of dioritic rock, rich in olivine. Asbestos is serpentine deposited in extremely fine linear crystals.

A question of interest connected with the origin of the mineral, and one of great practical importance to those engaged in the asbestos industry, is the cause of the difference in texture of various veins. In some cases the fibers are very soft and flexible, while in others they are extremely harsh and brittle, and are much less valuable, and analysis shows that this latter variety contains less water than the softer kind.

The writer found 14.05% of water in very flexible fiber, while in a harsh-fibered sample only 12.62% was present. It is well known that if soft fibers be heated to a temperature that will drive off a portion of the water of combination, there results a substance so brittle that it may be readily crumbled between the fingers. Wherever asbestos is found in rock that is faulted and shattered, the fiber is likely to be harsh at or near the surface, although at greater depths it may become softer. If the aqueous origin of asbestos be admitted, it seems reasonable to suppose that all the fiber when first deposited was soft and flexible, containing a maximum amount of water, and that movements of the rock, and the intrusion of molten matter, now constituting dikes, have driven off a portion of the water, and thereby destroyed the softness of the original fiber. Veins at considerable depths may have been subjected to the heat produced by these causes, and yet not deprived of any portion of their original water, because of the resistance of overlying rocks.

Mining.—Asbestos mining is carried on in open quarries. The rock is blasted, the portions containing asbestos are separated from barren rock, and go to the cobbing house, where old men and boys knock off the long-fibered asbestos from the serpentine. The better qualities of asbestos separate readily from the inclosing rock. But in the case of narrow veins the separation of fiber from rock by hand is impracticable, and machinery such as rock breakers, rolls, screens, and blowers have been introduced for this purpose.

The asbestos separated from the inclosing rock is divided into three grades, according to length of fiber, color, and freedom from foreign matter. The grading is not uniform, but each miner follows his own ideas as to what should be considered No. 1 or No. 2. Material not good enough for any of the three grades, yet containing fiber, is known as "waste," and really constitutes a fourth grade. The sorted asbestos is packed in bags containing usually 100 lbs., and is shipped as crude asbestos.

The percentage of asbestos in the rock mined varies, but in the actual mining areas it is estimated that it constitutes about one per cent. of the stone broken, and that the average cost of mining is about $56 per ton of asbestos.

The principal uses of asbestos are now, as they have been since its introduction into the arts, in connection with the use of steam. In the form of yarn, and more largely as millboard, it is used as steam packing, and it is also employed extensively as the principal ingredient in various non-combustible and non-conducting coverings for boilers and steam and hot-air and water pipes. These principal uses of asbestos depend upon its fibrous texture and its infusibility, and to the fact that the flexibility of the fiber is not impaired by the temperature to which it is subjected.

Its infusibility gives it a decided advantage over hair and other fibrous materials which char under continued exposure to heat, while the exceeding flexibility of its fibers gives it a like decided advantage over mineral wool and other fibrous but brittle mineral substances. While asbestos is infusible, yet if heated to redness the flexiblity of its fiber is destroyed, and a brittle mass is obtained.

Asbestos itself is a very poor non-conductor, but if teased out and worked into a fluffy mass, it makes a non-conducting material incombustible and unaltered by steam temperatures; but it is air inclosed by the fiber that is the real non-conductor, the asbestos serving simply to entangle the air.

Canada is still, as she has been during the past few years, the producer of the largest part of the world's supply of asbestos. The location of the principal mines, as well as the chemical composition and properties of the mineral, are fully described in THE MINERAL INDUSTRY for 1892. No new mines were opened in Canada in 1893, and no new discoveries of the mineral were made.

Reports are current that Newfoundland is likely soon to be a producer of asbestos on a commercial scale. Some prospecting has been done at points on the west coast, and after an examination of portions of the exploratory work, the authorities of the Newfoundland Geological Survey write: "The indications are certainly good, the quality of the fiber excellent, and should the serpentine deposit, in which the mineral occurs, be found to occupy any considerable area, there is a reasonable prospect that asbestos will accompany it." But owing to the distance from the coast, and the total lack of means of communication, it will be some time before the Newfoundland deposits can seriously compete with those of Canada, even if the sanguine hopes of interested parties as to quantity of ore are realized.

Meanwhile of the various mineral industries of central Canada it is safe to say that no one is in a sounder condition than asbestos mining. The unhealthy boom of three years ago has collapsed, and the period of recovery has more than set in. Equilibrium has been established between supply and demand and producers have turned their attention to rational development of their properties. When No. 1 asbestos was selling for $250 per ton, in 1891, mineral was extracted regardless of the condition in which the mines would be left. The result was that in many mines much deadwork was required, and one of the features of the year 1893 in asbestos mining has been the large amount of this work that has been done. There is every prospect that an increased demand for asbestos will arise in the near future, and miners have been preparing to meet it.

Another feature of the year has been the working over of the dumps. In the early days of the industry certain grades of asbestos were not marketable, and consequently found their way to the dump, and moreover in some cases it has since been found that these dumps are situated on ground rich in asbestos. During the year several of the mining companies have made their chief output of mineral from working over the dumps. This work has shown the necessity of dressing machinery, which will be more largely used in the future, the experiments already made in this direction having shown the lines along which such plants should be constructed.

The following table gives the production of asbestos in Canada from 1878 to 1893. The figures for 1892 and 1893 are for shipments from the mines, kindly furnished by miners and railway companies. In these years the production has been about equal to the shipments.

Year.	†Tons.	Value.	Year.	†Tons.	Value.	Year.	†Tons.	Value.
1879	300	$19,005	1884	1,141	$75,097	1889	6,113	$426,554
1880	380	24,700	1885	2,440	142,441	1890	9,860	1,260,240
1881	540	35,100	1886	3,458	206,251	1891	9,279	1,000,000
1882	818	52.650	1887	4,619	226,976	1892	*7,431	999,878
1883	955	68,750	1888	4,404	255,007	1893	*5,539	581,595

* Exports. † Short tons of 2000 lbs.

The following are the prices per ton at present at the mines, the range being due to the fact that the grading is not uniform: No. 1, $120@$140; No. 2, $60@$80; No. 3, $40@$50; waste, $15@$25.

During the past year the asbestos industry suffered from the general depression in common with other business. This and the national reaction from the recent boom in asbestos mining has made mining unusually dull and but few new properties have been opened. The mines which have remained in operation were compelled to lower the price of the crude because of prevailing business conditions. While the demand for the manufactured product has been poor, prices have been maintained fairly well on standard goods.

Among the new uses to which the material has been applied during the year is the manufacture of various articles for domestic purposes. While some of these have been produced heretofore, it is comparatively recently that such things as asbestos knitting yarn, baking paper, lamp shade guards, and other small articles have been placed on the market. The first is a yarn about the thickness of ordinary worsted yarn for knitting and is easily worked into various designs. Asbestos theater curtains have become a necessary part of the equipment of a theater and are being placed on all new and nearly all of the old stages. For flies and drops the material would be equally valuable, but its weight and expense prevent its wide use.

Since the disastrous fire in the cold storage building in Chicago experiments have been under way to produce an asbestos rope which would stand the heat of a fire and also support the weight of persons using it as a means of escape. It is reported that these experiments have succeeded. A small rope has been produced which is said to bear a weight of about 1500 lbs. after being exposed to heat. Another use for which asbestos cloth is being adopted is in fireproofing parts of buildings, such as elevator shafts, trap doors, or other openings through which fire can be communicated. In a like manner it has been applied as a cover to bookcases or to valuable works of art. In gold chlorinating works in the West a fine grade of the cloth is being largely used for filtering purposes. In Europe a recent use is to replace brattice cloth in coal mines. For this purpose it is not inflammable, like the ordinary cloth, and is otherwise well adapted, but its greater cost will probably prevent its extensive use.

ASPHALTUM.

By J. W. Howard.

Asphaltum and its natural and artificial compounds enter into many branches of engineering, architecture, and manufactures. It is used in civil engineering for pavements, reservoir linings, etc.; in mechanical engineering for foundations for dynamos, steam hammers, and other machinery where jarring is to be suppressed, and in other ways. It is employed in various forms and for various purposes in naval, military, sanitary, electric, and mining constructions. It is an important factor in architectural work, entering buildings as a "damp course" to prevent moisture ascending the walls, also as an elastic and durable surface for floors and roofs. Iron pipes dipped in hot asphaltum are far better for all purposes than those dipped in coal tar or gas tar. It is employed in varnishes, photography, and otherwise. The use of asphaltum has increased rapidly within forty years in Europe and twenty years in America, and now some knowledge of it and its compounds is necessary to every engineer and constructor.

Properties.—The word "asphalt" is from the Latin *asphaltum*, Greek ἄσφαλτος (asphaltos). It is a natural mineral pitch, which is practically unchangeable at ordinary temperatures, even if exposed for centuries. When pure, or nearly pure, it is of a dark brown to black color; when struck with a hammer at ordinary temperatures, it is brittle. Its fracture is dull and conchoidal. It is sectile. When rubbed or freshly broken it emits a bituminous odor. Its specific gravity in its natural state varies from .98 to 1.68, according to its impurities and porosity. Its hardness at 70° F. is 2½ to 3, Dana's scale. It is not soluble in water, but dissolves in carbon disulphide, and is partly soluble in alcohol, turpentine, ether, naptha, and petroleum. It begins to melt at about 190° F., and flows at about 200° F.

Asphalt, which often goes by other names, such as mineral pitch, Jews' pitch, Trinidad asphalt, Cuban asphalt, chapapote, bitumen, etc., is found in large or small quantities in almost every country. Many deposits, however, are not of commercial value. There are no deposits which supply a product adapted for all purposes, each having its individual characteristics and but few uses.

Asphalt belongs to a group of minerals called the *bitumens*, which are hydrocarbon compounds, and are arranged in order of their density at 70° F. as follows:

1. Natural gas. 2. Natural naptha. 3. Petroleum, or mineral oil. 4. Maltha, or soft, sticky bitumen. 5. Asphalt, or stiff, non-sticky bitumen. 6. Glance pitch, or dry, brittle bitumen. Glance pitch is often called gilsonite. There are also other bitumens, but they are of less importance.

Occurrence.—Asphalt is seldom found native or pure, but is usually mixed with earthy matter, sand, sandstone, or limestone. The three natural compounds of practical value are asphalt mixed with more or less earthy matter,—as at the Trinidad asphalt lake, in south central California, and elsewhere,—asphaltic limestone, and asphaltic sandstone. The first is used, after having been freed from water, a part of the earthy matter, and other foreign substances, for the manufacture of asphaltic cement, which enters into paving and other artificial compounds where a waterproof, pliable, and durable cement is needed. Asphaltic limestone, called sometimes in commerce "rock asphalt," is found in France, Sicily, and elsewhere. Asphaltic sandstone, which is as yet the least valuable of the three compounds, because no practical process has been discovered for correcting variations in it, occurs in California, Utah, Kentucky, and in Europe, where in a few places asphaltum is extracted from it. A process has lately been introduced also for the extraction of asphalt from the asphaltic sandstone in Kentucky. In California this material is often referred to as "asphalt rock," causing slight confusion. The principal deposits of natural asphalt and compounds are as follows:

Asphalt mixed with Earthy Matter.	Asphaltic Limestone.	Asphaltic Sandstone.
Bagdad.	Austria.	California.
California.	California.	Colorado.
Colorado.	Dalmatia.	Cuba.
Colombia.	France.	France.
Indian Territory.	Germany.	Germany.
Mexico.	Hungary.	Indian Territory
Montana.	Indian Territory	Kentucky.
Palestine.	Italy.	New Mexico.
Peru.	Russia.	Russia.
Texas.	New Mexico.	Spain.
Trinidad.	Michigan.	Texas.
Utah.	Sicily.	Utah.
Venezuela.	Spain.	
	Switzerland.	
	Texas.	
	Utah.	
	Washington.	

Trinidad Asphalt.—Deposits of asphaltum mixed with earthy matter and typically represented by those of Trinidad, whence about 90% of all the asphalt used in the world is obtained. Trinidad is an island near the north coast of South America, upon which is found the famous asphalt lake, known also as the "Pitch Lake," which is a large, flat deposit, somewhat resembling a crater, filled with asphalt mixed with earthy and vegetable matter. The island is a colony of Great Britain, and the lake is the property of the Government. It is about one mile from the southwest corner of the island and covers nearly 116 acres. The surface is hard, except at the center, at which place there is a soft spot, which will not sustain the wagons and persons that go upon the lake to dig the asphalt.

In mining this material it is simply loosened by picks and thrown into carts, by which it is carried to the beach, where it is piled awaiting shipment. The vessels in which it is carried are loaded by means of scows or lighters.

The following analyses of average samples of crude Trinidad asphalt illustrate its composition:

	I.	II.	III.
Water	16.37%	27.85%	27.85%
Asphalt	39.83	38.14	38.14
Earthy matter	33.99	26.38	34.01
Vegetable matter	9.31	7.63	
Total	100.00	100.00	100.00

I. Analysis by Bowen. II. Richardson. III. Richardson.

These constitutents are not combined chemically, but merely form a mechanical mixture. If powdered and kept in a warm room, the mixture soon loses its water.

The following table gives the composition of the pure asphaltum, exclusive of earthy matter, etc.

Place Chemist	Trinidad. Bowen.	Mexico. Regault.	Peru. Bossingault.	Cuba. Bossingault.	Colombia. Bossingault.	Palestine. Kayser.
Carbon	85.89%	80.34%	88.67%	81.50%	88.31%	80.00%
Oxygen	.56	10.09	1.65	6.90	1.68	.40
Hydrogen	11.06	9.57	9.68	9.60	9.64	9.00
Nitrogen					.37	10.00
Sulphur	2.49					.60
Ash						
Total	100.00	100.00	100.00	100.00	100.00	100.00

Although the foregoing table has a scientific interest, asphalts are better compared by other means if we desire to know concerning their commercial value. Preliminary comparisons are best made by testing the solubility of the sample in carbon disulphide (after each sample has been carefully dried *in vacuo*, at a temperature below 212° F.), in alcohol of standard specific gravity, in turpentine, ether, petroleum, and naptha. The softening point should be determined, and the temperature at which it flows. The losses in per cent. at different temperatures must be tested by distillation. The determination of the amount of water, clay and earthy matter is made by the usual methods in such cases. Final comparisons in pavements, etc., are best made by actual trial.

Trinidad asphalt is refined by heating to remove the water, the vegetable matter, and a little of the clay contained in the crude material. This is done, as a rule, in large tanks maintained for several days at a temperature not exceeding about 400° F. The refined asphalt is combined with residuum oil of petroleum of a standard specific gravity, at a given temperature, to make asphaltic cement, which is almost hard at ordinary air temperatures, but when heated to nearly 300° F. becomes liquid, and can be mixed by suitable machinery with such substances as are desired for paving or other purposes. Asphaltic cement is used in work where a cementing material is desired which is both waterproof and not subject to cracking under jarring and slight movements.

Probably 96% of the asphalt imported into the United States from Trinidad is used in pavements, which are laid briefly as follows: The street is graded, rolled with a steam-roller, and covered with a layer of concrete, generally five or six inches thick; or in case the street is macadamized or paved with stone blocks, the foundation of hydraulic cement concrete is not needed. If macadam or old stone blocks are used for a foundation, a thin layer of asphaltic concrete, called "binder," about 1½ in. thick, is first laid upon the old surface. The asphalt paving mixture, called the wearing surface, is then spread with hot rakes to the thickness desired on the foundation previously prepared and compressed with a steam roller. The wearing surface is sometimes 1½, sometimes 2, and in certain places 2½ in. thick.

The Trinidad asphalt paving mixture is compounded as follows: Hot refined asphalt is mixed with residuum oil, stirred by air or otherwise in the proportion of 100 lbs. of the former to 15 or 18 of the latter. This product serves to cement together the sand and powdered limestone entering into the paving mixture, which is as follows: Asphaltic cement, 12% to 15% by weight; sand, 83% to 70%; powdered limestone, 5% to 15%. The proportions vary, however, according to the kind of sand used and the climate. Less asphaltic cement is used in hot climates than in cold. The ability to adapt this pavement to various climates is one of the reasons of its success in so many cities North and South, the amount of Trinidad asphalt pavement in the United States on Jan. 1, 1894, being almost 14,000,000 sq. yds., or a little more than 900 miles, which has been laid in sixteen years by thirty different companies or contractors.

Asphaltic Limestone.—Mines of asphaltic limestone are found in several countries, but the substance is as yet known at only a few points in the United States, though from time to time new discoveries are reported. Asphaltic limestone is a natural compound of limestone and asphalt, but maltha and other bituminous substances are sometimes present, while sulphur, sand, etc., are often found in it. Its fracture is from brown to chocolate black, the color being darker in the specimens containing larger amounts of asphaltum. The percentage of asphaltum permeating the limestone varies, in different deposits and in different parts of the same mine, from zero to above 20%. The grain of asphaltic limestone is very fine, and under the microscope the smallest particle still appears coated with asphalt. A piece cut by a sharp blow of an axe shows a grayish-white color at the gash, due, probably, to the squeezing of the asphaltum from the line of the cut, leaving only the limestone exposed. It is possible to break with the hands a piece containing above 10% of asphalt. A piece heated over a fire falls apart, and if heated in a pan to a high temperature the asphalt is driven off and gray-white, powdered limestone remains. If a piece contains above 4% of asphalt and is freshly broken a bituminous odor is perceptible.

Asphaltic limestone is called at times "rock asphalt" and "bituminous limestone," the first being the usual commercial name in America, while in England, with a few exceptions, it is called bituminous limestone. In France it is called "calcaire bitumineux," and in Germany "asphalt kalkstein," or for brevity, "asphaltstein." One of the paving companies of France, however, still uses the name "asphalte," meaning asphaltic limestone.

An undisturbed outcropping of asphaltic limestone appears of a grayish color, and sometimes is almost white, which should be borne in mind when prospecting for it. This is due to the action of the weather. Asphaltic limestone is generally mined in the cool months by open quarrying, and in warm months by tunneling. Tunneling is carried on, however, in some mines at all seasons.

The following table of analyses of representative asphaltic limestones shows their general composition:

Place Chemist	Val de Travers. Ponts et Chaus.	Seyssel. Ponts et Chaus.	Ragusa. Ponts et Chaus.	Limmer. Vor. Lab.
Asphaltum	10.15%	8.15%	8.92%	14.30%
Calcium carbonate	88.40	91.30	88.21	67.00
Clay and iron oxide	.25	.15	.91	17.52
Sand	...	...	.60	
Mag. carbonate	.30	.10	.96	
Insoluble	.45	.10	...	...
Loss	.45	.20	.40	1.18
Total	100.00	100.00	100.00	100.00

Asphaltic limestone containing above 11% of asphaltum cannot be thus used for street pavements, but it can be reduced by carefully mixing it in powdered form with an asphalt of a lower percentage, so that the contents of asphaltum in the resulting mixture is from 9% to 10%. The rich rock is generally used for manufacturing asphaltic mastic, employed for sidewalks, roofs, floors, etc. Foundations for steam hammers, dynamos, high-speed engines, etc., where jarring must be suppressed, are very successful when built of asphaltic concrete, which can be made from asphaltic mastic, composed of asphaltic limestone enriched by Trinidad or other suitable asphalt, and compounded with finely crushed stone; or of crushed stone, sand, and limestone powder united with asphaltic cement.

Asphaltic limestone is mined in large lumps and then crushed, generally in a rotary, toothed crusher, to pieces two inches and less in diameter, which are passed through a pulverizer, either of the centrifugal or the ball type. The powder is about as fine as mustard seed, and is stored, preferably under cover, for future use, unless needed at once. It is used for laying what is known as "compressed rock asphalt pavements" by heating to 275° F., either upon flat hearths or in revolving heaters. It is raked to such a depth over a concrete foundation that, when compressed by heated rammers or otherwise, it will be generally 2 in. or 2½ in. thick. This form of asphalt pavement for streets is not popular in the United States, and is found at but few places in cities near the Atlantic coast.

Asphaltic limestone street pavements become polished and slippery under heavy fog or a light rain, and also when clean in clear, cold, dry weather. The pavement made with Trinidad asphalt, and others on the same system, are not slippery at any time, except when covered with a sheet of ice, which is due to the fact that they are composed of about 80% of sand, making them gritty and not susceptible of polish. In Paris and Berlin large supplies of sand are kept near the streets paved with asphaltic limestone for use during fog, slight rain, and snow.

Asphaltic Sandstone.—This substance, which has as yet but little value, is composed of sand, generally very fine, cemented together with from 1% to 70% of asphalt. Maltha and petroleum are often present, to the decided injury of the material. Asphaltic sandstone is sometimes referred to in California as "asphalt rock," which is not, however, as good a name as the former. It is mined in open quarries. Sometimes it is prepared for use by crushing, but generally it is reduced to a soft state by the injection of steam into the mass, or by surrounding it by pipes conducting steam. The softened material has the appearance of wet, black sand. It is laid in pavements simply by raking into position and compression by a steam roller. Success has not yet crowned the efforts to make durable asphalt pavements from natural asphaltic sandstone, but in time it is possible that better results will be achieved. One great hindrance lies in the varying quality of the asphaltic sandstone in the mines and the difficulty in securing it of the same composition.

Statistics.—In comparing statistics of asphaltum and asphaltic limestone, it must be remembered that in pavements Trinidad or similar asphalt forms only from 10% to 17% of the mixture, and a long ton of crude Trinidad asphalt will lay, when refined and mixed with residuum oil, sand, and limestone powder, more than 37 sq. yds. of pavement. A ton of asphaltic limestone will lay less than 9 sq. yds., because it is used in its natural state, only about 10% of it being asphalt. For example, the 20,346 tons of asphaltic limestone or "rock asphalt" imported in 1891 would lay less than 183,114 sq. yds. of pavement; whereas, if it were simply asphalt from Trinidad, it would have furnished the cementing material for 752,802 sq. yds. Therefore the necessity of using the factors 9 and 37, as above, when comparing the two materials.

The following table gives the exports of asphalt from Trinidad:

EXPORTS OF ASPHALT FROM TRINIDAD. (*a*)

(Reduced from Trinidad reports. Tons of 2240 lbs.)

Year.	To the United States.			To Europe, etc.			Total Exports from Trinidad.
	Refined.	Crude.	Total.	Refined.	Crude.	Total.	
1867	....	....	700	....	....	3,027	3,727
1868	....	....	200	....	....	1,325	1,525
1869	....	....	....	....	....	8.297	5,297
1870	....	....	2,953	....	....	5,857	8,810
1871	....	....	828	....	....	3.222	4,050
1872	....	....	2,114	....	....	9,854	11,968
1873	....	....	746	....	....	6,913	7,659
1874	....	....	711	....	....	9,204	9,915
1875	....	....	1,100	....	....	13,632	14,732
1876	....	....	3,979	....	....	11,715	15,694
1877	....	....	1,441	....	....	11,596	13,037
1878	....	....	5,860	....	....	9,926	15,786
1879	....	....	9,078	....	....	13,633	22,711
1880	....	....	7,178	....	....	15,614	22,792
1881	....	....	8,523	....	....	17,753	26,276
1882	....	....	15,075	....	....	14,878	29,953
1883	....	....	24,781	....	....	15,025	39,806
1884	....	....	19,685	....	....	17,913	37,598
1885	*b*184	*b*15,573	15,757	*b*6.547	*b*12,932	19,479	35,236
1886	....	25,720	25,720	5.416	4.505	9,921	35,641
1887	2,246	23,937	26,183	5,780	11,135	16.915	43,098
1888	2,494	31,424	33,918	5,731	9,367	18,098	52,016
1889	2,546	56,503	59,049	9,013	10,062	19,075	78,124
1890	1,441	42,990	44,431	9,199	25,211	34,410	78,841
1891	951	75,025	75,975	9,080	10,933	20,013	95,989
1892	....	88,215	88,215	9,560	13,643	23,203	111,418
1893	....	....	....	....	....	....	....

Reducing refined to equivalent crude, the total exports during 1892 become: To the United States, 88,215 tons; to Europe, etc., 27,983 tons; grand total equivalent crude exported, 116,198 tons.

(*a*) The figures previous to 1885 are from the harbor master's records; the subsequent ones are from customs returns, etc.

(*b*) Not known separately for years previous to 1885.

Because vessels do not arrive the same year as they sail, and because some vessels are lost at sea, the following table of Trinidad asphalt imported into the United States according to official records is given:

Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]
1880	3,913	1882	14,263	1884	19,630	1886	27,757	1888	35,137	1890	54,692	1892	70,744
1881	6,707	1883	23,309	1885	15,289	1887	26,593	1889	52,881	1891	71,112	1893	[b]66,059

(*a*) 2240 lbs. (*b*) Very close estimate.

The imports of asphaltic limestone and mastic blocks into the United States from France, Germany, Switzerland, Italy, etc., are approximately given in the following table:

Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]	Year.	Tons.[a]
1867	*n*	1874	421	1881	4,705	1888	*n*
1868	*n*	1875	68	1882	*n*	1889	2,433
1869	181	1876	*n*	1883	6,259	1890	11,255
1870	*n*	1877	2,761	1884	12,582	1891	20,346
1871	422	1878	*n*	1885	1,145	1892	[b]9,100
1872	*n*	1879	*n*	1886	1,314	1893	[b]2,200
1873	1,400	1880	6,649	1887	914	....	....

(*a*) Long tons, 2240 lbs. (*b*) Close estimates. (*n*) No available records.

It is very difficult to tabulate with any degree of certainty the production of asphalt and asphaltic materials in the United States. The reason for this is, chiefly, because heretofore different materials have been grouped when they should have been separately recorded. Gilsonite, or glance pitch, has often been reported as asphaltum, and asphaltum has been included in records of asphaltic sandstone, etc. As a whole, the asphalt mining industry in the United States is not a success, and the demand for the material offered is far less than the available supply. Gilsonite is very valuable in varnishes, etc., but not for pavements.

Because there is practically no limit to the supply of maltha, asphalt, gilsonite, and asphaltic sandstone in the American deposits, and because 50,000 tons annually from these mines would more than supply the market for their products, a few favorably situated as to freight, etc., fill all the limited orders, at very cheap rates.

PRODUCTION OF ASPHALTUM, ASPHALTIC SANDSTONE, ETC., IN THE UNITED STATES.

Year.	Long Tons.	Short Tons.	Value.	Year.	Long Tons.	Short Tons.	Value.
1882........	2.679	3,000	$10,500	1888.........	45,044	50,450	$187,500
1883........	2,679	3,000	10,500	1889.........	46,192	51,735	171,537
1884........	2,679	3,000	10,500	1890.........	36,465	40,841	190,416
1885........	2,679	3,000	10,500	1891.........	40,227	45,054	242,264
1886........	3,125	3.500	14,000	1892.........	42,000	36,680	198,072
1887........	3,571	4,000	16,000	1893.........	31,200	34,944	174,720

California has deposits of maltha, asphalt, gilsonite, and asphaltic sandstone. Some material is prepared under the name of "petro-carbon asphalt," but this is not natural mineral asphaltum; it is really a by-product, and should not be included in this list. Asphalt and asphaltic sandstone are mined in California, chiefly in Los Angeles, Kern, Ventura, Santa Cruz, Santa Barbara, and San Luis Obispo counties. Deposits exist in other counties.

Colorado has deposits of asphalt, gilsonite, and possibly asphaltic sandstone in the western part of the State, and mining has been undertaken.

The Indian Territory has deposits of maltha, asphalt, asphaltic sandstone, and limestone, but they have not yet been developed.

Kentucky has deposits of asphaltic sandstone in Breckenridge, Grayson, Meade, Logan and Hardin counties, which are mined to a limited extent.

Texas has asphaltum, gilsonite, asphaltic sandstone, and limestone, none of which is mined more than tentatively.

Utah has deposits of asphalt, gilsonite, asphaltic sandstone, and limestone, chiefly in Uintah, Utah, Wasatch and Emery counties, all of which substances are being mined.

West Virginia has some gilsonite or grahamite, but it is no longer mined.

Other States have small outcroppings which, when the demand warrants the investment, may become sources of supply.

AREA AND EQUIVALENT LENGTH OF ASPHALT PAVEMENTS IN EUROPE JAN. 1, 1894.

	Berlin.	Paris.	London.	Other Cities.	Total.
Square yards.....	1,280,796	401,617	370,000	271,000	2,323,413
Miles (*a*)..........	83.20	26.33	24.26	17.77	151.56

(*a*) Equivalent to a roadway 26 ft. wide.

AREA AND LENGTH OF ASPHALT PAVEMENTS IN THE UNITED STATES JAN. 1, 1894.

Kind of pavement.........	Trinidad Asphalt.	Asphaltic Limestone.	Asphaltic Sandstone and Other Asphaltic Materials.	Total.
Square yards..............	13,900,000	*151,000	*619,000	*14,670,000
Miles.......................	911.29	9.90	40.58	961.77

* Close approximations, including good and bad materials and workmanship. The above is street roadway pavements, and does not include sidewalks.

AREA AND EXTENT OF TRINIDAD ASPHALT PAVEMENTS IN THE UNITED STATES AND CANADA LAID ANNUALLY.

Year.	Sq. Yards.	Miles.	Value.	Year.	Sq. Yards.	Miles.	Value.
1878........	86,074	5.6	$258,222	1886.........	699,229	45.8	$2,097.687
1879........	157,243	10.3	471,729	1887.........	878,042	57.5	2,634,126
1880........	46.913	3.0	140,739	1888.........	867,040	57.4	2,601,120
1881........	136.905	8.9	410,715	1889.........	1,198,713	78.5	3,596,139
1882........	234,822	15.3	704,466	1890.........	2,150,907	141.0	6,452,721
1883........	384,612	25.2	1,153,836	1891.........	2,158,257	141.4	6,474,771
1884........	397,498	26.0	1,192,494	1892.........	2,117,631	138.9	6,352,893
1885........	399,821	26.2	1,199,463	1893.........	*1,986,293	130 2	*5,958,879
				Total....	13.900,000	911.2	$41,700,000

* Close estimate; final reports not received.

From 1888 to 1892 about 60,000 tons of an inferior asphaltum came from Trinidad. It was what is known as "land, or overflow," asphalt from places outside of the Trinidad asphalt lake, containing variable impurities, and lacking cementing qualities. It is no longer imported into the United States.

CITIES IN THE UNITED STATES USING ASPHALT PAVEMENTS.

Albany, N. Y.	T.	Dunkirk, N. Y.	T.	Newport, R. I.	T.	St. Louis, Mo.	T.
Altoona. Penn.	T.	Erie, Penn.	T.	New Orleans, La.	T.	St. Augustine, Fla.	V.
Amsterdam, N. Y.	T.	Evanston, Ill.	T.	Newport, Ky.	T.	St. Joseph, Mo.	T.
Atlanta, Ga.	T.	Fort Wayne, Ind.	T.	New Haven, Conn.	V.	Syracuse, N. Y.	T.
Augusta, Ga.	T.	Fresno, Cal.	V.	Norwood, Ohio	T.	San Diego, Cal.	V.
Avondale, Ohio	T.	Grand Rapids, Mich.	T.	Oakland, Cal.	V.	Sacramento, Cal.	V.
Allegheny, Penn.	T., V.	Holyoke, Mass.	V.	Omaha, Neb.	T.	Stockton, Cal.	V.
Baltimore, Md.	T.	Harrisburg, Penn.	T.	Peoria, Ill.	T.	Santa Barbara, Cal.	V.
Binghamton, N. Y.	T.	Indianapolis, Ind.	T.	Philadelphia, Penn.	T., V.	Terre Haute, Ind.	T.
Boston, Mass.	T., V.	Kansas City, Mo.	T.	Providence, R. I.	T.	Tacoma, Wash.	V.
Brooklyn, N. Y.	T.	Lancaster, Penn.	V.	Portland, Me.	V.	Toledo, Ohio	T.
Buffalo, N. Y.	T.	L. I. City, N.Y.	T.	Portland, Ore.	T., V.	Toronto, Canada	T.
Camden, N. J.	V.	Los Angeles, Cal.	V.	Pittsburg, Penn.	T., V.	Trenton, N. J.	V.
Chicago, Ill.	T.	Lockport, N. Y.	T.	Reading, Penn.	T.	Topeka, Kan.	T.
Chattanooga, Tenn.	T.	Long Branch, N. J.	T.	Rochester, N. Y.	T., V.	Troy, N. Y.	T.
Cicero, Ill.	T.	Louisville, Ky.	T.	Savannah, Ga.	T.	Utica, N. Y.	T.
Cincinnati, Ohio	T.	Lowell, Mass.	V.	San Francisco, Cal.	V.	Washington, D. C.	T., V.
Cleveland, Ohio	T.	Minneapolis, Minn.	T.	Salt Lake City, Utah.	V.	Westport, Mo.	T.
Columbus, Ohio	T.	Milwaukee, Wis.	T.	Schenectady, N. Y.	T.	Wichita, Kan.	T.
Covington, Ky.	T.	Montreal, Canada	T., V.	Sedalia, Mo.	V.	Wilkesbarre, Penn.	T
Dayton, Ohio	T.	Mount Vernon, N. Y.	T.	Scranton, Penn.	T.	Youngstown, Ohio	T.
Denver, Colo.	T., V.	New York, N. Y.	T., V.	Seattle, Wash.	V.	Yonkers, N. Y.	T.
Detroit, Mich.	T.	Newark, N. J.	T.	St. Paul, Minn.	T.	Wyandotte, Kan.	T.

T. Trinidad. V. Various other kinds.

The use of asphaltic limestone for street pavements in the United States has almost ceased, but in the form of asphalt mastic blocks it is imported as well as manufactured here. Asphaltic mastic is of great value in architecture and engineering. In this form it is applied to many uses, except street paving. Asphaltic sandstone pavements are used in cities near the mines, especially in California. Coal tar has long since become known as a spurious imitation of asphaltum and has long been abandoned for street pavement, except in one or two cities where other influences than those of technical engineers prevail.

The asphalt pavements made from domestic materials have not succeeded very well, but these materials are being constantly experimented with and may in time succeed. As the United States becomes more densely populated, known deposits will pay better, and new and valuable mines will be found. Improved methods of paving will be used to the further advantage of our streets and the people of our cities. Moreover, other branches of engineering and construction absorb each year more and more asphaltum.

Principal Dates in the History of Asphalt.—Without dwelling upon the knowledge of asphalt in ancient times, I will pass at once to modern times. Asphalt was known in parts of Germany in 1626 as "Hartzerde" (pitch earth), and in 1692 was described by Dr. Amiest as asphalt. Dr. Erynis mentions bituminous limestone and asphalt in several publications from 1711 to 1721. The deposits at Seyssel, France, were discovered in 1802. Count de Sassenay united the asphalt interests of France and Switzerland in 1832. Paris adopted asphalt sidewalks in 1838, of which there exist to-day almost 1200 miles within that city. Engineer Merian developed compressed asphaltic limestone in 1849, and Engineer Darcy in 1850 advanced this system. Soon afterward M. Leon Malo, an eminent engineer, began his long and successful career in connection with the use of asphaltic mastic for sidewalks, areas, floors, etc., and compressed asphaltic limestone powder for roadways. Presumably for brevity, he applied the word "asphalte" to asphaltic limestone and unwittingly caused a slight confusion of terms. Paris received its first successful asphalt street pavement in 1854; London, 1869; Buda-Pesth, 1871; Dresden, 1872; Hamburg, 1872; Berlin, 1873, and Brussels, Geneva, Leipsic, Frankfurt, etc., soon afterward. The desire for a smooth quiet pavement in the United States enabled a spurious article to be laid upon certain streets of several cities in 1870 to 1873. This was composed of coal or gas tar, sand, etc., and soon became known as "tar poultice pavement." However, from 1871 to 1873 successful experiments with an artificial asphaltic sandstone pavement were made in Newark, N. J., and in New York. In 1876 this pavement was pronounced a success in Washington, and became known as Trinidad asphalt pavement, because refined Trinidad asphalt was used in cementing together the sand and powdered limestone which composed the pavement. In 1878 this had become the standard pavement of Washington. It has been rapidly adopted by 72 American cities, and is now being laid by several companies at the rate of about 2,140,000 sq. yds., or 140 miles, annually. In addition, asphaltic limestone, asphaltic sandstone, and several asphalt paving mixtures, are tried each year. Asphalt pavement of some form is found in 92 American cities.

It is necessary to select carefully the materials and constantly supervise all asphalt constructions. It is as necessary to examine the size and quality of the sand, powdered limestone, crushed stone, etc., to be used for asphalt pavements as the asphalt itself. The composition and permanent cementing qualities of the Trinidad or other asphaltic cement, offered for sale or for use, should be carefully determined.

BARYTES.

Barytes, or sulphate of barium ($BaSO_4$), commonly called heavy spar, is a common mineral of 4.3 to 4.72 sp. gr. In color it varies from white to black, but it is most commonly white, gray, or blue, the last two varieties being either transparent or translucent. When pure and broken minutely the crystals are in all cases transparent and colorless, and decompose solar light. The variation in the color of the mineral is due sometimes to diffraction and sometimes to impurities, chiefly oxide of iron. Pure barytes contains 65.7% oxide of barium and 34.3% sulphuric anhydride, but strontium and calcium sometimes replace part of the barium, and silica, clay, and bituminous substances are often present as impurities. Barytes is easily distinguished from other white minerals by its high specific gravity, its insolubility in acids, and the green coloration which it gives to the blow-pipe flame.

Occurrence.—Barytes is widely distributed in all parts of the world, being found frequently as a gangue in metal-bearing veins (especially galena and zincblende), and also occurring in veins and pockets in limestone. The limestone deposits and the float mineral from them constitute the chief commercial source of barytes.

Although barytes is found at many places in the United States, nearly all that mined and used in the arts is obtained from Virginia and Missouri, small amounts only coming from North Carolina, Illinois, and other States. In Virginia barytes is found usually in nodules and boulders scattered through an ocher clay, between beds of slate and limestone, the latter underlying. The lumps are much discolored on the outside, but on fracture show the characteristic color of pure mineral. Before shipment each piece is broken with a hammer, and the fragments are thrown into separate piles, according to quality. In Missouri barytes is found at the surface as boulders of "float" mineral imbedded in clay, and also in regular beds at a moderate depth. The former are worked by open trenches, and the latter by the usual methods of underground mining. The mineral is prepared by picking or washing away the clay, after which it is sent to St. Louis for subsequent treatment.

Good barytes should be as free as possible from metallic impurities, which discolor it, and from quartz, which increases the wear on the machinery for grinding it to a fine powder. The Missouri mineral is thought to be of a somewhat better quality than the Virginian.

History.—Barytes has been used for about half a century in the United States for the manufacture of white paint, and is rapidly growing in importance for this purpose, its consumption having increased almost threefold during the past ten years. It was originally introduced from Europe, where it has been used as a pigment for several hundred years. The early history of the industry in the United States is not well known; it is certain, however, that the mineral was mined and utilized early in the fifties by a St. Louis company (the Western Color Works), which supplied the Western market, while the Stamford Manufacturing Company erected mills at New Haven in 1854, which are still in operation. The latter works drew their supply from deposits at Cheshire, about thirteen miles from New Haven. These deposits were exhausted in 1879, and since then the works have been run on imported mineral. Deposits of barytes were opened in the vicinity of Lynchburg and Wytheville, Va., and works were erected at the former place in 1878. A few years later mining and manufacturing were begun in North Carolina.

Production.—Barytes mining in Missouri is carried on in an exceedingly irregular manner, the more part of the product being obtained by farmers at seasons of the year when they and their teams would otherwise be idle. Most of the sorting and cleaning are done by the women and children of their families, and the industry is a great help in certain communities. The farmers haul their product to the nearest town, where they exchange it for dry goods, groceries, and other supplies, or sell it for cash. The local merchants, who collect it thus, ship it to the works at St. Louis. In previous statistical compilations great complaint has been made of the difficulty of arriving at accurate statistics of the production of barytes owing to the peculiar conditions of the industry, and the figures reported for the years previous to 1891 are doubtless incorrect and sometimes very misleading.

It is reliably established by them, however, that the production of barytes in the United States decreased very much between the years 1880 and 1891, and then rose to a higher figure than had previously been recorded. There are no complete statistics for the years preceding 1880. It is known, however, that there was a considerable increase in production during the civil war, which was caused by the high value of lead. When the price of lead began to fall, the production of barytes also declined; but this was checked by the Franco-Prussian war in 1870, wherefore not only was the price of lead increased, but German ships were unable to bring mineral to America. The result of this was a sharp increase in the American production, which amounted to about 20,000 tons in 1873. Then the output fell off to about 15,000 tons in 1875. In 1876 the silver-lead mines of Leadville, Colo., were discovered, and in 1878 their lead began to be put on the market in large quantities, causing a fall in prices, which, in 1879–80 began to affect the barytes industry. The tariff act of March 3, 1883, reducing the duty on crude and manufactured barytes, brought the industry down to a very low point in the years between 1884 and 1887. In the latter year the American White Lead Association was formed. The price of white lead being advanced thereby, the production of barytes was stimulated, and in 1889 amounted to

21,460 short tons, according to the report of the Eleventh Census. In 1890 the McKinley tariff increased the duty on crude and manufactured barytes, and in 1891 the production of the mineral was increased fully 50%.

PRODUCTION OF CRUDE BARYTES IN THE UNITED STATES.

Year.	Short Tons.	Value.	Year.	Short Tons.	Value.	Year.	Short Tons.	Value.
1880	22,400	$80,000	1885	16,800	$75,000	1890	21,911	$86,505
1881	22,400	80,000	1886	11,200	50,000	1891	31,069	118,363
1882	22,400	80,000	1887	16,800	75,000	1892	28,476	142,380
1883	30,240	108,000	1888	22,400	110,000	1893	26,632	133,160
1884	28,000	100,000	1889	21,460	106.313			

Manufacture.—The process of preparing barytes for use as a pigment is simple in theory, but in practice the steps have to be varied according to the different structure of the crystals, and there are difficulties encountered which must be overcome by various expedients, some of them proprietary and held as trade secrets. The first step in the process as carried out both in Europe and in America is the sorting of the crude mineral received from the mine, which is then crushed coarsely, after which the European and the American practice differ. In Europe the crushed mineral, either coarse or finely ground, is conveyed to stone tanks, where it is boiled in dilute sulphuric acid, or some other acid, to remove the oxide of iron. When this has been completely effected the solution is drained from the tank and the mineral is washed with water until free from acid. It is then dried, and if coarse is ground in buhr-mills, sometimes dry and sometimes wet; if the latter, it is again dried on flagstones set over flues. In the United States some manufacturers grind the coarsely crushed mineral under granite stones in water; then boil in acid, and finally wash and dry the powder. Other American manufacturers boil the coarsely crushed mineral in acid and grind it after washing and drying. In "floated barytes" the fine crystals are sorted from the coarser ones by a current of water, but this process is expensive and little employed, most of the so-called "floated barytes" being merely mineral ground according to one of the previously described processes.

Uses.—The chief use of barytes is in the manufacture of pigments. In Europe it has been employed for this purpose for many years, and has there outlived all controversy with regard to it. In America, however, it is still a subject of heated discussion in the paint trade. In general there is doubtless a prejudice against it, but nevertheless it must be confessed that the highest European authorities recognize it as a legitimate and valuable pigment. The following paragraphs from *Painters' Colors, Oils, and Varnishes,* by G. H. Hurst (London, 1893), state concisely the merits and advantages of barytes paints:

"Barytes is one of the most important white pigments at the disposal of the painter; probably in this respect ranking next after white lead, both as to the extent of its use and to its qualities as a pigment. It is quite insoluble in all acids and alkalies, properties which distinguish it from other white pigments. It is quite unaffected by any injurious influences such as affect white lead, and therefore as a pigment it is the most permanent white known; for this reason it has been called and sold as constant white, permanent white, etc.

"Freeman's non-poisonous white lead (one-third each barytes, zinc-white, and white lead) is a very good pigment, is more permanent under exposure to atmospheric influences than white lead, and is equal to white lead in body, or covering power, and in freedom of working. It is rather heavier than white lead (owing to weight of its barytes), weighing about 180 to 190 lbs. to the cubic foot; sp. gr. 5.90 to 6.

"Griffith's white (62% barytes and 32% zinc-white) is good color, in body is nearly if not quite equal to white lead, and is one of the most permanent pigments known. It mixes well with oil, working freely under the brush; in this respect it is equal to white lead. Lithophone (68% barytes and 32% zinc-white) possesses a good body and works well in oil; it has a slight yellow tint."

Church states in *Chemistry of Paints and Painting* (London, 1890) that "two parts white lead and one part barytes give a color much less affected by sulphureted hydrogen than flake (pure lead) white," and that "Freeman's white (equal parts of white lead, zinc-white, and barytes-white) possesses distinct advantages over the common (pure lead) paint."

Such evidence from the highest authorities could be indefinitely corroborated, and it must be concluded, therefore, that from 50% to 60% barytes is a useful and valuable ingredient in white paint. The amount should not exceed 60%, and it is probable that the most useful proportion is between 35% and 50%.

As a vehicle or extender of colors barytes has always been recognized, without controversy, as a very valuable agent. It is perfectly neutral and assimilates oil in about the same proportion as does white lead. It dries as readily as white lead, being much preferable in that respect to zinc-white. When reduced to a fine uniform powder it combines well with both white lead and zinc-white, though most of the barytes now used is not fine or uniform enough for such a mixture.

Price.—The value of barytes paint was highest during the civil war, and after its close it decreased rapidly till the beginning of the Franco-Prussian war, when it rose sharply until the financial crisis of 1873, since which time it has been steadily declining. There has always been a marked difference in the prices of the barytes pigments of different makes, and of the various grades of the same maker, both domestic and foreign. The lowest grade of any given make is usually sold for about one-half the price of the best grade of the same make. At all times a floated barytes prepared by the Western Color Works, and its successor, the Page & Krause Mining and Manufacturing Company, of St. Louis, has commanded in New York from 25% to 30% more than the best grade of any other make. This product was sold in New York at one time during the civil war for $90 per ton. Ten years later it brought $50 per ton, and since then it has declined to its present value of $25 per ton. The prices of other varieties, both domestic and imported, have fallen off proportionately, and at the present time the best grades bring from $18 to $20 per ton.

The data for tracing the fluctuations in the value of the crude mineral are very fragmentary. Thirty years ago it was sold in St. Louis for $10 a ton, ten years later it brought $7 per ton in the same market, and then steadily decreased to $5 per ton, which price was reached in 1889. After the imposition of the McKinley tariff the price in St. Louis rose to $6 per ton, at which it is now selling. The value of imported crude barytes in New York during the past twenty years has ranged between $7 and $9 per ton.

BAUXITE.*

BY HENRY MCCALLEY.

BAUXITE, the triple hydrate of aluminum, is, comparatively speaking, a new mineral that is known to but few. On account of its abundance, solubility, and purity it is now regarded as the principal or most important of all ores for the manufacture of aluminum and its alloys and compounds. It is named from Baux, a village in the southern part of France, near which it was first discovered in 1821. It was not known as bauxite, however, until about 1868, when it was used commercially as an ore of aluminum. Since then it has been found in several other parts of France, and in Germany, Austria, Ireland, Scotland, Italy, and Asia Minor. The clay variety is called "wocheinite," from its occurrence at Wochein, Germany. Bauxite is found also in French Guiana, South America, and in the United States.

Bauxite was first discovered in the United States near Hermitage, Floyd County, Ga., in 1881, by Edward Nichols. Since then it has been found in several other counties of Georgia and also in Alabama and Arkansas. The first discovery in Alabama was in Calhoun County, in 1890, by R. S. Perry, now General Manager of the Southern Bauxite Mining and Manufacturing Company, Piedmont, Ala. Previous to this time the Alabama bauxite had been known to the iron ore miners in one locality as an "iron ore blossom," and in another as a Clinton fossiliferous iron ore. It was first discovered in Arkansas by the Geological Survey of that State in 1891, having been previously known there as a honeycomb rock.

As to the reported existence of bauxite in North Carolina, South Carolina, Tennessee, and West Virginia, the best authorities in those States say that either it has not been discovered or they know nothing of it. Hon. Thomas Whitehead, Commissioner of Agriculture of Virginia, says that it has been

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* From advance sheets of the *Alabama Geological Survey Report*. In the preparation of this article I have visited and examined in person the bauxite deposits of Alabama and Georgia, and have received much valuable information from the officers of the different bauxite companies. I am especially indebted to Mr. R. S. Perry, General Manager of the Southern Bauxite Mining and Manufacturing Company, for assistance rendered. I have also made use of all available literature on this subject, including THE MINERAL INDUSTRY, Vol. I. (1892), and the *Mineral Resources of the United States* for 1892.

found in several counties in his State, but that so far it has attracted little attention, and that no scientific investigation of it has ever been made.

Characteristics.—Bauxite has few specially distinctive features except its usual pisolitic or concretionary character, which perhaps accounts for its having been so long overlooked and for the comparatively few localities where it is known to occur. The red variety of bauxite was thought to be a pisolitic iron ore until its true character was shown by analysis.

Bauxite is usually a concretionary or pisolitic mineral, though sometimes it is a hard, compact, homogeneous, fine-grained rock, commonly oölitic, and sometimes an earthy, clay-like material. It may, therefore, be hard or soft and friable, compact or porous, but the best grades are hard and have a metallic ring. The concretions vary in size from small peas to large bowlders, which are cemented together by fine-grained hard bauxite, bauxitic clay, or silicious material. In nearly every case, however, the concretions or nodules are better mineral than the cementing material. The concretions, also, are usually harder than the matrix, especially in the surface ore.

On the surface bauxite beds are generally marked by hard, rough bowlders or loose nodules and pebbles of ore in the top soil. Below the surface, however, the nodular and pebbly ores are often comparatively soft and crumbly, and the compact oölitic and fine-grained ores are sometimes a soft powder.

The compact bauxite has sometimes a few small concretions, and has often a waxy luster and the metallic ring. The porous, spongy, or vesicular ore has a pitted appearance, and is for the most part superficial. It will doubtless disappear entirely as the beds are opened deeper. This ore is a porous mass produced by the leaching of the soluble or hydrated alumina from concretionary ore. The vesicles are often partly filled with a fine silicious powder. The earthy or clay-like variety (wocheinite) of ore is a bauxitic kaolin or clay, or a mechanical mixture of bauxite and kaolin or clay. It sometimes shows irregular streaks of quite pure halloysite. The bowlder ore, with smooth, uneven surfaces, and with often light-colored exterior and reddish interior, is usually of very fine quality, though its occurrence is variable. Its matrix is usually a plastic, unctuous kaolin or clay, sometimes white, but usually more or less red from iron stain.

Bauxite varies in color from almost pure white to a deep red or black. It is also of cream and pearl-white color, grayish, yellowish, amber, pinkish, and speckled or mottled. It is nearly always stained more or less with iron. The colors or stains are also sometimes due to manganese or other minerals, and sometimes to organic matter. These colors often shade into one another, sometimes suddenly and sometimes gradually, and it is seldom, if ever, that a bank or deposit is wholly or uniformly one colored ore. As a rule, the lighter colored ores appear to be softer than the darker. The amber, red, black, and dark brown ores sometimes have spots as hard as quartz, while some of the white or light-colored ores, especially the impure or bauxitic clays, are almost as soft as clay itself. The hardness of the good ore varies from 1 to 3, while its sp. gr. varies from about 2.40 to 2.55.

Physical Occurrence.—In Europe the bauxite is said to be of sedimentary character and to occur in highly tilted beds alternating with sandstones, limestones, and clays. It is also said to occur, when the strata are denuded, in pockets and cavities in the limestones and in rounded masses in the clays, and when the strata are undenuded, in round concretionary grains disseminated in pockets in compact limestones. The limestone containing the bauxite and that adjacent to it are concretionary, some of the concretions being as large as the fist. The accompanying clays are usually colored with iron oxide, and some of them are very probably bauxitic. The surface around some of the outcrops is strewn with fragments of very light and white lustrous quartz (menilite).

In the United States bauxite occurs in residual clays in irregular or ill-defined beds or deposits. In Alabama and Georgia, at least, it must have an analogous origin to the limonite and manganese ores with which it is so closely associated, and by which it is so often more or less replaced. It may be that here, as in some instances in Europe, it existed originally in ferruginous, manganiferous, and argillaceous limestones and dolomites, and that on the decomposition of these it was concentrated in the residual clays of the parent rocks. If such is the case, the bauxite of Alabama and Georgia, like some of that in Europe, will doubtless be found at greater depth in rounded concretionary grains disseminated in the compact limestones and dolomites. The above supposition is strengthened by the fact that the bauxites of the United States always show more or less stratification, or, more correctly speaking, always follow the strike and dip of certain strata. The deepest diggings in this country have not as yet reached solid bedded rocks, though some of them are from 60 to 70 ft. deep. The clays in and with which the bauxites of this country occur frequently form very extensive deposits. They are usually unctuous and free from grit, and are often very white or pure, and sometimes pure halloysite. They are also of mottled, reddish, pinkish, bluish, brownish, blackish, etc., colors. They occur not only over and under the bauxite, but also frequently in it as clay-horses and as irregular seams and masses.

The bauxite deposits are indicated by either its loose concretionary nodules and pebbles scattered over the surface, or by projections above the surface of hard, rough bowlders of mineral. The loose ore and soil and débris from it and from other rocks form a cover over the bedded ore up to 10 ft. thick. The bauxitic soil, or the soil from the disintegration of the bauxite, is usually of a yellowish color.

Geological Occurrence.—The bauxites of Europe are partly, at least, of Tertiary (Miocene), Jurassic, and Triassic formations. Those of the United States are of either Tertiary or Lower Silurian age. Those of Georgia and most of the Alabama deposits are in the lower part of the Knox dolomite of Safford of Tennessee (Middle Cambrian). Some of the Alabama deposits, however, are in a still lower formation or are at the top of the Weisner quartzites, the Chilhowee sandstones of Safford (Lower Cambrian), or at the juncture of the Weisner quartzites and the Knox shales and sandstones of Safford. The Arkansas deposits are of Tertiary age, with in some places soft Tertiary beds both above and below them, though they are adjacent to crystalline or eruptive rocks (granites).

Origin.—It does not seem possible for all the known bauxite deposits to have been formed in the same way, and so there are various theories as to the formation in different places. One theory is that it is a sedimentary deposit from mineral springs (geysers), the springs being on land when the deposits are in isolated pockets, and at the bottom of lakes when they are more or less continuous or connected. Another theory is that when it rests upon or is associated with limestones (or dolomites), as in some of the deposits of France, Ireland, Austria, Italy, Alabama, and Georgia, it is due to a double decomposition of chloride of aluminum and iron in contact with carbonate of lime (or magnesia), forming alumina (bauxite), iron oxide, and calcium (or magnesium) chloride. Still another theory is that when it rests upon gneiss and is intimately associated with basalt, as in some of the deposits of France, Germany, and Ireland, it is due to the decomposition of basaltic rocks, as shown by its external and internal indications and by its chemical composition.

Occurrence.—The principal European deposits are in France, Germany, and Ireland. They are very extensive. Those in France are said to be nearly 100 miles long, and from 30 to 35 ft. thick. They probably exist only at intervals within this distance, and at places are not so thick. The wocheinite at Carniola, Germany, is reported to be about 12 ft. thick, and the deposit at the famous Irish Hill mine, in County Antrim, Ireland, is very extensive.

The deposits in the United States are known to be extensive, and it is probable that future discoveries and identifications will prove them to be much more so. The Alabama and Georgia deposits, so far as known, are comprised within a strip of country that is about 75 miles in length from northeast to southwest and about 25 miles in width from northwest to southeast. Within this strip there are numerous outcrops of the ore, though there are large areas within it without any known deposits. The known deposits of Alabama are in Cherokee, Calhoun, and Cleburne counties, and those of Georgia are in Polk, Floyd, Bartow, Gordon, and Chattooga counties. The beds vary in thickness from a few feet to 40 ft. They have been mined sufficiently to bring into sight an immense amount of ore, sufficient to supply the present demand for many years. They are, however, so irregular in their occurrence that they can be estimated only so far as they can be seen. The Arkansas deposits are in Saline and Pulaski counties. They are said to cover a total area of about 640 acres, and to vary in thickness from a few feet to 40 ft., with an average of about 15 ft.

Composition.—Bauxite is a triple hydrate of aluminum (Al_2O_3, $3H_2O$), in which more or less of the alumina is replaced by iron or maganese; it is usually contaminated with silica and other accidental impurities, such as titanic acid (TiO_2), phosphoric acid, sulphuric acid, carbonic acid, lime, magnesia, etc. The silica is present either as free silica or as a silicate (clay). The ore is very variable in its composition, and is so deceptive in its looks that its quality cannot be determined by inspection alone. The value of an ore in general is dependent on its percentage of alumina and freedom from iron and silica. The ore has a strong affinity for water, which is much stronger in some cases than in others. Titanic acid appears to be nearly always present in Irish ores, and also in those of Alabama and Georgia. It and the iron, unless in large quantities, are not regarded as very objectionable impurities in that used for the manufacture of alumina, as the iron gives a valuable by-product, and as so much of the titanic acid as becomes a sulphate remains with and acts like the alumina in setting the size or color in paper manufacture or in dyeing.

The composition of European bauxites is shown by the following analyses :

A.—FRENCH BAUXITES.

	1.	2.	3.	4.	5.	6.	7.	8.
Alumina	60.0%	75.0%	57.6%	55.4%	30.3%	33.2%	69.30%	76.90%
Ferric oxide	25.0	12.0	25.3	24.8	34.9	48.8	22.90	0.10
Silica	3.0	1.0	2.8	4.8	.....	2.0	0.30	2.20
Lime carbonate	......	....	0.4	0.2	12.7	......	......	......
Titanic acid	......	....	3.1	3.2	......	1.6	3.40	4.00
Water	12.00	12.00	10.8	11.6	22.1	8.6	14.10	15.80

C.—IRISH BAUXITES.

	22.	23.	24.	25.
Alumina	48.12%	43.44%	61.89%	73.0 %
Ferric oxide	2.36	2.11	1.96	4.26
Silica	7.95	15.05	6.01	2.15
Water	40.33	35.70	27.82	18.66

B.—GERMAN BAUXITES.

	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
Alumina	50.85%	49.02%	50.92%	76.3%	45.76%	55.61%	44.4%	54.1%	64.6%	64.24%	63.16%	72.87%	29.80%
Ferric oxide	14.36	42.90	15.70	6.2	18.96	7.17	30.3	10.4	2.0	2.40	23.55	13.49	3.67
Silica	5.14	10.27	1.10	1.0	6.41	14.41	15.0	12.0	7.5	6.29	4.15	4.25	44.76
Water	28.28	25.91	28.50	6.4	27.61	32.33	9.7	23.9	24.7	25.74	8.34	8.50	13.86
Potash and soda	0.26	0.31	....	....	0.38	.....	.....	.....	.....	.....	0.79	0.78	.....

1, 2, 3, 4, 5. From Baux (3, compact variety; 4, pisiform; 5, hard and compact calcareous paste). 6. From Calabres. Its analysis gives 5.8% of corundum. 7. From Thoronet, Var. Red variety. 8. From Villevevae Hérault White variety. 9. From Langsdorff. 11. From Vogelsberg. 12. From Klein-Steinheim. 13, 14. From Hadamar (Hesse). 15, 16, 17. From Feisstritz (15, red brown; 16, yellow; 17, white). 18, 19, 20. From Wochein (wocheinite). (18 has in it also lime 0.85%, magnesia 0.38%, sulphuric acid 0.20%, and phosphoric acid 0.46%; 19, dark variety; 20, white variety.) 21. From Prussia, white wocheinite. 22. From Irish Hill. 23. From County Antrim. 24. From Glenravel. 25. From Dublin, from commercial quantities used for making alum. It is dirty white, hard, dense, compact, and has also lime 0.59% and some titanic acid.

The French bauxites, of the conglomerate and oölitic kind, as can be seen from the above analyses, carry sometimes as much as 48% of ferric oxide, and those in the South of France, principally in the departments of Hérault, Bouches du Rhône, and Vanconlan, as much as 75% alumina. The small amount of water in the French ores refers them to the monohydrate (diaspore). The red mineral of the Var is said to have cavities in it which are lined with a white bauxite (diaspore) that carries as much as 85% of alumina. The diaspore, or monohydrate, is not as easily worked or as soluble as the true bauxite or triple hydrate. The Vogelberg ore is said to be of the Gibbsite (hydrargillite) or stalactitic variety, the purest form of bauxite, being freest from iron, silica, and titanic acid. The wocheinite ore has a dense earthy structure. The Irish ores are very similar to those of France. They are high in alumina, but unfortunately they are also high in silica and titanic acid. The best of them have silica as high as 6% to 11%, titanic acid about 6%, and peroxide of iron from 0.5% to 1.5%. The iron peroxide, however, in the ores that are low in silica is said to run as high as 10%. The ore of the famous Irish Hill mine, in County Antrim, is of peculiarly good quality, one ton of it making three tons of alum.

The ores of the United States are quite as pure as those of Europe, as shown by the following analyses of Georgia, Alabama, and Arkansas mineral :

A.—GEORGIA BAUXITES.

	1.	2	3.	4.	5.	6.	7.	8.	9.	10.
Alumina	46.72%	52.13%	39.75%	56.10%	58.61%	43.18%	36.86%	59.82%	51.22%	53.31%
Ferric oxide	2.14	1.12	1.62	10.64	2.63	8.74	1.28	2.16	4.83	12.92
Silica	29.01	19.56	41.47	2.56	8.29	28.11	40.02	6.62	13.33	1.16
Water	20.15	24.21	16.14	30.10	27.42	19.22	20.61	31.10	29.82	29.60
Titanic acid	0.87	2.08	......	......	3.15	...	......	.....	.....	3.22

A.—GEORGIA BAUXITES—*Continued.*

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
Alumina	45.21%	61.25%	67.53%	60.61%	60.63%	61.88%	44.37%	52.04%	58.46%	58.34%	59.22%	52.21%	57.25%	56.88%
Ferric oxide	0 52	1.82	trace	0.21	trace	0.21	3.53	11.51	1.43	4.51	3.16	13.50	3.21	1.49
Silica	35.88	1.98	1.34	2.47	3.20	2.13	22.95	3.50	8.25	3.35	3.30	2.80	......	2.30
Water, combined..	17.13	31.43	28.00	32.00	31.00	31.50	22.30	26.65	28.10	28.30	28.80	27.72	......	......
Moisture	......	......	......	......	......	......	4.50	3.60	0.70	2 10	1.90	......	......	......
Titanic acid	......	2.38	2.92	4 18	4.76	4.04	2 35	2.70	2.96	3.40	3.62	3.52	3.60	3.55

A.—GEORGIA BAUXITES—*Continued.*

	25.	26	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.
Alumina	82.38%	78.87%	67.53%	60.61%	60.63%	31.96%	21.90%	17.33%	20.02%	46.88%	51.16%	50.31%	27.73%	30.12%
Ferric oxide..	1.63	1.13	trace	0.21	trace	......	......	..	......	......	......	......	......	......
Silica...	1.62	1.97	1.34	2.47	3.20	......	......	......	......	......	......	......	......	......
Water, combined...	13.35	17.93	28.00	32.00	31.00	......	......	......	......	......	......	......	......	......
Moisture....	......	......	......	......	......	......	......	......	......	......	......	....	......	......
Titanic acid, etc. ..	......	......	2 92	4.18	4.76	......	......	......	......	......	......	......	......	......

Titanic acid is always present in the Georgia bauxites. When it is not determined it is counted with the alumina. The above analyses show these ores to be very variable. The analyses from 1 to 16, inclusive, are taken from a report on northwestern Georgia by Dr. J. W. Spencer, and, with the exception of from 13 to 16, inclusive, were made by Prof. H. C. White. They are said to be of samples that were chosen as types of the different varieties from various localities, and not because they were of good quality. The analyses from 17 to 21, inclusive, are of average samples of the different mines near Hermitage, Floyd County, and were made by Mr. H. B. Christiansen, chemist of the Bauxite Republic Mining and Manufacturing Company. Those from 22 to 24, inclusive, were made of surface samples from near Hermitage by Mr. Edward Nichols, the discoverer of bauxite in Georgia. Nos. 25 and 26 were made by the N. P. Pratt Laboratory, Atlanta; 27 to 29, inclusive, by the Pittsburg Reduction Company; and 30 to 38, inclusive, by Mr. R. S. Perry.

1. From Flowery Branch (Lot 21, District 23), near Hermitage, Floyd County. A white porcelanous mass with subordinate pisolitic grains, associated with white clay beds upon the side of a ridge.

2. From Mr. Doyle's farm (Lot 906, District 3), about seven miles northeast of Cave Spring, Floyd County. Large concretionary pellets of whitish color stained with iron oxide. The interior of the pellets are partly dissolved out, leaving a semi-vesicular mass somewhat poorer in alumina than would be expected. It occurs in a valley.

3. From land of Mr. Culberson, one mile from Cave Spring. A grayish white mass of small pisolitic concretions. It occurs on the top of a ridge.

4. From Mr. John Henry's farm (Lot 910, District 3), near New Prospect Church, six miles northeast of Cave Spring. A light, reddish, somewhat earthy, porous mass. It occurs on the side of a ridge.

5. From near the same locality as No. 4. A whitish mass, with occasional pisolites. Taken from the side of a narrow gully.

6. From the land of Montague & Co. (Lot 97, District 16), Bartow County, north of Kingston. An earthy white ore with reddish concretions. It is from the side of a ridge.

7. From Lot 61, District 23. An earthy-looking mass of large concretions. Selected to see if much bauxite was lost in the rejection of the poorer and more clay-like ores. It is a clay mixed with much bauxite.

8. From the land of Mr. Bobo (Lot 534, District 3), about three miles north of New Prospect Church, Floyd County. A small concretionary bowlder with small pisolitic grains, stained along the fracture lines with iron oxide. It occurs on the side of a ridge.

9. From the land of Mr. Shaw, two miles southwest of Adairsville, Bartow County. A mixture of white and red vesicular concretions.

10. From Lot 23, District 16, Bartow County. A hard, red, porcelanous mass of concretions. It occurs on the side of a ridge.

11. From Mr. Seay's land (Lot 108, District 16), east of Linwood. A white mass of small pisolitic grains.

12. From Lot 115, District 16, on the Barnsley estate of Woodland. A white mass of small pisolitic grains. On a flat-topped ridge.

13, 14, 15. From the Julia mines, Barnsley estate.

16. From the Knowles property.

17. From Frady Bank. A hard, rough, honeycomb ore.

18. From Holland Bank. A dark red ore in very hard lumps.

19. From Church Bank. A soft, white, clay-like ore.

20. From Stockdale Bank. Balls or concretions of about the size of hickory nuts (marble ore), with white exteriors and reddish interiors.

21. From Grier Bank. Solid lumps of a yellowish color tinted with brown.

22. From near Hermitage, Floyd County. Dark variety, surface specimen.

23. From near Hermitage. Light-colored variety, surface specimen.

24. From near Hermitage, Floyd County. Light-colored variety, surface specimen. This analysis shows phosphoric acid 0.066%, sp. gr. 2.35.

25, 26, 27, 28, 29. From Georgia Bauxite Company. Analysis: 25 and 26, N. P. Pratt Laboratory, Atlanta, Ga.; 27, 28, and 29, Pittsburg Reduction Company, Pittsburg, Penn.

30. From Gordon's deposit. A beautiful white ore, though seemingly clayey, and with only a few small concretions.

31, 32. From Barney's deposit, about five miles northeast of Rome, Floyd County. A pisolitic silicious, bauxitic clay, with irregular streaks of halloysite. Full of cups with a reddish silicious powder. The alumina is said to exist as a clay or silicate.

33. From Reese's deposit on the Chattanooga, Rome and Columbus Railroad, about eight miles from Rome, Floyd County. From bottom of old shaft dug for copper. A bauxitic clay with small concretions.

34. From the Henry deposit (Lot 910, District 3), near New Prospect Church, six miles northeast of Cave Spring. A concretionary porous ore of a somewhat earthy appearance.

35, 36. From Shaw deposit, two miles southwest of Adairsville, Bartow County. A vesicular ore.

37, 38. From Braham-Howell deposit (Lot 13, District 3), Floyd County. In large bowlders with few concretions.

B.—ALABAMA BAUXITES.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Alumina	39.44%	64.68%	58.25%	55.73%	61.87%	59.91%	58.53%	61.68%	61.00%	58.21%	53.87%
Ferric oxide	2 27	......	1.50	...	2.38	2.79	1.12	1.20	2.20	3.60	8.16
Silica	37.87	......	2.22	......	0.40	1.75	4.55	2.10	2.10	2.90	4.52
Water, combined	12.80	......	30.00*	......	30.50*	32.15*	38.20*	31.45*	31.58*	31.89*	24.86*
Titanic acid	......	......	......	......	......	......	......	......	3.12	3.40	.....

B.—ALABAMA BAUXITES—*Con.*	12.	13.	14.	15.	16.	17*a*.	18*b*.	19*c*.	20*d*.	21.
Alumina	40.93%	45 13%	45.91%	47.52%	41.38%	41.00%	48.92%	57.00% to 62.00%	55.00% to 62.00%	56.00% to 60.00%
Ferric oxide	22.60	1.50	11.86	19.95	0.85	25 25	2.14	under 1.00	2.50 to 3.00	about 2.75
Silica	8.99	22.40	18.87	7.73	23.72	10.25	21.08	about 2.50	about 5.00	about 7.00
Water, comb'd.	20.43	23.41	21 20	23.57*	23.72*	21.97*	23.86*	29.00 to 30.00	about 30.00	25.00 to 30.00

* These include also the hydroscopic moisture. (*a*) This sample also had 2.53% TiO_2. (*b*) This sample had 2.52% TiO_2. (*c*) This sample had 2% to 4.5% moisture. (*d*) This sample had 2% to 5% moisture.

1. From the Carr Bank, Cherokee County. An average sample of the white or gray ore on the outcrop. Analyst: Dr. W. B. Phillips, University of Alabama.

2. From Warwhoop Bank, Cherokee County. It contains also a trace of manganese monoxide, 0.50% lime, and 4.98% insoluble residue. Its loss by ignition was 3.08%. Analyst: Illinois Steel Company.

3. From Warwhoop Bank, Cherokee County. Average sample of hard ore underlying soft ore. Analyst: R. Swain Perry, Piedmont, Ala.

4. From Warwhoop Bank, Cherokee County. Average sample of soft ore over hard ore. Analyst: R. Swain Perry.

5. From Warwhoop Bank, Cherokee County. An average sample of ore under shed, shipped May 18, 1892. Analyst: R. Swain Perry.

6. From Gaines's Hill Bank, Cherokee County. An average sample. It contains large concretions. Analyst: R. Swain Perry.

7. From Washer Bank, or Bank 142, Cherokee County. A medium hard ore that is full of soft pink colored eyes (concretions). Analyst: H. B. Christiansen, chemist Republic Mining and Manufacturing Company.

8. From Washer Bank, or Bank 142, Cherokee County. An average sample of the ore with large dark red eyes. Analyst: H. B. Christiansen.

9. From Washer Bank, or Bank 142, Cherokee County. A white, uniform ore, with only a few eyes. The eyes are slighly colored. Analyst: H. B. Christiansen.

10. From Washer Bank, or Bank 142, Cherokee County. A nearly white ore withs mall red eyes. Chemist: H. B. Christiansen.

11. From Washer Bank, or Bank 142, Cherokee County. Given by Mr. John H. Hawkins, Superintendent of Republic Mining and Manufacturing Company, as about an average analysis of the ores of this mine.

12. From Burst-up Bank, or Bank 145, Cherokee County. Given by Mr. John H. Hawkins, as about an average analysis of the ores of this mine.

13. From near Piedmont, Calhoun County. Analyst: R. Swain Perry.

14. From near Jacksonville, Calhoun County. An average of two analyses of the red ore on the outcrop. Analysts: R. Swain Perry and chemist of the United States Geological Survey.

15. From near Jacksonville, Calhoun County. An average of two analyses of the white ore on the outcrop. Analysts: R. Swain Perry and chemist of the United States Geological Survey.

16. From near Jacksonville, Calhoun County. An average sample of the ore on the outcrop. Analyst: Dr. W. B. Phillips, University of Alabama.

17. From near Jacksonville, Calhoun County. The red variety. Analyst: Dr. W. B. Phillips.

18. From near Jacksonville, Calhoun County. The white variety. Analyst: Dr. W. B. Phillips.

19. From near Jacksonville, Calhoun County. The red variety. This analysis shows a trace of phosphoric acid. Analyst: W. F. Hillebrand.

20. From near Jacksonville, Calhoun County. The white variety. This analysis shows a trace of phosphoric acid. Analyst: W. F. Hillebrand.

21, 22. From near Anniston, Calhoun County. Analyst: R. Swain Perry.

23. From Warwhoop Bank, Cherokee County. The "hard, white ore." The average of consumers' analyses of between 500 and 1000 tons of ore shipped in 1893. Given by R. Swain Perry.

24. From Warwhoop Bank, Cherokee County. The "Warwhoop ore," or putty-colored ore. Average of car-load samples. Given by R. Swain Perry.

25 From Cherokee County. Average of analyses of car-load samples from different mines in Cherokee County in 1892. Given by J. M. Garvin, Superintendent Bass Furnace Company, Rock Run, Ala.

The Alabama ores have up to this time improved with depth, though in some instances the Georgia ores have deteriorated, the iron or silica, or both, increasing in these instances.

C.—ARKANSAS BAUXITES.	1.	2.	3.	4.	5.	6.	7.	8c.	9.
Alumina	55.59	57.62	62.05	55.64	51.90	55.89	46.40	58.60	44.81
Ferric oxide	6.08	1.83	1.66	1.95	3.16	19.45	22.15	9.11	1.37
Silica	10.13	11.48	2.00	10.38	16.76	5.11	4.89	3.34	33.94
Water, combined	28.99	28.63	30.31	27.62	24.86	17.39	26.68	28.63	17.28
Titanic acid		..	3.50	3.50	3.50	......	......	......	2.00

These analyses of Arkansas bauxites are of average samples, and were made by the State Geological Survey.

1. From Section 24, Township 1 N., Range 12 W., Pulaski County. Black variety. Used in building a pike.

2. From Section 36, Township 1 N., Range 12 W., Pulaski County. Black variety. An average sample.

3, 4, 5. From Pulaski County. From *Mineral Resources of the United States*, 1891.

6. From Section 3, Township 2 S., Range 14 W., Saline County. Black variety. Taken for an iron ore.

7. From Section 3, Township 2 S., Range 14 W., Saline County. Red variety. Taken for an iron ore.

8. From Pulaski County. Red variety. From *Mineral Resources of the United States*, 1891.

9. From an article by Dr. Branner, State Geologist. An average sample.

The Arkansas bauxite in a few localities is very high in iron, so much so that attempts have been made to mine it for an iron ore. Some few samples carry as high as 50% of metallic iron. Some of its white varieties are said to have the composition of clay.

The manufacturers say that the Alabama and Georgia bauxites are more soluble than those of Europe, and so they prefer them notwithstanding the fact that they often carry less alumina and that they have to pay more for them. Their greater solubility is believed to be due to their carrying more water of hydration or to their being truer bauxites or triple hydrates, while the European ores are probably partly monohydrates (diaspores). They are closely associated with iron and manganese ores of the following composition. Iron ore : Ferric oxide, 71.36% ; silica, 6.73% ; titanic acid, none ; phosphorus, 0.066%. Manganese ore : Manganese, 43.730% ; phosphorus, 0.129% ; silica, 0.353% ; metallic iron, 0.101%.

Mining.—The bauxite industry in America is a comparatively new one, and so probably many improvements will be made in the present modes of mining and drying the ore or in preparing it for shipment. The mines in this country as yet are nothing more than irregular holes in the ground on the sides of hills, with deep open drainage channels leading from them. The ore is easily mined from its comparative softness beneath the surface, being usually soft enough to be dug up with the pick, though it is expensive to mine because it is so variable in quality, requiring assorting. Almost every mine carries several grades of ore. It is concentrated and assorted by means of screens and by hand. The only other preparation that the ore undergoes for shipment is the drying. It is exceedingly hygroscopic, and so it pays to keep the mines well drained. The ore is now, in Alabama and Georgia, dried by simply spreading it over the yard or under the shed, leaving the rest to the sun and the winds. The drying process therefore goes on only during favorable weather, at the expense of time and completeness. Artificial means of drying will doubtless be resorted to as soon as the profits of the business will warrant the outlay of the additional capital.

There have been four companies engaged in mining and shipping bauxite, viz.: Republic Mining and Manufacturing Company, formerly of Hermitage, Ga., now of Rock Run, Ala., the pioneers in the business; Southern Bauxite Mining and Manufacturing Company, Piedmont, Ala.; Georgia Bauxite and Mining Company, Linwood, Ga. ; and Summerville (or John D. Taylor) Bauxite Company, Summerville, Ga. Only the first two of these companies are now actually engaged in the work. They have had mines in both Georgia and Alabama, but have now concentrated all of their forces in Alabama, in the "Dyke's District," Cherokee County. They each have there two mines, though the Southern Bauxite Mining and Manufacturing Company is at present working only one. The Georgia Bauxite Company ceased active operations a few months ago, and is now awaiting the settlement of the tariff question in Congress. The Summerville or Taylor Bauxite Company has done only development work in trying to find out the extent and quality of the ore, in which work about eight car loads were mined and shipped. The ore that is now being shipped is mainly of the very best quality, and so there is accumulating at the mines a considerable quantity of an inferior grade, though some of it is very good. This is much to be regretted, especially since nearly all the present output of this country and Europe is used for the manufacture of alum, and a much inferior ore, or an ore much higher in iron and silica, might be used for this purpose just as well. This shipment of only the best grade of ore, however, has been a necessity hitherto because the mines of this country are new enterprises and had to put out their best in order to successfully meet the competition of the shippers of cheap foreign ores, who had, moreover, an established reputation. They have now succeeded so far that they have almost killed the import trade.

Imports.—The United States now consumes from 25,000 to 35,000 long tons of bauxite per annum. This came wholly from France and Ireland until 1889, when it began to be mined in Georgia. Since 1889 the home production has been increasing and the imports decreasing. This is shown in the following tables:

IMPORTS OF BAUXITE INTO THE UNITED STATES.

Years.*	Lbs.	Value.	Years.*	Lbs.	Value.	Years.*	Lbs.	Value.	Years.*	Lbs.	Value
1873		$44,995	1879		$7,080	1884	10,066,496	$25,188	1889	28,945.674	$60,292
1874		86,820	1880		14,737	1885	20,510,540	41,376	1890	27,503,730	46,137
1875		45,725	1881		9,795	1886	15,988,807	33,223	1891	17,936,501	46.252
1876		20,875	1882	12,008,101	30.525	1887	10,824,749	29.809	1892	12,804,253	57,948
1877		345	1883	10,592,552	19,533	1888	20,809,516	46,450	1893	11,431,678	28,217
1878		685									

* Fiscal years ending June 30 until 1886; calendar years subsequently.

Production.—The French and Irish mines appear to furnish now about all the output of Europe. The output of Var and Hérault in 1888 is said to have been about 20,000 long tons, and that of the famous Irish Hill mine alone about 30,000 long tons in 1893.

PRODUCTION OF BAUXITE IN THE UNITED STATES.
(In long tons—2240 lbs.)

Year.	Alabama.	Georgia.	Total.	Value.
1889		728	728	$3,640
1890		1,850	1,850	9,250
1891	600	3,300	3,900	19.500
1892	4,900	4,900	9.800	49,000
1893	7,063	3.965	11,028	55.205

PRODUCTION OF BAUXITE IN THE UNITED STATES IN 1893 BY COMPANIES.*
(In long tons—2240 lbs.)

Company.	Alabama.	Georgia.	Total.	Value.
Republic Mining and Manufacturing Company	5,263	1,125	6,388	
Southern Bauxite Mining and Manufacturing Company	1,800	190	1,990	
Georgia Bauxite Company		2,500	2,500	
Summerville Bauxite Company		150	150	
Total	7,063	3,965	11.028	$55.205

* These figures were furnished by officers of the different companies.

The total capital invested in the industry in 1893 was $200,000, and the value of the output at the works of consumers was $110,500.

Cost of Production.—There being no duty on foreign ore and the freight being very low, it can be laid down in Boston, New York, and Philadelphia at from a little over $5 to about $6.50 per long ton. The freight on bauxite from the South of France to the United States has been known to be as low as 50c. per long ton, and is frequently as low as $1.25 per ton. It never exceeds $2.25 per long ton.

The American output now is furnished by the three Alabama mines, which are situated in a broken country from three to four miles northeast of the Rock Run Furnace, whither the ore has to be hauled in wagons to be loaded on cars. One of these companies gives employment to from 15 to 25 men, and the other 15 to 40, exclusive of teamsters. The ore now costs, as stated by one company, about $3.45 per long ton to mine and place it on the cars at Rock Run Furnace. The exact cost, however, as stated by this company, is hard to get at, since the mines are new, and a great deal of expense for prospecting and dead work has to be included in the computation. The cost per ton at the different mines would therefore vary very materially. The ore from one of the mines in Georgia, however, is said to have been placed on the cars at $1.15 per long ton. The freight rate to the present market varies from $4.50 to $6 per long ton, according to the length of haul, with an average of about $4.70 per long ton. So it now costs between $4.50 and $9 per long ton to lay the Georgia and Alabama ores down in their present market. If the above figures are correct, there can be at present but little, if any, profit in the mining and shipping of this ore. It is, however, sold at from $7 to $13 per long ton, according to the quality of the ore and the location of the market. If the market is a seaboard city, the ore has to be sold at a less figure than in the interior, in order to meet the foreign competition.

Markets.—The present markets for the ore in this country are New York, Philadelphia, Pittsburg, Buffalo, Brooklyn, Bayonne, Syracuse, Cleveland, Natrona, and Lockport, where are situated alum and aluminum works. It is also stated that, on account of their very superior quality, some of these ores have been sought for shipment to Germany.

Uses.—The ore was used when first discovered, before its true character was known, both in this country and in Europe, for an iron ore, but it was soon found to be too refractory for this purpose. It was used in Arkansas as a road material. It is now considered, however, the most valuable and most desirable of all minerals that can be gotten in large enough quantities for the manufacture in commercial quantities of metallic aluminum and its alloys and compounds. Before being used for any of these purposes, however, it is purified, *i. e.*, its soluble alumina is separated out from the impurities present by one of two processes, known as the sulphuric acid and the sodium carbonate methods. The ore is comparatively soft and easily manipulated. It gives metallic aluminum of almost perfect purity at a very reasonable cost, and has been used in the manufacture of aluminum and aluminum alloys since 1885.

The principal use of bauxite, however, is for the manufacture of aluminum salts or compounds, especially alums, which are used largely in manufacturing paper, dyes, and baking powders. About one-half of the large output of the Irish Hill mine, or some 15,000 long tons, is converted into alum, it is said, by the one firm of Peter Spence & Sons. Another salt that is also extensively manufactured from it is aluminate of soda, which is used in large quantities in dyeing and calico printing. The greatest value and use of the ore in the future, it is believed, will be for the manufacture of the highest grade refractory materials, like crucibles and firebrick. The better class of ores should be kept for this purpose, while those of inferior quality could be converted into alum and other compounds. An ore carrying as much as 10% ferric oxide and 20% silica can be easily used for the manufacture of alum.

Another important and remunerative use for bauxite is now claimed in the preparation of alumino-ferric cake, a cheap by-product employed for the purification and deodorization of sewage, and for the making at the same time valuable fertilizers of their foul and evil smelling effluents. This discovery, it is claimed, has been shown on the Thames and Clyde to be especially adapted to the cleaning of rivers and large streams, and will no doubt come into general use.

BISMUTH.

Bismuth is a reddish-white metal of a high luster and foliaceous texture. It is so brittle that it may be pulverized, and it breaks with a highly crystalline fracture. Its sp. gr. is 9.83. It melts at 264° C. (507° F.). Like water, it may be cooled 6° or 7° C. below its congealing point; but when solidification sets in, the temperature rises to 480° F. and continues to rise until the mass is completely solid. Like ice, also, it expands about .03 of its volume on solidification, a property which is communicated to its alloys and renders them valuable for certain purposes.

Bismuth very frequently occurs native, disseminated in gneiss, other crystalline rocks, and clay slate, whence much of the metal of commerce is derived. It also occurs commonly as bismutite or bismuth spar (hydrous carbonate of bismuth, $2Bi_8C_3O_{18}+9H_2O$), bismuthinite or bismuth glance (Bi_2S_3), and bismuth ocher (Bi_2O_3).

The chief sources of bismuth are the mines of Schneeberg in the Erzgebirge of Saxony, and mines in Peru, Bolivia, and Australia. Bismuth minerals also occur commonly with those of silver in the United States and elsewhere, but these ores are not often used as sources of the metal.

Occurrence of Bismuth Ores.

Austria.—Bismuth ores are found in the silver and tin deposits of the Austrian Erzgebirge, Bohemia, which are an extension of the Saxon mineral ranges, and with some of the ores of Styria, Carinthia, and Salzburg. Mention should also be made of the veins of Cziklova in the Banat, and of the gold and silver mines of Rezbanya in Siebenbürgen, where the metal occurs as telluride of bismuth, both the precious metals also occurring in combination with tellurium. Bismuth ores are mined in Austria at three places in Bohemia, while a small quantity is won as a by-product in the preparation of uranium oxide at Joachimthal. The total output of ore in Austria in 1892 was 855.8 metric tons, which was 227.5 tons less than in 1891. Nearly the whole product was shipped to the Saxon works for reduction, only 24.2 tons being treated at home. The production of metal from this ore was 548 kilos, or 2.26%, against 6.42 kilos in the previous year. All of the output in 1892, with the exception of 130 kilos, came from private works and was exported to Saxony.

Australia.—Bismuth is known to exist in all the Australian colonies, but up to the present time it has been mined only in New South Wales and Queensland. It is usually found in association with tin and other ores, but in one instance a mass of native bismuth, weighing 30 lbs., was found in the colony first mentioned. The principal mine in Queensland is the Kingsgate, at Glen Innes, in the New England district, where the mineral is generally associated with molybdenum and gold ; this mine, which was formerly a large producer, is at present closed. There is another mine at Baven, in the same colony.

Bismuth is found in the Degilbo district, Queensland, as telluride, sulphide, and carbonate, with varying tenor in gold, silver, and copper. The country rock is a crystalline metamorphic slate (intersected here and there by dikes of porphyry) and a coarse, micaceous granite.* Bismuth was first found in this district about 1886, on the property of the Mount Shamrock Gold Company, Limited, in the decomposed outcrop of a chimney of ore deposited in the pipe of an ancient geyser, 40 ft. in diameter, which has since been followed downward to a depth of over 225 ft. No regular vein of bismuth was found, but occasionally boulders of rich ore assaying high in both gold and bismuth were encountered, the average of many assays having been about 40% bismuth and 200 oz. gold per ton, while one lump, weighing 10 lbs., contained 66% bismuth and 2150 oz. gold per ton.

About twelve miles east of the Mount Shamrock property the Bigginton Mining Company has a large deposit of gold-bearing magnetite, containing about one per cent. bismuth, which is separated from the iron magnetically, the iron at present being thrown over the dump as waste. Parallel with the deposit of magnetite there is a large body of hornblende carrying half an ounce gold per ton, and from one to two per cent. bismuth.

In treating this auriferous magnetite, the ore is crushed in Huntington mills, and the pulp passed over copper plates in order to amalgamate the gold. The tailings are then concentrated on Frue vanners, giving headings consisting of magnetite and from 10% to 12% bismuth. This concentrate is run through a Ball-Norton magnetic separator once or twice, according to the percentage of magnetite, the aim being to make a product containing about 20% bismuth. This is then put up in bags holding about 50 kilos each and shipped to London, where 20% ore brings about £100 per long ton (2240 lbs.) net.

Bolivia.—The most important bismuth mines of Bolivia are those at Tasna and Chorolque, which produce also tin and the noble metals. Bismuth occurs in them native, and as ocher, oxychloride, carbonate, arsenantimoniate, and sulphide ; also in selenium and tellurium-bearing ores. Chorolque is situated in the Andes at an altitude of 5603 meters, while Tasna is 5106 meters high. The ores occur in quartz veins and are much mixed. They contain 22.8% to 30.05% bismuth, 10.2% to 16.9% iron, and 9.5% to 12.15% sulphur, with traces of antimony, silver, and lead. The veins of Chorolque occur in porphyry, while those of Tasna are in slates.† These mines are said to show already enough ore to supply the whole world for more than ten years, and their owners (Germans and Bolivians) send each year to market only sufficient to meet the feeble demand.‡

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* W. B. Roberts, *Engineering and Mining Journal*, June 25, 1892, p. 668.

† Fuchs and De Launay, *Les Gîtes Métallifères*, pp. 159–167.

‡ *Zeitschrift für praktische Geologie*, June 1, 1893, p. 241.

England.—Bismuth has been produced at various times by certain of the tin and copper mines of Cornwall, but their output has never been important, and is now quite insignificant.

France.—Bismuth ores have been mined at Meymac, where there is a vein in granite containing wolfram, arsenopyrite, and some arsenates and phosphates near the outcrop, and bismuth ores at greater depth, of which, however, only the oxide and hydrocarbonate are important. All the other ores, however, contain bismuth, as, for instance, the arsenopyrite, which has from 1.62% to 6.58%. According to Carnot, native bismuth from this place contains 99% bismuth, 0.09% arsenic, 0.15% antimony, 0.41% lead, 0.10% iron, and 0.06% sulphur.

Saxony.—Bismuth occurs at Schneeberg, Altenberg, and vicinity, chiefly as native metal, but also as bismuthinite, bismutite, etc. By far the most important producers of bismuth are the mines of Schneeberg, where the metal is found native in the veins which are worked for cobalt ores.

United States.—Bismuth occurs in the United States very frequently in connection with silver ores in the mines of the Rocky Mountains, but these have never been used regularly as sources for the metal. Carbonate of bismuth has been found near Phœnix, Ariz., while a grayish-green impure oxide, averaging from 8% to 10% bismuth, is said to occur near Tucson. There are several veins carrying bismuth at a point twelve miles west of Beaver City, Utah, which occur in magnesian limestone and are said to be upward of a foot in thickness. The ore is native bismuth, with pyrite and galena together with some silver, in a quartzose gangue. One of these mines, the Bismuth, in the Granite district, shipped a small amount of ore in 1871, which is said to have carried 7% bismuth.* Bismuth is found in Colorado at numerous points in conjunction with silver. The most important occurrence of the metal, however, is probably in the Bismuth Queen Lode, about five miles north of Golden, where there is a vein of bismutite and bismuthinite from two to eight inches wide. About one ton of bismuth was produced in the United States in 1885,† coming probably from this source. There is no other record of production of bismuth in the United States.

METALLURGY.

The chief producers of metallic bismuth are the Blue-Color Works, at Oberschlema and Pfannenstiel, in Saxony, which are in possession of the important deposits of bismuth ore at Schneeberg, and Johnson, Matthey & Co. of London, who reduce imported ores, chiefly from Australia, of which about 40 tons, averaging 60% bismuth, are imported into England annually.‡

Bismuth was obtained formerly from its ores in Saxony by liquation, the mineral being heated in iron tubes laid in a furnace in a slanting position, so that the metallic bismuth was melted and drained off. By this process, however, only so much of the bismuth as existed in the ore in the metallic state was obtained, and the loss of this was large. The residue from the tubes, which also contained the cobalt of the ore, was sent to the cobalt furnaces, where the bismuth collected

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* *Mineral Resources of the United States*, 1883-84, p. 654.

† *Mineral Resources of the United States*, 1885.

‡ Ernest A. Smith, *Journal of the Society of Chemical Industry*, April 29, 1893, p. 317.

in the cobalt speiss, from which it was again separated by liquation. This process, however, has long since been abandoned.

The method now in use in Saxony consists in roasting the ores and smelting them subsequently, with carbon, iron, and slag, in crucibles. The metal is reduced and settles in the bottom of the crucible in two layers, the upper consisting of cobalt speiss and the lower of bismuth. The latter is run off in the liquid state as soon as the layer of speiss has solidified, this separation being easily possible by virtue of the low melting point of bismuth, 264° C. The bismuth thus obtained contains small quantities of iron, cobalt, nickel, lead, silver, sulphur, and arsenic. It is purified by liquating on a sloping iron plate, whence the pure metal drains off into a warm iron pot from which it is cast into hemispherical molds, each containing 10 to 12 kilograms of metal. The metal enters the market in this form.

Bismuth is won at Freiberg, Saxony, from the litharge obtained in cupeling bismuth-holding silver-lead bullion. In cupeling bullion of this kind the lead is oxidized more rapidly than the bismuth, which is concentrated in the lead bath toward the end of the operation, and forms consequently a notable proportion of the last litharge. This is kept separate from the other litharge and is treated with hydrochloric acid for the recovery of the bismuth. The oxide of bismuth dissolves in the acid, the strength of which is regulated so as to prevent the formation of insoluble salts, and the solution is drawn off to precipitation vats, where the bismuth is thrown down as oxychloride by diluting the solution with water. The oxychloride of bismuth is reduced by smelting with charcoal, silica, and carbonate of sodium in iron crucibles.

A small amount of bismuth is obtained from the tin ores of Altenberg, in Saxony, by a process similar to that used at Freiberg, the roasted tin ore being leached with chlorhydric acid and the bismuth subsequently precipitated as oxychloride by diluting the solution. The amount of bismuth won at these works, however, is very small, amounting to only about 500 kilograms per annum.

The composition of the bismuth of commerce is shown by the following analyses :*

Kind.	Bi.	Sb.	As.	Cu.	Ag.	S.	Total.
Saxon	99.77	nil	nil	0.08	0.05	0.01	99.91
Peruvian	93 372	4.570	nil	2.058	....	....	100.00
Australian	94.103	2.621	9.290	1.944	....	0.430	99.38

The sample of Saxon bismuth is of refined metal, while the Peruvian (Bolivian) and Australian are crude.

The bismuth of commerce usually contains a notable percentage of gold and silver. Mr. Ernest A. Smith gives in the *Journal of the Society of Chemical Industry*, April, 29, 1893, p. 318, the result of a series of assays. One sample contained 0.0018% gold and 0.223% silver ; a sample of Australian bismuth contained 0.011% gold and 0.3319% silver ; German bismuth 0.0003% gold and 0.0729% silver ; while a sample marked American bismuth contained 0.0005% gold and 0.075% silver. For methods of assaying gold and silver bearing bismuth the reader is referred to the article cited.

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* Wagner's *Chemical Technology* (Crookes and Fischer), p. 202. New York, 1892.

For certain purposes for which bismuth is largely employed—for example, in medicine—it is necessary to obtain a metal of exceptional purity. Thus the presence of tellurium in bismuth preparations gives rise to a very unpleasant odor of the breath, as if the patient had been freely eating onions. The metallurgical purification of bismuth has been so completely carried out, however, by the firm of Johnson, Matthey & Co., that it is very rare that gold and silver, still less tellurium, can be detected in the fine product. The precious metals can be completely extracted from molten bismuth by the addition of two per cent. zinc, on the same principle that lead is desilverized.* Arsenic and antimony also are very completely removed from bismuth by a simple process. If arsensic-holding bismuth with, for example, 0.65% arsenic is heated in the air to 395° C., all the arsenic is volatilized without loss of bismuth. Arsenic-holding bismuth is refined in England in this manner in lots of 10 or 12 tons. Antimony-holding bismuth is purified by stirring the molten metal with a stick of dry wood, and removing the oily scum, which arises, until no more appears. Thus a lot of 350 kilograms of molten metal, containing 96.2% bismuth, 0.8% antimony, 0.4% iron, 2.1% lead, 0.5% copper, and a trace of arsenic, was kept for four hours at a temperature of 458% C., at the end of which time it was free from antimony. The oily, glasslike, transparent scum of oxide of antimony (with more than 30% antimony) may contain as much as 10% bismuth.†

USES.

Bismuth is used in the metallic form only in alloys, but its salts are employed extensively for various purposes ; thus the oxide, with boric and silicic acids, is used for optical glasses, and to a considerable extent for porcelain colors, while the basic nitrate is used as a cosmetic (*blanc de fard*) and also in medicine.

The alloys of bismuth are remarkable for their ready fusibility and their property of expanding on solidification. Bismuth forms alloys with nearly all the other metals, but the following are the most important in the arts : Newton's fusible metal, named for Sir Isaac Newton, which melts at 94.5° C., is composed of 8 parts bismuth, 3 parts tin, and 5 parts lead ; Darcet's metal contains 2 parts bismuth, 1 part lead, and 1 part tin, melting at 93 C.; another alloy with 5 parts bismuth, 2 parts tin, and 3 parts lead, melts at 91.6° C.; Rose's metal, containing 420 parts bismuth, 236 parts lead, and 207 parts tin, a composition corresponding to the formula Bi_2Sn_2Pb, fuses below 100° C. and on cooling remains pasty for a considerable range of temperature below that point. This alloy has other curious properties ; it expands regularly with heat from zero to 35° C., but on further heating it contracts up to 55°, from which point up to 80° the rate of expansion is more rapid than below 35°. Above 80°, however, the normal rate is resumed.

The fusibility of bismuth alloys is increased by the addition of cadmium ; thus Wood's fusible metal, containing a small proportion of cadmium, melts between 66° and 71° C., while Lipowitz's metal, containing 8 parts lead, 15 parts bismuth, 4 parts tin, and 3 parts cadmium, softens at about 55° C. and is completely liquid

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* Edward Matthey, *Proceedings of the Royal Society*, 1889; *Journal of the Society of Chemical Industry*, 1889, p. 286.

† Matthey, *Chemical News*, 1893, 63, 67.

at a little over 60°. This alloy is silver-white in color, and has a sp. gr. of 9.4. (See article on Cadmium.)

Fusible alloys containing bismuth have been used to some extent as safety plugs for steam boilers, but it has been found that these are untrustworthy owing to the liquation of the more fusible components of the mass when subject to continued heating near but below the melting point, leaving a more refractory alloy behind. More recently these alloys have found an application in the automatic sprinklers placed on the ceilings of buildings as protection against fire, the sprinkler plugs melting with a rise in temperature above the safety point and allowing the water to flow from the sprinklers.

BORAX.

The story of the borax industry in 1893 is told by the statistics, which show a decrease in production from 12,538,196 lbs. in 1892 to only 8,699,000 lbs., a falling off of nearly one-third, which occurred chiefly on the part of the California deposits. This is to be attributed to the prevailing depression in all branches of industry, which cut off the demand for the product. The market, which is in the hands of the Pacific Coast Borax Company, remained steady, however, and the price averaged about the same as in the previous year. Some new locations of borax property were made, but with present conditions there will be scant prospect for their development. The production of borax in the United States is given in the following table:

The occurrence, sources of borax, and methods of treatment were discussed at length in THE MINERAL INDUSTRY, Vol. I., by Prof. J. F. Kemp, to which article the reader is referred. The following additional information concerning the Tuscan sources of borax and boracic acid is taken from *British Consular Report*, 1893, No. 1250:

"Boracic acid in its native form exists in large quantities at several places in Pisa and Grosseto in Tuscany. There are, according to Professor Garollo, twelve boracic acid establishments in the two provinces, whose total annual output exceeds 60,000 cwt. All the boracic acid works of Tuscany are in the hands of four proprietors, who sell their product to merchants in Leghorn. The demand for the boracic acid of Tuscany continues to be large. Although the exports in 1892 and 1893 were less than in the previous years, this falling off is rather to be attributed to the general slackness of trade than to any causes particularly affecting this branch of it. The shipment to England is always large. Of the 38,283 cwt. exported from Leghorn in 1891, 27,807 cwt. were sent to the United Kingdom, almost the whole of the remainder being taken by the United States of America, Russia, Belgium, and France. Borax, having boracic acid as its source, is also produced in considerable quantities in Tuscany. The export of borax and borate of soda in 1890 was 14,889 cwt., in 1891, 12,341 cwt., and in 1892, 14,323 cwt."

Mr. H. N. Warren of Liverpool, England, has described a new process for manufacturing borax from commercial boracic acid and common salt, discovered by him.* The process consists in heating a mixture of salt and boracic acid in

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* *Engineering and Mining Journal*, Oct. 21, 1893.

an atmosphere of superheated steam in clay retorts. The method is based on the fact that if boracic acid is melted at a low red-heat in a crucible or retort, as long as aqueous vapors are given off volatilization of the boracic acid is perceptible until about 70% of the water present is discharged, while the remainder of the water is expelled in a nearly pure condition. Boracic anhydride is almost entirely fixed at elevated temperatures, while boracic acid is one of the most feeble of acids. The retorts used by Mr. Warren are composed of acid-resisting material, and the tops are provided with tubes for the introduction of the steam. After the retorts have been charged with an intimate mixture of well-ground salt and boracic acid, the neck of the retort is connected with a refrigerator for the purpose of condensing the acid given off. Directly the retorts are heated to low redness, hydrochloric acid is disengaged in large quantities. The heat is then slightly raised, and the supply of steam so regulated that water in the form of steam is allowed to enter through the tubulure in sufficient quantity to condense in the refrigerator the hydrochloric acid formed. The result is a quick and complete decomposition of the salt, with the production of anhydrous borax, which remains in the retorts, while a dense and pure acid collects in the condenser. When the reaction is completed the contents of the retort are ejected, while still red-hot, into cold water. It is allowed to remain in the water for two days in order that it shall all be dissolved. After that time it is recrystallized out in the form of ordinary borax.

PRODUCTION OF BORAX IN THE UNITED STATES.

Year.	Chief Fields producing.	California, Pounds.	Nevada, Pounds.	Total Product.	Av. Wholesale Price in N. Y. in Cents.
1864..	Borax Lake, Lake Co., Cal.	24,304	....	24,304	39
1865..	" " "	251,092	....	251,092	37½
1866..	" " "	401,632	....	401,632	33
1867..	" " "	439,824	....	439,824	35½
1868..	" " "	64,513	....	64,513	33⅓
1869..	....	....	....	....	35⅕
1870..	....	....	....	....	30½
1871..	....	....	....	....	31¼
1872..	Hackinhama, Lake Co., Cal.	280,000	....	280,000	32
1873..	San Bernardino, Cal., and the Nevada marshes...	1,030,000	970,000	2,000,000	24⅘
1874..	" " " " " ...	1,829,771	2,170,138	3,999,909	14⅕
1875..	" " " " " ...	2,336,000	2,804,000	5,140,000	12⅝
1876..	" " " " " ...	2,873,909	2,307,001	5,180,910	10⅞
1877..	" " " " " ...	1,986,970	2,740,310	4,727,280	9¾
1878..	" " " " " ...	746,840	2,055,960	2,802,800	8⅞
1879..	" " " " " ...	727,146	827,840	1,554,986	9
1880..	" " " " " ...	1,219,948	2,640,800	3,860,748	12¼
1881..	" " " " " ...	1,380,205	2,665,200	4,045,405	13¾
1882..	Same and Death Valley and Amargosa, Cal......	1,465,732	2,770,559	4,236,291	13¾
1883..	Same and Calico Mine, Cal.	1,800,000	3,800,000	5,600,000	14¾
1884..	" " "	2,037,940	5,675,363	7,713,303	9¾
1885..	" " "	1,885,300	5,586,104	7,471,404	8¼
1886..	" " "	2,569,630	6,524,542	9,094,172	6¾
1887..	(Suspension at Death Valley and Amargosa)......	2,029,380	5,571,735	7,601,115	5¾
1888..	Calico, San Bernardino, and Nevada marshes....	2,809,088	4,004,355	6,813,443	7
1889..	Same and Saline Valley, Cal.	1,939,650	5,333,482	7,273,132	7½
1890..	" " "	6,402,034	5,487,794	11,889,828	7½
1891..	" " "	8,533,337	3,296,663	11,830,000	7½
1892..	" " "	11,050,495	1,487,701	12,538,196	7½
1893..	" " "	7,499,562	1,199,438	8,699,000	7½

BROMINE.

Bromine is an element closely allied to chlorine. It is not found in the free state in nature, but always in combination with some other element as a bromide. At ordinary temperatures it is a liquid of dark reddish brown color (in thin layers it is bright red), about three times as heavy as water, and highly poisonous. It has a strong odor, which resembles that of chlorine. It boils at 63° C., being converted into a dark-red vapor ; at 7.2° C. it solidifies, forming a reddish-brown crystalline mass. Bromine is rather freely soluble in water, giving a reddish-brown solution, which is decomposed on exposure to light with the formation of oxygen and hydrobromic acid. At 15° C. 100 parts of bromine water contain 3.226 parts of bromine. Bromine is also soluble in hydrobromic, hydrochloric, and aqueous sulphurous acids, in ether, alcohol, chloroform, and solutions of hydrogen sulphide and potassium bromide.

Occurrence.—Bromine occurs chiefly as potassium bromide in sea water and in the water of many saline springs. Although the amount of bromine existing in the ocean is immense, the tenor of the sea water, which contains only about 0.06 grain per liter, is too small to make its extraction profitable. The bromine of commerce is obtained entirely from the brines of certain salt regions, in the mother liquors of which it is concentrated to so high a degree that it is economical to save them and recover the bromine as a by-product. This is done at Stassfurt and Leopoldshall, in Germany, and in Midland County, Michigan, and the Ohio-Pennsylvania-West Virginia salt district of the United States.

History.—The bromine industry in the United States was established in 1846 by Dr. David Alter at Freeport, Penn. He continued the business until 1856, but from that time until 1866 no bromime was made in this country. In the latter year the manufacture was resumed at Freeport, and was also begun at Tarentum, Penn., but these works were abandoned in 1871 and 1874, respectively, and no bromine has been made in either place since. The production of bromine was begun at Canal Dover, Ohio, in 1871. The manufacture was first undertaken in Michigan in 1885 at Midland, Midland County, where an isolated system of wells yields a bittern containing about four per cent. bromine. Previous to this attempts to recover bromine from Michigan brines had been unsuccessful, bromine being present in too small an amount to make its extraction profitable.

Manufacture.—In recovering bromine at Stassfurt the mother liquors (of 1.32 sp. gr.) containing 0.15% to 0.35% bromine are mixed with dilute sulphuric acid, whereby hydrobromic and hydrochloric acids are formed. The liquor is then heated to 120° C., when the hydrochloric acid is driven off, while the less volatile hydrobromic acid remains behind. On cooling, sulphate salts formed by the combination of the H_2SO_4 with the alkaline bases from which the bromine has been displaced crystallize out, while the hydrobromic acid is concentrated in the remaining liquor, which is poured off from the crystals, mixed with manganese peroxide (pyrolusite) and sulphuric acid, and distilled. The hydrobromic acid is oxidized by the pyrolusite, and bromine is set free, which passes over into a receiver, where it is dissolved as bromide and bromate of sodium. The last solution is evaporated to dryness, and the residue is ignited to convert the bromate into bromine, when it is again mixed with sulphuric acid and pyrolusite and redistilled, pure bromine (which is best collected and preserved under concentrated sulphuric acid) being obtained.

Not all kinds of pyrolusite are suitable for the preparation of bromine, that of a medium hardness being considered the best. From 1½ to 2 lbs. of pyrolusite are required for each pound of bromine produced. The process of bromine manufacture in West Virginia and Ohio is practically the same as that carried out at Stassfurt.

Bromine is shipped in strong glass bottles with ground stoppers, the latter being coated with melted shellac, then luted with lime and finally covered with muslin and coated with resin. A number of such bottles are packed together in a box. When the importations from Germany commenced it was at first liquid bromine which found its way into this country, but later, as the difficulty of obtaining freight for the article increased,—its transportation being disliked and considered highly dangerous by the carrying companies,—the imports were made chiefly in the form of bromides.

Uses.—The manufacturing chemists are the principal consumers of bromine, using it in the preparation of bromides, chiefly potassium bromide. A small part of the product is used in the manufacture of eosene (tetrabromfluoresceine), one of the aniline colors. Smaller amounts are used as a disinfectant. It has been proposed for many years to use bromine as a substitute for chlorine in the treatment of gold ores, but it was not employed for this purpose to an important extent until the past year, when a considerable quantity was thus consumed.

Production.—The production of bromine at Stassfurt and Leopoldshall amounts to about 300,000 kilograms, or 660,000 lbs., per annum. The production in the United States is given in the following table:

Year.	Ohio.	West Virginia.	Michigan.	Pennsylvania.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Value.
1880....	....	....	....	....	404,690	$114,752
1881....	....	....	....	....	300,000	75,000
1882....	....	....	....	....	250,000	75,000
1883....	194,450	106,650	....	....	301,100	72,264
1884....	181,591	99,509	....	....	281,100	67,464
1885....	125,000	85,000	40,000	60,000	320,000	92,800
1886....	126,866	126.391	125,528	49,549	428,334	141,350
1887....	75,737	45,350	....	78,000	199,087	61,717
1888....	64,540	81,124	61,609	100,113	307,386	95,290
1889....	165,973	90,028	45,968	116,922	418,891	125 667
1890....	101,813	118,184	59,696	108,154	387,847	104,719
1891....	....	....	....	....	368,786	73,757
1892....	....	....	....	....	379,480	64,512
1893....	113,575½	80,852	42,568	111,403½	348,399	87,100

The only imports of bromine into the United States in recent years have been as follows: Year ending June 30, 1886, 22,099 lbs., valued at $6288; calendar year 1887, 66,307 lbs., valued at $16,216; 1891, 19,020 lbs., valued at $2473.

The works for the treatment of gold ores at Rapid City, South Dakota, have recently been using bromine almost exclusively instead of chlorine. Dr. L. D. Godshall conducted a series of experiments in the assay office and in the mills to determine the relative merits of the two agents, bromine and chlorine.* The tests in the mill were made in the chlorinating barrels, of which there are two, each capable of treating about four tons of ore at a time; the charges were treated alternately with bromine and chlorine. In the assay office the tests were made to cover as many conditions of the ore as possible. The following results were obtained:

Assay Office Tailings.				Mill Tailings.			
Bromine.	Chlorine.	Bromine.	Chlorine.	Bromine.	Chlorine.	Bromine.	Chlorine.
$2.60	$2.40	$1.40	$3.40	$5.00	$3.80	$3.60	....
2.60	2.20	2.20	2.00	4.80	4.40	4.40	$4.80
2.80	2.00	3.00	2.80	4.40	4.80	4.20	....
4.40	1.80	4.20	3.00	4.60	3.20	4 60	4.80
2.80	3.20	2.80	3.20	4.40	4.80	4.60	3.80
2.60	1.60	2.20	4.80	3.80	3.80	4.00	4 80
5.80	5.20	3.00	2.80	4.20	4.00	4.00	4.80
4.20	4.00	3.40	2.80	4.80	4.20	4.00	3.80
6.20	4.00	2.60	3.20	4.00	3.80	4.40	4.20
5.80	3.00	2.40	2 20	4.20	4.20	4.60	3.80
5.60	4.20	1.40	1.40	4.00	4.00	....	....
1.60	1.40	Average		4.80	3.40	Average	
7.80	7.80	$3.48	$3.10	4.00	3.60	$4.32	$4.13

Some of the assay office results were from fine ore, while all of the mill tests were with coarse ore. Dr. Godshall concludes that the difference in favor of chlorine, as shown in the tests, is more than overcome by the difference in cost of the two agents, not to mention other advantages in favor of the bromine, such as purer sulphides, less of the obnoxious gas, which is very hard on the workingmen, and avoiding the handling of sulphuric acid, an excess of which soon rots all filter cloths unless asbestos be used. Ore well roasted should not require more than 1½ lbs. of bromine per ton,—in fact, considerably less than this was used at Rapid City at times,—whereas with chlorine it takes an exceptionally well roasted ore to bring the cost to 50c. per ton of ore, taking Western prices of chemicals as a basis.

Market Conditions.—The bromine industry in the United States has been subject to severe competition and sharp fluctuations in price during the past ten years. At the beginning of 1885 the price of bromine had fallen to 19c. per lb., owing to the increased production, when a combination of all the producers (known as the National Bromine Company) was formed, and the entire product was pooled and sold by one agency. As a result of this the price rose steadily until 33c. per lb. was reached at the end of 1886. This price was maintained through 1887–88. The great increase in production in 1886 led to large accumulations of stock, which, together with the dullness of trade, caused the manufacturers to discontinue operations temporarily during the next year, and the production in 1887 fell off more than one-half as compared with the abnormal

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* *Engineering and Mining Journal*, Jan. 13, 1894, p. 32.

figures of 1886. In 1888 production again increased to about the average rate, and in 1890 the price declined to an average of about 27c.

Until March, 1891, there had been an agreement between the National Bromine Company and the German producers to limit their sales to the United States and Europe, respectively. The National Bromine Company also had an understanding with some of the largest consumers in this country concerning the sale of the product controlled by it. In March, 1891, these contracts expired, and the National Bromine Company, being unable to renew them, dissolved; the agreement with the German producers was, of course, ended thereby. The stocks which had accumulated in the United States were offered for sale abroad, and some lots were sold in England, France, and Germany at reduced prices. This move on the part of the Americans brought about a retaliation from the German makers, who sent bromine as well as bromides to this country, and made sales at prices lower than before quoted in this market. The lowest point reached was 17.5c. per lb. for bromine, at which figure it was quoted at the end of the year.

These low prices continued in 1892, but in October of that year the Stassfurt manufacturers succeeded in making an arrangement with the American firms by which the ruinous competition was discontinued. The result of this agreement was the reëstablishment of the old higher price for bromine, viz., 25 to 30c. per lb. At the end of 1893 it was quoted at 35c. per lb. in car-load lots.

CADMIUM.

By Walter Renton Ingalls.

Cadmium is a metal closely allied to zinc, with the ores of which it frequently occurs. It is tin-white in color, malleable and ductile, and brilliant in luster when fresh, but becomes dull on exposure to the air. Its sp. gr. after fusion is 8.604, which is increased to 8.694 by hammering. It breaks under a gradually increasing strain with the characteristic fibrous fracture of a soft tough metal. It is harder than tin, but softer than zinc, and, like the former metal, it gives out a peculiar crackling sound when bent. It crystallizes in octahedra, differing in this respect from zinc, which takes a rhombohedral form. It melts at a temperature below redness (315° to 320° C.), and boils at 746.2° C. (Becquerel), or 860° (Deville and Troost), giving off a yellowish-brown vapor. It unites readily with most of the heavy metals to form alloys, and it amalgamates with mercury. When exposed to damp air it is oxidized, but only superficially; heated in the air to redness, it burns to a yellowish-brown oxide; and in a state of vapor decomposes water with the formation of cadmium oxide and the evolution of hydrogen. It is soluble in sulphuric, hydrochloric, nitric, sulphurous, and acetic acids.

Occurrence.—Cadmium does not occur in the metallic state in nature, and there is only one definite mineral, greenockite, which contains a high percentage of it. Greenockite, which is sulphide of cadmium (CdS), having 77.8% cadmium and 22.2% sulphur, is a yellow mineral, of adamantine luster, of 4.8 to 5.00 sp. gr., and 3 to 3.5 in the scale of hardness. It is found at Bishopstown, in Renfrewshire, Scotland, associated with prehnite in a doleritic rock. It also occurs on sphalerite (ZnS) at Friedensville, Penn., at Granby, Mo., and elsewhere. These occurrences are, however, only of mineralogical interest. The chief sources of the metal are cadmiferous zinc ores, it occurring in some blendes as sulphide isomorphous with the sulphide of zinc, and in calamine (smithsonite) as carbonate. Silesian calamines often contain 2% and sometimes as much as 5% cadmium.

Cadmiferous blende is usually of the resinous variety with a reddish hue, like some from Webb City, Mo., which is almost ruby-red. The blende ores of Missouri are frequently cadmium bearing. Cadmiferous blende occurs at the Morning Star mine, in Marion County, Arkansas; on the property of the Empire Mining Company, at Joplin, Mo.; and at Galena, Kan. At the last mentioned place greenockite is found as a coating on blende. The smithsonite of the Morning Star mine ("turkey-fat" ore) of Marion County, Arkansas, also contains cadmium. An analysis of a sample of this ore by F. W. Clarke, chief chemist of the United States Geological Survey, gave the following result: Silica, 0.06%; carbonic acid, 34.68%; copper, trace; cadmium sulphide, 0.25%; cadmium oxide, 0.63%; zinc oxide, 64.12%; ferrous oxide, 0.14%; calcium oxide, 0.38%—total, 100.26%.* Although cadmium is so generally associated with zinc, however, it is only in Upper Silesia that it is won from these ores on an industrial scale.

Metallurgy.—The method of cadmium winning is simple, depending on the difference in temperature at which it and zinc are volatilized. In roasting blende containing sulphide of cadmium, the latter is oxidized together with the zinc. In the retorts the oxide of cadmium is reduced by the carbon and distills before the zinc, burning at the ends of the condensers with the characteristic brown flame of cadmium before the blue-green zinc flame appears, and its presence in ores is thus made known. A part of the cadmium vapor is collected in the condensers and "ballons" as metal and oxide, from which it may be recovered.

If cadmium is to be saved, the first deposit in the condensers and "ballons" is collected apart and reserved for further treatment. In furnaces fitted with the Kleeman or Dagner condensers, which are now generally used in Silesia, wherewith the escaping fume is conducted to a collecting chamber through one large pipe, the cadmium is burned to oxide and deposited in the part of the latter nearest the furnace, whence it is removed periodically, or when the collecting chambers are cleaned out. This fume may contain 5% or more of cadmium oxide, and is a product well suited for further treatment. When a sufficient quantity of this fume has been accumulated, it is subjected to a second distillation for enrichment, and the product is finally reduced with wood charcoal and distilled in small cylindrical retorts of cast iron, with conical cast-iron condensers, in which the metallic cadmium is collected. It is then cast into rods (*stängen*) the thickness of a finger and weighing from 60 to 90 grams, in which form it is marketed. The loss in distilling cadmium oxide is high, only a small proportion of the metal in the product treated being recovered. The loss occurs partly in metal held by the retort-residues, but more through imperfect condensation.

Cadmium may also be obtained from cadmiferous zinc in the wet way by treatment with dilute hydrochloric acid. The acid dissolves the zinc in preference to the cadmium; hence, the latter remains precipitated so long as there is an excess of zinc. The residue, which will contain lead if that metal is present, is concentrated as far as possible and is then treated by distillation for the recovery of the cadmium.

Uses.—The uses for cadmium are limited, there being none whatever for it alone in the metallic form. With lead, tin, and bismuth it forms alloys, which are fusible at very low temperatures. Wood's metal, so called, is composed of 12 parts cadmium, 14 parts tin, 50 parts bismuth, and 24 parts lead. It melts at 66° to 71° C. Lipowitz's metal has 50 parts bismuth, 27 parts lead, 13 parts tin, and 10 parts cadmium, and melts at 60° C.

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*I am indebted to Dr. W. P. Jenney of the Dakota School of Mines for this analysis.

The only compound of cadmium of much importance in the arts is the sulphide, which gives a splendid and permanent yellow pigment (*jaune brillant*) of various shades, ranging from lemon-yellow to orange-yellow, according to the manner in which it is precipitated. It is best prepared by precipitation with sodium sulphide from a solution of cadmium sulphate, washing, pressing, and drying the precipitate. Cadmium sulphate and cadmium iodide find a restricted use in medicine and photography.

The price of cadmium in New York is now $1.30 per lb., having advanced from $1, at which figure it had long been held by the producers, on account of the increased demand for it in the manufacture of aluminum solder. It can be bought in Germany for 11 marks per kilogram, or $1.19 per lb. In all probability, however, this rise in price is only temporary, as the metal can be produced in far greater amount than at present if there is any need for it.

PRODUCTION OF CADMIUM IN UPPER SILESIA.*

Year.	Kilograms.	Value, Marks.	Year.	Kilograms.	Value, Marks.	Year.	Kilograms.	Value, Marks.
1880........	3,000	30,284	1885........	3,190	25,099	1890........	4,158	14,610
1881........	3,000	27,596	1886........	4,960	36,599	1891........	2,849	10,067
1882........	4,400	34,735	1887........	7,321	48,497	1892........	3,200	11,400
1883........	2,500	21,536	1888........	4,796	22,855	1893........	5,285	21,844
1884........	2,750	23,155	1889........	5,138	19,503			

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* From *Statistik der Oberschlesischen Berg- und Hüttenwerke*, published by the Oberschlesischen Berg- und Hüttenmännischen Verein.

CEMENTS.

By Spencer B. Newberry.

Hydraulic cements, in the broad sense of the term, are compounds of lime with the constituents of clay (chiefly silica, alumina, and oxide of iron), and owe their value for building purposes to their property of hardening, after mixing with water, to a stone-like mass. Mixtures of carbonate of lime and clay in varying proportions are found abundantly in nature in the form of hydraulic limestones. When a limestone containing a small proportion of clay, perhaps 8% or 10%, is burned in the lime-kiln, the burned rock may be slaked by adding a small amount of water; the resulting dry powder possesses hydraulic properties, and is known as hydraulic lime. If, however, the proportion of clay in the limestone is greater than 18% or 20%, the burned rock cannot be slaked with water, but when ground to fine powder produces hydraulic or natural-rock cement, a product possessing much stronger hardening properties than hydraulic lime. Artificial mixtures of carbonate of lime and clay may also be prepared, and the proportion of the two constituents accurately adjusted. In this case the mixture may be burned at a white heat without fusing, and by grinding the resulting "clinker" Portland cement is obtained, a material greatly superior to all others in hardening power and ultimate strength. Finally, it has long been known that certain materials, such as "pozzuolana," a volcanic rock found in Italy, and also some kinds of blast-furnace slag, possess the power of giving hydraulic properties to common lime. Mixtures of ground "pozzuolana" or slag with slaked lime are also used as cements, but these mixtures are generally of inferior value.

The following classes of hydraulic building material are therefore recognized:

1. *Hydraulic lime*, made from a limestone containing a small proportion of clay, by burning at a low temperature and slaking the burned rock with water.

2. *Hydraulic* or *natural-rock cement*, made from a limestone containing a relatively large proportion of clay, by burning at a low heat and grinding the product to powder.

3. *Portland cement*, obtained by making an artificial mixture of carbonate of lime (chalk, ground limestone, or marl), with a certain proportion of clay, burning at a white heat, and grinding the clinker to powder.

4. *Pozzuolana* or *slag cement*, obtained by mixing ground scoria or slag with a small proportion of slaked lime.

Of these four classes, only the second and third have any commercial importance in this country.

Chemically considered, the active agent in all these classes of cement is probably much the same. It has been proved by Le Chatelier and others that the chief sources of the hardening power of cements are the basic silicates and aluminates of lime formed during the burning. These gradually take up water, forming hydrated silicates and aluminates, and also crystallized calcium hydrate. It is probable that in the quick-setting natural-rock cements, formed at low heat, the aluminates predominate, while in Portland cement the silicate of lime is the chief active principle. American natural cement-rocks contain also a high proportion of carbonate of magnesia. This, it is thought, plays an unimportant part, as it does not appear to combine with the silica and alumina of clay after the manner of lime; calcined magnesia, however, has in itself cement properties, as it hardens gradually with water.

The theory and practice of the manufacture and use of cements are fully discussed by Feichtinger, *Technologie der Mörtelmaterialien*, Leipzig, 1884; Candlot, *Ciments et Chaux Hydrauliques*, Paris, 1891, and in many earlier works. Unfortunately, there is no good modern book in English on this subject. Gilmore, *Practical Treatise on Limes, Hydraulics, Cements, and Mortars*, New York, 1864, is a standard work, but the views held in regard to the chemistry of the subject have been greatly modified since it was written.

Hydraulic Lime.—The manufacture of hydraulic lime, from limestones containing a small amount of clay, is carried on to a considerable extent in France, but has never been established in this country, probably owing to the abundance of superior natural cement-rock in the United States. The material used in France is of variable composition. At Seilly, Paviers, and other well-known localities, the hydraulic lime is made from a limestone containing from 10% to 20% of clay, while the rock from which the celebrated Teil hydraulic lime is made is a purely silicious limestone, containing over 20% of silica, with only 1% to 2% of iron oxide and alumina. The rock is burned in continuous kilns in the same manner as common lime. The calcined rock is then spread out and sprinkled with water in suitable quantity. The lime gradually slakes and falls to a dry powder. This is then screened to remove hard-burned particles which have resisted the slaking, and packed in bags for shipment. The unslaked portions are generally ground and sold as hydraulic cement. At Teil, since the material is nearly free from iron, these hard particles (called *grappiers*) furnish a white cement, which is considerably used for ornamental purposes.

Hydraulic lime is inferior, for most purposes, to natural-rock cement. It forms a very light and bulky powder, requires from one day to several days to set, and hardens very slowly. It shows a tensile strength, tested neat, at one month, of 56 to 84 lbs.; 1 year, 140 lbs.; two years, 210 lbs. It is remarkable, however, that hydraulic lime shows practically as high results with three parts sand as when tested neat. Teil lime, with three parts sand, showed after two years a tensile strength of 310 lbs. per square inch.* This is as high a result as any natural-rock cements, or even some Portland cements, would give. It has also

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* Candlot, *Chaux Hydrauliques*, p. 18.

been found that the Teil hydraulic lime resists the long-continued action of sea water much better than natural or Portland cement; this advantage is probably due to its comparative freedom from alumina and magnesia, which, it has been shown, are the constituents of cements most readily attacked by sea water.

Natural-rock Cement.—This material, also known as hydraulic cement, common cement, Roman cement, quick-setting cement, etc., is manufactured on an enormous scale in various parts of the United States. It is also made on a large scale in France, and to some extent in England and Germany, though in the latter countries the industry has sunk into insignificance in consequence of the recent great development of the manufacture of artificial Portland cement. The material is in all cases a limestone or marl containing a considerable proportion of clay, usually more than 23%. In the United States the limestone used is in almost all cases dolomitic; *i.e.*, containing a large percentage of carbonate of magnesia. In Europe, on the other hand, magnesian limestones are seldom employed.

The effect of the presence of magnesia in cement-rock is not well understood, and various views have been published regarding it. It is well known that if a pure magnesian limestone, free from clay, be burned at a very low heat, the magnesia loses its carbonic acid almost completely before the carbonate of lime begins to be decomposed. The burned rock then possesses hydraulic properties, owing to the hardening of the free magnesia with water. When magnesian limestones containing clay are heated to a higher temperature, however, so that the carbonate of lime is decomposed, it is probable that the magnesia becomes nearly inert, and that the hydraulic properties of the cement so prepared are due to the combination of the lime with the constituents of the clay, the aluminate of lime being the chief source of the setting properties.

The following table shows the composition of cement-rocks from various sources:

	Rosendale, N. Y.	Lasalle, Ill.	Bellaire, Ohio.	Coplay, Penn.	Essex, England.
Carbonate of lime........	45.91%	42.25%	46.52%	74.12%	50.7%
Carbonate of magnesia..	26.14	31.98	26.40	2.41	5.7
Silica....................	15.37	....	16.41	15.03	21.9
Alumina.................	....	22.18	5.44	3.97	3.5
Iron oxide	11.38	....	3.38	1.93	8.2

The manufacture of natural-rock cement consists in burning the rock in continuous kilns, as in burning common lime, and grinding the product in millstones. The industry is carried on to a great extent in this country, the principal centers of production being the Rosendale district in Ulster County, New York; Onondaga and Erie counties, New York; the Louisville region in Indiana and Kentucky; Lasalle and Utica, Ill., and Milwaukee, Wis.

The cement industry suffered somewhat from the general business depression during the latter half of the year 1893, and the total production shows a considerable decrease from that of 1891 and 1892. Prices were also lower than in the year preceding. In some localities the average selling price was not over 25c. per barrel, in bulk, at the mill. This is but little, if any, higher than the price of common lime, and it is difficult to understand how the industry can exist at these figures. The reason for these low prices is probably chiefly the heavy cost of shipment to centers of consumption, as most of the regions where the manufacture of natural cement is carried on are remote from the large cities in which it is chiefly used. This is especially the case with the Louisville region, where prices appear to be lowest. Large quantities of Louisville cement are shipped to Cleveland, Toledo, Detroit, and other cities along the shores of the Great Lakes, and find there a ready market at 65c. to 75c. per barrel. After deducting 15c. for the barrel, and at least 25c. for freight and handling, this price leaves little margin of profit to the manufacturer.

The following table shows the product of natural-rock cement in various regions during 1892 and 1893:

PRODUCTION OF HYDRAULIC CEMENT IN 1892 AND 1893.

	1892.			1893.		
	No. of Works.	Barrels.	Value, Including Barrels.	No. of Works.	Barrels.	Value, Including Barrels.
Georgia	1	50,393	$41,294	1	40,000	$32,000
Illinois	2	472,876	236,438	2	522,000	283,000
Indiana and Kentucky	13	2,100,000	1,365,000	13	1,750,350	962,692
Kansas and Missouri	2	110,000	77,000	1	60,000	36,000
Maryland and West Virginia	5	252,092	220,991	5	232,590	193,451
Minnesota	1	100,000	75,000	1	75,000	56,250
New Mexico	1	10,000	10,000	1	1,500	1,500
New York, Ulster County region	17	2,833,107	2,408,141	17	2,738,884	2,191,107
New York, Onondaga County	8	240,580	152,550	8	176,308	106,721
New York, Schoharie County	1	32,000	27,840	1	30,000	25,000
New York, Erie County	4	675,000	486,250	4	675,000	496,250
Ohio	2	56,863	53,863	3	68,000	60,000
Pennsylvania	6	664,594	502,511	5	567,000	406,000
Texas	1	40,000	40,000	1	40,000	40,000
Utah	1	5,000	7,500	1	5,000	7,500
Virginia	1	10,000	10,000	1	17,000	15,000
Wisconsin	2	558,676	284,772	2	494,753	268,326
Total	68	8,211,181	$5,999,150	67	7,503,385	$5,180,797

Natural-rock cement is a light yellowish or brownish powder, weighing about 300 lbs. to the barrel. On mixing with water it sets quickly, usually within a few minutes. Its tensile strength, neat, is generally from 50 to 80 lbs. in seven days, and from 100 to 150 lbs. in a month. Some natural cements reach a strength of 300 to 400 lbs. at the end of a year. Tested with one part of sand, good natural cement will show 30 to 50 lbs. in seven days, 50 to 80 lbs. in a month, and perhaps 200 to 300 lbs. in a year. Natural-rock cement is extensively used for mortar, concrete, the foundation of asphalt pavements, and for cistern, aqueduct, and reservoir linings. For these purposes it is generally used with not more than one part of sand by weight. Good results are obtained in all cases in which impermeability to water, rather than great tensile strength, is required, as the cheapness of the material allows it to be liberally used. For flooring and sidewalks natural cement hardens too slowly and imperfectly to give good results. For such purposes, and in fact for all uses in which the work is to remain exposed to the air, it is not to be recommended, as its permanence in air is greatly inferior to that which it shows when kept under water.

Portland Cement.—The manufacture of artificial Portland cement is constantly increasing in Europe, and has reached great magnitude. The industry was first established in England, and is carried on in that country on an enormous scale, but in the past few years Germany has surpassed England in the quantity and also, as is generally admitted, in the quality of her product. The

Association of German Cement Manufacturers includes representatives of 50 factories, the total production of which amounts to more than 11,000,000 barrels of Portland cement per year.

The materials employed in England are chalk and clay; in Germany soft limestones, or marls consisting of mixtures of carbonate of lime and clay, are generally used. In the wet process of mixing, formerly exclusively employed, the raw materials are mixed in proper proportions in a wash-mill, with the addition of much water, the mixture is allowed to settle in basins, and is finally molded into bricks for burning. The more modern dry process has lately been extensively introduced, especially in Germany. In this the materials are separately dried, then mixed, and finely ground together between millstones; finally the mixture is moistened and molded into bricks.

The burning is usually done in intermittent kilns, using coke as fuel, the material and fuel being placed in alternate layers. The charging, burning, and emptying of each kiln occupies about a week, and yields from 50 to 100 barrels of cement. After burning, the clinker is sorted by hand, and ground to dust between millstones. In Germany the Hoffmann ring-furnace is extensively used. Within the past few years continuous kilns, of the Dietzsch and Schöfer type, have come largely into use in Europe. In these the bricks of material and soft coal are periodically charged at the top, while the burned clinker is withdrawn at the bottom. These continuous kilns have proved successful and economical.

Full information in regard to the various systems of burning Portland cement, with drawings of the various kilns employed, may be found in an interesting paper by Pierre Giron, *Proceedings of the Engineers' Club of Philadelphia*, Vol. X., No. 3, July, 1893.

In the United States, Portland cement was first made at Coplay, Penn., in 1878. Since that time the industry has been successfully established at other points in Lehigh County, Pennsylvania; near Syracuse, N. Y.; at South Bend, Ind.; Bellefontaine and Sandusky, Ohio; Yankton, So. Dak.; and at several other localities. As compared with the importation of Portland cement into this country, however, the home production still remains insignificant. Nearly 3,000,000 barrels of cement were imported into the United States during 1893, while the total American product did not exceed 500,000 barrels.

Excellent material for the manufacture of Portland cement is found abundantly in this country. In the Lehigh County region, in Pennsylvania, the material used is the hydraulic limestone from which the common cement is made. This is brought to the right composition by the addition of small amounts of pure limestone. At Syracuse, N. Y., and in Ohio, shell-marl—which occurs at these points in large deposits—and clay are the raw materials. The common intermittent kilns are in general use in this country, though the Dietzsch continuous kiln is used at Bellefontaine, Ohio. At several works the process of burning cement in rotary cylinders has been introduced, and appears now to be an established success. This process was first tried in England in 1885, and abandoned, chiefly owing to the difficulty of successfully using gaseous fuel. This obstacle has been overcome in this country by the use of crude oil, which gives an intense and easily regulated heat. In the rotary furnace the burning of a given portion of the charge occupies not more than half an hour, while in the common kilns the material is at a white heat for from 12 to 24 hours at least. This necessitates more careful preparation of the raw material for the rotary process, since perfect combination cannot take place in so short a time unless the raw material is perfectly mixed and free from coarse particles. With attention to this important detail, however, cement of excellent quality is produced by this process.

The simplest method of making cement yet devised is certainly that employed at Montezuma, N. Y., described in THE MINERAL INDUSTRY, Vol. I. (1892). At these works the marl and clay were mixed in the wet state in which they were taken from the ground, and the wet mixture was fed directly into the upper end of an immense rotary cylinder, 70 ft. in length, heated by an oil flame. The drying and burning thus took place in one operation, the drying being done by the waste heat from the burning, which by the ordinary method is lost. There is no reason why this process should not have proved very economical. Unfortunately, the works were destroyed by fire in June, 1893, while the process was still in the experimental stage, and they have not been rebuilt.

Two other extensive Portland cement factories were destroyed by fire in 1893. In February the works of the Warners Company, near Syracuse, were burned, and in July the new plant of Millen & Sons, at Wayland, N. Y., suffered the same disaster. Both these works have since been rebuilt, and are once more in operation.

In the past year three new factories were started, viz., at Middle Branch, Ohio; Sandusky, Ohio; and Deer Park Glen, Ill.

The manufacture of Portland cement suffered greatly from the depression in business during the last half of the year. Want of orders and large accumulated stocks caused several works to shut down late in the autumn, and those which continued running did so with reduced force and diminished output. Great quantities of foreign cement, shipped from Europe before the state of business in this country became apparent, were offered at the seaports and lake cities at prices far below any figures previously known. Good Belgian and English cements could be bought on the wharf at Buffalo, Detroit, and Chicago, at the close of the year, at $2 per barrel, or even less. While this state of affairs continues, the prospect of growth of the American industry is not encouraging.

The following table shows the amount and value of Portland cement produced at various localities during 1893:

PRODUCTION OF PORTLAND CEMENT IN 1892 AND 1893.

	1892.			1893.		
	No. of Works.	Barrels.	Value, Including Barrels.	No. of Works.	Barrels.	Value. Including Barrels.
Colorado	1	10,000	$30,000	1	10,000	$25,000
Dakota	1	34,000	68,000	1	30,000	60,000
Indiana	1	12,000	30,000	1	20,000	45,000
New Jersey	1	20,000	40,000	1	60,000	100,000
New York	4	124,000	279,000	6	142,714	285,428
Ohio	2	46,600	108,500	4	51,500	103,000
Pennsylvania	6	300,840	597,100	..	281,317	534,411
Total	16	547,440	1,152,600	14	595,531	1,152,839

Slag Cements.—The use of volcanic scoria, such as the Roman "pozzuolana" and the "trass" from the Rhine, dates back to ancient times, and is still continued to some extent. Within a few years it has been discovered that certain kinds of iron slag, especially that from the basic steel process, have the power of giving hydraulic properties to common lime. For this purpose about two parts of scoria or slag, finely ground, are mixed with one part of slaked lime. The mixture forms a slow-setting and slow-hardening cement, which in time gains great strength. Slag cement has been condemned as an inferior product by the Association of German Cement Manufacturers, but is made to a considerable extent in Germany.

So far as is known, slag cement has never been made in this country. At one of our Portland cement works the product is adulterated by the addition of 30% or 40% of ground slag. Other manufacturers have attempted to make a merchantable cement by mixing ground slag with imported Portland, but so far as reported the attempts have not proved profitable. On account of the similarity in color of ground slag to pure cement, and its ready solubility in acids, this adulteration is difficult to detect. The tensile strength of cement appears also to be much less affected by adulteration with slag than with any other material. In fact, Michaelis reports that a basic Bessemer slag tested by him, when finely ground, showed setting and hardening properties equal to the best cement.* Erdmenger also states that he found a slag which, when mixed with Portland cement to the amount of 50%, caused no diminution in the tensile strength of the cement.†

Testing Cements.—The methods generally followed by American engineers in testing natural and Portland cements are those adopted by the American Society of Civil Engineers. (*Proceedings*, January, 1885; reprinted in full in *Scientific American Supplement*, Jan. 30, 1886, p. 8395.) Capt. W. W. Maclay has lately published an interesting paper on the "hot test" of cements (*Proc. Amer. Soc. Civil Eng.*, 1893), in which the method of testing pats of cement by exposure to steam for several hours is strongly recommended, and complete directions for carrying out the test are given. The hot test of cements has been rejected in Germany as too severe, since many cements which show cracks in the hot test prove perfectly sound after years of use. Nevertheless there is much to be said in favor of this test for the protection of the consumer, since a cement which stands exposure to hot steam is certain to show no cracking or deterioration after months or years. For important work, in which absolute permanence must be secured beyond all doubt, there can be no question that the hot test as described by Capt. Maclay is superior to all other tests of quality and constancy of volume.

A very valuable work (in German) on the practical uses of Portland cement in architectural work has lately appeared. This is *Der Portland-Cement und seine Auwendungen im Bauwesen*, Berlin, 1892, prepared under the direction of the Association of German Cement Manufacturers.

IMPORTS OF CEMENT, 1892 AND 1893.

Year.	Barrels.	Value.
1892	2,440,654	$3,778,331
1893	2,674,149	3,470,169

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* *Thonindustrie Zeitung*, 1893, No. 49, p. 1254. † *Idem*, 1893, No. 52, p. 1344.

THE CHEMICAL INDUSTRY.*

THE HISTORY OF ALKALI MANUFACTURE IN GREAT BRITAIN.

BY A. M. GIBSON.

THE statistics of the alkali trade of Great Britain are of very great significance. But an array of figures dealing merely with the manufacture of soda and chlorine compounds will not convey an adequate idea of the importance of the industry. The magnitude of the capital invested, of the volume of the yearly turn-over, and of the army of laborers employed, cannot fail to impress; nevertheless, these aggregates are relatively unimportant in comparison with the vastness of the other industries whose prosperity depends on the cheap supply of the products of common salt.

The wonderful development of four of the great industries of Great Britain, the soap, glass, paper, and textile trades, would not have been possible without cheap soda and bleach. It is scarcely an exaggeration to say that the health and comfort of our physical being, as well as our intellectual expansion, are measurably due to the wonders wrought during the present century in cheapening the production of alkali and bleaching powder.

The history of alkalies, as important substances derived from the ashes of trees and plants, dates back to an early period of our era. But the first definite account we have of a distinctive property existing in the product of the ashes of marine plants is given by Geber, the Arabian alchemist, who was a native of Mesopotamia and lived in the eighth century. The production of soda, so named from the plants which yielded the greatest percentage of it, for instance, salsola soda, had become an industry of some importance in Spain, Italy, and the North of England toward the close of the eighteenth century. But the alkali base in general use up to the end of the first quarter of the nineteenth century was potash, so called because it was obtained by the concentration of lixiviated wood ashes in iron pots. Pearlash was potash calcined in iron pots heated red hot. The principal consumption of potash was in the manufacture of certain kinds of glass, especially English crystal and plate glass, and in making soft soap.

The alkali obtained from the ashes of marine plants, such as salsola soda, salsola kali, salsola clavifolia, and also from kelp, a marine plant found on the

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* See footnote on page 135.

coasts of the North of Ireland and Scotland, was used to make the better qualities of hard soap. Potash lyes will not produce hard soap without the addition of common salt, as all country wives know, and the product is very inferior to that made with the soda lyes. The chief sources of the supply of marine plants yielding soda were Alicante and Carthagena in Spain, Sicily, and Teneriffe. The soaps of the Mediterranean countries made from olive oil and from barilla, as Spanish alkali was known, were of a very superior quality, and the industry of soap-making was of considerable importance. The exportation of the seed of the marine plants producing barilla was prohibited by Spain. The growth of the textile industry of Great Britain stimulated soap-making, and it was found that certain marine plants of Northern Ireland and of Scotland, generally known as kelp, yielded ashes containing about an equal percentage of potash and soda, and soapers' lyes made from kelp, as this alkali was called, produced a fair quality of soap. The greater proportion of the soap made in Scotland was of the soft variety. The Lancashire soap-makers depended for the most part on barilla, imported from Spain, and their product was chiefly hard soap.

The principal supplies of potash and pearlash came from North America and Russia. The production of these alkalies was an important source of revenue to the settlers of the heavily timbered regions of the United States and Canada, where water transportation enabled shipments direct to England.

The extent of the manufacture of kelp in Great Britain was insignificant compared with the present production of soda. The industry appears to have been established in Glasgow in 1798, but it existed in the North of Ireland early in the eighteenth century. The earliest mention of the production of kelp in Northern Scotland is in 1730, when MacLeod is said to have introduced it from Ireland. Later on it was established on the coast of Wales. It is probable that the first soap works of Cheshire and Lancashire depended on Welsh kelp. There are no statistics available as to the annual production of kelp in Great Britain. Macdonald, Lord of the Isles, is said to have derived £10,000 a year from his kelp shores. In 1800 Lord Dundas established a works at Dalmuir for making kelp, and in 1804 his annual output was 129 tons, the price being about £37 per ton.

Nicholas Leblanc discovered, in 1791, the black-ash reaction, which made it possible to obtain, on a commercial scale, crude soda from sulphate of soda, by combining with it limestone and sawdust, and furnacing the mixture and then lixiviating the fluxed product. But it was not until about 1818 that this process of making alkali from common salt was introduced into Great Britain. The growth of the new industry was not rapid until after 1852, the manufacture being attended with many difficulties, mechanical as well as chemical, and the perfection of appliances and methods necessitated many great improvements upon the original process. Potash and pearlash continued to be largely employed in glass manufacture until after 1842, and in that year statistics show that large quantities of barilla and potash were in use in soap-making. There were then 66,373 tons of hard and soft soap produced in Great Britain.

In 1852 the raw materials consumed in the production of alkali in Great Britain amounted to 785,549 tons, and the manufactured products were 151,099 tons, having a value of £1,234,580. The salt decomposed amounted to 137,547 tons, and the capital invested in plant was £702,000. By 1862 the production of British alkali had nearly doubled. In that year the raw materials employed were 1,834,400 tons, and the merchantable products aggregated 293,800 tons. The capital employed was £2,010,000. The workmen engaged at the works and in getting raw materials numbered 19,140, and their annual wages amounted to £871,750. In 1867 the alkali works on the Tyne alone used up 1,070,000 tons of raw materials, and put out 216,330 tons of manufactured articles, worth £1,929,-825. The Lancashire district had 26 alkali works with an output of 220,387 tons of manufactured products, valued at £2,007,003. By 1876 British alkali works used up 3,701,000 tons of raw materials, and the soda manufactured (calculated as 48%) footed up 430,800 tons, worth £2,209,284. The capital employed was £7,000,000, and the number of men 22,000, receiving annual wages amounting to £1,405,000.

In 1860 Great Britain exported 102,479 tons of alkali, worth £965,346, and in 1869, 175,719 tons, valued at £1,379,108. In 1879 the exports rose to 381,336 tons, worth £2,438,634. From 1880 to 1892 the exports of alkali were 4,208,091 tons, worth £26,749,000, while the bleach exported amounted to 1,036,562 tons, worth £6,883,742, an annual average of 403,455 tons exported, giving a yearly return of £2,887,134.

The total amount of salt decomposed in 1892 in the manufacture of soda and chlorine compounds, in all countries, was about 1,200,000 tons, of which Great Britain used the grand total of 824,190 tons.

In 1893 the raw materials employed in the manufacture of alkali from sodium chloride in Great Britain aggregated 4,811,860 tons. The two processes employed were the Leblanc and the ammonia-soda. The former was used in 106 and the latter in 8 works. The United Alkali Company, formed in 1889, controls practically all of the Leblanc works and also one large ammonia-soda works, while Brunner, Mond & Co. of Northwich, Murgatroyd & Co. of Middlewitch, Bell Brothers of Middlesborough, and Bowman, Thompson & Co. of Lostock-gralan are the owners of the principal plants turning out alkali by the ammonia-soda process. The capitalization of the companies engaged in alkali manufacture in 1893 was £11,000,000. The workmen employed constituted an army of 28,275 men, and their annual wages were £1,809,600.

A tabular statement of quantities of the raw materials consumed in 1893, classified under the respective processes employed, will give at a glance an idea of the importance of the alkali industry of Great Britain.

RAW MATERIALS CONSUMED IN 1893.

(In tons of 2240 lbs.)

	By Leblanc Process.	By Ammonia-Soda Process.
Salt	519,593	304,897
Pyrites	311,757	....
Sulphate of ammonia	....	10,213
Limestone	623,914	368,735
Coal	2,073,380	306,533
Nitrate of soda	5,000	....
Timber, iron, and brick	207,838	75,000
Total	3,741,482	1,065,378
Output	541,326	200,370

The brilliant lights of the French Academy during the French Revolution were Claude Louis Berthelot, Antoine François de Fourcroy, and Louis Bernard Guyton de Morveau. These three distinguished men, joined to Lavoisier, who unfortunately fell a victim to the indiscriminating rage of democracy during the Reign of Terror, were the founders and organizers of modern industrial France. The necessities of the nation, cut off from all intercourse with neighboring countries, rendered the condition of the French Republic desperate. There was demand for material of war—cannon, muskets, sabers, gunpowder, clothing for the soldiers. Saltpeter had always been imported, and without it gunpowder could not be made. Steel was not made in France, and the process of making it had to be found out and the working of it improved. In this extremity Berthelot was an indefatigable genius. He traversed the country in all directions and pointed out the mode of extracting saltpeter from the soil of cellars, taught how to purify it, and supervised the establishment of gunpowder works. He reported on steel-making, and under his guidance foundries for casting cannon and works for the manufacture of muskets and sabers were erected in different parts of the country. Morveau's speciality was disinfection. He first applied chlorine fumes, generated by the action of sulphuric acid upon salt. His great work was his "Dictionary of Chemistry" in the *Enclyclopédie Méthodique.* For sixteen years he was the head of the Polytechnic School of France. Gay-Lussac another genius, was a pupil of Berthelot.

Owing to the blockade of French ports, barilla could not be imported, and soap-making and all industries dependent on a supply of this prime necessity languished. The success which had attended the efforts of Berthelot in other directions encouraged the Directory to offer a reward for processes which would enable alkali to be obtained from common salt. As already stated, Duhamel, in 1737, had shown that salt contained a fixed alkali base identical with that yielded by the incineration of marine plants. Glauber, nearly a hundred years before, had discovered that sulphuric acid converted salt into sulphate of soda, or, as he termed it, sal mirable, and gave off muriatic acid, which he called the spirit of salt. But all attempts to effect the necessary reactions to obtain the soda as carbonate or caustic from the sulphate, on a commercial scale, had proved abortive.

Nicholas Leblanc was originally an apothecary in Paris and had developed into a manufacturer of chemicals on a small scale. Inspired by the discovery and suggestions of Duhamel, he had been experimenting with sulphate of soda, and in 1787 had hit upon what is now known as the black-ash reactions. He submitted his process to the commission created by the Directory, and it was selected from a number of others as the simplest and most promising. This was in 1791. The salt was treated with sulphuric acid in cast-iron pans and heat applied to convert it into sulphate. The sulphate was mixed with sawdust and limestone, broken small and roasted, an intense heat being generated by chemical action as well as by firing, and the result was black ash. This was at first used by soap-makers in its crude state. to make their lyes, but shortly after in French works it was lixiviated in tanks and the liquid decanted and concentrated, undecomposed salt crystallizing out, and leaving crude carbonate of soda with a residue partly causticized. This working out of the black-ash reactions was undoubtedly a grand discovery, and it gave its discoverer immortality, but no pecuniary reward. The Directory was taxed to the utmost to repel the invaders of France, and there were no public funds for the reward of the meritorious inventor. He died by his own hand in his house within the walls of the small chemical works where he worked out his famous process. The railway station at St. Denis, near Paris, stands on a portion of these works. He came to England with the expectation that the Government or English capitalists would take immediate advantage of his invention. But he was grievously disappointed. He was the recipient of small charities, but no English manufacturer would venture his money in a new method for the production of an article which was not in general use.

Leblanc's own countrymen were more venturesome. By 1807 alkali works were established and working at Marseilles, Chauny, Rouen, Lille, Amiens, and elsewhere, and were regularly producing crude soda, or black ash, soda ash, and soda crystals. One works at Marseilles, that of Chaptal & D'Arcet, were in 1816 turning out about two tons of crude soda per day.

The conditions for many years following Leblanc's discovery were nowhere favorable to the development of a large alkali industry. The consumption in France was not great, and elsewhere it was employed only in soap-making. In glass manufacture it was held for a long time that potash was essential, and that soda would never be substituted for it in the production of plate and crystal. In England there was a heavy duty on salt until 1823. The manufacture of kelp was a considerable industry in the north, and vested interests are hard to disturb in England. The process of manufacture was very crude and wasteful. For soap-makers the seaweed was bruised, mixed with quicklime, and lixiviated, and the lyes resulting were used without concentration. Kelp was far inferior to Spanish barilla, since it yielded only from 9% to 25% of ash, calculated on the weed dried at 100° C., and this ash contained about equal quantities of alkali and potash. Good barilla ranged from 27% to 46% in Na_2CO_3.

It was the application of chlorine to bleaching purposes that eventually gave a great impetus to alkali manufacture in Great Britain and made the Leblanc process so important, and it is to this that its survival is due. In 1785 Berthelot made a series of experiments to determine the applications of chlorine industrially, and extended greatly the investigations of Scheele, in 1774, as to its effect in decolorizing fabrics. James Watt, of steam engine fame, was in Paris while Berthelot was conducting his researches, and the latter communicated to him the progress he had made with chlorine as a bleaching agent, and exhibited the results achieved by steeping colored cloth in water impregnated with chlorine gas. The father-in-law of James Watt, Mr. Macgregor, was a bleacher in the neighborhood of Glasgow, and his son-in-law communicated to him the knowledge he had received from Berthelot. Macgregor immediately tried the effect of water impregnated with chlorine gas on brown linen and found it was very successful. Prior to this discovery bleaching was a tedious, troublesome, and expensive process. The brown cloth had to be thoroughly washed, boiled in weak lye, spread upon the grass exposed to the sun, steeped in buttermilk or sour milk, and again spread upon the grass. To effect the requisite amount of oxidization, the boiling, exposure on the grass, and steeping had to be continually repeated during several months. The chlorine process worked quickly and efficaciously, but it was attended with some risks to the material as well as to the workmen, and the smell of the chlorine was a public nuisance. In 1789 the French, at the Javelle works, near Paris, added potash to the water in which the chlorine was dissolved; hence the name "eau de Javelle," as chloride of potash is still called. The Duke of Gordon in 1795 employed Professor Copeland to establish a works at Aberdeen for the production of eau de Javelle, which was sold to the neighboring bleachers.

In 1798 Charles Tennant, a bleacher at Barnley, near Glasgow, tried the effects of quicklime and applied for a patent for "lime-bleaching liquor." But the patent was disputed and had to be abandoned. Tennant then experimented with carefully slaked and screened dry lime and succeeded in producing a bleaching powder which is in use to this day. The lime absorbs the chlorine gas and acts as a carrier. When the bleacher wishes to have a bleaching liquor he has simply to dissolve the powder in water. This time Tennant's patent held, and his discovery completely revolutionized the bleaching industry. The same year works were erected by Mr. Tennant and his associates at St. Rollox for the manufacture of bleaching powder, which was the beginning of the present great alkali works built up there by the Tennant family, and the foundation of their wealth.

The method of producing the chlorine at the outset was by the decomposition of a mixture of salt, manganese, and sulphuric acid in a leaden still heated by a water bath. The gas evolved was conducted to a leaden receiver containing lime which was agitated from time to time to assist in the absorption of the chlorine. The demand for bleaching powder grew rapidly, and the utilization of the by-products and the stopping, in some measure, of the growth of the waste heaps, soon became important. In 1803 the Leblanc process was used on a small scale and an impure soda, or black ash, was made from the still-residues. Soon after the lead stills were given up, and stone ones constructed and heated by external application of steam. When Tennant began making bleach it sold for £140 per ton. In 1805 it was worth £112 per ton. In 1810 it commanded £93; in 1815, £81; and in 1820, £60 per ton. It dropped, in 1825, to £27, and in 1830 it fell to £25 per ton.

These prices seem excessive, but the process of manufacture was very crude and the waste enormous; besides, the raw materials were correspondingly high. In 1798 salt sold in Glasgow for £13@£18 per ton, and in 1804, on account of the increase of taxation, one of the penalties of the Napoleonic wars, it rose to £19 per ton. In 1809 the price was £11, and as late as 1839 it was a guinea per ton in Glasgow, although the tax was taken off in 1823. Sulphuric acid in 1800 sold for £60 per ton, and in 1805 the cost of production was £28 15s. per ton of acid. Down to 1840 great improvements in apparatus and considerable reductions in cost price were made, but it was subsequent to this time that the use of pyrites was introduced and the Gay-Lussac and Glover towers were employed, which effected very great economies.

The manufacture of alkali in Great Britain continued to be principally from kelp, or as a by-product from the residuum of chlorine stills, until about 1818. In 1800 Lord Dundas made alkali at Dalmuir, Scotland, from soap lyes and salts, and 1804 his works turned out 128 tons, which brought £37 per ton. In

1806 the Dalmuir works consumed from Paisley 150 tons of soapers' salts and produced 120 tons of soda crystals and 21 tons of muriate of potash. There were 15 workmen employed and 1200 tons of coal burnt. The soapers' lyes were evaporated in circular pans, holding about 500 gallons each, and the resulting salts were charged in furnaces with sulphate of potash, sawdust, and a little quicklime. The charges were about 12 cwt., and six hours were required to flux them. The black ash was lixiviated, and the soda and muriate of potash crystallized out alternately. The net cost of a ton of soda crystals made in this way was £29 6s.10d. The selling price was about £60. When the greatest care was exercised the muriate of potash was rarely free from soda, and the soda scarcely ever pure.

The St. Rollox works, near Glasgow, were built in 1799, and in 1803 the chlorine still-residuums were worked up into an impure black ash. James Mactear, in his *Report on the Alkali and Bleaching Powder Manufacture of the Glasgow District*, gives the following description of the process used at the St. Rollox works at this time:

"The methods which were adopted at the St. Rollox works were very various as fresh light was thrown on the science of chemistry. Almost immediately after the commencement of bleaching-powder manufacture the waste products of the stills were utilized for the production of alkali for soap-making. These residues, consisting chiefly of sulphate of soda and manganese, with varying quantities of common salt and sulphuric acid in the free state, were in the first case used in the manufacture of Glauber salts; this was followed by a method of making sal-ammoniac from urine collected in Glasgow in casks. This process was found unsuitable, probably from the difficulty of obtaining ammonia in sufficient quantity, and was soon displaced (in 1803) by a process, or rather a sequence of processes, which, with slight variations, continued in use for many years, until the introduction of the complete Leblanc system of alkali-making.

"This was the production of a crude alkali, or black ash, for use in soap-making instead of kelp, then usually employed. The earliest details which I have been able to find show that the still-residuums were run into wooden tubs, where they were mixed with ground coal, or sawdust, till in a thick pasty state; this mass was then transferred to a reverberatory furnace and melted. When the decomposition had ceased it was run out, and, when cold, broken up and lixiviated with caustic lime, and the caustic lyes thus formed were used in the saponification of the fatty matters. This was followed by the method of mixing the liquor, obtained by lixiviating the above black ash, with sawdust, and again furnacing, when a barilla was obtained worth, at that time, about £28 per ton. The soap lyes, after having become spent, were boiled down to salts, and barilla again made from them, much on the system already described as in use at Dalmuir."

The works at St. Rollox made the sulphuric acid consumed in making bleach, and the process of manufacture left as a by-product a considerable quantity of "sulphur ash," a mixture of unburnt sulphur and sulphate of potash. This was furnaced with soapers' salts, and gave an increased yield of muriate of potash.

From 1803 to 1818 the crude methods described were employed in England, as well as in Scotland, for the production of alkali. The Leblanc process was used for obtaining the black-ash reactions while employing the residuums from the chlorine stills and spent soapers' lyes. It was undoubtedly profitable in Scotland, because there was a greater demand there for bleach than in England. But in 1818 French alkali made from common salt by the Leblanc process began to be sold in London. It was in three qualities—crude soda or black ash; soda crystals; and soda ash, or carbonate of soda. The prices were from £25 to £30 per ton.

The Scotch and English manufacturers, with commendable enterprise, investigated carefully the French methods and immediately began to imitate them. The St. Rollox works was probably the first in the field, for the Tennants were wide-awake and enterprising men. They soon turned out a better quality of crude soda than the French manufacturers, and were able to improve their methods of obtaining chlorine for bleach-making. Carbonate of soda began to be largely used in soap-making, and the demand for soda crystals increased. The first Lancashire alkali works for the manufacture of alkali from common salt was built in 1823 by James Muspratt, and Cheshire salt and all other raw materials being near at hand, with water carriage, the pioneers of the field made steady progress in the development of a great industry.

The earliest method of making sulphate of soda in Great Britain was by using a reverberatory furnace, which was followed by iron cylinders set in furnaces. The hydrochloric acid, as it was given off, was conducted to upright earthenware condensers. But this was confined to the Glasgow district, where bleach-making was the chief object, the alkali being for many years rather a by-product. The iron cylinders were rapidly destroyed by the action of nascent chlorine, and pans and pots of different forms were successively tried. The earthenware condensers gave great trouble, and escaping chlorine and sulphur fumes made the neighborhood of the alkali works unfit to live in.

The early Lancashire works made no attempt to save the hydrochloric acid. They were started to supply the soap-makers with alkali. The decomposing pots were open, and the salt and sulphuric-acid charges were heated by furnace fires. Lee & Gamble introduced large cast-iron pots, holding about 8 cwt. of salt, set in a furnace, having two drying flats whereon to complete the decomposition. A charge was placed in the pot and fired for a time and then removed and spread on one of the flats; then a second charge was made, and this, in turn, went on the second flat, and a third charge was put in the pot. In this way the decomposition was, in a way, continuous, but slow and very imperfect. In 1836 the most progressive Lancashire manufacturer, William Gossage, began to save the hydrochloric acid. Semi-circular covers were placed on the pots, and the drying flats were arched over with brickwork, making them reverberatory furnaces. But with the best possible arrangement of this kind the escape of hydrochloric acid was enormous, and muffle furnaces took the place of the drying flats.

A charge then was 16 cwt. of salt and 1800 lbs. of sulphuric acid of 1.45 sp. gr. at 120° F. The mixture was raked about, covered with the hood, and the firing begun and continued for one hour. In this way two such furnaces would turn out about 10 charges per day, being about 16 tons of salt treated, yielding 19 tons of salt cake. The pot was 9 ft. in diameter, from 2 to 7 in. thick, with a cover having two doors. The "muffle" was on one side, about 30 ft. long by 6 ft. wide. It was heated by firing from one end, flues carrying the heat underneath and up to and through the roof.

The different forms of furnaces, in their order of employment, were as follows: The single-bed reverberatory, oblong in shape. The circular single-bed followed, then the double-bed, then closed iron vessels of single-bed form, and after these double and triple iron vessels worked in series. The iron pan, or pot, with the muffle furnace attachment, known as pan and roaster, was the one which was found most satisfactory. Many attempts were made to improve upon the decomposing plant, and mechanical furnaces were invented by Jones & Walsh and by James Mactear, both of which gave good results. Mactear claimed, in 1881, that one of his furnaces, working in the Newcastle district, was capable of turning out 350 tons of salt cake per week, or at a rate of one ton in 25 minutes, saving 60% in cost of labor and 30% in fuel over pots and muffles.

Both the Mactear and the Jones & Walsh salt-cake furnaces were ingenious contrivances, but many manufacturers preferred the old arrangement of pots and muffle roasters, claiming that they had less difficulty in collecting and condensing the hydrochloric acid. The Mactear furnace was ingenious, and produced salt cake continuously, dispensing largely with hand labor. The salt and sulphuric acid were fed in continuous streams into a central pot, where they were mixed into a thin, pasty mass which flowed over into the first division of the roasting bed. The mixture was slowly moved by stirrers and plows into and through other divisions, and from the last into a delivery trough running around the furnace.

Two things are important in the salt-cake process—first, to prevent escape of gas, and second, to prevent ingress of air, which dilutes the hydrochloric acid, the resulting chlorine from which is weak. Mactear claimed to be able to condense all the hydrochloric acid without conducting it to condensing, or wash, towers. But the wash towers, introduced by Gossage, undoubtedly gave the best results in condensation. By the very best furnaces, and the most careful handling, from 2% to 4% of salt is not decomposed, and there are difficulties in obtaining regular flows of uniform hydrochloric acid, even when working the furnaces in series.

The Hargreaves.—Undoubtedly one of the greatest improvements in the production of salt cake is the direct process invented and worked out by James Hargreaves of Widnes, Lancashire. By this beautiful process the sulphurous acid gas from the pyrites burners, at a high temperature, is brought into contact with salt in iron cylinders, worked in series, and sulphate of soda, of a purity of 99.25%, is turned out in one operation without handling or manipulation. The production of sulphuric acid—the conversion of the sulphurous anhydride into a mixture of sulphuric acid and nitrate of sodium by means of the "niter pot," and passing the mixed gases into chambers and effecting by the introduction of steam a combination which forms chamber acid—is done away with. Not only is the entire sulphuric acid plant dispensed with, but all the trouble and labor of mixing the salt and sulphuric acid in pots, heating the mixture, spreading the partly decomposed mass on "flats" or on muffle furnace floors, to complete the conversion, are avoided by the Hargreaves direct sulphurous acid process. Mechanical furnaces for making salt cake, no matter how ingenious their construction, or how perfect their provisions for stirring and passing on the mixture, cannot compete with the Hargreaves process in cost or purity of product.

The Hargreaves salt-cake plant consists of special pyrites burners designed to avoid, as far as possible, loss of heat by radiation, and a series of iron cylinders, 15 ft. in diameter and 12 ft. high. They work in two rows, the series being six, eight, or twelve. They are provided with charging holes and doors for withdrawing the sulphate. The salt molded into bricks is placed in the cylinders, to which the sulphurous acid gas is conducted from the pyrites burners by flues of small section specially protected to prevent radiation. In this way a minimum of fuel is required in firing the cylinders to bring the temperature up to 800° or 900° F. The sulphurous acid gas comes off at a red heat, and the reaction set up in the cylinders being a source of heat, less than one-third of the fuel ordinarily required to make a ton of sulphate is consumed.

The gas coming from the pyrites burners is too concentrated to be allowed to pass direct into the cylinders containing raw salt, because the violent action set up would form it into a hard, compact mass. Therefore the temperature is raised as quickly as possible and the salt becomes covered with a coating of sulphate, and as the process is continuous the finishing cylinder receives the most concentrated gas as it comes from the burners. The arrangements for charging the cylinders and removing the finished sulphate are perfect, and workmen are not endangered by the escape of gases.

In dealing with the salt cake to obtain the black-ash reactions various carbonating furnaces have been tried, but the revolving one is in general use. It is an iron cylinder lined with firebrick, revolving horizontally, into which are fed charges of sulphate, broken limestone, or chalk, and fine coal.

The perfecting of the revolving furnace required a long time and repeated trials at the works of Stevenson & Williamson of Jarrow. Its importance in the development of the alkali industry will be apparent when it is stated that with one of the largest "revolvers" the same amount of salt cake can be decomposed that could formerly be handled in ten hand furnaces by 40 men, and with from 10% to 15% greater efficiency.

Producer gas is usually employed for firing, the flames entering the combustion chamber through a port in the end, and the waste heat, passing out at the other end, is conducted to the concentrating tanks containing the lixiviating liquors. When the fluxing is complete the furnace is stopped and the fluxed material is run out into iron barrows. The waste of heat is enormous, notwithstanding the employment of a portion to partly concentrate the liquors from the lixiviating vats.

The black-ash "balls" from the revolver, broken into lumps, are placed in vats arranged to work on the specific gravity system, and water at a temperature of 120° F. is supplied. The black ash swells, disintegrates, and yields up its soluble salts, forming a greenish-blue liquor. By regulating the specific gravity of this liquor, which is done by adding varying quantities of black ash to the different vats, it is made to flow from one to another in the series.

The discoverer of this system was Shanks, one of the technologists of the alkali industry, who conferred a great benefit to the trade. Prior to his invention the gravitation system had to be employed, which required more space and involved additional labor. The specific gravity as it leaves the final vat is about

1.3. The average time required to work off a vat is forty-eight hours. The liquors contain from 10 to 11 lbs. of soda per cubic foot, or about 13.5% by weight. These vat liquors contain many impurities which have to be eliminated. It is very difficult to prevent formation of sulphocyanides and ferrocyanides, and the presence of these gives a yellow color to the sodic carbonate. The vat liquors are boiled down and the residue is calcined in furnaces heated also by the waste heat of the revolving furnace. The result is soda ash containing 65% to 73% carbonate and 13% to 14% caustic soda, 4% to 7% sulphate of soda, and 2% to 6% sodium chloride. To get purer soda ash it has to be mixed with about its own bulk of sawdust or small coal, and heated in a "calker furnace," where it must be constantly worked by paddles at a temperature of 600° to 700° F. This burns off the sulphur and carbonates the caustic soda. In crystallizing out the soda ash by boiling the vat liquors a "mother" or red liquor is left, containing much caustic soda. This is reduced in strength and run into a "causticizer," air is blown in and heat applied by means of steam, and lime added. When this operation is completed the liquor is run off and concentrated. The operation is tedious and involves many manipulations and complicated apparatus.

The Gossage Process.—The Gossage sulphide carbonic acid process is a very great improvement on the old black-ash methods of converting salt cake into carbonate and caustic. The salt cake is mixed with alkali waste, from which the sulphur has been recovered, in the proportion of three to one, slack coal is added, and the mixture is furnaced in the ordinary revolver. The fluxed product is lixiviated in the usual manner, and the sulphide, or sulphydrated, solution is drawn off, first into one of a series of three vessels. In the first it is treated cold with carbonic acid gas, pumped from closed lime kilns, to precipitate the silica, alumina, and iron, which are filtered from the solution in this vessel. From the first vessel the solution is then transferred to the second, where it is raised to the boiling point and treated with mixed gases—carbonic acid gas and weak sulphureted hydrogen. When the contents of the second vessel are about depositing solid bicarbonate of soda they are discharged into the third, kept boiling, and treated with carbonic acid gas in excess, the result being the formation of monocarbonate of soda, together with a small amount of bicarbonate in solution. The excess of carbonic acid gas and other gases passes into the second vessel, where the carbonic acid gas is absorbed and strong sulphureted hydrogen is given off. When the solution in the third vessel is free from sulphide of sodium—*i.e.*, all converted into carbonate of soda—it is run off and then dealt with as carbonate, or caustic, as desired. If caustic is wanted, the solution, of course, must be causticized.

The sulphur contained in the strong sulphureted hydrogen is recovered by the Chance process—or, rather, can be recovered without the employment of a large part of the Chance apparatus, which was designed to deal with the alkali waste as it comes from the old-fashioned lixiviation vats. The complement of the Gossage process would, of course, be the Hargreaves direct sulphurous acid process of making salt cake, by burning the sulphureted hydrogen in an appropriate kiln to sulphurous acid and conducting that to the cylinders containing the salt. There is a loss of sulphur, not exceeding 20%, which would have to be made up from pyrites burners.

The saving estimated by Mr. Gossage is about 10s. per ton of carbonate, or soda ash of 58% plus the value of sulphur recovered, or used as sulphurous acid in making salt cake. He has, he claims, proved this by making over 1200 tons in a continuous run. This run also demonstrated that the lining of the revolver was not materially injured, the one objection that was urged being that such lining would be quickly destroyed. Mr. Gossage is now making the necessary preparations to put up the plant in his works at Widnes to produce all the alkali used in his soap works.

The United Alkali Company has the option to acquire the rights for Great Britain from Mr. Gossage, the demonstration of the process on a commercial scale having been made at one of the company's works. This option has not yet been exercised.

From start to finish in the Leblanc process the thermic waste is immense. The consumption of coal is a fraction over four tons of fuel to each ton of salt decomposed. This, of course, includes the coal burned to give the extra thermic duty required in the several reactions to convert salt into finished soda and chlorine compounds. In the preliminary operation of burning pyrites and forming salt cake there is, according to Hargreaves, a waste of five times the heat required, and the most conservative estimate puts the loss of thermic energy in the Leblanc process at fifty times the heat theoretically required.

In no other of the great fields of industrial activity have inventive genius, scientific methods, and executive ability been more signally displayed than in alkali manufacture. And yet how slowly progress was made for a long time in the development of the industry! It is nearly a century and a half since Duhamel discovered that common salt contained a fixed alkali base identical with that obtained from the ashes of marine plants, and a century and a quarter has elapsed since Scheele obtained the reaction of manganese upon hydrochloric acid and produced chlorine and tested its bleaching properties.

But from Duhamel's discovery of the alkali base of salt to the isolation of sodium by Sir Humphry Davy nearly three-quarters of a century elapsed. Duhamel, starting where Glauber stopped more than a century before, succeeded in finding out the reactions by which sodic sulphate, or Glauber salt, could be converted into soda. But it was more than half a century before means were worked out by Nicholas Leblanc to effect these reactions upon a commercial scale. The fact that chlorine was an element was not proved till Sir Humphry Davy and Gay-Lussac completed their memorable investigations of the gases, in 1811, and it was late in the thirties that Liebig discovered the theory of the hydrogen acids, and established conclusively the contention of Davy and Dulong that oxygen was not a necessary constituent of all acids. The knowledge of these facts was necessary to enable technologists to successfully deal with the production of chlorine on a commercial scale from hydrochloric acid.

It must be remembered, also, that quantitative analysis was practically unknown till the time of Lavoisier, to whom belongs the credit of introducing the balance as an indispensable part of a laboratory outfit. Sir Humphry Davy laid the foundations of electro-chemistry, but experiments extending over a quarter of a century were necessary before the laws respecting the action of the electric current upon conducting solutions could be worked out by Faraday.

But without modern means of supplying electrical energy a commercial application of electro-chemistry was an impossibility.

From William Gossage, the father of scientific alkali manufacture, to Frederick H. Gossage, the inventor of the sulphide-carbonic acid-soda process, covers a period of seventy years. When William Gossage began his career as a soapmaker, caustic soda, of a very inferior quality, was obtained at a loss of raw materials and waste of products as follows: The whole of the sulphur being left in alkali waste, all the hydrochloric acid escaped in gas, which contaminated the atmosphere and destroyed all vegetable life for miles around the alkali works. To-day, by the evolution which has been caused by the inventions of the elder Gossage, of Hargreaves, Weldon, Deacon, Chance, and finally of Gossage junior, the cycle in the Leblanc process has been completed. Starting with salt, pyrites, coal, limestone, manganese, or (for the Deacon chlorine process) cupric sulphate, soda and bleach can be produced, with a minimum loss of undecomposed salt, utilizing half the chlorine, and recovering practically all the sulphur.

The sulphur-recovery process was a necessity forced upon alkali manufacturers from two directions. The accumulation of alkali waste is so enormous that the disposition of it is a serious problem. If it is impregnated with sulphur it becomes, by the action of the elements, a frightful nuisance. After the adoption of pyrites as the source of obtaining sulphur, which was necessitated by the great advance in the price of Sicilian sulphur in 1838, the monopolies controlling Spanish pyrites were, in time, able to dictate terms to the alkali makers. This gave a fresh impetus to the endeavors of those at work upon a sulphur-recovery process.

In 1837 Mr. William Gossage discovered the reaction of carbonic acid upon the sulphureted hydrogen gases, but, as he declared, "he devoted thirty years of his life and a fortune" in futile efforts to work it out upon a profitable commercial scale. Mr. Chance, in a paper read before the Society of Chemical Industry in 1888, describing his process, generously said that if Mr. Gossage had had at his disposal the powerful carbonic acid gas pumps of Ludwig Mond he would doubtless have succeeded.

Ludwig Mond partially succeeded in 1868 in a process which subjected the lixiviating vat residues—the alkali wastes—to oxidation, by forcing through the mass currents of air and using the weak liquors from former lixiviations to wash the waste while the blowing proceeded. The treatment occupied about ten hours, the washing being repeated three times. The resulting liquor was run into tanks and maintained at 150° F. by steam, and hydrochloric acid of 20° Baumé was added. Then more liquor, and again acid, and so on alternately while the temperature was maintained at 60° C. As the tanks filled, the liquor was agitated, and, when full, acid was added until an odor of sulphurous anhydride was perceptible. Then the liquor, thus treated, was run into settling tanks and allowed to settle, when the sulphur was thrown down. Mr. Mond was never able, under the most favorable circumstances, to recover more than 60% of the sulphur in the waste.

Mactear, at the St. Rollox works, in 1871, endeavored to recover the sulphur from the drainage of alkali waste heaps by treating it in wooden vats, while agitated, with hydrochloric acid and a solution of sulphurous acid, the liquor being heated to about 140° F. The result, by properly proportioning the acids, was chloride of calcium and sulphur. Hydrochloric acid was then used to give a solution of calcic chloride and sulphur, the latter being collected, dried, and melted. The Mactear process had some advantages over that of Mond, but it only answered as an abatement of a nuisance at the St. Rollox works, where the seepage from the alkali waste heaps was so contaminating the Clyde that the Tennants were forced to stop it.

When the demand for bleaching powder became so active that hydrochloric acid, as the source of chlorine, was too valuable to use in the Mond and Mactear processes, of course they had to be abandoned. Mond's process had an advantage over Mactear's, because the weak liquors from the lixiviating vats, containing a considerable quantity of hydrochloric acid, were utilized. But when improved chlorine processes came in, this vat waste, with the weak liquors, was treated in the chlorine stills.

The Schaffner and Helbig process, which Chance Brothers of Worcestershire took up in 1880, was to decompose the calcium sulphide of the waste from the lixiviating tanks with a strong solution of magnesium chloride: $CaS+MgCl_2+H_2O=CaCl_2+MgO+H_2S$. The sulphureted hydrogen coming off was burned to sulphurous acid and used in the vitriol chambers to make sulphuric acid. The commercial result reached by Chance Brothers was to get their sulphuric acid at about what it would cost to make it from pyrites if the sulphur therein could be bought for 3d. per unit. In 1883, when they had reached this point after spending £10,000, the Spanish pyrites companies were charging 6d. per unit of sulphur. The principal alkali manufacturers then gave the pyrites companies the alternative of reducing the price of sulphur to 3d. per unit or of seeing the Schaffner and Helbig process, as improved by Chance Brothers, generally adopted. The Tharsis Company broke up the pyrites monopoly by bringing down sulphur, on long contracts, to 3d. per unit.

The Chance Process.—This reduction made it impossible for Chance Brothers to work their process at a profit, and they abandoned it. But in 1883 C. F. Claus patented his kiln for the recovery of sulphur from hydrogen sulphide. The object of the inventor was mainly to purify coal gas and recover sulphur from the hydrogen sulphide. Alexander M. Chance immediately made arrangements with the company owning the Claus patent to use the kiln in the recovery of sulphur from alkali waste.

The problem was to get a strong sulphureted hydrogen to deal with. All previous attempts of treating calcium sulphide had resulted in intermittent flows of sulphureted hydrogen by the action of carbonic acid, and Mr. Chance could get no forwarder. His difficulty was that the best constructed lime kiln will only afford a mixed gas composed of 30 parts carbonic acid, the remaining 70 parts being mostly made up of atmospheric nitrogen. The nitrogen, inseparable from the carbonic acid, has no effect upon the alkali waste, but it dilutes the sulphureted hydrogen to such a point that it cannot be burned into sulphurous acid gas.

Chance's invention consists of an arrangement of cylinders into which the alkali waste, mixed with water to about the consistency of thin cream, is charged, and then carbonic acid gas pumped in, forming carbonate of lime, and the unabsorbed part acts on the calcium sulphide, producing sulphureted hydrogen, which, passed on and meeting alkali waste, forms, by absorption, sulphydrate of calcium. Thus a double absorption takes place, first of carbonic acid, and second of sulphureted hydrogen. The inert gases left, chiefly nitrogen, are allowed to escape through a pipe provided for this purpose. The carbonic acid from the lime kiln continuing to enter the first vessel acts on the calcium sulphydrate already formed and gives off two equivalents of sulphureted hydrogen for each equivalent of carbonic acid absorbed. Then it is found that the escaping gas begins to give evidence of sulphureted hydrogen. The test is made with a Bunsen burner, and when the escaping gas will burn the escape cock is closed and another cock is opened which allows the sulphureted hydrogen to flow to a gas holder. In this way a regular and constant composition of sulphureted hydrogen is, by working a series of seven cylinders, obtained and conducted to the gas holder.

If commercial sulphur is wanted the sulphureted hydrogen, mixed with a regulated quantity of air, is conducted to the Claus kiln. It passes through the perforated bottom of a circular fire chamber, then through a layer of broken firebrick, and then through a layer of oxide of iron. Steam and sulphur vapor are produced, which pass out through an outlet pipe to a small brick chamber, where the heat from the reaction causes liquid sulphur to be deposited; a considerable portion of the sulphur vapor, however, passes into a larger chamber with an arched dome roof, and here, as cooling takes place, flowers of sulphur are deposited.

If sulphuric acid is desired, the sulphureted hydrogen is burnt in a kiln to sulphurous acid in the usual way, and conducted to vitriol chambers furnished with a Glover's tower and a Gay-Lussac absorbing column.

The recovery of sulphur by the Chance process is about 90% of that contained in the alkali waste. There is about 10% of the total sulphur contained in pyrites left in the cinders, so that the total recovered is about 80%.

The Weldon Process.—In 1837 William Gossage proposed to prepare an artificial oxide of manganese for chlorine-making by causing the precipitated protoxide, while in the state of hydrate, to be agitated with atmospheric air so as to absorb the oxygen from it. From Gossage to Weldon, during the intervening thirty-odd years, some fifteen inventors endeavored, without success, to work out a manganese regenerating process. During that period all the essential reactions were discovered, and nearly every requisite appliance tried except one detail, the use of an excess of lime. This was hit upon by accident by Weldon and his assistants, who after two years spent in experiments succeeded in working out one. The difficulty was purely mechanical, the principal problem to solve being the economical handling of large quantities of material and supplying vast volumes of atmospheric air by blowers.

Starting with the stone stills, into which the charge of manganese, from 400 to 800 lbs., was placed, the hydrochloric acid was run in, from elevated cisterns, and heat was applied by the introduction of steam. Three-fifths of the total chlorine was lost in the residual liquors which were thrown away. Weldon's invention is running these liquors into wells, 7 ft. deep by 20 ft. in diameter, and neutralizing them, while agitated, by chalk, or other forms of carbonate of calcium, to transform the iron and aluminum present into oxides. Then the liquors are pumped into settlers, oblong iron tanks, wherein the gypsum and oxides of iron and aluminum are deposited and the resulting clear pink liquor is drawn off. The settlings, after washing to remove any manganese, are thrown away. The pink liquor runs into "oxidizers"—cylindrical iron tanks, from 8 to 12 ft. in diameter, and 22 to 35 ft. in height. A large pipe admits a blast of air and another a jet of steam. The oxidizers are commanded by tanks filled with milk of lime, and when the injected steam brings the liquor up to 150° to 170° F., the lime milk is run in, and air forced through in as large volumes as possible. An excess of milk of lime is added and the blowing kept up until from 80% to 85% of the manganese is converted into peroxide; the result is a thin black mud composed of chloride of calcium solution containing in suspension about 2 lbs. of peroxide of manganese per cubic foot, and varying quantities of protoxide of manganese and lime, generally from $\frac{1}{2}$% to $\frac{3}{4}$%.

The mud is run into "mud settlers," where it subsides about one-half and the top clear liquor is drawn off, and the settlings, containing about 4 lbs. of peroxide of manganese to the cubic foot, is ready to be charged into the stills. These being about half filled with acid, the manganese mud is run in, say 500 cu. ft. to the charge, and the stills are heated by blowing in steam.

Thus starting with the manganese ore, and using the Weldon regenerating process, the manganese is used over and over again, the small loss in the settlings of the oxidizers being made up by fresh additions of ore. The secret of success in this process is the employment of an excess of lime. The precipitation of protoxide of manganese by lime being well known, Weldon hit upon using an excess of it to carry the peroxidation to the extreme point. The amount of air to be blown in depends on the depth of the oxidizers, the rapidity of oxidation increasing with their depth, within, of course, reasonable limits.

By the Weldon process one ton of bleach is made from 2.832 lbs. of hydrochloric acid, generated by the decomposition of 2 tons 7$\frac{1}{2}$ cwt. of salt. The loss of acid is 15%, and from 4% to 10% of manganese is lost. The practical result is that by the Weldon chlorine process one-third of the chlorine contained in a given quantity of salt is utilized.

The Deacon-Hurter Chlorine Process.—The Deacon chlorine process is the latest perfected improvement now employed by the Leblanc alkali manufacturers. Walter Weldon worked out his process in the works of Gamble & Co. at St. Helens, and Henry Deacon began his efforts about the same time in the works of Gaskell, Deacon & Co., at Widnes. Associated with Deacon was Dr. Ferdinand Hurter, then the chemist of Gaskell, Deacon & Co., and now the consulting chemical technologist of the United Alkali Company. Deacon and Hurter began their experiments in 1867, and up to the time of Mr. Deacon's death, in 1876, the process, although giving great promise, was not considered a commercial success. The Weldon process meantime had been adopted and was in general use, and very nearly all the bleaching powder of Great Britain, France, and Germany was made by it. Even as late as 1880 there were only two or three alkali manufacturers using the Deacon process outside the works of Gaskell, Deacon & Co.

But Dr. Hurter is very persistent as well as very clever, and his perseverance has at last been rewarded. The defects which so long militated against the Deacon process have been cured, and improvements have been made until a ton of bleach showing 35% chlorine, as packed in casks in the summer season, is now regularly produced for every ton of salt decomposed. And the United Alkali Company has decided to substitute the Deacon process, as improved by Dr. Hurter, for the old Weldon plant in all their works. The reactions upon which this process of obtaining chlorine from hydrochloric acid gas are founded were not discovered by Deacon, but the practical working out of the method of utilizing them, on a grand commercial scale, was sufficient to entitle him and his co-laborer, Dr. Hurter, to the highest honors.

The fundamental basis of the process is the reaction caused by passing a mixture of hydrochloric acid gas and oxygen over a catalytic substance at a high temperature with the result that $2HCl+O$ is resolved into H_2O+2Cl. Laboratory experiments demonstrating this are easily made. If small pieces of brick are dipped into a solution of cupric sulphate and dried, fitted into tubes, and hydrochloric acid gas mixed with atmospheric air is passed through at a temperature of 373° C. to 400° C., the chlorine will be liberated. The reaction itself causes great heat, but in practical work the gases, before they enter a decomposer, must be heated to 400° C., because there must be sufficient heat maintained in the decomposer to prevent the water formed and the nitrogen present from absorbing too much of this heat.

The aim of the inventor, at the outset, was to take the gases as they came direct from the salt decomposing pans and roasters to the chlorine generator, and from thence to the bleach chambers. This necessitated the heating of these gases in iron U-shaped pipes to 400° C., then conducting them into an apparatus called a decomposer, which contained the catalytic substance,—for instance, balls of baked clay steeped in cupric sulphate,—where the chlorine was liberated, whence it passed on to the bleach chamber. This would have dispensed with the Gossage coke towers for condensing the hydrochloric acid gas to hydrochloric acid, and the Weldon chlorine stills and the manganese regenerating plant. But in order to combine the necessary oxygen with the hydrochloric acid gas as it came from the salt decomposing pans and roasters, such a large volume of atmospheric air, and consequently nitrogen in large quantities, had to be drawn in by a fan, that the chlorine was diluted by the nitrogen to such an extent that it was too weak to make bleach in the ordinary chambers. Hence a new form of bleach chambers had to be devised.

It was also found that only the gases from the pans could be utilized direct, and therefore those from the roasters, or from the muffle furnace, had to be conducted, in the usual way, to the Gossage condensing towers, which necessitated the employment of a Weldon plant if the condensed hydrochloric acid was employed in bleach-making. The Deacon plant was expensive and complicated and manufacturers would not put it up, although, worked in conjunction with the Weldon process, it undoubtedly effected a reduction in the cost of bleach. A very ingenious arrangement for heating the gases and utilizing the waste heat to work the salt decomposing plant was worked out by Dr. Hurter. Then it was found that the balls, or marbles, holding the cupric sulphate, became after a time inert. A new form of gas decomposer had to be designed which would allow these balls to be drawn out and new ones put in without interfering with the work of the plant. The Root blowers, employed to draw the gases from the salt decomposers through the heated pipes and into the gas decomposers and draw off the chlorine, made it extremely difficult to construct the plant so that an excess of air would not get in and still further dilute the already weak chlorine. But after a quarter of a century of persistent efforts and the application of the highest scientific knowledge and wonderful engineering ability, the Deacon-Hurter process is now as nearly perfect as any human contrivance can be made. Something more than half of the theoretic quantity of chlorine in a given quantity of salt can be obtained and utilized in making bleaching powder. The value of this achievement to the United Alkali Company can scarcely be overestimated. Its soda products are made at a loss at present selling prices, and it is from the profits derived from its chlorine products that interest on a capital of £8,500,000 must be paid.

Hasenclever Process.—Robert Hasenclever of Stolberg, Germany, by his independent experiments, was able in 1883 to recover a mixture of dry hydrochloric acid gas and air which enabled the Deacon process to be successfully worked at his establishment near Aachen. He ran hot sulphuric acid from the ordinary lead evaporating pans through a series of vessels along with a certain quantity of liquid hydrochloric acid, while he passed in the opposite direction a current of air through the same vessels. In this way he obtained a composition of gas which answered for making bleach in the Deacon chambers. The sulphuric acid, diluted by this employment of it, was reconcentrated in the leaden pans and could be re-used. The Hasenclever process is generally used in Germany for bleach-making at Leblanc works.

Weldon-Pechiney Process.—At Stassfurt, where the remarkable deposits of potassium, magnesium, and sodium chlorides are found, separated from one another by interposed layers of clay, a large industry is being steadily built up in the manufacture of bleaching powder, and it is here that the electrolytic production of chlorine from potassium chloride is being developed on a large scale. There is also a considerable amount of bleach made from magnesium chloride by the Weldon-Pechiney process.

Walter Weldon, after he had worked out his manganese regenerating process, turned attention to the employment of magnesium as a reagent for the liberation of chlorine from hydrochloric acid, and Pechiney and Boulouvard, two remarkably clever French chemical engineers, subsequently worked out an apparatus therefor which, in 1888, excited great interest in England. It was thought at first by many chemists that the recovery of chlorine from magnesium chloride would eventually transfer the bleach-making industry from England to Germany. Professor Dewar of the Royal Institution, whose series of lectures on the liquefaction of atmospheric air has just been concluded, believed that the Weldon-Pechiney magnesium chlorine process, if established at Stassfurt, must very seriously injure the alkali trade of Great Britain.

The apparatus designed by Pechiney and Boulouvard for carrying out the process was described by Ludwig Mond as "one of the finest specimens of the art of the chemical engineer." It was Mr. Mond's opinion that to those manufacturers who "produce strong solutions of magnesium chloride as a waste product the process offers such large returns, not only at the present (1888) price of chlorine products, but also at considerably lower prices, that they can well afford to work out those improvements themselves, and to adapt their plant from time to time to the experience gained in the course of manufacture." But since England did not afford magnesium chloride nor magnesite, the Leblanc alkali makers had to look to the Deacon chlorine process as the one which might save their bleach industry. It now appears that, notwithstanding Ludwig Mond was, in 1888, of opinion that "no future process for obtaining chlorine from chloride of magnesium or from hydrochloric acid will produce that commodity at less cost than the Weldon-Pechiney process," the electrolytic process is actually producing chlorine products from Stassfurt magnesium chloride, as well as from potassium chloride, in competition with the Weldon-Pechiney and all other old processes in Germany.

The starting point of the Weldon-Pechiney process was magnesium chloride, however obtained. The intention, of course, was to apply it in connection with the ammonia-soda process for the recovery of the chlorine and make bleaching powder. For this purpose magnesia was to be employed to decompose the ammonium chloride of the ammonia-soda process instead of lime. To a hot solution of the magnesium chloride, which is left after the ammonia has been recovered, free magnesia is added and a solid hydrated oxychloride is obtained having six equivalents of water. This is then heated at a low temperature until a great part of the water is driven off. A high temperature is applied, with a current of air, and half the chlorine is obtained in a free state and half as vapor of HCl, magnesia remaining. The magnesia can, therefore, be re-used to decompose the ammonium chloride.

The process is chiefly interesting now because the plant worked out by Pechiney and Boulouvard at Salindres, France, illustrates what wonders can be wrought by modern chemical engineers. Ernest Solvay, who had accomplished wonderful results by his chemical engineering ability in perfecting the ammonia-soda process, tried to design apparatus for handling cheaply large quantities of magnesium chloride, but failed. Then Weldon hit upon converting the magnesium chloride into solid infusible oxychloride and heating it in a current of air. The serious difficulty, however, was to get apparatus to enable these reactions to be carried out on a commercial scale at a profit. This was the part Pechiney and Boulouvard accomplished. One of their most ingenious devices was a furnace which was an adaptation of the principle of the old-fashioned bake-oven. It was a series of vertical chambers, the dividing walls of which were much thicker than the spaces between them. Products of combustion were passed through, and the thick walls stored up heat as regenerators in the Siemens open-hearth steel furnaces do. After the products of combustion had traversed the vertical chambers they went to a regenerator, and then to the apparatus for driving off, at a low temperature, the excess of moisture in the hydrated oxychloride. The thick dividing walls being sufficiently heated, the products of combustion were shut off and the oxychloride, in lumps, was charged into the narrow chambers. As they became heated, by absorbing the heat stored in the massive dividing walls, a current of air was admitted and the oxygen reacted upon them and replaced some of the chlorine, which passed off as free chlorine, with nitrogen, excess of air, and vapor of hydrochloric acid. This mixture was conducted to apparatus for condensing out the HCl, and the gases passed on to mechanical bleaching-powder chambers. The operation being completed, the residual magnesia was discharged through doors at the bottom of each compartment of the furnace, and then the heating-up was begun again and another operation was carried out.

The Ammonia-Soda Process.—The manufacture of alkali by the ammonia-soda process has been developed into a great industry during the past ten years. Although the reactions upon which the process is based were discovered and made known in 1838, and many attempts were made to provide the mechanical means for carrying them out upon an industrial scale, it was not until 1861 that Ernest Solvay succeeded in designing apparatus which enabled this to be done. Manufacturing works employing his inventions were established at Couillet, in Belgium, about 1863. His first patent was applied for in 1861, and the second, and most important, bears the date of 1863. But it was some years subsequent to this before he succeeded in demonstrating, by the price at which the product of his works was sold, that the new process had come to stay.

The period from 1852 to 1862 had witnessed an extraordinary development of alkali manufacture in Great Britain, the production by the Leblanc process having nearly doubled. At the time Solvay was reaching a successful stage in his engineering problems great improvements had been worked out in the Leblanc process by William Gossage and other enterprising manufacturers in Worcestershire, Lancaster, and Scotland, and a number of remarkably clever chemical technologists, Walter Weldon, James Hargreaves, Henry Deacon, Ferdinand Hurter, Ludwig Mond, and James Mactear, were beginning to see their way to complete cycles in the different stages of manufacture by the old process.

The merit of discovering and applying the ammonia-soda process undoubtedly belongs to two English chemists, Harrison Grey Dyar and John Hemming of London. Their patent was applied for in 1838. They mixed a solution of common salt with solid carbonate of ammonia, separating the bicarbonate of soda formed from the residual liquor, boiling the liquor to dryness, and heating the dry product with chalk in order to recover the carbonate of ammonia employed. This, it is evident, could not have been successful for manufacturing purposes, because the loss of ammonia would have been so great. But two years later they, through Mr. Delaunay, applied for a French patent, which discloses a decided advance in the application of their process. This was to pass a current of carbonic acid gas through the brine saturated with ammonia, then to collect the saline deposit on filters and add lime to decompose the ammoniacal salts and recover the ammonia gas. They also indicated different ways for re-employing the recovered ammonia. In fact, this French patent of 1840 described in detail all the successive operations by which the manufacture of alkali by the ammonia-soda process is to-day carried out on an immense scale. Nevertheless, simple and beautiful as the process was, and seemingly one that should not involve any great difficulties of a mechanical nature in conducting the different stages of it, twenty-five years elapsed before Solvay perfected apparatus which enabled the manufacture to be established on a solid foundation. Meantime very clever technologists had tried and failed after expending great sums of money. Kunheim, at Berlin, and Seybel, at Liesing, near Vienna, tried it, but obtained only an imperfect decomposition of the salt. Our indefatigable and enterprising inventor, Mr. Gossage, worked at it for several years and took out a patent in 1854 for the preparation of pure carbonic acid to be employed. In 1855 Bowker, at Leeds, and Muspratt, near Liverpool, built plants and worked for some time to perfect it. Turck, at Nancy, in 1854, endeavored to improve apparatus, and about the same time Schloesing was trying on the same line. Henry Deacon, the inventor of the Deacon chlorine process, applied, in 1854, for a patent for apparatus to apply carbonic acid under pressure. But the difficulties he encountered were so great that the patience of his partners was exhausted before the mechanical problems were solved. First, one of his associates, Mr. William Pilkington, retired, and was succeeded, in 1855, by Holbrook Gaskell, who had great faith in Deacon's ability, but after another year of abortive experimenting insisted that the attempt to work out a practical ammonia-soda process must be abandoned.

None of these inventors had succeeded in designing apparatus for a continuous process. In 1858 Schloesing and Rolland at Puteaux, near Paris, designed a plant which, on an experimental scale, worked continuously. They had cylinders fitted with agitators for absorbing the carbonic acid and applied means to keep down the temperature. A centrifugal apparatus separated the bicarbonate, and a device in connection therewith prevented the loss of ammonia. By means of a drying plant they succeeded in collecting all the carbonic acid gas in a gasholder to get pure strong carbonic gas. They devised an improved lime kiln and evaporators using waste steam. These inventors appeared to have failed because the syndicate of capitalists behind them became discouraged. They endeavored to get some concession from the Government by reduction of the tax on sal employed in the manufacture of alkali by their process, and failing in this declined to spend any more money.

The Solvay Process.—The first apparatus designed by Ernest Solvay for mixing the salt solution with ammonia and keeping a regular temperature during this stage was very simple and ingenious, consisting of two cylinders with agitators working in them, and between the two a third, containing the ammonia with a cooling worm inside. But in using a solution of natural salt, or the brine as it came from the wells, the contained salts of magnesium and calcium in salts had first to be removed, the one by milk of lime, and the other by ammonium carbonate. There had to be means provided for removing the precipitate as it formed in the apparatus for saturating the brine with ammonia.

The next difficulty Solvay had was to provide an automatic arrangement for regulating the saturation of the lime with ammonia, so as not to go beyond a certain point. This he did by availing himself of the difference in specific gravity between the pure brine and that saturated with ammonia, employing a system of communicating tubes. The brine saturated with ammonia rises to a greater height to balance the pure brine, and a lateral pipe carries away the saturated liquid when it rises to a certain point. The dissolver in which the brine and ammonia were mixed connected with two reservoirs, one of which measured the brine and discharged it into the dissolver and the other drew off the same quantity after it was sufficiently saturated. The filtering and cooling apparatus were ingeniously contrived and worked by means of compressed air.

The working out of the absorbing apparatus for the treatment of the ammoniacal brine with carbonic acid gas involved an exhaustive study of the laws determining the absorption of the gas by the brine. This resulted in a system of absorbing columns, which was the subject of his patent of 1863. The previous attempts to apply the carbonic acid gas had resulted in considerable loss of ammonia, which, being expensive, increased the cost largely. Solvay discovered that this loss was due to the free ammonia being carried away by the carbonic acid gas which was forced in against the current of brine. Hence his absorbing columns were designed to have the gas first come in contact with brine that had been partially acted upon by it. His columns, great tall cylinders, are divided into compartments by means of a number of finely perforated plates, spherically shaped, with other interposed plates having only a few holes. The ammoniacal brine enters at the middle of the columns and passes up toward the top, because it can flow freely in that direction. The gas is forced in at the bottom by a pump, and meeting brine deprived of its free ammonia, any that is carried along by the gas meets the descending liquid and is taken up by it. The ingenious device for keeping the liquid circulating in this way enabled the absorption of the carbonic acid gas to be carried on thoroughly. The gas also performs mechanical work in the columns. It is compressed by the pump and expands after entering the column, absorbing a large part of the heat caused by the reaction that it makes, and thereby keeps down the temperature to some extent. But as a low temperature is absolutely necessary to the successful working of the process, the columns have copious streams of water running on them all the time.

The products from the reaction of the carbonic acid gas on the ammoniacal brine are bicarbonate of soda and ammonium chloride. The bicarbonate has to be converted into monocarbonate, and theoretically one part of carbonic acid should be saved. But, of course, there is a mechanical waste, and so something more than half the quantity of carbonic acid gas has to be constantly supplied from lime kilns, for treating the ammoniacal liquor. As this is drawn from the kilns by powerful fans it passes through coke towers and meets streams of water which wash and cool it. The pumps which force the cooled and washed gas into the absorbing towers compress at 1½ atmospheres, and this heats it considerably, but the expansion that takes place in the columns more than compensates therefor.

A portion of the contents of the absorbing columns is drawn off every half hour in a pasty mixture, which is separated into solid sodium bicarbonate and a solution of ammonium chloride with a little carbonate and sodium chloride, by means of vacuum filters. These are iron cylinders of 10 ft. diameter and 5 ft. high with gratings covered with filtering material—linen or woolen fabric, covered by wire gauze. A vacuum is created below by an air pump, and the mother liquor is drawn off rapidly. The bicarbonate left is washed, by rose sprinklers, with warm water to get rid of the ammonia smell and to dissolve any sal-ammoniac crystals. Late improvements in the filtering apparatus make this operation continuous.

The drying and conversion of the bicarbonate into monocarbonate, or ordinary soda ash, was one of the difficult problems Solvay had to solve. He designed and experimented with various kinds of apparatus for this operation, but the best form is a specially planned revolving cylindrical furnace or roaster. These are provided with cunningly contrived scrapers, which keep the soda stirred and the bed of the furnace scraped. Usually two furnacings are required—one at a low temperature, and the other at a bright red heat. As the carbonic acid gas is given off it is conducted to a washing apparatus which retains any ammonia contained in it, and thence it passes to the absorbing columns.

The ammonia is recovered from the solution, or mother liquor, coming from the vacuum filters. This liquor consists of ammonia-chloride, some ammonium bicarbonate, an excess of undecomposed sodium chloride, and some free carbonic acid. The recovery is by means of stills designed for distilling off the ammonia. These stills are elaborate constructions and appear complicated, but their operation is very simple when understood. The principle is that of spirit-rectifying apparatus. Free ammonia present, and ammonium carbonate, are first allowed to go off, and then quicklime is added while exhaust steam is blown in. The steam and heat generated by the slaking lime supply the requisite heat for the distillation. The liquor first enters into a column still, where no lime is added, and then passes through a distributor, where the exhaust steam is also admitted into four stills which work in series. The lime is added in the first two stills to decompose the ammonium chloride. The loss of ammonia, by most improved recovery apparatus, is not more than 4% in Brunner, Mond & Co.'s and Solvay's works. But both companies, it is said, have secrets which they have been able to conceal in working the process in its different stages.

The whole of the chlorine of the salt decomposed comes from the ammonia stills as calcium chloride. To recover from this compound the chlorine, and utilize it for making bleaching powder and other chlorine products, has been the problem which has exercised all the inventive faculties of Solvay and Ludwig Mond for the past ten years. So long as the lack of an economical process for the recovery of the chlorine was not supplied, the cycle of the ammonia-soda process was incomplete. And while soda ash of great purity could be produced much cheaper than by the Leblanc process, still the contest of the rival processes was an unequal one, because the Leblanc had completed its cycle and was able to utilize all the sodium and a great part of the chlorine and recover valuable reagents like sulphur and manganese. In 1885, when Walter Weldon, Pechiney, and Boulouvard had succeeded in working out the magnesium chloride process, already described, it seemed as if the ammonia-soda process would thereby get its complete cycle. Magnesium would decompose the ammonium chloride equally as well as lime, and the resulting magnesium chloride gives up its chlorine much more readily than calcium chloride does. But the great expectations built up on the Weldon-Pechiney magnesium chloride process were not realized.

The Mond Process.—Ludwig Mond, a chemical technologist of remarkable ability, grew up in the Leblanc alkali industry. He was a friend of Ernest Solvay, and was in touch with him during all his struggles to work out the appliances for accomplishing economically, on a grand scale, the beautiful reactions which Dyar and Hemming had discovered in 1838. When success crowned Solvay's endeavors, Mond, in connection with the Brunner family, under the firm name of Brunner, Mond & Co., began in 1874 the erection of ammonia-soda works at Winnington, in Cheshire, where brine could be pumped from the salt wells. In 1874 these works, with a capacity of producing 20 tons of soda ash per day, were completed. At that time Solvay's works at Couillet, Belgium, were turning out 10 tons a day. He was working with brine made from dissolved salt. The Winnington works were, therefore, the first to use natural brine as it came from the salt wells. All the plant for these works was designed by Mond under the guidance of Solvay.

By 1881 Mr. Mond had made great improvements upon the original Solvay apparatus and secured them by patents. From his designs the construction of a plant for a new works was begun. It was upon a grand scale, and very considerable economies were effected by working upon the larger scale, as well as by Mond's improved apparatus, in saving labor, repairs, and first cost. By the employment of the Siemens gas producer, subsequently replaced by producers invented by Mond, a great saving was effected in fuel. The Mond producer gasifies the coal at relatively low temperature and enables a considerable quantity of ammonia to be saved.

The rapid development of the manufacture of alkali by the ammonia-soda process in Great Britain, chiefly under the technical direction of Ludwig Mond, is shown by the following table giving the tons of salt decomposed by it year by year from 1877 to 1893.

Year.	Tons of Salt.	Year.	Tons of Salt.	Year.	Tons of Salt.	Year.	Tons of Salt.
1877..........	9,082	1881..........	29,783	1885........	113,200	1889.........	219,279
1878..........	16,230	1882..........	56,914	1886........	137,220	1890.........	252,260
1879..........	22,669	1883..........	77,015	1887........	158,636	1891.........	278,528
1880..........	27,416	1884..........	89,759	1888........	212,181	1892.........	304,897

The beginning, in 1874, was at Brunner, Mond & Co.'s Winnington works, where 20 tons of soda ash per day, or about 6000 tons per annum, were made. Now 8 ammonia-soda works in Great Britain have an output of 200,370 tons of 58% alkali.

The largest of these 8 works are those of Brunner, Mond & Co., at Winnington and Northwich, Cheshire. In 1881 the firm of Brunner, Mond & Co. was converted into a limited liability company with a capital of £600,000, the purchase price being £120,000, in 12,000 fully paid ordinary shares of £10 each and £80,000 in cash. On this capital of £600,000 the company paid, in 1881, a dividend of 17%, in 1882, 20%, and 35% in 1883. In 1884 the capital was increased to £1,500,000 by the creation of 90,000 shares of £10 each, of which 22,500 went as bonus to ordinary shareholders, and 22,500 at a premium of £10 each, the remaining 45,000 to be allotted as ordinary or preference, according to resolution of a general meeting of shareholders. In 1890 the 35,000 shares of the increase of 1884 were made up to 45,000 7% cumulative perference shares, and 22,500 were issued at a premium of £1 10s. per share to shareholders, and 10,000 at a premium of £4 per share. In 1884 the dividend was 27½%; in 1885, 20%; in 1886, 20%; in 1887, 25%; in 1888, 25%; in 1889, 27½%; in 1890, 35%; in 1891, 40%. In 1892 the capital was increased from £1,500,000 to £2,000,000, and a cash and share dividend of 100% was paid. In 1893 the dividend was 30%.

In 1880 Prof. George Lunge of Zurich was of the opinion that a very general extension of the ammonia-soda process would be prevented by a rise in the price of ammonia. The price had risen enormously from 1870 to 1880, owing to the increasing demand for ammoniacal fertilizers. But the introduction of Chilean nitrates on a large scale brought down the price of ammonia, the production of which was at the same time greatly increased. It was estimated by Professor Lunge in 1880 that 100,000 tons of sulphate of ammonia could be sold at £18 per ton. In 1892 the production of sulphate of ammonia in Great Britain alone was 149,826 tons, and the price had fallen below £14 per ton.

In 1888 Ludwig Mond, in the course of a discussion on chlorine processes at a meeting of the London section of the Society of Chemical Industry, stated that he had devoted his best energies for two years to experimenting with a process for recovering chlorine from calcium chloride, and declared he was "firmly resolved to carry it to a successful issue." It was intended to convert hydrochloric acid gas into chlorine, and was specially applicable to the treatment of impure gases such as are obtained from the ordinary salt-cake roasters from the Hargreaves process, etc. He said: "I propose to pass these gases over certain oxides or salts at suitable temperatures, so as to convert the latter into chlorides, and then to heat the product by a current of hot air so as to obtain chlorine and regenerate the original material used. I specially recommend the oxides of nickel and cobalt for this purpose, but I also mention magnesia as one of the oxides which can be used. I may state here that I prefer the oxides of nickel and cobalt, because they allow of a complete conversion of the hydrochloric acid into chlorine, while the magnesium chloride always retains a certain quantity of water, which, on subsequent treatment with air, gives rise to the formation of a certain percentage of hydrochloric acid, which contaminates the chlorine gas. This process has given me very good results in the laboratory, but I have had no opportunity yet of trying it on a larger scale."*

Four years later, in the fall of 1892, the announcement was made in the London *Times* that the Mond process for the recovery of chlorine from calcium chloride had proved to be a complete success upon a commercial scale at the works of Brunner, Mond & Co., and a detailed description of the reactions and the methods of obtaining them was given. The following is condensed from that announcement.

By means of refrigerating apparatus the ammonia-chloride coming from the ammonia stills is brought to an extremely low temperature, whereby crystallization is caused. These ammonia-chloride crystals are dried and vaporized at very high temperature, and the fumes brought in contact with metallic oxides producing chlorides. Magnesium oxide being employed at extreme high temperature, hydrochloric acid in the shape of magnesium chloride is obtained, and the ammonia passes off to be collected and re-used in the ammonia-soda process. The magnesium chloride is submitted to the action of hot air, as in the Weldon-Pechiney process, and splits up into chlorine and magnesia. The latter, after oxidation, is re-employed, and the chlorine, as a weak gas, or by concentration reduced to a strong dry gas, is conducted to bleaching chambers.

The improvements by Mond on the Weldon-Pechiney process are the employment of the extremes of cold and heat in the preliminary treatment of the calcium

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chloride to obtain magnesium chloride, instead of using magnesia as a dissolvent of the ammonium chloride in place of lime, as the former inventors did. Otherwise the processes are the same. The Mond process, with plant for carrying it out designed by that expert technologist, is in operation at Brunner, Mond & Co.'s works, producing 7500 tons of bleaching powder per annum. But it is generally believed by competent experts that the commercial results are unsatisfactory, and that they are accepted by a rich and powerful corporation as means to an end in its competitive struggle with the United Alkali Company.

That these two great corporations recognize that their different processes have to do desperate battle with a common foe in electrolysis is shown by the activity of their rival technologists, Dr. Hurter and Ludwig Mond, in conducting investigations and experiments with electrolytic appliances. During the past year both of them have filled several provisional specifications for patents covering alleged improvements in the electrolytic production of soda and chlorine products.

The development of the alkali industry of Great Britain to its present vast proportions has involved the discovery of new chemical reactions, and the invention and application of mechanical appliances on a grand scale, to enable manufacturers to perfect the Leblanc and ammonia-soda processes. Thus when the King of Sicily, in 1838, granted a monopoly of Sicilian sulphur to a French company, and the price of sulphur rose from £5 and £6 to £12 and £14 per ton, the outlook was indeed very dark. But a manufacturer of sulphuric acid near Liverpool, a Mr. Hill, had years before successfully employed iron pyrites, coming from Anglesea, in his works. The difficulty of burning these pyrites, and obtaining sulphurous acid sufficiently regular and concentrated to employ in the ordinary acid chambers, did not justify their employment so long as Sicilian sulphur could be bought for £5 and £6 per ton. But when the price of Sicilian sulphur went up to prohibitive rates, Gossage, Muspratt, and others not only improved the pyrites burners, and Gay-Lussac invented the absorbing tower, and Glover his denitrating tower, but a means of employing the burnt ores was discovered which materially reduced the cost of the sulphur in the pyrites. Irish pyrites contained an average of 32% of sulphur combined with iron, and occasionally some carried a small percentage of copper.

In 1850 Gossage succeeded in getting by smelting the burnt ores a regulus which he sold to Vivians of Swansea, and after the introduction of Spanish pyrites the smelting of the burnt ores became a considerable industry at Widnes and St. Helens. But by and by the refiners of the regulus made their own price for it, and in turn the copper smelters fixed their price for the burnt ores.

In this emergency Henderson of Widnes discovered a process of calcining the ore with common salt, lixiviating it, and precipitating the copper with iron. The alkali manufacturers then combined, bought the Tharsis pyrites mine and Henderson's patent rights, and began working up their own residues from pyrites burners. They not only recovered the copper by the Henderson process, but the oxide of iron, or purple ore, left after lixiviation sold readily to iron smelters. When, in 1879, the three great pyrites companies combined to fix the price of sulphur at 6d. per unit, Chance Brothers were ready, as we have seen, to introduce a sulphur-recovery process which would enable sulphuric acid to be made from alkali waste as cheap as from pyrites, reckoning the contained sulphur at 3d. per unit. The reduction of price to this figure by the pyrites combination only stimulated Chance to renewed exertions in perfecting a sulphur-recovery process, which he accomplished in 1887.

From 1859 to 1869 the imports of Spanish pyrites through the Mersey rose from 26,441 tons to 133,864 tons. By 1880 the imports of copper pyrites into Great Britain had increased to 658,017 tons. The extraction of copper from Spanish and Portuguese pyrites soon developed into a great industry in Lancashire, on the Tyne, and subsequently in the Newcastle district. The ores carry small percentages of silver and gold, but to recover these a simple and expeditious process was necessary. This was discovered by Claudet, and introduced, in 1870, at the works of the Widnes Metal Company. The silver is precipitated from the copper liquors by a soluble iodide, along with lead sulphate and chloride and sub-salts of copper. These are removed by washing with dilute hydrochloric acid, and the remaining precipitate is decomposed by metallic zinc, the zinc iodides being re-used to precipitate further quantities of silver. The annual recovery of copper from pyrites ore burnt for sulphuric acid in Great Britain amounts to about 15,000 tons. The silver recovered from the same source runs over 300,000 oz. and the gold nearly 2000 oz. per annum.

The improvements necessitated in the production of sulphuric acid by the development of the alkali industry and the forced employment of the sulphur of pyrites have been of great benefit to mankind in addition to cheapening the cost of alkali and bleaching powder. The great industry of artificial fertilizers, so essential to our well-being, could not have been created without cheap sulphuric acid. The spreading broadcast of intelligence—the dynamic force of our age—is, in large measure, due to the reduction in the cost of chemically combining two atoms of hydrogen, one of sulphur, and four of oxygen.

As heretofore stated, sulphuric acid sold, in 1800, at £60 per ton. There was a large profit to the manufacturer at this price, but still the cost to produce at that time, as shown by items taken from manufacturers' books, was about £32 per ton. The progress made in chemical manufacture during the next ten years is measured by the reduction in cost of making sulphuric acid, it being a little less than one-half, or £13 5s. per ton. Thirteen years more were required to reduce the cost to £3 10s. per ton. And as Liebig, with very little exaggeration, said that the degree of a country's wealth and civilization may be measured by its consumption of sulphuric acid, a brief *résumé* of the improvements introduced in the manufacture of this important chemical ought to prove very interesting.

The earliest sulphuric acid manufactured in England was from copperas, one ton of copperas producing an average of 168 lbs. of acid, which sold for 2s. per lb., or £220 per ton. In 1736 Dr. Ward began to make sulphuric acid by burning sulphur and saltpeter together in large glass globes and concentrating the fumes in glass retorts. In 1746 Dr. Roebuck of Birmingham introduced the leaden chambers. The sulphur and saltpeter were burnt within the chamber on an iron plate supported on a lead stand. The next advance was to burn the mixture of sulphur and saltpeter, 8 lbs. of the former to 1 lb. of the latter, in a furnace outside the lead chambers. The furnace was a round oven of fire bricks, 4 to 5 ft. in diameter, with a floor 2 ft. from the ground, and an arched roof, the crown being 2 ft. from the floor. Air was admitted by a small aperture, with a sliding cover of tin, in the iron charging door. The sulphurous acid was drawn off through the roof by an iron pipe of 12 in. diameter.

The next improvement of importance was the employment of the niter pot to generate nitrous fumes to mingle with the sulphurous acid gas from the brimstone furnace, whereby the proportion of niter was reduced to one-tenth of the sulphur burnt. The gases were conveyed through a leaden vessel containing water to cool them. In 1828 Kestner introduced the use of steam in the chambers. Pyrites were first used as the source of sulphur in acid manufacture by Hill, in 1818, but it was not till 1839 that their general adoption became necessary on account of the high price of Sicilian sulphur, as already stated. One of the difficulties in making sulphuric acid, even with the use of brimstone, was to regulate the flow of the sulphurous acid gas. The employment of pyrites greatly increased this difficulty, which was caused by another, that of regulating the supply of oxygen to the burners. The oxygen must be obtained by admission of atmospheric air to the burners, and since the iron, or copper, absorbs oxygen also, an excess of air has to be introduced, and consequently the excess of nitrogen dilutes the sulphurous acid. Then, as the burning off of the sulphur from a charge of pyrites proceeded, the sulphurous acid gas varied in strength. Again, the crushing of the pyrites ore gave a quantity of "smalls," which caused trouble in burning.

Much ingenuity and many experiments were necessary, involving the expenditure of very considerable money, before a fairly good pyrites burner was obtained. The Gay-Lussac tower for the absorption of the nitrous fumes escaping from the chambers was introduced in 1842 at the St. Gobain works, in France, and effected an economy of 50% of the niter theretofore required. The Gay-Lussac tower is an adaptation of the Gossage tower for condensing hydrochloric acid—being filled with coke, and having, instead of a stream of water, one of concentrated sulphuric acid percolating, which, after absorbing the nitrous gases, returns to the chambers. The Gay-Lussac towers did not come into general use among British alkali makers till Spanish and Portuguese pyrites began to be employed. The improvement of Gay-Lussac still left something to be desired, because there was a loss of nitrous fumes by absorption in the chamber acid, which steam will not altogether denitrate, and some escaped in the towers.

The Glover tower was necessary to perfect the denitration and to improve condensation. It only remained to secure perfect working of the whole apparatus, as improved during the course of fifty years of experimenting. This required a close study of the different reactions by observing and trained chemists, and the invention of special instruments for the rapid and accurate estimation of the constituents of the gases entering and leaving the chambers. Winkler, Weber, Schwarzenberg, and others in Germany by their patient investigations first gave a clear idea of the reactions taking place in the absorbing columns and the chambers. Dr. Ferdinand Hurter's study of the dynamic theory of the manufacture of sulphuric acid, communicated to the Liverpool section of the Society of Chemical Industry in 1882, gives a clear conception of the chemistry of the subject, and the operation of the latest improved plant can now be scientifically conducted. There should not be a loss of 1% by escaping sulphur, and the consumption of niter should be less than 2% of the sulphur burnt. The cost of sulphuric acid 140° Tw., with sulphur in pyrites at 2½d. per unit, should not now exceed 20s. a ton.

The building of the great chemical industry of Great Britain would not have been possible without the technical education which the demand therefor stimulated. The incentive to study, to experiment, to design, and to create was offered, and the founders and builders of the business were liberal in affording the opportunities and the means to all who could give a reason for the faith within them. Walter Weldon was a journalist whose sixteen years' struggle for fame and fortune in London had brought only disappointment when he met Colonel Gamble of St. Helens, in 1866, and exhibited to him some experiments he had made on the oxidation of protoxide of manganese by blowing air through it while suspended in water. Mr. Weldon, to use his own language, was not a trained chemist—"I never heard a chemical lecture in my life. Though few men were more intimately acquainted with the whole literature of chemistry, I had never entered a chemical laboratory or seen a chemical experiment when I patented, not Weldon's process as it is, but what led to it."

Colonel Gamble was a discerning man, with a practical knowledge of inorganic chemistry, and at once saw that Weldon had hit upon a reaction which might be of the utmost value in completing the cycle of the manganese chlorine process, and that the middle-aged man who had failed in journalism was, nevertheless, clever and capable. Without hesitation he placed his laboratory and all the resources of his alkali works at St. Helens at Weldon's command, and for two years, notwithstanding many discouraging results, supplied the capital required to make experiments and to construct apparatus, and thereby enabled the inventor to perfect a process which brought him both fame and wealth.

James Hargreaves grew up in a chemist's shop at Preston, where his father dispensed drugs, and, as all druggists in the North of England do to this day, prescribed for patients. Acquiring at an early age a taste for chemistry, he taught himself French, because at that period (about 1850), as Fourcroy said—"*La chimie est une science française.*" He was still a young man when William Gossage employed him as technical chemist at his Widnes soap works. There he had a useful training, because Gossage was always experimenting. Modest, unassuming, with a head full of ideas and a thorough knowledge of chemical technology, as then developed, he proved a very useful assistant to an energetic, capable, and resourceful master. His mind was always directed to the improvement of thermic duty—to the saving, or utilization, of waste heat, and to obtaining direct results. His attention was first drawn to the salt-cake process, which he subsequently worked out by observing the waste of thermic energy in the old methods of manufacture. The method and means of application were all thought out, but an elaborate and expensive experimental plant was required to demonstrate that he had found the right way.

Thomas Robinson, a blacksmith by trade, and a mechanical genius, a friend of Hargreaves, undertook to supply the experimental plant required to demonstrate Hargreaves' direct salt-cake process, and he did it at a cost of several thousand pounds. The process worked satisfactorily on a small scale, but a plant to turn out hundreds of tons a week in a large alkali works meant the expenditure of at least £20,000. R. G. Davis, an experienced alkali manufacturer, had the courage to say that his firm would find the money to build the plant and would take a license from Hargreaves and Robinson, paying a royalty of several shillings per ton on all salt cake made by the process. The plant was erected, but it was nearly two years before it worked to the entire satisfaction of the inventor and the manufacturer. As designed it consisted of twelve cylinders which were to work in one series. By an accident, after nearly two years of trouble and worry, it was discovered that six cylinders, working in series, gave perfect results. From that day to this the plant has worked without a hitch, and has turned out thousands upon thousands of tons of salt cake at an average saving of from 10s. to 15s. per ton.

The mind of James Hargreaves was specially engrossed with thermic and electric problems, the discovery of means for economizing fuel in smelting operations and in obtaining motive power, and the application of electrolysis to chemical manufacture. He recognized that, precedent to the solving of the problems connected with the working out of a direct and continuous electrolytic process, great advances must be made in the conservation and application of heat energy derived from the combustion of fuel. For more than twenty years he devoted himself to this object. The thermo-motor, designed by him, originally worked by the direct combustion of solid fuel, and gave very remarkable results. A horse-power per hour was obtained from something less than a pound of coal. The use of solid fuel, however involved difficulties, chiefly in the nature of a mechanical feeding apparatus, and was abandoned for the liquid refuse of coal-tar products. A horse-power per hour was secured from less than half a pint of this refuse. But the mechanical construction presented great obstacles, since the gasification and combustion in the cylinder produced such intense heat that it was extremely difficult to prevent the melting of cast iron.

Coincident with the prosecution of work on his thermo-motor Mr. Hargreaves was experimenting with a new system of combustion and the application of producer gas to an improved type of the open-hearth furnace for steel-making and glass-melting.

The commercial result of his improvements in the production of steel, working with a three-ton open-hearth furnace, was a ton of medium soft steel with less than 6 cwts. of slack coal and a regular output of 13 charges from Sunday midnight to Saturday noon, or in 132 hours. The 6 cwts. of fuel per ton of steel made include that required to prevent cooling down from the knocking off on Saturday to the starting on Monday morning. This result is phenomenal compared with the very best results ever obtained in the United Kingdom. The average consumption of fuel per ton of steel made in Siemens' open-hearth furnace is 12 cwts., and the lowest claimed anywhere is 9 cwts. of selected coal. The average number of charges, in continuous work, per working week, is from 9 to 11, the latter being exceptional.

The superiority of the results obtained by the Hargreaves furnace is largely due to the richer gas obtained from his improved gas producer. But the perfect working of the whole depends upon the exact proportioning of the requisite amount of air necessary to secure perfect combustion in the furnace, the storing up and entire utilization of the heat coming from the exit port, and the direction of the flame through the inlet port upon the mass of metal.

The most recent form of producer employed by Hargreaves is one consuming 36 tons of slack per twenty-four hours with appliances for the recovery of ammonia and coal tar. The tests to which this producer has been subjected indicate that a gas extremely rich in combustible volumes will be regularly obtained from the refuse of coal mines, accompanied by a saving of by-products in ammonia and coal tar which will more than pay first cost of the fuel, interest on plant, and labor charges in working it.

The following table gives the tests of the gases from this producer during a four days' trial under the supervision of experts for whose capacity and independence I can vouch:

	CO	H	Total Combustible.	CO_2	N	Total Inert.
Hargreaves, ordinary coke gas................	32.52	13.12	45.64	1.70	52.66	54.36
" rich gas...........................	35.36	24.92	60.28	1.86	37.86	39.72
" average of combined gas.........	33.94	19.03	52.97	1.78	45.26	47.04
" average of six regular runs......	34.04	18.26	52.30	2.48	45.23	47.71
Siemens, average gas..........................	18.70*	5.20	23.90	5.30	70.80†	76.10

* Includes $CH_4 = 2.5$. † Includes $O = 2.2$

The rich hydrocarbon gas, of 60.28% combustible volumes, can be employed separately, after scrubbing and condensing ammonia in towers, for motor power gas, and the coke gas, high in CO, can be used for heating purposes, or the two can be combined, giving the high average of 52.97% combustible volumes.

The best type of steam engine will give in England a horse-power per hour at a cost of a farthing (½ cent). This may possibly be reduced materially by firing boilers with producer gas, or, better yet, by using gas engines. It is possible to recover from a ton of slack coal, used in the most improved form of producer, 45 lbs. of sulphate of ammonia, worth, at present prices, £14 per ton. Slack in Cheshire and Lancaster can be delivered at tide water to salt for 5s. per ton. Thirty-six tons of this coal, converted into gas containing 55% combustible matter, will give, with present type of gas engines, 3000 horse-power for twenty-four hours, or 72,000 horse-power hours, at an expense for fuel of £9. The value of the sulphate of ammonia recovered would be worth £10 2s. 6d. The coal tar recovered would be worth something, and therefore it is quite safe to say that motive power will cost little, if anything, in favored localities, the by-products recovered more than paying for the coal consumed, interest on capital in plant, and labor employed. This is not a hypothetical estimate; it is based on actual results obtained in England though now first made public.

ELECTROLYTIC PROCESSES.

An electrolytic process has a margin in its favor in making bleaching powder and other chlorine compounds, because it should give the theoretical yield of chlorine (less mechanical waste) from the ton of salt decomposed, which will give 1½ tons of 35% bleach, while the very best results by the Deacon chlorine process are 1 ton of 35% bleach from a ton of salt. This gives a great advantage, and doubtless it is this advantage which enables the German electrolytically produced bleach to compete successfully with bleach made by the old methods.

The commercial possibilities of Ludwig Mond's process for recovering chlorine from the calcium chloride waste of ammonia-soda works are, after a year's trial, not demonstrated. Gossage's sulphide-carbonic-acid process for making soda ash has been shown to be a decided improvement on the black-ash reaction; but the economy claimed is only 10s. per ton of 58% carbonate. This does not bring the cost of production down to that of Brunner, Mond & Co. by the ammonia-soda process. Therefore it is not probable that these new reactions which have been worked out will affect the contest between a new method and the two old processes in control of the field. Soda ash made by means of the ammonia-carbonic-acid reaction cannot compete with electrolysis if this product can be made by it as cheap, and if, at the same time, bleach can be turned out very much cheaper.

According to the *Chemical Trade Journal* of Manchester, an authority on chemical trade statistics, "The Gesellschaft Elektron already places upon the market more than a thousand tons of bleaching powder yearly, which is obtained by the electrolytic decomposition of chloride of potassium." The same authority states that "the preparation of bleaching powder from the Stassfurt chloride of magnesium by the electrolytic method has changed to an important degree the position of the market," and "soda is also now being prepared by the electrolytic method, and especially threatens to completely abolish the Leblanc process."

The production of chlorine for bleach manufacture by electrolysis has undoubtedly attained to very considerable proportions in Germany, especially from the Stassfurt potassium chloride, as well as from sodium chloride. There are some products made by the electrolysis of fused salts in Germany, but this application of electro-chemical work has been very slightly developed. It is more than forty years since Bunsen predicted that it would become an important branch of industry, but it is only during the past year or two that much attention has been attracted to the process as a manufacturing possibility. The manufacture of soda by the electrolysis of salt solutions has, so far as we can learn, nowhere been attempted on a large commercial scale; but caustic soda is actually made by electrolysis in England and is used by paper-makers. One large paper mill at Snodland, Kent, a short distance from London, has an electrolytic plant working which supplies all the caustic and bleach consumed by it. But the process employed is very imperfect, requiring a high voltage and yielding a product containing a large proportion of undecomposed salt, which has to be separated from the caustic by crystallization.

It is claimed that with even very expensive motive power a considerable saving is shown on the present selling prices of caustic and bleach. This is doubtless true, but it does not prove that it would be a commercial success if operated on a large scale in competition with the old methods.

There are, among other obstacles to be overcome before the electrolytic production of soda can be a commercial success, four problems to be solved.

First.—The soda products must be obtained directly, and comparatively uncontaminated by undecomposed salt. That is to say, 77% caustic and 58% carbonate must be yielded by a direct method containing less than .5% of undecomposed salt.

Second.—This must be accomplished with a low voltage of from 2½ to 3 volts.

Third.—Durable diaphragms and anodes must be found, and the former must be of such a composition that they will offer the minimum of resistance to the electric current, and at the same time permit the cations to freely pass to the cathode, but without having filtering properties; and they must be so arranged as to allow the cation product to be readily and steadily removed as formed at the cathode.

Fourth.—Cheap motive power, other than water-power, must be secured. Salt and coal are found in almost all countries so placed as to be brought cheaply together, but the localities where sufficient water-power and salt deposits are contiguous are very rare.

The estimates hitherto made as a basis for predicting the commercial success of the electrolytic production of soda and bleaching powder are entirely fallacious. It is assumed that the average selling price of the products during the past few years will be maintained; but the fallacy of this is now apparent, since 48% soda ash is selling in England at £3 0s. per ton. The cost of making this ash by the ammonia-soda process is about £2 5s. per ton. This is also approximately what it costs Brunner, Mond & Co. It is undoubtedly true that by the Leblanc process, with all recent improvements, including the Deacon chlorine and Chance sulphur recovery processes, soda ash cannot be made nearly so cheap as Brunner, Mond & Co. make it by the ammonia-soda process.

The United Alkali Company, which practically controls the production of alkali by the Leblanc process in England, since it consolidated under one management all the important works using that process, has for the past year made the whole of its profits from bleaching powder. Its 48% soda ash, now selling for £3 0s. per ton, costs, it is believed, at least £5 per ton to make. Caustic soda costs about £8 per ton, and the average selling price for 1893 was £8 10s. Bleaching powder, of 35% strength, costs by the Deacon chlorine process within a fraction of £3 15s. per ton. Possibly by the Hargreaves and Robinson salt-cake process and the Deacon chlorine process bleach can be made for £3 5s. per ton. The selling price has ranged from £8 10s. to £10 per ton during the last year.

In the autumn of 1888 Dr. Ferdinand Hurter, the distinguished chemical technologist, in a paper read before the Liverpool section of the Society of Chemical Industry,* took a very despondent view of the possibility of the application of electrolysis to the manufacture of heavy chemicals, basing his conclusions on experiments made by himself which served to prove that it would require an electrical intensity of 12 volts to drive a volume of 1000 ampères through an electrolyzer containing a solution of sodium chloride, having the anode and cathode compartments separated by a porous diaphragm.

Starting from the theoretical assumption that common salt, heated to a high temperature and passing steam over it, would result in a decomposition represented by the equation $31{,}660c + NaCl + H_2O = HCl + NaHO$, the conclusion is reached that a consumption of fuel of about 4 lbs. to every 58.5 of salt would be sufficient, but it is impossible to make available, for either mechanical or molecular work, the theoretical energy which the 4 lbs. of fuel should supply, and, even if this were possible, the 31,660 units of heat would be unavailable at the temperature at which the reactions desired in the decomposition of salt could take place. If the decomposition of salt by electrolysis is possi-

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* *Jour. Soc. Chem. Ind.*, Vol. VII., pp. 719–725.

ble according to the theoretical equation, $2NaCl+2H_2O=2NaHO+H_2+Cl_2$, then the reaction would only require 53,060 units of heat per 58.5 of sodium chloride, whereas the black-ash reaction alone requires a consumption of 20 cwts. of fuel for every 22 cwts. of sulphate of soda, or greatly more than 53,060 heat units per 58.5 of sodium chloride. The electrolytic method would be, if practicable, superior to even the direct method of heating the salt to a high temperature and passing steam over it, which theoretically would only require 31,660 units, because (1) the energy can be supplied by electrolysis, at ordinary temperatures, and (2) heat is transformed into mechanical work at greater intervals of temperature than can be made use of in the direct application of heat.

But these advantages, Dr. Hurter claims, "are accompanied by serious drawbacks." These are, first, the extent of plant which will be required; second, the impossibility of utilizing a reasonably low voltage in electrolytical decomposition; and, third, the difficulty of obtaining the products of decomposition in a relatively pure state.

Professor Ostwald, in his new Chemistry, points out that "Faraday's law only considers one factor of electrical energy, viz., quantity; the other factor, electromotive force, remains unheeded." According to Ostwald, the assumption that the electricity had to do work upon entering an electrolyte, by effecting decomposition before it can avail itself of the fragments for its transport, is erroneous. He says: "Electricity, according to our experience, moves in electrolytic conductors with the same freedom as in metals." The quantity of electricity moving with 1 gram of hydrogen, or with the equivalent quantity of another ion, is 96.540 coulombs, and conversely a coulomb requires for its transport in an electrolyte .00001036 gram equivalents of any ion. But the electro-chemical equivalents of a given metal are not always the same—they vary according to the nature of the compounds containing it. For instance, the electro-chemical equivalent of copper in dilute hydrochloric acid is 63.3, cuprous chloride being the product, while in dilute nitric acid it is 31.7, for then cupric nitrate is formed.

In the outset of the electrolysis of a solution of sodium chloride, or an electrolyte of nearly similar elemental components,—*i.e.*, elements having the same valency,—the process proceeds, as Faraday proved, according to the quantity of electric current; but in a very brief time reactions are set up, just as Dr. Hurter says, and, as long before him, Faraday discovered, and these reactions interfere with the natural electrolytic process. To prevent these reactions from taking place, the earliest experimenters, in seeking to apply electrolysis for the production of soda and chlorine products from common salt, introduced a porous diaphragm to separate the anodes from the cathodes. The idea was doubtless suggested by the employment of porous cups in constructing batteries. But from the beginning of these experiments to our time the common form of an electrolytic apparatus has been a tank divided into anode and cathode compartments by a diaphragm and filling this vessel, or cell, with the electrolyte. Therefore there is a vessel of a given size having two compartments, or complements of two, divided by a diaphragm, or diaphragms, and designated anode and cathode divisions as they contain these respective electrodes. When the operation begins, if there were no diaphragms to separate the anodes from the cathodes, there would be no obstacle to the passage of the ions, and little, if any, resistance, according to the nature of the electrolyte. Consequently it is the diaphragms that cause resistance. But if there were no diaphragms interposed, reactions would take place and in a relatively short time the electrical efficiency would cease altogether.

The difficulty is that the diaphragms do not permanently prevent the reactions while increasing resistance and necessitating greater electromotive force. Dr. Hurter, in contrasting the means of separating and keeping separate the products resulting from the decomposition of salt by the different processes, is very happy in his language when he says: "Let us now glance at the other part of the problem, that of keeping the newly-formed molecules from rearranging themselves. The Leblanc process uses, of course, the ordinary chemical means for this purpose. It separates the chlorine from the sodium by converting the chlorine into a gaseous compound, which is but little soluble in the solution from which it is evolved at the temperature of reaction. When the sulphur has to be separated from the sodium, the sulphur is converted into an insoluble solid compound. Similarly the ammonia-soda process converts the soda into a comparatively insoluble compound, while the chlorine remains in solution. Both these processes therefore solve that part of the problem very effectually.

"Now the electrolytic method, in those metallurgical operations to which it has been successfully applied, does exactly the same thing. The copper of the impure anode is dissolved and reprecipitated at the cathode in the pure condition, the impurities partly remain in solution, partly are deposited at the bottom of the tank. Thus this very essential condition of keeping the products separate from each other and from the raw material is complied with. But when we inquire about this aspect of the question with regard to the electrolysis of common salt we find most serious difficulties, which have not, so far as I am aware, yet been met by any inventor, and, I am afraid, difficulties which will require some considerable increase of our knowledge of electrolysis in general before they can be surmounted.

"In the first place, if we wish to utilize to the utmost the horse-power of the engines, it is necessary to have the electrodes as little distant from each other as possible. But if in the close proximity—indeed, surrounding the spot where chlorine is to be generated—there happens to be present a solution of caustic soda, where is the chemist who would expect the whole of the chlorine due to the current to be obtained, and who would expect the caustic soda to remain such in the presence of a current of chlorine gas?"

But these very difficulties to which Dr. Hurter refers had all been encountered and struggled with long before his time. Charles Watt, whose patent is dated Sept. 25, 1851, appears to have been the earliest inventor to attempt the electrolysis of common salt and of the various chlorides of alkalies, as well as of nitrates and sulphates, commercially. He had a steam jacketed vessel filled with the electrolyte, into which the electrodes were placed, the source of his electricity being a Daniell's constant battery. The steam jacket was not a bad idea, because a certain degree of heat undoubtedly assists the process of electrolysis. He did not aim at getting pure products of sodium and chlorine, but was satisfied with hypochlorites and chlorates. Until the dynamo as a source of electricity had been greatly improved it was not probable that any serious attempt would be made to apply, for commercial purposes, an electrolytic process.

Some twenty years after Watt's patent inventors began to make attempts to utilize the dynamo, then still in a very imperfect state of efficiency, for electrolyzing solutions of common salt. But they adhered to the tank form of apparatus filled with the electrolyte, employing diaphragms to separate the anodes and cathodes. Without troubling ourselves with a few earlier patents we will begin in 1872. Desmon Gerald Fitz-Gerald, electrician, of the county of Surrey, and Bernard Charles Molloy of Elm Court, Temple, presumably a barrister, applied, in 1872, for letters patent for "improvements in treating compound substances by the agency of electricity and thereby decomposing them, or resolving them into their components and in apparatus therefor." Their apparatus was a tank divided lengthwise into two compartments by a porous partition, each containing the salt solution. If the operation was to be conducted on an extended scale, large tanks, divided into a number of compartments by porous diaphragms of unglazed earthenware, fitted into grooves in the sides of the tanks, were employed.

As Dr. Hurter well says: "The application of a porous diaphragm does not, however, stop the recombination of the caustic soda and the chlorine formed; it simply lessens it, and it lessens it at a very great expense." But the expense of electro-motive force is not so great as Dr. Hurter figures out. He reasoned from analogy, assuming that in copper-refining there was a total resistance equivalent to 1.25 volt, and that the resistance of the diaphragm was equivalent to only 0.1 volt, and polarization to 2 volts; then by Ohm's law it would require 12 volts to send 1000 ampères through the tanks. It is possible, as has been shown by actual working on a considerable scale with the tank apparatus slightly modified from the above described form, to work with about 6 volts. This, of course, is too high a voltage, and would alone render commercial success impossible. But the most serious difficulty is that, even at this expense of electro-motive force, the diaphragm with electrolyte on both sides of it only postpones for a time rearrangement of the newly formed molecules, and hence the process is not continuous and pure products are not obtainable. The earliest attempts to avoid, or obviate, these secondary reactions were by the employment of carbonic acid to transform the soda product of electrolysis into bicarbonate, which is a less soluble salt and could be removed as it precipitated.

Among the first chemists to recognize and attempt to remedy, by the employment of carbonic acid gas, the secondary reactions produced at a certain stage in the electrolyte, was Julius Marx of Ulm, Germany. In his British patent, No. 6417 (1887), he clearly states the difficulties which had been encountered. He says: "For example, the soluble products obtained from a solution of chloride of sodium, treated by electrolysis, become decomposed if the electrolytic action be continued over a certain time, and the redecomposition of the NaOH then taking place together with the decomposition of NaCl gives rise to a serious drawback, as during electrolysis solutions of caustic alkalies are concentrating around the anode, where chlorine is evolved from the NaCl, so that there is a recombining of both $NaOH+2Cl=NaClO+HCl$, and by the active oxygen which is always present $NaOH+2O+2Cl=NaClO_3+HCl$, and the hydrochloric acid formed will recompose the chloride of sodium, $NaOH+HCl=NaCl+H_2O$.

"Similar reactions will take place round the cathode to which the current transports some of the chlorine evolved round the anode, where likewise NaCl will be recomposed, either by HCl, or by reduction, it may be directly—(1) $NaOH+2Cl=NaClO+HCl$; $HCl+NaOH=H_2O+NaCl$, or (2) $NaClO+2H=H_2O+NaCl$, or (3) $Na+Cl=NaCl$. At the same time chlorine and soda may be recombined by simple diffusion.

"These reactions have all the same tendency and effect, viz.: they cause a loss of chlorine and soda and a great waste of the otherwise useful energy in developing the recombined chlorine and soda. Loss of energy is also caused by the chemical energy becoming free by the combining of chlorine and soda, which energy is given off as useless heat, or as electricity having a reverse direction to that of the original electricity; therefore, a corresponding amount of electric power is polarized.

"A further very great waste, as hereinbefore mentioned, is caused by the decomposition of water brought about by the redecomposition of NaOH. (1) $2NaOH=2Na+H_2O+O$; (2) $2Na+2H_2O=2NaOH+2H$.

"As soon as these reactions take place the liquor becomes, as I have demonstrated, unfit for practical electrolysis, and it is likewise unfit for economically recovering the caustic soda contained therein. This accounts for the failures which have hitherto resulted from attempts to employ electrolysis for the manufacture of alkalies and compounds of alkalies."

Marx's method of remedying the evils he had pointed out, as the consequence of the reactions enumerated, was to introduce carbonic acid into the cathode compartment of his tank as soon as caustic soda began to be formed, and precipitate it as sodium bicarbonate. He removed the bicarbonate and brought up the concentration of his electrolyte by the addition of more sodium chloride. To render his process continuous he employed mechanical arrangements for keeping his electrolyte in circulation, causing it to flow in diverse directions in the anode and cathode compartments.

But he was disappointed in the working of his apparatus, and in 1888 patented another, which was to provide a diaphragm which was to have an osmose, or dialysis, effect in conjunction with the electrolytic action. These diaphragms were neither permeable nor porous except as rendered so by their construction —*i.e.*, they were built up of non-permeable materials so as to permit communication of liquids from side to side only by diffusion. His tank was divided, by three of these diffusing diaphragms, into four compartments; the two middle ones contained the electrodes, and the two end ones were to receive, by osmosic action, the products of electrolysis and osmose. But he filled the four compartments with his electrolyte—a solution of sodium chloride. In the two electrode compartments he suspended, in perforated vessels, or troughs, a quantity of common salt and turned on his electric current. He claimed the result would be as follows:

"Chlorine and caustic soda are developed and diffused into the osmose compartments, where they are precipitated, and then a further quantity diffuses in, and as long as the precipitation is kept up the osmose continues, and as long as the osmose is kept up the electrolysis goes on properly, and as long as the electrolysis is kept up the dissolution of fresh quantities of salt continues. Therefore all that has to be done is, to close the electric circuit, to supply the salt as it becomes dissolved, and to remove the precipitate. But this very simple process may be still further simplified. The supply of salt is easily made by mechanical means, and may be regulated to keep any convenient strength of the solution; likewise the adding of the precipitator, and the taking out of the precipitated substance, may easily be done mechanically, so that nearly no manual labor has to be done, and supervision is reduced to the utmost."

If he did not want to precipitate his chlorine in part to get chlorate of potash, or a bleaching liquid, he drew it off by suction from the anode compartment and could dispense with what he termed his anosmose compartment—*i.e.*, the one next to the division holding the anodes.

By 1890 Marx had come to the conclusion that his two previous contrivances would not answer as well for electrolysis as an apparatus which dispensed with diaphragms, and in which he arranged his anodes and cathodes "above each other, but not, as has been sometimes done, in the same vertical plane, but one above or below the other in a different vertical plane." A thin-spread stream of electrolyte was made to pass by the electrodes so arranged. The contrivance was ingenious, but it is useless to describe it in detail. It could possibly be made to work in the laboratory, but for manufacturing purposes it would be worthless. In several respects Marx was bordering on rational lines of working, but failure to reach a practical solution was inevitable, because all his efforts to separate and keep separate the products of electrolysis as formed were, at best, only makeshifts.

In 1890 Carl Kellner of Vienna, Austria, applied for his first electrolytic patent, No. 5285 (1890), which was for "improvements in the process of and apparatus for bleaching vegetable fibers." There was an attempt to separate the products of electrolysis "by causing the ions to circulate constantly through the bleaching vats, and by not conveying them back to the electrolyzer until, under the action of the decomposed organic coloring matters, all the active chlorine contained in the solution had been converted into hydrochloric acid." His next attempt was No. 20,060 (1891), with "reference to the manufacture, or production, of chlorine by electrolytically decomposing hydrochloric acid, instead of by the chemical action of certain substances, usually manganese oxides, on chlorine-containing substances, as heretofore usually employed."

By his patent No. 20,713 (1891) Kellner discloses that he had reached the point Marx arrived at four years earlier—viz.: the necessity for a means of converting the soda products into carbonate which was not readily soluble. He provides a mechanical arrangement by which "the electrolyte kept constantly in a saturated state is admitted to the electrolyzer and caused to flow past the electrodes with such rapidity that but a very small part of it is decomposed into ions, which are not removed from the solution until they have passed out of the apparatus. This apparatus comprises anodes arranged in cells separated by diaphragms made as hereinafter described, the hydrogen set free being removed by continuous suction." This mechanical appliance is ingeniously contrived, but it is necessarily complicated. The electrolyzer itself is a very compact arrangement of anodes and cathodes with separating diaphragms. The electrolyte passes by the anodes and cathodes in reverse currents.

It is at once apparent that the phenomena of electro-chemical action are to be disregarded in Kellner's apparatus. The regular action in electrolysis is for the ions to act as vehicles for the transport of the electricity, the cations with the so-called positive, and the anions with the negative, respectively, to the cathodes and anodes. But here it is supposed that the ions will pass along with the current of electrolyte outside the electrolyzer and there be removed from it. And still Kellner constructs diaphragms having "their pores filled with some gelatinous matter in such manner that the electric diffusion (circulation of the ions) is free to take place under the action of the current, while the mechanical diffusion of the several substances formed is prevented." Evidently there is a confusion of ideas in the specification, because the patentee declares that "a very small part" of the circulating electrolyte, as it passes the electrodes, "is decomposed into ions, which are not removed from the solution until they have passed out of the apparatus."

After struggling for some time with his mechanical means of separating the products of electrolysis, Kellner appears to have abandoned them for the production of soda and chlorine compounds for an apparatus having a mercury cathode. (No. 17,169, 1892.) He is undoubtedly a clever engineer, and his devices for employing the least possible quantity of quicksilver display a great deal of ingenuity. But after long-continued experiments, conducted in one of the most complete engineering establishments in the North of England, it would appear that other difficulties than obtaining the thinnest possible film of mercury in working have been encountered. The amalgam formed by sodium with the mercury promotes the decomposition of water when in contact with it, and as the sodium is supposed to be removed from the amalgam outside the cell by washing with water, it seems that the water of the electrolyte performs the same function. Therefore Kellner's latest improvement, No. 13,722 (1893), is a "whirling" mercury cathode. The rotary mercury diaphragm, however, forms the principal feature of H. Y. Castner's patent, No. 16,046 (1892), for "an improved process of, and apparatus for, the electrolytic decomposition of alkaline salts." In his specification Castner succinctly and fairly accurately states that "the electrical decomposition of haloid compounds of the alkali metals for the production of the corresponding hologens and alkaline hydrates has long been known, but, so far as I am aware, has never been commercially carried on, for one or more of the following reasons: 1. The required use of a porous partition, or diaphragm, to separate the electrodes, and the consequent products of the electrolysis, necessarily interposes a considerable electrical resistance. Such electrical resistance increases relatively to the effectiveness of the chemical separation. 2. As the chemical separation has never been perfect in a single cell, the intermingling of the two products of the electrical decomposition gives rise to a new series of products, which more or less interfere with the continuance of the electrical action, besides meaning a direct loss in current efficiency. 3. The caustic solutions produced contain more or less salt, and are very dilute as the strong solutions more rapidly diffuse through the porous partition or diaphragm. Thus pure caustic soda cannot be obtained, and the concentration and production of solid caustic materially increases the manufacturing cost. 4. In the various kinds of apparatus which have been designed to overcome these many difficulties the parts are more or less complicated, and thus both expensive and almost impossible to work practically on a large scale."

The mechanically moving body of mercury which Castner employs as a diaphragm is not, as in Kellner's apparatus, both a cathode and a diaphragm. It is interposed between the anodes and cathodes, and since mercury permits the passage of electricity without much resistance, the ions—cations—passing toward the cathode are caught in the mercury and held there until removed. In Castner's apparatus the mercury is charged into the bottom of the electrolytic cell, which is divided into two compartments by an impermeable partition. At the foot of this partition there is the means, in form of a metal shoe which revolves, of withdrawing part of the mercury from the anode to the cathode compartment, and *vice versa* by the same revolution. In operation the anode compartment is filled with the electrolyte and the cathode one with water. The electricity passing from anode to cathode leaves the cations in the interposed mercury, forming a sodium amalgam. The shoe, slowly revolving, draws part of this amalgam into the cathode compartment and returns an equal amount of pure quicksilver, the water removing the sodium in amalgam, and, by union of oxygen in the water, forms caustic soda solution. The electrolyte is maintained at the necessary strength by fresh additions, and water is also added in the cathode side as the caustic solution is drawn away.

Undoubtedly this method will give a very pure, but dilute, caustic solution. However, it is certain that the sodium in amalgam in the anode compartment must, to a certain extent, cause a decomposition of the water of the electrolyte, as well as recombine with the chlorine, to form both hypochlorite and chloride. It is practically impossible to prevent the secondary reactions if any of the sodium is left on the anode side or given an opportunity to get back.

Ernest Arthur Le Sueur of Ottawa, Canada, is the inventor of an apparatus employed in electrolysis which, as heretofore stated, is working on a small commercial scale at Bellows Falls, Vt. The British patents are Nos. 5983, 11,519, and 15,050, of 1891. The apparatus has some features of interest, but it is practically upon the same lines as all other attempts to utilize a tank, or a series of tanks, filled with the electrolyte. A rectangular vessel contains the solution to be electrolyzed. The positive electrodes, or anodes, are contained in an inverted bell, or large cup of earthenware, or similar non-corrosive material, and over the open mouth a diaphragm is stretched. The anodes are preferably gas retort carbons cut to even lengths and fitted in the bell, or cup, being suspended by metallic supports with connections protruding through holes in the top. The diaphragms are made of asbestos, or similar fiber, cemented together by blood albumen, and the cathode is wire gauze placed adjacent to the diaphragm. The cell is placed at an incline in the electrolyte, supported at one side by a block while the opposite edge rests on the bottom of the tank. If the apparatus is upon a large scale the tanks are of greater dimensions and a number of inverted bells are placed within. It will be obvious that this form of apparatus does not get rid of the difficulties inseparable from the others having compartments separated by diaphragms and with the electrolyte on both sides. The secondary reactions must ensue, and soon lower to minus quantity the efficiency of the electricity; the process cannot be continuous, and to obtain the small percentage of caustic it must be separated as far as possible from the undecomposed salt by crystallization. The voltage must be relatively high, and the diaphragms will not last more than forty-eight hours.

The apparatus patented by Richardson and Holland,* now working at Snodland, Kent, near London, is a series of large covered tanks with non-porous partitions extending from the top about two-thirds of the depth. In two of the divisions thus formed, in the upper part of the tanks, the anodes are fixed, and in the divisions between the two others the cathodes are suspended. The theory of working is that the chlorine will rise in the outer divisions and pass off through a pipe provided therefor, while the caustic soda solution will be brought to the surface in the central part by the hydrogen gas evolved, and while this gas is conducted off by a pipe the caustic solution can be drained off from the top of the electrolyte. In another form of apparatus a copper oxide, in a finely divided state, is continuously carried on suitable carriers through the lower part of a tank and acts as the cathode. The anodes are suspended in the upper part of the electrolyte. The use of the copper oxide is to absorb hydrogen, which, it is supposed, prevents, if left free to rise, the caustic solution from concentrating at the bottom of the tank. By the employment of about 6 volts per tank a caustic soda solution is obtained, after fishing out undecomposed salt, which is used at the paper mill of which Colonel Holland, one of the patentees, is manager. The operation has excited considerable interest among paper-makers as possibly affording a way for them to manufacture, on their own premises, the caustic and bleach employed in paper-making, and thereby render them independent of alkali manufacturers. But with soda ash, which can be causticized, selling at £3 0s. per ton and bleach at £8, it is extremely doubtful if by the Richardson-Holland apparatus paper-makers could electrolytically produce these articles without losing money.

Thomas Craney † of South Bay City, Mich., has during the past two years obtained letters patent for a number of alleged improvements in methods of constructing diaphragms, making carbon anodes, and for different forms of electrolytic apparatus. A careful examination of all his British specifications has not resulted in the discovery of any features indicating that he has succeeded in overcoming any of the obstacles standing in the way of the successful application of electrolysis, on a commercial scale, in alkali manufacture. His apparatus are all upon old lines, having anode and cathode compartments, or divisions, filled with electrolyte. In some cases there are practically separate cells, or vessels, connected by a contrivance which is supposed to act as a capillary diaphragm, but both vessels contain electrolyte. It is obvious that secondary reactions cannot be prevented by any such means, and the electric resistance must be greatly increased. The caustic solution that is obtained is, of course, contaminated by undecomposed salt.

A great number of specifications relating to electrolytic apparatus have not been mentioned simply because they embody no novel features. There have been several attempts at designing mechanical arrangements for overcoming the difficulty of separating the products of electrolysis as they are formed, and thus render impossible the secondary reactions which have hitherto proved the *bête noir* of electrolytic processes. Some of these display mechanical genius, but their applicability to an industry like that of alkali manufacture is an impossi-

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* British patents Nos. 2296 and 2297 (1890).

† British patents Nos. 18,822 and 23,919 of 1892, Nos. 9295, 9297, 11,105, 11,106, 11,107, 11,108, and 17,127 of 1893.

bility. In respect to the employment of mercury as a separating medium, the difficulties are insurmountable, not only on account of the first cost of the article and the deleterious effects upon workmen which its use in immense quantities would cause, but because practically it does not accomplish the end aimed at.

A careful survey of the progress of invention during the last quarter of a century in this particular field, and a patient examination of the patent and general literature on the subject, reveal a surprising paucity of original ideas. All those who have attacked the problems of electrolysis have persisted in following in old ruts, and, until very recently, no one has seemed to grasp the full import of the facts so clearly exposed by Faraday in his paper on electro-chemical decomposition, read to the Royal Institution, June 20, 1833.

All the phenomena attending the transference of ions of electrolysis are therein related, and especial stress is laid upon the fact that the influence upon the molecules ceases when they are delivered at the electrodes, or when, to employ Faraday's language, "the evolved substances are expelled from the decomposing mass." It would seem that an original mind pondering the ways and means of utilizing, for manufacturing purposes, electro-chemical phenomena should have sought for a method of receiving and removing "the evolved substances" the instant they "are expelled from the decomposing mass," and thereby prevent them from again coming within the sphere of influence—chemical affinity—whence they had been expelled by electric action. But strange as it may appear, the idea of seeking to accomplish this was a very long time in suggesting itself to inventors, and when the necessity therefor was forced upon them they apparently never thought of finding a simple and direct means of doing it.

James Hargreaves, who began many years ago to study the dynamics of the chemical reactions involved in alkali manufacture, first devoted himself to the solution of certain thermic problems with special regard to the utilization of heat units in a given quantity of fuel, first, to secure perfect combustion, and, second, to transform the energy rendered available into motive power with the minimum of loss. The end he had in view was the application of electrolysis to chemical manufacture. Having accomplished certain results in this direction, which, while by no means satisfactory to his conception of perfectibility, clearly demonstrated that cheap motive power was obtainable, he applied himself to electrolytic experiments. He had, while in the employ of William Gossage, made some experiments with the view to determining the possibility of securing endosmosic action by an interposed media. When, therefore, he came to meditate upon the points from which to attack the problems of electrolysis, and, with that clearness of perception which is one of his mental characteristics, saw that the first thing to be done was to capture and lead away "the evolved substances" as they "are expelled from the decomposing mass," his previous experimenting upon endosmosis proved a valuable aid.

It was apparent to him that there must be a radical departure from the old lines of attempting electrolytic decomposition, for instance, of sodium chloride, in order to accomplish an effectual separation of the cations. A simple, direct method would be to have the electrolyte on one side only of a diaphragm. This necessitated a combined diaphragm and cathode, the latter being exposed, which must be made the boundary of at least one side of an electrolytic cell or vessel. This is the basis of his master patent. It is an entirely novel, a wholly original, conception, and yet so simple that the wonder is it did not occur to some one of the many experimenters who had preceded him in this field of invention. But the conception, to be entertained and worked upon for a practical, definite purpose, could not have occurred without antecedent knowledge which had been gained by the experiments in the endosmosis line.

To construct a combined diaphragm and cathode, which could be employed as the boundary of an electrolytic cell, vessel, or tank, required not only boldness of conception but constructive ability of a very high order, combined with the necessary technical knowledge in several directions. The diaphragm itself must have, and lack, certain qualities, and in a degree of perfection by no means easily arrived at. The first absolute condition was that it should offer the minimum of resistance to the electric current, and, second, it must permit electrical endosmosic action without, in the ordinary sense, filtrating. Hence, in the ordinary conception, it must not be porous. And again, it must, in a sense, be intimately associated with the cathode.

The theory of the process of electrolysis of, say, sodium chloride, by the means of a combined diaphragm and cathode forming a boundary, or boundaries, of the electrolytic tank, is as follows: The vessel being filled with the electrolyte, in which the anodes are placed, the cathode side, or sides, of the combined boundary, or boundaries, being exposed,—*i.e.*, not directly in contact with the electrolyte,—the electric connection is made, and the cations "expelled from the decomposing mass" are delivered on the cathode, whence they are instantly removed by any suitable means. It is well known, because the experimental researches of Faraday established the fact beyond peradventure, and the phenomena have been over and over again demonstrated, that once the ions arrive at the limits of the electric influences, the electrodes, they are set free, and if not suffered to get back within the range of the chemical affinity, for which they have a strong predisposition, they will form the new compounds desired, if given the opportunity. Therefore, say carbonate of soda is wanted, remove from the exposed cathode the cations—sodium—instantly, by bringing it in contact with carbonic acid gas, say from a combustion engine, and the solution of carbonate of soda only requires concentration and the merchantable article is ready. If caustic soda is wanted, it is only necessary to exclude carbonic acid gas, and the sodium, combining with water, gives, after concentration, NaHO, the sodium hydrate, or caustic soda, of commerce.

The broad principle of the Hargreaves invention is the combined diaphragm and cathode forming the boundary of an electrolytic cell, the outer surface of the cathode being so exposed as to enable the cation products to be instantly removed, as they "are expelled from the decomposing mass." But there are many other novel features of the apparatus, in addition to the details of the constituents of the diaphragm and the method of making it, which contribute to distinguish it as an entirely new departure. In working, a moderate degree of heat is applied, the arrangement of the cells permitting the exhaust from the engines, as well as steam from the condensing plant, to be applied.

The initial difficulty was encountered in making the diaphragm. The process of manufacture is most ingenious and interesting. Asbestos, or other suitable fiber, and a proper indurating material, are, in combination, or consecutively, deposited on copper wire gauze, or perforated metal, in a deckle frame, as in paper-making. Thereafter comes drying, pressing, redrying, and then silicating, or analogous treatment. The result is a cardboard-like structure in which the wire gauze is slightly embedded, giving a firm adherence of the one to the other, the two combined not exceeding in thickness medium bristol-board. There is no difficulty in making diaphragms of any superficial dimensions from 6 up to 60 sq. ft. They can also be made with particular reference to varying, or differential, hydrostatic conditions, and the method of, and appliances for, manufacture are so perfect that any required special quality can be exactly and invariably obtained.

In actual working, upon a relatively large scale, these diaphragms enable at least an average of 80% of the theoretical electric efficiency to be obtained, and give a product, from the electrolyte, 99.5% pure. As high as 90% electrical efficiency has been obtained, not spasmodically, but consecutively. The voltage is remarkably low, from 2½ to 2¾ volts, and not rising above 3 volts. There is no filtration, in the sense of filtering liquids, while the passage of the electricity and the transference of the cations, by what is apparently electric endosmosis, is not interfered with. This is proved by the low voltage and the approximation to the theoretic yield. The cells employed are of both horizontal and vertical types. In the horizontal type the combined diaphragm and cathode forms the bottoms, and in the vertical type two sides, of the cells.

The means for removing the product as delivered on the cathode is spraying the exposed surface either by jets of water or by steam. That it is effectual is proved by the fact that no secondary reactions occur in the electrolyte to dissipate the electric efficiency. There is no transfusion of sodium chloride, of any moment, an average of less than 4% being the maximum, under good condition, and under the best conditions less than .5%. There seems to be no reason to apprehend want of durability in the diaphragms, since after continuous tests in actual work they show no signs of deterioration.

At the anode side the results are correspondingly good, the chlorine being remarkably pure. This is not surprising, since the caustic soda, being removed as formed on the exposed cathode, cannot transfuse into the electrolyte. Neither hypochlorites nor chlorates appear to be formed in the electrolyte. The low voltage required does not seriously affect the carbon anodes, even when they are made in the ordinary way in which electric light carbons are turned out. But retort carbons, specially treated, or carbons specially made from a mixture of coarsely ground coke and certain coal, are found to answer best.

In the development of the central conceptions, and in elaborating the details of arrangements, as well as in designing and constructing the apparatus, Mr. Hargreaves has had associated with him a very clever mechanical and electrical engineer, Mr. Thomas Bird of Cressington, Liverpool, who is co-patentee. Mr. Bird has been connected with Mr. Hargreaves for a number of years, in fact since he began working upon the thermo-motor engine and gas producer. The complete apparatus, in design, is simplicity itself, and the cost of construction cannot be great. The anodes, and the combined diaphragms and cathodes, are durable, as well as inexpensive to make. The arrangement of the cells, or tanks, the electric connections, feeding apparatus, pipe connections, and concentrating plant are, of course, engineering details which are of no very great moment now that the capabilities of the chemical engineer are so well known. The cells, especially of the vertical type, are compact arrangements, occupying relatively but little space—many thousands of square feet of cathode surface being obtainable within the compass of a comparatively small cubic area.

In the electrolytic production of soda and bleach the bulky materials to be dealt with are reduced to common salt, fuel, lime for the bleach chambers, and packages to contain the finished products. The vast quantities of pyrites and limestone consumed in the Leblanc process are, of course, entirely dispensed with, and there is no resulting immense "alkali waste" to be disposed of. The reduction of fuel-bulk must also be considerable, and less salt will be required, since in the Leblanc manufacture, to obtain the chlorine required for bleach-making, much more salt cake has to be produced than is transformed into carbonate and caustic. The demand for salt cake has ceased to such an extent that it is almost impossible to sell it at any price.

The successive rehandling of bulky, weighty materials, which in large part must be, in the Leblanc works, by hand, will not be an item in electrolytic manufacture. From start to finish, except the packings, in the latter process the work can be automatically performed. The salt brought into the works, or the brine pumped from the wells, will be automatically supplied to the electrolyzers; the carbonated or caustic solutions will run by gravitation into the concentrators; the chlorine will flow to the bleach chambers; the fuel will be fed from hoppers to the gas producers; the exhaust from the engines and the steam from the concentrating plant will find their way through pipes to the electrolyzers; and consequently manual labor and supervision ought to be reduced to the minimum.

A syndicate of wealthy gentlemen, among whom are several old alkali manufacturers, has acquired a controlling interest in the patents which have been applied for in all the important countries of the world. A complete plant for working, at the outset, upon a commercial scale has been put down at Widnes, and is now regularly producing caustic and bleach. In addition to the electrolysis of sodium and potassium chlorides the process and apparatus are applicable to a great variety of chemical manufacture as well as to metallurgical work.

NOTE.—The author has not thought it worth while to append voluminous notes, or give particular references to authorities in support of general statements contained in the text. He acknowledges his indebtedness especially to Professor Meyers' *History of Chemistry* for facts bearing upon the development of the science of chemistry, and to the papers read at different times before the British Institution, the Society of Chemical Industry, and other scientific bodies, by the late William Gossage and Walter Weldon, and by Alexander M Chance, J. K. Muspratt, and other chemical manufacturers. He is especially indebted to James Hargreaves and Thomas Bird for details respecting their electrolytic inventions, as well as to Frederick H. Gossage, Esq., for particulars relating to his father, William Gossage. The statements and comments made respecting the general subject of the electrolysis of sodium chloride and other halogen compounds are based upon a careful and critical examination of all the patent specifications relating thereto found in the British Patent Office, and also upon the results of exhaustive searches, made for the author, of the records of the United States and German Patent Offices. It is believed that no important patent relating to electrolysis, granted by the Governments of either of the three countries named, has been overlooked. It is also believed that the general literature of the subject in English, French, German, and Italian has been exhaustively dealt with. Mr. James Hargreaves, who has spent months in examining the many scientific publications in French and Italian, kindly placed at the author's disposal all his voluminous notes. The author must also acknowledge his indebtedness to Messrs. Cross & Bevan, chemists, of London, for information and courtesies extended to him, as well as for the use of their well-equipped laboratory in making tests and experiments.

THE CUTTEN ELECTROLYTIC SODA PROCESS.

A new method and apparatus for producing soda and chlorine electrolytically have recently been invented by Mr. Elisha B. Cutten of New York. The essential features of the process are based on the well-known fact that the action of an electric current upon a solution of common salt is such as to decompose the sodium chloride, liberating chlorine at the anode and the sodium at the cathode, where it is decomposed by water, producing caustic soda (NaOH). The difficulty which has occurred heretofore in the electrolytic separation has been the chlorinated soda which has formed by the combination of chlorine and the caustic soda in the cell, requiring energy for its decomposition, and, further, the electrolyte was weakened because of the decomposition of the solvent (water), which also consumed part of the current. These objections are said to be obviated by the new method, which consists, first, in allowing that part of the solution which becomes heavily charged with soda to accumulate at the bottom of the containing vessel by its own gravity, and second, in decreasing the chances for any recombination of the separated chlorine and soda, by mechanically removing the former as fast as it accumulates. This results in the production of a saturated soda solution from which the soda may be obtained by simple evaporation, while the chlorine is taken away in gaseous form and subsequently utilized.

The apparatus consists of an iron cell or containing vessel, above which are brackets supporting a bell of earthenware closed by a dome which is connected with an outlet pipe, for the chlorine. In the bottom of the vessel there is a layer of wire gauze covered by a steel plate lying directly over an outlet opening for the soda solution. On the steel plate is a support and flanged disk of earthenware upon which are supported a number of bars of gas carbon which serve as anodes, the iron vessel or cell itself serving as the cathode. When in operation the cell is filled above the lower edge of the bell with an aqueous solution of sodium chloride and the electric current passed through. An exhauster or pump connected with the chlorine outlet is now started, and as the operating proceeds, the chlorine produced at the anodes is withdrawn from the solution, while the caustic soda descends by its own gravity and filters through the wire gauze into the bottom of the vessel, whence it is periodically drawn off.

THE CHEMICAL INDUSTRY IN EUROPE IN 1893.

BY GEORGE LUNGE.

THE chemical industry in Europe during the present year has been, on the whole, prosperous. In some of the most important countries large—nay, in some instances enormous—profits have been realized. The last balance sheet of Messrs. Brunner, Mond & Co. closes with the respectable figure of 100% dividend, together with considerable amounts put back for depreciation and reserves. The United Alkali Company, although not approaching that figure by a long distance, has, principally owing to the practical monopoly of the supply of bleaching powder which it enjoys for exportation, paid a respectable dividend for the first half-year; in the face of the great English coal strike it is uncertain what the second half may bring. In Germany the sulphuric acid and alkali works have also been prosperous. Their dividends for 1892 averaged 6.38%; but some of the best managed and situated among them netted between 15% and 20%, and the present year must have been at least as good as its predecessor. The average dividends of the manufacturers of fine chemicals in 1892 were 12.60%, those of coal-tar colors 23.19%, those of explosives 15.86%, those of artificial fertilizers 9.85%. In other countries we are not as well informed about the average dividends of the whole trade, but the balance sheets of some single companies show an equally favorable face.

The sulphuric acid industry was in full swing all over Europe. The manufacture of superphosphates is steadily extending, and has far more than compensated the sulphuric acid works for the decrease of consumption by the Leblanc Soda Works. In Germany, the largest zinc producer of the world, the whole of the sulphur of the blende is now turned into sulphuric acid. England and Belgium have followed suit to some extent; but it is certain that this addition to the ordinarily employed quantities of pyrites does not suffice to meet the increased demand for raw material, and that much larger quantities of pyrites will have to be used in the future. There is at present no lack of that indispensable material for the production of sulphuric acid. More than 1,000,000 tons of pyrites are still roasted annually in Spain in open heaps to the great annoyance of the neighboring population, and all this would be available for the wants of acid makers as soon as there was a demand for it. We may take it that in the European sulphuric acid industry both demand and supply are in a healthy condition, and that that industry has every prospect of a steady increase.

The year 1893 has not brought any important technical improvements in the manufacture of sulphuric acid, but some of those brought out in former years have made more progress. The author does not like to speak of his own share in this matter, but he is bound to mention that Mr. Hasenclever, a great practical authority and general manager of one of the largest alkali companies (owning six different works), has published a proposal that a syndicate of German sulphuric acid manufacturers should erect a special works fitted up with "Lunge towers." Coming from such a responsible quarter, that proposal, although not likely to be carried out in the form of a syndicate, proves with what appreciation that system is meeting in competent eyes. In France also large erections of such towers have been recently made.

Another improvement which has now passed the experimental stage, and must be considered a full success, is the "Heræus composition" of gold-lined platinum stills for the concentration of sulphuric acid. It is now proved beyond doubt that such stills last much longer than ordinary platinum stills, and yield a most abundant return for the somewhat increased prime cost of the apparatus. It should be pointed out that that composition is totally different from ordinary gilding or gold plating, which does not at all fulfill the same object. Another apparatus, consisting of a stepped series of glass beakers, about the patent right for which Mr. Webb and Mr. Levinstein are still disputing, is probably the cheapest apparatus for making acid of 66% Baumé; but, although certainly successful, such apparatus will hardly displace platinum stills for turning out very large quantities of acid.

While we may look for a certain stability in the manufacture of sulphuric acid, the case is very different with the alkali industry proper It is unnecessary to say that the world will consume soda in a constantly increasing ratio; but the sources of supply may be completely changed from the present conditions. Already the intimate connection formerly universally existing between soda and chlorine has been somewhat loosened. In England the Leblanc process is constantly receding, and the ammonia soda process is progressing in a corresponding degree. In 1890 the production of ammonia soda was less than half of the Leblanc soda; but in 1892 the ratio was inverse, and in Germany and France the ammonia soda has left the Leblanc soda far behind. This change is sure to increase, and it means that all that large mass of ammonia soda is produced without the simultaneous production of chlorine, for hitherto none of the numerous processes intended to fulfill the latter object has been economically successful; nor is it as yet proved that the case is different with Mond's magnesia process, about which so much noise was made some time ago. America is altogether likely to take a good share in the further extension of the ammonia soda process, and that not merely in the form which it has received at the Solvay works; for instance, the Frasch process, which takes quite an independent line from the Solvay process, deserves the most serious attention. Apart from that, the development of the exploitation of the immense stores of natural soda contained in the lakes west of the Rocky Mountains is merely a matter of time. Thus the United States will probably at no distant future cease to be a considerable buyer, and may even become an exporter of soda, and the Leblanc process will be correspondingly reduced.

Where will the world get its chlorine if so much less soda is made by the only process which up to the present time has furnished chlorine? Evidently the Leblanc process would be able to meet the demand for chlorine even with a restricted output of soda, and would pay all the better if the proportion of chlorine obtained from hydrochloric acid could be considerably increased. Of the chlorine contained in the common salt, formerly only 30% was obtained in the shape of bleaching powder or its equivalent; and even with the last improvements of the Deacon-Hasenclever process, certainly the best of all those carried out in actual practice, I doubt if more than 50% is realized, although we must confess that we do not know how this stands, as the works are very reticent about it. With the decrease in the value of soda and the increase in that of chlorine, the temptation has been very strong to recover more chlorine from the salt, and a legion of processes has been patented for that object. The majority of these referred to the employment either of magnesium chloride or of nitric acid. Great expectations were held out in both quarters, but so far with very incomplete fulfillment. At Stassfurt some hydrochloric acid and chlorine have been made from the waste magnesium chloride, but the amount is small, and the predictions that Stassfurt was to be the purveyor of the world, not merely with potash (which it undoubtedly is), but also with chlorine, seem to be far from the truth. It is likely that ultimately the problem of setting free the chlorine from hydrochloric acid, as made in the Leblanc process, will be economically solved to a much greater extent than at present; but it is far more probable that in future hydrochloric acid itself will not be drawn upon for that purpose, but chlorine will be manufactured directly from common salt or other chlorides by electrolysis. I have no reason to modify my former opinions on that subject, although on the surface the progress made in 1893 in that direction has not been very great. It should not be overlooked that during the greater part of this year the commercial depression prevented any enterprise in America and greatly retarded it in Europe. This has been a hindrance to the practical trial of some of the new electrolytical processes, which would otherwise have come in for a greater share of attention; and the reluctance of investors to any form of speculation has extended to the purchase of inventions which in better times would have found a ready market.

Evidently this state of affairs will not be permanent, and in a few years the manufacture of chlorine products will have quite a different aspect. Already now the Elektron Chemical Works, near Frankfort, supply several thousand tons of electrolytical bleaching power per annum, and I expect the year 1894 to show a large development of different methods in that direction.

In one respect the change is already accomplished. As I predicted in 1889, the manufacture of chlorate of potash by electrolysis has now definitively been proved to be the cheapest way of obtaining that product. The works at Vallorbes, in Switzerland, have been largely increased; the company owning them has acquired considerable additional water-power in France, and will soon be in a position to supply the major portion of the European demand.

On the other hand, the attempts to bleach paper stuff and textile fabrics by direct electrolysis of chlorides are steadily pursued, and present every appearance of meeting with ultimate success. That would mean a very sensible reduction of the amount of bleaching powder required by the market; but even then large quantities would still be required—even more than the total present consumption—if the price should be considerably reduced, as it must be if the new inventions greatly reduce the cost.

I feel bound to point out once more, as I did in Vol. I. of THE MINERAL INDUSTRY, that the United States enjoys an immense advantage over Europe with reference to all electrolytical processes, by its possessing both the greatest water-powers and the greatest stores of coal of all industrial countries. Changes like those which I have hinted at cannot be quick or sudden, but in the end that immense natural superiority in the conditions of manufacture, coupled with an almost unlimited internal market, must needs lead to a powerful development of the alkali and chlorine industry in the United States.

As far as technical progress is concerned, nothing of great importance has been added in 1893 to the well-known processes of the alkali and chlorine manufacture as they are carried on in the actual practice of the large works, at least so far as they are not kept entirely secret. The manufacture of sulphate of soda is more and more tending to go back from the mechanical furnaces, in which the recovery of the hydrochloric acid is never as good as in the hand-worked muffle-furnaces, and to return to the latter form of furnace, especially in the shape of "plus-pressure" furnaces. There has been a controversy between the author and Dr. Hurter as to the best form of apparatus for condensing hydrochloric acid, which is perhaps best settled by referring to the fact that excellent result-have been obtained with "Lunge-towers" for condensing the hydrochloric acid at a large German works. In the manufacture of the soda from the sulphate by the Leblanc process nothing has been altered. The Chance process for the recovery of sulphur from the soda waste has obtained general introduction in Great Britain, but it has extended very little beyond that country, and the important question of recovering the considerable amount of sulphur now going away with the gases from the "Claus" kilns still remains to be solved. Nor am I in a position to report any alterations in the manufacture of ammonia soda as carried on in Europe. I have already spoken of the attempts at recovering the chlorine in that manufacture. Very little is known, at least with any degree of reliability, about the trials made with the numerous new processes for making soda and chlorine. The author is himself interested in some new processes, but about these he is not yet at liberty to report.

The Chemical Industry of Russia.

By D. I. Mendeléeff.

The chemical industry of Russia is at the first stage of its growth, and its further progress can only be looked for in the development of other kinds of industries offering a demand for chemical products. As regards certain of them, when their exploitation is begun Russia can produce an abundance of the raw material needed. For instance, native hydrous sulphate of sodium, glauberite, or mirabilite occurs in large quantity in some of the Central Asiatic lakes, and in a dried-up lake near the Zhandarmsk Mountain, near Tiflis; it is now being deposited in large and small lakes in the neighborhood of Batalpashinsk, not far from the Black Sea, to the north of the Caucasus, and in many other localities. Its exploitation has hardly begun, but some time it may form the basis for the manufacture of exceedingly cheap carbonate and caustic soda.

The vast masses of copper pyrites occurring in the Urals are now hardly touched, and are used only for sulphuric acid at Polovtsev's works and on the

Kama. The pyrites occurring at Borovichi, and in the Sub-Moscow and Donets coals are utilized at small works only. The exploitation of the vast beds of native sulphur in Daghestan, in the Caucasus, and in the Kara-Koumsk steppes in Transcaucasia has hardly been entered upon, though they are not inferior to the Sicilian deposits, and offer the important advantages of being near the surface and of being very rich.

A similar untouched source of wealth exists in the very thick beds of pure alunite, or alum stone, discovered beyond the Caucasus at Zaglik, in the Government of Elisevetpol. These, together with the extensive deposits of phosphorites in the Governments of Podolsk, Riazan, and Smolensk; of manganese ore in the Caucasus, Dnieper, and Ural; of chrome iron ore in the Ural; of nickel ore in the Ural; and of many other useful minerals—all are still awaiting the attention of enterprising individuals.

The natural conditions favorable to the development of a large chemical industry in Russia are such that when production attains its maximum possibility it will not only be able to satisfy the home demand in excess, but will supply foreign markets with its goods. At the present time, however, it is only possible to report a feeble beginning in the growth of this industry.

Sulphuric acid is now made in various parts of Russia, and its total production must be counted as not under 4,000,000 poods; that is, of concentrated acid containing from 90% to 95% H_2SO_4. The material employed for its manufacture is still mainly sulphur.

The exploitation of native sulphur is yet very small, but the production of pyrites is already considerable and is increasing. In 1890 the consumption of pyrites for the manufacture of sulphuric acid was as follows: Urals, 358,000 poods; at the Sub-Moscow works, 391,000 poods, from the coal mines; at Borovichi, from the river Msta, about 100,000 poods; while altogether over 1,000,000 poods were registered by the Mining Department.* In 1893 the production of pyrites for the manufacture of sulphuric acid must be reckoned as nearly twice that amount.

The chief producers of sulphuric acid are those works which provide it to the Artillery Department for the preparation of smokeless gunpowder, and those which use it for the preparation of sulphate of sodium, soda, and sulphate of alumina. Such are, for instance, the works of Oushkov & Co., on the Kama, near Elabouga, and the Tentelevsk works, near St. Petersburg. In the Moscow district there are as many as 20 sulphuric-acid chambers, chiefly for supplying the demands of neighboring works. At Baku there are three works preparing concentrated acid for petroleum refining. In Poland, Kazan, Odessa, Kiev, and various other parts of Russia there are several sulphuric-acid works, with not less than fifty chambers all told, though only a small number of these are of considerable dimensions. At many works the concentration of the acid is effected in platinum vessels, but the small works, and in some cases the larger, perform this in glass retorts. Many of the better works are furnished with Gay-Lussac and Glover towers, and the manufacture of sulphuric acid may already be considered as standing upon a sound technical and economical basis, although there

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* From *Industries of Russia*, Vols. I. and II., 1893.

is still a lack of competition, which is seen from the fact that the price of acid concentrated to 93.5% is rarely under 75 kopecks per pood. Nevertheless, the import of foreign sulphuric acid is small.

The second important branch of the chemical industry in Russia is the manufacture of caustic soda and carbonate of soda from common salt, by the Leblanc and ammonia processes. Both of these manufactures may be regarded as firmly established in Russia, although not long ago nearly all the soda required was imported. The importation of sodium carbonate began to fall in the middle of the eighties, when it was produced in considerable quantities at the works of Lubimov & Solvay (ammonia process), at Beresniaki, on the Kama. But the imports of caustic soda, bleaching powder, and sodium sulphate have not decreased. Lubimov & Solvay have now erected a second large soda works for the manufacture of carbonate and caustic soda in the Donetsk district, near Lissichansk, and Oushkov & Co. are turning out 300,000 poods of caustic soda and as much as 250,000 poods of bleaching powder. Besides the larger works many small ones have been started for the manufacture of these important products, so that in the near future the cessation of the foreign imports, a revival of competition, and a fall in prices may be looked for.

Among the important chemical products of Russia the third place is occupied by nitric acid and its products, especially those used in the preparation of gunpowder, such as niter and the nitro-compounds. The fundamental material of niter was for a long time, and is even now, extracted from the niter heaps in the east of Russia, where, owing to the great fertility of the soil, the manure has no economical importance as a fertilizer. Native niter occurs in the Caucasus, in Daghestan, and in the Trans-Caspian provinces, but it is only exploited on a small scale for local wants, and the importation of sodium nitrate from Peru and Chile gives the cheapest material. This amounts to between 200,000 and 300,000 poods annually, and is mainly used for the preparation of potassium nitrate for ordinary black, or for nitro-compounds for making smokeless powder. These manufactures are carried on at the Government and private powder mills, of which there are three each.

The conversion of sodium nitrate into potassium nitrate is done either with the Stassfurt potassium salts or with Russian potash, chiefly prepared from the ash of grasses in the east of Russia. In former times there were at least 195 potash works in Russia, producing material to the value of 1,000,000 rubles, and potash was exported from Russia in considerable quantities. Since the appearance of the Stassfurt potassium salts, however, the export has greatly fallen, and not more than 60 works, with 300 workmen, are occupied in the production of potash. These works turn out from 200,000 to 250,000 rubles' worth of potash annually.

This decrease in the production of potash may be partly ascribed to the fact that soda is now generally employed in its place. Potassium salts are only required for the preparation of potash-alums and of bichromate of potassium, while the demand for potassium salts for the manufacture of gunpowder, etc., becomes smaller and smaller. Thus niter does not enter at all into the composition of smokeless powder, and sulphate of aluminum is more and more employed in the place of potash alum, while either chromic anhydride or bichromate of sodium is used instead of the potassium salt.

The manufacture of alum was established in Russia earlier than the other branches of the chemical industry. In the fifties alum was prepared from clays, by first treating them with sulphuric acid and then with potash, while in the Caucasus alum was prepared from the local native alunite and other alum minerals. In the seventies, and especially in the eighties, several works in Russia followed the example of the Tentelevsk works in St. Petersburg, and began to prepare both alum and sulphate of alumina from foreign bauxite. Now the works of Oushkov & Co. produce annually about 200,000 poods of sulphate of aluminum and 100,000 poods of alum. Both these substances are also prepared at many other Russian works.

Natural Soda.—A very complete article by J. M. Chatard on this subject was presented in Vol. I. of THE MINERAL INDUSTRY, regarding the natural soda industry during 1893. Mr. Chatard says that no change of special importance can be noted. In the early part of the year there were fair prospects that extensive operations would be undertaken, but the financial disturbances, both at home and abroad, have postponed those projects. Nevertheless, such widespread interest in this new branch of industry has been aroused that it is not unlikely that 1894 will witness important developments.

The works at Ragtown, Nev., and at Owens Lake, Cal., are, so far as we know, the only ones in operation, and their plant and output have not been increased. Late information from the Inyo Development Company at Owens Lake is to the effect that the total vat area is 85 acres, and the output for 1893 about 2500 tons. All of this is sold to borax makers in an uncalcined condition, and at very remunerative prices. The average output per acre of vat is, therefore, about 30 tons, but the company expects to raise this average to 50 tons per acre in 1894.

THE NEW YORK HEAVY CHEMICAL MARKET IN 1893.

General Market.—The past year was an unusually eventful one, and the factories which are the chief users of heavy chemicals were among those most affected by the business depression. Like most lines of business, the chemical trade experienced a very good and a very bad period. The first half of the year was characterized by good business—better, indeed, than the corresponding period of 1892. This improved demand, however, was more than offset by the exceeding depression of the second six months. The difference was so great that the total business for the year shows a decrease as compared with 1892. The following table gives the great variation between the two periods:

SHIPMENTS OF HEAVY CHEMICALS FROM ENGLAND TO THE UNITED STATES DURING 1893.
(Tons of 2240 lbs.)

	1893, First Half.	1892, First Half.	1893, Second Half.	1892. Second Half.	1893, Total.	1892, Total.
Caustic soda	13,540	12,103	7,849	10,950	21,389	23,053
Bleaching powder	25,765	21,498	12,877	23,525	38,642	45,023
Soda ash	38,353	27,119	16,579	37,940	54,932	65,059
Crystal carbonate	1,356	973	448	1,049	1,804	2,022
Sal soda	3,056	2,610	2,434	3,056	5.490	5,666
Salt cake	8,901	6,612	434	9,448	9,335	16,060

It will be seen from the above table that, with the exception of sal soda, which is of secondary importance, the total imports of heavy chemicals in 1893 show a considerable decrease compared with 1892, notwithstanding the fact that, without exception, the imports during the first half of 1893 exceeded those for the corresponding period of 1892.

Caustic Soda.—Caustic soda sold at the beginning of the year at 2.70@3c. per lb., according to quantity, percentage, etc., and at these prices the majority of contracts were closed. Then, owing to the general depression, shipments from England to this country grew smaller and smaller, ceasing almost entirely on account of the coal miners' strike, which caused so great a scarcity of fuel in England as seriously to affect the operations of the principal works of the United Alkali Company, Limited. Prices during that time advanced about 10%, but were reduced later in the year. Imports of caustic soda during 1893, according to the United States Bureau of Statistics, were 52,116,492 lbs.

Bleaching Powder.—This material was active during the early months of the year, as the experience of 1892, when cholera created so great a demand for disinfecting purposes, was remembered. It was feared that there might be a repetition of the epidemic, and heavy contracts for rather prompt delivery were signed at 2⅛@2½c., according to quantity, make, etc. The cholera did not come, but business depression and financial stringency did, and many contracts were canceled. The English coal strike also tended to reduce shipments from that country. Business improved in the fall. Supplies available for prompt delivery were not abundant. When a demand for bleaching powder sprang up it was not easy to meet it, and prices advanced to 2.40@2.70c. per lb. These high values induced German makers to ship larger quantities of softwood casks, and prices declined again to about 2c. per lb. The United States Bureau of Statistics reports total imports of bleaching powder into this country at 98,618,147 lbs. in 1893, against 109,888,561 lbs. in 1892.

Alkali.—In alkali the chief feature was the reduction in prices which occurred in the fall. Considerable competition developed among English makers, and the price declined from 1.20@1.30c. to as low as .90c. Values rallied later, however, with the increased demand which followed and the compromise established by the competing manufacturers, and prices closed this year at 1.05@1.15c. for casks.

The United States Bureau of Statistics reports the following imports of chemicals into this country during 1893: Bleaching powder, 98,618,147 lbs.; caustic soda, 52,116,492 lbs.; sal soda, 22,601,871 lbs.; soda ash, 326,370,635 lbs.; chlorate of potash, 3,881,791 lbs. Prices for goods on the spot closed as follows: Caustic soda, 60%, 2.77½@2.82½c.; 70%, 2.60@2.70c.; 74%, 2.62½@2.82½c.; 76%, 2.85@2.90c. Carbonated soda ash, 48%, 1.10@1.25c.; 58%, 1.05@1.15c. Alkali, 48%, 1.05@1.15c.; 58%, 1@1.10c., according to package. Sal soda, English, .95@1c.; American, .80@.90c. Bleaching powder, 2.12½@2.50c.

POTASH SALTS.

Although the market for manufactured fertilizers suffered in common with general business from the depressed conditions of 1893, a distinct improvement took place in the case of the German potash salts. Importations show an increase over the preceding year, due to the growing popularity of these salts as a fertilizing material. The United States Bureau of Statistics reports imports into this country as follows: Muriate of potash, 74,663,116 lbs. in 1893, against 70,227,971 lbs. in 1892; other potash salts, 24,730,551 lbs. in 1893, against 22,651,335 lbs. in 1892.

Prices were fixed by the syndicate, and were as follows for 50-ton lots or over and for shipment during open navigation on the river Elbe during the year, if contracted for on or before Jan. 31, 1893. After that date the usual advance of 3c. per 100 lbs. for muriate and sulphate of potash, and 2c. per 100 lbs. for double manure salt, took place.

	New York and Boston.	Philadelphia.	Charleston and Savannah.
Muriate of potash, 80% to 85%	$1.75	$1.77½	$1.80
Muriate of potash, minimum 95% (all per 100 lbs., basis 80%).	1.78	1.80½	1.83
Double manure salt, 48% to 53% (all per 100 lbs., basis 48%.)	1.10	1.12½	1.15
Sulphate of potash, 90% to 95%	2.05	2.07½	2.10
Sulphate of potash, 96% to 99% (all per 100 lbs., basis 90%.)	2.09	2.11½	2.14

Other potash salts were as follows at New York, Philadelphia, and Boston: Kainit, minimum 23%, $8.50 per gross ton, foreign invoice weights and test; sylvinit, 36½c. per unit of sulphate of potash per gross ton, invoice weights. Charleston, Savannah, and Wilmington, N. C., were 75c. per ton higher. Prices for 1894 as announced by the syndicate are as follows for lots of 50 tons on contracts closed prior to January 31. Double manure salts, 48% to 53% (basis 48%): New York and Boston, $1.10; Philadelphia, $1.12½; Charleston, Savannah, Wilmington, N. C., and New Orleans, $1.15. High-grade manure salts, 90% to 95% and 96% to 99% (basis 90%), respectively: New York and Boston, $2.05@$2.09; Philadelphia, $2.07½@$2.11½; Charleston, Savannah, Wilmington, N. C., and New Orleans, $2.10@$2.14. Muriate of potash, 80% to 85% and minimum 95% (basis 80%), respectively: New York and Boston, $1.75@$1.78; Philadelphia, $1.77½@$1.80½; Charleston, Savannah, Wilmington, N. C., and New Orleans, $1.80@$1.83. Kainit (minimum, 23%) in cargo lots for invoice and actual weights respectively: New York, Boston, and Philadelphia, $8.75@$9; Charleston, Savannah, Wilmington, N. C., and New Orleans, $9.50@$9.75. Sylvinit, 27% to 35%, per gross ton, invoice weights per per cent.: New York, Boston, and Philadelphia, 36½c.; Charleston, Savannah, Wilmington, N. C., and New Orleans, 40c. Actual weights, 1c. more per cent. The coming year, judging by the orders already in, promises to show a good increase in the volume of business over that of 1893.

IMPORTS OF CHEMICALS.

Year.	Nitrate of Soda.		Bicarbonate of Soda.		Caustic Soda.		Sal and Ash Soda.	
	Pounds.	Dollars.	Pounds.	Dollars.	Pounds.	Dollars.	Pounds.	Dollars.
1867....	29,429,469	563,624	20,902,050	805,348	12,942,017	548,858	128,493,598	2,736,237
1868....	18,433,173	283,785	23,544,057	607,771	12,101.490	460,609	132,880,771	2,547,860
1869....	28,866,364	600,691	18,092,250	540,263	13,705,254	448,661	151,049,787	2,592,506
1870....	31,122,795	752,664	15,014,628	347,530	20,804,681	653,790	149,245,792	2,327,720
1871....	50,290,377	1,254,965	18,998,399	421,177	27,952,469	877,710	174,665,704	2,669,474
1872....	35,817,597	934,118	13,530,188	374,231	29,992,539	1,037,328	164,764,752	3,119,324
1873....	59,757,241	1,469,243	10,571,049	369,867	28,171.629	1,269,142	215,680,880	5,261,009
1874....	61,978,316	1,338,141	11,873,182	435,434	34,282,189	1,516,132	180,330,438	7.679,555
1875....	52,105,826	968,855	6,853,588	231.754	37,669,885	1,419,292	198,559,205	3,912.457
1876....	51,887,218	1,055.357	4,482,911	125,587	32,093,691	1,107,200	185,577,166	3,217,062
1877....	54,246,531	1,324,299	3,765,165	98,277	33.375.447	1,043,933	219,280,164	3.473,317
1878....	45,258,855	973,223	3,693,494	92,917	33,178,762	1,015,554	227,946.540	3,306.990
1879....	76,285,858	1,324,299	2,392,719	60,701	45,767.366	1,209,469	245,599.656	3,175.714
1880....	68,043,426	1,830,396	7,716,289	133,264	43,693,333	1,056,497	307,065,268	4,704,438
1881....	126,613,909	2,909,368	1,791,330	56,808	50,500,802	1,155.215	287,516,778	3,525,084
1882....	150,297,385	2,045.127	2,115,891	53,535	60,802.359	1,336,497	331,388,943	4,009,237
1883....	128,333.230	2,469,013	2,041,103	51,099	65,593,102	1,436,450	327,121,598	3,921,278
1884....	145,825,237	2,218,217	1,863.057	38,432	70,871.734	1,628,684	288,610,304	3,396,011
1885....	89,573,975	1,332.969	3,033,498	54,352	79,880,338	1,659,930	303,148,263	3,387,351
1886....	139,381,060	2,373,068	3,417,803	59.967	79,726,941	1,553,158	301,963,864	3,244,700
1887....	163,776,049	2,253,806	1,803,183	31,603	89,162,856	1,651,337	280,777,373	2,843,892
1888....	154,834,445	2,168,607	1,502,096	22,709	81,620,366	1,370,552	299,756,473	2,887,534
1889....	169,746,583	2,500,137	1,124,065	18,443	75,418,604	1,253,072	307,256,243	2,937,084
1890....	293,007,228	3,090,900	916.355	16,962	88,345.462	1,882,728	360,521,656	4,176,422
1891....	219,712,640	2,579,930	1,500,663	26,936	68,154,226	1,700,532	347,822,902	4,509,611
1892....	213,456,320	2,933,174	(*a*)	(*a*)	54.384,120	1,309,500	361,648,637	4,698,379
1893....	257,626,880	3,673,537	(*a*)	(*a*)	52,116,492	1,171,878	348,972,506	3,982,772

Year.	Other Soda Salts.		Nitrate of Potash.		Muriate of Potash.		Chloride of Lime.	
	Pounds.	Dollars.	Pounds.	Dollars.	Pounds.	Dollars.	Pounds.	Dollars.
1867....	80,335	1,461	8,544,912	295.250	875,205	88,787	27.142,919	798,391
1868....	80,250	1,440	6,137,155	197,286	777.855	68,634	24,495,594	636,608
1869....	346,763	3,938	8,878,996	313.114	877,432	78,288	33,800,056	819,610
1870....	105,158	1,386	4,759.968	173,731	1,235,946	127,333	24,202,766	467,459
1871....	619,782	10,231	5,072,381	208,423	2,170,473	284.809	32.111.839	635,910
1872....	927,024	14,283	4,409,789	207,242	6,995,825	346,529	35,043,050	930,953
1873....	364.406	7,534	10,681,948	498.932	8,886,852	337,240	43,920,383	1,259.970
1874....	294,993	5,242	8,280,341	392,515	8,831,331	352,806	39,184,641	1,027,644
1875....	187,887	4,327	9,457,954	380,286	13.159,522	374,011	48,443,540	1,059,371
1876....	176,166	2,894	7,507,213	279,634	11,549,733	333,337	46,934,185	850,216
1877....	262,569	3,340	10,322.255	382,091	16,164,862	473,805	47,592,989	711,601
1878....	341,618	6,276	8,126,384	332,162	21,584,874	503.739	49,576.896	602,201
1879....	417,476	5,884	9,243,193	282,088	23,958,425	471.969	61,026,447	661,325
1880....	728,629	13,106	12,762,545	498,959	27,530,294	681,768	70,047.541	994,359
1881....	3,204,484	26,487	13,041,704	487,916	27,205,496	737,878	86,952,887	822,510
1882....	9,968,465	66,197	10,451,272	391,532	45,925,535	1,004.831	93,619,703	847,564
1883....	9,434,953	56,310	11,884,592	395,443	32,732,473	743,940	103.348.329	1,350,838
1884....	9,411.103	53,412	10,262,228	303,561	39,814,102	591,343	93,451.223	1,651,237
1885....	4,443,355	28,386	11,838.354	314,380	44,794,335	687,033	94.301,180	1,337,485
1886....	10,593,355	40,770	10,132,805	278,859	47,062,984	723,010	102,249,640	1,418,023
1887....	16,171.131	51,665	9.601,381	264.560	40,891,063	597.588	103,086,679	1,686.742
1888....	19,205,872	70,417	7,240.636	191,894	66,955,744	989,915	101,172,022	1,625,799
1889....	17,686,879	98,353	9.822,848	270,008	68,059,738	1,015.263	96.571,074	1,517.402
1890....	21,664,033	132,443	13,563,798	408,460	63,733,938	978,024	105.696,046	3,314,548
1891....	16,226,334	114,955	15.292,057	469,591	78.144.810	1,220,119	108,880,831	1,632,127
1892....	40,954,822	284,853	13,012,087	382,771	70,227,971	1.098,267	109,888,561	1,962,084
1893....	29,872,509	205,790	13,374,016	369,274	74,663,116	1,192,516	98.618,147	1,843,410

NOTE.—Fiscal years from 1867, inclusive; calendar years from 1883, inclusive. (*a*) Not stated.

Nitrate of Soda.

The course of the nitrate of soda market during the past year was not characterized by the speculative tendency which prevailed during a part of 1892. Stocks were light in January, during which month the spot price was $2.15@ $2.25 per cwt. From then on values gradually declined, touching $1.60 in August. Late in the fall the spot supply became light again and prices advanced to $1.92½.

Imports of nitrate of soda, as reported by the United States Bureau of Statistics, were 13,374,016 lbs. in 1893, against 13,012,087 lbs. in 1892, an increase of 361,929 lbs. in favor of last year.

The following table shows the highest and lowest monthly prices per cwt. of nitrate of soda on the spot during 1893:

January.		February.		March.		April.		May.		June.	
Highest.	Lowest	Highest.	Lowest	Highest.	Lowest	Highest.	Lowest	Highest.	Lowest	Highest.	Lowest
$2.25	$2.15	$2.50	$2.20	$2.45	$2.20	$2.35	$2.20	$2.25	$1.85	$1.90	$1.65

July.		August.		September.		October.		November.		December.	
Highest.	Lowest	Highest.	Lowest	Highest.	Lowest	Highest.	Lowest	Highest.	Lowest	Highest.	Lowest
$1.80	$1.62½	$1.70	$1.60	$1.75	$1.70	$1.92½	$1.80	$1.90	$1.85	$1.90	$1.75

Messrs. Mortimer & Wisner, the well-known nitrate brokers of this city, supply the following statistics:

	1886.	1887.*	1888.	1889.	1890.	1891.	1892.	1893.*
Imported into Atlantic ports from west coast S. A. from Jan. 1, 1893, to Jan. 1, 1894 .... Bags.	386,718	481,505	478,751	484,555	688,124	632,536	641,165	767,332
Imported from Jan. 1, 1893, to Jan. 1, 1894, from Europe...... "	11,984	....	....	....	....	18,802	5,862	16,712
Total .... "	398,702	481,505	478,751	484,555	688,124	651,338	647,027	784,044
Stock in store and afloat Dec. 31, 1893, in New York............ "	66,580	42,940	81,843	21,209	33,954	50,685	14,034	36,838
Stock in store and afloat Dec. 31, 1893, in Boston................ "	....	....	......,.	500	....	900	420	3,000
Stock in store and afloat Dec. 31, 1893, in Philadelphia........... "	....	....	....	....	....	....	....	....
Stock in store and afloat Dec. 31, 1893, in Baltimore............. "	3,500	6,000	5,200	300	2,500	2,000	1,000	5,100
To arrive, actually sailed........ "	....	....	....	....	155,000	188,000	164,000	125,000
Visible supply to April 15, 1894.. "	....	....	....	....	191,454	241,585	179,454	169,938
Stock on hand, Jan. 1, 1893...... "	84,811	70.080	48,940	84,043	22,009	36,454	53,588	15,454
Deliveries, December............ "	18,232	22,982	11,451	33,430	46,573	36,098	35,280	134,837
Total yearly deliveries.......... "	413,433	502,645	440,648	546,589	673,679	634.207	685,158	754,560
Prices current, Dec. 31, 1893...........	$1.95@$1.97½	2⅛c.	2⅜c.	$1.90	$1.70	$2.07½	$2.15	$1.77½@$1.80

* Included in the deliveries of 1887 and 1893 are 23,678 and 9500 bags, respectively, shipped to European ports.

THE ACID MARKET.

Few markets were so much affected by the financial and commercial depression as that for acid. Consumers were unable to take the amount called for in their contracts, and producers could not enforce the contracts. Consumers bought merely enough to meet their immediate requirements, for there was no fear either of a sudden scarcity of supplies or of higher prices.

For the first half of the year business and production generally compared favorably with the corresponding period of 1892, but during the second half every acid plant was obliged to reduce its chamber capacity, and it is safe to say that the production suffered a decrease of 50% compared with the production for the second half of 1892. Probably the total production of acid for 1893 was not much more than 65% of the production of the year before. The manufacture of acid is co-extensive with so many other industries throughout the country, and there are so many private works, that it is impossible to obtain detailed statistics of production.

In the matter of prices the market did not show much change through the year. Values were low to begin with, and the margin for a further depreciation was not great. Still, prices reached a lower point than during the preceding year.

Closing prices for acids per 100 lbs. in New York and vicinity, in lots of 50 carboys or more, were as follows: Acetic, in barrels, $1.62½@$1.75; muriatic, 18°, 80c.@$1; 20°, 90c.@$1.10; 22°, $1@$1.25; nitric, 40°, $4; 42°, $4.50@$4.75; sulphuric, 75c.@$1. Mixed acids according to mixture, oxalic, $6@$7.

PRICES OF ACIDS DURING 1893.

	Highest.	Lowest.		Highest.	Lowest.
Muriatic acid, 18°, per cwt.........	$1.10	$0.80	Nitric acid, 40°, per cwt...........	$4.00	$3.75
Muriatic acid, 20°, per cwt.........	1.25	0.90	Nitric acid, 42°, per cwt...........	4.75	4.00
Muriatic acid, 22°, per cwt.........	1.35	1.00	Sulphuric acid, 66°, per cwt.......	1.10	0.65

CHROME IRON ORE.

Chromium is used in the metallic state only in making chrome steel, though even for that purpose it is not introduced in the form of pure metal, but as ferrochromium, which is prepared by reducing chromic oxide together with ferric oxide. For the properties of metallic chromium and the method of producing it the reader is referred to the article on the "Rare Elements" in another part of this book. Although metallic chromium does not occur in nature, and is seldom seen as such even in the laboratory, its commonest ore, chromite, is distributed widely over the surface of the globe, and in considerable quantity.

Chromite, or chrome iron ore, is an iron-black or brownish-black mineral of submetallic luster and brown streak. Its hardness is 5.5, and sp. gr. 4.321 to 4.568. It is brittle, breaking with an uneven fracture, and is sometimes magnetic. It is readily distinguished from magnetite, however, by its reactions before the blow-pipe, giving beads with borax and salt of phosphorus, which when cold show the characteristic green color of chromium compounds. It is represented by the symbol $FeCr_2O_4$, or FeO, Cr_2O_3, ferric protoxide forming 32% and chromic sesquioxide 68%. Part of the iron and chromium, however, are generally replaced by magnesium or aluminum, so the chrome ore of commerce seldom contains more than 55% sesquioxide of chromium.

Chrome iron ore occurs in Asia Minor, Greece, Norway, and Russia (Ural) ; in New Caledonia, New Zealand, and several of the Australian colonies ; in Canada and the United States—in the former in the Province of Quebec, and in the latter in the States of Pennsylvania, Maryland, and California. Chromite is always found in association with serpentine, which has usually resulted from the alteration of rocks consisting largely of olivine, hornblende, and pyroxene ; the chromic oxide has separated from these minerals and from a chrome spinel (picotite) often found with them. The chromite is thus found scattered through the serpentine in irregular masses, which are often of considerable size.*

Since nickel minerals are very frequently associated with serpentine, it would follow that nickel and chrome ores might be expected in the same districts. This is, indeed, the case in New Caledonia ; in the Ural ; at Frankenstein, in Prussian Silesia ; at Webster, in North Carolina ; and at Riddles, in Oregon—nickel occurring as silicate in each of these localities.

Chrome Ore in the United States.

Formerly large quantities of chrome iron ore were produced in Maryland and Pennsylvania, but these mines have not been worked on an important scale for

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* J. F. Kemp, *Engineering and Mining Journal*, Jan. 2, 1892.

nearly fifteen years, and almost the entire domestic supply of the mineral since 1878 has been obtained from California, where deposits of ore were first discovered in 1869. Subsequently the mineral was found to exist at many places in the Coast and Sierra ranges of mountains, probably half the counties in the State having been productive. The chrome-ore mining industry in California has never been put upon a permanent basis, however, owing chiefly to the irregularity in the occurrence of the mineral and the peculiar local conditions. As elsewhere in the world, the chrome ore there is found in serpentine, whence it is easily mined, but it usually occurs in small pockets, which are soon exhausted. Indeed, as a rule the deposits are too small to warrant the outlay of much capital for their exploitation, and mining is consequently comparatively expensive. In fact, very little systematic mining has been done, the Pick and Shovel mine, in San Luis Obispo County, which has about 2500 ft. of drifts, cross-cuts, and raises, being the most extensively developed. The production of chrome ore (in tons) in California since 1880 and the imports into the United States since first reported are given in the following table :

UNITED STATES: PRODUCTION AND IMPORTS OF CHROME ORE.

Year.	Production.		Imports.		Total.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
1880	2,288	$27,808	....	....	....	....
1881	2,000	30,000	....	....	....	....
1882	2,500	50,000	....	....	....	....
1883	3,000	60.000	....	....	....	....
1884	2,000	35,000	2,677	$73,586	4,677	....
1885	2,700	40,000	12	239	2,712	....
1886	2,000	30,000	3,356	43,721	5,356	....
1887	3,000	40,000	1,404	20,812	4,404	....
1888	1,500	20,000	4,440	46,735	5,940	....
1889	2,000	30,000	5,474	50,782	7,474	....
1890	3,599	53,985	4.353	57,111	7,952	....
1891	1,372	20,580	4,560	108,764	5,932	....
1892	1,650	16,500	4,930	55,589	6,580	....
1893	1,620	16,000	6,354	58,629	7,974	....

The production of chrome ore in California is practically controlled by the Tyson Mining Company of Baltimore, and the Kalion Chemical Company of Philadelphia, which firms are the only important consumers of the mineral in the United States. These concerns were formerly engaged in mining on their own account, owning considerable mineral land in the State, but some years ago they withdrew from the field, and since then have only been buying ores. Having another source of supply in the rich mineral from the Mediterranean, which can be obtained in abundant quantities, the buyers are practically independent of the miners. Nevertheless there is always a ready market for mineral containing 50% or more of chrome oxide. Unfortunately, the average grade of the California ore is below this standard.

For several years past the condition of the chrome iron ore industry in California has been unsatisfactory, owing to the exhaustion of the easily accessible deposits of high-grade ore, and production has fallen off. Undoubtedly there is yet much rich ore to be had, but these deposits are remote from railways and wagon roads. The uncertainty of their extent prevents their development or the construction of roads to them, the cost of the latter often exceeding the value of the mineral which might be obtained. These deposits, however, constitute a reserve for the future when the country may be more thoroughly opened. The Kalion Chemical Company writes in a private communication that its investigations and work on the Pacific coast show conclusively that with better inland transportation facilities the time will come when its entire supply of ore will be derived from California and Oregon.

The future of the chrome industry in California seems to depend upon more careful dressing of the ore, either by hand or mechanically, and not upon the imposition of a tax upon imported ores, which would raise the cost of bichromate salts to the consumers by compelling the manufacturers to use a more expensive and in every way less desirable ore. The advantage of concentration has already been recognized in California, and some work that has been done in that direction is described in another part of this article. The erection of bichromate works on the Pacific coast has also been frequently discussed, and last summer it was proposed to erect a plant at Sonoma, in Sonoma County, but the scheme fell through on account of the financial crisis. It was the intention to use in these works a new process devised by Mr. E. K. Stevenot, by which it was claimed that poorer ores than those used in the Eastern works might be utilized. It is very doubtful, however, if bichromate works on the Pacific coast would be successful, on account of the high cost of fuel and labor and the limited market for the product.

COST PER TON OF CALIFORNIA CHROME ORE DELIVERED IN NEW YORK.*

Source of Ore, County.	Average in Cr_2O_3.	Royalty.	Mining.	Haul. to R'ilway.	Fr't to S. Francisco.	Carting to Ship.	Interest and Insurance.	Freight to New York.	Total.
Del Norte	45%	....	$3.00	$3.00	$4.50	$0.75	$1.00	$5.00	$17.25
Placer	52%	$0.25	3.00	8.00	3.00	0.70	1.00	5.00	20.95
San Luis Obispo	47%	2.00	3.00	2.55	3.85	....	1.00	5.00	17.40
Shasta	45%	2.50	3.00	1.00	4.25	0.75	1.00	5.00	17.50
Tehama	45%	2.00	1.50	3.50	3.00	2.25	1.00	5.00	18.25

* Eleventh Census *Report on the Mineral Industries of the United States*, p. 333.

Eastern States.—Chrome ore has been found in Maryland, Pennsylvania, Virginia, and North Carolina, the first two States mentioned having been formerly very large producers. Mr. James W. Tyson of Baltimore furnishes the following information concerning the beginning of the chrome industry in the United States:

"Chrome ore was first discovered in this country by Isaac Tyson, Jr., about the year 1820, at Bare Hills, seven miles north of Baltimore, in a barren serpentine formation of moderate extent, but the quality was poor, and the deposit was soon exhausted. His next discoveries were at Soldier's Delight, about fifteen miles northwest of Baltimore, and in Harford County, about twenty-five miles northeast of Baltimore. Several thousand tons were mined at these points and shipped to Europe for the manufacture of bichromate of potash. The most important discovery was made in 1831, when the great Wood Pit was opened in Lancaster County, Pennsylvania, near the Maryland line. In this was mined for a period of forty to fifty years the greater part of the world's supply of chrome ore. The mine was worked to a depth of nearly 700 ft., more than twice the depth of any other deposit in this country. Chrome ore does not make in veins, but in masses in serpentine, which are usually largest near the surface, and do not hold to any great extent.

"Previous to about 1845 all the American ore was exported, but in that year Mr. Tyson started the Baltimore Chrome Works on a small scale, and began to use his product at home. This did not suit the Glasgow manufacturers, who dropped their price about 50% and tried to smother the infant industry, with partial success for a while, but, as is well known, the Baltimore works held out, and soon became prosperous.

"In 1869 Mr. Tyson's successors opened two or three large deposits of chrome ore in California, and for a period of twenty years shipped 1500 to 2000 tons per annum, principally to Baltimore. Shipments of chrome iron ore from this country to Europe ceased several years ago, but during the past year a few tons of a natural chromate of iron have been shipped from Baltimore to Liverpool, where it is sold to the potters, who use it for glaze."

The Maryland-Pennsylvania chrome ore producing region begins in the Grene Spring Valley in Baltimore County, Maryland, and extends through Harford and Cecil counties of the same State into Lancaster, Chester, and Delaware counties of Pennsylvania. Within this area the ore occurs irregularly in pockets and masses in serpentine rock. The most noted deposits in this region were those worked in Reed's mine, Harford County, Maryland, which, according to David T. Day, produced over 100,000 tons of ore; Wood's mine in Little Britain, Lancaster County, Pennsylvania, and Low's, Linepit's, and Jenkin's in Fulton Township of the same county; at Elk, Nottingham, and Oxford, in Chester County, Pennsylvania; and at Middletown and Marple, in Delaware County of the same State.

South of the Maryland-Pennsylvania district chromite is found at Drainesville, near the Potomac, in Fairfax County, Virginia, and at Webster, Jackson County, North Carolina. It also occurs in the latter State at numerous points in Guilford, Macon, Madison, Yancey, Clay, Mitchell, Burke, and Watauga counties, but only in small quantities.

California.—Chrome ore has been found in many parts of California. In Siskiyou County, in the north, near the coast, there are very large deposits of ore, ranging from 38% to 47% chromic oxide. Farther south, in Del Norte County, there is ore of a higher grade. These deposits belong to the Tyson Mining Company, which has held them for many years as a reserve. In Humboldt County there are numerous deposits similar in appearance to those of Del Norte County. The bay counties, viz., Marin, San Mateo, Contra Costa, and Alameda, have ores assaying over 50% chromic oxide, but the general average is only from 43% to 47%.

Some of the most important chrome-producing lands in California are found in San Luis Obispo County, where mining has been principally carried on in the Santa Lucia and Buchon ranges, a few miles northwest and northeast of the town of San Luis Obispo, which is the nearest shipping point. The mineral occurs in pockets and veins in the serpentine country rock of the region, and also as loose fragments on the mountain-sides and in the ravines. The best developed mine in this country is the Pick and Shovel, which is situated on the south fork of Chorro Creek, in the Santa Lucia Mountains, at an elevation of

1800 ft. During the past year, however, the mine has been worked by only two men, who took out about 100 tons of ore. The following analysis of chrome ore from Chorro Creek is reported:[*] Chromic oxide, 52.68%; alumina, 11.40%; ferric oxide, 3.52%; magnesia, 16.23%; protoxide of iron, 11.77%; protoxide of maganese, 0.15%; silica, 3.40%; water, 0.94%—total, 100.09%.

Besides those previously named, chrome ore has been found in considerable quantities in Shasta, Fresno, Solano, and San Benito counties, but the difficulty of shipping the ore makes the deposits unprofitable at present. With the development of the country, however, many of these will become available.

Mr. H. G. Shaw, of San Francisco, Cal., to whom we are indebted for much valuable information in this article, reports the following average analyses of typical California chrome ores:

	San Luis Obispo Co.	San Luis Obispo Co.	San Luis Obispo Co.	Tehama County.	Alameda County.	Shasta County.	Del Norte County.
Cr_2O_3...	43.70%	52.70%	40.00%	34.46%	46.00%	42.45%	47.29%
FeO.....	14.80	14.20	14.20	14.16	16.00	15.00	14.00
Al_2O_3....	15.96	12.50	22.00	19.00	14.00	16.75	15.20
MgO....	16.49	15.50	16.80	20.50	15.70	16.50	16.56
SiO_2.....	7.96	4.00	6.10	10.96	7.40	7.50	5.90
CaO.....	.66	.40	.70	.80	.50	.90	.75
H_2O	.49	.50	.30	.25	.29	.80	.45
Total .	100.06	99.80	100.10	100.13	99.89	99.90	100.15

Present prices for California chrome ores delivered on the Atlantic coast are $23 per short ton (2000 lbs.) for each 50% ore, with $1 additional for each unit over 50%, and a corresponding reduction for ores under 50% down to 48%, which is the lowest grade accepted. The difference in the prices paid for the Turkish and Californian ores is due to the superior quality of the former, which are exceptionally low in silica. Silica is a very undesirable element in the manufacture of bichromate salts, since it combines with the alkalies to form silicates instead of chromates, thus causing a waste of alkali.

The dressing of low-grade chrome ores to bring them up to the market standard is a subject which is now engaging much attention in the industry in California, and several works built for this purpose are already in operation. The object in concentrating chrome ores is to remove the gangue, usually serpentine, from the chromite, and the process is carried out in the usual manner. Mr. Shaw gives the following analysis of a lot of California chrome concentrates: Chromic oxide, 52.86%; protoxide of iron, 15.45%; alumina, 11.59%; magnesia, 16.26%; silica, 3%; lime, 0.76%; water, 0.10%—total, 100.02%. These concentrates were made from a crude ore from San Luis Obispo County, which had the following composition: Chromic oxide, 43.70%; protoxide of iron, 14.[illegible]0%; alumina, 15.96%; magnesia, 16.49%; silica, 7.96%; lime, .66%; water, .49%—total, 100.06%. Since the percentage of chromic oxide in the chromite varies, however, it is necessary to make preliminary tests in a pan or hand-jig, and a careful chemical examination of the concentrates, in order to determine whether the dressing process will be successful. There is, for instance, a kind of pebble ore, a "float" ore from which the gangue has been removed by attrition, which is ill suited for concentration. On the other hand, soft granular ore generally yields very good con-

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[*] *Chemical News*, May 22, 1891.

centrates. The following results of a series of experiments in concentrating chrome ores is reported by Mr. Shaw:

Crude Ore, Per Cent. Cr_2O_3.	Concentrates.		Remarks.
	Yield, Per Cent.	Assay, Per Cent. Cr_2O_3.	
45.44	65	51.20	Good ore.
50.44	70	54.24	“ “
24.08	30	50.00	“ “
50.12	70	52.88	“ “
36.68	65	43.28	Bad ore.
40.48	70	41.84	“ “ float ore.
38.16	70	44.64	“ “
46.88	85	53.04	
38.44	60	44.32	Bad ore ; float ore.
45.56	70	51.76	Good ore.
43.84	60	53.76	“ “
47.68	75	51.36	“ “
44.32	60	49.44	“ “
45.92	65	54.24	“ “
41.76	80	43.20	Bad ore ; float ore.
46.40	70	50.40	
45 60	65	47.20	Bad ore ; float ore.
47.44	65	51.04	Good ore.
46.56	70	50.40	“ “
47.92	75	50.48	“ “

One of the chrome-dressing works now in active operation in California is equipped as follows: Rock breaker, 6 ft. Huntington mill, and four Woodbury vanners, with corrugated belts; together with settling tanks, drying floors, and the usual driving machinery, etc. The plant, which is capable of turning out from 20 to 25 tons of dry concentrates per twenty-four hours, cost about $12,000. The process is carried out as follows: The ore is crushed by the breaker and the Huntington mill so as to pass a 40-mesh sieve. The pulp is separated on the Woodbury vanners, which are run at a speed of about 200 revolutions per minute. The concentrates are collected in settling tanks, whence they are removed to the drying floors, and finally packed for shipment in strong jute bags. The fuel used is wood, oak and willow, the former under the boilers and the latter under the dryers. The crude ore does not cost over $7 per long ton (2240 lbs.) for the best grade delivered at the mill. The cost of running this plant for one month, and the net results of the same, are given in the following table:

900 tons 42% ore, at $5.50 per 2240 lbs	$4,950
10,000 jute bags, with twine, at 9c. each	900
60 cords of oak at $5 per cord	300
30 cords of willow at $4 per cord	120
1 head millman at $4 per day	120
1 assistant millman at $3.50 per day	100
5 helpers at $1.50 per day	225
Office and laboratory expenses	100
Miscellaneous expenses	100
Total	$6,915

Production: 700 tons (2000 lbs.) 50% concentrates.

Cost per Ton (2000 *lbs.*) *for* 50% *Concentrates.*

	Per Ton.
Cost of raw material and fuel	$9.10
Cost of labor	.90
Cost per ton at depot or wharf nearest to works	$10.00
Freight from depot or wharf to San Francisco	4.00
Freight (water) from San Francisco to New York	6.00
Total cost per 2000 lbs. for 50% concentrates delivered in New York	$20.00

This gives a net profit of $3 per ton for 50% concentrates, and a further profit of $1 per ton for each 1% above 50% at present prices.

FOREIGN SOURCES OF CHROME ORE.

In Europe and Asia chromite is found in Austria, Hungary, Norway, Germany, Greece, Turkey, Bosnia, Russia, and Asia Minor, the two countries last mentioned being the most important producers. In Australasia it occurs in New Caledonia, New Zealand, and several of the colonies of Australia, but the first mentioned is the only one which exports the mineral at present, though some has been sent out from New Zealand in the past.

Asia Minor.—This country has been for many years the most important producer of chromite in the world, having at Brusa (fifty-seven miles southeast of Constantinople) one of the largest known deposits of the mineral. It was discovered by Prof. J. Lawrence Smith in 1848. Another large deposit, also discovered by Professor Smith, exists at Harmanjick, about 15 miles south of Brusa, and there is a third near Antioch. At each of these places the ore occurs in pockets and masses in serpentine, similar to those of California, but they are larger and the ore is richer, averaging over 52% Cr_2O_3.

Owing chiefly to their softness, their richness in chromic oxide, and their low silica contents, the Turkish ores have been in great demand, and for many years have constituted the principal source of supply of both American and European consumers. Mr. Shaw contributes the following analyses of these ores:

	Per Cent.	Per Cent.	Per Cent.
Sesquioxide of chromium	55.04	51.70	56.80
Protoxide of iron	12.63	14.20	12.06
Alumina	11.84	14.10	14.00
Magnesia	16.19	14.30	15.00
Silica	2.00	3 50	1.45
Lime	1.46	1.70	.70
Water	.40	.30	.15
Total	99.56	99.80	100.16

The value of these ores in Europe at the present time is about £5 10s. per ton (2240 lbs.) for ores containing 50% chromic oxide, with 5s. additional for each unit above 50%. In the United States (where there has been a 15% duty on chrome ores*) Turkish ores have brought the following prices: 48%, $26 per ton (2240 lbs.); 50%, $27.50; 52%, $31.80; 54%, $34.50. Recent reports are to the effect that the supply of these ores is showing signs of exhaustion, more especially with respect to those of the higher grades.

Australia.—Very little chromite has been found in Victoria or South Australia, but several extensive deposits occur in New South Wales near Jundagai and Tamworth, and also in Queensland, especially in the Pine Mountain district, where ore containing from 42% to 60% of chromic oxide can be obtained.† Transportation facilities are not good, however, and these deposits have not yet become productive.

Austria.—Chromite occurs at Kraubath, in the Leoben district, but no work has been done there since 1881.

Bosnia.—Chrome ore of good grade exists in Bosnia. Mineral from this source has been used at the Diosgyör Works, in Hungary, for basic linings in

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* According to the Wilson tariff bill, now pending before Congress, chrome ores are to be admitted to the United States free of duty.

† R. W. E. MacIvor, *Chemical News*, Vol. LVII., pp. 1. 2,

steel furnaces. This averaged* 50% to 52% Cr_2O_3, 39% to 45% $Al_2O_3 + Fe_2O_3$, and 2.5% silica, together with some lime and magnesia. The total production of chromite in Bosnia amounts to 1200 or 1300 tons per annum, having been 1258.8 tons in 1892.

Canada.—Chrome iron ore is found irregularly and in small pockets at many points in the serpentine belt of the eastern townships of Quebec, from the boundary of Vermont to the Schickshock Mountains in Gaspé. Attempts at systematic mining have not been attended with much success. Chrome ore has been gathered in the townships of South Ham, Wolfestown, Leeds, Thetford, Bolton, and others, but the amount won has been small. There is much unexplored territory, however, which may prove productive, and the opinion was expressed by the late Dr. T. Sterry Hunt as long ago as 1863 that the manufacture of bichromate of potash in Canada ought to be a profitable undertaking, although the Canadian ores lack a few per cent. of the required standard, *i. e.*, 50% Cr_2O_3. The Canadian Geological Survey has not reported any production of chrome ore in Canada since 1887, in which year there was an output of 34 metric tons, against 54 tons in 1886.

Central America.—M. Boussingault reports that he has observed the existence of chrome ore in abundance at Antioquia, the walls of some of the houses being built of it. He also claims that chromium pig iron was obtained there in 1867 from a blast furnace in the neighborhood of Medellin.†

Germany.—A large deposit of low-grade chromite is found in Lower Silesia, on the southern slope of Mount Zobten, between Schweidnitz and Jordansmühl. The ore body, which occurs in serpentine, was 23 ft. thick near the surface, but it increased in magnitude as more depth was gained. The composition of the ore is as follows: Cr_2O_3, 35% to 42%; F_2O_3, 19% to 22%; Al_2O_3, 19% to 22%; MgO, 16% to 18%; silica, 3% to 5%. Magnetite in variable quantities is mixed with the ore. The deposit, which was first mined by open workings, was exploited subsequently by a shaft and levels,‡ but operations were not continued long, the material not being sufficiently refractory for use in basic-furnace hearths, and of inferior quality for the manufacture of bichromates.§

Veins of chromite traversing serpentine are also known to exist in the vicinity of Frankenstein, in Upper Silesia, but attempts to work them have not proved remunerative.‖

Greece.—Chromite is mined at Volos. The production is irregular, varying from 200 to 1470 metric tons per annum, the latter amount having been the output in 1892.

New Caledonia.—Chrome iron ore occurs in great abundance in New Caledonia, where it was first mined in 1875, the ore being a constant associate of the serpentine rock of which a great portion of the island is composed. The most important deposits are those of Mont d'Or, N'Go River, and Canoe Bay, which are near the sea, and are connected with the port of shipment by a short railway. The ore exported averages 50% chromic sesquioxide, and is worth about $8 per ton at Nouméa.

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* *Jernkontorets Annaler*, XIV., 419.

† R. A. Hadfield, "Alloys of Iron and Chromium," *Journal of the Iron and Steel Institute*, 1892, No. 2, p. 64.

‡ *Stahl und Eisen*, Vol. X., p. 1085.

§ *Stahl und Eisen*, Vol. XI., p. 643.

‖ *Thonindustrie Zeitung*, 1890, No. 48.

Alluvial ores are also met with at a great number of points in the south of the island, forming beds 30 in. in thickness. Samples of these ores after washing have shown the following composition :*

Cr_2O_3.	Fe_2O_3.	Al_2O_3.	SiO_2.	H_2O.	MgO, etc.	Total.
42.60%	37.20%	12.80%	1.20%	1.10%	5.10%	100.00%
41.80	19.02	29.10	2.10	3.40	5.10	100.52

There are also in New Caledonia large deposits of chrome iron ore containing 50% of iron and 2% to 5% chromium. These occur in large masses of red clay in the serpentine country rock which have been formed by the decomposition of the rock itself. The ore is low in phosphorus (0.06% P_2O_5), and perhaps it may some day be exported to New South Wales for the manufacture of steel, but under present conditions this would be unprofitable.

Hungary.—Chrome ore occurs in Hungary in important amount only at Orsova, near the Danube. This contains: Cr_2O_3, 38.95%; FeO, 16.13%; SiO_2, 8%; Al_2O_3, 17.50%; CaO, 2.2%; MgO, 17.2%.† This ore occurs in serpentine country rock. Works for the manufacture of ferro-chrome were erected by Gauss Brothers of Vienna at Orsova several years ago. In 1892 Messrs. Busek & Co. of Vienna offered to sell ore averaging 38% Cr_2O_3 at 33s. per ton, f. o. b. at Orsova.

New Zealand.—Chromite occurs abundantly in the Nelson district, at Jackson's Bay, in the Lake Harris Range, at Milford Sound, and at Moke Creek (Otago). It is found where olivine rocks occur, and in Nelson as a constituent of the peculiarly hard variety of serpentine known as dunite, sometimes forming more than 50% of the mass. The ore is rich, averaging over 55% Cr_2O_3. In the Dun Mountain Copper Mining Company's property there is a band of chrome ore 10 ft. wide, while one in the Roding River Company's ground is over 15 ft. wide and has been proved vertically for 300 or 400 ft.‡

According to the official reports, the quantity of chrome ore exported from New Zealand (representing the production of the colony) has been as follows :

Year.	Tons.§	Value.	Year.	Tons.§	Value.	Year.	Tons.§	Value.
1858	3	£25	1861	52	£520	1864	768	£4,910
1859	8	120	1862	3,843	24,719	1865	...	....
1860	116	1,440	1863	595	4,318	1866	281	1,315

The exports ceased suddenly in 1866, and none have been reported since that time.

Norway.—Chrome iron ore is found at Drontheim and Roeraas. Mines are worked at these places, but the production is small, never having exceeded 400 tons per annum.

Russia.—Chrome iron ore is found in several localities in the Ural. Messrs. W. Venator and E. Etienne report the following analyses :

Cr_2O_3.	FeO.	Al_2O_2.	MgO.	CaO.	SiO_2.
51.62%	17.94%	14.52%	13.15%	0.73%	1.71%
55.75	21.56	3.37	13.85	0.60	5.37

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* Jules Garnier, *Mémoires de la Société des Ingénieurs Civils*, Vol. XL., pp. 244-266.

† A. Gouvy, *Stahl und Eisen*, Vol. IX., p. 729.

‡ George J. Binns, "Mining in New Zealand," *Transactions of the Federated Institution of Mining Engineers*, IV., Part I., p. 68, Jan. 20, 1893.

§ Long tons, 2240 lbs.

The first was from the bank of the Kamenka, and the second from the bank of the Topkaja.* The Russian ores are found particularly in the soapstones and serpentines of the Ural Mountains. Gustave Rose classifies them under three heads: (1) those which occur in large granular masses in serpentine in several places near Ekaterinburg, also eight miles from Bisserk, and again near Kyschtinsk; (2) those where the mineral is finely disseminated through the rock, as at Mostrowaja, north of Ekaterinburg, and near Auschkul Lake; and (3) mineral found in the platinum and gold washings, especially at the platinum placers at Nizhnee-Taghilck and the gold placers at Malo-Mostowskoi. In Liberia the mineral is found in masses at Orenburg.

The manufacture of bichromates from the ore obtained in the Ural has been established recently in Russia through the efforts of M. Ushakoff, who built works for this purpose near Elabougi, on the river Kama. About 2000 tons of ore are treated there yearly, and owing to the establishment of this industry the importation of chromium compounds into Russia has ceased.

Tasmania.—In the Ironstone Hills district, near the river Tamar, at Port Lampriere, there are large deposits of brown hematite ore containing about 3% of chromic sesquioxide, and but little sulphur and phosphorus. It is estimated that there are over 500,000 tons of such ore, large and small, in boulders, in sight on the surface. The rocks of the district are contorted slates, sandstones, and limestones. In the immediate vicinity of the ore deposits there is a great mass of serpentine containing many thin veins of asbestos and magnetite. In several of these rocks there are extensive outcrops of ironstone, protruding in great masses from the red surrounding soil, which has been obviously formed by their destruction, or there are heaps of ironstone boulders, of all sizes, formed from the disintegration of the beds. The geology of the district has been described by Mr. Gould, the Government Geologist, who considers the formation to be of Lower Silurian age. About 1872 the Tasmanian Iron and Charcoal Company, at Ilfracombe, near Launcestown, smelted some of this ore in its blast furnaces, and produced an alloy containing 6% or 7% chromium, of which several hundred tons were shipped to England. The company came to grief, however, and it is only recently that the mines have been reprospected.†

Uses of Chrome Ore.

Chrome iron ore is used in the arts for the manufacture of potassium and sodium bichromates, for the preparation of basic furnace hearths, and for reduction to ferro-chromium, which is employed in making chrome steel. By far the most part of the mineral produced is employed for the first purpose, for which only that of high grade can be economically used, while for the manufacture of ferro-chromium, which is growing in importance, and for furnace hearths (for which purpose chromite has been almost entirely supplanted by magnesite), ore of lower grade suffices.

The only works engaged in the manufacture of bichromate salts are situated in France (one), Scotland (two), Norway (at Trjöndhem), Russia (at Kazan),

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* *Chemiker Zeitung*, Vol. XI., p. 53.

† R. A. Hadfield, "Alloys of Iron and Chromium," *Journal of the Iron and Steel Institute*, 1892, No. 2, p. 65.

England (at Sowerby Bridge, near Halifax), and the United States. In the United States the only manufacturers are Jesse Tyson & Sons (Baltimore Chrome Works), who commenced the business in 1845, and Harrison Brothers (Kalion Chemical Works) of Philadelphia, who began in 1880. The processes employed at these works have not been described, their proprietors being loath to give out any information concerning them. The general principle of bichromate manufacture is, however, well understood.

Chromate of potassium (K_2CrO_4), the yellow, neutral salt, is prepared by heating chrome iron ore, previously pulverized and elutriated, with potassium carbonate and nitrate on the hearth of a reverberatory furnace. The oxygen of the saltpeter superoxidizes the ferrous oxide and chromium sesquioxide, the latter being converted to chromic acid, which combines with the potash to form potassium chromate. The thoroughly sintered (not molten) mass is withdrawn from the furnace, cooled, crushed, and lixiviated with boiling water to extract the chromate. Wood-vinegar is added to the solution to precipitate any alumina and silica that may have been dissolved, after which the clear liquor is evaporated to proper strength for the crystallization of the potassium chromate. The neutral salt is converted to the acid salt, or bichromate ($K_2Cr_2O_7$), by adding sulphuric or nitric acid to the solution. It is preferable to use nitric acid on account of the formation of potassium nitrate, which may be used in the decomposition of a fresh quantity of ore.

In Vacquelain's process the chrome iron ore is decomposed by heating with chalk and leaching with hot water slightly acidified with sulphuric acid, which converts the calcium chromate formed in the furnace to calcium bichromate. The ferrous sulphate taken into the solution is precipitated by chalk. The calcium bichromate is converted to the corresponding potassium salt by the addition of potassium carbonate, which throws down the calcium as carbonate while the potash takes its place in combination with the chromic acid.

The Tighlman process consists in heating the ore in a reverberatory furnace with lime and potassium sulphate. In Swindells' process the chrome ore is ignited at the highest possible heat with an equal amount of either sodium or potassium chloride, exposing the mixture at the same time to a current of superheated steam, the formation of sodium or potassium resulting.

The most important improvement in the manufacture of potassium chromate, according to Wagner's *Chemical Technology* (Crookes and Fischer), 1892, p. 469, has been the substitution of potash for saltpeter and the use of a furnace so constructed as to admit of the proper access of air to the strongly heated mass, the oxygen of the air being made to oxidize the chromic oxide to chromic acid. Another improvement is that, in using lime instead of alkali, the oxidation of the chromic oxide is greatly accelerated, because the heated charge does not become pasty, but remains pulverulent, and admits a readier access of air, as well as preventing the sinking of a portion of the chrome ore to the bottom of the hearth, where it is withdrawn from the chemical action of the furnace.

Sodium carbonate has been partially substituted for potassium carbonate in the decomposition of chrome ore on account of its less cost, the resulting product being, of course, bichromate of soda. There were difficulties in this innovation which prevented its introduction for a long time, but about 1880 a successful process was devised by German chemists, since which time the sodium bichromate industry has become very important, bringing down the price of potassium bichromate rapidly. In 1882 the price of potassium bichromate was 15¼c. per lb., in 1893 it fell to 12c., and in 1884 to 10½c. At the present time the price is still 10½c. The manufacture of sodium bichromate was undertaken at the Baltimore Chrome Works in 1884.

The process of sodium bichromate manufacture in Europe has recently been described by C. Häussermann in an article from which the following is reproduced :*

"The raw material employed in this manufacture is chrome ore, which is chiefly obtained from Turkey or Asia Minor. The analysis of a sample of such an ore gave the following figures : Cr_2O_3, 51.20% ; Al_2O_3, 12.80%; Fe_2O_3, 1.45% ; FeO, 13.32% ; MgO, 12.55% ; CaO, 3.15% ; SiO_2, 4.95% ; CO_2, 0.20% ; loss, 0.38%.

"The ore must be ground to an almost impalpable powder, and for this purpose roller mills have been found to give the best results. The powdered ore is then mixed with lime and sodium carbonate, which must also be very finely ground. The mixture is then submitted to an oxidizing roasting. The reaction taking place is expressed by the formula :

$$2FeCr_2O_4 + 4Na_2CO_3 + 7O = Fe_2O_3 + 4Na_2CrO_4 + 4CO_2$$

"In practical working the addition of lime is indispensable, making the mass porous and preventing the sodium carbonate from fusing, which would lead to incomplete oxidation. The proportions in which the above ingredients are to be used are, in England, according to Atcherley, 4.5 parts of ore, 7 parts of burnt lime, and 2.25 parts of alkaline carbonate. In Russia, according to Walberg, there are used 6 parts of ore, 3 parts of chalk, and 3 parts of soda-ash. Generally, mixtures containing more lime than soda give the best results as regards the percentage of chromium rendered soluble. Even less sodium carbonate, as required according to the above equation, may be employed, in which case a corresponding quantity of chromate of lime is formed. The roasting operation is carried out in reverberatory furnaces so constructed as to heat the air to a temperature of about 400° C. before it enters the furnace proper.

"A furnace consuming four tons of coal in twenty-four hours will roast during the same period two tons of ore. The working space of the furnace is divided into three beds, each succeeding bed being slightly higher than the one nearest to the firebox. One-third of the daily charge is first introduced into the furnace through a hopper over the third and highest bed of the furnace ; after eight hours it is raked down on to the second bed, while the third or top bed receives a fresh charge. After another eight hours the first two charges are worked down to the first and second beds respectively of the furnace, the top bed again receiving a fresh charge. The temperature of the first bed close to the firebridge ought to approach that of melting gold, the last bed that of melting aluminum. The yield of roasted material is about 5% less than the weight of the unroasted charge. Scarcely more than 1% of the ore escapes oxidation into chromic acid. The roasted mixture together with about twice its weight of water and sufficient

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* *Dinglers Polytechnische Journal*, 288, pp. 93, III., 161; *Journal Society Chemical Industry*, Sept. 30, 1893, p. 760.

soda-ash to leave an excess of 5% over and above the quantity required for the formation of the normal chromate, is then transferred into iron cylinders provided with agitators and heated to from 120° to 130° C. for about two hours. The solution is eventually separated from the insoluble residue by filter-pressing. The composition of the residue is exhibited in the following analysis: Na_2O, 0.2%, CaO, 46.5%; MgO, 12.2%; Fe_2O_3, 7.5%; Al_2O_3, 5.4%; Cr_2O_3, 1.0% soluble in HCl; CrO_3, 1.8%; SiO_2, 1.4%; CO_2, 5.2%; H_2O, 16.0%; insoluble, 1.2%.

"The solutions obtained from the filter-presses are concentrated until they attain a sp. gr. of 1.5. They receive then the addition of such a quantity of sulphuric acid (containing 80% H_2SO_4) as will suffice to neutralize the excess of alkali present and convert the whole of the monochromate into bichromate. The largest quantity of the sulphate thus formed at once precipitates in its anhydrous form, the bichromate remaining in solution. This operation is carried out in lead-lined iron pans which are provided with a steam jacket. The solution of the bichromate is separated from the precipitated sulphate by first siphoning off the clear solution of bichromate and hydro-extracting the residue. The bichromate solution is further concentrated in iron pans. Considerable quantities of sulphate crystallize out, but as soon as a sp. gr. of 1.7 is reached the hot solution is filtered and allowed to stand and crystallize. If the crystallization proceeds undisturbed, large crystals of $Na_2Cr_2O_7 + 2H_2O$ are obtained; but if during crystallization the solution be agitated, the salt crystallizes in the form of small orange needles. The sp. gr. of the larger crystals is 2.6.

"Bichromate of soda is very deliquescent and imparts to absolute alcohol a yellow color; the corresponding potassium salt does not give this reaction. The yield amounts to about 90% of that calculated. To convert the sodium salt into the potassium salt, solutions are used containing respectively 1500 grams of $Na_2Cr_2O_7 + 2H_2O$ and 300 grams of KCl per liter, the latter solution being added to the former. The bulk of the bichromate of potash is at once precipitated and recrystallized, large crystals being obtained from solutions containing 570 grams $K_2Cr_2O_7$ in one liter. The mother liquors are used for the crystallization of fresh quantities of the crude salt. The mother and wash liquors obtained in this manufacture which are too much contaminated with foreign salts are treated with reducing agents and the chromium oxide precipitated, and subsequently filter-pressed. The chromium oxide cakes thus resulting are mixed with lime in the proportion of 1 Cr_2O_3 to 1.5 CaO. The mixture is dried and heated to redness, until the mass possesses a homogeneous yellow appearance and contains about 36% of CrO_3. The roasted mass is then extracted with carbonate of soda. In the same manner the chromium may be recovered from the waste liquors of alizarin works. The hurtful effects of chromates upon the health of the workpeople can be considerably minimized by adopting the necessary precautions. No workmen ought to be allowed to work while suffering from abrasions or wounds on exposed parts of the body; as upon these, on contamination with chromates, ulcerated sores, healing but slowly, are formed. The hands ought to be rubbed with vaseline and no food or drink allowed in the work sheds.

"The conversion of chromite of soda into chromate can be effected by means of the electric current. On submitting a solution of chromic oxide in caustic soda to electrolysis, using platinum as anode and iron as cathode, the following reaction takes place :

$$Na_2Cr_2O_4 + 2NaOH + 3O = 2Na_2CrO_4 + H_2O.$$

"A current of two ampères was employed, and it was found that one hour-ampère converted 0.563 gram of the chromite into chromate. One hour-ampère yielding theoretically 0.298 gram of oxygen, which would oxidize 1.336 gram of $Na_2Cr_2O_4$, it follows that the useful effect represented by $\frac{100 \times 0.563}{1.336} = 42\%$ is attained.

"By using a solution of 58 grams $Na_2Cr_2O_4$ in 0.5 liter of water and electrolyzing this solution, the resistance was at first very high, but fell in the course of a quarter of an hour to eight volts, and eventually to six volts, where it remained stationary during the rest of the experiment. A current of from 2 to 3.5 ampères was used. The liquid at the cathode contained 14 grams of caustic soda and 0.4 gram of monochromate. The liquid at the anode yielded after concentration a crystallization of over 40 grams of $Na_2Cr_2O_7 + 2H_2O$. As in this manner the bichromate is obtained with caustic soda as a by-product (instead of sodium sulphate), it appears that the conversion of monochromate into bichromate by means of the electrolytic process indicates an important step in the progress of the manufacture of bichromates."

Potassium bichromate is used extensively in the preparation of chrome yellow and chrome orange, which are employed as pigments in calico printing ; chrome black, used in dyeing ; for the oxidation of caoutchouc and Berlin blue; the discharge of indigo blue ; the bleaching of palm oil and other fatty substances ; the preparation of mixtures for the heads of lucifer matches ; and the preparation of mercurious chromate and chromic oxide, which are used as green pigments in the ceramic art. Potassium chromate is further used in the manufacture of aniline colors and chlorine gas, in defuseling brandy, and for many other purposes in the chemical industry, where it is an exceedingly important reagent.

The potassium and sodium bichromates form the base from which numerous chromium compounds are obtained. Chromic acid, CrO_3, is obtained by decomposing potassium bichromate with sulphuric acid. It is used instead of nitric acid in galvanic batteries. Neutral lead chromate, or chrome yellow, $PbCrO_4$, is prepared by precipitation of a solution of potassium chromate with a solution of lead acetate, or by the use of lead sulphate or chloride. This salt, which has a beautiful sulphur-yellow color, is a valuable pigment. The basic lead chromate, known also as chrome red or Austrian cinnabar, which is represented by the formula $PbCrO_4 + PbH_2O_2$,* is obtained from the yellow or neutral chromate of lead by boiling with a solution of potassium hydrate or by fusion with potassium nitrate, the effect being that half of the chromic acid is withdrawn from the neutral chromate. The pigment known as chrome orange is a mixture in various proportions of the basic and neutral chromate of lead. Chromic oxide or chrome green, Cr_2O_3, is especially valuable as a pigment, being indelible, wherefore it is employed in printing bank notes. Chromic oxide is prepared in various ways,

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*According to Dr. Duflos (*Handbuch der Angewandten Pharmaceutisch-Technisch Chemischen Analyse*, etc., Breslau, 1871, p. 293), the formula of this salt is 2PbO, CrO_3, and the dry salt does not contain water as a component part.

one method consisting in heating a mixture of potassium chromate with sal-ammoniac and subsequently treating it with water, leaving the insoluble chromic oxide as a fine powder. Another method is to heat an intimate mixture of potassium bichromate and charcoal. The hydro-oxide of chromium ($Cr_2O_3, 2H_2O$), known also as Guignet's green, is obtained by melting together at a red heat potassium bichromate and crystalline boric acid, the melted mass being leached with hot water and the residue finely ground. Other salts of chromium employed in the arts are chromic chloride (Cr_2Cl_6), basic ferric chromate $Fe(CrO_4)_3$, and chrome alum $\left(\begin{matrix}Cr_2\\K_2\end{matrix}\right\} 4SO_2 + 24H_2O$, which is obtained in rather large quantities as a by-product in the manufacture of certain aniline colors, and is employed to some extent as a mordant in dyeing, for rendering gum and glue insoluble, for making woolen fabrics waterproof, and for some other minor purposes.

Chromite has been used instead of dolomite and magnesite in the preparation of basic furnace hearths. It was employed with much advantage for this purpose at the Terre Noire iron works, in France, when they were in operation, and it is still used at the Alexandrovsky works, in Russia. It has been employed at other open-hearth steel works in Russia and Finland, and at the Trollhätta and Kolsva works, in Norway; but, according to Odelstjerna,* the results were not satisfactory and its use was soon discontinued.

In preparing basic furnaces with chromite linings all parts of the walls with which the metal bath and slags come in contact are laid with pieces of chromite cemented with a mortar consisting of two parts (by volume) of finely ground chromite and one part of lime burned as free from carbonic acid as possible. The hearth is made of stamped chrome ore mixed with the same kind of mortar. The ore should be as rich as possible in chromic acid, containing 40% or 45%. It is remarkable that with such high percentages of chromic acid in the hearth only small amounts are to be found in the metal made on it, but that is the case.†

Ferro-chromium, which is an alloy of chromium and iron, is made by reducing the mixed oxides of iron and chromium with charcoal in brasqued crucibles, adding fluxes (borax and glass) to slag off earthy matter and to prevent oxidation. This is the method employed at Unieux (France), Sheffield (England), and Brooklyn (N. Y.). At Brooklyn finely pulverized chromite is reduced with charcoal in ordinary graphite crucibles, about 45% of ferro-chrome, assaying 30% chromium and 3% carbon, resulting. Ferro-chrome has also been made in blast furnaces, this method being in use at Terre Noire and Boucau (France), where five or six tons per campaign are made, with, of course, a heavy consumption of fuel. The percentage of chromium in ferro-chrome may be as high as 84; the alloy invariably contains carbon, and usually silicon and manganese.

In making chrome steel at the Brooklyn Chrome Steel Works from 0.25% to 2% of ferro-chrome (30% chromium) is melted with Swedish or bloomary wrought iron in 70-lb. charges in crucibles in common crucible furnaces, which melt six charges per twenty-four hours, with a consumption of two parts anthracite to one of steel. For an account of the properties of chrome steel and its uses the reader is referred to Howe's *Metallurgy of Steel*, and to an

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* *Jernkontorets Annaler*, Vol. XLIII., Nr. 7.

† W. Söltz, *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, XLI., 2, 21, Jan. 14, 1893, p. 19.

article by R. A. Hadfield in the *Journal of the Iron and Steel Institute,* 1892, No. 2, p. 64.

ANALYSIS OF CHROME ORES.

Mr. H. G. Shaw contributes the following description of the Clark process for the analysis of chrome ores, which is considered the most approved method:

Powder about one gram of ore as finely as possible in an agate mortar, and mix with caustic soda and calcined magnesia, in the proportion of 10 parts caustic soda to 6 parts calcined magnesia. Heat the mixture in a deep platinum crucible, over a Bunsen flame, for about three-quarters of an hour with the lid off, then with the lid on for a quarter of an hour. Oxidation takes place almost immediately, and is practically complete in less than an hour.

The crucible and its contents are then placed in a porcelain basin containing water, the contents warmed and washed out as far as possible with water and afterward with dilute sulphuric acid, which must be free from nitric acid. An additional quantity of dilute sulphuric acid is then added to the contents of the basis and more heat applied, when everything should dissolve except a few flakes of silica. To the clear yellow solution are added a weighed quantity of pure sulphate of iron and ammonia, of known strength, and more than sufficient for the reduction of the chromic acid. The unoxidized iron is then estimated by a standardized bichromate of potash solution, and the amount of sesquioxide of chromium in the ore calculated from the amount of iron oxidized, thus:

$$\frac{6\mathrm{Fe}}{336} : \frac{\mathrm{Cr_2O_3}}{153} :: \frac{\mathrm{Fe\ oxidized}}{x}.$$

It frequently happens that a little of the chrome ore escapes decomposition. This must be filtered off after the chromic acid in solution has been estimated, and again fused with a mixture of soda and magnesia.

To estimate the chromic acid by precipitation, add chlorhydric acid, then sodium sulphite to reduce the solution, then ammonia to precipitate the Cr_2O_3, and boil; then wash well by decantation several times, after which filter and continue washing, until the filtrate gives no precipitate, with chloride of barium ($BaCl_2$); then dry, ignite, and weigh the Cr_2O_3. Keep the precipitate, fuse it with soda and magnesia mixture, and continue estimating as per Clark's process, already described.

CLAY.

By Heinrich Ries.

Pure clay is a hydrated silicate of alumina, having the formula Al_2O_3, $2SiO_2 2H_2O$, or silica 46.3%, alumina 39.8%, water 13.9%. This is the mineral kaolinite, and generally results from the decomposition of granitic or other feldspathic rocks. The three essential component minerals of granite are quartz, feldspar, and mica, and of the feldspars, orthoclase, or the potash feldspar, is the most commonly present. The surface waters percolating through the rocks attack the feldspar and leach out the potash as carbonate, or possibly as a silicate if the amount of carbonic acid is small. This breaking up of the feldspar destroys the bond for the quartz and mica, and the rock begins to crumble. As a further result of the leaching, some of the silica is set free and left in a hydrated condition. The alumina of the feldspar, some of the silica, and some water unite, forming kaolinite, the basis of all clays. A deposit of this kind formed in place is a residual clay, and its purity is largely influenced by the composition of the parent rock and mechanical conditions, both of which vary.

Subsequent action of the surface waters washes the kaolin, together with other substances, into the oceans and lakes, where it settles in the quiet water, forming beds of "sedimentary clay."

Clays suitable for the manufacture of common brick are by no means rare. The impurities in them often run quite high, and yet a very fair product may be made. The use of clay is largely determined by the amount and kind of impurities present.

Properties of Clay.—Plasticity is the property possessed by clays of forming a pasty mass when mixed with water, and becoming a hard mass when subjected to high heat. This burned clay, if not ground and mixed with water, is no longer plastic, as all the water of combination has been driven off. Plasticity is also largely due to the kaolinite base which occurs in the form of small hexagonal tablets. Dry kaolin is not plastic. Prof. G. H. Cook found that this property was also influenced by the degree of fineness of the kaolinite; furthermore, in many slightly plastic clays the kaolinite was found to be collected in bunches, while a subsequent thorough grinding of the clay in order to break up these aggregates increased the plasticity. A tough, plastic clay is termed by the brick-makers "fat," while a clay of little plasticity and loose, sandy texture is said to be "lean."

Sand, which destroys plasticity of clay, is one of the commonest impurities. Others are feldspar, mica, lithia, titanic oxide, lime, magnesia, potash, and soda. Sulphur in the form of pyrite often occurs. Page states that "the admixture of a proportion of sand which results in a combination containing as much as 90% silica is not incompatible with the formation of a good brick. Uncombined silica if not in excess is beneficial, as it preserves the form at high temperatures; in excess it destroys cohesion and makes the brick brittle and weak. Fire clays should not contain over 3% to 4% of iron, alkalies, etc.

The fusibility of a clay usually increases with the amount of impurities present. Richter found that potash was the most fusible of the impurities, and next in order come iron, lime, and magnesia. Phosphates also have a slight effect.

Iron is mostly present in the form of a lower oxide, and in burning is converted to a higher one, coloring the product red. According to Seger, the color produced by iron is influenced by the amount present, the chemical composition of the clay, the mechanical division of the coloring substance, and the degree of burning, and whether the fires of the kiln are reducing or oxidizing. The intensity of the coloration increases with the percentage of peroxide of iron from 4% to 8%. From this up to 21% no change was noticed in the color. If iron is present in the form of sulphates it usually decomposes at the point of fusion, giving a lower oxide, which fluxes and produces a distortion of the material. A reducing flame is detrimental to the formation of sulphates. If 8% to 10% of iron is present and the ware is intensely heated, the iron combines with the silica to a blue mass.

Carbonate of lime counteracts the red color of iron by the formation of a light-colored silicate of iron and lime. Clays rich in carbonate of lime become yellow on burning, and an excess of lime produces a cream color in the oxidizing flame. It has been stated that a clay with over 3% of lime is not fit for use; but this limit is too low, as clays with 5% and 6% will often make a very good product, and the celebrated Milwaukee brick have over 20%. Magnesia also tends to check the development of the red color in bricks. A white or light-colored product is sometimes produced if the clay contains a large amount of organic matter which will reduce the iron.

Lithia is occasionally found in clays, and titanic oxide is almost universally present in amounts varying from .01% to 2%.

Clays weigh 100 to 125 lbs. per cu. ft., and have a sp. gr. of 1.75 to 2.

The refractory quality of a clay may be computed by the following formula of Bischoff, who divides the clay into two parts, the silica and alumina constituting the refractory part, and the impurities the fluxing part. If we take the alumina divided by the total impurities as the dividend, and the result of the silica divided by the alumina as a divisor, the quotient will be a measure of the refractoriness of the clay as compared with another clay treated in the same way. RO designates the impurities in the formula : $\frac{Al_2O_3}{RO} \div \frac{SiO_2}{Al_2O_3}$.

Kinds of Clay.—The amount of impurities in a clay largely determines its use. China clays are the purest. They are usually non-plastic, and when used in the manufacture of china are mixed with plastic clays. Feldspar and quartz are also added to the china clay. China clay is usually washed before using. It is also employed to a considerable extent for filling-paper.

Fire clays are usually those clays having less than 4% of impurities. It is seldom possible to use the fire clay as it is mined, an admixture of sand and other materials being necessary. Plasticity is often wanting, as in the "flint clays."

Pottery clays may be considered as coming next in the order of decreasing refractoriness. They are plastic and often quite pure, resembling kaolin in composition. Their chief use is for giving plasticity to mixtures for china, and when used alone to make stoneware and terra cotta. If these clays vitrify and keep their shape in burning, they may be used for sewer pipe or paving brick.

Brick clays include a wide range of plastic materials, and bricks are often made from partly plastic sandy mixtures which are not properly clay. It is said that a good brick can be made from a clay containing 90% silica.* The requisites of brick clays are given under the head of Brick-Making.

It will be a matter of great interest, when a sufficient number of complete clay analyses are available, to compare them and determine the oxygen ratio in the different kinds. Mr. Edward Orton, Jr., has done this with the Ohio clays, with the following results:

Stoneware clays: O in silica: O in base: : 34.72 : 11.52, or as 3:1. O in alumina : O in flux : : 10 : 1.

Stoneware slip clays gave the following ratio: 2.5 acid : 1.0 base and 1 alumina: 1 flux.

Yellow-ware clays: 2.57 acid : 1 base and 9 alumina : 1 flux.

Paving and sewer pipe: 2.19 acid : 1 base and 2.72 alumina : 1 flux; also 3.12 acid : 1 base and 2.77 alumina : 1 flux.

Fire clay: 1.36 acid : 1 base and 51 alumina : 1 flux.

Geological Distribution of Clays.—Clays occur in nearly every geological formation. The feldspathic Archæan rocks furnish many beds of kaolin, among the localities being Pennsylvania, Wisconsin, North Carolina, etc. Some kaolins, however, like those of Florida and New Jersey, are sedimentary. Shales occur in the Silurian and are extensively used. In southern New York the Devonian shales make an excellent tile and sewer pipe. The Carboniferous, however, is the great producer of refractory material. It is the source of extensive fire-clay deposits in Pennsylvania, Ohio, West Virginia, Tennessee, Kentucky, Missouri, Kansas, and California.

Triassic shales are of little use, but the Cretaceous beds contain immense supplies of all grades of clay in many States. The well-known plastic clays of New Jersey are of this horizon. Tertiary beds are also of great commercial value. In the Northern States the glacial clays are widely distributed, and used at many localities for brick-making.

Prospecting.—In prospecting for clay a knowledge of the geological structure of the region to be examined is often of great value. North of the terminal moraine many deposits of clay are found underlying the flat valleys which are old lake beds, or again at other localities the clay underlies terraces along the sides of the valleys. The region to be examined must first be gone over carefully and all the surface features examined.

The presence of clay can often be detected in railroad cuttings, and in the

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* D. Page, *Economic Geology.*

sides of gullies or ravines. In many cases, however, its presence can only be surmised, and borings must be made to determine its existence. As a deposit of clay is seldom of uniform thickness throughout its extent, a sufficient number of borings should be made in order to fully determine this point; a bed of clay may be 40 ft. thick in one place and thin out to 5 ft. or 6 ft. within a distance of 15 ft. The writer has seen several instances in which expensive plants were erected and came to a speedy end simply because the clay supply failed, whereas the disaster might have been averted by previous exploitation. Although boring is a rapid method and gives an approximate idea of the extent of the clay, trial pits are, on the whole, more desirable, where the expense seems warranted, as in the case of high-grade clays. Pits are also desirable in sandy soil, as the latter falls into the hole upon withdrawal of the auger. Augers are often used to a depth of 40 ft. Another important point to determine is the presence of sand for molding. In many localities this overlies the clay, but it often has to be transported considerable distances. The question which next arises is whether the material is available for the required purpose, and what class of machinery is best adapted to work it. By far the best way is to take several barrels of the clay and have them made into the desired product by different methods.

Methods of Working.—If the deposit lies at or near the surface the first step is the stripping, which may vary from a foot or two of soil to 20 or 30 ft. of sand and gravel. Having uncovered the clay several methods are employed to mine it.

1. Digging the clay entirely from the base of the bank. The haulage of clay in this case is all at the same level; but with this method the bank is apt to be undermined, with a consequent mixing of the several strata, which in some cases is undesirable.

2. A second method is to loosen the clay by plows and bring it to the yards by means of a scraper, provided the bank adjoins the yard. It costs about 20c. per 1000 brick to plow the clay and bring it down with the scrapers. To this must be added 12c. to 15c. per 1000 brick for carting the clay from the dump to the molding machine, a distance of about 50 ft. The bank is usually worked at an angle of about 30°. The method has no especial advantage.

3. Working in benches. This method, or variations of it, is in common use at many localities where the bank is over 30 ft. high. The benches are 6 to 8 ft. wide and 7 to 9 ft. high. Roads lead up to the separate benches, and each bench is worked in advance of the lower one. By this method the bank can be worked at a number of points simultaneously, and the benches prevent the occurrence of a slide if the clay bank is high and the material loose.

4. Steam shovels are occasionally employed. The cost of digging is 6c. to 8c. per cu. yd.

5. Dredging. This is practiced at only one locality in New York. The dredged clay is dropped into hoppers, which when full are run up inclined planes on shore and dumped. The cost is 12 @ 15c. per 1000, delivered on shore, and 12c. per 1000 brick additional for haulage from dump to machine.

6. Undermining. Many manufacturers use this method when the clay is tough. Wedges are driven in on the surface a foot or so from the edge of the bank, and at the same time the face is undermined by picks to a distance of two or three feet.

7. Blasting is often resorted to in banks of very tough clay, and is always used if the material is shale.

8. In New Jersey the clay is usually dug in pits, whose depth is the thickness of the bed. A special form of shovel is used for digging the clay. When the pit becomes too deep to permit throwing the clay to the surface, platforms are put in, and the clay is thrown to these and then out. Sometimes a windlass and bucket are used instead.

9. If the deposit is a considerable distance below the surface, drifts are run into it. In New Jersey these are driven side by side, one at a time, each one having a cross-section sufficiently large to admit a man and wheelbarrow. Sometimes a shaft is sunk, and from the base of this galleries are driven. The drifts, or tunnels, have to be timbered, and sufficient clay or shale is usually left to form a roof. Underground mining is extensively followed in Pennsylvania; also in the fire-clay beds of Missouri.

As much china clay is exported from Cornwall to America, it may be of interest to mention the method of mining it. The Cornwall kaolin occurs in masses resulting from the decay of granite. In order to mine it a shaft is first sunk, to a depth of 60 or 70 ft., preferably in the rock. From the base of this a level is run into the main mass of the kaolin, and from the end of the level a raise is excavated to the surface. A buttonhole launder is then put down the raise and the space around it filled in. A small pit is then dug around the top of the launder and a stream of water directed on to the clay, which is broken up with picks. The loosened material is sorted by the water, the fine material being carried off by the water while the clay remains behind, and the sand which is left behind is shoveled out of the way. The water, with the fine clay in suspension, goes down the launder and along the level to the base of the shaft, where it is pumped up. As the pit becomes enlarged the upper portions of the launder are removed. From three to eight tons of sand per ton of clay have to be removed. The water which is pumped up the shaft is directed into stone channels with drags, where the sand and rougher mica particles are dropped; the stream passes through a second series of channels called the micas. These are 11 in. wide and 100 ft. long, and more mica is collected in them. The pure clay next goes to pits 30 to 40 ft. in diameter and 7 to 10 ft. deep, where it is allowed to settle and the clear water drawn off and used over again. The mica recovered is sold to makers of soft paper, pasteboard, and inferior pottery. The sand is sold for cement.

Haulage.—The manufacturer generally locates his plant near the supply of clay, so that the haulage distance is from 100 to 300 ft. Within these limits it is economical to use one-horse carts, but above 300 ft. other devices are adopted. There are exceptions where carts are used for distances up to 1000 ft., but the haulage is down grade. The cost is 20c. per 1000 brick for 500 ft. lead. Cars are employed for distances above 500 ft. They are run on tracks and drawn by horses. The loaded cars are sometimes run to the yard by gravity. The cost of haulage in this way is about 10c. per 1000 ft. Locomotive haulage is a cheap method where the scale of operations warrants it; *i.e.*, a yard with a capacity of 10,000,000 bricks and a haulage distance of 600 ft. or more. The cost is 5 @ 7c. per 1000 brick for a 600-ft. lead. Wire-rope haulage and gravity planes are sometimes used. In all cases where cost has been given it does not include wear and tear of plant. The cost has been given for 1000 brick, the equivalent of about one and a half cubic yards of clay.

THE BRICK INDUSTRY.

Building brick were among the earliest clay products of the United States. They were made in Virginia as early as 1612, and in 1647 brick and tile were made in New England. In 1685 brick were made in Philadelphia, and shortly thereafter numerous yards were in operation along the Delaware. Since then brick-making has been carried on more or less actively in all the Eastern States. A great impetus was given to brick-making in 1835, when Nathaniel Adams of Cornwall, N. Y., invented the hand-power brick machine. Shortly after this he designed and constructed one operated by horse-power. He was also the inventor of the tempering wheel. In 1840 Adams endeavored to equip a yard at Philadelphia with his machines, but the plant was destroyed by a mob of angry workmen and he had to flee from the city. The methods of brick-making have improved wonderfully within the last twenty years, especially in front brick, which are of better quality, form, and color. Of common brick, however, the same cannot be said. In districts such as the Hudson Valley, where the supply often exceeds the demand, there is a consequent reduction in the selling price, to meet which the manufacturer endeavors to lower the cost of production, and the result is generally a falling off in the quality of the brick. When the price gets down to $4.75 per 1000, as it does sometimes in New York City, and the brick costs the manufacturer nearly $5 per 1000 delivered, there is little or no profit. As a rule common brick bring from $6 to $7 per 1000. Sometimes the price gets up to $12 in districts where there is little competition and the brick is of good quality.

Bricks may be divided into four classes, viz.: common, front, ornamental, and paving. Probably three-quarters of the clay products of the country are used in common brick.

Common Building Brick.—For this purpose a clay is required that will burn to a comparatively dense product of a good red color and regular form. The requirements of such a brick are as follows:

1. It should have plane surfaces, parallel sides, and sharp edges and angles. The regularity of form depends largely on the clay from which the brick is made and the method of drying and burning.

2. It should be of fine, compact, and uniform texture, quite hard, and should give a clear, ringing sound. The compactness and uniformity of texture, which greatly influences the durability, depend on the method of molding. Hand machines produce a brick of a homogeneous character. Tempered clay bricks are denser inside, while dry-clay machines are claimed to produce a thoroughly homogeneous brick.

3. It should not absorb over 10% or 15% of water. A simple method of testing is to place the brick for twenty-four hours in a bucket of water, weighing it before and after immersion, the increase in weight being the amount of water absorbed. This applies only to hard-burned bricks, as a green or salmon brick will absorb much more.

4. It should have a sp. gr. of 20 or more.

5. It should have a crushing strength of at least 3000 lbs. per sq. in.

Common bricks run quite uniform in size. There is a difference of about three-sixteenths of an inch between a brick made in a new mold and one from an old one. The average size is $2\frac{3}{8}$ by $3\frac{1}{2}$ by 8 in. Building brick may be divided into three classes—arch, red, and salmon. The first and second sell at $5 @ $8 per 1000, according to the market.

Paving Brick.—The paving-brick industry, although in its infancy, gives indication of rapid growth. In the Western States brick is becoming a favorite paving material. Brick pavements have been employed in Europe for a number of years; in this country they were first used at Charleston, W. Va., in 1875, and are now found in about 300 cities and towns. Brick pavements are comfortable, do not wear slippery, and are clean. The cost of laying is considerably cheaper than granite or asphaltum. At Wheeling, W. Va., the cost per square yard was $1.05, and at Memphis $2.32, while granite cost $2.50 @ $4 per yard, according to location. It was formerly thought that only fire clays could be used for the manufacture of this class of product, but this idea is being rapidly abandoned, for there are many clays which are not refractory enough for firebrick, and make excellent paving material. In order to produce good paving brick the clay should be one which will hold its shape at a heat sufficiently high to cause vitrification. It should shrink evenly in burning. It should be tough but not brittle, and should withstand abrasion. It should also be able to withstand considerable pressure. It should be homogeneous throughout, and so dense as not to absorb much water. Uniformity of color is not essential in paving bricks, nor are sharp edges desirable.

Brick-Making.—In the manufacture of paving brick the clay must be thoroughly prepared before being molded. Some clays can be ground, screened, and pugged as soon as taken from the bank, while others have to be weather soaked before crushing. The machine used for molding depends on the clay. Some clays make a first-class brick in a dry-press machine, while others give the best results with a soft-mud machine. The stiff-mud process is by far the most widely used. In any case the green brick should be as dense as possible. After molding, the bricks are dried by artificial means, and this step should not be hurried.

Burning is usually done in down-draft kilns. The latter should not be too high, or the bricks in the lower portion will be crushed out of shape by the weight of those above them when the fires are hottest. In burning, the fires are raised until the temperature of vitrification is reached, and they are held at that from twenty-four to thirty-eight hours. Cooling is done very slowly, thus annealing the brick. The term "vitrification" is a misnomer, for to vitrify a brick would be to convert it into a glass, in which condition it would be useless. Actually the temperature is raised sufficiently to flux the potash, lime, and iron with the silica and give a dense brick, and it is in order to thoroughly accomplish the latter object that the brick is kept for a number of hours at that heat.

Road-metal.—This is a comparatively new application of burned clay. The clay is burned in small pieces to vitrification. Some of the Western railroads, the Chicago, Burlington and Quincy, Atchison, Topeka and Santa Fé, Rock Island and Pacific, and Wabash, use it as road ballast, claiming it superior to stone.

A number of interesting tests were made by the Ohio Geological Survey to determine the relative merits of fire clays and shales for the manufacture of paving brick, as well as the influence, if any, of the method of manufacture used. Twenty-three varieties of shale brick, or bricks whose largest constituent is shale, were grouped together, of red or dark color; fifteen varieties of fire-clay brick or bricks whose largest constituent is fire clay, of light color; four varieties composed of shale and fire clay mixed in equal proportions, whose color was speckled white or red; and three varieties made of Ohio River sedimentary clays, dark red or brown in color. The average results of these four classes were as follows:

Kind.	Absorption.	Rattling.	Crushing.		Rank.
			Per Sq. In.	Per Cu. In.	
Shales	1.17	17.61	7307	1764	1
Fire clay	1.62	17.32	6876	1678	2
Mixture	1.44	18.72	5788	1400	3
River clay	1.36	19.02	4605	1176	4

Taking nine samples of bricks made on end-cut machinery, whether plunger or auger, and comparing them with twelve side-cut repressed bricks, the following figures were obtained:

Kind.	Absorption.	Rattling.	Crushing.		Rank.
			Per Sq. In.	Per Cu. In.	
Side-cut	.72	17.78	6925	1649	1
End-cut	.92	17.49	5418	1354	2

This showed a distinct advantage in general for the side-cut material; but the end-cut material in this test was made in many different kinds of machinery and of very different clay. Separating the various kinds more closely, the following figures were obtained with end-cut material plunger machines. Three samples were made in sewer-pipe press and then repressed, and one sample made in a Penfield plunger machine and then repressed.

Kind.	Absorption.	Rattling.	Crushing.		Rank.
			Per Sq. In.	Per Cu. In.	
Sewer-pipe press	1.18	11.13	5903	1480	1
Penfield machine	1.08	32.77	4465	1138	2
Average for plunging machine	1.15	16.54	5544	1395	

Five samples made on the Penfield automatic cut-off end-cut auger machine and then repressed gave:

Kind.	Absorption.	Rattling.	Crushing.		Rank.
			Per Sq. In.	Per Cu. In.	
End-cut auger brick	.73	18.25	5318	1322	2
Side-cut auger brick	.72	17.78	6525	1649	1

By still further eliminating the causes of variation in these samples aside from the effect of the mode of manufacture, the following figures are deduced of four samples of end-cut repressed auger brick made of shale clays against eight samples of side-cut repressed auger brick, also made from shales:

Kind.	Absorption.	Rattling.	Crushing.		Rank.
			Per Sq. In.	Per Cu. In.	
End-cut shale	.58	18.94	5326	1338	2
Side-cut shale	.74	15.64	7690	1187	1

In this last comparison the sources of variation have been eliminated largely, and the results are therefore much more valuable; they point strictly to the general superiority of side-cut over end-cut. Further experiments made by Mr.

E. Orton, Jr., to determine the relative qualities of plain and repressed brick, showed that while the former stood a greater pressure, the latter absorbed less water. Experiments made with large and small bricks showed that while the large ones stood the rattling test better, the small ones had a greater crushing resistance per sq. in.

Front Brick.—Up to a few years ago, in order to obtain a smooth, sharp-edged brick, such as is needed for the front of buildings, the brick was first molded either by hand or in a soft-mud machine and subsequently repressed. At the present day, however, such a product can be produced in one operation. Repressing machines which are operated by hand-power and press one brick at a time are still used by many manufacturers, but steam-power repressing machines have been recently introduced and cannot help proving more economical. A front brick should have smooth faces, sharp edges, and square corners; it should also be denser than a common brick. The clay should be thoroughly prepared; some manufacturers allow their clay to weather for six months or even a year. Very often better results are obtained by mixing two or more clays. Repressed bricks require a longer time to burn, and on account of their greater density have to be dried very slowly and carefully. The former regulation shade of red has been, in a measure, superseded by other colors. At present front bricks are made of different shades of yellow, brown-red, and white, as well as combinations of these colors, giving the brick a speckled appearance.

Ornamental Brick.—Ornamental brick are really an elaborated form of front brick, and are also molded by machinery. When the design becomes so intricate that they have to be molded by hand they are properly terra cotta. Their manufacture requires even greater care than ordinary front brick.

Enameled Brick.—The manufacture of this material has been carried on for some years in New Jersey, Pennsylvania, and Ohio, but the production is not large. Though American manufacturers have not been able thus far to surpass the enameled bricks made in England, a very fair quality is produced in the United States.

METHODS OF BRICK-MAKING.

Bricks are usually made by one of the following three processes: (1) soft-mud, (2) stiff-mud or wire-cut, and (3) dry clay. These processes are not wholly distinct from one another, for there are machines which may be used as well in connection with one as another. For instance, in preparing the clay for molding either a pug mill or a pan crusher may be used. Whatever the method, the manufacture of the clay into brick involves the following steps: Preparation, molding, drying, and burning.

Preparation of the Clay.—This step is of great importance in the manufacture of clay products, and success or failure often depends on it. No fixed rule can be laid down for the preparation of all clays, as the method to be used depends on the character of the clay and the method of manufacture to be employed. Clay may be prepared by weathering, grinding, or screening. The first method is explained by its name. Grinding is done by either rolls or dry-pans. The former are commonly used where the clay contains stones or pebbles. There are usually two rolls which revolve at different velocities, or there may be two pair of rolls, in which case the material is reduced to the desired size only after passing through both pair. Rolls are also applicable to shale. Dry-pans consist essentially of a circular pan 7 to 9 ft. in diameter, the floor of which is perforated so that the material can pass through as soon as it is ground fine enough. In the pan there are two iron wheels 6 to 14 in. wide, which weigh from 2000 to 6500 lbs. each, and the materials are crushed by their weight. The bottom of the pan revolves and the wheels are thus caused to revolve by friction. The crushed material falls through the perforated bottom of the pan into the discharge box. The capacity of the dry-pan varies with the size of the screen plates and the character of the clay. The maximum on record is 200 tons of shale fire clay in ten hours through a $\frac{1}{8}$ and $\frac{3}{16}$ mesh bottom. The average capacity of one pan with $\frac{1}{8}$ in. bottom is 1000 tons in ten hours.

Screening.—The material from the dry-pan is next passed through screens. All manufacturers do not screen their clay, however, trusting to the dry-pan to reduce it to sufficient fineness. The simplest form of screen is a fixed inclined sieve, 10 to 14 ft. long, with a wire-cloth or perforated metal bottom. Rotary screens, cylindrical or octagonal, often have automatic devices to agitate the clay and force it through the holes quicker. These screens require constant attention and need many repairs, but they occupy little room and have great capacity. Shaking screens are usually fixed at one end and driven by a crank and piston or eccentric; they are often inclined, and have a perforated metal bottom. They are cheap and simple in operation.

Soak-Pits.—This is the most primitive device at present used for preparing clays, and is only employed where the clay is brought directly from the bank and molded in a soft-mud machine. It consists of a rectangular pit six by four feet, into which the clay is dumped, water poured on it, and the whole allowed to soak over night. The following morning the tempered mass is shoveled into the machine, from one to one-quarter the volume of sand being added, but the latter is not always necessary. The object of adding sand is to counteract the effect of the alumina and prevent an unequal shrinkage of the brick in burning. Coal dust is also added to the clay by some makers. When soak-pits are used, two men dig the clay at the bank in an afternoon, while a third man, the temperer, who receives $2.25 per day, levels the material as it is dumped into the pit, and also adds the requisite amount of water. In the morning the two diggers of the previous afternoon shovel the clay from the soak-pit into the machine. In large brickyards separate groups of men do the pit-shoveling and dig the clay. Soak-pits are extensively used by the Hudson River brickmakers.

Ring-Pits.—These temper the clay more thoroughly than soak-pits, but are not so extensively used; first, because it costs more to operate them, and secondly because most manufacturers claim that the molding machine pugs the clay sufficiently. A ring-pit is circular, 25 to 30 ft. in diameter, 3 ft. deep, and lined with boards or brick. In this revolves an iron wheel so geared that it travels from the center to the circumference and back again to the center. In this manner the clay is thoroughly broken up and mixed with the sand, if the latter is added. The pitful, which is sufficient for about 30,000 brick, is tempered in about six hours. With ring-pits there is a similar arrangement of labor as with soak-pits, the only difference being that the temperer is employed in the morning to wheel the clay in a barrow from the pit to the machine, some 10 ft. As a rule there are two ring-pits to a machine, so that while the clay is being shoveled from one pit to the machine the other pit is tempering clay for the next day. Sometimes one pit holds enough clay for two machines.

Pug-Mill.—This machine consists of a horizontal, semi-cylindrical trough, in which revolves a shaft bearing knives or a worm-screw. The material is put in at one end and discharged from the other into the brick-machine. Water is also added from a faucet at the upper end of the trough. The angle of the knives with the shaft is changeable, so as to regulate the speed with which the clay passes through. Pug-mills take up less room than ring-pits and do not require so much power to operate them. They are used chiefly with stiff-mud machines. Some pug-mills are closed. Such consume more power, but have greater capacity, and temper the clay more thoroughly. If the clay does not burn to a nice red color, hematite is sometimes added to the material while in the pug-mill to produce the desired color in the product.

Wet-Pans.—These resemble dry-pans, but the bottom is not perforated. Two scrapers are placed in front of the wheels to throw the clay in their path. Water is added to the clay, which is charged in lots of from 600 to 1200 lbs. The more refractory the clay the finer it has to be ground. The action of the wet-pan is very rapid. For bricks a charge can be tempered in two or three minutes, and for sewer pipe in four or five minutes. The material can be discharged by means of a trap door in the floor of the pan, or with an automatic shovel. With the latter the capacity of the pan is said to be increased 20% to 30%. Wet-pans have a greater capacity and more efficiency than pug-mills, but they require more power.

Molding.—Having prepared the clay by one means or another according to its character, it is next molded into bricks. The old-fashioned method of molding bricks by hand is rapidly dying out; still, it is seen occasionally. In this country most of the smaller manufacturers use the soft-mud process. There are several different types of machines for this, but the principle of all is the same. The soft-mud machine consists essentially of an upright box of wood or iron, in which there is a vertical shaft bearing several knives, while at the bottom of it are curved arms, which force the clay into the press-box. The molds are put in at the rear of the machine and fed forward automatically beneath the press-box, the empty mold sliding into the place of the filled one, which passes out to the delivery table. A boy sands the molds before placing them in the machine, in order to prevent the clay from sticking. The clay is fed into the machine at the upper end of the box. These machines have a capacity of about 5000 bricks per hour, 6 bricks being molded at a time. Steam-power is used to run the machines, but some of the smaller yards use horse-power. The amount of pressure which the brick gets can be regulated, as bricks dried on pallets require to be molded stiffer than those dried on open yards. Four men are required to operate the machine—a "molder," who scrapes off the extra clay on top of the mold as it is delivered; a "mold-lander," who takes the mold of brick from the delivery table and places it on the truck; a "sander" to sand the molds, and a boy to watch the machine. Their wages aggregate about $6 per day. Besides these there are four truckmen, who wheel the machine to the yard, where they are dumped on the drying floor by two mold setters. In the afternoon these men are employed in hacking the bricks and wheeling the dry ones to the kilns. One machine makes about 23,000 bricks per day.

Stiff-mud machines are so called from the fact that the clay is tempered quite stiff. It is then forced from the machine, through the die in the form of a bar which is cut up into brick. The clay is sometimes tempered in pug-mills, but pan-crushers are mostly used for this purpose. Stiff-mud machines are of two types—auger, and plunger machines. Plunger machines are similar to soft-mud machines, but the clay, instead of being forced into molds from the press-box, is forced from the machine in the form of a bar. As the bar issues from the machine it is received on the cutting table, and at proper length a series of parallel wires is drawn forward and cuts it into a number of bricks, which are removed before more clay issues from the machine. Auger machines consist essentially of a cylinder tapering at one end, in which there revolves a shaft bearing knives; at the free end of the shaft nearest the die there is a screw. The clay is charged at the wide end, and as it moves forward becomes compressed. The screw on the end of the shaft forces it out through the die to the cutting table. Auger machines are either end-cut or side-cut, according as the section of the bar of clay has the same area as the greatest or smallest plane surface of the brick.

The capacity of a stiff-mud machine may be increased by forcing out more than one bar of clay at a time. The clay as it issues from the auger machine may be cut up as with plunger machines, or this may be done by an automatic cutter, in which case the action of the machine is continuous and its capacity greatly increased, for which reason they are growing in importance. They also require less power to operate than plunger machines. Stiff-mud machines are among the cheapest used, and most of the paving brick of the country are made on them. They have one objection, however, applying especially to auger machines, which is that they give the brick a laminated structure. This is due partly to the center of the clay flowing through the die having a tendency to pass through quicker, and partly due to the screw of the auger machine. It has been found that rich, fat clays laminate most. Stiff-mud machines have an average capacity of from 25,000 to 30,000 brick in ten hours, but some automatic end-cut auger machines have been known to produce 75,000 in that time. In that case more than one bar of clay was forced from the machine.

A combination machine consists of "a vertical pug-mill to force the clay downward and a large mud-wing or revolving arm to give the final propulsion to the clay. This mud-wing forces the clay down into a set of molds arranged around the periphery of a horizontal table. Each mold box is filled with clays, and when full comes under a pair of plungers acting vertically, one working up under the clay and one down on it. The clay is thus compressed into a solid block, which is subsequently removed, when the movable bottom of the box is elevated to the surface of the table." The advantages of this machine are that the brick has no structure, and the machine will work a very plastic clay and has a daily capacity of about 25,000 brick.

Dry-clay Process.—The introduction of this method into the United States dates back only fifteen or twenty years, it having been first tried at Louisville, Ky. It is, however, rapidly gaining in favor, on account of its simplicity. In New York it has not been in use over five years, and as yet has been adopted by only five firms. The clay, having been dug, is usually stored in sheds to dry. When ready for use it is taken out and charged into the dry-pan or disintegrator. If the latter is used and the clay is charged in too moist a condition it will not be thoroughly pulverized, but if it is too dry the particles will not adhere when molded. The powdered clay is next carried by belts or elevators to a screen above the molding machine, through which it passes, the tailings going back to the disintegrator.

The molding machine consists of a massive frame of forged steel about 8 ft. high. Three ft. above the ground is the delivery table, sunk into which is the press-box. Connected with the hopper above the machine by means of two canvas tubes is the charger, which slides back and forth on the table. It is filled on the backward stroke, and on the forward stroke charges the clay into the mold box. The charger then recedes to be refilled, and at the same time a plunger descends, pressing the clay into the mold. As the upper plunger descends, a lower plunger which forms the bottom of the mold ascends, so that the clay receives pressure from above and below. The upper plunger then raises, and the lower one moves upward until the lower surface of the brick is even with the table. Again the charger comes forward, shoving the green brick forward, while the mold is at the same time filled again. The faces of the mold are of hard steel heated with steam to prevent the adherence of the clay. The pressure from above is applied by a toggle-joint arrangement, and the manufacturers claim that the pressure exerted on each brick is 150 tons. One to six bricks are molded at a time. The green bricks are either put in drying tunnels or set directly in the kiln. They contain about 15% of water in this state, and require great care in handling. The drying must be done very slowly to prevent cracking, and the burning is usually done in down-draft kilns. By setting directly in the kiln it takes longer to water-smoke. It is claimed by some that one-sixth to one-quarter more fuel is required to burn bricks made by this process. Dry-pressed bricks are the densest made, but they consist simply of an agglomeration of particles which owe their conjunction to pressure, and even though they may become vitrified in burning, they do not, in most instances, unite. The chief application of this method is in the manufacture of front brick.

Drying.—Bricks made by the soft-mud process are usually spread out on floors or set on pallets to dry; though many yards use tunnel dryers. Drying should not be hurried. Bricks dried too quickly are apt to crack. They should also be well dried before setting in the kiln, and if this is not done the product is very apt to be poor. Bricks made by the soft-mud process are usually dried in one of three ways: (1) open yards; (2) pallet yards; (3) covered yards. The first method is the most used, the second next, and the third least.

In the first method the bricks are spread out in the open air on a hard floor, which is of brick covered with sand. At one end are the molding machines, and at the other the kiln sheds. After the day's production has been spread out, the boy who tended the machine in the morning goes along the rows and stamps them with a piece of board, set on the end of a long handle, which is termed "spadding." After this the bricks are turned on edge by another boy who goes along the rows with a special tool, turning six bricks at a time. The next morning the bricks are hacked ; that is, they are piled on one another in a double row eleven to fifteen courses high along the sides of the yard, and left until sufficiently dry to be set up in the kiln and burned.

In case of rain the hacks are covered with planks. In open yards the bricks are exposed to the rain, and if a shower comes while they are spread out they become "washed," getting a rough, uneven surface. Though they are quite as strong as unwashed brick, they sell for 50% to 75% less per 1000. In practice they amount to about 15% of the total production.

Covered yards are provided with a roof, which is hinged in sections, and on pleasant days is opened upward to allow the sunlight to enter, and closed to prevent washing of the bricks in case of rain. But the bricks do not dry so fast as in open yards, and therefore more room is needed for a yard of the same capacity.

With pallet dryers the bricks are dumped as they come from the machine directly on pallets, which are pieces of board long enough to hold six bricks, and which are placed on racks or cribs until the bricks are sufficiently dry to be set in the kiln. The bricks must be molded stiff enough to retain their shape, as they cannot be spadded, and this stiffer molding involves the use of stronger machinery, which presses the brick more tightly into the mold, and consequently a sand which permits the bricks to slip easily from the mold is needed. The capacity of the yard is increased, and the bricks, though drying slower, are not subjected to a sudden drying action as in the sun of a hot summer's day, which may warp or crack them. Furthermore, they are subjected to only one handling between the machine and the kiln. Some manufacturers claim that a pallet dryer decreases the cost of production greatly, but they have not produced figures to substantiate their statement.

With tunnel dryers the bricks when molded are piled on cars, which are run into hot ovens or tunnels. If soft-mud bricks are dried in this manner, the cars must have pallet racks to carry the bricks. The tunnels are built of brick or wood, five feet high and four feet wide. Several methods are used to heat them. There may be a fireplace at one end and a system of flues or steam pipes underneath the floor; exhaust steam is used during the daytime and lime steam at night ; a hot blast may be used ; or hot air heated by steam-pipes may be drawn through the tunnels by means of a fan, though in most instances only the natural draft is required. Six or more tunnels are generally built in a set, and drying takes from twenty-four to thirty-six hours. The green brick are put in the end nearest the machine, and drawn out at the opposite end. With flue dryers the cost is claimed to be 25% per 1000 with coal at $2.50 per ton.

Burning is one of the most important steps in the whole process of manufacture. Three-quarters of the manufacturers who make bricks by the soft-mud process burn them in temporary up-draft kilns, or "scove kilns," as they are called, and the others generally use an up-draft kiln which differs from the preceding in having permanent walls, and some few prefer down-draft kilns. The following description of the burning applies directly to scove kilns; but the principle, whether it be applied in a temporary or a stationary up-draft kiln, is practically the same.

When the bricks are thoroughly dry, they are set up in arches, each of which contains from 35,000 to 40,000 bricks, and is about forty courses high. About fifteen arches make up a kiln. The open portion of the arch is fourteen courses high, and the bricks above it are set three one way and then three on top at right angles, kept slightly separated by putting small lumps of clay between them. The first row of brick on top of the arch is called the tie-course, and the first fourteen arches above the arch, including the tie-course, are called the "lower bench," while the rest of the courses above are called the "upper bench." When the arch and upper and lower benches have been set, a layer of brick, called the "raw platting," is laid flat over the top of the kiln, and on top of this is put a course of burnt bricks at right angles, which is called the "burnt platting." Hanging from the roof of the kiln shed and at the same level are a number of bricks, which serve as a guide for the height of the kiln. A wall of two thicknesses of burnt brick is put around the outside of the kiln, and is daubed over with mud to prevent the entrance of air except through the doors, which consist of iron frames fourteen inches high, with a plate to close the opening. They are set in the courses of double-coal brick, at the bottom of the arches on both sides of the kiln. Double-coal brick contains six or seven times as much coal as the others to supply the necessary amount of heat to the outer portions of the kiln which do not receive sufficient heat from the arch fires. These bricks bear some distinguishing mark, and sell for about $2 per 1000, because they are not as strong as other brick. It takes two setters and four wheelers about one day to erect an arch of 35,000 brick. Two men can daub the outside of a fifteen-arch kiln in one day.

Having walled up the kiln, the next step is to start the fires with coal, wood, or oil fuel. After every alternate brick of the burnt platting is stood on end to allow the "water-smoke," or steam, to escape as quickly as possible, a fire is started in the mouth of each arch, on the windward side of the kiln, so as to allow the smoke to blow through the arches. A fire is next started in the other end of the arch, and the two fires are built up slowly until they meet in the middle. The time of crossing the fires varies, being longer with machine-made than with hand-made bricks. Along the Hudson River the time of crossing is from forty to sixty hours. The steam should escape evenly from every part of the roof, and the upper limit of the fire should follow directly after the steam, the latter acting as a blanket. It is the duty of the foreman to watch the burning carefully, and increase or reduce the fire in each arch according as the steam is coming off too rapidly or too slowly, the water-smoke being maintained at a bluish-black color when flames issuing from the top of the kiln may be seen in the night-time. When the kiln is hot the bricks commence to shrink or settle, and all the platting is turned down, but up to this point care must be used to increase the heat gradually. The bricks now get their heaviest heat, and become red by the oxides of iron being changed to the anhydrous peroxide. But if the heat in the arches is too great, they run, stick together, or become distorted and cracked. After the firing is done the doors are closed and plastered over to prevent air from entering. If the bricks are put into the kiln before they are sufficiently dried, or if they are heated too quickly, they are very apt to "check" or crack. Where coal firing is used the grates have to be put in a few inches above the level of the floor, and with oil special burners are needed.

Particles of lime cause a splitting of the brick by subsequent slacking. Imperfectly burnt bricks are called "pale" and sell for about $3.50 per 1000.

The cost of burning with wood is 60 @ 75c. per 1000 brick, and with coal 40 @ 60c. per 1000. Oil is a few cents cheaper, but involves a greater first cost for plant. The heat can probably be better regulated with coal or oil than with wood, and those manufacturers using it claim that the amount of pale brick produced is a half less than with wood firing. Crude oil is used by comparatively few manufacturers, though it is clean, convenient, economical, burns quicker, and is more easily controlled than any other fuel.

In permanent kilns it takes less time to set the brick, and one man is supposed to attend three arches while burning, which takes from seven to ten days. Continuous kilns are of very recent introduction. It is claimed that with them one ton of coal slack burns from 15,000 to 20,000 brick. Down-draft kilns are much used at the present day for burning brick. They are either rectangular or round. Burning is usually done with coal, but natural gas and oil have been tried with great success.

Repressed Brick.—The brick made by the stiff-mud or soft-mud process are often repressed, to give them a new shape, a smooth or ornamental surface, and additional strength. These machines are run by steam or hand power, one or two bricks being repressed at a time, or from 1000 to 1200 in ten hours. According to Mr. E. Orton, Jr., three men, at $3.75 per day, can repress 20,000 brick per day, which is less than 2c. per 1000.

Cost of Production.—This varies much, depending on many conditions, such as the method of manufacture employed, cost of labor, locality, etc. By hand-power the cost of production is $3.75@$4 per 1000 brick, delivered at the yard. On Long Island, where the soft-mud process is almost exclusively used, it is $3 per 1000, delivered at the yard, while in the Hudson Valley it is claimed to be $5 per 1000, delivered in New York City, which figure includes $1.25 per 1000 for transportation and 25c. per 1000 commission. The brickyard is generally owned by the manufacturer, but the clay is worked on one of the following bases: (1) The manufacturer owns the bank, which is by far the best arrangement; (2) the brickmaker pays a certain rental, usually 9% or 10% of his profits; (3) the owner of the clay bank gets a royalty of from 25c. to $1.25 per 1000 on the brick sold. Of the three methods of manufacturing, the soft-mud process requires the least expensive plant, but it is more costly than the others to operate, more labor being used. The stiff-mud method is claimed by some to be cheaper than the dry-clay method, on account of the shortness of the time required for burning and the less consumption of fuel. With the soft-mud process one man is needed for each 1000 brick produced per day, and a further economy can be made by the use of labor-saving machinery for hauling. A saving of 30c. per 1000 can usually be made by burning coal instead of wood, and gas is considered about 25c. cheaper per 1000 than coal.

In Ohio under favorable circumstances the cost of production is about $4 per 1000; paving blocks can be produced probably for $7 per 1000.

DRAIN TILE.

Clay that will make good building brick will in most cases make good drain tile, which may be somewhat porous. It is of importance that the clay should be thoroughly tempered before molding, and this is usually done in a stiff-mud machine, from which it is forced out through a die of the desired size and shape, and is cut into proper lengths as it issues from the machine. Drying is sometimes done on pallets such as are used for common brick, or it may be performed in inclosed sheds or in tunnels. The tile should be thoroughly dry before setting in the kiln. It is burned in clamps or down-draft kilns, the smaller tiles being set in the lower portions of the kiln and around the sides, and the larger ones in the center. Very often when several sizes are burned at the same time they are nested, or placed one inside another.

The following styles of drain tile are made: Horseshoe tile, having a horseshoe-shaped cross-section; sole tile, cylindrical with a flat base; pipe tile, cylindrical; and flange tile, like the preceding, but with a flange at one end. It is considered by many that the best form is the sole tile, having an oval section, placed with the smaller end at the bottom, thereby keeping the water collected in the smallest possible space and securing a good current to carry off the sediment. The horseshoe tile is objected to, as it is likely to break from the lateral pressure of the soil. In Westchester County glazed sewer pipe is generally used for draining the soil, but it is doubtful if there is enough advantage in its use to warrant the extra expense. Drain tiles range in size from 2 to 12 in. in diameter, and from 1 to 3 ft. in length.

Firebrick and Refractory Ware.

The firebrick manufacture is not so prosperous as formerly, which is due to various causes, among which are that firebrick made in England are brought to this country as ballast, and sell for $9 per 1000, a figure with which home manufacturers find it hard to compete, the decrease in the number of iron furnaces in blast, and the introduction of new refractory materials.

The most important and best known deposits of clay used for firebrick are in New Jersey, and there are large factories at Woodbridge, Perth Amboy, and Sayresville. Firebrick of excellent quality is also made from the coal measure clays at Sciotoville and Mineral Point, Ohio, and at St. Louis, Mo. In New England firebrick is made at Boston and Bridgeport; at the latter locality stove linings are also made. On Staten Island, N. Y., firebrick and gas-retorts are made from Cretaceous clays, while at Troy, N. Y., the New Jersey clays are employed. In Pennsylvania the firebrick manufacture is an extensive industry, the chief centers being Pittsburg, Farrandsville, and Beaver Falls. The Cretaceous clays of Alabama are made into firebrick at Birmingham, Anniston, Bibbville, and Bessemer, but the works at the last two localities were the only ones in that State in operation in 1893. At Cleveland, Tenn., refractory materials have been made since 1886, and at Chattanooga firebrick is made from one of the largest deposits in the South. Firebrick is made from clays of the timber-belt bed at Athens, Texas, and used in the iron furnaces. Golden, Colo., is also an important producer of a high-grade firebrick, and a few are made at Lincoln, Cal. According to the secretary of the Firebrick Manufacturers' Association, there are 300 firebrick factories in the United States.

A fire clay to be refractory should not contain over four per cent. of impurities. The plastic and flint clays are usually mixed in equal proportion. The former generally make a brick of greater toughness, and the latter a more refractory one. Fire clays vary in color from black to gray, red, green, blue, and white. The color is not a proof of quality, for a pure white clay may owe its color to lime, and would not be refractory. Many clays are soft and can be dug with pick and shovel, while others occur in the form of shale and require blasting.

Fire ware must be able to withstand great and sudden changes of temperature, and should resist intense heat without shrinkage or fusion and the corrosion of fused mineral substances. Coarse-grained ware resists a high temperature, but the fine-grained ware withstands corrosion better. The porosity of a firebrick is often caused by the coarseness of the component grains of sand, and may be remedied by the addition of ground burnt clay, or "cement clay," as it is called; while if the material contains an excess of alumina, ground quartz is added. A preliminary washing of the clay is often necessary. The quality of the product depends on the correct preparation and proper mixing of several varieties of fireclay; consequently the proportions of the different clays used is generally kept a secret by the manufacturer.

Weathering the clay often lasts several months, and it is generally necessary to break it up and lessen its shrinkage in burning. The percentage of injurious substances is also lessened by leaching. Some manufacturers temper the clay in a dry-pan and pug-mill, others use dry-pan and wet-pan, and still others a wet-pan alone. As a further step toward the production of a homogeneous brick, it is first passed between rollers to break it up, and is then put into a ring-pit, after which the material is soaked for a few hours in a wooden pit with the addition of other grades of clay and sometimes of sand, and is then transferred to a pug-mill for further tempering, after which it is ready for molding. This order is often changed to suit the nature of the clay, so that no fixed rules for treatment can be laid down. Molding is done by hand in wooden molds to bring the lump of tempered clay into a convenient and approximately rectangular form before repressing it, though at some works the brick receives its total compression and shaping in one operation; in any case, the molded bricks are spread out on a drying floor of brick, heated by flues passing beneath it, or, after repressing, the bricks are transferred to tunnel dryers, where they are left for a day or more, and in the case of crucibles or glass-pots for weeks. In some New Jersey works the brick is molded in stiff-mud machines.

Burning is done generally in circular or rectangular down-draft kilns, though a few manufacturers still use the old-fashioned up-draft kilns. The circular kilns are 15 ft. in height and 20 to 30 ft. in diameter, and the burning takes five or six days, and cooling, which has to be done very slowly, several days more. The kiln has two openings, and while the burned bricks are being taken out of one door the green ones are carried in through the other and set up for burning.

Glass Pots.—The manufacture of glass pots is one of the highest branches of the refractory material business, since they not only have to stand a high degree of heat, but are also subjected to the corrosive action of the ingredients of molten glass. Only the best grades of clay can be used for this purpose, the greater part coming from Missouri and Germany, though Ohio and New Jersey furnish a small quantity. The clay is carefully broken up before use and all impurities are carefully separated. Calcined flint clay and thoroughly cleaned old pot shells are then mixed in, and the whole is ground in a dry-pan and subjected to successive temperings in a pug-mill, after which it is piled up and allowed to sweat, sometimes for two years. The pots are built by hand, piece after piece being added, so that it takes a month or six weeks to complete one, but each workman can have twenty or thirty under way at the same time. They are dried in tight rooms, and subsequently further dried in air. No heat is applied until they are in position in the glass furnace, when they are gradually warmed up and not allowed to cool until the campaign is ended. A new departure in glass-making is the use of iron tank furnaces, lined with blocks of refractory clay, some of which weigh 800 or 1000 lbs.

Pottery and Porcelain.—Although the commoner grades of earthenware and stoneware were manufactured in this country in early times, the production of fine china and porcelain is of comparatively recent development. Pottery and tobacco pipes were made at Philadelphia in 1690. China manufacture was attempted in South Carolina as early as 1765, and soon afterward in Philadelphia, but for financial reasons and lack of knowledge it was not successful. A stoneware pottery was erected in 1735 behind the old City Hall in New York, but did not remain long in operation. The business was begun again in 1820, but shortly after this the works were transferred to Philadelphia, where they are still in operation. In the same year a stoneware factory was opened at Sayresville, N. J. Earthenware was made at Norwich, Conn., and at Bennington, Vt., in 1794, the latter pottery becoming subsequently one of the important works of the country, and producing some fine examples of parian ware. At present it is not in operation.

Potteries making common earthenware and stoneware are now found in nearly every State, but the great centers of the china and porcelain industry are at Trenton, N. J., and East Liverpool, Ohio. The first yellow or Rockingham ware was made at the latter place in 1838, but now the products include white granite ware, china, ironstone china, decorated tableware, and toilet sets. There are twenty-nine potteries, nine decorating works, two stilt and triangle factories, one sagger factory, and three doorknob works in the place.

Pottery works were established at Trenton in 1852, and there are now thirty-seven establishments whose yearly production is valued at $4,000,000 to $5,000,000. All grades of ware are made, from common pottery to majolica and fine porcelain.

At Cincinnati, Ohio, are the celebrated Rookwood potteries, whose product is a true faience. Art pottery is made at Cambridge, Mass., the product including vases, pedestals, and similar wares. At Baltimore, Md., parian and majolica ware are produced, the latter pronounced by many to be equal to the famous Wedgwood ware of the same grade. Clay pipes are made at numerous localities, among them being St. Louis, Mo.; Fulton, Ill.; and in Virginia and New Jersey.

Earthenware.—This class of pottery embraces the commonest forms of porous ware, such as flower pots, and is made at a lower heat than stoneware. Any plastic clay of suitable color can be utilized, but the choice depends on the color of the ware to be produced, a mixture being sometimes employed. The process of molding is the same as in the case of stoneware. The clay is sometimes washed, especially if using a mixture, as it appears to decrease the porosity, and is easier to work on a jolly-wheel. For burning earthenware several types of kilns are used. One Ohio manufacturer has a double-decked form, the lower chamber for burning stoneware, while flower pots are burned in the upper story by the waste heat from below.

Stoneware is made from a natural clay, and the burning and glazing are done in one operation. A vitrified body and the use of a glaze distinguish it from earthenware, while it differs from Rockingham ware in having only one stage of burning. The requisites of a stoneware clay are that it must be plastic, so it can be spun or molded into any desired shape without the use of much power; it must be refractory enough to stand up well and keep its shape at the heat necessary to melt the glaze (at this latter temperature it should also undergo a vitrification which will make the body impervious to moisture, and while undergoing this change it must keep its shape) ; when burnt in an oxidizing atmosphere it must be of a clear, uniform tint, yellow to buff if soft burnt, and blue to gray if hard, and it should not blister, or show any blemishes on its surface after burning.

Clay for making stoneware is prepared either by grinding or washing, the process used being determined by the kind of ware to be made. Much more care is exercised in the preparation of clays abroad than here. Weathering slacks the clay to a fine state of division, and greatly lessens the subsequent labor of the machine. The grading process is the standard method of preparation. A simple device used for this purpose in Ohio is a circular trough about 12 ft. wide and 12 in. deep. Wheels with iron tires and heavy weights on their axles revolve in this and sink into the clay. A machine largely used is the "tracer," or "chasing-mill," which consists essentially of a circular iron pan, in which revolves a horizontal oblong frame, carrying heavy iron wheels about 36 in. diameter and 6 in. face. This frame is continuously rotated by a vertical shaft with a large overhead gear, while the wheels work slowly from the circumference to the center of the pan and return. A charge of clay consists of from 1000 to 2000 lbs., which is ground, with the addition of water, in from one to two hours. Much power is required, but the clay is thoroughly tempered. Some works use the ordinary wet-pans, such as are employed in the manufacture of sewer pipe or paving brick, the cost being about the same and the work accomplished in a shorter time. There is an objection to this in the frequent wetting which the clay requires, and that in the removal of the tempered material it is not done all at once, so the portion last removed has received more temper than the rest. One wet-pan has about the capacity of three tracers.

Washing clay is a recent innovation. The earliest attempts consisted in simply boiling the clay in iron pans, but in the present practice the clay is reduced to a slip in a "blunger," which is a vat of wood or iron, containing an upright revolving shaft bearing blades which knead the clay to a pulp. Sometimes two shafts are so placed that the circles of revolution of their blades overlap. From the blunger the slip passes to rectangular screens of 40-mesh wire cloth, which are shaken rapidly. The fine clay and water run through to the "agitator," while the coarse particles are retained. The agitator is similar to the blunger, but has a much greater capacity, its function being to keep the clay from settling. From here the slip is removed by pressure pumps, some of which are connected with air-compressors, and work at a pressure of 125 to 150 lbs., and passes into a strong tank from which it is forced by air pressure into the "press." This consists of a series of iron or wooden frames suspended on iron sidebars and covered with duck. Through the center of each is a hole also lined with duck. When the press is ready for use it is closed, the frames being set close against each other by means of a screw, the canvas between the edges of the frames making a gasket joint while the holes in the center coincide, so that between the canvas of each two frames there exists a duck-lined cavity, communicating by a central hole with the chamber on either side of it. When the slip is pumped in, it fills these cavities, and the water passes out through the canvas, leaving the clay behind. When the cavities are full and no more slip can be pumped, the operation is complete. The clay is then removed in sheets one to two inches thick, each weighing 30 to 40 lbs. After this it is tempered in the ordinary pug-mill. The cost of the machinery for such a plant is from $1000 to $1500.

Some manufacturers use steam to assist in disintegrating clay in the blunger, as warm water acts quickly and the material filters faster. The washed clay is fine and even in its structure, and free from soluble salts. Washed clay, on account of its fine grain, is not considered so safe as unwashed, and is liable to check in cooling, but for jolly-work it is preferable to turned clay. According to experiments made by the Ohio Geological Survey, all the alkalies are not removed by washing, probably because present as insoluble silicates. Ground clay has a certain toughness and strength which washing destroys, and is therefore better for turning or spinning; though as it is no purer than raw clay, it fuses as readily in the kiln. The cost of washing enough clay for a day's work of a 72-leaved press (14,000 lbs.) is 36c. per ton, 50c. per ton being about the average price for a charge of 2000 lbs. The cost of grinding 1200 lbs. is about 30c. per ton.

The manufacture of pottery embraces the following methods: 1. Turning. 2. Jollying in molds. 3. Casting. These processes are common to all branches of pottery-making. Ten years ago nearly all the stoneware made was turned, but at present about 50% of it is jollied, as the old process involves wedging, turning, and drying. Wedging consists in taking a lump of clay of sufficient size to make the desired article and alternately cutting it in two and reuniting the halves, the object being to remove all air-blebs and to increase the density. Turning is done by placing the clay on a rapidly revolving disk, wetting it, covering with a fine pulp of clay, and then shaping with the hands as the mass turns. In Ohio the turner works by a standard, called a day's work, which represents a certain number of gallons. After turning, the ware is set on shelves for twenty-four hours and then goes to the drying room. In jollying, the clay is tempered to a soft pulp, and poured into a mold which fits on a rapidly revolving wheel. The jolly-man with his hands makes the clay cover the inside of the mold evenly, and then a pivoted arm bearing a scraper or shoe is brought down to give it the exact inside shape of the article to be molded. Jugs and bottles are made in two parts and cemented before dry. The mold is set in the drying room, which is heated by steam, and as the moisture evaporates from the piece of ware it shrinks and is easily removed. It is then trimmed and smoothed. A jolly-man is paid by the amount of finished product. Casting consists in pouring a slip or paste into a dry, porous mold which absorbs the water and deposits the clay. After the operation has gone on long enough to deposit the required thickness of clay in the mold, the latter is inverted and the remaining slip poured out.

The mold is then dried in hot closets and taken apart in two or more pieces while the casting remains. This process is adapted to high-grade wares.

Slip clay is a natural glaze used to coat stoneware. One of the best in the country is the Albany slip, which is said to neither crack nor craze. The fusibility of slip clays is usually lowered by the addition of lead or borax, but this does not improve their quality. The color to which slip clays burn depends upon the heat, and it is possible to produce varying colors by a mixture of different clays, or the addition of fluxes. Formerly all ware was glazed with salt, but carbonate and sulphate of lime, which are common in clays, often interfered. In drying, these substances were apt to be brought to the surface and form a film which would prevent the salt vapors from getting at the silica of the clay. The action was therefore mechanical and not chemical. If the temperature be carried high enough to decompose the lime salts and cause them to form a lime soda silicate, a greenish color results, and coloration due to iron often shows, though some manufacturers add manganese to the salt to prevent this. A few manufacturers put on a slip of china clay first, and over this the salt glaze, producing a ware which has a high reputation, but is quite costly, since the slip clay alone costs $6 to $15 per ton at the mine in New Jersey.

In setting ware for burning, it must be placed firmly in the kiln, but not too close, setting the largest and heaviest pieces in the middle farthest from the admission of the fires. Burning takes from 24 to 90 hours. At Akron the average time is 55 hours, and at Zanesville 30. About half the time is spent in warming the kiln and bringing the ware to a dull red. After this, burning can be pushed rapidly. According to determinations by Mr. Orton with a lunette pyrometer, the temperature at the height of burning varies from 1850 to 1900°.

The chief types of kilns in use are the Akron square kiln, round down-draft kiln, and the muffle up-draft kiln. The first is of rectangular form, about 15 ft. wide by 30 ft. long, with an arched roof. The kiln is fired at the ends by two or more fire holes, which open into a combustion chamber, which is intended to assist the combustion and prevent reducing action. The kiln floor is checker work, to permit the escape of the gases to the flues connecting with the chimney. This kiln is well adapted to burning large wares, being easy to set and draw and compact in form, but the first cost is high, the heat irregularly distributed, and the consumption of fuel large. Round down-draft kilns, which are much used, vary in diameter from 16 to 25 ft., the latter having a capacity of about 12,000 gallons. The floor of the kiln is above the level of the yard, and by this construction requires less draft and burns less coal, while the first cost is low and the heat evenly distributed. On the other hand, it occupies considerable room, is easy to smother, and hard to set and draw. The muffle up-draft kiln consists of a circular bench containing the fireplaces, which are equally spaced around the center, and deliver their heat to an inside pocket and a central stack. The kiln proper is built on the fire bench, and is round, tapering to a small diameter 25 ft. above the floor. A perforated arched crown is sprung across the inside at a height of 8 ft., and the bags come to within a foot or so of it, while the stack runs up through the center of the kiln. These kilns heat and cool slowly and show but little reducing action, so they are especially adapted for burning slip-glazed ware. Such a kiln holds 6000 gallons of closely nested ware and costs

$1000 to $1350. It consumes more fuel than a down-draft kiln, but has an advantage in safety in burning. Old-fashioned up-draft kilns are going out of use, and are used only by small potteries.

Cooling and annealing, which offer no especial difficulties, take two to three days, according to the weather. The critical point in cooling is when the ware is at a black heat, just below redness. Every air inlet in the bottom of the kiln is then shut tight and daubed with mud, while the vent-holes in the crown are opened, so that what little draft gets into the kiln passes upward.

The following figures represent the cost of production in Ohio: Clay, 51c. per 100 gallons; fuel, 46c.; pottery work, $1; common labor, 91c.; office supplies and contingent expenses, 42c.—total, $3.30. The average selling price is $4 per 100 gallons.

Yellow or Rockingham ware, made of a natural clay, goes through two stages of burning, and thereby differs from stoneware. The glaze is composed largely of lead oxide. Clays for yellow ware should be very plastic, smooth, pure potters' clays, containing enough iron to give a fair color, but it need not be very refractory, as the heat used in glazing is low. The preparation of the clay is of more importance than in stoneware, and is done by washing, in the manner previously described, except that 60 to 100 mesh screens are used. The regulation up-draft muffle kilns and sometimes double-decked ones are used for burning small ware; white or C.C. ware being burned in the lower story, while the yellow ware gets its first or biscuit burning in the upper. While there is a saving in cost by this method, the heat must be regulated to favor one kind of ware to the detriment of the other. According to measurements made by Mr. Orton with a lunette pyrometer, the temperature at the top of the peep-hole was 1710° and at the bottom 1680°, which is about 175° cooler than stoneware kilns. After coming from the biscuit kiln the ware is cleaned, inspected, and glazed. The glazes are composed of litharge, flint, feldspar, paris white, and some white clay ground to a slip and applied in that form. The ware is again put in saggers, the pieces being separated by stilts made of refractory clay, so that only about one-third as much can be put in as was in the biscuit kiln.

C.C. ware, white granite, and china cannot be made from a natural clay, so an artificial mixture is compounded. This is usually composed of kaolin for the body, ball-clays to give plasticity, silica to counteract shrinkage, and feldspar as a flux. Each potter has his own recipe for the mixture, and the proportions are kept secret.

C.C., cream colored or common clay wares are a low grade of white pottery, the same materials being used but of inferior quality. White granite stone china, or ironstone china, calls for the best materials. Cobalt is added to counteract the yellow of the iron, thus producing a greenish tint. The body of white granite is not intended to be vitrified. China is more vitrified in its nature, and if thin is translucent. The vitrifaction of the body is accomplished by the use of more fluxes. When fluxed by feldspar the ware is termed "spar china," and shows a yellowish color by transmitted light. When part of the feldspar is replaced by bone-ash the ware is termed "bone china." The body is prepared in blungers and the slip run through 100 to 160 mesh silk or brass cloth screens. The operations of pressing and pugging are similar to those in stoneware manufacture, but the burning is done in saggers glazed inside. The heat required varies with the ware. Mr. Orton gives the following figures:

	Top of Kiln.	Bottom of Kiln.	Average.
C.C. ware	1930°	1950°	1940°
White granite....	2160	2010	2085

The composition and adjustment of the glazes require great care and skill on the part of the potter, and bad work will be quickly indicated by the ware cracking. For white-ware "fret-glazes" are used, the constituents being weighed out, mixed, and melted in a sagger. After cooling, other material is added, and the whole ground to extreme fineness in a mill lined with French buhrstone, and colored by metallic oxides. In burning in the glost-kilns it is of the utmost importance to have the saggers tightly closed in order to prevent the admission of sulphurous gases from the fires.

Decoration of Ornamental Pottery.—Pottery and porcelain are decorated either over or under the glaze. In over-glaze decoration fusible colors are applied to the glazed surface of the finished ware, and are fixed at a comparatively low temperature in the enameling kiln, which does not injure or destroy them. In under-glaze decoration the colors are placed on the ware, either in the "green" or unfired state, or on the "biscuit" before it is glazed, and must be subjected to a heat sufficiently intense to fuse the glaze which is afterward applied. The colors which will stand this great heat are limited in number and are likely to change in the kiln; consequently the manipulation of the under-glaze colors requires much experience and skill in order to produce satisfactory results. Decorations are either painted by hand or printed, the latter process being much used at the present day. Hand coloring, or gold lines, are often applied over the printed design. The raised gold work seen on many wares is produced by tracing a design with a yellow paste on the glazed ware to give the relief. This is then fired in the decorating kiln, and afterward covered with either bright or dull gold, and fired again. Majolica ware is decorated by applying colors mixed with the glaze, either with a brush or by dipping, or by both methods. As the colors are soft, they blend easily at a temperature somewhat higher than the usual enamel or over-glaze heat, and produce very beautiful effects.

Among the other wares which are manufactured in the United States is faience, which is a collective name for the various kinds of glazed earthenware and porcelain, such as the under-glaze ware made at the Rookwood pottery, the faience of Chelsea, Mass., and the Lonhuda ware of Steubenville, Ohio. There is also produced in this country an excellent quality of belleck, or thin porcelain, noted for its great thinness, light weight, and variously tinted pearly glaze. Its body is similar to parian ware, which is a fine grade of porcelain, usually unglazed, with a surface resembling ivory-tinted marble. It is found in the island of Paros.

Sewer Pipe.—The clays required for sewer pipe are such as will vitrify, and are prepared in the same manner as in brick manufacture, but much more thoroughly. The molding is done in the sewer-pipe press, which consists of two vertical cylinders separated by a heavy cast-iron frame; the upper being the steam cylinder, with a diameter, usually, of 40 in. The clay cylinders are made up to 24-in. diameter. The piston is moved both upward and downward by the steam. The clay cylinder is filled when the piston is at the top of its stroke. Inside this cylinder, at its lower end, is the "bell" which regulates the interior size of the pipe. As it issues from the press the pipe is received on a pallet and carried to the drying floor. Seven men are required to operate the press and carry away the pipes. In drying, the pipes are placed upon a warm floor and the process carried on very slowly to prevent cracking. Burning is usually done in round down-draft kilns, and requires from five to seven days. The glaze is obtained by putting salt in the fire-holes, whence it volatilizes and combines with the silica in the clay. The operation requires from one to two hours, the following reactions taking place: $NaCl + H_2O = HCl + NaOH$; $2NaOH + nSiO_2 = NaO_2nSiO_2 + H_2O$.

Manufacture of Terra Cotta.—The name terra cotta is usually given to clay products of an ornamental character which are used in connection with brickwork for interior or exterior decoration. The material is generally red, but other colors are also produced, which are due to either the composition of the clay or the addition of some foreign matter.

Terra cotta in most instances can be made from any clay that will make a good strong brick of regular shape. Following are some analyses of clays used for this purpose:

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alkalies.	H_2O.	TiO_2.	Organic Matter.
Bluish-gray clay, Glens Falls, N. Y.	48.35%	11.33%	4.02%	15.38%	3.17%	6.05%	....	....	1.18%
Red clay, same locality.............	57.46	21.15	5.52	3.65	1.50	4.72	....	....	....
Shale, Alfred Centre, New York....	53.20	23.25	10.90	1.01	0.62	2.70	6.39%	.910%	....
Shale, New Brighton, Penn....... .	67.78	16.29	4.57	0.60	.752	2.00	6.34	.780	....

In order to produce good terra cotta the clay should shrink evenly in burning, and not over one inch per foot. It should burn to a hard product of even color, and should not contain an excess of soluble salts, which would cause it to "whitewash."

The shrinkage can be regulated by the addition of "grog" (powdered brick or terra cotta). Clays which are too sandy are washed by dumping them into a circular trough filled with water, in which revolve paddles attached to a vertical axis. The material is thus stirred and the clay suspended in the water is carried to settling vats while the sand remains behind. Weathering improves many terra-cotta clays, while others can be pugged directly upon being brought from the bank. Sometimes two or more kinds are mixed, the proportion being determined by experiment and usually kept secret by the manufacturer. When mixing is done it is important that the clays should be thoroughly ground and pugged, and the same thing is necessary when producing large ware or more intricate designs. After thorough pugging the mass should be piled up and allowed to "cure," or settle by its own weight, becoming denser, while the excess of water evaporates. Some manufacturers give the clay a further working over to expel as much of the contained air as possible.

Molding is done either by machines or by hand, the former method being used for simple forms and the latter for more elaborate designs. Hand molding or modeling is slow and difficult, and requires care. Plaster molds are used, and the forms are allowed to remain in them until they have dried and shrunk sufficiently to allow removal. If the design is intricate, the mold is made in sections. The surface of the molded article is finally trimmed and smoothed before drying and burning. Large pieces of terra cotta are made hollow, with cross partitions for rigidity, a thickness of two inches usually being sufficient for the largest pieces. Occasionally the ware is glazed by means of either salt or slip-clay.

Burning is done in down-draft kilns and takes seven to nine days. The kilns are conical or dome-shaped, lined with firebrick, and banded on the outside with iron. The side flues connect with a chimney in the center, and are sometimes so arranged that the flames do not come in contact with the ware, avoiding discoloration by gases from the fuel, though this precaution is not always necessary. Small articles are burned in saggers. The kiln has to be fired very cautiously at first to prevent the ware from cracking. The heat within is regulated by means of dampers on the roof and sides, and large lumps of clay are placed just inside the doors of the kiln to serve as tests. As a rule coal is the fuel used, but some firms have adopted oil as being cheaper and easier to regulate.

Roofing Tiles.—These are made from clay or shale, or a mixture of both. In either case the material is thoroughly worked in a stiff-mud machine, which forces it out of an opening of such size or shape as may be desired. It is then cut into slabs and repressed by hand or steam power to the shape required, a hand-power repress having a daily capacity of about 1500 slabs. After being thoroughly dried, the tiles are set on edge in saggers and burned for about seven days.

Encaustic tiles for flooring or interior decoration are made either of one color or a pattern of several colors, and may or may not be enameled. The process of manufacture consists, essentially, in grinding the clay mixture in a slip vat, washing, and drying. It is then mixed with sufficient water to make it plastic, pressed to remove any surplus, again dried and powdered, and this product compressed by hand-power machines into a mold of the desired shape. If the surface is smooth it is wiped with a blanket, and the tiles, with flint or quartz to keep them from sticking together, are carefully packed in saggers and placed in the biscuit kiln to receive their first burning. Upon coming out of this they are carefully examined, the edges trimmed, and transferred to the glaze room, where the face is dipped into bowls of the slip, care being taken to keep it from the sides. They are then set on racks and allowed to dry before receiving the final burning, which requires about thirty hours.

Massachusetts.—Clays suitable for brick and tile are common, large quantities being produced near Boston and Taunton. Higher grades of clay products are also manufactured, but the clay used is obtained chiefly from New Jersey and Long Island, though there is a large bed of high-grade kaolin at Blanford which is used at East Russell in the manufacture of terra cotta. Slip-decorated ware is manufactured at North Cambridge, and at Watertown works which have been in operation since 1765 produce art pottery, vases, and pedestals. At Chelsea art tiles are made, and at Boston there are extensive terra cotta, fireproofing, and firebrick works. The Labor Bureau of Massachusetts gives the following statistics concerning the clay industry in that State: In 1891 there were 46 establishments manufacturing bricks, tiles, and sewer pipe. The capital invested was $1,556,345; value of stock used, $431,631 ; value of goods made, $1,498,114. In 1892 there were 46 establishments representing $1,662,676 capital, $408,766 value of stock used, $1,478,979 value of product. The stock used was as follows : In 1891, clay,

$85,346; coal, $39,209; coal dust, $3220; wood, $166,167; not classified, $137,689. In 1892, clay, $73,531; coal, $28,645; coal dust, $2516; wood, $154,958; not classified, $149,116. The product was as follows: In 1891, common brick, $703,581; face brick, $58,751; firebrick, $201,290; not classified, $534,492. In 1892, common brick, $670,937; face brick, $57,345; firebrick, $212,225; not classified, $538,472. Average values per ton: 1891, clay, $1.91; coal, $4.16; coal dust, $2.50; wood, per cord, $3.94. In 1892, clay, $1.80; coal, $3.92; coal dust, $2.13; wood, per cord, $3.94. Value of product, per thousand, 1891, common brick, $6.08; face brick, $14.88; firebrick, $40.13. In 1892, common brick, $6.13; face brick, $14.88; firebrick, $52.50. In 1891 there were 7 establishments producing cement, kaolin, lime, and plaster, representing $113,566 capital, using $118,393 of raw material, and product valued at $171,081. In 1892 there were the same number of establishments; but the capital invested was $90,300, value of raw material $167,540, and value of product $239,886. In 1891 6 establishments produced earthen, plaster, and stoneware, the capital invested being $345,000, value of raw material $99,135, and value of product $381,572. In 1892 the capital invested was $383,000, value of raw material $88,669, and value of product $336,787.

New Hampshire.—The clay resources of this State, which are not extensive, have been described by Professors Hitchcock and Upham in a very complete report upon the subject. The center of the brickmaking industry is in the Merrimack Valley, the drift clays being largely used for this purpose.

Maine.—Brick clays occur in the valleys of the principal streams.

Rhode Island.—Bricks are manufactured in several localities. On Block Island cretaceous clays are found.

Connecticut.—Alluvial clays of Quaternary age are abundant in all the valleys, resembling in character those of the Hudson Valley and northern New Jersey, and forming the basis of an extensive brick industry. While there are factories in this State which produce the higher grades of clay products, the materials used are nearly all obtained from other States. Stoneware and stove linings are made at Bridgeport from Long Island and New Jersey clays. Some of the feldspar mined in the State is utilized at Bridgeport in the manufacture of door-knobs. Architectural terra cotta is manufactured by two firms, one at New Britain and the other at Meriden, the two works producing annually about $75,000 of material.

Vermont.—Kaolin is said to occur at a number of localities, and firebrick and enameled ware have been made from it at Bennington, Brandon, and Monkton. A pottery was in operation for a number of years at Bennington and produced considerable quantities of parian ware. Brick clays are abundant all over the State, especially along Lake Champlain, and near Rutland a brickyard is in operation. Some of the clay found near Brandon and Monkton is used for paper filling.

Pennsylvania.—Of prime importance among the resources of Pennsylvania are her fire-clay deposits. These occur in the coal measures, and are found especially in the western portion of the State, many of the beds being persistent and occupying well-marked stratigraphical positions.

The Bolivar fire clay belongs to an extensive bed which occurs just under the Freeport Upper Coal measures. This deposit is of excellent quality and has been mined at many localities for firebrick, a typical one being at the east end of

Conemaugh Gap. Other exposures are in Wharton and Stewart townships, Fayette County; Ligonier Township, Westmoreland County; at many localities in Indiana County, and in Beaver County. An immense bed of clay averaging 10 ft. in thickness, lying immediately under the Kittanning coal, throughout Beaver County, is extensively used and produces a high-grade product. A bed of plastic clay usually underlies the Kittanning coal in Westmoreland County.

A third continuous bed occurring near the top of Conglomerate XII. is mined at Johnstown, Cambria County; Indiana County; and in Beaver County, under the Clarion coal. It also crops out under Bed A, at Sandy Ridge, Blue Ball, Woodland, and Hope Station in Clearfield County; Benezette, in Elk County; Brookville, Jefferson County; and at Queen's Run and Farrandsville. The bed averages four feet in thickness. Chester and Delaware counties produce large quantities of kaolin.

Brick clays are of common occurrence throughout the State, especially north of the terminal moraine. Much drift occurs in the valleys of the Ohio and Beaver rivers, and the terraces along these streams afford abundant clay materials, the fourth one especially being underlain by extensive deposits, which are much used at New Brighton for terra cotta, brick, and stoneware. The last product is also made from the Coal measure clays, and bears the reputation of being the best produced in the United States.

The clays of the Columbian formation, which are found around Philadelphia, have been used for years to make a high grade of repressed brick. One of the largest works in the country, having a yearly capacity of 60,000,000 brick, is situated here.

Some of the kaolin mined at Brandywine Summit is used to produce the face on enameled bricks made at Oaks, and feldspar mined at the same place is shipped to East Liverpool, Ohio, and Trenton, N. J. Encaustic tiles are made at Pittsburg and Beaver Falls. Blast-furnace brick, stove brick, and Bessemer tuyères, nozzles, and sleeves are manufactured at Pittsburg from the fire clay mined at Benezet, Blair County, while the hard clay at Arthur Station, Clarion County, is used in connection with soft clay from Missouri in the manufacture of furnace block, some weighing 600 to 800 lbs.

New Jersey.—The valuable clay deposits of this State have been described in detail in the *Report of the Geological Survey of New Jersey* for 1878. The clays are Quaternary and Cretaceous, the latter including beds of fire clay, fire sands, and kaolin, which extend across the State in a belt five to eight miles wide, from Perth Amboy to Trenton. The series is about 300 ft. thick, and the beds dip towards the southeast.

Three districts are recognized: 1. Middlesex County, from east of New Brunswick to Staten Island Sound and Raritan Bay. The northern limit is a line parallel to the Pennsylvania Railroad between New Brunswick and Rahway, while Chesquake Creek forms the southern boundary. The district covers about 68 sq. miles, and includes the Woodbridge and Perth Amboy beds. 2. This district is a continuation across the State of the first one, extending along the Delaware River from Trenton to Bordentown and southwest to Salem County, including Trenton, Florence, and the Pensauken Creek clays. 3. The third district includes more recent deposits south and southeast of the greensand marl belt.

The chief localities are Wheatland, the Union Clay Works in Ocean County, and Conrad's clay pits in Gloucester County. The formation has a decreasing dip to the southeast. In the Raritan clay beds the dip is 60 ft. per mile; in Woodbridge and South Amboy, 48 to 51 ft., and in the stoneware clay bed only 30 ft. Nearly all the strata produce refractory materials.

In this district the following beds are recognized: 1. Raritan potter's clay bed; the lowest member, which rests on Triassic shale and sandstone. This bed lacks the homogeneity of character which the upper ones have, but much of it is very white and resembles some of the Woodbridge fire clay, though it will not stand the fire. 2. Raritan fire-clay bed, which is separated from the Raritan potter's clay by a thin bed of lignitic sandy clay. It occurs at Woodbridge and near Bonhamtown, and is of a drab color, dense, and similar to clays used for glass pots and firebrick. 3. Fire sand is found above the fire clay, and consists of sharp angular grains of quartz sand, sometimes iron-stained. 4. The Woodbridge fire clay. This is the most important stratum. The upper and lower layers are rather sandy. The clay is usually a bluish white color. Pyrite nodules are sometimes present. 5. Pipe clay is found above the Woodbridge fire clay, and is of a darker color, sandy, and contains more potash. The percentage of iron in the red clay of this bed often runs up to 7. It is sometimes used for No. 2 firebrick, but more frequently for drain pipe, sewer pipe, and saggers. 6. Feldspar bed comes next above. According to Professor Cook, "the feldspar is more properly a kaolin, though not answering fully all the characters implied in that term. It is a mixture of a rich clay with white quartzose sand and fragments of quartz, nearly all of which are slightly rounded on their edges and lack the sharp grain character of the quartz in most of the true kaolins." 7. Kaolin bed intimately connected with the previous one. 8. The South Amboy fire-clay bed follows next with a thickness of 20 ft. It has been extensively worked at several points, particularly south of the Raritan River. The South Amboy bed, like the Woodbridge, shows much variation in its character. Three grades of clay are found in it, viz.: sandy white to buff-colored clay, blue fire clay, and sandy-mottled red clay. The three are not distinct, but grade into each other. Pyrite nodules are not uncommon. 9. Passing up through 50 ft. of sand and sandy clay, the next bed of importance is the stoneware clay, which outcrops southeast of the South Amboy fire-clay bed, and in Sayreville and Madison township. This bed is overlain by sandy clay and sand, and this in turn by beds of sand and sandy clay containing lignite.

The New Jersey clays form the basis of an important industry. Firebrick and other refractory materials are extensively manufactured at Woodbridge and Perth Amboy. Some of the largest architectural terra-cotta works in the country are also found here. Within the last few years there has been a great demand for speckled front brick made from New Jersey clays, the speckling being produced by pyrite, which at a high heat is converted to a dark silicate of iron. Sewer pipe also forms an important item of production. The Trenton potteries have a wide reputation, but their product is not made entirely of New Jersey clays. According to the Census of 1890 the production of 31 establishments amounted to $4,531,202. Common brick and hollow brick are manufactured in enormous quantities, the former especially around Hackensack. Many of the New Jersey clay products find their way to the New York market, where the finer grades of ware are readily disposed of.

Delaware.—Porcelain clay of superior quality is extensively mined at Hockessin, Newcastle County. Fire-clay deposits of Cretaceous age have also been worked in the State. Brick clays abound, the Columbian formation being the chief source of supply.

Maryland.—According to the report of the Commissioner of Statistics for 1884–85 there were 80 clay-working establishments in Maryland, 61 of which were in the vicinity of Baltimore. They produce brick and terra cotta, and employ about 5000 hands. The clay used belongs to the Potomac formation and is similar to that used around Washington. Kaolin clay occurs near the head of Big Elk Creek, Cecil County; in granite near Annapolis, Anne Arundel County; near Abingdon, Harford County; and also in the region of feldspathic rocks in Montgomery, Howard, Carroll, and Baltimore counties. Pottery clays are said to occur on the banks of Bohemian, Cape, John, and Sassafras creeks, in Cecil County. The manufacture of firebrick, retorts, and stove linings is confined to North East, Cecil County, Mount Savage, and Baltimore, the Mount Savage brick being made from fire clay of the coal measures.

The method of calcining clay and burning brick at Mount Savage is described as follows by Mr. R. A. Cook:* "The kilns for calcining the clay are brick with a boiler-iron shell, 15 ft. high and 8 ft. diameter, with a dome-shaped roof. A few feet above the bottom are the fire-holes. The clay is charged through a hole near the top and drawn out at the bottom, each kiln having a daily capacity of about 20 tons. The bricks are burned in a gas kiln, having some of the peculiarities of the Hoffman form, but differing in not being continuous. The kiln is about 200 ft. long, forming a tunnel with rows of holes through the roof for admitting coal and gas. These holes are covered by iron caps which are easily removed. Along one side of the kiln is a flue leading to the stack, and flues leading out at right angles to this run across the kiln so that the gas goes in at the top and out at the bottom. At one end are the fire-holes. The bricks are set at this end first, and the kiln filled for a certain distance. Care is taken to leave a clear space under each hopper in the roof, so that the fuel introduced can fall to the bottom. Iron plates covered with clay are used to shut off the brick already in the kiln, thus making a chamber of each section. The fires are lighted and burn very slowly until the bricks are thoroughly heated. Some coal is then dropped in through the roof, gas is admitted and the fire-holes are closed so as to allow the entrance through the red-hot bricks of only enough air for the combustion of the gas. The gas producer is on a truck which runs on a track the full length of the kiln. As fast as the brick of one section are burned it is moved along, and as it progresses the iron plates are drawn out and placed farther up the kiln, thus adding new chambers. The brick are gradually dried in this way, and a greater heat is developed at small cost."

A kiln of this size holds 300,000 brick, and requires thirty days to burn from end to end. One man and a boy are required to operate the producer.

West Virginia.—The clays of West Virginia are among the least developed of

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* *Engineering News*, 1886, XV., p. 227.

her resources, and at the same time one of the most widespread. Building bricks are made in many localities. Those of the Kanawha Valley are of a good red color, very smooth, and some which were used to pave the streets of Charleston twenty years ago are still in good condition. A sandy, clayey soil is used for common brick in many parts of the State. Fire clay is abundant in the Kittanning horizon of the coal measures. While the fire-clay industry is growing, paving brick are at present the chief product. In 1867 6,000,000 were made in the State; in 1892 Hancock County alone produced 70,000,000, besides sewer pipe, tile, and pottery. The manufacture of coke-oven bricks has also given the clay-working industry a great impetus. Potter's clay is abundant through the State and is often associated with the fire clay. Pottery works have been established for a number of years. In Berkeley County the clay is associated with the anthracite and soapstone, and has been used at Martinsburg for many years for making pottery. Much fire clay is worked in Harrison County, and stoneware is made at Shinnston and Bridgeport. Sewer pipe is made in Marion and Lewis counties, while Ohio County supplies the pottery industries at Wheeling. Parkersburg also has several pottery works.

Wisconsin.—Brick clays constitute the most important resource of the State. Extending inland for many miles from the shores of Lake Superior and Michigan are beds of stratified clay of lacustrine origin, having been deposited when these lakes were of much greater size. All of these clays are very calcareous and produce a cream-colored brick, of which the celebrated Milwaukee brick is an example. These white or cream bricks are burned at a high heat and lose their color only by incipient vitrification. The following is the average output at different towns: Racine, 3,500,000; Milwaukee, 34,000,000; Appleton and Menasha, 1,600,000; Clifton, 1,700,000; Waterloo, 1,600,000. Other localities of production are Fort Atkinson, Jefferson, Edgerton, Geneva, Ozaukee, Sheboygan Falls, etc. Good brick clays also occur in the interior of the State, as along the Catfish Valley, Dane County. In the driftless area of Wisconsin are a number of kaolin deposits which have been described by Prof. R. D. Irving.* The kaolin occurs in a belt about 50 miles long and 15 miles wide, from Black River, in Jackson County, to the Wisconsin River, in the vicinity of Grand Rapids. It is a residuary deposit from the decay of granitic rocks, and often retains the structure of the parent mass.

Minnesota and *Michigan* abound in stratified drift clays similar to those of Wisconsin. An important industry has grown up in Jackson, and many firebrick and sewer pipe are made. The clay is obtained near the Spring Arbor coal mines. Clay in large quantity occurs on Batcheldor's Place, five miles north of Jackson, and near Marquette, Mich. While granitic rocks occur in both States, and feldspar has been mined in Michigan, no extensive beds of kaolin have been noted. The alkaline clays of Minnesota are of the earlier drift and have been derived from the Cretaceous deposits. The later alluvial clays make a red brick. A clay occurring at Rowley, Mich., is much used by Ohio stoneware manufacturers for slipping their ware. At St. Joseph, Mich., a brick is made containing 75% sand, the other 25% being a cementing substance.

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* *Trans. Wis. Acad. Sci.*, 1870-76.

Kaolin in Florida.—Mr. C. Gustavus Memminger gives the following information. The chief kaolin deposits of Florida are in Lake County, occurring at intervals along and contiguous to Palatlakaha Creek, which flows in a northwesterly course, emptying into Lake Harris. The country is rather hilly, and is the highest part of Florida.

The total area of the deposits is from 1000 to 1500 ft., and they appear to be of sedimentary origin, resting upon the hard micaceous sandstone which lies above the Eocene limestone. This sandstone is depressed in places, forming pockets of from 25 to 50 acres in extent, which are generally filled with the kaolin intermixed with a very fine white sand, the thickness of the deposits varying from 15 to 30 ft. Upon washing, the mixture yields from 25% to 50% of pure, white kaolin. Usually there is a light overburden of soil from 2 to 6 ft. covering the kaolin.

Practical tests which have been made both in this country and in Europe seem to indicate that the washed clay is equal to the best qualities imported from abroad. At present two mining plants of small capacity are operating and shipping their product to New Jersey and Ohio. It has been sent at various times to all of the leading potteries in the United States, and all have expressed a willingness to use it in large quantities as soon as they can be assured of a permanent supply.

The following analyses, made by Johnson and Sons, 23 Cross Street, Finsbury, London, E.C., show the composition of Florida kaolin: Silica, 46.11%; alumina, 39.55%; iron, 0.35%; sulphur, 0.07%; magnesia, 0.13%; oxygen combined water, etc., 13.78%.

Indiana.—This State ranks among the foremost in the value of its clay resources. Extensive beds of kaolin occur in the coal measures. It is usually of a white color, but sometimes red, gray, brown, or green. Large beds are found in Lawrence, Harrison, and Owen counties. While the material is used to a considerable extent in the manufacture of porcelain, it is not considered as well suited for this purpose as other American kaolins. The name of Indianaite has been given to this kaolin. Brick clays are common, and usually occur as surface deposits. They are found from Boone to Clinton counties on the west, to Randolph County on the east. In northern Indiana, below the yellow surface clay, is an extensive deposit of blue clay. Paving brick of excellent quality is made at many localities, among them Terre Haute, Brazil, Evansville, and Vedersburg. Pottery clays also occur and are utilized at Evansville. Encaustic tiles are manufactured at Indianapolis, two of the largest works in the country being situate there. A mixture of clays is used, those for dark ware being obtained in the State, while the white clays are brought from South Carolina and Kentucky. The tiles are burnt by natural gas. The following statistics are from the Labor Bureau reports. Bricks: 1882, $1,004,425; 1883, $2,179,277; 1884, $2,309,922. Tile: 1882, $782,445; 1883, $1,133,515; 1884, $1,659,820. Plain enameled tile, Indiana County, 1892: Material used, $60,000; value of product, $150,000. Encaustic floor enamel, Anderson, 1892: Material used, $20,000; value of product, $100,000.

Illinois.—The clay resources are similar to those of Indiana. Fire clays are found in the coal measures, while surface clays are in great abundance and extensively used for making brick. At Decatur and Jacksonville the drift clays are used for paving brick, and the Carboniferous clays at Galesburg, Rock Island, Ottawa, and Bloomington are utilized for the same purpose. Pottery is made at Peoria, and clay pipes are made at Fulton from native clays. The counties containing the most extensive clay deposits are Pope, Lasalle, Fulton, and Union. In the western part of the State the clays of the Mississippi Valley are used for making brick.

Missouri.—Next to Ohio, Missouri is perhaps the most important center of the clay-working industry in the Mississippi Valley, the clay-working interests being situated near St. Louis and Kansas City. In the counties of Bates, Cass, Henry, Jackson, Johnson, Lafayette, and Vernon the production in 1890 was as follows: Structural brick, 88,380,000; gallons of pottery, 955,000; tons of clay made into sewer pipe, 65,000; feet of drain tile, 65,000; feet of chimney flues, 3000. According to Mr. Ladd of the Missouri Geological Survey, the formations in this region which furnish clay materials are Quaternary, Coal Measures, and Lower Carboniferous. The Quaternary includes the loess, alluvium, drift, soils, and residual clays. The alluvium occurs along many of the streams and is used for brick-making, while the loess is found chiefly along the Missouri. The residual clays are derived from the shales and are largely used in the manufacture of pottery. The coal measures furnish shale and potters' and paint clays. Many of the clays of the lower measures are used for making firebrick. The beds occurring near the surface are often very silicious, and are shipped or used locally for pottery, sewer pipe, or paving brick. The clay shales vary in thickness from 4 in. to 40 ft., and often grade into sandstone. Potters' clay is found at many places in the lower measures, often interbedded with coarse masses of hematite or limonite. The coal measure clays are used at Kansas City for the manufacture of terra cotta, and at Calhoun art pottery and brown stoneware are made.

In the county and city of St. Louis the clay-working industries are of much importance. The following was the production in 1889: Structural brick, $2,288,795; fire clays, sewer pipes, and pottery, $1,722,685. The three sources of clay are the coal measures, Quaternary, and residuary products of limestones. They first underlie an area of 200 sq. miles in St. Louis County, and are utilized in the production of pottery, sewer pipe, and firebrick. Tile clays occur near the base of the coal measures, and are used for making sewer pipe. They overlie the fire clay, and are separated from it by shale or sandstone, while several feet of loess clay, or at times 8 to 12 ft. of decaying limestone, overlie them. These clays are usually red and brown, sometimes shaly, and have a soapy feel. When used for sewer pipe the tile clays are mixed with fire clay. Fire clays occur in beds from a few inches to 7 ft. thick. It is hard when mined, but crumbles on weathering and is very variable in quality. The occurrence of glass-pot clays is limited, but those from Cheltenham are of a high quality. These clays are washed and weathered for several years before using. Much terra cotta is made from the clay shale which overlies this clay. Often the loess and fire clay are utilized for the same purpose. Extensive pottery works are situated at St. Louis, the product being stoneware, pans, and jugs. There is also an art pottery at St. Louis, but the material employed comes from a distance. The mixture used for pottery is one of pipe clay to nine of fire clay; others use loess or pipe clay with fire clay in the proportions of one to two.

According to Professor Wheeler of the Missouri Geological Survey, white china clays of high quality are found in Franklin, Crawford, Jefferson, and Cape Girardeau counties, and good kaolins are found in the counties of Bollinger, Howell, Wright, and Reynolds. Good feldspar occurs in St. Genevieve County, and flint in Franklin, Jefferson, and Cape Girardeau counties. The following table gives the value of clay products produced in Missouri during 1891, as compiled by the Missouri Bureau of Labor Statistics:

PRODUCTION OF CLAY PRODUCTS IN MISSOURI IN 1891.

County.	No. of Works.	Product Made.	Value of Product.
Atchison	1	Brick and tile	$6,450
Audrain	2	Firebrick	191,000
“	1	Brick	12,000
Bates	1	“	9,750
Boone	1	“	8,400
Buchanan	8	“	135,000
Callaway	1	Firebrick	35,000
Cape Girardeau	3	Brick	6,100
Carroll	2	“	12,200
Cass	1	“	13.000
Chanton	1	Brick and tile	12,200
Clay	1	Brick	10,800
Cooper	2	Pottery	16,000
Franklin	4	Brick	8,000
“	1	Pottery	1,300
Grundy	1	Brick	6,500
Gentry	2	Brick and tile	9,872
Greene	1	Pottery	6,000
Holt	4	Brick	22,700
Henry	3	Brick and tile	57,000
“	6	Potteries	82,900
“	1	Sewer pipe	35,000
Howard	3	Brick	13,000
Jackson	14	“	384,000
Jackson	1	Pottery	$12,000
“	1	Sewer pipe	150,000
Jasper	1	Brick	18,000
“	1	Pottery	6,000
Jefferson	1	Brick	5,500
Lafayette	6	Brick and tile	48,000
Lawrence	1	Brick	6,500
Marion	1	“	13,000
Moniteau	1	Pottery	4,500
Nodaway	3	Brick and tile	8,950
Randolph	2	Brick	18,570
St. Charles	2	“	11,400
Saline	4	Brick and tile	28,200
Stoddard	1	Brick	7,000
“	1	Pottery	3,500
Vernon	1	Brick	16,500
St. Louis City	9	Brick and sewer pipe	1,556,174
In 93 brick, sewer pipe, and tiling factories in 30 counties and St. Louis City			2,752,875
In 8 counties	14	Pottery	132,200

Kentucky.—The fire clays of Kentucky are of two kinds—the indurated ones of the coal measures and the silicious Tertiary clays, which are more friable and plastic. Potters' clay is also abundant. The fire clays are common in Carter and Madison counties, the former including the flint clays. In the Jackson Purchase, between the Mississippi, Ohio, and Tennessee rivers, extensive Tertiary clay deposits interstratified with sands underlie a great portion of the region. In the uplands the brown, clayey loam is much used for brick, and along the Mississippi River the loess is utilized for the same purpose. The black and blue clays of the Cretaceous and Lower Tertiary pass through Callaway, Marshall, McCracken, and Ballard counties, while the fire clays of the eastern part of the State come chiefly from the coal measures. Superior deposits of shale and marls occur in the Chester formation, and are used for the manufacture of paving brick at Cloverport, Breckinridge County. In Louisville there are also works making these bricks, and in Pottertown, Murray, Bell City, and Paducah potteries are in operation.

Arkansas.—A great variety of clays occur in the Mesozoic regions of southeast Arkansas. Potteries are in operation at Benton, Hope, Malvern, Texarkana, and other Tertiary areas, but the Cretaceous clays have not yet been used. According to Mr. R. T. Hill,* kaolin occurs in Pike, Pulaski, Saline, and Ouachita counties, but is seldom over two feet in thickness. The kaolin of Pulaski County is residual, while that of Ouachita County is regular beds, interstratified with Tertiary rocks. One important bed 12 ft. thick occurs in Township 12, South, Range 18, W. Good brick clays are found in all second-

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* *Arkansas Geological Survey*, 1888, II.

bottom streams, and bricks are made at Little Rock, Texarkana, Arkadelphia, etc. Paving brick are made at Fort Smith.

Kansas.—The existence of brick clay is reported by Professor Hay from sixty-one counties and pottery clay from fourteen counties. Formerly all good building brick had to be brought from St. Louis, but now they are made at many localities within the State. Most of the clays are surface deposits of Quaternary age, but in the western part these disappear and are replaced by alluvial clays. The loess is extensively used in the eastern counties. Some beds of the plains marls have been used, but with poor results. There are numerous localities where common brick are made. Pressed brick are made at Fort Scott, Leavenworth, Junction City, Wichita, and Kansas City. At Marion Centre bricks are made from the Permian shale. Paving brick are made at Atchison, Topeka, Leavenworth, Osage City, and Pittsburg. At this latter city a 10-ft. bed of Carboniferous shale is used. Firebrick are also manufactured from the shale. In 1893 the production was: Vitrified brick, 3,500,000; firebrick, 500,000. At Leavenworth the clay shale and loess are mixed. The production of brick for 1892 is as follows: Atchison, 4,000,000; Leavenworth, 1,000,000; Topeka, 2,500,000; Osage City, 200,000; Pittsburg, 2,000,000—total, 9,700,000. Pottery clays are reported from the counties of Barber, Bourbon, Chautauqua, Cherokee, Kingman, Leavenworth, Lynn, Neosho, Osage, Ottawa, Pawnee, Reno, Rice, and Saline. Pottery manufacture has been attempted at several localities, among them Fort Scott and Geneseo. Drain tile are made at Burlingame and Paola. Although fire clays occur with the coal beds, yet no firebrick are made in Kansas, and all those used come from Illinois or St. Louis.

*Wyoming.**—Surface deposits of brick clays such as are common in the central States are lacking in Wyoming. The loess is utilized at many localities, but the quality of the brick produced is poor. A good quality of brick, however, is made from the clay underlying the coal in the Cambria Coal Company's mine at Cambria. Large beds of fire clay are found in the Mesozoic strata, but they are little developed and not used for firebrick. At Rock Creek station, on the Union Pacific Railroad, a deposit of paper clay occurs, and a large amount of it has been shipped to New York. The clay runs rather high in iron.

Oregon.—Many samples of clay and kaolin were exhibited by this State at the World's Fair, and the deposits which they represented were said to be extensive. Among the products were pressed brick, sewer pipe, and terra cotta. Portland is the center of the clay-working industry.

Washington.—Clays occur at several points in Washington, and various grades of product are made from them.† Analyses are given of those from Green River fields, Pierce County; Black Diamond fields, King County; and Skagit County fields. Mr. T. G. Plummer, Chief of Engineers, writes that the clay products of the State comprise drain tile, pressed brick, ornamental tile, sewer pipe, and earthenware.

Nebraska.—The clay resources are similar to those of Kansas. Brick clays are used locally in the vicinity of the more important towns, among them being Lincoln and Sioux City, the former using the loess. A fine kaolin-like clay is found

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* *Bull. No.* 14, *Wyoming Experiment Station.*

† *Report State Geologist*, 1891.

on Pine Creek, Cherry County. The income from the clay-working industry for 1889–90 was as follows:

	Establishments.	Employees.	Capital.	Value Raw Material.	Value of Product.
Brick	68	1,235	$6,360,000	$48,400	$658,358
Pottery	1	25	20,000	2,500	20,000

North Dakota.—With the exception of a few brickyards, little has been done toward developing the clay resources of this State. The following classification of North Dakota clays is made by Professor Babcock: *

Post-Tertiary	Post-Glacial Glacial	Yellow and blue brick clays of Red River Valley; probably largely washed from adjoining Cretaceous.
Tertiary	Laramie	Plastic clays, white earthenware, and fine clays and coal of Dickinson. Clay and coal at Minot, and at Plenty Mine, Mercer County.
Cretaceous		The upper non-fossiliferous shales, about Park River, Langdon County, and cement clay of Pembina Mountains.

These abound in all sections of the State, and in the eastern part two distinct beds are recognized, viz., an upper yellow clay which immediately underlies the soil, and a deeper blue clay, the former being preferred by brick-makers. Shale deposits which occur in the north-central part are said to be of proper quality for making drain pipe and brick. These shales outcrop about Park River, Milton, Langdon, and other places. Good outcrops of clay also occur near Bismarck and about Dickinson. The yellow clay in the Red River Valley affords good material for a cream brick, and is utilized at Grand Forks. Clays suitable for sewer pipe and architectural terra cotta are often found under the surface brick clays. Professor Babcock also notes the occurrence of semi-refractory clays at Minot, Ward County, where they underlie the coal; also at Plenty Coal mine, on the Missouri River, in Mercer County. Northeast of Olga, near Langdon, in the Pembina Mountains, is a white clay which burns to a pink color and stands considerable heat. Fire clays are found near the summits of the hills surrounding Dickinson, the layers being from 10 to 15 thick. The reports of the Commissioner of Agriculture and Labor show that in 1890 there were 5 brickworks, the product of which was valued at $27,700, and in 1891–92 there were 8 brickworks and potteries whose product was valued at $33,599.

South Dakota.—Prof. W. P. Jenney of the State School of Mines writes that there are extensive clay materials around the Black Hills. He divides them as follows: 1. Black and drab clay shales of marine origin belonging to the Fort Benton group. These form a nearly uniform deposit several hundred feet thick, and entirely encircle the Black Hills. These Cretaceous shales make an excellent dry-pressed brick. 2. Jurassic and Cretaceous No. 1 clays. Some of these are shallow marine deposits, while others are thin fresh-water deposits, filling basins in the thicker beds. These deposits occur locally in the foothills belt, and are suitable for making firebrick. At present a very refractory brick for blast-furnace linings is made from these clays at Rapid City.

Colorado.—There are extensive deposits of clay along the base of the Rocky Mountains. The centers of the clay industry in this State are Golden and Denver. At the former especially there are valuable beds of clay and shale of Laramie age, interbedded with seams of coal which is used to burn the wares. The material is

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* *Report Commission of Labor and Agriculture*, 1891–92.

mined by shafts or open cuts, and about 3,000,000 firebrick are produced annually, selling from $20 to $30 per 1000, and supplying the demand in Colorado, New Mexico, Arizona, Wyoming, Idaho, Utah, and even Portland, Ore. Other products of the Golden works are assayers' supplies, roofing tile, and front brick. Terra cotta has not yet been attempted. The sewer pipe made from the local clays at Argo, near Denver, are sold in Colorado, Utah, Wyoming, and New Mexico. Two-thirds of the clay comes from Golden, the rest from Denver. About 4,500,000 gallons of pottery and 85,000,000 brick were made in 1892. Clays are also worked at Boulder, Morrison, and Pueblo, the production of brick at the latter being valued at $168,319.

California.—Kaolin of good quality is found near Little Geyser Creek, but up to the present it has only been used for paint. Brick clays are very common, and front brick are made at several localities. The production of brick in Alameda County is about 17,000,000 per year, and the yards at San José have an annual capacity of 12,000,000. At Stockton, in Hoffman County, the clay is dug with a steam dredge, and the bricks burned in a continuous kiln, using coal screenings. Clay beds of great extent occur at Lincoln, Placer County; Carbondale, Amador County; Elsinore, San Diego County; Los Angeles, and Sacramento. The clay at Lincoln occurs in a ridge capped by a layer of volcanic breccia 15 ft. in thickness. It is used at this locality for making terra cotta, stoneware, sewer pipe, and roofing tile, the works having been in operation since 1875. Firebrick are also made, the clay being brought from Carbondale. Potteries have been in operation in Alameda County since 1864, those at East Oakland securing their clay from Carbondale for $3.50 per ton, delivered at the factory. The chief clay products here are sewer pipe, chimney flues, and flower pots. Sewer pipe is also made at Los Angeles and Carbondale. In 1892 there were shipped 800 car loads of clay from Carbondale to factories in different portions of the State, the price being 80c. per ton, f.o.b. A good quality of fire clay is also found in the Black Diamond coal mine, and large quantities of stoneware, crucibles, and firebrick have been made from it.

North Carolina.—The Tertiary and Quaternary in the eastern part of the State abound in clay for pottery and brick, but contain no kaolin deposits of importance. Snow-white kaolinite is found as the result of decomposition of orthoclase at most of the mica mines in Mitchell, Yancey, Macon, and other counties, and good qualities occur six or seven miles from Newton, Catawba County; as also in Lincoln, Burke, and other counties. The deposit in Jackson County is much sought after by the Trenton potters for the best china. It is said to contain some CoO_2, which imparts a desirable bluish tint to the ware. In 1890, 4000 tons were mined.* In 1892 the localities of production were Sylva, Didsborough, and Webster, in Jackson County, the output for the year being 3900 tons, valued at $31,200 at the works.†

Virginia.—Brick clays are extensively worked in the vicinity of Washington. Kaolin is reported from a number of localities in Augusta, Wythe, and Cumberland, and residual clays are common in the hilly region in the western section of the State. Paving brick are made from local clays at Middle, Athens, Steuben, near Roanoke, and a short distance from Lynchburg.

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* *Mineral Resources*, 1891.

† *Mineral Resources*, 1892, p. 734.

Louisiana.—While clay materials are abundant in the Eocene and Miocene formations throughout the State, they have been but little developed. In the region north of the Vicksburg, Shreveport and Pacific Railroad clays of various quality are not uncommon. Pottery clays and jug clays are especially abundant in the region occupied by the "red sandy clay" in contact with the underlying gray clays, which in their unaltered condition often furnish good material for bricks. Fire clays are often found underlying the surface brick clays. Kaolin of a white color has been found at several localities known as the "Chalk Hills," on the Alexandria and Harrisburg Railroad. It burns to a white color and stands a high heat. The alluvium of the Mississippi River is extensively used around New Orleans for the production of a good brick. The manufacture of French china from imported materials and by imported labor was carried on in New Orleans from 1880 to 1890.

Georgia.—Building brick are made at all the chief towns from the alluvial clays of the valleys, and often are of excellent quality. The brickyards at Rome have a yearly capacity of 12,000,000 common and 4,000,000 repressed and ornamental brick. The product is shipped to Florida, Virginia, and Mississippi. Buff ware is also made. There are similar plants at Atlanta, with a capacity of 50,000,000, and also terra cotta works. At Macon about 30,000,000 are produced, the color being lighter than those made at Rome. Augusta's annual production is about 15,000,000. The sandy clays found in the vicinity of Savannah and Brunswick make a gray brick. At Milledgeville firebrick, sewer pipe, earthenware, and stoneware are made from local clays. Kaolin, sometimes of a pure white color, occurs in pockets in the residual earths of the Knox dolomite. Clays from the decay of the Palæozoic shales are also common, but many of them are easily fusible. According to Professor Spencer, some of the most extensive clay deposits occur along the northern belts of the Tertiary strata in the southern portion of the State.

*Alabama.**—The Alabama clays belong to crystalline schists of the metamorphic formation, Cambrian or Lower Silurian, lowermost Cretaceous, and Tertiary. The schists are highly feldspathic, and by their decay give a residual kaolin. These beds occur at many points, notably at Socapatoy, Coosa County; Louina, Randolph County; also in northwestern Randolph County, and the adjacent parts of Cleburne County. Those in the former are of high quality, suitable for porcelain, and in the latter region the deposits near Wood's Corner mine have been tested and found to stand 5000° heat. The Cambrian formation includes the residual bauxites and kaolins of Cherokee and Calhoun counties. A 30-ft. bed of white kaolin occurs in Cherokee County, at one of the banks of the Rock Run Furnace Company. Near the base of the Subcarboniferous, and close to the black shale of the Devonian, is a hard white clay, found at many localities, and resembling halloysite. It is quarried near Valley Head, De Kalb County, the better qualities being used for fine porcelain, and the less pure layers for tile and stoneware. Cretaceous clays of the Potomac formation occur at several places, but are rather sandy. They occupy a belt about thirty miles wide, extending from Columbus, Ga., to the northwest corner of Alabama, and passing through Wetumpka, Tuscaloosa, Fayette, Court House, and Pikeville. A fine bed has been opened at Mountain Creek, Chilton County. These clays are used at Bibbville for making

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* E. A. Smith, "Clays of Alabama," *Proceedings Alabama Industrial and Scientific Society.*

firebrick, and at Bessemer they are mixed with imported clays for the same purpose. These two works were the only ones in operation in 1893, though there are firebrick works at Birmingham, Anniston, and Brierfield. A hard silicious clay belonging to the Buhrstone division of the Tertiary, and resembling the Mount Savage clay, is found in large quantity along the Alabama and Tombigbee rivers. Plastic clays belonging to the late Tertiary of southern Alabama are found in Washington, Mobile, Baldwin, Escambia, and Covington counties. Mr. H. McCalley, in a report on the Warrior coal field, notes the occurrence of silicious drift clays of proper quality for pottery in Marion County, and under the coal measures beds from two to three feet thick occur in Winston, Cullman, and Jefferson counties. At Coaldale there is a large brick and tile works, and both brick and earthenware works are found in many other localities.

*Mississippi.**—The Eocene and Miocene are the most important clay-producing horizons in this State, though beds of good quality also occur in the Carboniferous and Cretaceous. In the Miocene formation there are many beds, some excellent ones being in Marshall County, where they are used. Pottery clay suitable for earthenware occurs near Holly Springs and in Panola and Calhoun counties, near Hartford. Fire clay is reported in Yazoo County, at the base of the hills between the bluff along the alluvium and the ridge of hills crossing the county from north to south. The Eocene also furnishes clays of varying quality. A refractory clay occurs near Red Hill in T. 9, R. 7; in T. 10, R. 7; and in Chickasawhay River, Wayne County. Pipe clays are also found in Wayne County on Section 14, T. 7, R. 6 W., and near Woodville, Section 28, T. 2, R. 2 W. Hilgard also notes extensive kaolin deposits in Tishamingo County, which are said to underlie an area of 50 to 60 sq. miles. With the exception of brick and tile little else in Mississippi is manufactured from clay.

Tennessee has clay resources similar to those of Kentucky.† The Carboniferous fire clays and shales are abundant in the eastern part of the State. The pottery clays of the Eocene and Lafayette and Eocene formations are extensively used and developed in the western part. Bricks are manufactured throughout the State from the alluvium of the rivers and from the loess and Lafayette clays in the western portion. Firebrick are made at Cleveland and Chattanooga, and sewer pipe is manufactured at Knoxville and Chattanooga. Large quantities of paving brick are made at Robbins and Knoxville. The following statistics are given by the Census of 1890. Brick and tile: Memphis, 4 works, product, $266,250; Chattanooga, 6 works, product, $125,607.

Texas.‡—Brick clays of varying quality are abundant throughout the State, and are found in all the different formations. The product varies from cream to yellow, as at Austin, but various shades of brown and red are also produced. The bricks made in eastern Texas and the Carboniferous area are usually mottled, due to the iron in the clays, but when these are selected, a high grade of front brick is produced, as at Rusk and New Birmingham. During 1889 the production of the State was 95,000,000 bricks. Many of the Tertiary clays are suitable for drain, tile, and terra cotta, especially those of the timber belt and Fayette formations. Fire clays occur in the timber belt beds in Fayette, Henderson, and

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* *Geology of Mississippi*, 1860.

† R. T. Hill, *Mineral Resources*, 1891.

‡ *Texas Geological Survey.*

Limestone counties, and in the Fayette beds in Fayette County. These last, however, run rather high in impurities. Firebrick of good quality are made at Athens from a bed of clay 12 to 18 ft. thick, and used in the iron furnaces at Rusk. This same clay is used for making sewer pipe, jugs, and tiles. Both Albany slip and salt are used as a glaze. A blue sandy clay occurring near Marshall is used as a lining for cupolas, and pottery clays occur in Marion County and near Jefferson. Mr. W. Kennedy[*] notes the occurrence of clay in several portions of Grimes County, and good brick clays near Anderson. A large deposit of clay occurs near Piedmont Springs, which resembles the kaolite slip clays used in Ohio. Extensive deposits of clay occur near Courtney. The Brazos County clays are of little value, and although brick clay is common, bricks are made only at Bryan, where the annual production is about 750,000. Brick clays are plentiful in Robertson County, but are not worked to any extent. In 1892 the output was 1,250,000 brick, valued at $12,500. Finer clays occur in the northeastern part of the county, some of them resembling the Kasse fire clays. In Navasota paving bricks are being manufactured from local clays. In his report on the Colorado coal field of Texas[†] Mr. N. F. Drake notes the occurrence of two classes of clay, one composing the regular strata of the beds, and the other Quaternary deposits, or accumulations of clay worn from the outcropping beds and deposited in the valleys at the foot of escarpments. These clays are very silicious, but suitable for making brick. Similar deposits are common in the coal measures, especially in the Strawn and Cisco divisions.

While clays of excellent quality are known to occur in the remaining Western States, at present they are not used or in many cases needed. Wood is the chief building material, and in the Southwest adobe bricks are employed, requiring but little skill to make. Clays of Cretaceous age are abundant in New Mexico, and kaolin is also reported. Fire clay occurs near Socorro, and is made into brick. Brickyards are situated at Santa Fé, Albuquerque, Las Vegas, and Ratan.

In Arizona a mass of pure white kaolin is said to form the wall rock in the Longfellow mine.[‡] Mixed with two parts of sand it has done good service at Clifton as a fire-resisting material in reverberatory furnaces.

Utah abounds in adobe soils, and good brick clays are worked into pressed brick at Salt Lake City. Fire clay of excellent quality is reported from Camp Floyd, and of inferior quality from Camp Douglass.[§]

A fire clay similar in quality to that at Camp Floyd, Utah, is said to occur at Eureka, Nev., where the Palæozoic shales reach an enormous thickness. Kaolin occurs, but not in large masses, so far as is known.

Ohio.—An exhaustive report on the clay-working industries of Ohio by Mr. Edward Orton, Jr., was published by the Geological Survey of that State in 1884, but since that time these industries have expanded so enormously and become of such importance that another report on the subject by the same author has just been issued. A chapter on the distribution of clays in the State also appears in the new volume, the main facts of which are given here.

The principal centers of development are those regions which have furnished

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[*] Report on Grimes, Brazos, and Robertson Counties, *4th Ann. Report Texas Geological Survey.*

[†] *Ibid.*, p. 423.

[‡] *Transactions Institute Mining Engineers*, XV., p. 171.

[§] *Ibid.*, I., p. 80.

coal. The geological section of Ohio extends from the Trenton limestone to the top of the Carboniferous, and over this in two-thirds of the State comes the Glacial drift. The Medina shale is the oldest argillaceous stratum in Ohio which is known to be worked, and is No. 4 of the geological column. Its outcrops have a thickness of 25 ft., and are known only in southwestern Ohio. The shale, which is interbedded with limestone, varies in color from white to yellow or blue, but is chiefly red, a possible objection to it being the rather high percentage of lime.

The Clinton and Hudson River shales, although occurring abundantly in the same part of the State, are very calcareous and are not at present utilized. The Niagara is also represented in part by a calcareous-argillaceous stratum. Its chief outcrops are in Adams County, where the formation attains a thickness of 100 ft. It has not proved of economic value thus far. There are a few outcrops of the Hamilton shale, but they are unpromising. The Ohio shale, which extends across the State in a north and south belt, is used on a large scale at Columbus for the manufacture of sewer pipe and dry-pressed brick. The weathered portions of this stratum offer very valuable material to the clay-worker and are beginning to be appreciated. The Bedford shale, which closely resembles the former in its geological history, is mined and worked into pressed brick near Independence. The Cuyahoga shale also offers great possibilities, especially for the manufacture of paving blocks. It has an outcrop of 150 to 450 ft., and is found in many counties from the lake shore to the Ohio Valley.

The Subcarboniferous limestone contains the most valuable flint-clay deposits found in Ohio and Kentucky. In the former State this element of the formation is mined at Portsmouth, Sciotoville, and Logan, Hocking County. Wherever it is found it is used for the manufacture of refractory materials requiring a high grade of clay. The Carboniferous Conglomerate contains, besides several profitable seams of coal, half a dozen beds of fire clay, viz., the Tionesta clay and shale, Upper Mercer clay, Lower Mercer clay, Quakertown clay and shales, and Sharon shales, named in descending order. The Sharon shale overlies the Sharon coal, and varies in thickness from 1 to 50 ft. It is dark blue to black in color, and extensively used at Akron for the manufacture of sewer pipe, paving blocks, and roofing tile. It contains from 10% to 15% of iron, which gives a very desirable color to the product. The Quakertown clay and shale occupy from 5 to 30 ft. between the two divisions of the Massillon sandstone where such a division occurs, and are associated with the Quakertown coal. These clays are worked in Summit County for material to supply the Springfield potteries, and in Portage County for the Mogadore potteries. The clay also occurs at Massillon, in Stark County, furnishing a refractory product of high grade. The Lower Mercer clay and shale is found below the coal which underlies the well-marked Lower Mercer limestone. The material, which is sometimes clay and sometimes a shale, forms the basis of important manufactures in Stark, Tuscarawas, Muskingum, and Hocking counties. The formation varies in character and none of the clays obtained from it are of a very high grade. The Upper Mercer clay and shale is a persistent bed which is always of a plastic nature, and at Haydensville, which is the only locality where it is worked, it forms a bed 8 ft. thick. The Tionesta clay is a valuable deposit occurring 15 or 20 ft. above the preceding, and used by the Columbus Brick and Terra Cotta Company at Union Furnace, Hocking County.

The Lower Coal measures contain several clay deposits of importance in Ohio. They are in their ascending order : 1. The Putnam Hill limestone, which contains well-developed beds of clay in the counties of Muskingum, Coshocton, Tuscarawas, and Stark, in all of which it is worked. Other promising areas of it occur in Perry, Hocking, and Vinton counties, to the south. This clay furnishes the large tile works at Zanesville with most of its raw material, and good pressed brick of a buff color is also made from it, and also paving brick, near Canton. The seam, which may be divided into an upper plastic portion and a lower silicious portion, varies in thickness from 6 to 30 ft. This horizon must be counted as one of the valuable clay deposits of the State, though its use has only begun. The areas occupied by the seam in the districts named are large and the exposures in natural sections are abundant. It can be mined under cover to good advantage, the limestone furnishing a strong and excellent roof.

The Ferriferous limestone clays occur next in the scale, and are of a good quality but not utilized at present. The Kittanning clay and shale is the great clay horizon of the State, equal in value to all the other sources of clay in the coal measures. Its position is between the Ferriferous limestone and the Lower Kittanning coal. In the more important districts it ranges in thickness from 6 to 30 ft., and in cases where it is more or less continuous with the next clay above it the section is 50 ft. thick. The districts producing this clay are Columbiana and Jefferson counties, in Eastern Ohio, and Lawrence, Jackson, Vinton, and Hocking counties, in Central Ohio, but it is also fairly well developed in Tuscarawas, Stark, and Muskingum counties. This horizon usually produces a white plastic clay which is the main source of supply of the great pottery industry of Eastern Ohio, but it also yields a flint clay in parts of Stark, Tuscarawas, and Carroll counties which is known as the "Mineral Point Clay," and ranks high in quality. The clays of this horizon are much used for making saggers, yellow and Rockingham ware, stoneware, sewer pipe, and ordinary firebrick.

The Middle Kittanning and Lower Freeport clay are of fair quality. The Upper Freeport clay and shale is an extensive deposit of good quality, but is not used to any extent. The Lower Barren Measures contain extensive beds of shale which are at present but little developed. Several paving-block factories are, however, working these shales with great success. A fire clay of desirable grade is found under the Pittsburg coal in Athens County. In conclusion it can be safely asserted that every portion of the coal measures in Ohio can be depended on for a supply of argillaceous materials, fire clay, potters' clay, or shale, covering a wide range of composition, from nearly pure kaolin to brick clays, and adapted to nearly all the lines of manufacture in which these substances are employed. The drift clays are used for common brick in almost every township of northern and western Ohio.

Clay Products Made in Ohio.—Earthenware, while manufactured at a number of localities in the State, is chiefly produced by three firms in the Zanesville district. The value of their product in 1891 was $108,000. Of stoneware Akron produces the largest amount, while Zanesville ranks second. According to Mr. Orton, Jr., there are 41 firms manufacturing stoneware in Ohio, with a combined annual capacity of 24,350,000 gallons. In 1891 about 13,590,000 gallons, with a value of $540,000, were produced ; of this quantity, Akron produced 7,000,000 gallons and Zanesville 4,000,000 gallons. The ware is shipped to all parts of the United States. Yellow ware is made by eleven firms, most of them situated at East Liverpool, which is the center of the china industry in this country. There are in this locality 29 potteries, 9 decorating works, 3 stilt and triangle factories, 1 sagger factory, and 3 door-knob factories. At Cincinnati the celebrated Rookwood pottery is made. This is a true faience, of which three grades are produced, viz., cameo or shell tinted ware; dull finish ware; glazed Rookwood faience. The clays used come chiefly from the Ohio Valley, a red variety from Buena Vista, a yellow clay from Hanging Rock, and a white or cream colored clay from Tennessee. Metallic oxides are used to give artificial colors, and the decoration is done under the glaze. Crude petroleum is used for burning. Encaustic tiles are made at Cincinnati from imported clays and at Zanesville from native clays. Sewer pipe of excellent quality is made at Akron and several other localities. The Akron district is the largest producer in the country. The Scioto district is the chief producer of refractory material. The Ohio Valley is also the center of a large brick industry, but the bricks are sold indiscriminately as fire bricks and pavers.

The production of fire clay in Ohio from Dec. 31, 1883, to Dec. 31, 1891, was as follows: 1884, 168,208 tons; 1885, 153,756 tons; 1886, 266,709 tons; 1887, 366,476 tons; 1888, 471,794 tons; 1889, 574,129 tons; 1890, 833,159 tons; 1891, 1,687,560 tons. The increased output is largely due to the increased use of clay for paving brick.

Canada.—While Canada is not lacking in clay materials, they have received comparatively little attention, and have not been developed to any extent except in the more thickly populated eastern provinces, as Quebec and Ontario, the latter perhaps being the center of the Canadian clay-working industry.

Ontario.—Good fire clay is said to occur near Toronto and many acres of it are found beyond the Humber. It is of a shaly character.* Kaolin, covered with white sand, is reported on the Missinaibi River, a branch of the Moose, a little below Coal Creek. The Medina shale and its disintegrated outcrops form an important material for brick-making in the province. It crops out along the base of the Niagara escarpment from the Niagara River to Georgian Bay, and is of a red color, with some bands of green clay which are used for the higher grades of ware. Near the forks of the Credit River in Peel County the shale is 175 ft. thick. This red shale clay is employed at Milton for pressed brick. At Deseronto the same material is employed in the manufacture of red and white dry-pressed brick, tiles, and terra cotta, the forms produced being tiles, panels, roofing tile, finials, and garden vases.

Up to 1887 most of the pressed brick used in Ontario came from Ohio, New Jersey, and Philadelphia, at from $20 to $30 per 1000, but the discovery of these extensive shale beds has given a great impetus to the pressed-brick manufacture in Canada. Other localities where the Medina shale is worked are Streetville, Campbellville, Beamsville, Napanee Mills, Freeman, and Hamilton, in Wentworth County, and Limehouse, in Halton County. This shale has also been used for paint. The Hudson River shale is used near Toronto for making pressed brick.

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* *Report of Royal Commissioner of Mines*, 1890, p. 54.

Much of the sewer pipe used in Toronto is imported from Scotland and the United States. The production of clay products in Ontario in 1891 was: Common brick, 160,000,000, valued at $950,000; pressed brick, roofing tile, and terra cotta, 13,617,909, valued at $156,699; drain tile, 7,500,000, valued at $90,000; sewer pipe, 1,375,000, valued at $270,000; pottery, valued at $45,000.

Quebec.—While in Ontario brick clays of two kinds have been found producing a white and red brick, in Quebec the deposits mostly worked are the Leda clays, which overlie the bowlder clay, forming heavy bands in the St. Lawrence Valley between Quebec and Montreal, and also up the Ottawa River Valley. Most of the pottery made in Canada comes from Quebec, the products including flower-pots, jars, crocks, and Rockingham ware, and drain pipe is made at St. Sauveur, but Montreal may be called the center of the clay industry in the province. The waste from the slate quarries of the Rockland Slate Company has been used for some time for making brick.

Nova Scotia.—Good brick clays occur at Stillwater, along the banks of the river, but they are not much used. Other large deposits are found along Middle River, near Sylvester, Pictou County. Fire clay associated with the coal seams of Pictou County is not uncommon. The Nova Scotia fire clays, however, are rather high in alkalies.

The *Canadian Geological Survey Report* of 1891 states that the amount of fire clay and firebrick imported in 1873–74 was firebrick for refractory linings for stoves, ovens, and furnaces to the value of $78,040, and fire clay to the value of $10,873. The Steel Company of Canada alone imported in 1875 about 2,000,000 firebrick for its establishments at Londonderry, and Mr. R. E. Chambers states that the quantity used in 1892 by the New Glasgow Iron, Coal and Railroad Company in the construction of its furnaces was 850,000; by the Pictou Charcoal Company, 100,000. A dark fire clay has been extracted from a tunnel on the west bank of the East River of Pictou, near Stellarton, and another variety, altered felsite, is reported from the base of Sporting Mountain.

New Brunswick.—Clays occur in abundance along the St. John River, but the demand for bricks is limited. Much clay also occurs around the Baie des Chaleurs.

Northwest Territories.—Clay for bricks and pottery is common in the bowlder clay region and also throughout the Pierre and Edmonton series, the latter supplying a smooth clay which bakes to a porcelain-like mass. Clay is also said to occur with the coal beds along the North Saskatchewan River. An analysis of it is given.

NOTE.—Full information concerning the production, imports, and exports of clay and clay products in Canada is given in statistical tables which will be found on other pages of this volume.

In the following table will be found analyses of different kinds of clay occurring in various parts of this country. This list is very complete and is compiled from official sources:

	Comb. SiO_2	Free SiO_2	Al_2O_3	Fe_2O_3	Ca O.	Mg O	TiO_2	Alk.	P_2O_5	Comb. H_2O	Free H_2O
Fire Clays.											
Woodbridge, N. J.	42.23	0.50	39.53	0.50	0.10	....	1.40	0.49	....	13.59	1.21
“ “	42.05	5.70	35.83	0.77	....	0.11	1.10	0.44	....	12.20	1.50
Raritan River, N. J.	37.85	10.50	35.75	0.95	......	trace.	1.60	0.37	....	12.30	4.00
Sand Hills, N. J.	39.80	8.10	36.34	1.01	....	0.04	....	0.15	....	12.90	1.20
South Amboy, N. J	42.71	0.70	39.24	0.46	0.20	....	1.60	0.89	....	13.32	1.58
Sayreville, N. J.	41.10	3.10	38.66	0.74	....	....	1.20	0.46	....	13.55	1.00
South Amboy, N. J.	19.50	53.20	17.58	1.42	trace.	0.43	....	2.24	....	4.50	1.20
Mineral Point, Ohio	35.39	17.13	31.84	0.67	0.50	0.19	1.68	0.59	....	11.68	0.69
Sciotoville, Ohio	43.78		40.82	....	....	....	....	....	....	13.77	0.82
Portsmouth, Ohio	50.95	with clay.	39.49	with Al_2O_3	0.30	0.28	....	0.31	....	9.18	.....
Columbus, Ohio	60.77	“	25.74	1.61	0.89	0.63	....	1.20	....	9.46	.....
Steubenville, Ohio	29.22	31.34	24.97	1.66	0.63	0.40	1.30	0.28	....	8.90	1.69
Zanesville, Ohio	31.07	27.71	26.47	1.22	0.59	0.32	0.94	0.99	....	9.96	1.04
Wilmington, Del	72.40		14.80	trace.	0.35	....	....	0.85	....	12.90	
Newcastle, Del	72.33		16.75	1.29	2.00	0.07	....	....	....	7.98	
Winchester, Ill	69.85		17.08	3.47	....	0.28	0.90	1.10	....	4.40	
New Windsor, Ill	76.10		15.04	1.08	0.62	0.30	....	1.55	....	5.20	
Boone Furnace, Ky	48.56		37.47	trace.	0.11	trace.	....	0.57	0.26	13.03	
Summit, Ky	67.99		25.00	....	1.99	undete	....	rmin'd	....	2.15	
Fulton County, Ky	81.06		13.61		0.31	0.14	....	0.25	0.05	3.60	
Union County, Ky	73.90		17.60	3.00	0.34	undet.	....	0.10	....	5.70	
Cheltenham, Mo.*	61.02		25.64	1.70	0.70	0.08	....	0.73	....	10.00	
“ “	56.01		31.68	1.13	1.17	0.21	....	0.09	....	9.71	
St. Louis, Mo	61.73		27.24	....	0.48	....	....	....	....	11.23	
Mount Savage, Md.*	50.46		35.90	1.50	0.13	0.02	....	....	1.15	13.90	
Moore County, N. C.*	75.34		17.06	1.94	2.56		....	....	... .	3.10	
Harnett County, N. C	70.60		20.46	1.82	1.85		....	....	....	5.27	
Richmond County, N. Y	64.26		24.76	0.83	0.73	trace.	....	2.35	....	......	
Dickinson, N. Dak	64.22		17.22	2.09	trace.	0.37	....	0.55	....	10.29	
Henderson County, Texas	68.55		26.00	trace.	trace.	0.11	....	trace.	....	6.00	
Spragueville, W. Va	47.88		33.99	1.37	0.36	0.35	3.19	0.48	....	12.39	
Great Kanawha, W. Va	55.67		30.39	0.61	....	trace.	......	0.12	....	12.87	
Marion County, W. Va	45.86		44.23	....	0.24	0.36	....	trace.	....	9.05	
Preston County, W. Va	68.16		24.11	0.01	trace.	trace.	....	trace.	....	7.51	
Crook County, Wy	61.08		17.12	3.17	2.69	1.82	....	0.20	....	12.98	
King County, Wash	57.50		34.37	1.24	0.50	1.00	....	0.68	....	4.71	
Pierce County, Wash	69.71		18.39	1.44	0.35	0.15	....	1.02	....	8.94	
Woodland, Penn	45.29		40.07	1.07	0.26	0.08	....	0.05	....	13.18	
Tyrone, Penn	48.35		36.37	1.99	0.07	0.12	....	2.54	....	10.56	
Queen's Run, Penn	46.65		36.36	1.19	0.08	....	2.64	1.30	....	13.01	
Savage Mount, Penn	53.86		35.48	1.23	0.30	0.14	....	....	....	8.75	
Benezet, Penn	47.23		38.41	0.39	....	0.19	....	....	....	13.77	
Farrandsville, Penn	45.26		37.84	2.03	0.08	0.02	0.20	1.26	....	13.30	
Retort, Penn.*	42.32		37.01	0.95	0.47	0.16	3.83	1.29	....	17.94	
New Bethlehem, Penn.*	44.61		38.01	1.25	0.08	0.41	1.02	1.74	....	13.63	
Bolivar, Penn.*	59.83		24.58	1.66	0.28	0.87	1.17	3.11	....	7.83	
Salina, Penn.*	51.92		31.64	1.13	0.03	0.44	1.16	0.40	....	13.49	
Beaver County, Penn	65.18		30.35	1.43	trace.	0.22	....	2.36	....	0.42	
Louina, Ala	37.29		31.92	trace.	....	0.72	....	....	....	29.37	
Jacksonville, Ala	44.60		38.92	0.78	....	1.03	......	....	....	14.28	
Choctaw County, Ala	36.30		5.12	1.60	0.46	....	....	....	....	6.60	
Poinsett County, Ark	61.76		22.91	3.32	0.75	0.90	....	1.00	....	8.75	
Greens County, Ark	70.43		19.15	1.70	0.52	trace.	....	1.84	....	24.27	
Carbondale, Cal	57.02		31.06	0.53	....	....	....	2.32	....	8.95	
Carville, Cal	88.30		0.85	0.15	1.03	0.48	....	5.07	....	5.40	
Lincoln, Cal	44.82		34.54	1.86	1.55	0.96	....	4.74	....	10.00	
Golden, Colo	56.76		34.15	1.30	0.83	0.19	....	....	....	6.74	
Paving-Brick Clays.											
Bloomington, Ill	67.80		11.55	6.50	8.90	5.32	....	2.42	....	0.20	
Burlington, Ia	77.40		11.74	12.31	1.60	1.91	....	4.23	....	......	
Clinton, Ia	73.82		15.88	9.16	trace.	trace.	....	4.50	....	3.50	
Franklin County, Kan	59.60		17.86	14.94	0.79	0.81	....	....	....	6.00	
Leavenworth, Kan	58.45		21.96	8.43	1.05	1.47	....	4.00	....	6.51	
Flint Ridge, Kan.*	58.20		29.80	5.40	6.00	....	....	....	....	0.60	
Cheltenham, Mo	61.22		25.64	3.47	....	....	....	1.31	....	9.68	
Montgomery, Mo	43.93		40.09	1.70	....	....	....	0.20	....	14.60	
Kansas City, Mo	64.37		19.73	9.07	0.82	2.32	....	3.78	....	......	
Cumberland, W. Va	69.02		22.07	4.53	1.70	0.38	....	2.68	....	......	
Nuzum's Mills, W. Va	59.25		32.26	1.67	7.16	....	....	....	....	6.30	
Mount Savage, Md	39.90		30.08	0.88	....	....	....	2.30	....	13.90	
Robbins, Tenn	70.57		15.19	7.97	0.78	0.32	....	2.30	....	......	
Hornellsville, N. Y	67.29		15.85	6.16	0.95	0.19	....	8.71	....	... ..	
Warners, N. Y	52.30		18.85	6.55	3.36	4.49	....	6.00	....	8.34	
Woodbridge, N. J	42.23		39.53	0.50	0.01	....	1.40	0.49	....	16.80	
Phillipsburg, N. J	56.78		17.38	0.50	4.14	3.15	....	3.42	....	7.60	
Columbus, Ohio	57.45		21.06	7.54	0.29	1.22	....	3.66	....	7.80	
Canton, Ohio	53.38		19.36	14.86	1.48	1.06	....	....	....	......	
East Palestine, Ohio	57.80		25.54	2.51	0.25	0.61	....	2.69	. .....	10.60	
Haydensville, Ohio	76.24		16.87	0.16	....	0.50	....	1.09	....	4.90	
Woodlawn, Penn	42.15		31.43	2.32	0.32	2.01	1.00	....	....	10.60	
New Brighton, Penn	67.36		22.05	5.61	0.86	0.36	....	5.40	....	......	
San Francisco, Cal	56.51		21.33	0.29	....	3.53	....	trace.	....	6.30	
Golden, Colo.*	52.41		32 21	0.66	0.20	0.60	....	0.61	....	14.05	
Winchester, Ill	23.15		17.08	....	....	0.28	1.20	1.10	....	......	
Brick Clays.											
Sayreville, N. J	56.10		27.42	2.68	....	0.18	1.00	2.71	....	9.50	
Fort Smith, Ark	57.10		23.74	8.18	0.53	1.04	....	2.40	....	7.21	
Jonesborough, Ark	74.65		12.99	5.10	0.31	0.47	....	2.06	....	4.42	
Paragould, Ark	79.07		8.79	2.54	0.25	0.23	....	1.89	....	3.55	
Cartersville, Ga. (shale)	71.60		11.50	5.59	....	1.30	1.10	4.55	....	3.95	

Brick Clays.	SiO_2		Al_2O_3	Fe_2O_3	Ca O	Mg O	TiO_2	Alk.	P_2O_5	H_2O	
Cartersville, Ga	69.18		15.43	5.83	....	0.71	....	1.98	....	6.83	
Rome, Ga	67.80		13.82	5.74	....	0.81	1.67	2.55	....	7.60	
Bedford, Ind	79.94		9.37	3.20	0.64	0.58	....	....	....	6.21	
New Albany, Ind	48.83		14.95	6.00	7.83	4.31	....	....	....	8.01	
Homer, La	82.83		6.48	1.42	0.15	0.08	....	....	....	8.04	
Gay Head, Mass	57.50		31.21		0.19	0.20	....	0.40	....	9.83	
West Cambridge, Mass.*	48.99		28.90	3.89	7.10	3.66	....	4.73	....	3.31	
Quinnipiac, Me	63.69		17.02	10.18	0.97	....	....	4.02	....	4.15	
Makato, Minn	70.10		16.99	trace.	....	....	....	10.69	....	1.98	
Rochester, N. Y	50 55		15.46	4.38	10.95	3.35	....	6.30	....	......	
Hudson River, N. Y	59.81		22.00		4.35	2.29	....	....	....	8.55	
Newfield, N. Y	51.30		12.21	3.32	11.63	4.73	....	4.33	....	1.50	
Spout Spring, N. C	56.63		26.22	5.93	0.30	....	....	....	....	10.92	
Lenoir County, N. C	72.25		11.28	3.62	....	1.75	....	....	....	11.10	
Marquette, Mich	54.62		12.82	2.00	13.68	4.25	....	....	....	12.01	
Grand Forks, N. Dak	51.27		9.33	3.52	11.15	2.31	....	2.58	....	......	
Bismarck, N. Dak	58.73		14.98	5.63	2.10	0.74	....	1.15	....	16.67	
Mercer County, N. Dak	60.79		16.23	4.49	0.65	1.02	....	0.47	....	16.35	
Morrison, Texas	72.30		19.33	2.47	trace.	0.50	....	4.44	....	......	
Courtney, Texas	40.69		12.68	3.90	18.12	0.92	....	1.14	....	22.55	
Cisco Division, Texas	55.57		22.04	7.35	0.35	....	....	4.50	....	8.77	
Rock Creek, Wyo	59.78		15.10	2.40	0.73	4.14	....	....	....	16.26	
Milwaukee, Wis	38.22		9.75	3.84	13.24	7.90	23.20	2.81	....	2.80	
" "	40.22		8.47	2.83	15.45	7.80	....	3.20	... ...	20.71	
Pottery Clays.	Comb.	Free.					....			Comb.	Free
Woodbridge, N. J	19.44	48.40	21.83	1.57	0.28	0.24	....	2.24	....	5.90	0.80
East Liverpool, Ohio	42.28	18.02	24.12	1.46	0.59	0.68	....	2.42	....	7.77	0.86
Zanesville, Ohio	25.48	42.65	20.80	1.20	0.42	0.37	....	2.55	....	5.72	1.00
" "	25.40	40.81	21.13	1.28	0.51	0.18	....	1.80	....	6.29	1.65
Roseville, Ohio	28.61	34.79	23.01	1.50	0.41	0.62	....	1.26	0.35	8.03	1.97
Golden, Colo	68.40		18.88	1.56	0.55	0.45	....	1.71	....	8.20	
Pope County, Ill	46.90		31.34	0.16	....	0.10	....	0.95	....	20.00	
Reelsville, Ind	60.56		27.00	3.48	0.73	....	....	2.80	....	6.57	
Putnam County, Ind	66.18		21.15	5.30	0.70	0.14	....	0.33	....	4.86	
Sumanville, Ind	68.50		17.55	1.38	1.20	0.25	....	2.61	....	8.51	
Evansville, Ind	59.50		26.22	0.80	0.56	2.76	....	2.96	....	......	
Huron, Ind	41.13		39.26	0.20	0.37	....	....	19.05	....	......	
Murray, Ky	57.84		30.34	1.18	0.11	0.05	....	1.14	....	9.44	
Bell City, Ky	56.98		32.16	2.16	trace.	0.21	....	0.95	....	7.54	
Frankfort, Ky	69.30		21.78		0.16	0.33	....	2.94	....	5.44	
Hickman County, Ky	76.36		14.95	2.11	0.33	0.17	....	0.71	....	4.31	
Fulton County, Ky	71.02		17.98	3.42	1.02	0.26	....	0.95	....	5.28	
Makato, Minn	73.34		14.75	5.45	0.28	0.05	....	trace.	....	4.71	
Great Neck, N. Y	62.06		18.09	5.40	1.05	trace.	....	6.11	....	......	
Northport, N. Y	62.66		18.09	0.97	0.79	....	....	2.23	....	......	
Glen Cove, N. Y	70.45		21.74	1.72	0.24	0.30	....	5.00	....	......	
West Neck, L. I	61.01		19.23	5.43	0.96	1.88	....	4.60	....	......	
Marion County, Texas	58.20		23.97	4.43	....	....	....	7.11	....	5.36	
Athens, Texas	69.20		21.03	1.37	trace.	0.94	....	2.30	....	5.16	
London, Tenn*	45.06		30.03	4.50	4.70	4.80	....	....	....	10.10	
Pipe Clays.											
Woodbridge, N. J	67.70		19.91	1.69	....	0.72	1.00	2.56	....	6.50	
" "	62.10		23.80	1.60	trace.	0.57	1.70	2.77	....	6.70	
Toronto, Ohio	57.75		28.66	1.94	0.15	0.24	....	2.55	....	8.35	
Elliottsville, Ohio	77.61		12.78	3.32	0.55	0.45	....	1.30	....	4.10	
N. U. Walker, Ohio	56.75		33.72	....	0.29	1.58	....	1.01	....	6.89	
Columbus, Ohio	71.30		12.63	5.07	1.05	....	....	....	....	7.30	
Carbondale, Cal	48.90		38.18	2.40	0.50	0.09	....	1.85	....	8.65	
New Providence, Ky	61.68		28.50	1.68	0.10	0.14	....	1.98	....	5.92	
Marshall County, Ky	62.92		29.88		trace.	0.21	....	1.74	....	5.56	
Angola, N. Y	65.15		15.29	6.16	3.50	1.57	....	5.71	....	......	
Langdon, N. Dak	50.45		17.57	2.80	0.25	1.79	....	0.93	....	26.21	
Kaolin.											
Talladega, Ala	43.21		37.27	trace.	0.11	0.10	....	0.68	....	18.50	
Clifton, Ariz	42.40		32.50	16.17	2.17	trace.	....	... ...	....	......	
Golden, Colo	56.41		26.37	....	0.29	0.20	....	15.5	....	14.66	
Huron, Ind	40.50		36.35	0.15	....	0.13	....	0.14	....	22.60	
Edwards County, Texas	48.41		43.17	....	0.38	0.10	....	1.78	....	6.05	
Grand Rapids, Wis	78.83		13.43	0.74	0.64	0.07	....	0.44	....	5.46	
Nelson County, Va	69.50		19.10	... ...	....	....	....	1 00	....	12.12	
Brandywine Summit, Penn	46.28		36.25	1.64	0.19	0.32	....	2.53	....	13.54	
Chestnut Hill, Penn	67.10		20.10	3.90	0.10	0.70	....	2.00	....	5.90	
Blandford, Mass	52.03		31.76	trace.	trace.	0 54	....	trace.	....	15.55	
Slip Clays.											
Brimfield, Ohio	63 63		13.57	7.77	2.55	1.47	....	3.51	....	6.65	
Springfield, Ohio	42.24		11.08	5.07	15.99	6.36	....	2.68	....	16.58	
Bronhar, Ohio	61.01		21.61	5.38	2.83	1.59	....	2.28	....	5.56	
Albany, N. Y	60.59		12.46	5.79	6.84	3.28	....	4.39	....	5.82	
Rawley, Mich	43.94		11.17	3 81	11.64	4.17	....	3.61	....	19.56	
Piedmont Springs, Texas	58.50		18.39	3.29	2.34	1.61	....	7.63	....	8.70	
Terra Cotta Clays.											
Savage Mount, Penn	56.04		28.59	0.86	0.44	0.91	....	....	....	......	
New Brighton, Penn.*	61.97		22.94	1.82	0.44	0.52	1.98	1.75	....	8.85	
Chico, Cal	88.70		4.50	0.50	0.93	0.36	....	0.63	....	4.46	
Glens Falls, N. Y	57.46		21.15	5.52	3.65	1.50	. ...	4.72	....	......	
" "	48.35		11.33	4.02	15.38	3.17	....	6.05	....	1.18	
Wyandance, L. I	59.83		24.45	trace.	0.23	0.59	....	8.75	....	4.28	
Adobe Soils.											
Salt Lake City, Utah	19.24		3.26	1.09	38.94	2.75	....	trace.	.. ...	31.24	
Humboldt City, Nev	26.67		13.19	5.12	13.91	2.96	.... ..	2.30	....	10.81	
Sante Fé, N. M	66.69		14.16	4.38	2.49	1.28	....	1.88	....	6.94	

COAL.

By H. S. Fleming.

The coal fields of the United States are divided primarily under two heads—anthracite and bituminous; the former embracing an area of about 1000 square miles, and the latter 300,000 square miles, though of course only a portion, variously estimated as between 15% and 20% of the total, may be regarded as likely to become commercially productive. In 1893 the combined output of these fields amounted to 181,319,490 tons (of 2000 lbs.), of which 53,810,214 tons were anthracite and 127,509,276 tons bituminous.

The anthracite fields are divided as follows: New England basin (Rhode Island and Massachusetts), 500 square miles; Appalachian region (Pennsylvania and Virginia), 484 square miles; Rocky Mountain region (Colorado and New Mexico), 15 square miles.

Commercially speaking, Pennsylvania produces practically all the anthracite coal mined in this country. In Arkansas, Colorado, Nebraska, New Mexico, Virginia, Massachusetts, and Rhode Island, though anthracite exists, the amounts produced are so small that they may be disregarded. In the Rhode Island basin the term "anthracite" as applied to the mineral produced is somewhat of a misnomer, since but a small portion of it is suitable for or is used as fuel. The coal beds and their accompanying strata have been subjected to a high degree of metamorphic action, which has resulted in the formation of a mineral closely resembling graphite. The principal use made of the product is in the manufacture of foundry facings and similar materials, though for some time a certain quantity was used in Pittsburg by the Carbon Iron Company in its direct process for the manufacture of steel, but subsequently fine coke replaced the Rhode Island material.

In Pennsylvania the anthracite fields are generally known to the trade under three divisions—the Wyoming, Lehigh, and Schuylkill regions. Geologically there are five well-defined areas, known as the Northern, lying almost entirely in Wyoming and Lackawanna Counties; the Eastern Middle, lying principally in Luzerne County; the Western Middle, lying within Schuylkill, Columbia, and Northumberland Counties; the Southern, lying in Carbon, Schuylkill, and Dauphin Counties, and the Loyalsock, lying in Sullivan and Wyoming Counties. These are subdivided into numerous local districts, and by the State into eight inspection districts. The anthracite region lies in the extreme northeastern part of the great Appalachian coal fields, in the eastern part of Pennsylvania. The total area of the field embraces about 1700 square miles, of which 484 miles are coal bearing.

Many widely diverging estimates have been made as to the original and present contents of this field. Of late years particular attention has been directed toward this matter through fear of the exhaustion of the beds, which is being hastened by the extremely wasteful methods followed in mining and preparing the coal for market. As early as 1868 Mr. Richard P. Rothwell referred to this matter in a report made to the Lehigh Coal and Navigation Company on their coal property near Mauch Chunk, Penn. He said, among other things: "Calculating from the mine plans, and other data, we find the area of beds worked over yields 39,000,000 tons, . . . but, since only 11,868,291 tons were sent to market from the company's mines, it follows that only 30½%, or less than one-third of the coal worked over, was made available. . . . It is to be hoped that before many years have passed this loss will be greatly diminished. . . . The value of a coal property is not measured alone by the quantity of coal it contains, but is influenced by a variety of conditions, such as the thickness of the beds, their depth below the surface, whether they can be mined above water-level by tunnels, or below by shafts and slopes. The nature of the coal, the presence or absence of fire-damp, and of large quantities of water—in short, the value of a property is determined by the amount of coal we can get from it, not the amount it contains. . . . The system of mining introduced and adopted in our anthracite mines thirty years ago is still practiced universally. . . . Certain it is, we cannot long continue to work our mines in the present disgracefully wasteful manner. We are now sowing the seeds which in a few years will yield a fruitful harvest of trouble and expense. We are wasting throughout the anthracite region from one-third to two-thirds of our coal where it is cheaply and easily mined."

It is unfortunately true that so little improvement has since been made in working our anthracite mines that these statements are as pertinent to-day as they were a quarter of a century ago. The only improvements which have taken place, as regards lessening waste, have been in the breaker machinery; in popularizing the use of fine coal, rendered possible by the invention of the base-burning stove; and in some mines the filling of the rooms with culm washed down from the surface through pipes.

The result of the existing system of mining is already becoming apparent, and the final exhaustion of the beds is now within measurable distance. Even the great coal companies which own in fee the greater part of the very limited and immeasurably valuable anthracite fields of Pennsylvania have done little or nothing to adopt any improved method of mining by which the whole of the bed can be extracted. Possibly the practical monopoly of the anthracite trade, which has for years been exercised by these few powerful companies acting together, accounts for this neglect to improve radically the system of mining which a quarter of a century ago was justly characterized as "disgracefully wasteful." It is so much easier—when one has the power—to make the public pay for waste in mining and extravagant freights than it is to introduce better methods and greater economy.

Many estimates have been made of the original coal contents of the Pennsylvania anthracite fields, but the most of these have been wild exaggerations. An estimate by Mr. R. P. Rothwell, published in 1877 in the *Engineering and Mining Journal*, was the first that called attention to the comparatively small amount of coal remaining and the short time it would last under the wasteful system of mining then and now in use. The latest estimate of the anthracite yet remaining was made in 1893 by the Pennsylvania Commission on the Waste in Coal Mining. This estimate is made on a larger area than was known, in 1877, to contain coal, and would therefore be somewhat larger, but the commission states that its estimate is probably too large. The estimates which for years have been circulated have usually been from two to four times as large as these, and are wholly misleading. The area and contents in coal of the anthracite basins of Pennsylvania in 1877, as compiled by Richard P. Rothwell, was as follows:

Field.	Area, Square Miles.	Aver. thick. Coal, Feet.	Total Quantity of Coal in Tons of 2240 Lbs.							Per Cent.
			Per Acre.	Total Original.	Per Cent.	Marketed to End 1877.	Exhausted, including Waste.	Yet Remaining.	Amount yet Obtainable, allowing for Waste.	
Wyoming	185	19	34,580	4,097,730,000	36	151,475,872	378,689,680	3,719,040,320	1,859,520,160	41
Lehigh...........	43¾	20¼	36,855	1,030,120,000	9	72,422,227	206,910,302	823,209,698	329,283,879.2	07
Schuylkill	215	25	45.500	6,256,250,000	55	157,776,236	450,766,703	5,805,483,297	2.322.193,318.8	52
Total and aver.	373¾	22	40.084	11,384,100,000	100	381,674,335	1,036,366,685	10,347,733,315	4,510,997,358	100

The estimate made in 1893 by the Pennsylvania Coal Waste Commission above referred to was as follows:

Field.	Area, Miles.	Quantity of Coal, Tons of 2240 Lbs.				Obtainable at 40%.
		Original.	Market to End 1892.	Wasted to End 1892.	Remaining, Total.	
Wyoming............. Lehigh.................	176 45	7,300,000,000	575,250,000	624,750,000	6,100,000,000	2,440,000,000
Schuylkill	263	12,200,000,000	309.750,000	790,250,000	11,100,000,000	4,440,000,000
Total................	484	19,500,000,000	885,000,000	1,415,000,000	17,200,000,000	6,880,000,000

According to the report of this commission, 62½% of all the coal in the beds mined over was wasted and but 37½% was marketed. If we estimate the percentage marketed in the future at 60%—and unless some radical improvement be made in the system of mining or marketing, or both, not much more than this can be expected—the amount yet available would be but 6,880,000,000 tons, while in 1887 Mr. Rothwell estimated it as 4,511,000,000 tons.

The present rate of output is nearly 50,000,000 long tons. If we assume that this will increase to an average of 70,000,000 tons a year during the remaining life of the field, our supply would hold out but from 70 to 100 years. Of course, when the unworked portions of the field become small the output will decline, and anthracite will become a luxury and not an industrial fuel. The outlook is certainly serious enough to command the earnest attention of those interested in the anthracite trade, if not the citizens of the State.

THE BITUMINOUS COAL FIELDS.

Coal Fields	States.	Area, Square Miles.	Coal Fields.	States.	Area, Square Miles.
Triassic	North Carolina	2,700	Northern	Michigan	6,700
	Virginia	180			
		2,880	Central	Indiana	6,450
Appalachian	Mass. and Rhode Island	....		Kentucky	4,000
	Pennsylvania	9,000		Illinois	36,800
	Ohio	10,000			47,250
	Maryland	550	Western	Iowa	18,000
	Virginia	2,000		Missouri	26,700
	West Virginia	16,000		Nebraska	3,200
	Kentucky	10,000		Kansas	17,000
	Tennessee	5,100		Arkansas	9,100
	Georgia	200		Indian Territory	20,000
	Alabama	8,660		Texas	4,500
		64,395			98,700
Rocky Mountain.	Dakota, Montana, Idaho, Wyoming, Utah, Colorado, and New Mexico. Area unknown.		Pacific Coast.	Washington, Oregon, and California. Area unknown.	

The Triassic coal field in Virginia was the first to be developed in this country, but it never reached a high state of productiveness owing to the difficulties encountered in mining. Lying on the James River close to Richmond, on navigable water, it has had every inducement to become a large producer, but since 1833, when the output reached its maximum, 159,040 tons, there has been a steady decline. In North Carolina, in what are known as the Deep River and Dan River basins, the Triassic coal is found in five distinct seams, two of which, one three and the other two feet in thickness, are regarded as workable. Prior to 1889 no mining worthy of note was done in the State.

In 1891, 20,355 tons were mined, but in 1893 this had decreased to 17,000 short tons. Serious faulting in the seams, extensive barren areas, dangerous mine gases, and often an unusual amount of water, are met with here, as in the Virginia Triassic basin.

The Appalachian coal field, while not the largest in area, is by far the greatest producer. Extending nearly 900 miles from New York State to Alabama, parallel to the seacoast, with a width varying from 30 to 180 miles, it has been crossed by all of the great trunk-line railroads. This coal field has supported, and still supports, the iron and steel industry of the country. In the past twenty-three years over sixteen hundred millions of tons of coal have been produced from it, and over a thousand million tons of this were bituminous.

The various coal seams in this field vary widely in character and composition through all classes from anthracite to cannel, from those containing an almost inappreciable amount of ash to others holding as much ash as fuel. The coal beds lie in all degrees of regularity and irregularity, sometimes horizontal and extending without break over considerable areas, and again folded completely over themselves, distorted and disconnected. In Pennsylvania the upper and middle seams of the measures are most fully developed, but as they proceed southward the middle and lower measures become most productive, until at the southern limit of the field, in Alabama, the lowest measures are the only ones remaining and they supply all the coal mined. Various estimates have been made as to the average total thickness of the coal seams in the Appalachian field, some placing it at 20 ft. and others at 35 ft. The average workable thickness is, however, much less than this, and would probably not average above 10 ft. for the entire field, as in but few places are there more than two seams which can be considered as commercially available, while over a portion of the field only one seam can be worked.

The most interesting developments in the Appalachian field during recent years have been in West Virginia, Kentucky, Tennessee, and Alabama. During the past ten years the output of these States has increased over 150%, and in the two first named developments in the past three years have shown such an unusual variety and excellence of coal that even in the face of the extreme depression many new operations have been commenced. In the southern part of the field the troubles heretofore experienced from high ash and sulphur in coal used for coking have in a large measure been overcome by the use of coal-washing machines, many of which have been erected during the past two years.

The northern field is confined entirely to the State of Michigan and is but a small producer. The beds are usually difficult to work, the seam varying from 3 to 4 ft. in thickness, with a poor roof and wet bottom. The formation is full of curves and faults, which, with the other difficulties, place the coal at a disadvantage in competing with the Ohio product.

The central field is the second largest producer, its output in 1893 being 26,828,032 tons. Western Kentucky, which embraces 4000 square miles of this field, produced 1,791,261 tons. This basin contains twelve workable seams of coal, though all are not present in any one place. On its outer edge the coals of the lower measures come to the surface, but in the middle of the basin the upper measures remain. Nearly all of the coal is high in sulphur. Illinois comprises 77% of the total area of the central field, its output in 1893 being 18,955,000 tons. The coal-bearing measures in this State, as also in Indiana, consist of alternations of sandstone, shales, and bituminous slates, with coal and its accompanying clays. Sixteen different seams of coal have been defined, the total depth of the measures aggregating nearly 1200 ft. in the southern part of the State, and from 600 to 800 ft. in the northern part.

The Western coal field is by far the greatest in area, but in point of production it stands third, the output for 1893 being 12,468,607 net tons. This field, in Iowa and Missouri, is a continuation of the central field of Illinois and Indiana, possessing the same common features. It has been divided, in the two States named, into the Upper, or Missouri stage, and the Lower, or Des Moines stage; the former, consisting essentially of the Upper Coal Measures, occurring typically in Northwestern Missouri, averaging about 800 ft. in thickness, and the latter of the Lower Measures, averaging about 400 ft. in thickness and extending down through Missouri into Kansas and Indian Territory. The coal seams in these beds vary from a few inches to 10 ft. or over in thickness, though the average of seams being worked will not exceed 4 to 5 ft.

In Nebraska the Carboniferous, Cretaceous, and Tertiary formations all contain some coal or lignite, but the only operations have been in Pawnee County, near Du Bois, in an 18 in. seam. The Kansas beds are divided into five fields or basins, in which the coal lies at depths varying from 30 to 150 ft. from the surface, the veins seldom exceeding 3 ft. in thickness and averaging about 22 in. Arkansas coal beds are found in the Carboniferous formation in the western part of the State, from which they extend into Indian Territory. The coal beds vary in thickness from 4 to 7 ft. The coal found in this field belongs properly in the semi-bituminous class, though some of it might be termed bituminous and other semi-anthracite. The coal in Indian Territory is a continuation of the same beds. The coal fields of Texas are extremely important from an economic standpoint, but, while the field covers a considerable area, variously estimated between 4000 and 15,000 square miles, the coal thus far found has been generally high in sulphur.

The lignite fields are far more extensive than the coal area. Four distinct seams have been recognized, varying from 3 to 15 and even 20 ft. in thickness, though the latter figures are exceptional. A coal basin but recently opened in Texas is in the Cretaceous formation on the Rio Grande, near Eagle Pass. This is a continuation of the coal field in Mexico in which the Honda mines are operating, and so far has shown encouraging results.

The Rocky Mountain field is a comparatively new one, only three of the producing States having engaged in mining operations prior to 1880. It is made up of numerous detached basins of greater or less extent, each having its own peculiarities in quality of coal and the accompanying formation, though in the latter respect there is a general similarity throughout the field. The varieties of coal vary from a fair quality of anthracite through bituminous to lignites or lignitic coal, the latter two predominating. Throughout this field the Carboniferous strata are not, economically speaking, coal bearing, nearly all of the productive measures being in the Upper Cretaceous. In Colorado the area of the coal measures is estimated at 18,100 square miles, and their depth in some basins at 3000 ft., containing between thirteen and twenty-five distinct seams of coal, though where the latter number is reported, in Huerfano County, seams of four inches were included. In Utah the available coal area is computed at 2000 square miles.

The Pacific coast field is credited with the least production of any, that for 1893 being 1,428,769 tons. In California the coal-bearing strata occur in the older Tertiary rocks, consisting of white sandstone with smaller amounts of shale. Most of the coal found is lignite. In Oregon one mine is in operation at Newport, in Coos County, where a very fair quality of bituminous coal is found. Washington is the largest producer in this field, part of its product being lignite, part semi-bituminous, and the remainder bituminous coal.

PRODUCTION OF COAL IN THE UNITED STATES.

The coal production in 1893 was greater than during any previous year in the history of this country. In the first six months there was a very large increase in the output, and had the conditions then prevailing held through the balance of the year the production of this country would probably have been many million tons greater than in 1892. During the six months from July to December, 1893, however, the business depression so affected coal mining that a portion of this gain was lost.

Since coal furnishes the motive power for all industries, the amount consumed during the year is one of the best indicators of the degree of activity in manufacturing. Had the fall of 1893 been unusually cold there would have been an increase in consumption for domestic use, but the contrary was the case, and further throughout the year there was unusual economy practiced, so that it is probable that the use of this fuel for domestic purposes actually declined and the portion used industrially increased still more than the production would indicate.

Comparing the output during 1893 with that of previous years shows the steady and remarkably rapid increase which has taken place. While the rate of increase from 1867 to 1877 was scarcely as rapid as that of Great Britain during the same years, yet it was far greater than that of any other country, and since 1877 the output of the United States has grown at a marvelous rate never before attained by any country. Already we produce more than the amount consumed in Great Britain, and in three or four years this will be the chief coal-producing country in the world.

UNITED STATES COAL PRODUCTION AND VALUES.

State.	1892.			1893.		
	Net Tons.	Value per Ton	Total Value	Net Tons.	Value per Ton	Total Value
Alabama	5,314,227	$1.00	$5,314,227	5,170,042	$0.95	$4,911,540
Arkansas	739,300	1.25	924,125	750,000	1.25	937,500
California	131,431	2.43	319,377	167,219	2.34	391,292
Colorado	3,771,234	1.60	6,033,974	3,947,056	1.44	5,683,761
North Dakota	240,000	1.00	240,000	325,000	.94	305,500
Georgia	165,000	1.01	166,650	372,191	.91	338,694
Illinois	17,949,939	1.01	18,129,489	18,955,000	.95	18,007,250
Indiana	4,494,811	1.03	4,629,655	4,583,000	1.01	4,628,830
Indian Territory	1,004,765	1.50	1,507,147	1,229,562	1.50	1,844,343
Iowa	3,820,000	1.25	4,775,000	3,790,000	1.24	4,699,600
Kansas	2,794,000	1.22	3,408,680	2,590,700	1.28	3,316,096
Kentucky	3,020,050	.94	2,838,847	3,290,032	.90	2,961,029
Maryland	3,036,283	.88	2,671,929	3,727,079	.87	3,242,559
Michigan	70,000	1.61	112,700	104,620	1.49	155,884
Missouri	3,017,285	1.27	3,831,952	3,285,000	1.11	3,646,350
Montana	648,701	2.07	1,342,811	783,300	2.12	1,660,596
Nebraska	1,500	2.75	4,125	2,000	2.50	5,000
New Mexico	434,291	1.41	612,350	457,045	1.39	635,293
North Carolina	6,417	1.54	9,882	17,000	1.50	25,500
Ohio	14,599,908	.94	13,723,914	14,719,929	.89	13,100,737
Oregon	34,720	3.20	111,104	50,000	3.00	150,000
Pennsylvania, Bituminous	46,576,576	.78	36,329,729	42,942,532	.71	30,489,198
Pennsylvania, Anthracite	52,472,504	1.71	89,727,982	53,810,214	1.73	93,091,670
Rhode Island	14,000	2.00	28,000	5,000	2.00	10,000
Tennessee	2,413,678	.91	2,196,447	1,857,432	1.05	1,950,304
Texas	300,000	2.25	675,000	322,745	2.00*	645,490
Utah	363,020	1.51	548,160	416,605	1.45	604,077
Virginia	800,000	.85	680,000	842,933	.80	674,346
West Virginia	8,710,878	.78	6,794,485	8,891,323	.77	6,846,319
Washington	1,000,000	2.81	2,810,000	1,211,550	2.98	3,610,419
Wyoming	2,454,449	1.41	3,460,773	2,243,401	1.39	3,118,327
Total, short tons	180,399,017	$1.18½	$213,958,514	180,859,510	$1.17	$211,687,504
Total, metric tons	163,656,915			164,074,671		

* Bituminous coal, $2.25; Lignite, $1.75.

COAL PRODUCTION OF THE UNITED STATES.

In the table of the mineral statistics of the United States, in the latter part of this volume, will be found the production, imports, and exports of coal of this country.

This vast output is no doubt due largely to the low and constantly decreasing cost of production. The average selling price of coal at the mines of the whole country was in 1893 about $1.17 per ton of 2000 lbs., or $1.29 per metric ton, as against $1.30½ per metric ton in 1892; $1.75 per metric ton in 1890; and $1.60 in 1880. These figures leave a fair average profit above cost of producing. This difference was estimated by the census investigators in 1890 as amounting to 16½c. per metric ton, or 11.7% on the cost.

UNITED STATES PRODUCTION OF COAL FROM 1870 TO 1892 BY STATES AND TERRITORIES.

Tons of 2000 lbs.

Year.	Alabama.	Arkansas	California.‡	Colorado.	North Dakota.	Georgia.	Indiana.	Indian Territory.	Illinois.	Iowa.	Kansas.	Kentucky.	Maryland.	Michigan	Missouri.
1870*.	10,999	....	129,629	4,500	....	....	437,870	....	2,624,163	263,487	32,939	150,582	1,819,824	28,150	621,930
1871..	20,000	....	135,285	15,860	....	....	600,000†	....	2,700,000	340,000	35,000	250,000	2,627,691	25,000†	650,000
1872..	30,000	560	164,704	68,540	....	....	800,000†	....	3,000,000	300,000	40,000	340,000	2,555,500	30,000	700,000
1873..	44,800	2,240	150,378	69,977	....	....	1,120,000	....	3,920,000	392,000	200,000†	336,000	2,971,852	20,000†	784,000
1874..	50,400	5,600	240,035	87,372	....	40,000	909,440	....	3,360,000	560,000	280,000	403,200	2,700,202	13,440	799,680
1875..	67,200	10,080	186,030	98,838	....	50,000	896,000	....	3,920,000	1,120,000	308,000	560,000	2,623,905	13,440	840,000
1876..	112,000	15,780†	172,201†	117,666	....	62,000†	1,064,000	....	3,920,000	1,680,000	368,000†	738,000	2,355,290	35,000†	1.008,000
1877..	196,000	23,480†	158,372†	160,000	....	75,000†	1,120,000	....	3,920,000	1,680,000	428,000†	952,000	2,063,259	69,197	1,008,000
1878..	224,000	29,190†	144,543†	200,630	....	87,000†	1,120,000	....	3,920,000	1,680,000	488,000†	100,800	2,180,840	85,322	1,008,000
1879 .	280,000	36,900†	130,714†	322,732	....	100,000†	1,340,068	....	3,920,000	1,792,000	528,000†	1,120,000	2,238,393	82,015	1,008,000
1880..	380,000	44,610†	116,885†	375,000	....	112,000†	1,680,000	....	4,480,000	1,792,000	550,000	1,120,000	2.692,497	129,053	1,680,000
1881..	420,000	47,000†	103,055	706,744	....	120,000†	1,984,120	....	6,720,000	3,920,856	750,000	1,232,000	2,833,348	130,130	1,960,000
1882..	896,000	50,000	113,255	1,061,479	....	130,000†	2,213,646	....	11,017,069	3,502,236	750,000	1,456,000	2,025,321	135,339	2,240.000
1883..	1,568,000	50,000	76,162	1,220,593	....	140,000†	3,072,000	....	12,123,456	4,457,540	900,000	1,848,000	2,476,075	71,296	2,520,000
1884..	2,240,000	75,000	77,485	1,130,024	35,000	150,000	2,531,200	....	12,208,075	4,370,566	1,552,154	1,736,000	2,765,617	36,712	2,800,000
1885..	2,492,000	100,000	71,615	1,398,796	25,000	150,000	2,375,000	500,000	11,834,459	4,012,575	1,440,057	1,904,000	2,833,337	45,178	3,080,000
1886..	1,800,000	125,000	100,000	1,436,211	25,955	223,000	3,000,000	534,580	11,175,241	4,315,781	1,390,000	1,550,000	2,517,577	60,434	2,800,000
1887..	1,950,000	129,600	50,000	1,791,735	21,470	313,000	3,217,711	685,911	12,423,066	4,473,829	1,570,079	1,933,185	3,278,023	71,461	3,209,916
1888 .	2,900,000	276,871	95,000	2,185,477	34,000	180,000	3,140,979	761,986	14,328,181	4,952,440	1,700,000	2,342,059	3,479,470	81,407	3,909,967
1889..	3,572,983	279,584	121,820	2,400,629	28,907	225,000	2,845,057	752,832	14,017,298	4,095,358	2,152,766	2,205,417	2,939,715	67,431	2,223,477
1890..	4,090,409	399,888	110,711	3,075,781	30,000	228,000	3,305,737	869,229	15,274,727	4,021,739	2,516,054	2,483,144	3,357,813	74,977	2,437,399
1891..	4,759,781	542,379	93,301	3,512,632	30,000	171,000	2,973,474	1,091.032	15.660.698	3.825,495	2 753,724	2.916.069	3.820.239	80,307	2,650,018
1892..	5,314,227	739,300	131,431	3,771,234	240,000	165,000	4,494,811	1,004,765	17,949,989	3,820,000	2,794.000	3,020,050	3,036,283	70,000	3,017,285
1893..	5,170,042	750,000	167,219	3,947,056	325,000	372,191	4,583,000	1,229,562	18,955,000	3,790,000	2,590,700	3,290,032	3,727,079	104,620	3,285,000

Year.	Montana.	New Mexico.	Ohio.	Oregon.	Pennsylvania.		Tennessee.	Texas.	Utah.	Virginia.	West Virginia.	Washington.	Wyoming.	Total.
					Bit.	Anthr.								
1870*.	....	....	2,527,284	....	7,798,517	15,650,275	133,418	....	5,800	61,802	618,878	17,844	50,000	33,003,315
1871..	....	....	2,478,185	....	8,909,584	19,464,877	150,000	....	15,000†	75,000	650,000	20,000†	147,328	39,308,810
1872..	....	....	5,953,129	....	10,442,000	24,734,172	200,000	....	20,000†	89,688	700,000	23,000†	221,745	50,410,038
1873..	....	....	5,096,031	....	13,098,829	25,626,631	392,000	....	25,000†	80,000	672,000	26,000†	259,700	55,100,938
1874..	....	....	3,659,395	48,384	12,320,000	24,267,472	392,000	....	33,600	81,872	1,120,000	30,352	219,061	51,637,005
1875..	....	....	5,447,970	32,256	11,760,000	23,120,730	403,200	....	38,800	88,704	1,120,000	99,568	300,808	53,121,029
1876..	....	....	3,920,000	30,000†	12,880,000	20,721,132	616,000	....	59,000†	97,888†	896,000	110,342†	334,550	51,328,217
1877..	....	....	5,880,000	35,000†	14,000,000	23,327,560	504,000	....	80,800†	107,072†	1,120,000	120,896†	342,853	57,371,989
1878..	....	....	6,120,000	40,000†	15,120,000	19,717,893	420,000	....	102,600†	116,256†	1,120,000	131,660†	333,200	54,505,434
1879..	....	....	6,720,000	42,000†	16,240,000	29,279,811	504,000	....	124,400†	125,440†	1,400,000	142,666	400,991	68,189,630
1880..	....	....	7,840,000	45,000†	21,280,000	26,249,711	717,967	....	146,200†	125,440	1,404,008	144,315	527,811	73,647,997
1881..	....	....	9,212,000	40,000†	22,400.000	31,920,018	840,000	....	168,000†	125,440	1,803,984	167,554	628,181	88,247,430
1882..	....	157,092	10,584,000	41,000†	24,640,000	32,614,507	952,000	....	190,800†	125,440	2,416,960	177,540	707,764	98,202,748
1883..	19,695	211,347	9.216,960	43,000†	26,880,000	35,418,353	1.120,000	....	195,000†	282,240	3,132,222	244,990	779,689	108,082,118
1884..	80,376	220,557	8,568,069	45,000†	28,000,000	36,558,478	1,344,000	....	200,000†	336,000	3,249,839	166,936	902,620	110,395,208
1885..	86,440	306,202	8,754,120	50,000	26,000,000	38,335.973	1,612,800	150,000	213,120	567,000	3,369,061	380,250	807,328	112,609,811
1886..	49,846	271,285	9,447,436	45,000	27,094,501	39,035,446	1,920,004	100,000†	200,000	684,951	3,598,664	423,525	829,355	114,660,292
1887..	10,202	508,034	11,537,912	31,696	31,516,856	42,088,196	2,128,000	75,000	180,021	825,263	4,936,820	772,601	1,170,318	130,975,305
1888..	41,467	626,665	12,220,259	75.000	33,796,727	46,619.564	2,203,372	100,000†	258,961	1,073,000	5,375,564	1,215,750	1,481,540	145,470,206
1889..	363,301	486,943	12,216,271	64,359	36,174,089	39.656,635	2,156,771	128,216	236,651	865,786	5,405,172	1,030.578	1,388,276	138,116,702
1890..	517,477	375,777	13,203,522	61.514	42,302,173	46,468,640	2,429,935	184,440	318,159	784,011	6,002,800	1,263,689	1,870,366	156,073,611
1891..	541.861	462.328	14.616.209	51.826	42,788.490	50.665.431	2.703.319	172,100	371.045	736.299	8.155.201	1,076.249	2.327.841	169,543,948
1892..	648,701	434,291	14,599,908	34,720	46,576,576	52,472,504	2,413,678	300,000	368,020	800,000†	8,710,878	1,000,000	2,454,449	180.399,217
1893..	783,300	457.045	14,719,929	50,000	42,942,532	53,810.214	1,857.432	322,745	416,605	842,933	8,891,323	1.211,550	2,243,401	180,859,510

* Census year. Nebraska, 1424 tons; Rhode Island, 14,000 tons, all anthracite of very refractory nature. The present average annual production of coal in Rhode Island may be taken at 5000 tons, and of Nebraska, all bituminous, at 1500 tons. † Estimated. ‡ Nearly all lignite. In 1891–3, Nebraska produced 1500 tons per annum. In 1889 North Carolina produced 192 tons; in 1890, 10,262; in 1891, 20,355; in 1892, 6417; in 1893, 17,000 tons.

In several States the selling price is much below $1 per ton and the cost delivered on the railroad from 50 to 75c. per ton, and in a few individual cases much less than this. Railroad freights to tidewater ports are in some instances ¼c. per short ton per mile, and a common rate is ½c. per ton per mile, so that even where the mines are 400 miles from tidewater the coal is often delivered f. o. b. vessels at $2 to $2.25 per ton, a figure which fully accounts for the growing exports of coal in recent years, and also for the enormous consumption in the domestic industries.

The possibilities of building up an enormous export trade in coal can be readily appreciated by a consideration of these figures, for there are many markets now supplied with British coal that could get their fuel with advantage from the United States, and that this is being done will become apparent as from year to year our exports increase. The quality of American coal is fully established and nearly all the record-breaking trips of the great ocean steamships have been made when using Pocahontas or Maryland coal.

World's Production of Coal.

The production and consumption of coal in the principal countries of the world is shown graphically in the accompanying diagram, and for all countries in the accompanying tables. From the diagram it will be seen that the United States has practically consumed all of the coal produced, while in the United Kingdom, Germany, Austria-Hungary, Belgium, and Russia the production has been in excess of consumption, the balance being exported. France produces less than it consumes and is a large importer.

In the United Kingdom the lines of production and consumption follow each other closely, but the former has increased with greater rapidity than the latter because of the growth of the export trade. The most striking feature of the diagram, however, is the line of production in the United States. Since 1878 there has been a rapid increase, creating almost a straight line, with the exception of a slight falling off between 1883 and 1886, and the drop in 1889, the census year. This latter is undoubtedly either through too low returns from the census agent or too high estimates for the few years preceding, more likely the latter, since during 1889 the country was in a prosperous condition and such a material decrease in the coal production could not have taken place without seriously disturbing industrial progress, which was not the case. Comparing it with the production of Great Britain it is seen that even though the output of that country should not decline further, it will be but four or five years before the United States becomes the leading coal producer of the world, as it is now the greatest in pig iron, in steel, in copper, and some other things. Even in 1892, when the production of coal in every other nation declined, that of this country increased 9,847,717 metric tons.

In Germany the increase in the production of coal has been almost identical with that of the United Kingdom, though as shown on the diagram it has been less seriously disturbed between 1870 and 1880 than either the latter country or the United States. The other nations show no unusual features. The production of coal has gradually increased in all. In France and Belgium the output

COAL PRODUCTION OF THE WORLD. (IN METRIC TONS.)

Year.	Africa.	Australasia.					Austria-Hungary.	Belgium.	Canada.		France.	Germany
		New South Wales.	New Zeala'd	Queens land.	Tas-mania.	Vic-toria.			Alberta. Brit. Columb.	N. Br'ck Nova Scotia.		
1820	......	......	......	......	......	......	......	......	......	h11,459	......	......
1821	......	......	......	......	......	......	......	......	......	13,075	......	......
1822	......	......	......	......	......	......	......	......	......	8,625	......	......
1823	......	......	......	......	......	......	e135,391	......	......	10,334	......	j1,155,294
1824	......	......	......	......	......	......	150,474	......	......	10,334	......	1,195.360
1825	......	......	......	......	......	......	154,608	......	......	10,334	......	1,238,507
1826	......	......	......	......	......	......	172,678	......	......	14,467	......	1,200,860
1827	......	......	......	......	......	......	179,768	......	......	13,949	......	1,294,980
1828	......	......	......	......	......	......	172,744	......	......	24,074	......	1,298,506
1829	......	b793	......	......	......	......	178,747	......	......	25,185	......	1,291,816
1830	......	4,064	......	......	......	......	210,630	f1,913,677	......	31,310	i1,862,748	1,369 310
1831	......	5,080	......	......	......	......	194,344	2,270,000	......	42,678	1,760,465	1,316,202
1832	......	7,258	......	......	......	......	213,837	2,449,000	......	57,864	1,962,945	1.422,026
1833	......	6,922	......	......	......	......	195,842	2,708,000	......	74,337	2,057,724	1,566,567
1834	......	8,626	......	......	......	......	237,431	2,747,000	......	58,343	2,489,954	1,576,742
1835	......	12,591	......	......	......	......	250,782	2,902,000	......	64,797	2,506,531	1,624,332
1836	......	12,850	......	......	......	......	273,735	3,143,000	......	123.537	2,842,075	1,717,609
1837	......	16,341	......	......	......	......	283,133	3,263,650	......	136,568	2,980.871	2,468,000
1838	......	17,497	......	......	......	......	335,012	3,685,402	......	122,547	3,113,394	2,192,959
1839	......	21,626	......	......	......	......	432,065	2,812,256	......	167,591	2,994,997	2,926,754
1840	......	30,743	......	......	......	......	473,420	3,929,962	......	116,195	3,003,513	2,545,435
1841	......	35,401	......	......	......	......	531,028	4,027,765	......	170,274	3,410,355	3,186,649
1842	......	40.542	......	......	......	......	523,983	4,140,462	......	148,930	3,592,248	3,641,632
1843	......	26,278	......	......	......	......	520,595	3,982,274	......	120,745	3,692,707	3,448.922
1844	......	23,490	......	......	......	......	688,282	4,445,240	......	124,558	3,782,912	3.817,420
1845	......	22,683	......	......	......	......	721,707	4,919,156	......	173,003	4,202,283	4,345,769
1846	......	39,592	......	......	......	......	799,053	5,037,402	......	169,365	4,469,745	4,618,015
1847	......	41,388	......	......	......	......	834,028	5,664,456	......	231,533	5,153,435	4,910,753
1848	......	45,999	......	......	......	......	......	4,862,694	......	215,450	4,000,083	4,731,137
1849	......	49,297	......	......	......	......	......	5,281,843	......	200,464	4,049,285	4,954,671
1850	......	72,362	......	......	......	......	1,125,934	5,820,588	......	206,771	4,540,207	5,477,757
1851	......	68,698	......	......	......	......	1,361,323	6,233,801	......	176,246	4,780,218	6,041,413
1852	......	68,489	......	......	......	......	1,681,822	6,795,564	......	217,096	4,904,123	6,920,252
1853	......	98,368	......	......	......	......	1,750,232	7,173,015	......	249,647	5,938,271	7,565,432
1854	......	118,519	......	......	......	......	1,858,018	7,948,105	......	269,035	6,817,311	8,692,302
1855	......	139,283	......	......	......	......	2,101,051	8,409,722	......	273,517	7,453,439	10,208,585
1856	......	193,027	......	......	......	......	2,338,195	8,213,794	......	291,058	7,926,062	11,185,608
1857	......	213,722	......	......	......	......	2,513,322	8,384,284	......	337,795	7,802,161	12,204,462
1858	......	219,881	......	......	......	......	2,910,643	8,926,121	......	260,324	7,352,935	13,319,811
1859	......	313,175	......	......	......	......	3,131,884	9,161,120	......	310,349	7,482.941	12,768,187
1860	......	374,801	......	d12,525	......	......	3,503,896	9,601,336	......	370,399	8,304,061	13,804,750
1861	......	347,574	......	14,440	......	......	3,965,221	10,057,163	......	374,803	9,423,750	15,080,074
1862	......	484,194	......	24,454	......	......	4,552,485	9,935,645	......	456,268	10,290,825	20,660.677
1863	......	440,875	......	24,386	......	......	4,575,190	10,345,350	......	512,979	10,710,147	22,366,203
1864	......	557,851	......	25,402	......	......	4,662,438	11,158,336	......	591,152	11,242,634	26,167,100
1865	......	594,952	......	33,531	......	......	2,028,089	11,840,703	......	747,310	11,840,000	28.327,800
1866	......	786,703	......	39,949	......	......	4.893,931	12,774,662	......	695,705	12,000,000	28,624,600
1867	......	782,409	......	18,278	......	......	6,098,804	12,755,822	g31,742	545,857	11,856,945	30,982,500
1868	......	969,594	......	19,927	......	......	7,021,756	12,298,589	44,713	489,629	12,053,047	33,274,400
1869	......	934,582	......	11,299	......	......	7,663,043	12,942,894	36,378	607,369	12,580.820	34,379,600
1870	......	882,548	......	23,003	......	......	8,355,945	13,697,118	30,323	641,841	13,300,000	34,880,600
1871	.....	913,254	......	17,273	......	......	8,437,401	13,733,176	45,725	690,081	12,759,400	38,391,300
1872	......	1,028,726	......	28,173	......	......	8,825,896	15,658,948	46,891	901,133	15,204,170	43,059,300
1873	......	1,212,067	......	34,154	......	......	10,104,769	15,778,401	46,459	1,074,396	17,479,341	47,131,800
1874	......	1,325,616	......	44,142	......	......	12,631,364	14,669,029	82,304	892,771	16,907,913	46,286,300
1875	......	1,351,138	......	32,624	p7,843	......	13,062,738	15,011,331	111,771	793.737	16,956,840	48.532,400
1876	......	1,341,169	......	51,442	6,198	......	13,000,000	14,329,578	141,238	721,071	17,101,448	49,154,700
1877	......	1,467,523	......	61,898	9,622	......	13.500,000	13,938.523	156,479	769,692	16,804,529	48.454,700
1878	......	1,600,862	c164,830	53,427	12,509	......	13,900,000	14,899,175	173,753	783,010	16,960,916	50,519,899
1879	......	1,608,873	234,941	55,999	9,667	......	14,500,000	15,447,292	244,880	800,964	17,110,979	53,470,716
1880	......	1,489,785	304,751	58,987	12,416	......	14,800,000	16,886.698	272,314	1,049,336	19,361,564	59,118,035
1881	......	1,798,088	342,691	66,668	11,343	......	15,304,813	16,873,951	231,671	1,142,371	19,765,983	61,540,485
1882	a25,163	2,143,241	384,362	75,634	8,944	......	15,555,292	17,590.989	286,540	1.387,800	20,603,704	65.378,211
1883	20,277	2,562,051	428,554	106,436	9,015	......	17,047,961	18,177,754	216,429	1,445,456	21,333,884	70,442,648
1884	9,145	2,793,370	488,572	122,671	7,310	......	18,000,000	18.051,499	400,343	1,411,663	20,023,514	72.113,820
1885	16,745	2,925,212	519,291	213,348	6,761	a938	20,435,463	17,437,603	370,876	1,373,975	19,510,530	73,675,515
1886	21,405	2,875,741	542,956	232,337	10,558	1,322	20,779,441	17,285,543	375,586	1,526,805	19,909,894	73,682,584
1887	26,026	2,969,548	567,613	242,658	28,078	3,411	21,879,171	18,378,624	495,360	1,709,754	21,287,589	76,232,618
1888	44,277	3,255,019	623,778	316,426	42,246	8,867	23,859.608	19,218,481	614,155	1,810,525	22,602,894	81,960,083
1889	82,036	3,714,488	595,886	269,782	37,291	15,394	25,328,416	19,869,480	688,097	1,790,319	24,303,509	84,973,230
1890	99,791	3,110,157	647.659	343.791	51,332	24,852	27,504,030	20,365,960	820,087	2,023,167	26,083,118	89,290,834
1891	156,603	4,102,940	679,562	275,949	43,952	29,625	28,822,439	19,675,664	1,195,665	2,077,605	26,024,893	94,252,278
1892	250,000	3,841,842	684,155	269,354	36,243	30,445	29,225,004	19,583,173	1,006,721	1,974,059	26,178,073	92,544,050
1893	......	......	......	......	43,893	......	......	19,407.251	......	2,556,085	25,738,073	95,476,208

(*a*) From *British Mineral Statistics.* (*b*) From Annual Report Department of Mines, N. S. W. There were 50,855 tons of coal mined prior to 1829. (*c*) From Official Reports on the mining industry of New Zealand. (*d*) From Annual Reports, Department of Mines, Queensland. (*e*) From 1885 to date these figures are official; prior to 1885 they are taken from British Commissioners' Report. (*f*) From 1861 to date figures are from *Statistique des Mines*, by M. Emil Harzé; previous to 1861 the figures are from *La Crise*, by Max Goebel, and *La Houille*. (*g*) From Annual Report of Mine Inspector. Production of Northwest Territory is included from 1886 to date. (*h*) Figures previous to 1864 are obtained by taking sales and adding 13% for consumption at colliery; from 1864 to date figures are from Annual Reports of Mine Inspector. New Brunswick is included from 1887 to date. (*i*) From 1830 to 1863 figures are from *Les Houilleries de la France*, by Burat, and

COAL PRODUCTION OF THE WORLD. (IN METRIC TONS.)

India.	Italy.	Japan.	Russia.	Spain.	Sweden	United Kingdom.	United States.	All Other Countries.	Total.	Year.
....	....	....	....	....	....	....	....	....	....	1820
....	....	....	....	....	....	....	....	....	....	1821
....	....	....	....	....	....	....	....	....	....	1822
....	....	....	....	....	....	....	....	....	....	1823
....	....	....	....	....	....	....	....	....	....	1824
....	....	....	....	....	....	....	....	....	....	1825
....	....	....	....	....	....	....	....	....	....	1826
....	....	....	....	....	....	....	....	....	....	1827
....	....	....	....	....	....	....	....	....	....	1828
....	....	....	....	....	....	....	....	....	....	1829
....	....	....	....	....	....	....	....	....	....	1830
....	....	....	....	....	....	....	....	....	....	1831
....	....	....	....	....	....	....	....	....	....	1832
....	....	....	....	....	....	....	....	....	....	1833
....	....	....	....	....	....	....	....	....	....	1834
....	....	....	....	....	....	....	....	....	....	1835
....	....	....	....	....	....	....	....	....	....	1836
....	....	....	....	....	....	....	....	....	....	1837
....	....	....	....	....	....	....	....	....	....	1838
....	....	....	....	....	....	....	....	....	....	1839
....	....	....	....	....	....	....	....	....	....	1840
....	....	....	....	....	....	....	....	....	....	1841
....	....	....	....	....	....	....	....	....	....	1842
....	....	....	....	....	....	....	....	....	....	1843
....	....	....	....	....	....	....	....	....	....	1844
....	....	....	....	....	....	....	....	....	....	1845
....	....	....	....	....	....	....	....	....	....	1846
....	....	....	....	....	....	....	....	....	....	1847
....	....	....	....	....	....	....	....	....	....	1848
....	....	....	....	....	....	....	....	....	....	1849
....	....	....	....	....	....	....	....	....	....	1850
....	....	....	....	....	....	*m*54,869,400	....	....	....	1851
....	....	....	....	....	....	*n*54,869,400	....	....	....	1852
....	....	....	....	....	....	54,869,400	....	....	....	1853
....	....	....	....	....	....	65,702,450	....	....	....	1854
....	....	....	*m*155,512	....	....	65,490,764	....	....	....	1855
....	....	....	....	....	....	67,718,442	....	....	....	1856
....	....	....	....	....	....	66,447,562	....	....	....	1857
*a*242,077	....	....	....	....	....	66,055,288	....	....	....	1858
280,407	....	....	....	....	....	73,138,639	....	....	....	1859
381,035	*k*30,280	....	299,901	....	....	85,395,785	....	....	....	1860
293,774	33,531	....	....	....	*m*30,222	87,424,445	....	....	....	1861
325,296	43,381	....	....	....	29,768	82,952,715	....	....	....	1862
359,905	36,189	....	....	....	29,604	87,681,520	....	....	....	1863
341,189	38,210	....	*360,000	....	27,826	94,281,758	*m*22,853,778	1,462,326	173,770,000	1864
332,790	37,490	....	382,162	....	33,031	99,730,811	24,783,653	1,369,678	182,080,000	1865
407,740	50,319	....	*440,000	....	34,096	103,266,796	29.309,634	1,451,865	194,776,000	1866
486,948	42,476	....	*508,000	....	34,654	106,182,938	28,807,983	1,595,644	200,730,000	1867
*526,900	51.386	....	*550,000	....	43,461	104,801,730	31,974,183	1,506,687	205,626,000	1868
*567,000	56.201	....	*620,000	....	45,780	109,157,141	34,292,076	1,744,817	215,649,000	1869
*607,000	58,770	....	694,782	....	35,805	112,241,531	29,940,607	2,433,127	217,823,000	1870
*647,000	80,336	....	*900,000	*m*633,492	40,674	119,241,396	35,660,952	1,503,540	233,695,000	1871
*690,000	93,555	....	*1,000,000	721,002	37,565	125,485,734	45,731,986	2,748,921	261,262,000	1872
*730,000	116,884	....	1,173,546	679,436	49,123	129,061,717	49,987,570	4,609,337	279,269,000	1873
*770,000	127,473	....	1,291,723	723,983	55,719	127,081,509	46,845,080	4,589,074	274,325,000	1874
*810,000	116,955	....	1,701,192	693,990	62,605	133,990,165	48,191,398	3,872,973	285,300,000	1875
*850,000	116,399	....	1,824,574	752,713	75,406	135,491,617	46,564,958	3,301,489	284,824,000	1876
*890,000	120,588	....	1.789,133	677,179	91,620	136,777,996	52,047,868	3,292,650	290,850,000	1877
*930.000	124,117	....	2,524,291	672.327	90,425	134,742,853	49,447,330	4,446,282	292,046,000	1878
*960,000	131,318	....	2,921,935	690,680	99,699	136,165,760	61,861,632	4,476,665	310,792,000	1879
*1,000,000	139,369	....	3.291,555	847,128	98,343	149,182,402	66,813,453	4,643,864	339,370,000	1880
1,013,603	134,582	*l*940,094	3,488,901	1,209.882	114,992	156,666,667	80,058,068	4,180,147	364,825,000	1881
1,148.439	164,737	944,173	3.765,957	1,196,255	139,683	159,065,550	89,089,534	4,347,792	383,302,000	1882
1,337,163	214,421	1,019,576	3.972,192	1,070,758	149,110	166,373,498	98,052,097	4,597,720	408,577,000	1883
1,420,323	223,322	1,158,290	3,925,107	979,350	160,714	163,345,979	100,150,533	4,219,469	409,005,000	1884
1,315,058	190,413	1,314,506	4,623,056	945.904	169,707	161,916,976	102.159,621	3,696,502	412,818,000	1885
*1,450,000	243,325	1,396,334	4,570,869	1,001,432	166,054	160,054.529	104,019,817	4,061,468	414,208,000	1886
1,585,515	327,665	1,774,412	4,528,104	1,037,305	164,774	164,729,941	118,820,797	5,375.037	442,164,000	1887
*1,500,000	366,794	2.039,992	5,179,478	1,036,566	169,006	172,671,176	131.976,571	4,679.558	473,976,000	1888
1,468,629	390,320	2,427,071	6.206,166	1,153.755	186,719	179,765.083	125,299,473	4,207,756	482,773,000	1889
2,203,434	376,326	2,650,277	6,007,457	1,238,395	187,512	184,538,278	141,589.980	3,973,563	513,130,000	1890
2,366,067	289,286	3,226,975	6,233,025	1,320,139	198.033	188,465.340	153,810,270	1,854,690	535,101,000	1891
*2,400,000	295,713	*3,000,000	*6,913,351	1,461,196	199,380	184,713,640	163,657,988	1,500,000	543,645,133	1892
....	....	....	....	1,565,910	....	....	164,445,986	....	....	1893

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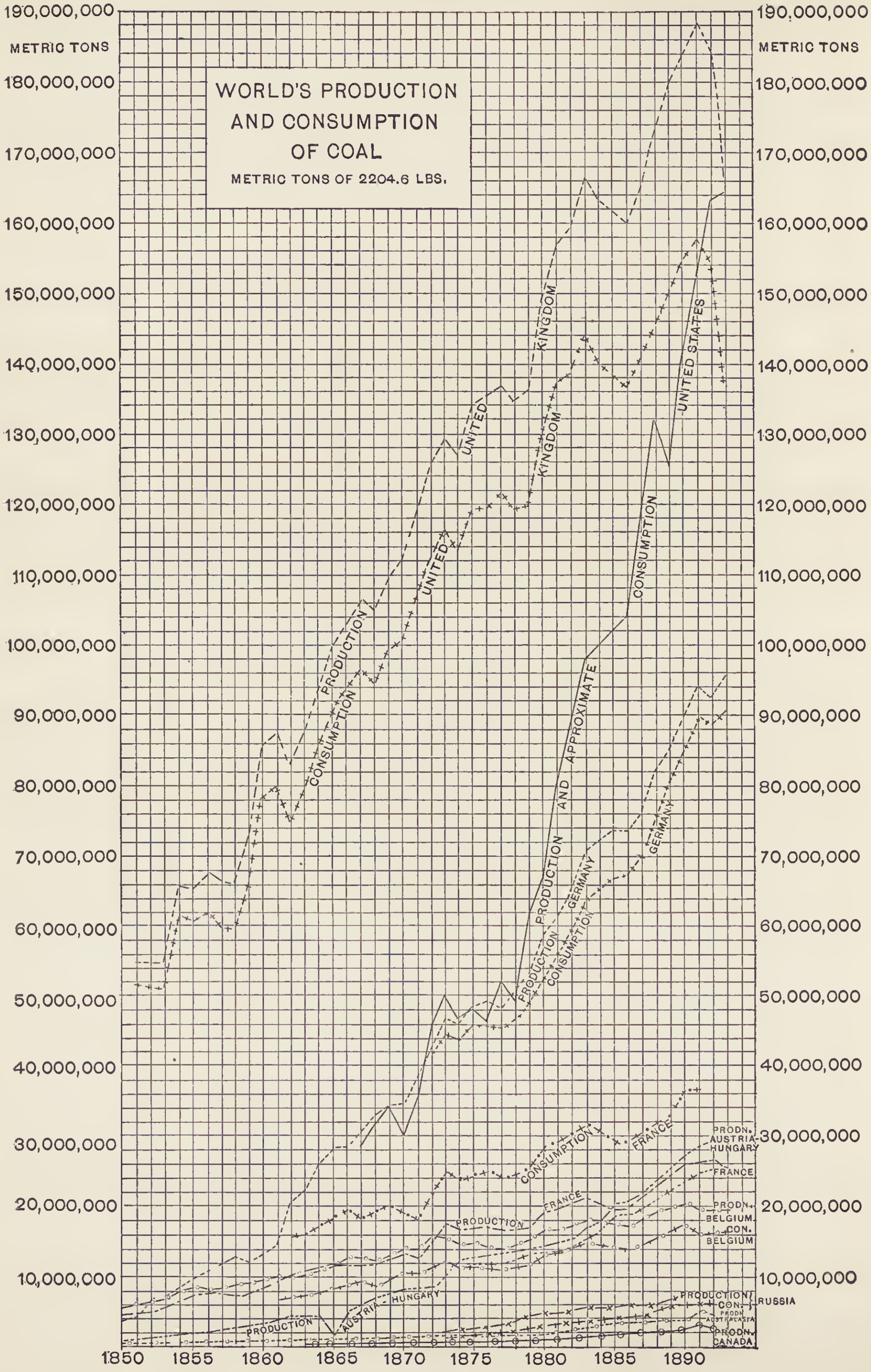
from *La Houille*. From 1864 to date they are from official *Statistique de l'Industrie Minérale*. (*j*) Prior to 1862 figures are for Prussia only; from 1823 to 1872, from *Zeitschrift für das Berg Hütten und Salinen Wesen;* from 1872 to date, from *Vierteljahrs und Monatshefte zur Statistik des Deutschen Reichs*. (*p*) For years 1880–91, inclusive, figures are from Report of Secretary for Mines; in other years figures are furnished by Mr. A. Montgomery, Inspector of Mines. (*k*) From official *Rêvista del Servizio Minerario*. (*l*) From *Mining Industry of Japan*. (*m*) From official sources. (*n*) It is estimated that during the 350 years prior to 1850 there had been produced in the United Kingdom 2,895,885,000 metric tons of coal. See British Report on Coal, 1871. All British figures are from official blue books. * Estimated.

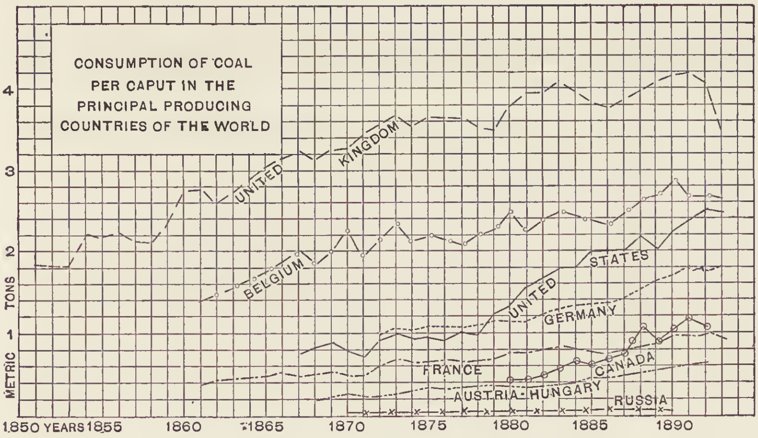

WORLD'S PRODUCTION
AND CONSUMPTION
OF COAL
METRIC TONS OF 2204.6 LBS.
METRIC TONS
190,000,000
180,000,000
170,000,000
160,000,000
150,000,000
140,000,000
130,000,000
120,000,000
110,000,000
100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
1850
1855
1860
1865
1870
1875
1880
1885
1890
PRODUCTION UNITED KINGDOM
CONSUMPTION UNITED KINGDOM
PRODUCTION AND APPROXIMATE CONSUMPTION UNITED STATES
PRODUCTION GERMANY
CONSUMPTION GERMANY
CONSUMPTION FRANCE
PRODUCTION FRANCE
PRODN. AUSTRIA-HUNGARY
FRANCE
PRODN. BELGIUM
CON. BELGIUM
PRODUCTION AUSTRIA-HUNGARY
PRODUCTION
CON.
RUSSIA
PRODN. AUSTRALASIA
PRODN. CANADA

for a few years has declined, but this can be only temporary, though increasing cost of production no doubt affects the industry very seriously. In Austria-Hungary it is almost stationary.

The table giving the coal production of the world shows the increasing outputs of the smaller producing countries. Natal and Cape Colony, Africa, have materially increased their outputs, and in India, Russia, and Spain there is a noticeable advance. In Japan there has not been any material advance in the coal-mining industry within the past two years.

No better illustration of the wonderful growth of the industry can be had than that shown by the total production of coal in the world. It has increased with leaps, doubling in the sixteen years from 1864 to 1880, and almost doubling again in the succeeding thirteen years. With the single exception of 1876, a greater or less part of this increase has taken place in each year, the greatest gain being in 1888 and 1890, in each of which the production was over 30,000,000 tons more than in the preceding year.

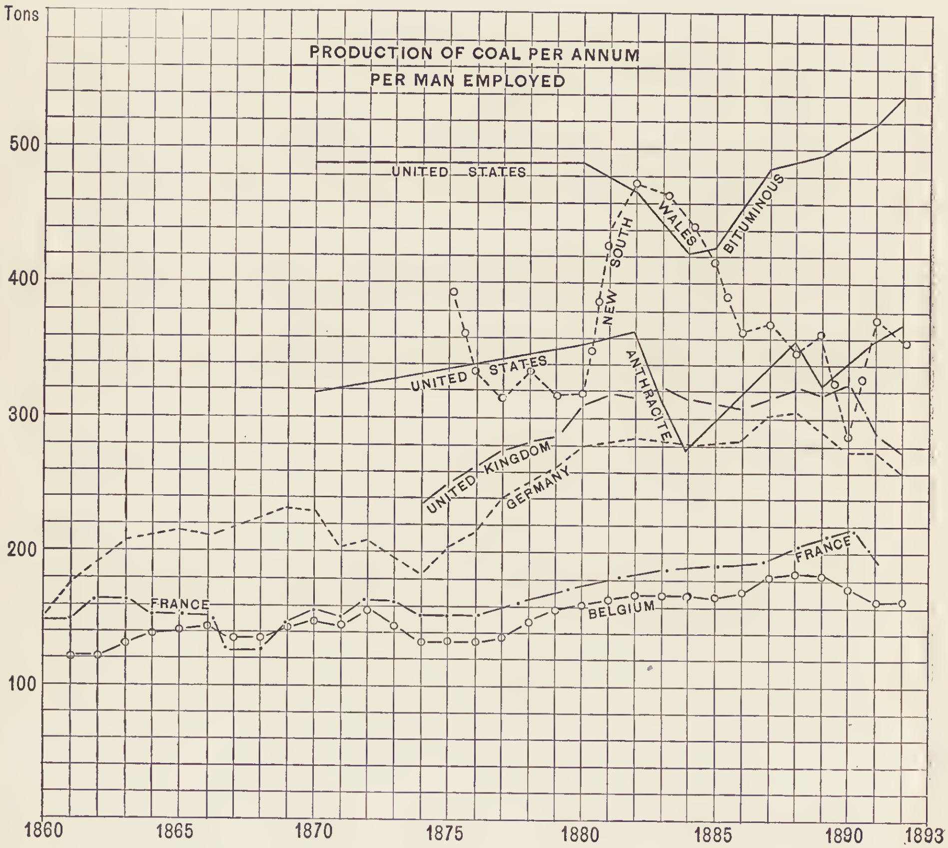
The diagram showing the consumption of coal per capita is exceedingly interesting, inasmuch as it measures with great accuracy the growth of industry in any country. In this respect the United Kingdom leads with a consumption in 1851 of $1\frac{3}{4}$ tons per capita, and in 1892, $4\frac{1}{4}$ tons, an increase in forty-one years of $2\frac{1}{2}$ tons per capita, or 142%. This increase has been subject to numerous fluctuations and in the past twenty years has not advanced in so great a ratio as before. From 1870 to 1890 the increase was 0.95 ton, or but 29%. In Belgium, Germany, and the other countries shown, with the exception of the United States, the increase has been considerably less than this.



In the United States, however, the advance in consumption per capita has been almost phenomenal, increasing from less than 1 ton in 1870 to 2.25 tons in 1890, over 200%. From 1889 the line commences to rise more rapidly, pointing toward the descending lines of the United Kingdom and Belgium in such manner so as to leave little doubt but that within a comparatively short period it will cross them both.

The Production of Coal per Person Employed.

While it is not proposed in this volume to take up the study of the statistics, yet in connection with the coal trade, and as illustrating the possibilities of extending the foreign markets of the United States, it may be well to refer very briefly to the vast difference in productive efficiency between the average American and the European coal mines. The accompanying diagram shows at a glance the output per man employed per annum in the various countries.



In the United States 490 tons bituminous coal per man per annum was the average for the ten years from 1870 to 1880. In 1884 it was 420 tons, but in 1887 had again advanced to 490, and in 1892 to 540 tons. In the United Kingdom, starting with a production of 240 tons per man per year in 1874 it increased to 320 tons in 1883, falling below this again, and in 1890 reaching 327 tons. Since then it has declined, and in 1892 was but 278 tons. In Germany the producing power is still less, and in France and Belgium smaller yet. In the latter country there has been but little increase in the yield per man, the record of 1861 showing 120 tons per annum, and in 1892 165 tons. In France the increase has been greater, rising from 150 tons per man per annum in 1860 to 215 tons in 1890, though it fell again to 200 tons in 1891.

The greatest production in the United Kingdom was 327 tons in 1890. In the United States it was 540 in 1892, a difference of 213 tons, or 65% greater. The averages in the United Kingdom for the past eighteen years have been 300 tons per man per annum, and for twenty-two years in the United States, 480 tons per man, a difference of 60% in favor of the latter. It is very evident, therefore, that in the item of labor cost of producing coal the average annual wages in the United States might be from 60% to 300% greater than those paid in Europe without making our cost of production greater than that ruling there. This comparison would probably hold good also in cost of transportation by rail per ton-mile.

This brief reference to one important direction in which the study of the mineral statistics of the world may give much needed light and knowledge on the conditions which affect the development and prosperity of the mineral industry is made more as a suggestion than as an example. The statistics thus far collected do not permit of an exhaustive study of the subject.

AVERAGE OUTPUT OF COAL PER MAN EMPLOYED ABOVE AND BELOW GROUND.

	Belgium.	France.	France.*	Germany, Westphalia	Great Britain.	N. S. Wales.	U. S. Bituminous	U. S. Anthracite.
1860	....	149	....	....	....	....	....	....
1861	123.1	148	....	....	....	....	....	....
1862	123.7	164	....	208	....	....	....	....
1863	134.6	164	....	199	....	....	....	....
1864	139.8	155	....	211	....	....	....	....
1865	143.7	156	....	216	....	....	....	....
1866	147.3	152	....	212	....	....	....	....
1867	136.6	128	....	215	....	....	....	....
1868	137.6	129	....	224	....	....	....	....
1869	143.9	149	....	230	....	....	....	....
1870	148.9	159	168	230	....	....	487	320
1871	145.6	153	162	202	....	....	....	....
1872	158.4	165	177	208	....	....	....	....
1873	146.2	166	183	195	....	....	....	....
1874	133.8	155	175	185	235	....	....	....
1875	135.6	155	188	202	250	401	....	....
1876	132.0	154	167	214	263	330	....	....
1877	137.5	....	148	240	276	315	....	....
1878	150.4	....	133	256	283	334	....	....
1879	158.1	....	153	264	285	319	....	....
1880	164.0	....	226	281	308	319	490	357
1881	166.4	....	260	284	316	439	....	....
1882	169.8	....	273	287	315	477	469	366
1883	170.2	....	283	284	323	467	374	313
1884	170.8	....	273	282	314	448	422	280
1885	169.0	....	270	284	311	412	426	....
1886	172.3	....	277	286	308	366	....	....
1887	182.4	195	303	303	313	371	484	....
1888	185.7	206	306	315	323	350	....	360
1889	183.2	....	316	293	319	361	495	326
1890	174.3	215	292	277	327	290	....	341
1891	165.4	197	252	269	291	373	519	366
1892	165.1	....	248	260	278	359	540	369

*Average output per miner employed.

PITTSBURG (PA.) COAL TRADE IN 1893.

During 1893 navigation on the Ohio was very uncertain, and between this and difficulties arising from strikes the year's shipments were the smallest in twelve years. There were no shipments by river from June until November. The 1,240,000 tons loaded in the harbor and pools had to be cared for at considerable expense. The largest shipment on record was in 1888, 4,394,080 tons; this year's only reached 2,497,800 tons. At the end of the year the lower markets were fairly supplied with coal, and prices were down to a low figure. The shipments for the past twelve years were as follows, in tons of 2000 lbs.:

Years.	Cincinnati.	Louisville.	Total.
1882	1,378,480	1,467,160	2,845,640
1883	1,261,320	2,258,480	3,519,800
1884	985,240	1,232,040	2,217.280
1885	1,303,600	1,693,360	2,996,960
1886	1,329,160	1,537,406	2,866,560
1887	830,800	1,438,920	2,269,720
1888	2,053,560	2,340,520	4,394,080
1889	1,214,400	1,515,800	2,730,200
1890	1,304,640	2,042,160	3,546,800
1891	1,125,000	1,931,600	3,056,600
1892	973,560	1,549,960	2,523,520
1893	879,950	1.617,840	2,497,800

These figures show the inroads made in recent years into the river trade of Pittsburg by the West Virginia and other fields.

THE GERMAN COAL MARKET IN 1893.

By reason of the miners' strike in France, Belgium, and Great Britain, coal has been firm and steady, with a generally increased production. The deliveries from the Ruhr basin in 1893 amounted to 32,463,540 metric tons, as compared with 30,678,260 tons in 1892. The deliveries from the Saar district were 4,564,290 tons, against 4,817,200 tons in 1892, and those from Silesia were 12,060,660 tons and 11,192,970 tons, respectively, in 1893 and 1892. It will be seen that the deliveries from the Ruhr basin in 1893 increased 785,280 tons and from Silesia 867,690 tons; on the other hand, the deliveries from the Saar district show a decrease of 242,910 tons. The aggregate deliveries from the three districts were 49,088,490 tons, against 46,688,450 tons in 1892, an advance of 2,400,040 tons, or 5.1%. While the deliveries made by railway increased, those made by water showed some falling off, having declined to 4,377,980 tons, as against 4,618,320 tons in 1892. Prices at the German mines have fluctuated somewhat, but a fair average would be about $2.64 per metric ton for coke, $1.92@$2.04 for gas coal, and $1.35@$1.48 for coking coal. The imports of foreign fuel increased slightly, from 11,604,018 tons in 1892 to 11,809,502 tons in 1893, and the exports from 10,688,894 tons to 11,579,729 tons. Exports of German coal to Italy over the St. Gothard route have declined somewhat, owing to the financial depression which prevails in that country, but this loss has been more than balanced by the immense orders for coke placed in Westphalia to be exported to the iron district of Bilbao, Spain.

AVERAGE PRICE OF COAL AT THE PRINCIPAL MARKETS IN GERMANY.*

(Price in marks per 1000 kilos. 1 mark = 23.8 cents.)

Year.	GERMAN.										
	Berlin, ex Wagon.			Breslau, at Pit Mouth.		Dortmund, at Pit Mouth.		Dusseldorf, at Pit Mouth.			
	Westphalian, Mixed, for Gas Works.	Upper Silesian, Lump and Lean Coal.	Lower Silesian, Lump and Long Flaming.	Lower Silesian, Gas, from Glück-hilf Mines, Average for Lump or Small.	Upper Silesian, for Gas, Lump Coal.	Lump Coal, Suitable for Export.	Good, Long Flaming, Run of Mine.	Flaming Coal, Run of Mine.	Long, Flaming Coal, Run of Mine.	Lean Coal, Run of Mine.	Gas Coal, Run of Mine.
1879	16.82	....	....	10.10	5.95	7.64	4.73	5.15	5.00	4.73	6.00
1880	18.53	18.90	18.69	10.29	6.27	8.29	5.99	6.53	6.00	5.35	7.51
1881	18.53	18.52	18.72	10.22	6.32	7.85	5.54	6.15	5.70	5.10	6.05
1882	18.52	18.69	18.39	10.14	6.27	7.79	5.63	6.50	5.96	5.45	7.30
1883	18.65	18.88	18.11	9.93	6.17	7.47	6.00	6.30	6.09	5.42	7.45
1884	17.97	18.43	17.73	9.90	6.12	7.19	5.46	6.04	5.52	5.07	7.52
1885	17.50	18.43	17.52	9.90	5.93	7.22	5.11	5.87	5.52	4.71	7.34
1886	17.27	18.40	17.27	9.90	5.97	6.65	4.51	5.85	5.62	4.82	7.22
1887	16.88	18.30	17.10	9.90	5.93	6.27	4.43	5.70	5.60	4.80	7.05
1888	17.58	18.25	17.23	9.79	5.90	6.43	5.50	6.25	6.02	5.30	7.51
1889	21.13	19.23	18.70	10.87	6.98	9.29	7.43	8.99	8.71	8.43	11.09
1890	24.04	20.29	22.08	13.43	9.50	12.88	9.92	12.64	12.07	12.36	14.92
1891	23.46	20.33	21.33	12.82	9.19	11.50	8.00	11.06	9.93	9.85	12.92
1892	21.25	20.29	20.29	12.66	9.07	9.15	7.30	9.83	8.61	8.34	11.83
1893	20.67	20.63	20.00	12.60	8.95	8.17	6.45	8.00	7.25	7.50	9.75

Year.	GERMAN.							ENGLISH.				
	Essen, at Pit Mouth.				Hamburg f. o. b.	Saarbrücken, at Pit Mouth, Free Cartage.		Berlin, ex Boat	Dantzig, On Board.		Hamburg, On Board.	
	Flaming Coal, Run of Mine.	Long Flaming Coal, Run of Mine.	Lean Coal, Run of Mine.	Gas Coal, Run of Mine.	Westphalian, Long Flaming, double-screen'd and Washed Nut, Nos. 1 to 3.	Flaming Coal, Run of Mine.	Long Flaming Coal, Run of Mine.	English Nut, Smith Coal.	English Nut, Smith Coal.	Scotch Machine and Lump.	Prime West-Hartley Steam, Screened Lump	Sunderland Nut.
1879	4.97	4.71	4.91	....	....	7.50	7.20	17.07	12.08	12.41	15.68	14.95
1880	7.41	6.58	5.85	....	14.17	7.80	7.40	17.20	13.39	13.77	16.19	14.55
1881	5.82	5.48	5.43	....	14.14	7.70	7.50	18.09	14.12	14.70	16.05	14.48
1882	6.14	5.77	5 19	7.16	15.15	7.60	7.40	16.98	13.79	13.27	14.00	12.91
1883	6.29	5.88	5.28	7.45	14.82	7.80	7.70	17.19	12.87	13.00	13.96	12.77
1884	6.64	5.22	4.74	7.34	14.75	8.20	7.60	16.87	12.87	13.24	13.46	12.48
1885	5.89	5.63	4.70	7.33	13.55	7.90	7.40	16.55	12.30	11.91	13.26	12.46
1886	5.85	5.60	4.90	7.19	13.36	7.90	7.40	16.95	12.32	11.53	12.91	12.15
1887	5.72	5.62	4.88	7.10	13.30	7.60	7.30	16.68	12.19	11.49	12.70	11.98
1888	6.32	6.04	5.30	7.52	13.60	7.50	7.40	17.27	12.42	11.91	13.05	12.43
1889	9.29	8.48	8.26	11.04	16.76	8.10	8.30	18.78	15.36	13.81	15.78	16.01
1890	12.36	10.72	11.00	14.58	19.10	10.70	10.90	20.38	19.72	16.18	18.25	18.63
1891	11.02	9.88	9.73	12.92	18.83	10.40	10.33	21.00	14.70	17.72	17.09	17.91
1892	9.75	8 50	7.75	11.75	17.73	10.38	9.53	21.17	16.59	12.98	15.09	15.73
1893	7.58	7.29	7.50	9.79	16.65	9.35	8.25	19.39	14.50	12.92	15.17	16.26

* From *Vierteljahrshefte zur Statistik des Deutschen Reichs*, 1894, Part I.

NOTES ON THE COAL INDUSTRY OF BELGIUM.

BY EMIL HARZÉ.

BELGIUM is one of the oldest coal-producing countries of Europe. The fundamental law on the exploitation of coal in the ancient country of Liége, also known under the name of Paix de St. Jacques, dates as far back as the fifteenth century.

Leaving aside the universal archæology, it is interesting to know the development which the coal industry has undergone since the separation of Belgium from the kingdom of the Netherlands, at the end of 1830.

Considering the six decades of which this period is composed, we give in the table below the average annual figures of the production and the number of workmen:

Decennial Periods.	Average Annual Production.		Value per Ton.	Workmen.		
	Quantity, Tons.	Value.		Number.	Annual Wages.	Annual Production, Tons.
1831-40	2,916,552	$6,442,100	$2.20	31,795	$88.60	92
1841-50	4,815,288	8,611,560	1.79	42,807	99.40	112
1851-60	8,085,216	17,509,400	2.14	66,429	134.20	123
1861-70	11,780,626	25,632,880	2.08	85,407	158.40	138
1871-80	15,033,215	39,606,420	2.64	103,096	202.60	146
1881-90	18,325,038	35,189,640	1.92	104,964	183.60	175

During the whole period, 1831–90, the total production of coal in Belgium amounted to 609,559,350 tons, valued at 6,649,600,000f., or $1,329,920,000. For the last few years the annual production has been about 20,000,000 tons, a quantity which was even slightly surpassed in 1890.

The fifth decade was during five years marked by great prosperity. This explains the high average value per ton as well as the higher wages. The wages stated in the above table are the average of all the hands, underground and surface combined, men, women, boys, and girls; the wages in the different districts differ greatly.

Although the increase of the output per workman has been continuous, the final output is far from equalling the output per man in competing countries, as is shown by the following table:

Period.	Annual Production by Workman.			
	Belgium.	France.	Prussia.	England.
1831-40	92	....	....	....
1841-50	112	....	....	....
1851-60	123	137	151	....
1861-70	138	152	205	....
1871-80	146	163	224	276
1881-90	175	200	280	314

To the coal output of the English workman is added iron ore and fire clay, substances which are mined at the same time as coal.

The small output of the workman in Belgium results essentially from the poor productive capacity of the coal seams. These fall below 0m. 40, and average only 0m. 65 in thickness. The age of the workings has also created difficulties which influence the productive power of the workman.

Although the wages form a great part of the cost on account of the small output of the workman, the various other expenses augment considerably the cost of mining. In 1890, for instance, the exploitation consumed 1,873,319 tons of coal, or 9⅕% of the quantity produced.

The Belgian statistics show how the value produced is distributed among the miners, sundry expenses, and mine owners. The table below shows how this distribution has changed during the last four decennial periods:

Decennial Periods.	Share of Profits in Percentage.		
	Workman.	Expenses.	Mine Owner.
1851-60	50.9%	35.2%	13.9%
1861-70	52.3	38.1	9.6
1871-80	52.8	37.9	9.3
1881-90	54.7	38	7.3

From this appears the interesting fact that the percentage of profit of the mine owner has steadily decreased, while the proportion going to the workman has increased.

COAL MINING MACHINES.

BY ALEXANDER DICK.

THE relative cost of mining coal by mechanical coal cutters and by hand labor is extremely important, and with the object of accumulating data for the elucidation of the subject the following contribution is offered to THE MINERAL INDUSTRY. The figures are not sufficiently complete to allow of a conclusive comparison between the merits of the various machines, but they will be found a valuable addition to the scant literature upon this interesting and important subject.

There are two classes of mining machines in use, viz: (1) Machines for driving headings and other narrow work. (2) Machines for holing or undercutting in the working face or chamber.

1. The Stanley heading machine is the only one adapted exclusively to the first class of work, and as yet but few have been placed in operation. By means of cutters placed on arms rotating around a central shaft, the machine drives a heading about five feet in diameter, performing the work, when the seam is favorable, in about one-fourth the time taken by hand labor. At one colliery in Scotland two machines of this type are used to drive a heading, one working a short distance ahead of the other, which follows, leaving about one foot of coal between the two cuts. This is subsequently removed, and an entry eleven feet in width is thus provided.

2. *Holing or Undercutting Machines.*—Machines of this type are designed to perform this most laborious part of coal-mining work. It is necessary that they should be light and strong, so as to be easily manageable in confined spaces, and yet not be liable to injury from falls of roof or coal or from rough handling. Their construction must be simple, and the cutters so made that they can be repaired readily at the mines. It is desirable that the machine cut its own way into the seam without requiring any preparatory work, and the cutters must clear themselves so as not to become clogged. Another important requisite is that the machine should have abundant surplus power, so as to be able to overcome hard streaks or nodules of ironstone or pyrites which may occur in the clay.

There are three types of these machines, viz.:

(*a*) Those which undercut by means of cutters fixed on a horizontally revolving disc or endless chain, such as the Gillott & Copley, Rigg & Meiklejohn, and Baird machines.

(*b*) Those fitted with a chisel bar giving a series of blows, such as the Harrison, Ingersoll-Sergeant, Choteau, and Yock machines.

(*c*) Those with cutters fixed to a revolving bar, such as the *Leichner or Jeffrey, Schlesinger, Thomson-Van Depoele and Edison machines.

Machines of the first type are best suited to workings where a long coal face can be obtained, as in the long-wall system. They are placed on rails and are held to the work by means of a rope passing over a revolving drum and attached to a prop set ahead. As a rule the motive power is compressed air. These coal cutters are each worked by four to five men, one to operate the machine and draw away the holing dirt, another to take up track from behind, and a third to lay a

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* The Jeffrey machine was formerly known as the Leichner.

new stretch ahead. The fourth man sets props and clears the face, and sometimes requires an assistant.

The Baird, which is an endless chain machine, has been in use for nearly twenty years and can undercut any depth up to five feet, will travel and cut in either direction, and breaks an opening for itself at the commencement. The cutting is two and one-half inches high, and as the cutters move from back to front the dirt is thrown out automatically. A difficulty sometimes encountered with these endless chain machines is that when a hard spot is encountered the chain will sag, and if an inside bearing is adopted to prevent this, the friction becomes an item of importance. At a colliery in Scotland this machine is said to have undercut 100 lineal yards of face in a 3-ft. seam of coal, 2 ft. 6 in. deep, in ten hours.

The Gillott & Copley is an English machine, operating like the Baird, except that the cutters are fixed to a revolving disc. It was said in 1890 that this machine, at the Wharncliffe Silkstone Colliery in Yorkshire, undercut in a 2 ft. 6 in. seam 600 lineal feet of coal face in sixteen hours, equal to 37½ ft. an hour. This is an extraordinary performance, and the conditions as to nature and uniformity of holing must have been perfect. The percentage of slack made by the machine was said to be 20, as compared with 40% by hand labor in the same mine.

In the Rigg & Meiklejohn machine the cutters work from front to back of the holing, thus carrying the dirt inside. An undercut large enough to admit the disc has to be made by hand. Working in a seam of coal 2 ft. 3 in. thick these machines have in ten hours undercut from 140 to 150 lineal yards, 2 ft. 6 in. deep, equal to a yield of 70 tons per day. At another colliery, where the seam was 5 ft. 9 in. thick, they cut 126 lineal yards per shift and made 20% small coal. At a third colliery, with a seam 3 ft. 9 in. of coal, one Rigg & Meiklejohn machine cut 126 yards, or 90 tons of coal. The cutting was done at night and the coal stripped and loaded in the daytime. There were employed 3 machine men, 4 brushers, 5 drawers, and 9 loaders—21 men in all, equal to a production of 4.3 tons per man per day.

In the second type of machines, the Harrison, using compressed air, is well known, over 200 being used in Illinois alone. This machine operates with a chisel cutter, moved backward and forward like an ordinary rock drill, striking about two hundred blows per minute. In commencing work the machine is firmly spragged on the floor, the cutter pointing to the holing. As it is light and easily handled, two men form a crew, one to operate and the other to clean away. In addition to these, loaders, timbermen, and the usual fixed mine crew are required, the total averaging about 12 men per machine.

In a bituminous mine in Pennsylvania five of these machines made an average cut of 27 square yards of floor per machine per day in a three-foot seam. Machine men received $1 per six tons of coal cut, and loaders 30c. per ton. In a test it was shown that 11¾ men produced 59½ tons of coal with the machine in 8¾ hours, at a cost of $26.03, or 43c. per ton. This is equal to a production of 5.06 tons per man per day, or 0.57 tons per man per hour. By hand labor in the same mine it required 20 miners to produce the same tonnage, at a cost of $40.40, or 68c. per ton.

In Illinois the average production of the Harrison machine is about 62 tons per day, or a production of five tons per man per day, working seams varying from 6 to 7 ft. in thickness. In Tennessee an output of 20 tons per day is secured from a three-foot seam. In a four-foot seam in Indian Territory the average day's work is to undercut 60 lineal feet of face to a depth of 4 ft., equal to a production of 31½ tons per machine. In Montana a Harrison machine in a five-foot seam undercuts 52 lineal feet per shift of nine hours, equal to an output of 27 tons per machine. In one colliery, where part of the coal is hand and part machine mined, the cost by hand mining is 20c. per ton more than by machine.

The Ingersoll-Sergeant is a new machine of a type similar to the Harrison. Some of these operating in Illinois mine an average of 57½ tons per day. Its average work is about the same as the Harrison.

Another machine of this pattern, but operated by electricity, is the Morgan-Gardner. In a recent test run in an Indiana mine one machine is reported as running 81½ hours in twelve days, cutting 570½ lineal feet with an average undercut of 4 ft. 8 in. This is equal to a cut of 7 ft. per hour, the greatest day's work being 65 ft. in nine hours, or 7.2 ft. per hour.

The Choteau and Yock machines are of types similar to the Harrison, excepting that the Yock is supplied with two drills and runs upon rails.

In the third type of machines information has been obtained regarding the performance of the Leichner or Jeffrey . In these machines the principle is as follows: The cutters are fixed to a revolving horizontal bar about 3 ft. long and parallel to the face of the coal. This is made to revolve on its axis by means of a sprocket wheel and chain gear from the engine or motor. As the cutters undercut the coal the bar is forced further into the holing until the desired depth is obtained. The machine is then moved along the coal face the width of the cutter bar and the operation repeated.

The Leichner machine was operated by compressed air, but otherwise was much similar to the Jeffrey. In a Pennsylvania mine this machine undercut 5 ft. deep in twelve minutes. The following figures show the actual costs: three operators at $2.25 each; 3 helpers at $1.50 each; 6 loaders at $1.50 each; 1 man drilling holes in coal, $2.25; 1 man chuting coal, $2—total cost, $24.50. There were 40 tons of coal mined, costing 61¼c. per ton, not including repairs to machines, depreciation, and other fixed charges. Each machine is reputed to undercut 25 tons per day, or about 3 tons per man per day.

The Jeffrey is operated by electricity and undercuts 6 ft. deep, 3 ft. in width, in from three and a half to five minutes. Between 600 and 1000 sq. ft. can be undercut in a ten-hour shift. At a colliery in Cape Breton one of these machines undercuts 5 ft. deep by 3 ft. 3 in. in width in from four to six minutes, and a room 25 ft. wide in fifty-five minutes. It requires about thirty minutes to move the machine from one room to another and make the necessary connections. At this rate about six rooms, or 150 lineal feet, can be undercut per shift, though if the time taken in moving from one room to another were saved the service would be almost doubled.

The following table shows, so far as can be ascertained, the relative service of various machines in use in this country and the United Kingdom, but in comparing one machine with another due allowance must be made for the fact that the conditions under which they were working differed widely both in various machines of the same type and in those of different types:

TONS CUT PER MAN PER DAY, AND GREATEST KNOWN PRODUCTION BY COAL-CUTTING MACHINES.

Name of Machine.	Greatest Depth of Undercut.	Greatest Distance Cut in One Shift of 10 Hours.*	Tonnage per Day.	Thickness of Coal Seam.	Tons per Day per Man.
Type I.—Baird	5′	300	....	2′ 6″	....
Gillott & Copley	4′	375	90	2′ 6″	....
Rigg & Meiklejohn	4′	450	70	2′ 3″	4.3
" II.—Harrison (Penn.)	....	....	59.5	3′ 0″	5.0
" (Ill.)	....	....	62.8	6′ to 7′	5.0
" (Tenn.)	....	....	20.0	3′ 0″	....
" (Ind. Ter.)	....	60	31.5	4′ 0″	....
" (Mont.)	....	57.7	27.0	5′ 0″	....
Ingersoll-Sergeant (Ill.)	....	....	57.5	6′ to 7′	3.44
" " (Tenn.)	....	....	20.0	3′ 0″	....
Morgan-Gardner	4′ 8″	72.2	....	....	....
Choteau	....	....	65.1	7′	4.64
Yock	....	....	30.4	6′	3.17
" III.—Jeffrey	6′ 0″	166.6	17.1	....	3.0
Leichner	5′	150	25.0	2′ 9″	2.85

* Lineal feet.

It will be observed that the first three machines show much greater service than any other. This was owing to the fact that they were used solely in longwall workings, while in all the other cases the machines were applied to pillar and room workings.

In the description of the Jeffrey machine used in Cape Breton the actual time cutting was only 66%, with 34% unremunerative labor moving the machine from one room to another. Had this machine been working in long wall the amount of cutting done would have been at least 250 instead of 150 feet. In the United Kingdom the long-wall system is more common than in this country, and it is in this form of work that machine mining is most advantageous, because the removal of the machine from one room to another adds greatly to the cost.

The figures given for the Gillott & Copley machine are from a paper read by Mr. G. Blake Walker before the Federated Institute of Mining Engineers of Great Britain. The rate of advance of the machine is 375 lineal ft. in ten hours, or 37½ ft. per hour.

The Rigg & Meikeljohn machine is reported by a colliery manager in Scotland to have attained a speed equal to 9 ft. per minute.

The figures regarding the Harrison and Ingersoll-Sergeant type in Tennessee, Indian Territory, and Montana are from figures supplied by the operators. Those for the Harrison and Ingersoll-Sergeant in Pennsylvania and Illinois and for the other types are from reports made by State inspectors.

The best comparison that can be made between the relative costs of hand and machine mining is obtained in the State of Illinois, where there are at present about 400 to 500 machines in use. Here the production per man per day is 3.55 tons by hand labor and 4.61 tons by machine, a difference of 1.06 tons per day per man in favor of machine mining. The consumption of powder is decreased by machine labor, and 95.3 tons of coal are produced per 25-lb. keg of powder, as against 39.5 tons in hand mining. The cost of mining by the two methods is variable, depending on many conditions. At one mine, using machines of Type II., it was said that the value of the machine as an economic factor in mining coal depends almost entirely on the skill of the operator running it. It requires not only a man of considerable physique, but with sufficient brains to have the knack of handling the machine without taking the jar himself. The experience at another place has been that out of 100 men who have tried to run machines, only about 5% could exceed an average of 60 lineal ft. per day. The difference between skillful and unskillful manipulation may be more than equal to the profit made by using them, and the want of competent men has several times resulted in abandoning the machine plant and returning to the old method of hand mining. An operator in Illinois reports that in machine mining he has found practically no difference either in cost or in the number of men employed for a given output.

Besides the question of cost, however, there is in machine mining the advantage that a larger quantity of lump coal is obtained as the cut is deeper and the break-away of the coal cleaner. A larger output can also be obtained from the same length of face. Much depends on the nature of the roof, coal, and floor. These should be carefully considered before determining what type of machine to adopt. For a seam with ironstone balls in the holing, machines of Type I. would not be so successful as those of the Ingersoll-Sergeant or Harrison class, as the latter can evade and cut around such obstructions, whereas the former cut through them and run the chance of losing all the cutters in the attempt.

In a seam with well-defined cleavage lines it is advisable to work the coal "on the horn," as, if the machine is worked on a face which is parallel to either the face or butt cleats, the coal often comes away on the top of the cutters. Machines working in a long wall should be able, after having cut from one end to the other, to start and cut back without requiring to be conveyed to the original starting point.

The heavier machines, such as the Gillott & Copley, are said to necessitate an expense of at least $5 in removing 1000 yards underground.

There is considerable diversity of opinion as to the relative merits of compressed air or electricity as a motive power for mining machinery. The former has the advantage of aiding ventilation, but the disadvantage of requiring pipes and hose connections. Electricity, on the other hand, has easily made connections, but is dangerous in gaseous mines. The relative costs of the two forms of power has never been determined with sufficient justice to both to permit discussion.

COPPER.

The copper production of the United States in 1893 was almost as great as in 1892 and greater than in any other previous year in the history of the trade, notwithstanding the fact that the price of the metal was lower than ever before. The elaborate tables of itemized cost of producing copper at the Michigan and some Arizona mines and the dividends they have paid, which were given in the first volume of THE MINERAL INDUSTRY, sufficiently explain this enormous output even when the market price of the metal was at such an unprecedentedly low level. The marvelously low cost there shown has been lowered again during the year 1893, and most of our copper mines have paid handsome dividends, larger in many cases than were earned when the metal sold at prices from three to four cents a pound higher. In other words, the cost of producing copper has declined more rapidly than the market price, and that notwithstanding the fact that the Western mines have worked out the greater part of their high-grade, oxidized ores near the surface, and are now extracting a much lower-grade material than formerly.

The important event in the copper industry is the rapid expansion of the electrolytic processes for refining. In this volume, which aims to photograph the state of the art as it is to-day, much space is devoted to the latest practice and most recent improvements in copper metallurgy. No such valuable treatise on the subject, it is believed, has heretofore been published.

In the statistics of production the utmost care has been taken to secure accuracy, not only in the report for the year 1893, but in that for 1892, in which a few changes have been made. A somewhat important change has been made in the figures of production of the Calumet and Hecla mine for 1891—for which year we had accepted the official figures filed in the State of Michigan; we have good reason, however, to believe that the actual production of refined copper by the Calumet and Hecla in 1891 was 55,586,620 lbs. and not 63,586,620 lbs., and in 1892 it was about 58,273,300 lbs. and not 72,273,300 lbs., as reported by the company to the State. The seriousness of this statement is fully appreciated, and it is not made without what is deemed sufficient evidence. In the absence of official statements to its stockholders of the actual production of this company we are unable to explain these discrepancies.

It is much to be regretted that a great enterprise, controlled and managed by men who enjoy universal confidence for probity, should be administered under a policy of secrecy which refuses to stockholders the information they have an undoubted right to demand from their trustees, the directors; and which justifies and encourages, with an illustrious example, the practices through which unscrupulous managements have so often brought disgrace and injury on the entire industry.

Arizona increased her output through the steady growth of capacity and from no forcing process. This Territory could indeed greatly increase production if the prudent management which controls most of the mines deemed it desirable to do so. The several producers have courteously furnished for this work the production of their mines from their opening. These returns change slightly the figures which we had received in past years as the work progressed.

COPPER PRODUCTION OF ARIZONA.

(Pounds of fine copper.)

Year.	Arizona.	Copper Queen.*	Commercial.	Detroit.	Old Dominion.	United Verde.	United Globe.	Other Mines.	Total.
1880	....	1,379,940	....	....	....	....	....	....	....
1881	....	3,866,581	....	....	....	....	....	....	....
1882	....	7,744,278	....	1,442,935	1,863,082	....	....	6,933,705	17,984,000
1883	....	7,523,981	....	2,819,530	4.401,149	1,325,534	....	7,803,806	23,874,000
1884	3,539,556	7,668,617	....	2,749.997	7,073,928	3,834,290	....	1,867,612	26,734,000
1885	6,772,239	6,663,782	....	3,345,523	4,691,146	168,388	....	1,065,288	22,706,366
1886	5,513,549	3,797,256	....	2,110,690	4,384,958	....	....	193,547	16,000,000
1887	5,539,771	5,707,728	....	4,175,717	1,386,979	272.124	....	707,681	17,790,000
1888	6,833,528	12,031,614	....	5,235,797	4,447,834	3,085,651	....	1,565,576	33,200,000
1889	6,787,201	12,152,910	....	4,875,696	5,678,890	1,923,748	....	1,514,555	32,933,000
1890	5,164,906	13,120,934	....	4,906,704	7,411,214	5,475,573	398,849	897,861	36,977,192
1891	5,673,611	13,022,957	....	4,194,672	6,982,101	7,350,087	2,302,765	4,671,271	41,894,699
1892	5,893,533	12,916,416	282,451	1,918,594	7,698,297	9,524,492	....	149,333	38,383,116
1893	7,871,819	13,795,618	273,330	4,942,728	7,665,293	9,121,146	....	103,741	43,773,675

* Includes the Holbrook & Cave.

Lest the readers of this work might get the impression that the profits of the copper business are fairly represented by the dividends of the Quincy, the Calumet and Hecla, or other mines whose itemized costs and profits for many years were given in the first volume of THE MINERAL INDUSTRY, we may cite the case of the Arizona Copper Company, which has a fine property of high-grade ore. These mines were opened in 1873 or 1874, but there are no records obtainable of the production previous to 1884, though it is estimated that it may have amounted to 30,000,000 lbs. during that decade. In 1882 the property, originally known as the Longfellow Copper Mining Company, was sold, together with the Metcalf, Queen, and Coronado groups, to the Arizona Copper Company. The sale was made at a high price just before the famous Montana properties were heard of and when copper was worth from 18c. to 20c. per lb. Had copper remained at the price then ruling, the property might have paid a moderate interest on the capital invested, but the rapid development of Butte, Mont., with its consequent flood of copper and low prices, played havoc with its prospects. In order that the mines might be worked economically it was necessary that a narrow-gauge railroad should be built to connect the mines with the Southern Pacific Railroad, and for this purpose $800,000 additional capital was raised on a mortgage bearing 10% interest—too heavy a burden to bear in the face of the low prices which have ruled in recent years. The shareholders have, so far, received no dividend, the profits being absorbed in the payment of fixed charges and in the erection of new plants.

During the year 1893 the company has built a sulphuric acid plant, with a capacity of 10 tons of acid per day, and also a leaching plant for the treatment of 100 tons per day of the tailings from its concentrator. The company's mines are in such condition that there is no reason to doubt the future. The smelting plant, consisting of three 60-ton furnaces and one 40-ton furnace, is equal to anything of the kind in the country. Its concentrating plant, with a capacity of 175 tons per day, is in advance of most works of this character. Its leaching plant has not been long enough in operation to show what it can do, but it is a financial as well as a technical success. The prospects of the company are to-day better than they have been, and there is at last a prospect of a dividend for the long-suffering shareholders.

In producing 8,199,811 lbs. of copper during the year the consumption of ore and of concentrates amounted to about 32,000 tons. The yield of the ores was 12.4%. The amount of flux (limestones) used was about 12,000 tons; of coke, about 8200 tons. The percentage of coke to the whole burden usually amounts to 15¾%, a percentage somewhat high on account of fines and concentrates.

Wages paid in 1893 were: Miners, per day, $2.70 to $3.25; Mexican miners, $2.25 to $2.50; common labor, $1.80 to $2; furnace feeders, $3.25 to $4; charge wheelers, $2.70 to $3.25; copper tappers, $2.92½ to $3.60; slag tappers, $2.70 to $3; carpenters, $3.60 to $4; blacksmiths, $4 to $5.

The Old Dominion Copper Company produced in 1893, 7,665,293 lbs. of fine copper. The operations of the mines were as follows: Ore smelted, 63,597,300 lbs.; lime used for flux, 14,618,208 lbs.; coke consumed, 11,040,775 lbs.; copper produced, 7,866,475 lbs., which is the second largest yearly output ever made by the company, having been exceeded in 1892, when 8,019,059 lbs. of copper were produced.

California.—The California copper production is still small, though the State possesses some good mines. Much of the product is put into sulphate and some other forms which find a home market. The great distance to markets, moderate richness of the mines, and high fuel and labor costs prevent successful competition with the more favored large producers of Arizona and Montana.

Colorado.—The copper output of this State declined very slightly, owing to the falling off in production of the Leadville silver-lead mines, which in depth are becoming more important copper producers. The production of true copper ore is, however, increasing in this State and a greater output may be expected.

Michigan.—There has been no material change during the year in the copper industry of Michigan. Preparations continue to be made by sinking deep vertical shafts—now the deepest in the world, and sunk at an unexampled rate of speed (Tamarack No. 3, 3824 ft., and No. 4, 3698 ft. deep March 1, 1894). The copper continues to the greatest depth thus far reached, though it is not certain that it maintains undiminished its extraordinary purity and high electric conductivity.

The following table gives the production of each of the chief Michigan mines and the total production of the State during the past four years; the production of each mine from its opening to the close of 1892 was given in the first volume of THE MINERAL INDUSTRY, to which the reader is referred.

COPPER PRODUCTION IN MICHIGAN.
(Pounds of fine copper.)

Mine.	1890.	1891.	1892.	1893.
Adventure	15,485	5,600	....	....
Allouez	1,407,828	1,241,423	546,530	....
Atlantic	3,619,972	3,653.671	3,703,875	4,221,933
Calumet & Hecla	58,836,904	55,586,620	58,283,000	62,750,000
Centennial	....	435,784	....	....
Central	1,413,391	1,321,417	1,625,982	1,177,500
Copper Falls	650,000	1,440,000	1,400,000	1,000,000
Evergreen Bluff	15,304	....	....	....
Franklin	5,638,112	4,319,840	3,767,000	3,504,244
Hilton	18,642	6,400	....	....
Huron	1,736,777	1,215,734	461,499	562,776
Kearsarge	1,598,525	1,727,390	1,580,192	1,546,318
Knowlton	23,145	7,120	....	....
Massachusetts	60,000	30,114	17,450	22,737
National	123,897	103,888	36,385	63,433
Osceola	5,294,792	6,543,358	6,894,256	6,216,975
Peninsular	1,108,660	1,599,670	973,217	....
Quincy	8,064,253	10,542,519	11,103,926	14,398,477
Ridge	17,645	43,049	41,462	25,988
Tamarack	10,106,741	16,161,312	16,426,633	15,085,113
Tamarack Junior	....	....	796,769	1,610,259
Wolverine	....	312,112	500,074	1,025,062
All other mines	944,927	102,989	11,750	251,304
Total	100,695,000	114,400,000	108,170,000	113,462,119

Montana.—This State's copper resources are elaborately treated by Dr. Ledoux in a separate monograph. The output of Montana for four years is given in the following table, but in the first volume can be found the production of each mine since 1885.

COPPER PRODUCTION IN MONTANA.
(Pounds of fine copper.)

Mine.	1890.	1891.	1892.	1893.
Anaconda	64,046,812	46,500,000	100,000,000	75,256,657
Boston & Montana	26,942,298	26,507,929	30,386,595	31,800,000
Butte & Boston	5,485,434	18,392,054	10,641,269	20,457,928
Butte Red. Works	3,001,209	2,915,000	2,864,000	2,985,485
Colorado S. & M. Co	2,320,000	3,641,384	4,560,972	6,703,488
Hecla Con. M. Co	159,980	91,090	159,859	77,565
Parrott	9,000,000	14,108,382	12,438,782	7,791,167
All others	....	....	....	9,227,810
Total	110,955,733	112,359,839	161,051,477	154,300,100

Utah.—Mining in this State has been seriously affected by the decline in the price of silver, and the production of copper has suffered slightly. The development of its copper mines is retarded by the low price of the metal and the high cost of labor and fuel.

East and South.—The largest of the Eastern copper mines remained closed during the greater part of the year, but the abundant supplies of low-grade pyrites at several points in many of the Eastern and Southern States and the advantageous conditions for working them should increase the copper output of this section far beyond its present limits. In Tennessee the renewed efforts to work the old mines near Ducktown have not yet resulted in any important production.

Copper Sulphate.—The production of this article is steadily increasing and in 1893 amounted to about 54,000,000 lbs., containing about 13,500,000 lbs. of copper.

COPPER PRODUCTION IN THE UNITED STATES, IN POUNDS OF FINE COPPER.

	1882.		1883.		1884.		1885.	
	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.
Arizona	17,984,000	8,029	23,874,000	10,658	26,734,000	11,935	22,706,366	10,137
California	827,000	369	1,601,000	715	876,000	391	469,000	209
Colorado	1,494,000	667	1,153,000	515	2,013,000	899	1,146,000	512
Michigan	57,131,000	25,505	59,257,000	26,454	69,328,000	30,950	72,759,000	32,482
Montana	9,058,000	4,043	24,664,000	11,010	43,093,000	19,238	67,797,864	30,265
New Mexico	369,000	388	824,000	368	59,000	27	80,000	36
Utah	606,000	270	342,000	153	266,000	118	126,000	57
Eastern and Southern States	1,955,000	873	1,007,000	449	1,222,000	545	252,000	113
All others	870,000	388	2,358,000	1,053	1,330,000	594	1,150,000	513
Total domestic production	90,794,000	40,533	115,080,000	51,375	144,921,000	64,697	166,486,230	74,324
From foreign ores	1,473,109	658	1,625,742	726	3,228,966	1,441	3,607,952	1,610
Total production	92,267,109	41,191	116,705,742	52,101	148,149,966	66,138	170,094,182	75,934
Stock, Jan. 1	....	....	....	....	30,000,000	13,394	30,000,000	13,394
Imports of bars, ingots, & old	531,000	237	632,039	282	195,378	86	574,514	256
Total supply	92,798,109	41,428	117,337,781	52,383	178,345,344	79,618	200,668,696	89,584
Deduct exports*	6,245,363	2,788	50,691,487	22,630	105,830,439	47,245	114,163,112	50,966
" consumption	....	....	36,646,294	16,359	42,514,905	18,979	51,505,584	22,993
Stock, Dec. 31	....	....	30,000,000	13,394	30,000,000	13,394	35,000.000	15,625

States.	1886.		1887.		1888.		1889.	
	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.
Arizona	16,000,000	7,147	17,790,000	7,944	33,200,000	14,821	32,935,000	14,703
California	430,000	192	1,600,000	714	1,570,000	700	1,700,000	759
Colorado	409,000	182	2,012,000	898	1,621,000	724	3,100,000	1,384
Michigan	80,260,000	35,830	75,792,000	33,836	86,503,000	38,617	87,414,000	39,024
Montana	57,611,485	25,718	78,700,000	35,134	98,504,000	43,977	104,589,000	46,691
New Mexico	558,000	248	284,000	126	1,631,000	728	3,686,000	1,645
Utah	500,000	223	2,500,000	1,116	2,131,000	952	2,400,000	1,072
Eastern and Southern States	346,000	154	200,000	90	100,000	45	90,000	40
All others	1,332,000	594	2,433,000	1,086	3,241,000	1,445	3,625,000	1,618
Total domestic production	157,446,485	70,288	181,311,000	80,944	228,501,000	102,009	239,539,000	106,936
From foreign ores	4,795,050	2,140	3,935,000	1,756	5,218,000	2,329	5,190,000	2,317
Total production	162,241,535	72,428	185,246,000	82,700	233,719,000	104,338	244,729,000	109,253
Stock, Jan. 1	35,000,000	15,625	40,000,000	17,857	40,000,000	17,857	75,000,000	33,482
Imports of bars, ingots, & old	531,789	238	212,539	94	107,946	48	122,998	55
Total supply	197,773,324	88,291	225,458,539	100,651	273,826,946	122,243	319,851,998	142,790
Deduct exports*	66,315,661	29,605	43,000,000	19,196	80,000,000	35,714	73,000,000	32,589
" consumption	91,457,663	40,918	142,458,539	63,598	118,826,000	53,047	181,851,998	81,184
Stock, Dec. 31	40,000,000	17,768	40,000.000	17,857	75,000,000	33,482	65,000,000	29,017

States.	1890.		1891.		1892.		1893.	
	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.
Arizona	36.977,192	16,508	41,894,699	18,703	38,383,116	17,135	43,773,675	19,542
California	1,600,000	714	3,750,000	1,673	3,200,000	1,430	2,825,773	1,261
Colorado	6,000,000	2,678	7,000,000	3,125	7,250,000	3,236	7,121,157	3,179
Michigan	100,695,000	44,953	114,400,000	51,071	108,170,000	48,290	113,462,119	50,653
Montana	110,955,733	49,534	112,359,839	50,161	161,051,477	71,898	154,706,859	69,066
New Mexico	870,000	388	1,600,000	714	500,000	223	273,515	123
Utah	600,000	273	1,700,000	759	2,000,000	893	1,312,171	585
Eastern and Southern States	4,200,000	1,875	1,300,000	580	1,300,000	580	415,025	185
All others	....	....	3,450,000	1,540	1,201,840	536	3,365,494	1,502
Total domestic production.	261,897,925	116,923	287,454,538	128,326	323,056,433	144,221	327,255.788	146,096
From foreign ores	6,017,000	2,686	11,500,000	5,185	10,200,000	4,553	7,723,387	3,448
Total smelted	267,914.925	119,609	298,954,538	133,511	333,256,433	148,774	334,979,175	149,544
Stock, Jan. 1	65,000,000	29,018	101,000,000	45,089	76,000,000	33,929	56,000,000	25,000
Imports of bars, ingots, & old	668,676	296	4.174,057	1,408	1,552,515	693	5,536,690	2,472
Total supply	333,583,601	148,923	404,128,595	180,008	410,808,948	183,396	396,515,865	177,016
Deduct exports*	40,000,000	17,857	115,122,067	51,394	90,036,800	40,198	180,066,880	80,387
" consumption	192,583,601	85,977	213,006.528	94,685	264,772,148	118,201	158,208,985	70,629
Stock, Dec. 31	101,000,000	45,089	76,000,000	33,929	56,000,000	25,000	58,240,000	26,000

* Exports are calculated from official reports of exports, counting "ore" as averaging 55% copper in 1887 to 1890, inclusive; since that date the actual contents is given.

Imports and Exports.—The imports of copper from Canada have not varied much from those of previous years; but from Mexico they show notable increase and amount now to 2,155,398 lbs. of copper, of which 1,863,700 lbs. were in pigs, bars, ingots, old, and other unmanufactured forms. Our total imports, as reported by the Bureau of Statistics, amounted to 13,260,077 lbs.

The principal sources of our imported copper are as follows: Canada, which sends us a little from British Columbia; an important amount from the Sudbury District in Ontario, where it is mined as nickel-copper pyrites; and a large amount from Quebec, where the Eustis and Nichols mines have been large producers for many years. The latter is not at present looking as well as usual.

Newfoundland sends us a little copper, and Spain a very important amount in pyrites which contain less than 2% of copper, that amount coming in free of duty under the McKinley tariff. Since some of our smelting works are "bonded warehouses" in which foreign ores can be received, smelted, and the products exported without paying duty, they offer a favorable market for the ores of the West Indies and South America, as well as those of Canada and Spain.

The Exports of copper from the United States increased enormously in 1893, owing to the great depression here in manufacturing, due to the monetary panic. The European refiners and manufacturers took no less than 80,387 long tons of copper from us, but at very low prices. This amount is much greater than we can spare under normal conditions of home trade, so that during 1894 it will undoubtedly suffer a heavy decline. The imports and exports of copper from the earliest date are given in the table of the United States mineral imports and exports in the latter part of this volume.

The Consumption of Copper in the United States and other countries is shown instructively in the accompanying diagram, and in the statistical tables at the end of this book. The consumption in the United States was much lighter than usual, but trade is already improving, and consumption will be greater during the current year, 1894, though it can scarcely be expected to reach the highest limit of the past. The per capita consumption of copper in the United States in 1893 was about 2.87 lbs., as against 4.07 lbs. in 1892 and 3.30 in 1891, as given in THE MINERAL INDUSTRY, Vol. I., p. 117.

Stocks of Copper on Hand.—The amount of copper held in the various marketable forms of ingots, bars, pigs, anodes, and matte, but not including Michigan "mineral,"—which, though as rich as matte, is not traded in,—amounted at the close of 1893 to 58,240,000 lbs., or 26,000 long tons, or 17½% of the production. This is a little more than at the close of 1892, when it was 25,000 long tons. Returns are made to THE MINERAL INDUSTRY by every producer and refiner in the country, and these figures are therefore reliable. This slight increase in stocks was due to the greater quantity held in anodes for electrolytic refining. This copper "in process" is clearly an available stock on hand, since it would come on the market were every mine in the country suddenly to cease working, and it is a constantly increasing stock, for the output from electrolytic refining works is rapidly augmenting. During 1893 there were produced in the United States 85,000,000 lbs. of electrolytic copper, as against 50,000,000 lbs. in 1892.

The stocks on hand when the market is considered "reasonably bare" may be counted as averaging about two months' production of our mines, and these figures have now been confirmed by direct returns during the past four or five years of the stocks held by each of the producers.

The Future of Copper Production in Montana.

By Albert R. Ledoux.

Just thirty years ago the Territory of Montana was created by Congress. It had previously been a part of the great "Louisiana Purchase." Only three years ago the Territory was admitted into the sisterhood of States, of which it now forms the third in area, covering 150,000 square miles. Its climate is mild as compared with that of some of the more easterly and southerly States, being affected to a greater or less degree by the influences which modify the climate of the whole Pacific slope. Its mean elevation above the sea level is also to its advantage, being less than 4000 ft., as compared with 5600 ft. for Nevada and New Mexico, 6400 for Wyoming, and 7000 for Colorado.

Considering its very recent settlement, it has a record of mineral production which, taken altogether, has never been equaled. It has a single gold mine which paid in dividends over $12,000,000 in eight years. Its placers yielded $86,000,000 in six consecutive years. During the last ten years its production of gold has been over $188,000,000, of silver $173,000,000, and of lead $8,000,000, and it has supplied the world with copper during this same period to the extent of over 900,000,000 lbs.

Equally extraordinary is the rapid growth of its copper production. In 1882 9,058,000 lbs. in round numbers were produced; in 1883, 24,664,000; in 1885, 67,797,864; in 1877, 78,700,000; in 1889, 104,589,000; in 1891, 112,359,839; and in 1893, 154,706,859.

The world had previously marveled at the output of the Lake Superior copper mines, whose production in 1882 was six times that of Montana, but in 1887 the production of Montana surpassed that of Michigan by 3,000,000 lbs., and in 1892 Montana increased its lead to 57,000,000 lbs.

Not the least remarkable thing about copper is the comparatively limited areas in which it is profitably mined, in spite of the fact that it is one of the most easily discovered ores. The productive Lake Superior mines are limited to a narrow belt 100 miles in length, while the production of Montana is still practically confined to the smallest county in the State, within the limits of a single town.

It is, of course, a matter of general interest whether the enormous production of Montana is to continue, or even to increase at anything like the ratio of the past decade. But there are people to whom it must be of vital importance to be able to form an idea as to the future of copper-mining in Montana; I mean the smelters and refiners of Europe and America. The Lake Superior product has aways come forward as refined copper, and will continue to do so, although there are said to be some indications that the quality of Lake copper, as great depth is attained, will not always be equal to the old standard. This is a subject which deserves to be studied carefully, not only by the Lake companies themselves, but by their rapidly increasing competitors, the electrolytic refiners. It should be easy to determine whether the alleged deterioration in conductivity, for instance, is due to impurities, or to closer concentration and increase in iron.

The copper from Montana until 1892 practically all left the State in the condition of "furnace material," and the smelters of two continents have enjoyed the profits of refining the great output. The refiners of Western States have handled some of it; much more has been treated at Atlantic ports,—Baltimore, New York, Bridgeport, etc.,—but by far the greater bulk has been exported.

Ten years ago the Montana product was ores, and only ores. They contained —car load after car load—from 40% to 60% of copper. Then followed mattes low in silver, then silver-bearing mattes, then bessemerized pig copper. At last, in 1893, electrolytic ingots and wire bars completed the series.

Were it necessary, Butte could still send out a very respectable amount of rich ore. In fact, in this month of January, 1894, several car loads containing over 65% copper and over 20 oz. silver per ton were received at our New York sampling works. These are rare exceptions now.

At the close of an article in THE MINERAL INDUSTRY for 1892 the writer of this said, "The year 1894 will see the end of the exports of mattes from America, and those smelters who rely upon such supplies must realize this fact." This prophecy bids fair to be fulfilled early in the current year, and the smelters of Great Britain, who are agreeing among themselves on what basis they will continue to purchase American mattes, among other things, are certainly performing a work of supererogation; they must face the fact that mattes and ores from America are soon to be only a memory.

Reviewing the progress of this great Montana industry, rivals as well as disinterested observers have been wondering for years why their predictions were not fulfilled that the "deluge of copper" from this State must soon cease. Successive dates have been appointed by various experts when the maximum production would be reached and after which we should witness a rapid falling off in the product and the closing down of the important mines. We believe that it was the year 1891 which, according to a Boston expert, was to witness the limit of profitable production in the Anaconda mines, and yet the year 1892 saw an increase of copper from the Anaconda equal in itself to the entire production for the year of Arizona—over 50,000,000 lbs. It has been equally hard for European producers to understand why this Montana industry refuses to die at the appointed time. Several Montana mines are producing more copper annually than it was reported, by learned experts, five years ago that there remained in them.

The Butte mines form a system unique and different from any other that the world has heretofore studied. It was but natural that experts familiar with the bedded veins or lenses of Ducktown, for instance, and others of the Appalachian chain, should expect their characteristics to be repeated in the Rocky Mountains; it was also only natural that the operators of great pyrites beds in Europe should expect to see the cost of mining overtake and pass the profit of selling when mining became comparatively deep. It was natural also for the experts of Lake Superior to be somewhat rash in applying to Butte the axioms derived from their experience in those splendid ore bodies also unique in mining experience. The Eastern miner looked for a rapid exhaustion of the rich brown and purple ores, and expected that, as in Ducktown, the transition through chalcopyrite to iron would be quick, but none of these prophets could calculate upon the increase in gold and maintenance of silver ratio in the Butte ores, nor have their expectations as to diminution in copper been fully realized. Were it a question of copper only, the predictions as to Butte's future would be somewhat simplified. Nobody denies, certainly not the writer, that the rich surface ores are disappearing, and it may be said here that so far as copper is concerned there has been an average depreciation of two per cent. for each 100 ft. in depth at Butte. But this is less and less rapid from 500 ft. downward.

Considering only copper, in the light of many opportunities and with considerable information before me, I will say that in my opinion the experience of deep mining in Chile rather than that of mining in Tennessee will be duplicated in Butte, and that we can depend upon a 5% ore down to the 1600 or 1800 levels. The deepest shafts in any copper mine in Butte are to-day not over 1300 ft., and in no mines is ore raised to-day from below the 1100. At 900 and 1000 ft., respectively, the writer saw from 40 to 50 ft. of pay ore in magnificent breasts in certain properties last July, and, much to his surprise, at the lower level almost 6 ft. of solid gray copper against the foot-wall. It is from such rich masses—isolated and infrequent though they may be—that copper *ore* goes forward to the smelters to be run directly into bar copper, or even sent forward to the East for treatment. But it is upon the second-class ore that the smelters must continue to depend for their supplies. Without making public the sources of information, I may sum up the results of my observation at my last visit to Butte, so far as copper is concerned, in the statement that I consider that the second-class ore now being concentrated assays on the average 6.72% copper and about 6 oz. silver per 2000 lbs. This is an average of the camp; it is higher in some and lower in other mines.

It is the aim of the smaller mines to bring up the average percentage of copper in ore mined to about 9%, and this there is no difficulty in doing as yet by the admixture of rich ores. The Boston-Montana also averaged for 1892, as reported, 9.17%. A comparison of the number of tons of ore mined, taken from statements made public by some of the mining companies, from an inspection of books kindly accorded me in other cases, and from careful figuring on the number of tons of fine copper produced by these mines during 1893, shows a net production from the Butte ores of about 5½% copper on the average. It is my belief that this average of copper product can be maintained by the Butte camp for at least ten years to come, at the present rate of output. Whatever may be the experience of individual mines, the new properties opened, though perhaps individually small, as well as the bodies of rich ore which will be encountered unexpectedly or otherwise in all the mines, will still maintain this average net production of copper.

If we disregard the gold and silver contents for a moment, let us ascertain at what price for refined copper the mines can maintain themselves with a net yield of 5½%. The cost of mining in Butte probably varies from $2.60 to $3.50 per ton of ore raised. The larger the vein the cheaper the labor; but, on the other hand, the dearer the timbering. It is not necessary to go into the particulars, but these figures are reliable. The cost of delivery of the ore to the smelter varies from 20c. per ton in one case to $1 per ton, and we may take an average of about 60c. per ton, considering the relative product of the different mines. Therefore $3.60 may be considered the average cost of delivering one ton of ore at the reduction works. The yield at 5½% is 110 lbs. of fine copper, say 3.3c. per lb. After reaching the reduction works the ore is usually concentrated, roasted, smelted into matte, and bessemerized. It is then either refined electrolytically or sent forward in the form of argentiferous pig or anode copper.

I can assure the readers of THE MINERAL INDUSTRY that these metallurgical operations cost to-day from $4\frac{1}{4}$c. to $5\frac{1}{2}$c. per lb. of fine copper; say an average of 5c. for the whole camp. It must be borne in mind that in the two largest works treating Butte ores power is obtained entirely, or to a large extent, from water. The average cost, then, of electrolytic copper on the cars in Montana, let us say, is 8.3c. per lb. Freight on this copper to the extreme Eastern market is not over $15 per ton of 2240 lbs., say, allowing for other expenses $\frac{7}{10}$c. per lb. Montana electrolytic, therefore, laid down in New York, costs to-day on the average—always remembering that we have as yet taken no account of the gold and silver—say 9c. per lb. and, after allowing reasonable commissions for selling, there would still be a profit at the market price at this writing, which is, approximately, $9\frac{1}{2}$c.

In the cost of the metallurgical treatment I have allowed a fair margin for interest and depreciation of plant, but have not done so in the figure given as the cost of mining. This needs special consideration. Such a factor is of greatest importance, especially where deep mining is to be a feature. It is certainly a reasonable allowance to place the interest on the capital represented in timber and machinery at the mines, the loss from wear and tear, and a fair allowance for amortization, at $\frac{1}{2}$c. per lb. of copper produced—55c. per ton of ore smelted.* This will bring our cost up to $9\frac{1}{2}$c. With electrolytic copper at $9\frac{1}{2}$c. there would be no profit to-day in plain copper mining in Montana if due regard were paid to the safety of the principal, as well as the interest, of stocks and bonds of the average mining enterprise. I have no doubt that my figures for mining, concentrating, and refining will be disputed, but I can assure the reader that I have taken into consideration all reasonable contingencies, and know they are within the limits for the largest producers, if not for all.

What has struck even the average observer of the copper industry during the past ten years has been the great decrease in the cost of production. Price of labor in Butte and vicinity has varied only a little, owing to the strength of the miners' union, but fuel and timber have fallen, largely on account of the increased railway facilities and competition. The introduction of steam stamps, water power, automatic water granulation of slag, bessemerizing in large converters under greater pressure, and a hundred other economies have brought the price of handling to its present minimum rate. The fall in freight rates, too, has been remarkable since competition came in. The quoted rate to-day is under $15 per ton, whereas upon the first consignments to my firm, only about ten years ago, the freight paid varied from $40 to $80 per ton. In fact, in some instances ore and matte reached New York by vessel from Oregon ports.

It may be interesting to consider the other alternative—supposing the copper produced in the form of converter bars assaying 96% copper. What is the cost of

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* This allowance is based on the value of mines and plants to-day—not upon their cost to date. It took many thousands of dollars to determine by experiment how best to treat these ores, and several times have the largest works been remodeled at enormous cost. If we were to take what the expenditures have been as a basis, instead of the outlay that would duplicate the plants as they stand to-day, our $\frac{1}{2}$c. would have to be doubled. But this would not be fair, as no such changes will be necessary in future.

refining these? Where water power is employed it is safe to place this at not over ¼c. for remelting and casting into anodes and 1¼c. for electrolyzing, say 1½c. (One cent per lb. will do it all before many years.) Subtracting this from the 9½c. laid down in New York, we have 8c. for the converter bars delivered to Eastern refiners or placed free on board ocean steamers if destined to Europe. What it costs Eastern electrolytic works to convert these bars into fine copper is probably not far from $28 per ton of 2240 lbs., with every proper charge considered, but if done on toll the rates probably would not exceed 1½c. per lb., say $33 per ton, thus bringing the cost of fine copper again up to 9½c. per lb. delivered in New York.

It is now time to consider the important question of the part played by gold and silver in this great industry of Montana. It is well known that in the copper mines the gold and silver have increased up to a certain point with the decrease in the copper, and if the ore to-day delivered to the smelters yields 5½% of copper, it is likely to net about 5 oz. of silver per ton. This is the usual ratio for similar ores at other places than Butte. The average product of one mine, which the writer examined, for six months of 1893 was 7.15% copper and 7.40 oz. of silver per ton. Another property yielded in second-class ore 6.50% copper and 6 oz. silver. In another mine the second-class ore, as shown by the books, averaged from 5% to 7% copper and from 6 to 10 oz. silver. The converter bars produced will probably average 80 oz. of silver per ton and 0.3 oz. of gold. The average anodes will contain about 88 oz. silver per ton and 0.3 oz. gold. Assuming that the refiner saves in the electrolytic process 95% of the silver and 75% of the gold, one ton of these anodes would yield him, say, 83 oz. silver and 0.22 oz. of gold. If the silver is taken at, say, 65c. per oz., and the gold at $20 per oz., the product in precious metals will net the refiner, say, $57 per ton, equivalent to about 2½c. per lb. of copper after express charges on the bullion are paid.

It will be seen, then, from what has gone before, that I consider four facts established: 1. The average yield of copper in the Butte camp is now 5½%, or 110 lbs. per ton net, and it will not fall below 5%. 2. This copper costs 9½c. per lb. to-day, delivered in the East. 3. The value of the precious metals in the copper is equal to-day to $57 per ton of copper, and should yield a net profit of over 2c. per lb., with silver at 65c. per oz. and electrolytic copper at 9½c. 4. The present output can be maintained for at least ten years to come.

Let us consider these points again in detail.

(*a*) As to the first, there should be little difference of opinion among those qualified to judge. I am certain that in future, at least, if not to-day, the second-class (say 6.70%) ore is all that can safely be depended upon. The loss in concentration is not less than 15%, probably more. The loss in smelting and refining is certainly another 10%; say 25% all told.

(*b*) It is not likely that the cost of mining in Montana will be much reduced in the future. There is little competition in labor, and the "union" is easily maintained. But timber and fuel are likely to become a little cheaper, and freights may fall slightly. A proper regard for development work will be a factor to be considered in all estimates of expense, and this will nearly offset the cheapening in metallurgical operations. I believe these can be brought down to 4c. per lb. of copper in favorably situated works, but 9c. in New York is not to be much improved upon.

(*c*) In estimating the profit on gold and silver contents in the product I have taken 65c. for silver as the price. This is about the average of English standard for 1893. What the price of silver is likely to average for the next ten years is a question unanswerable to-day. But with silver at even 50c. per oz., the estimated profit would still be about 2c. per lb. of copper; or with ore netting 5%, at least 1¾c. profit.

(*d*) There is little to add to the statement as to the future of the mines—as mines. In the largest of them there are from two to five years' supply of ore in sight at the present rate of production. If the diminution in copper, as depth increases, brings the figure of second-class ore down from 5½% to 5% net in the next 500 ft., the silver and gold available and the first-class ore that can be relied on from what is still virgin ground will maintain the *average of the camp* at about the present figure. There is not likely to be a very great—but nevertheless an appreciable—increase in output in the next ten years, if the present policy prevails. But Montana has shown her ability to nearly double her output for a while if challenged. This would be possible by again shipping mattes and other furnace material, but is highly improbable.

It is apparent that the future of the copper industry in Montana, as in the rest of the world, depends not only upon natural conditions, nor yet upon the skill and economy of the miner and metallurgist, but largely upon the wisdom of those charged with marketing the product. Shall America's bountiful supply be so husbanded and sold as to be among the stable articles of merchandise, or shall we continue to see zigzag lines and steep gradients contrasting with the comparatively uniform curves for lead, tin, zinc, and other metals upon the chart of commerce? This question no human mind can answer to-day, and yet nothing should be easier under existing conditions. I am not commercially interested in metals, nor am I a stockholder in any copper-mining company: I can therefore discuss this situation without prejudice.

The buyers of copper for manufacturing purposes, while earnestly and properly opposing anything in the shape of a "trust" in what is to them raw material, are most interested that prices shall be fairly steady; they do not care very much whether copper is 10c. or 12c. if it will only remain sufficiently uniform in price to warrant their carrying fair stocks, manufactured or unmanufactured. This is true, also, of the electrical supply companies, who do not themselves manufacture. It is noticeable again that over 70% of the copper produced in America in 1893 is the product of three localities of limited area, and under the actual or potential control of five individuals. These gentlemen know each other, admit the desirability of mutual protection, and have experienced its benefits in the past. Circumstances are even tending to bring them together in another way. When Lake Superior alone produced refined copper, and the product of Montana and Arizona was all marketed as furnace material or casting brands, Lake Superior could be very independent. To-day the electrolytic process has narrowed the difference in price until it is not a rash prophecy to say that within two years the public will take indifferently Lake or electrolytic for all purposes. Whether we consider this due to a slight lowering of the quality or standard of Lake on the one hand, or to the improvement and increasing uniformity of electrolytic on the other, is a matter of indifference. The same thing is going on in England with equal rapidity, and the day is apparently not far distant when we shall see both Lake and electrolytic copper delivered as "good merchantable" on the London Metal Exchange.*

An increase of 1c. per lb. of copper means an increase of over $3,000,000 per annum on the production of this country—a similar decrease, a proportionate loss. Were it necessary to form a "trust" to bring about this steadying of the market or to "corner" the product, or even to speculate for a rise on the London Exchange, there would be objections from several quarters. But none of these courses is essential to concurrent action. Wherein, then, lie the insuperable obstacles, and what hinders complete coöperation and mutual confidence between these great interests? When circumstances pointed out the need of coöperation in other trades, in this and in other lands, the obstacles have usually been brought down to one main issue—a difference of opinion as to the method of selling. Perhaps it is here that a measure of the trouble lies with copper. We have seen in America as well as in England (perhaps an outgrowth from the old system of "ticketings") "pool sales" of large quantities at stated intervals, and between these sales the market is feverish, owing to varying opinions as to the price likely to be established at the next. We see in all business everywhere rivalries and jealousies created by the varying commissions paid to agents, the rebates and drawbacks allowed to buyers, and the diversity in conditions of payment.

Sometimes producers in all trades seek to get on without agents and save commissions; others have employed agents and clothed them with unlimited authority to fix prices and terms, perhaps not realizing that they are solely interested in earning commissions and not at all or but slightly influenced by the cost to the producer of the article they sell. Others still have offended more conservative competitors by introducing or permitting speculation in or by means of their own product. This has been eminently true in copper in England if not in America. Large contracts have been made on the London Metal Exchange prices as a basis. The operations of the French "Copper Syndicate" began in speculation in Rio Tinto shares in Paris, and it is believed, justly or unjustly, by many that the selling price of copper in New York has more than once been determined by the price of copper stocks in Boston.

These differences have been removed and unity secured in many lines of business where hundreds of widely different interests were successfully harmonized. Europe stands ready to coöperate in copper, with or without the adherence of owners of old stocks or the coöperation of foreign capitalists through the Metal Exchange.

America will be a long step forward toward complete coöperation by adopting a *modus vivendi* between the five interests most prominent in copper, agreeing first, that they will sell by a uniform system, and second, that they will prohibit speculation by agents or principals. To sum up, the copper-mining industry of Montana is upon a sound basis so far as Montana is concerned, but the profit or loss of the next ten years depends most on Boston and New York.

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* A long contract closed with 1893 in England in which wire bars were paid for at £8 10s. above the average price of G. M. B.'s for the month. But in December similar wire bars sold at only £4 above G. M. B.'s. This copper, therefore necessarily 100% fine, brought only £2 10s. above G. M. B.'s, for it is a good delivery of "good merchantable" copper if it contains 96%. The difference of 4% represented £2 per ton. Considering the cost of refining, G. M. B.'s and electrolytic were, in this transaction, already at a parity.

The World's Copper Production.—Nearly every important copper producer throughout the world has courteously favored us with a statement of his output. From these official returns, supplemented, as to the less important producers, by the statistics of Messrs. Henry Merton & Co. of London, we are enabled to compile the following table:

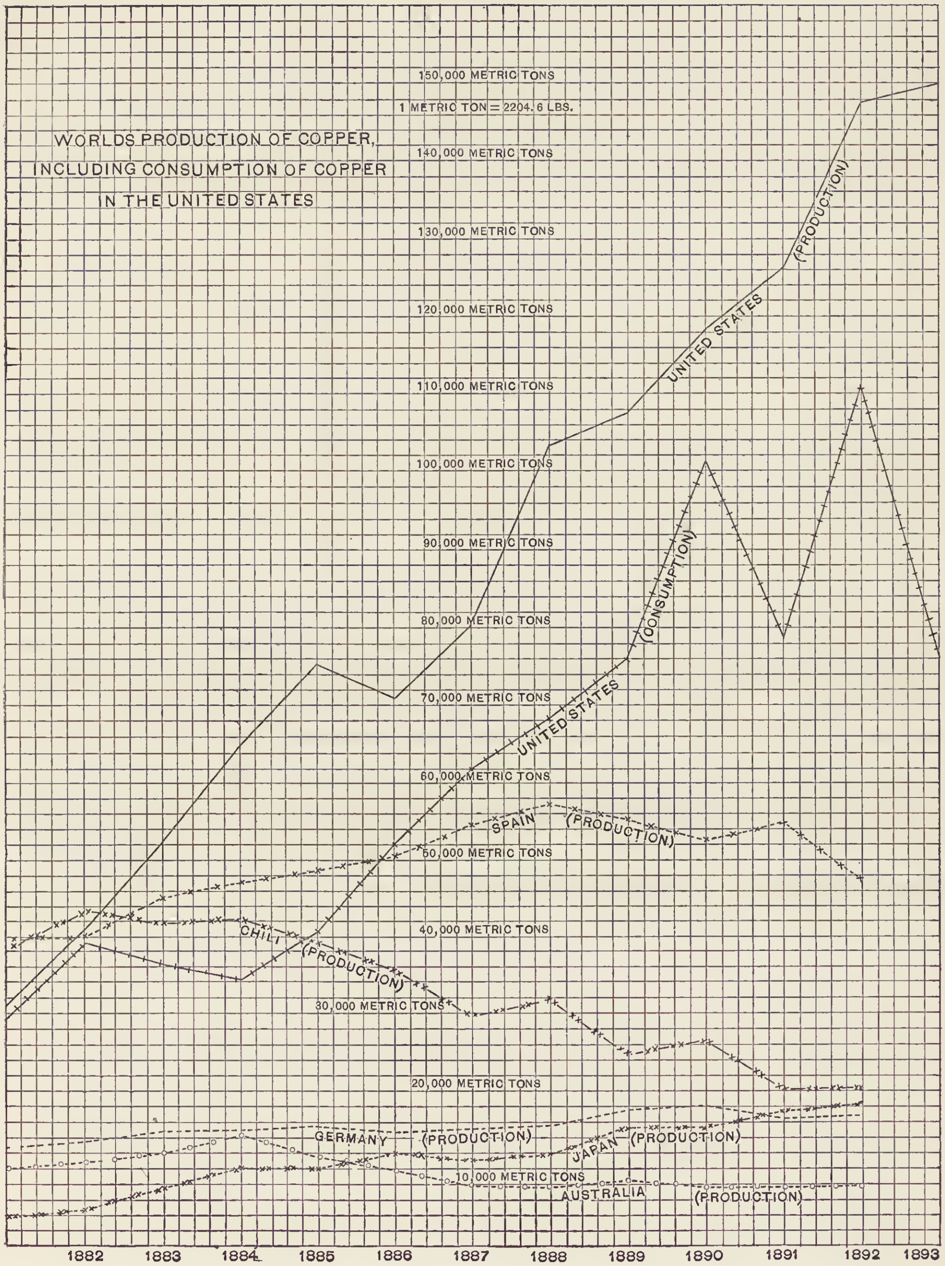
Countries.	1892.		1893	
	Tons of 2240 lbs.	Metric Tons 2204 lbs.	Tons of 2240 lbs.	Metric Tons 2204 lbs.
Australia	6,092	6,191	7,500	7,621
Austria-Hungary	1,385	1,407	1,400	1,423
Bolivia	2,860	2,906	2,500	2,540
Canada	4,130	4,197	3,732	3,792
Cape of Good Hope—				
Cape Company	5,350	5,437	6,374	6,477
Namaqua	1,378	1,405	890	904
Chile	22,065	20,326	21,350	21,694
England	492	500	443	450
Germany—				
Mansfeld	14,687	14,921	14,150	14,378
Other mines	2,000	2,032	2,951	3,000
Italy	2,000	2.032	2,460	2,500
Japan	18,000	18,288	18,000	18.288
Mexico—				
Boleo	6,313	6,415	7,979	8,107
Other mines	1,480	1,500	1,480	1,500
Newfoundland	2,400	2,439	2,000	2,032
Norway	1,410	1,433	1,740	1,768
Russia	5,000	5,080	4,920	5,000
Spain and Portugal—				
Rio Tinto	30,200	30,684	31,000	31,499
Tharsis	10,800	10,970	11,000	11,177
Mason & Barry	4,400	4,470	4,400	4,470
Sevilla	1,000	1,016	1,010	1,026
Other mines	7,700	7,824	6,500	6,605
Sweden	733	745	750	762
United States	145,170	147,491	144,011	146,330
Venezuela	3,065	3,114	2,861	2,907
All other countries	490	498	620	630
Totals	300,595	303,321	302,021	306.880

Mexico.—The Boleo, the only large producer in Mexico, continues to increase its output, though the conditions under which it works, the character of the deposit and the grade of the ore do not encourage the expectation that it will ever become a producer of the first rank. The output of this mine from its opening is given in the following table:

PRODUCTION OF THE BOLEO. (IN METRIC TONS.)

	Mineral	Black Copper.	Matte.	Fine Copper.	Yield. %		Mineral	Black Copper.	Matte.	Fine Copper.	Yield. %
1886..	10.042	49.371	192.180	196.267	6.11	1890..	61.720	926.316	4,292.541	3,500.039	5.68
1887..	36.317	554.028	1,902.379	1,821.769	4.98	1891..	75.106	1,194.918	4,484.886	4,175.821	5.56
1888..	44.180	760.940	3,017.788	2,595.816	5.87	1892..	92,513	2,113,000	7,009,000	6,415,000	6.03
1889..	57.207	1,216.328	3,549.724	3,332.744	5.86						
						Total	376,725	6,805,801	24,448,458	22,037,456	

There are a number of very promising copper deposits in Mexico, but the lack of railroads, and in some districts the high price of fuel, render them unavailable at present. The output of small mines, and of copper in silver-lead ores is increasing. The imports from Mexico into the United States in 1893 amounted to no less than 2,350,000 lbs., of which 386,300 lbs. was in ore, and 1,863,700 lbs. in the form of pigs, bars and old. As some copper was also exported to Europe, and a little was used in Mexico, it is safe to assume the Mexican production outside of the Boleo mine as amounting to 3,306,900 lbs., or 1500 metric tons, and this output may be expected to increase from year to year.


WORLDS PRODUCTION OF COPPER,
INCLUDING CONSUMPTION OF COPPER
IN THE UNITED STATES
150,000 METRIC TONS
1 METRIC TON = 2204.6 LBS.
140,000 METRIC TONS
130,000 METRIC TONS
120,000 METRIC TONS
110,000 METRIC TONS
100,000 METRIC TONS
90,000 METRIC TONS
80,000 METRIC TONS
70,000 METRIC TONS
60,000 METRIC TONS
50,000 METRIC TONS
40,000 METRIC TONS
30,000 METRIC TONS
20,000 METRIC TONS
10,000 METRIC TONS
UNITED STATES (PRODUCTION)
UNITED STATES (CONSUMPTION)
SPAIN (PRODUCTION)
CHILI (PRODUCTION)
GERMANY (PRODUCTION)
JAPAN (PRODUCTION)
AUSTRALIA (PRODUCTION)
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893

The accompanying diagram shows with what marvelous steps the United States has distanced all other countries as a copper producer. This pace, however, cannot be maintained, and while the output in the future will doubtless exceed that in the past, the rate of increase will decline, while that of some other countries, such as Japan, Mexico, and Russia, may be expected to increase. The condition of the labor market and the want of railroads in Australasia must for some years yet keep back the stream of copper which will eventually flow from that country of great possibilities, peopled with an enterprising and industrious race.

Spain with its magnificent deposits will continue to be a large producer; but the feverish energy which in the United States shows itself in enormous production of nearly everything is lacking in the older country, as is plainly apparent in this diagram of copper production.

Chile has for a number of years fallen off in its output of copper, partly because many of its mines have exhausted their rich and easily reduced surface ores, partly because of the high cost of fuel and other supplies, and partly because it possesses no home industries using copper and now has to share the European markets with the surplus American metal produced at a less cost than is copper anywhere else in the world.

While it is true that the great copper mines of the world are working deposits which have been known for years, it must not be supposed, because these mines are necessarily becoming deeper and more difficult to work and some of them are approaching exhaustion, that the world's annual output will hereafter be curtailed, or that the price of copper will permanently advance. The vast improvements which have been made in copper metallurgy in late years, and which are well illustrated in the technical processes described in another part of this volume, have more than offset the increasing difficulties which nature has imposed, and the costs of producing, and with them the market value of the metal, have declined. The tendency with this useful metal, as with iron and steel, is steadily downward in price and upward in consumption.

The American Copper Market in 1893.

In the beginning of the year it could hardly be foreseen that this report, made at the close of the twelve months, would have to chronicle such gloomy happenings as have been witnessed by the trade for months past. Of course, in the main the trouble with copper was consequent upon the convulsions which have stirred up the entire business community of the country. What caused these disturbances it is difficult to say with exactness, but we believe that the great expansion of business during the last few years contributed not a little, as it became possible through the granting of credits right and left, which were withdrawn as the money markets gradually became tighter and tighter and people were mostly thrown upon their own resources. These being so tied up as not to be readily available for such an emergency, things soon came to a standstill.

Throughout the whole year the position of copper itself was good, and to-day, at the close of the year, it is perhaps better than at any time for a great many years past. If prices still remain at a low level it is because all of the panicky feeling has not been dissipated, and that, therefore, home manufacturers are not yet able to take in the quantities of raw material they would take under ordinary circumstances and in normal times.

The copper-wire business, which has always required a vast amount of raw material, especially since the electrical railroad transmission of power has assumed such large proportions, was the first to contract because of the financial stringency, as that, in some cases, stopped construction work upon railroads already in course of building and prevented the starting of work upon others which had been projected. The consequent lessened demand upon the copper material manufacturers, both for wire and for other products, not only prevented their entering into new engagements for supplies of raw material, but obliged some of them to go into the market to resell what had already been contracted for. This hastened the decline, which would have assumed larger proportions had it not been that as prices gradually fell here people abroad began to take an interest in the matter and to buy, the support thus given being the salvation of the miners and smelters, who otherwise, with very few exceptions, would have had to close down. Fortunately this demand from abroad enabled the producers here, in spite of the fact that prices were lower than ever before, not only to maintain the usual rate of production, but to increase it, mainly through some of the great producers enlarging their output in order to reduce cost of production, while some of the smaller ones, who for several years had been struggling hard to make both ends meet, were compelled to close down altogether. The manufacturers, however, did not fare so well, as some of the oldest and most reliable concerns had to suspend and others were seriously crippled.

Early in the year the demand for raw material for consumption at home began to lessen, but no apprehension was felt that the falling off would be more than temporary, and some of the larger producers preferred to accumulate stocks rather than decrease production, expecting soon to realize for their holdings at least the average of the prices ruling during the last few years. But as the decline in price became more and more marked, and the demand from home manufacturers gradually ceased almost wholly, at the time when the money market was becoming so stringent as to make it utterly impossible to contract loans, the producing companies were forced to look to Europe for buyers who had cash with which to pay for what they bought and thus supply the companies with the funds necessary to meet pay rolls, etc. The quantities sold for export can be best judged by the shipments from the different ports to Europe.

EXPORT OF COPPER DURING 1893.

Month.	Long Tons.	Month.	Long Tons.	Month.	Long Tons.	Month.	Long Tons.
January	3,171	April	3,450	July	7,181	October.	11,473
February	1,815	May	4,482	August	9,127	November	7,821
March.	2,334	June	5,109	September	16,131	December.	8,293

The total shipments for the year, 80,387 long tons, as shown in the above table, can only be termed enormous. The exports in the year 1892, from all ports, amounted to but 40,385 long tons.

It was thought, at first, that these heavy purchases must be for speculative account and not for consumption, but this, after careful investigation, we must say was not wholly, perhaps not largely, the case. A vast amount was used for filling Government orders, those given out by Germany, Russia, and France being particularly heavy. Besides, there was the coal strike in England, greatly interfering with the production of fine copper, and naturally increasing the demand for American fine copper.

Early in January the price for Lake copper was $12\frac{1}{4}$c., for casting $11\frac{1}{2}$c., and for Arizona pig $10\frac{1}{4}$@$10\frac{3}{8}$c., while at the same time Lake copper was offered in Europe at £56, c., i., f. at Continental ports, or slightly less than the figure ruling here. There were but slight fluctuations from these figures until toward the end of February, when a decline of about $\frac{1}{4}$c. per lb. occurred. Up to that time all the different Montana companies had been free shippers of copper matte to Europe, but the completion of their electrolytic works enabled them to retain the furnace material and themselves make it into fine copper, bringing very near the time when little, if any, furnace material will be sent abroad, while large quantities of fine copper will continue to be shipped out. For such an accomplishment the home manufacturers are deserving of high praise, especially as their product of electrolytic copper is conceded to be fully up to the best standard abroad, where such copper is readily taken—in fact, much more readily than here, where there has always been more or less of a prejudice in favor of the Lake Superior product, a preference which, however, is gradually disappearing.

It was toward the end of March that the money markets began to grow unusually stiff, and the values of securities at once becoming lower, there was an immediate decline in the values of copper, Lake receding first to $11\frac{7}{8}$c., then to $11\frac{3}{4}$c., and then to $11\frac{1}{2}$c., with casting copper selling at $10\frac{1}{2}$c., and Arizona pig down to $9\frac{3}{4}$c. Even these low figures could not tempt consumers, until a large sale, of about 10,000,000 lbs., was made by the Calumet and Hecla Company in April at 11c. The lowering of the price of Lake brought down that for electrolytic to $10\frac{3}{4}$c., and for casting to $10\frac{1}{2}$@$10\frac{3}{8}$c. Of course this large transaction affected the markets abroad, whence orders were already coming for American copper, attention having been attracted by the low prices ruling here.

Next in sequence came the negotiations for a continuation in force, beyond June 30, of the agreement to restrict production, which, it must be said, had worked very well. The matter fell through, however, and consequently the agreement, which had existed for a year, terminated with the end of June, but not before it had become known that a very considerable amount had been quietly marketed by some of our dealers.

The opening of navigation on the lakes was delayed by the long-continued winter weather until about the middle of June, but when traffic was finally resumed the price for Lake copper quickly declined to about 10¾@10½c., and the producing companies appeared as free sellers. Then came the crisis of the summer's financial troubles, with its attendant failures of some and the inability of other consumers to take what they had contracted for, bringing things to a standstill so far as trade in copper at home was concerned. The decline in prices, however, was not stopped until large sales were made for export in Lake copper, netting 9¼@9⅜c. at New York, and even less for electrolytic copper. These sales greatly relieved holders here, and the turning point had arrived.

AVERAGE PRICE PER POUND OF LAKE COPPER AT NEW YORK.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Year.
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1860..	23¾	23⅞	23⅝	23¾	22⅞	22⅛	21⅝	21½	21⅝	21¾	20⅞	20	22¼
1861..	19½	19¼	19½	19⅝	19½	18½	17¾	18⅜	19⅝	20⅛	21⅝	24¾	19⅛
1862..	27½	26½	24	22¼	21⅛	21⅞	23½	24¼	25⅝	29⅞	31⅝	31	25¾
1863..	33	36	34	30½	30¼	30¼	30½	30	31⅝	33⅜	36¾	38⅝	32⅞
1864..	40⅛	41⅝	42	43¼	43½	46½	59¾	51¼	50	47½	48	49¼	46¼
1865..	48¼	45	39¼	34½	32	29½	29⅛	31⅛	31⅞	32½	39⅛	42⅜	36¼
1866..	40	36¾	32½	29¼	29⅞	32½	32¼	30⅝	31⅛	30⅞	28¾	27¾	31¾
1867..	28⅛	27½	25¾	24	24⅛	24¼	25	26	26¾	24¾	22⅞	22⅝	25⅛
1868..	22½	23¼	23½	23¾	24⅛	23⅝	23¾	24⅛	23⅞	23½	23¼	24⅛	23⅝
1869..	25	26½	25⅜	23⅝	24	22⅞	22	22½	22½	22⅜	22¼	21¾	23⅜
1870..	21⅜	20⅞	19¾	19⅛	19	19¾	20⅜	20½	21⅛	21¾	22¼	22¼	20⅝
1871..	22⅛	21⅞	21½	21½	21¼	21⅜	22⅛	22¾	23⅜	23½	24⅛	26⅛	22⅝
1872..	27¾	28⅜	33	41¼	36½	33½	33¼	33½	33⅛	32⅛	31⅜	32¼	33
1873..	34¼	34⅝	34¼	33¼	31⅛	29¼	27¾	27⅛	26	23¼	22⅛	24¼	29
1874..	24¾	24⅝	24⅜	24⅞	24¾	24⅝	21⅞	20	21⅛	21¾	2 ¾	23¼	23¼
1875..	22¼	22¼	21½	21⅛	21½	22¾	22¾	23	23¼	23⅛	23	23⅜	22½
1876..	23⅛	22⅝	22	22	21⅞	20	19¾	19	20	20¾	20¼	19¾	21
1877..	19¼	19¼	19¼	19⅜	19⅛	19⅛	19	18½	18	17⅞	17⅝	17⅝	18⅝
1878..	17½	17¼	17	16⅞	16½	16¼	16⅛	16⅛	16	15¾	15⅝	15⅞	16½
1879..	15¾	15½	15¾	15⅞	16	16⅛	16	16⅛	16½	19½	21½	21¼	17⅛
1880..	23	24⅛	23¼	21¾	19	18⅛	18½	19	18¾	18¾	18¾	19	20⅛
1881..	19¼	19¼	19⅛	18⅞	18½	17	16¼	16⅜	17½	18⅛	18⅛	19¾	18⅛
1882..	20¼	19½	19	18⅞	18⅛	18⅛	18⅛	18⅛	18⅛	18⅛	18	18	18½
1883..	18	17¾	17¼	15⅞	15⅞	15½	15	15	15⅛	15⅛	15	14⅞	15⅞
1884..	14⅞	14⅞	14⅞	14½	14¼	14⅛	14	13⅞	13⅛	13	12¾	11⅝	13⅞
1885..	11¼	11⅛	10⅞	11	11½	11⅜	11⅛	11⅛	11⅛	11	11	11¼	11⅛
1886..	11⅜	11⅜	11⅜	11⅜	10¼	10	10	10	10½	11¾	12	12	11
1887..	11⅝	11	10½	10¼	10	10	10⅜	10½	10½	10½	12⅝	17	11¼
1888..	16¼	16⅜	16⅛	16⅝	16⅜	16½	16¾	16¾	17¼	16½	16½	16½	16⅔
1889..	17¼	16⅞	16¼	16½	12¾	12	12	12	11	11	12⅝	14⅜	13¾
1890..	14⅘	14⅓	14½	14⅖	15⅛	16	16⅘	15⅖	17	16 9/10	16⅘	15 9/10	15¾
1891..	14¾	14½	14	13¾	13⅕	13	13	12⅕	12⅛	12¼	11	10⅝	12⅞
1892..	11	10⅝	10⅜	11½	11⅝	11⅞	11⅛	11⅛	11⅛	11⅛	11⅞	12⅜	11½
1893..	12⅛	12	11⅞	11⅜	11	11	10⅞	10	9⅞	9¾	10	10¼	10¾

During the month of August prices to the home trade were practically 9¾c. for Lake, 9⅜@9¼c. for electrolytic, and 9c. for casting, and during September and October trade continued very dull, the changes in values that occurred during that time having been insignificant. Then business in the East began to improve, but from the West no more encouraging reports came than had been received for some time previously. The Eastern manufacturers had so reduced their stocks during the summer, by filling the limited demand which came in to them and by refraining from taking in further supplies, that they were able to increase their hours, or to resume altogether with a smaller force of men, and this made it necessary for them to look about for supplies of raw material. Early in November the Calumet and Hecla made some rather large sales at 9½c. and up to 9¾c., at the same time selling 1000 tons for export, thereby cleaning themselves entirely out of metal. The market continued to grow firmer, and by the end of the month had advanced to 10c. Then orders for speculative as well as consumers' account were placed, and the price advanced to 10½c. for Lake, at which the demand lessened. Electrolytic copper did not improve as rapidly, continuing to rule at 9¾@9⅞c., with casting at about 9½c. The same state of affairs continued until the end of the month, the markets remaining dull and the already light demand slackening, as is usual with the approach of the holiday season. A few second-hand lots of Lake copper appeared in the market and were to be had at 10¼c., but they attracted no attention, and the close was lifeless.

Exports for this, the last month of the year, were as heavy as during the several preceding months.

During the whole year no new producers have started up, but, as already said, the output of electrolytic copper gradually and considerably increased.

THE LONDON COPPER MARKET IN 1893.

The year 1893 opened with the copper trade in a condition of suspended animation. Speculation was inactive, and the resumption of operations at the various works being very gradual and partial, there was no improvement in the demand for consumers' copper. The statistical position at the beginning of the year showed an increase of 2247 tons for the month of December, but this circumstance produced no effect on the market. January, however, showed a steady shrinkage of values, due partly to the prevailing slackness and partly to the talk of hidden stocks of copper in France,—pertaining to Syndicate times,—and to the expectation of a consequent large increase in the figures of supply. A third factor in the decline was the increase in arrivals of American copper against old contracts. The total decline in G. M. B. values from £46 15s., at which December closed, was little short of £2 per ton, the month closing at £45.

February opened with a rapid rally in G. M. B.'s to £46 2s. 6d. The incorporation (in the statistics for end of January) of the stocks,—some 3000 tons,—which had been removed from Havre to the interior of France at the time of the Syndicate crash, resulted in a much smaller increase than had been anticipated. The stimulus supplied by these favorable statistics was only transitory, and moderate sales in the ensuing week served to depress speculative values about 12s. 6d. per ton, at which reduction buyers were attracted, with the result that £45 12s. 6d. was paid by the close of the month. Consumption in England, Germany, and America during February was good, and there was a steady demand for fine sorts. The demand from other European countries (excepting for electrolytic copper) was indifferent, and India, too, bought very little, while the complaints of unremunerative prices for manufactured copper were worldwide. Fine sorts of copper were well maintained, and Best Selected was scarce at £49@£51. Furnace material was less acutely scarce than it had been, but it continued to realize good prices.

A point of interest at the close of the month was the reported sale, by the only outstanding large French holder of Syndicate stock, of all his holdings in England, amounting to about 12,000 tons out of his total of 17,000 tons. As to statistics for the month, these showed a net increase of 1087 tons.

In March there were considerable "bear" sales of G. M. B.'s, partly induced by the large sale of Syndicate stock just referred to, the result being that spot declined from £45 16s. 3d. on the 2d to £45 2s. 6d., a rally to £45 10s. being followed by a fall to £45 5s. The close was at £45 7s. 6d. The decline would, no doubt, have assumed larger proportions but for the support derived from the negotiations, now in progress, for a renewal of the agreement between producers in Europe and America for a further term from the end of June. The considerable decrease—viz., 1578 tons—in the mid-monthly statistics was scarcely heeded, owing to its negative character, due rather to small arrivals than to good deliveries. In furnace material some 5000 tons of Boston and Montana matte, argentiferous and ordinary, were sold at 9s. 1½d.@9s. 7½d. per unit for the copper contained. The Anaconda mine now resumed work, but it was announced that nothing would be shipped to Europe for three months. Altogether it appears certain that America will send to Europe less and less copper in the form of matte, the tendency being to convert increasingly large quantities into ingots, cakes, etc.

For refined copper a very steady demand continued, Best Selected being especially in request for British Government orders, the total of which up to the moment amounted to about 1400 tons. The average price for the month was about £49 15s. With India a fair business was done at 4¾d. for yellow metal squares and £52 12s. 6d. for copper braziers' sheets.

April opened dull, with speculation dormant, and left almost entirely to jobbing dealers. The position was such that no prominent operator had the pluck to "bear" the article, while general trade was not good enough to give it a lift. The market was depressed from £45 8s. 9d. to £44 12s. 6d. sharp cash, partly by rumors that the producers would probably not renew their arrangement. Speculation as to this point continued to affect the market until toward the close of May, when it was finally decided to allow the agreement to lapse at the end of June. Another factor adverse to the market was the distrust engendered by the condition of finance in Australia, and especially in America, where the disturbance of credit and the urgent need of converting everything possible into gold led producers to offer copper of all kinds freely, and they sought to market their heavy surplus stocks chiefly in Europe. Although there was some disposition on the part of consumers to avail themselves of the cheap prices resulting from the situation described, the more general result was to induce a hesitant and waiting policy, and consumers, in the main, continued to buy from hand to mouth.

The Continent reported an improvement in the brass trade, and here a good business took place in sulphate of copper, the second-hand stocks having been pretty well worked off and makers being sold out for near delivery. As to G. M. B.'s, a brief recovery to £44 17s. 6d. was followed by a fresh decline to £44 6s. 3d., and after touching £44 12s. 6d. the month closed at £44 10s. per ton. The continued scarceness of furnace material (mattes, etc.) led to purchases of Chile bars by smelters. The production in Chile was, however, much restricted by the difficulty of obtaining laborers.

During May the malign influences of the currency crisis in the United States and the numerous bank failures in Australia created a lack of confidence which was reflected in the fall of G. M. B.'s to £43, the lowest figure touched since February, 1892. A momentary clearing of the financial atmosphere and an improvement on the Stock Exchange was followed by a rally to £43 15s., but £42 16s. 3d. was reached before the month closed, the final refusal of the Americans to renew the arrangement with the European producers being the chief determining cause. In the market for consumption there was no fresh feature of importance. America's production and exports had remained during the term of the agreement well under the maximum quantities allowed, but they were very steadily on the increase now and were expected to augment in a more rapid ratio. Furnace material continued in request. In India sheets a largish business took place at £52. English Tough was obtainable at £46@£46 10s., Best Selected at £47 10s.@£48, "Strong" sheets at £54, and yellow metal squares at 4$\frac{11}{16}$d. These prices were, relatively to the G. M. B.'s values, disproportionately cheap. Prompt sulphate of copper was scarce at £16 f.o.b.

The copper market in June was largely dominated by the silver question. India resolving to close her mint to free coinage and at the same time setting a fixed value on the coined rupee, while America was entering on the struggle for the repeal of the Sherman purchasing act—silver passed through exceedingly wide variations, rising first to 38¾d. and then falling rapidly to 30d. by the end of June. Copper, more or less in harmony with these movements, first advanced £2, to £45 2s. 6d. about June 20, and then under the influence of steady selling, largely for American account, the market fell away to £43 2s. 6d. The volume of speculative business was on many days very large. On June 20, 2100 tons changed hands, the business consisting of covering "bear" sales and of speculative buying. This was the point when the highest value above named was reached. It was for a time hoped that the fixing of the rupee value would impart stability and lead to more active business with India, but these hopes were not realized to any noteworthy extent. Here the demand for fine sorts was of a hand-to-mouth character, consumers taking only small quantities, but prices stiffened nevertheless.* As to home trade in manufactured copper, the keen competition of French and German rollers for the meager orders obtainable was making itself much felt. In furnace material good prices were realized, up to 9s. 6d. being paid for argentiferous Montana matte, but the drop in silver meant a serious loss to producers of this form of copper, which forms, too, a very large proportion of the total production of copper. From Chile about 500 tons bars were sold at £45, three months, and £45 2s. 6d., four months.

In July the disorganization of American finance (which led to the flooding of Europe with cheap offers of copper) and the serious losses on Stock Exchanges (which completely damped any speculative ardor) were salient features, and the still unsettled state of the silver market was a third depressing factor. G. M. B.'s under such conditions experienced a further sharp decline from £43 12s. 6d. to £42 6s. 3d., the lowest point touched for about four years. In England consumption was proceeding at a fair rate, but demand was not brisk, and labor was just beginning to suffer under what proved to be very grave and protracted coal strikes. Such inquiry as existed was readily filled by cheap American copper, that country seeking to realize as much as possible.

Apart from the financial crisis, there were points in favor of copper, such as the very good statistical position and the lowness of prices. India bought rather more freely, both of refined copper and yellow metal. Good casting and tough copper was notably scarce, one of the largest works being closed for repairs and some others being practically out of the market. The complete figures of the working of the combination between American and European producers for the twelve months to June 30 show that the total production and American exports were kept considerably under the authorized maximum limits, although during May and June the rate was in excess of the proportionate monthly quantity; for example, the fine shipments from America were 5107 tons, or at the rate of 61,284 tons, as against 40,000, the maximum annual quantity allowed. The following is a summary of the year's working: Actual European production for the twelve

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* In sympathy with the G.M.B. advance, and owing to the scarcity of fine sorts, many of the makers of which were out of the market, B.S. rose to 15s., and Lake to 11c.

months, 80,712 tons, against 85,019 tons, the maximum allowed; actual American production (including that from pyrites), 134,465 tons, against 139,726 tons, the maximum allowed; actual American exports, 37,158 tons, against 40,000 tons, the maximum allowed.

The speculative market in August developed, during the greater part of the month, no striking amount of activity, and under the incubus of the continued financial stringency in the United States and the continued flow of American copper into this country values experienced a further heavy fall, viz., from £42 1s. 3d. to £40 12s. 6d.—the lowest for some years past. After a few intervening fluctuations between that figure and £41 15s., it closed at £41 12s. 6d. The improvement just noted, which came at the end of the month, was due mainly to the passing by the United States House of Representatives of the repeal of the Sherman act, it being argued that the confidence which this would inspire should favorably affect trade and finance in that country and check its heavy exports of copper to Europe. Also, notwithstanding these heavy shipments, statistics showed the—under the circumstances—astonishing decrease of about 2000 tons for August, a striking proof of the very large deliveries to consumers. In connection with American production two further points of interest may be noted, viz., the closing down of the Parrott mine, and the reduction of the Anaconda output. This, taken in conjunction with the heavy sales already made by America, pointed to the probabilty of much smaller quantities coming from that source in the near future. The very low prices at which a great part of the American sales had been made are supposed to have barely covered the cost of production. In furnace material 8s. 4½d. was paid for Montana matte, 8s. 6d. for argentiferous ditto and Anaconda, and 8s. 3d. for a parcel (about 800 tons) of Montana matte, forming a remnant of old Syndicate stock in New York.

September opened with a combination of the upward movement in G. M. B.'s, aided by the growing firmness in America, and sharp cash touched £42 15s. in the first week, rising further—after an intervening relapse to £42 7s. 6d.—to £43 12s. 6d. on the 12th of the month. In the third week the price fell to £42 8s. 9d., and in the last week to £41 15s., recovering finally to £42 1s. 3d. The margin between spot and forward, owing to the scarcity of the former position, was lower this month than for a long time past, the contango dwindling at one time to 6s. 3d. per ton.

American shipments for all September were very heavy; viz., about 15,400 tons, as against 9127 tons in August and 7181 tons in July, or a total for the three months named of 31,708 tons, compared with 10,000 tons, the maximum allowed under the expired agreement. These figures need no comment. As to offers and sales these had already much diminished in importance. A report spread at this time by rumor-mongers to the effect that the Calumet and Hecla Company was going to curtail or stop its production received eloquent disproof in the announcement of a dividend at the rate of 20% per share by that company.

The improvement in copper was checked by the delay on the part of the Senate in confirming the repeal of the silver bill. In England consumption remained fair, but users were already well supplied, and the pressure of copper in second hands tended to affect prices adversely. In sulphate of copper, however, a good business was done this month, while top prices were being realized for furnace material. For example, 9s. per unit was paid for about 1500 tons argentiferous copper matte (Montana).

October in this country was a month of bad trade, the coal strike hampering manufacture to a great extent and preventing railway and other companies from giving out specifications. Although consumption was proceeding on a fairly good scale, the demand was poor, and the manufacturing branches yielded little or no profit. Arrivals and deliveries continued at an abnormally heavy rate; but the published figures, it should be remembered, necessarily treat as deliveries all arrivals in ports (outside of England and France) whence accurate warehouse returns are unobtainable, and there is no doubt that a good deal of copper, thus treated as deliveries, had been put into store. A large proportion of the heavy American exports, and especially of electrolytic copper, was taken by Germany, where this sort was in active demand in connection with the much-extended use of copper wires for telegraphs, and also as a substitute for Best Selected copper. The repeal of the Sherman act, when it came, produced at first none of the beneficial effects expected here, these having been largely discounted by operators, while in the United States their development was also not immediately patent—the disorganization of trade and finance being only gradually replaced by a brighter and more normal state of things. The fall in silver which ensued directly upon the repeal caused depression in the London speculative market, and G. M. B.'s, after opening at £41 18s. 9d., declined to £41 11s. 3d., but rallied toward the close and advanced to £42 10s.

November opened at £42 6s. 3d., and fluctuated during the first fortnight between £42 2s. 6d. and £42 10s. Conditions in America showed more improvement, and although fair quantities of copper—chiefly electrolytic—were still offered, the general tendency was to offer less and less and at gradually rising prices. A striking sign of the turn things had taken was furnished by the actual repurchase by America of Lake copper and matte sold for shipment to Europe.

At home the most prominent event was the settlement of the coal strike, but here again the growth of demand was laborious and slow, the effects of such a protracted coal famine (with the resulting disturbance of multifarious branches of industry) not being so easily effaced. Consumers, too, for the most part, were well stocked with copper bought at the low prices ruling during the American crisis, while the presence in dealers' hands of considerable remnants of such cheap purchases tended to check the advance in prices of fine sorts. From India, too, the demand for both copper and yellow metal was very deficient.

As to G. M. B. values from £42 10s., there came first a relapse to £42 3s., and then a rise to £43 6s. 3d. on the 1st inst. The statistical figures for the second half of November, showing a decrease of over 1000 tons, had a good effect, and with a little more speculative activity we had an advance in the first week of this month to £43 16s. 3d. We closed to-day (Dec. 12) at £43 11s. 3d. spot and £44 1s. 3d. three months G. M. B.'s. Tough qualities of copper are quoted at £46 5s.@£46 15s., Best Selected qualities £47@£47 10s., India sheets £51@£51 10s., and yellow metal squares at £4 9s. 16d.

The Board of Trade returns are as follows:

Year.	Copper.	
	Imports.	Exports.
1891	138,990	76,055
1892	134,808	82,540
1893	132,648	70,983

PRICES OF CHILE BARS IN POUNDS STERLING PER TON OF 2240 LBS.

Year.	Stocks, Tons.	Jan. £	Feb. £	Mar. £	April £	May. £	June. £	July. £	Aug. £	Sept. £	Oct. £	Nov. £	Dec. £	Year. £
1866	29,388	95	93	88	86	80	83	79	74	83	80	75	72½	82⅞
1867	32,084	70	76	74	71	71	73	70½	68	73½	68½	68	69½	71⅜
1868	33,500	67	69½	71	73½	77½	77	75	68½	68	67	69	69	71
1869	41,921	73¾	73¾	72½	71	70½	68	67½	68	68½	67½	67½	66¾	69½
1870	43,365	66½	66¾	66¼	65¾	67¾	67¼	68½	63½	63½	63½	62½	62¾	65⅜
1871	40,092	64½	63½	66¼	64¾	65¼	67¼	68¼	68¾	67½	68½	68	76	67⅛
1872	36,497	86¾	85	83½	99¾	101	107½	103	102	91	83½	86	84¼	92⅞
1873	41,082	91	87½	85	91	88½	84½	80½	81½	84½	83	83½	83½	85¼
1874	36,868	83½	81½	77	75	74	74	78	76	77½	80	83½	83½	78⅛
1875	36,316	84	83	82	80	83	83	82	79	82½	82½	82	87½	82½
1876	36,962	81½	81	76½	77½	79½	77½	74½	72½	71¾	72¼	76½	81	76½
1877	42,313	76½	73	71½	70½	68¾	69	69	69	67½	65½	65½	76½	70¼
1878	48,399	65¾	65¾	63	63	62	64½	64	61½	61¼	60	57½	63½	62⅞
1879	57,837	58	56	54¾	56	56	55	56	53¼	54¼	58¾	66	58½	58⅞
1880	62,855	65¾	73¼	70¾	65½	60	56¼	60	61	61½	61¼	61	66½	63½
1881	58,149	61¾	62	61	61	59	59	58½	59	59	62¼	63¼	67	61⅛
1882	49,696	71	64	64	64¼	63¼	63½	67	68½	67¾	71	69	66¼	67
1883	49,878	65	65	65	64¾	62⅞	63¾	64	63⅝	64	63	61¼	59½	63½
1884	45,880	56½	55⅜	53⅞	56½	56	54⅛	55	53⅞	54⅛	52⅝	51¼	47¼	53⅞
1885	55,939	48¾	47⅝	46¼	44½	44⅝	44⅞	44¼	43¼	41⅞	39⅞	41⅛	41⅜	44
1886	61,741	40¼	40¼	42⅜	41¾	40½	39⅞	39⅜	39½	40¼	41½	40⅝	39¼	40½
1887	42,301	38⅞	39⅜	39½	39⅜	39¼	40	40	40⅛	39¾	44¼	66¾	75¾	45¼
1888	104,105	85	77⅛	78⅞	80⅛	80⅛	80¾	81	80½	89	100	78¼	77½	82⅜
1889	98,847	77½	77½	78	39¼	37¾	41	41½	42	43½	43	44⅛	50⅛	51¼
1890	65,636	48⅞	47	47½	49⅛	54½	58½	57	60¼	59½	58½	55½	53½	54⅛
1891	57,420	52½	52½	52⅜	52½	52⅛	53¾	54	52⅜	52½	49¼	45¼	45¼	51⅜
1892	55,462	44⅝	44¼	46¼	45⅝	46⅜	44⅞	44⅞	44⅜	44⅛	45⅝	47⅞	46⅞	45⅛
1893	....	46⅛	45¾	45⅝	45	43¾	44	43	41½	42⅝	42⅛	42⅝	43¼	43¾

AVERAGE YEARLY PRICE OF COPPER IN GERMANY.*

(Prices in marks per 100 kilos; one mark = 23.8 cents.)

Year.	Berlin.		Frankfort-o-R. German Double Refined in Plates and Ingots.	Hamburg, English Ingots, Bars. Mark, T C T.	Year.	Berlin.		Frankfort-o-M. German Double Refined in Plates and Ingots.	Hamburg. English Ingots Bars, Mark T C T.
	Mansfeld.	Foreign, A1, Mark Beede.				Mansfeld.	Foreign, A1, Mark Beede.		
1879	133.42	....	126.75	134.07	1887	......	....	94.08	92.89
1880	149.08	....	135.06	140.79	1888	160.05	....	154.21	157.00
1881	140.58	....	131.90	136.43	1889	118.50	....	110.92	115.44
1882	146.81	....	140.50	150.24	1890	129.75	119.67	121.33	122.31
1883	141.27	....	135.17	140.69	1891	119.50	111.56	111.54	116.02
1884	125.58	....	119.13	126.09	1892	107.35	99.42	97.92	100.54
1885	106.46	....	95.29	97.55	1893	101.58	96.33	95.04	97.52
1886	93.41	....	86.40	88.13					

* From *Vierteljahrshefte zur Statistik des Deutschen Reiches*, 1894, Vol. I.

IMPROVEMENTS IN THE METALLURGY OF COPPER.

BY EDWARD D. PETERS, JR.

DURING the past year the improvements in copper metallurgy consist in a series of small economies, and in the perfecting of furnaces and apparatus rather than in any radical innovations or new processes.

Heap Roasting of Ores.—I have often taken occasion to point out the paramount influence that this apparently rude and simple process exercises on the whole series of metallurgical operations that follow it. There is no preliminary operation in the metallurgy of copper that so richly repays a moderate expenditure of time and skill. The most perfect heap roasting practiced to-day is doubtless that at the Rio Tinto mine in Spain. The ore contains about seven per cent. copper, being the richer pyrites, sorted out by hand from the ore shipped for the manufacture of sulphur acid. The amount of fuel used to kindle the heap is almost infinitesimal, only a few light sticks being disposed around the edges of the heap and in small arches extending only three or four feet into it. These arches are built of the larger lumps of pyrites, up to the size of a man's head. The heaps are generally cone-shaped, 33 feet in diameter, and contain 400 tons of ore. Only two-thirds of a cord of wood is used for the entire heap, and this, as a rule, is bestowed equally in the twelve little radial fireplaces. Another remarkable feature of the roasting is the length of time covered by the operation, nine to twelve months being generally allowed for a 400-ton pile. The heap is well covered with fines from the start, and is carefully watched by an experienced man, who thoroughly understands how to keep the internal combustion down to the very lowest point compatible with its existence, as well as to draw the fire from one portion of the heap to another, as may seem best.

The result of this roasting is invariably so perfect as to rouse the enthusiasm of the most experienced. All of the large lumps are oxidized to their very centers, and every piece of ore in the heap presents the fissured, earthy appearance of a perfect roast. Minute kernels are found in the center of a few lumps, where the heat may have been a trifle too high, but these do not furnish sulphur enough for the remainder of the heap, and raw ore has to be added to the smelting charge. It does not follow that such slow and perfect roasting would be universally suited to American conditions, though there are but few cases where the advantages gained by the improved desulphurization would not outweigh the loss of interest on the large stocks of ore and the costly roast yard. But there can be no question that there is scarcely a heap-roasting plant in the world that would not be greatly benefited by doubling the care and supervision allotted to it, and by halving the wood used to kindle it and the temperature at which the operation is conducted.

With massive, free-burning pyrites—and it is of such only that I am speaking—one cord of wood to 500 tons of ore is ample, and in a reasonable climate the heap should be roasted to the very surface layer of fines. It is also a mistake to open a roast heap a day before everything is ready for its rapid removal and consumption ; for the moisture of the air at once causes the sulphates that exist throughout the roasted ore to become hydrated and to fall into powder, rendering the ore unfit for blast-furnace work, and much more liable to mechanical and chemical losses.

The Calcination of Fine Ore in Furnaces.—For some years past there have been constant and decided improvements in calcining furnaces of all classes, but especially in those that work mechanically. The most important mechanical calciners, so far as the treatment of copper ores or products is concerned, fall naturally into two classes : (*a*) Revolving Cylinders. (*b*) Stationary Furnaces, the ore being moved by mechanical stirrers.

(*a*) *Revolving Cylinders.*—The Brückner cylinder is being still enlarged, while decided improvements have been made in the means for saving the flue dust in the automatic transportation of the fresh ore to the hoppers of the cylinder, and, above all, in the method of transporting the enormous bulk of the red-hot calcined charge to its proper destination.

The Douglas cylinder, with internal flue for the passage of the products of combustion, has been perfected, and has done excellent work during the year. It is not only peculiarly adapted for the delicate calcination required for certain chemical processes, but is also an excellent apparatus for furnishing a strong and pure sulphurous acid gas from any suitable kind of pulverized sulphides. Its construction is very strong, its capacity quite astonishing, and the rate of calcination and of the development of gas is under entire control, and by the most simple means.

At the Cape Copper Company's works, in Wales, I have lately had the pleasure of seeing extremely economical and satisfactory calcining. The furnace used was a simple revolving cylinder, 7 ft. in diameter, 60 ft. long, and having five and a half inches' fall in the total. It made eight revolutions per hour, thoroughly calcining ten long tons of white metal each twenty-four hours, requiring only 2000 lbs. of coal for the ore and 1000 lbs. for the motive power. This white metal averaged about 76% copper, and was reported to be calcined down to 1% of sulphur, or practically "sweet." With proper appliances for conveying the matte to and from the furnace, the cylinder required only about one-fourth of a common laborer's time to fire it and remove the ashes, and the attendance of a small lad to watch and oil the machinery and see that the automatic feeding went on properly. This feeding arrangement was extremely simple, yet entirely efficacious. The matte, crushed through a screen with three meshes to the linear inch, was conveyed into an iron hopper at the rear end of the cylinder, whence it flowed by its own gravity into the furnace, in a constant thin stream, through a small rectangular slit in the floor of the hopper, which, though only two and a quarter inches by half an inch in size, fed the matte at the rate of 10 tons per day and without blocking up. After a somewhat extended experience in such matters, I was forced to consider this the cheapest and most satisfactory calcining that I had ever seen. The cost per ton of matte for this operation, taken from the experience of several years, and allowing for repairs and for interest on investment, was 37c. per ton of 2240 lbs. Coal and labor were both cheap ; yet even reduced to American prices, the figures would be below anything I know of in the United States.

(*b*) *Stationary Calciners, with Mechanical Stirrers.*—The past year has seen great improvements in the O'Hara calciner. This furnace has always been a favorite with certain of the Montana smelters, and although some trouble and expense were at first experienced in replacing the plows that were rapidly burned out, these matters are said to have been remedied, and all weak parts so strengthened that repairs are few and inexpensive, and a very high degree of economy has been attained by its use. It certainly ranks among the most important of the mechanical calciners of the day.

The new Pearce turret furnace is probably the most important addition lately made to the long list of mechanical calciners. Mr. Pearce's standing as a metallurgist is a sufficient guarantee that the new furnace has great merits. It yet remains to be seen how it can compete with its predecessors in general practice. In a general way, it may be described as resembling an O'Hara calciner bent into a circle, but with a large gap at one part of the circle. The main point of difference is in the arrangement for the mechanical stirring, which is said to be remarkably cheap and effective and to require very few repairs. Mr. Pearce gives the cost of calcining in this furnace at Argo at from 60c. to 75c. per short ton of ore, as compared with the former expense of calcining in long hand furnaces, which cost about $1.75. He states that the cost of construction of the turret furnace is much less than that of the Brown-O'Hara.

It is as yet an undecided question, especially where the subsequent smelting is effected in blast furnaces, just how far it may be profitable to push the calcination of the ore. It is possible that under certain conditions, and where the ores contain a superfluity of bases, it may be more advantageous to employ a very rapid, cheap, and somewhat imperfect calcination, thus producing a large quantity of low-grade matte, high in sulphur, which forms an excellent material for rapid bessemerizing. One must not overlook the cheapening of the smelting process, where the charge contains considerable percentage of sulphur, and yields a large proportion of hot, low-grade matte, that keeps everything fluid and greatly quickens the process.

On the other hand, calcination is a much easier and more manageable process than bessemerizing can be, until great improvements and economies are effected in the refractory lining of the converter and in the means for removing and replacing the same. Consequently any improvement in calcining furnaces is at present a matter of vital importance to the metallurgy of copper.

Improvements in Blast Furnaces.—I am not aware that any very marked advance has been made during the year in blast furnaces. The water-jacketed cupola, with some form of settler or fore-hearth to receive and separate the molten substances as they flow from the furnace, is almost universal in America, as well as in other countries where American metallurgists are employed. It is exactly this immediate withdrawal of the molten products from the reducing action of the interior of the furnace, combined with the increased rapidity of fusion which a more powerful blast, a better calcination of the ore, and a more careful fluxing of the charge have enabled us to bring about, that has entirely done away with the production of the metallic iron "salamanders" that were formerly the bane of the blast-furnace smelter. With proper settling facilities and a good slag there should be no difficulty in bringing down to an almost infinitesimal figure the amount of copper mechanically lost. But there is often a greater loss in chemically-combined copper than is supposed by those interested, and during the past two years, and in widely separated hemispheres, this matter has been emphatically brought to my notice. Certain, even quite basic, blast-furnace slags are not entirely decomposed by acids, even after long and careful warming. In many cases it is necessary to dissolve the silica with hydrofluoric acid, or to fuse the slag with alkalies (in the manner usually adopted for refractory silicates), before one can be sure that all the copper present is in solution.

This treatment frequently adds two or three tenths of a per cent. to the amount of copper supposed to be carried by the slag, and sometimes accounts for the abnormally low slag assay reported by certain chemists.

The Cyanide Assay for Copper.—It would seem scarcely necessary to refer again to the inaccuracy of this very convenient test. But it is only a few months since I saw considerable sums of money spent and extensive plans based on the strength of results obtained by a long series of cyanide assays, executed by severa different chemists in good standing, including a responsible and highly trusted Government official, whose results so exactly confirmed those of the other chemists that no doubt was felt by the investors as to the soundness of the project. Fortunately a practical metallurgist was employed to examine the property, and he soon discovered that when treated by the cyanide method the average of the mine would yield returns exactly as stated by his predecessors, but that when properly assayed the actual percentage of copper was about half as much. The matter was thoroughly investigated by the disappointed owners, it being found that the considerable per cent. of zinc that all the ore contained had bleached the cyanide reagent enough to about double the actual results so far as copper was concerned.

Pyritic Smelting.—This is perhaps the most important matter connected with blast-furnace smelting that has of late come before the profession. There seems to be a certain misunderstanding in the minds of many persons interested in such matters as to exactly what is meant by pyritic smelting, many people confounding it with bessemerizing or with Bartlett's process. By pyritic smelting is understood the treatment of sulphide ores in a blast furnace or a similar apparatus in such manner that a considerable proportion of the heat produced by the oxidation of the sulphides is utilized in their fusion, by which means a considerable proportion of the ordinary carbonized fuel—or, in favorable cases, the whole of it—may be omitted, the sulphide ores thus practically smelting themselves, and often furnishing enough superfluous heat to admit of a considerable addition of non-sulphide ores.

This process, for many years the goal of copper smelters' ambition, occupies a kind of intermediate position between the two widely diverse operations of calcination and bessemerizing. It differs from calcination in that it goes further, its object being not merely to oxidize (burn off) the sulphur contents of the ore under treatment, but also to effect this combustion of the sulphur so rapidly as to produce a smelting heat at a certain point in the furnace, the work being conducted with such skill as to leave the lumps of ore above this point in a solid condition, their interstices offering a free passage to the blast, while below this line the fusion is as complete as though coke had been used to effect the result.

It differs from bessemerizing in several particulars, the most important one practically being that in bessemerizing the air blast is forced through a bath of liquid sulphides (matte), the blast being of sufficient strength to support the molten column above it, and thus prevent it entering the small tuyère holes through which the stream of air is supplied, while in pyritic smelting it is essential that the charge above the tuyères, which are placed above that portion of the furnace in which the molten products collect, shall not begin to soften sufficiently to impede the circulation of the blast, which has only the very moderate pressure commonly used in copper smelting.

Much credit is due to Mr. W. Austin for his laborious and extended experiments in connection with this process. He apparently has succeeded where so many of us have failed. He sets forth his ideas fully in his patent claims. Yet it is only proper to add that other competent men, notably Mr. Robert Sticht, who so satisfactorily ran the pyritic smelting works of the Boulder Smelting Company at Boulder, Mont., on the complicated and refractory ores of that district, do not entirely agree with Mr. Austin's views, claiming that no particular form of furnace is essential to the success of pyritic smelting, but that it may be satisfactorily carried out in any kind of blast furnace that would be suitable for smelting with ordinary fuel.

Absence from the United States has prevented me from forming an independent opinion on this important process, but Mr. Sticht has been kind enough to furnish me with a detailed account of the results obtained at Boulder. With the aid of his notes, and such results as had already been obtained at other works before I left America, I will try to give a brief sketch of the present state of this process, together with its outlook for the future.

The success attained by modern pyritic smelting is due mainly to a more correct understanding of the mechanical principles involved, and the consequent ability to conquer those mechanical difficulties which in all previous trials that I am aware of—and I have somewhat carefully investigated the history of the matter in England, Spain, Austria, Italy, and the United States—have prevented this exceedingly captivating idea from becoming a practical success. In a brief review like the present only a few main points can be touched upon, and as it is essential that practical readers should fully realize the difficulties and drawbacks of a new process, I will enumerate the most important.

(*a*) Mounting of the heat toward the top of furnace, causing softening of the charge, soon followed by the scaffolding, or sticking-up, of the furnace. This is perhaps the most constant and gravest of all difficulties that the pyritic smelter has to contend with. It may result from a variety of causes, among which the most common is too dense a charge, i. e., too much fine ore in the charge. The only remedy is to increase the proportion of coarse ore in the charge, by using the pyritous ore in lumps of 20 to 40 lbs. weight; to use a large proportion of slag in lump form; and, if conditions permit, to employ a considerable proportion of limestone in lumps of rather large size. Too low a pressure of blast is sure to make the top of the furnace hot. The remedy is obvious. Heating the blast by means of extraneous fuel to a temperature of at least 1000° F. has an excellent effect on this condition of things, and usually far more than repays the cost of running and maintaining the necessary stoves. A much less common cause of a hot furnace top is the presence of too much iron pyrites in the charge. As is well known to all persons familiar with the calcination of iron pyrites (bisulphide of iron FeS_2), one of the two atoms of sulphur of which it is composed separates very easily from the pyrites, volatilizing at a low red heat, and burning with a blue flickering flame if sufficient oxygen be present to support combustion. This is exactly what happens in the upper zone of the blast furnace. One atom of sulphur, if volatilized in a metallic form and melting with the heat, runs into all the interstices of the charge, sticking it all together like glue, and soon forming an impermeable crust, which, of course, quickly blocks up the furnace. For this reason, pyrrhotite, or matte, which contains only one atom of sulphur, or even less, makes the best material for pyritic smelting. Whether this difficulty can be overcome by a greater pressure and higher heating of the blast, without too much loss of the precious metals, or whether it will be necessary to volatilize a portion of the sulphur by some cheap, preliminary operation, only the future can decide.

(*b*) The presence of volatile sulphides, such as zincblende and galena, has a very bad influence on this process. Still, by care and close attention, mixtures are successfully smelted containing at least 15% or 20% of these obnoxious substances. Nor can I learn that the loss in precious metals is as much increased by their presence as one would suppose.

(*c*) A charge that is in too fine a condition mechanically. This point has been already considered under (*a*).

(*d*) Too high a furnace. For both mechanical and chemical reasons it is important that the height should be no greater than is necessary to keep the top reasonably cool when the furnace is running properly. If this rule be followed, the height will be found ample for all the reduction that is needed, as well as for the proper and economical utilization of the heat. It is impossible to lay down any fixed rule, as different conditions demand varying heights; but a height of charge of six to seven feet above the tuyères will usually be found ample, and may often be lessened with advantage.

The pattern of furnace. I cannot find that this point is of any considerable importance in pyritic smelting. The new process, in this respect, is governed by the same general laws as is the ordinary operation of copper smelting in blast furnaces. As the process is slower than ordinary smelting, a large area with plenty of blast pressure is the main requisite. And as the maximum approved width or diameter of a copper cupola has been found to be 36 to 40 in., it is evident that the required area must be gained by increasing the length of the furnace. The pyritic furnace at Boulder, Mont., is 36 by 96 in. at the tuyères, and is good to smelt 60 tons, or more, of average ore each twenty-four hours, in addition to a considerable proportion of slag and limestone.

The pyritic furnace at Kokomo, Colo., measures 33 by 140 in., and Mr. Sticht ran through it in twenty-four hours 81 tons of ore, besides 35 tons of slag and 25 tons of limestone, a total of 141 tons per day (all tons of 2000 lbs.). The object of this large proportion of slag is mainly to keep the charge pervious. The first pyritic smelter at Leadville, Colo., was 30 by 140 in., the two later ones being 36 by 160 in. in section at the tuyères. The smelting zone is always surrounded by water jackets, the height to which they are carried above this point depending upon a compromise between the cost of repairing the fire-brick walls and the loss of fuel by heat wasted on the water-cooled sides.

The arrangement of hearth and fore-hearth is about the same as in ordinary smelting, the main object being to get the molten products out of the furnace as fast as they are formed, and allow them to separate quietly in a spacious fore-hearth in front. This fore-hearth may be water-jacketed to advantage if the matte contains less than 30% of copper, and is tolerably abundant. On the other hand, if it contains less than the specified proportion of copper, and especially if the rate of concentration be high, so that the matte is small in quantity, a brick-lined fore-hearth backed with non-conducting material should be used, or the matte will chill in it too rapidly. The same remarks apply to a bronze water-cooled tapping ring.

The degree of concentration obtainable by this method depends upon very much the same conditions as in ordinary smelting. With cold blast, powerful reduction, high pressure, and rapid smelting the concentration will be low—only three or four into one where heavy sulphides are treated. On the other hand, the same ores may show a concentration of five or six into one with hot-blast, lower pressure, and larger tuyères and a slower run.

With a considerable proportion of dry ores, usually added that their gold and silver contents may be extracted and the matte thus enriched, the concentration may reach even twenty into one, though only under the most favorable and unusual circumstances. Any one who reaches thirteen to one (the average rate in the Argo reverberatory furnaces) may feel well satisfied with the result of his concentration, and this will be reached only in exceptional instances.

Losses of Precious Metals.—I am not at liberty to give a series of very interesting results from runs extending over a month or more. But I can at least say that while the losses in silver are perhaps a trifle greater than they would be in ordinary matte-smelting, I am inclined to think that when the method is perfected and the furnace run under the best possible conditions, the losses will be no greater than by the ordinary method. The loss of gold was practically nothing ; but as there are usually small amounts of unreckoned gold in certain of the ores or fluxes, it will require more careful experiments to settle this point.

Presence of Copper Essential to Success.—It must never be forgotten, when planning a new matte-smelting enterprise, that a pure iron matte (and a long experience teaches me this in spite of various claims to the contrary) does not form a satisfactory medium for the collection of the gold and silver in the charge. Good results can be obtained with a very low percentage of copper. I have had perfectly satisfactory results on rich ores, with one-half per cent. of copper in the ore and about five per cent. in the matte. But if, by any accident, my matte went down below one per cent. of copper, the losses of both silver and gold became very heavy. A small amount of lead in the matte may partly answer the same purpose, but not nearly so effectually as copper. If the latter metal be very scarce, I have noticed that the presence of a few per cent. of tellurium has a remarkable effect in assisting the small quantity of copper present to collect the precious metals and carry them into the matte. But in the case of an iron matte, absolutely free from copper, the addition of tellurium ores produced no perceptible effect. Although it is more satisfactory to have the copper distributed through the silver and gold ores themselves in a sulphureted condition, still, with care, perfectly good results can be expected from adding the copper in an oxidized condition in the shape of carbonate or oxide ores.

Hitherto it has been generally customary to add about two to two and one-half per cent. of coke to the charge in pyritic smelting, though in reality rather to assist in keeping the charge porous and hastening its descent than for the heat it may supply. With good sulphide ores in lump form I cannot believe that this practice will be found necessary, for a theoretical calculation of the heat probably available from a ton of moderately massive iron pyrites shows it to be far in excess of what can possibly be required to smelt it. And indeed it is a common practice in Montana to make the scarce sulphide ores carry a considerable burden of dry ores. As it is perfectly possible, and has no doubt been already practiced by many American copper smelters, to combine the pyritic with the ordinary smelting, and force the surplus of sulphur in the charge to take the place of a certain proportion of coke, it is evident that, at least to some degree, this process will be of importance in the future. The conditions for its perfect development are so uncommon that the principle is more likely to be useful by so utilizing the sulphur of the charge as to replace a certain portion of coke than by attempts to carry out the process in its entirety.

Utilization of Blast-furnace Slag for Generating Steam.—This has long been a tempting idea to metallurgists, and I have tried and seen numerous devices for the purpose, some of which possessed a certain amount of merit. But the only practical solution of the problem is a patented apparatus that I saw a few months ago at the Broken Hill Proprietary Company's smelter, at its mine in New South Wales. The works were under the management of Mr. H. H. Schlapp, a well-known American metallurgist. Though the configuration of the ground prevented the establishment of the new plant in the most economical manner, it was effective enough to show the large saving that might be made under more perfect conditions, and especially where the price of fuel is high. The generation of steam from blast-furnace slag by this method demands the installment of boilers penetrated from their upper to their lower surface by a series of large conical tubes, the greater diameter of the cone being at the bottom. Each of these tubes is provided with an iron mouthpiece or hopper, into which the molten slag from the blast furnaces is poured direct from the slag pots, the boilers being placed at such a level that the slag pots can be run over them without difficulty. Underneath the long axis of each boiler is a small railway, on which runs a car to receive the cooled and solidified slag cones that promptly drop from the tubes on opening a gate at the bottom. I do not feel at liberty to give results, but the inventors state openly that the heat contained in the slag of an ordinary silver-lead blast furnace may be thus utilized to supply all ordinary power required for said furnace, such as blast, elevation of material, pumping water for jackets, etc. Where the conditions are suitable for its employment, it is probable that this invention may be added to the long list of economies which modern science and skill have produced, and which, within less than a generation, have halved the cost of producing copper from sulphide ores.

Improvements in Reverberatory Smelting.—The past year has forcibly exhibited the modern tendency toward larger furnaces, mechanical handling of ore and slag, and general economizing of labor and fuel.

The "direct" refining process, patented by Messrs. T. D. Nicholls, Christopher James, and the Cape Copper Company, Limited, of Great Britain, seems to me the most important and interesting novelty of the year in this branch of metallurgy. By the kindness of the inventors I have been able to witness the process in its daily routine, over 20,000 tons of best selected copper having already been made by it.*

This method of refining is based on the interesting and important reactions that take place at an elevated temperature between copper oxide and copper sulphide, the sulphur and oxygen combining to form sulphurous-acid gas, while the copper is reduced to a metallic condition ($Cu_2S + 2Cu_2O = 6Cu + SO_2$). All the copper present is reduced to the metallic form, owing to the presence of the very slight amount of oxygen in the two atoms of suboxide of copper. Without this almost infinitesimal proportion of oxygen in chemical combination, the melting of the copper sulphide in the neutral atmosphere of an ordinary furnace would have no effect at all, the matte coming out with just as much sulphur as it went in.

At first glance it might seem that it would be impossible to promptly produce a good refined copper—and especially to keep itin pitch during the long operation of ladling—from so crude a substance as matte, assuming that our material for refining, instead of the customary blister copper, is a good white metal, containing from 73% to 75% copper. It is a nearly pure subsulphide of copper. Mixing a portion of raw with a proper proportion of this calcined white metal we have in the charge nothing but sulphur, copper, and oxygen—exactly the reagents required to bring about the reaction described above. The 2% or 3%, or more, of iron that may be present is oxidized and slagged, the sulphides react on the oxides and sulphates of the calcined metal to produce metallic copper and enormous volumes of sulphurous-acid gas, while if arsenic or antimony be present, it is removed more effectively by the violence of the reactions than it can possibly be by any ordinary method.

A brief, practical description of the operation as executed daily at the works of the Cape Copper Company, Limited, in Wales, is certain to be of interest to metallurgists. White metal is by no means a difficult material to calcine when crushed comparatively coarse, and it oxidizes peculiarly well in the long revolving cylinder. Ten tons of 2240 lbs. are often calcined in twenty-four hours in this apparatus down to from 1% to 3% sulphur. Of course it would take more raw metal if it were calcined to a black oxide, but the extra cost of the calcination becomes too great. Under the conditions prevailing at these works it is found best to calcine thoroughly, though not perfectly; the calcined metal being in a condition to reduce (if one may speak so of a material which in itself is oxidizing) about one-half its weight of raw material to metallic copper; or rather, when fused with one-half its weight of raw metal, to yield the entire metallic contents of both calcined and raw metal as metallic copper. Tests are quickly made by an office boy by taking probable proportions of both raw and calcined metal from the material that is to form the charge and melting them with certain precautions in a crucible. The resulting metallic button indicates exactly whether

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* For a full discussion of these important reactions see *Modern American Methods of Copper Smelting*, p. 177, sixth edition.

the mixture has been correctly estimated, or whether a small addition of raw or of calcined metal must be made. Even if an error be made in the original proportions, it can be easily remedied by additions after the charge is melted.

The mixed, pulverized white metal is charged rapidly into the refining furnace, under the same conditions as one would charge "blister" into an ordinary refinery. After four or five hours of brisk firing, the thoroughly heated charge begins to swell and bubble, giving off such dense fumes of SO_2 that the draft is impeded and the gas pours from every crack. The active reaction between sulphides and oxides keeps up the temperature until the gas begins to subside and brisk firing can be resumed. In a short time the charge is sufficiently melted to allow the skimming of the scanty slag, and a quick, sharp heat soon clears the bottom and enables the skimmer to put a clean face on the metallic bath. Owing to the violence of the chemical reactions, and the fact that there are no foul crusts sticking to the bottom to raise and "throw back" the copper, the metal is very "forward," and as soon as the day men arrive they can begin flapping for "set copper." This operation takes about the same time that it occupies when "high blister" has been charged into the refiner. The rest of the operation is exactly like ordinary refining, and the ingot produced is of the best quality. I am informed by the assistant manager of the company that no complaints have been received of any of the 20,000 tons of copper sent out from this operation, while on one or two occasions having to send to some of their customers a lot of copper made from blister in the ordinary fashion, they received a request to furnish them permanently with the copper from the "direct" method.

The only serious difficulty encountered in accustoming the workmen to the new method was the impossibility of their understanding that hardly any slag was produced by the new method. They were so accustomed to the huge quantities of slag, largely silicate and oxide of copper, produced by the old "roasting" process when making blister copper, that they considered it necessary to skim something off the charge ; and as there is practically nothing but copper to skim, the result is disastrous. Even educated metallurgists frequently inquire where the slag all goes to, forgetting that in white metal there are no slag-forming substances except the copper itself, that is oxidized by the long exposure of the metallic bath to an oxidizing atmosphere during the ordinary process of "roasting for blister," while with care the amount of slag produced by the direct method may be so little that from a charge producing 26,000 lbs. of metallic ingots only about 500 lbs. of slag is made.

During the past six months the average yield of each 100 tons of white metal has been 71.5 tons of ingot and 15.6 tons of slag. The average amount of ingots produced from the roasting of 100 tons of white metal for blister in the customary fashion was about 52 tons, the weight of the accompanying slag being 34 tons. Thus nearly 20 tons more of copper was thrown back into slag by the old method than by the new. The quality of the ingot produced by the direct method is decidedly superior to that produced by the ordinary method. Probably this fact is due to the violent chemical reaction that takes place between the raw and calcined matte, the powerful ebullition of SO_2, in *statu nascendi*, having a tendency to remove all volatile impurities present.

Improved Bottoms for Reverberatory Smelters.—When examining the Welsh copper furnaces I was much interested in seeing some 20 reverberatories, including ore furnaces, blister furnaces, refineries, etc., in which all the smelting was done direct on a brick bottom, sand being entirely omitted. This form of bottom is patented by Messrs. C. James and W. Griffiths, with whose permission and assistance I publish the following brief notes.

The ordinary foundation of the furnace is brought up a little higher than usual, and on it is rammed a thickish layer of common brasque. This is slightly hollowed, to form the concavity of the superincumbent hearth, which is composed of a single layer of suitable refractory brick placed on end, and is thus nine inches thick.

Great care is taken to give this brick hearth the proper inclination toward the tap-hole, or ladling cavity, so that every drop of metal may drain to its proper destination. The side-walls and bridge are raised directly upon this bottom. There is no other peculiarity in the construction of the furnace. Whether the furnace be run on ores, mattes, or used as a roaster for blister copper, the brick bottom apparently lasts longer, and, so far as I can judge, is more satisfactory than the best sand bottom. I personally examined several brick bottoms that had been in over a year, in refineries and blister and ore furnaces, and they not only seemed perfectly clean and smooth, but, on being more carefully investigated, disclosed no perceptible signs of wear. A fragment nearly an inch deep, chipped off the surface of the bottom, showed the clean, unaltered texture of the brick in its deeper portion, no metal having penetrated it over half an inch. Of course, this immunity from the fluxing and slagging action of the constituents of the charge comes from the fact that the bottom is always protected from the air by a covering of matte or slag. If the mistake should be made of letting any portion of the brick bottom stick up so far as to be bathed by the slag and exposed to the air, it will be eaten away in a single fusion. In the same way, the lining walls of every reverberatory hearth are deeply cut and scorified after the smelting of a basic charge of ore, and are only kept in proper condition by constant fettling.

Apart from the ease with which the bottom of brick is put in, its cheapness, and its independence of skilled smelters, its great advantage in refinery and blister furnaces is the small quantity of metal that it absorbs. All copper refiners have experienced the annoyance, not only of tying up from 15 to 50 tons of valuable copper in each furnace bottom, but also the difficulty of working up the metallic bottom after it is taken out. It can neither be cut into pieces nor smelted en masse without great difficulty and expense. Careful tests were made on the first brick bottoms that were put into the refining furnaces to see how much copper they absorbed. The charge was carefully weighed, and when the small quantity of metal in the slag produced was added to the weight of the ingots there was a loss of only about 100 lbs. on the first and very little after that.

These bottoms are much easier to raise than the old sand bottoms. A heavy steel bar driven in obliquely from the side door easily raises a lot of brick, and after a commencement is made the remainder comes up with the greatest ease. One bottom that I examined had been refined on steadily for two years and seemed practically as good as new. I regard the brick bottom as an improvement of decided value in the metallurgy of copper.

Need of a Better Method of Tapping Refined Copper into Molds.—Some years ago Professor Egleston described an invention of his for this purpose. But as I have never seen it used outside of the works where it was first tried, I suppose it has not altogether answered the purpose. But the time has arrived when such an invention seems positively essential. Ladling the molten copper by hand from the refining furnace is one of the most severe jobs known to metallurgy, and employs four men for several hours to empty an ordinary refining furnace. This is bad enough even where all the product is to be made into ingot; but when, as is so frequently the case, the entire charge is to be cast into heavy shapes, such as cakes, wire-bars, or massive cylinders, or to be drawn out into large, seamless tubes, often weighing some hundreds of pounds each, as used for calico printing, it is a most arduous and senseless task to dip out the entire mass in single ladlefuls. Of course, the main difficulties to this project are the high melting-point of copper, its extreme malleability and tenacity, and the difficulty of cutting it after it has set. Coarse copper can be broken with great ease when hot; and it is the quality of red-shortness that enables one to so easily break apart the necks that connect the various pigs of a heavy bed of blister. Hence the slabs of copper containing the precious metals which are to be subsequently treated by electrolysis can be cast on a large scale by carefully tapping the furnace, for, as this copper is still coarse, it retains its red-shortness. But copper fit for ordinary commercial purposes cannot thus be easily handled, and no one who is not entirely familiar with the physical properties of this extraordinary metal at every degree of temperature and purity can realize the difficulties to be encountered before a method can be invented that will supersede the present system of ladling.

Paris, Dec. 12, 1893.

AMERICAN PRACTICE IN ELECTROLYTIC COPPER REFINING.

By Titus Ulké.

The object in electro-refining copper is generally twofold—the making of absolutely pure copper, and the concentration and extraction of the contained gold and silver, in both of which respects it has a great advantage over fire-refining. In the latter, even with ores as free from impurities as the exceptional Lake Superior ores, the copper produced is not as pure as the best electrolytic copper, nor is the contained silver or gold, frequently amounting to important quantities, saved as in electrolytic refining. In the practical application of electrometallurgy we find that it has not been profitable to treat copper ores direct by electrolysis nor even coarse metal or ordinary matte, although Hoepfner and Siemens & Halske make claims that they can accomplish this with substantial financial success. Copper-refining proper is in nearly every case restricted to the treatment of high-grade copper matte or blister copper containing, say, 98% copper For practical purposes it serves our purpose best to divide the subject-matter into (*A*) methods of copper-refining proper, and (*B*) treatment of the gold and silver bearing residues, and to divide the former into two classes, according to the employment of a sulphate solution or a chloride solution as electrolyte.

A.—Copper Refining Proper. The electrolytic treatment of copper matte and ores.

B.—Refining of the gold and silver bearing "slimes," or *anode residues*, from copper-refining.

It is estimated that in 1893 the United States produced about 45,000 tons of refined copper electrolytically from blister copper. The cost of refining a ton of 98% matte is said to have been about $15. Three processes, differing principally in the arrangement of the anodes, are in vogue, viz: (1) the multiple, (2) Smith's, and (3) Hayden's. In all these processes the anodes are blister copper and the electrolyte is a solution of sulphate of copper.

1. *The Multiple Process.*—According to Mr. F. B. Badt, in this process the anodes of blister copper and the cathodes of pure copper, of each cell, are arranged in a row alternately, but connected in multiple, and there is generally one more cathode than anode. The electrodes are suspended in a vertical position in wooden vats, lined with lead, and the vats are either in series, multiple, or mul-

tiple series, the best arrangement, however, being single series. This process is said to be used in the refineries of the Balbach Smelting and Refining Company, Newark, N. J.; Boston and Montana Consolidated Copper and Silver Mining Company, Great Falls, Mont.; Chicago Copper Refining Company, Blue Island, Ill., Lewisohn Brothers, Pawtucket, R. I.; Omaha and Grant Smelting Works, Omaha, Neb.; and the St. Louis Smelting and Refining Company, Cheltenham, Mo., whose respective plants are said to have estimated capacities for producing 650, 550, 150, 110, 30, and 60 tons of electrolytic copper per month.

2. In *Smith's process* there are no cathodes at all. The anodes are arranged horizontally, and the current causes the solution of copper from the under side of each plate, and a deposition of it on the upper side of the plate next below. A cotton cloth screen is placed between each plate to intercept impurities or foreign matter, such as gold and silver. The anodes and the vats are all in series. The Electrolytic Copper Company, Ansonia, Conn., and the Pennsylvania Salt Manufacturing Company, Philadelphia, Penn., are said to be using this process, with estimated capacities for producing 100 and 30 tons of electrolytic copper per month.

3. *Hayden's process* differs from Smith's only in the fact that his plates of blister copper are arranged vertically instead of horizontally, and that there are no screens between them. This process is in practical use by the Baltimore Copper Smelting and Rolling Company and the Baltimore Refining Company, Baltimore, Md., and also by the Bridgeport Copper Company, Bridgeport, Conn., whose works are said to have estimated capacities for producing 1200, 300, and 400 tons of electrolytic copper per month. In a modification of this process by Stalmann, the anodes of black copper and the cathodes of refined copper are arranged in ordinary series, but the plates of each pair of anodes and cathodes, except the initial and terminal ones, are riveted together to form a solid block without any electrolyte between. This process was formerly used by the Anaconda Mining Company, but has now been discarded, it is said, in favor of the ordinary Hayden process. The Anaconda Refinery has an estimated capacity for producing about 1200 tons of electrolytic copper per month, making the Anaconda and the Baltimore electrolytic plants the two largest in the world.

As most of the latest improved appliances and methods are used in the Anaconda Electrolytic Refinery, the results of my experience there may be of interest.

Although theoretically it is possible to refine any quantity of copper per horsepower, by increasing the size and number of the vats and the amount of copper under treatment, economy demands an arrangement where both the vats and the power are the smallest consistent with each other. This consideration has led to the adoption of a vat approximately 10 ft. long by 3 ft. high and wide. Each vat is constructed of well-seasoned 3-in. boards, lined with several coats of insulating paint. Five vats are placed in a row and there are 12 rows to a system. Each system is supplied with a current of 60 volts and 1000 ampères from an Edison generator. With six systems, 40 tons of electrolytic copper can be produced daily, or about 1200 tons per month.

The density of the current is also an important point to be considered in producing absolutely pure copper. Although the output per vat is very high, by using as much as 15 ampères density in the series process, the quality of the copper deteriorates with the higher density, and silver is apt to go over to the cathode. Therefore a maximum of 10 ampères per square foot of active cathode surface is seldom exceeded.

In Europe, according to Gore, the copper refiners prefer a current of two ampères to the square foot. At Anaconda this is considered too low a density, as the rate of deposition is then too slow, and three ampères per square foot has given the best results. Theoretically one pound of copper will be deposited per hour by a current of 386 ampères out of a solution of sulphate of copper.

It is necessary to keep up a constant circulation in the electrolyte in order that its resistance shall be constant. Sometimes this is effected by arranging each vat a little lower than the other, and by allowing the liquid to pass down the row in series. A better way is to supply all the vats from a common trough and to collect the overflow in a common reservoir and pump it back to the trough by means of lead pumps or injectors. However, the lead pumps require frequent attention and the injectors add too much water to the electrolyte. Badt proposes as an improvement the adoption of two collecting tanks which can be used alternately; as soon as one is full it can be made air-tight and a small air compressor will force the solution up to the distributing tank again. At the Chicago Copper Refinery, Montejus, with valves working automatically, are employed for this purpose. In Smith's process it is claimed that no circulation of the electrolyte is needed. The circulation may be effected by feeding in the solution through a gutta-percha feed hose reaching to within six inches of the tank bottom, and out through a top overflow launder, fixed to the side of the vat; or, as is preferred, the solution may be fed in at the top and taken from the bottom of the vat. A circulation of six gallons per minute has been found convenient.

The dimensions of the anode plates are 32 in. by 34 in. by $\frac{1}{2}$ in. They are cast with as smooth a surface as possible, and weigh 180 lbs. They are coated on one side with paraffine and dusted with finely powdered stove polish (graphite). They are set as close as possible in the tank, say $\frac{1}{2}$ in. apart, and plates are put in until the voltage (in this case 60 V.) is used up, and are connected in series. Between the plates there should not be over $\frac{1}{2}$ volt; generally $\frac{1}{3}$ volt gives the best results. If the voltage is much less, there is a short circuit, which can be tested by means of a prong volt meter. Tests should be made at frequent intervals to ascertain that there is no short circuiting from sprouts on the cathodes or from other causes. The tanks are loaded with plates by means of overhead blocks.

The electrolyte must be rich enough in copper and sulphuric acid, and not too rich in foreign substances. In the refinery solution 16% bluestone and 5% free sulphuric acid have given very satisfactory results. With a higher voltage than that mentioned above more acid must be used. If the current is too strong, foreign elements go to the cathode, which becomes lumpy and brittle. If the current is too weak, cupreous oxide goes to the cathode. A refinery solution containing 16% bluestone and 5% free sulphuric acid possesses a sp. gr. of about 1.150 or 73 lbs. per cub. ft. It should be heated, say, up to within 70° and 100° F.

According to H. F. Howe, the behavior of foreign elements is reported as follows:

Neutralize electrolyte	Go into slimes		Redissolves—Cu_2O.
			Dissolves if copious—Cu_2S.
			In neutral liquors, goes partly to cathode—$R''As_2O_6$.
Neutralize electrolyte and remove its copper	Go into slimes		Remains undissolved—Pb.
			Remains undissolved as basic sulphate—Bi, Sn.
	Dissolve—Fe, Zn, Ni, Co, FeS.		
	Dissolve till bath is saturated, then to slimes or cathode—As.		
Does not affect composition of electrolyte	Go into slimes		Remain undissolved—Au, Pt.
			If electrolyte is neutral, dissolves and goes to cathode—Ag.
	Dissolves in acid, goes to slimes in neutral electrolyte—As_2O_3.		
	Goes to slimes	Redissolves as Sb_2O_5	In normal bath part may go to cathode as basic salt. In neutral or copper, poor bath goes to slimes—RSb_2O_6.

The composition of the electrolyte must be frequently determined in order to properly control the refining process. In general it suffices to ascertain the amounts of bluestone and free acid, of arsenic, and of the antimony or bismuth present in the solution. To determine these the following methods of analysis have been adopted.

To determine the amount of bluestone and free sulphuric acid a quart bottle full of the solution from the main feed launder of each system is taken daily, and its specific gravity determined. Five cc. of each solution are placed in a small dissolving beaker, to which 10 cc. HCL are added to accelerate a clear filtration; the beaker is then filled three-quarters full with boiling hot water and enough hot $BaCl_2$ to precipitate all of the HS_2O_4 (free and combined) present. It is allowed to settle fifteen minutes and then filtered through a S. & S. German 12½ cm. filter, washed thoroughly with hot water, and the precipitate placed on the filter in an annealing cup, and this is set in a red-hot muffle. It is left there until the ash is white and then weighed. The weight of $BaSO_4$ in 5 cc. multiplied by 84 equals total weight in grams of H_2SO_4 in one liter.

A second portion (5 cc.) of the original solution is treated in a 200 cc. flask with 2½ cc. HNO_3 and diluted half full with water; 5 cc. ammonia are then added and the whole is titrated with KCN, running a check to determine the standard. The number of cc. KCN used × standard of solution = grams copper in 5 cc. This multiplied by 790 gives grams of bluestone in 1000 cc. Divide grams of bluestone in 1 liter by sp. gr. of solution and the result is the percentage of bluestone in the original solution. Multiplying the grams of bluestone in 1 liter by .393 gives the grams H_2SO_4 in 1 liter combined with copper. By subtracting this from the total weight of H_2SO_4 in 1 liter gives the amount in grams of uncombined H_2SO_4 in 1 liter as a remainder. Dividing this by the specific gravity gives the per cent. of free H_2SO_4 in the solution. If iron accumulates in the solution, the amount of H_2SO_4 combined with this element ought to be taken into consideration, as every gram of iron present in the form of green vitriol combines with 1.75 gram H_2SO_4. This must be subtracted, as was the H_2SO_4 combined with the copper, from the total amount of H_2SO_4 in order to find the amount of free H_2SO_4 present.

To determine the arsenic present, to half a liter of the solution is added a little nitric acid and a small crystal of iron sulphate, and heated. Ammonia is added, and it is then heated to boiling; the precipitate obtained is filtered, washed, and dried. After powdering the same, it is mixed in a large porcelain crucible with 6 to 8 parts of $Na_2CO_3+KNO_3$, and fused; at first at a low heat, and then strongly until fusion is complete. It is leached with water and the insoluble residue is filtered out. HNO_3 is added to the filtrate until the solution is acid; it is then boiled until all NO_2 and CO_2 have been driven off. The solution is neutralized with ammonia and sufficient $AgNO_3$ added. The resulting $Ag_3 AsO_4$ is dissolved in dilute HNO_3 (sp. gr. 1.2) and the combined Ag determined either by titration with AmCyS or by precipitating as AgCl and cupelling.

To determine the antimony and bismuth, a little HNO_3 and a small crystal of iron sulphate are added to another half liter of the solution, and heated; ammonia is added and heated to boiling, and the precipitate obtained is then filtered, washed, and dissolved in HCl. The antimony is precipitated with H_2S and leached with warm Na_2S. The filtrate is decomposed with HCL, and the resulting precipitate boiled in concentrated HCL, this then diluted, filtered, and H_2S is passed in the filtrate, allowed to settle, the supernatant liquid decanted off and the Sb_2S_3 transferred into a porcelain crucible. Fuming HNO_3 is carefully added, evaporated, ignited, and the Sb weighed as Sb_2O_4.

The purification of the electrolyte, or freeing it from the objectionable elements As, Sb, and Bi, may be effected by one or both of the following methods:

1. By precipitation of the Bi and Sb and part of the As on copper oxide or roasted granulated copper, through a bed of which the refinery solution is caused to filter. The rest of the As may then be separated by filtering the neutral or alkaline copper solution through freshly precipitated iron hydrate or lime, which is said to act like copper oxide.

2. By alloying the anode with a small quantity of metallic tin. As the anode dissolves, the tin, it is claimed, forms, like metastannic acid, an insoluble salt with the arsenic of the heated impure electrolyte, and thus prevents the deposition of the arsenic on the cathode.

Thofehrn introduces jets of air into the collecting basin and distributing reservoir, and claims thus to oxidize the electrolyte and remove the impurities that are constantly forming. When the electrolyte has become very impure it may be better to take out its copper contents and then discard it. This recovery of the copper can be easily effected either as impure copper by electric deposition on a copper cathode and the use of an insoluble anode, such as lead, or as blue vitriol, by crystallizing out the copper vitriol and arsenious acid after concentration, and redissolving the copper vitriol in just sufficient water to effect its solution without dissolving the arsenious acid. The latter can be used for the manufacture of Scheeles green, the mother liquor for recovery of sulphuric acid, and the copper vitriol solution employed over again as electrolyte.

The Siemens & Halske Process.—This process, like that of Hoepfner, has hitherto been practically applied only to the treatment of copper ores, but with what success I cannot say. The process consists in alternate leaching and electrolysis, with the important addition of ferrous sulphate to the electrolyte. This substance is avid for oxygen, and thus prevents polarization at the surfaces of the anodes; while the product of its oxidation is ferric oxide, which unites with a quantity of sulphuric acid 50% in excess of the corresponding ferrous oxide. The acid set free from the deposited metal is thus taken up by the ferric oxide and passes forward as ferric sulphate to the leaching tank, where it dissolves a further supply of metal, not only from the oxide present, but even from the sulphides. Hence in this process the ore may be treated in a raw state.

Siemens & Halske's estimate for a plant capable of producing 1000 kilos of fine copper per day of twenty-four hours from ores containing 4% to 4½% copper is 209,600 marks, or, say, $40,000; and the cost of working is estimated by them at .23865 mark per kilo of copper produced, or, say, 2c. per lb. For further information on the Siemens electrolytic process for the extraction of copper from its ores, see the *Engineering and Mining Journal*, March 19, 1892, p. 327.

Treatment of Slimes from the Copper Refineries.—In well-conducted refineries the cathode copper deposited from "blister copper" carrying 100 oz. silver per ton should not exceed one or two oz. of silver per ton of copper, and practically the entire precious metal contents of the blister copper remains insoluble and accumulates in the bottom of the tanks. This deposit slimes, or mud, may contain gold, silver, platinum, metallic copper, cuprous oxide, cuprous sulphide, basic sulphates of bismuth and tin, lead sulphate, free sulphur, basic salts of iron, more or less oxidized and combined antimony, sulphur, and arsenic, and certain rare elements. Owing to the great differences which exist in the quality of the blister copper submitted to electrolysis, these slimes vary greatly in composition. Samples of Anaconda mud I found to average 35% copper, 45% silver, and less than .2% of gold; samples from France contained 25% copper and 5% silver. The Chicago Copper Refining Company obtained about 3¾ lbs. of pulp or slime from every 100 lbs. of anode copper. This pulp contains 41.7% Ag and 1.3% Au and is melted down to doré bullion. Formerly the washed, dried, and screened mud was shipped directly, or first melted into bars to avoid losses by dusting, and then sold to the lead refiners.

The lead-refining companies, which still treat a large portion of the silver mud obtained in refining copper, employ two methods. The first method, which is used in the Lautenthal works, Germany, consists in adding the slimes, freed from adhering acid solution by a filter press, directly to molten lead bullion on a cupel hearth and cupelling. The resulting silver bullion is parted in the usual way. The second method, which is employed at the Hamburg and Biache (France) refineries, consists in first smelting the slime with litharge or a reducing flux in a blast furnace and then cupelling the mixture of metals obtained with argentiferous lead. At Alteneau the slimes are mixed with lime, pressed into bricks, dried, and smelted in a blast furnace with a lead charge and basic slags. At Oker the slimes are put through the so-called "Reichschmelzen" in a blast furnace, and a product is obtained consisting of rich lead bullion, matte, and speiss. This lead bullion from Oker and Alteneau is then cupelled and parted in the ordinary way.

Principally to save the profit otherwise made by the lead refiners, many electrolytic refining companies treat their silver slimes in their own works, as installations for this purpose can be run at a comparatively small expense in connection with the copper-refining plants. The copper refineries use one of the five following methods of treating slimes:

1. The Moebius process. 2. The Thofehrn process. 3. The Cabell-Whitehead process. 4. Treatment with concentrated sulphuric acid. 5. Treatment with dilute sulphuric acid and air.

1. *The Moebius process*, or method of double electrolysis, consists in a preliminary concentration of the slimes by electrolysis and in a subsequent electrolytic deposition of the contained silver, the gold being collected separately. As the base mud usually contains at least as much copper as one-third of the silver in it, it must first be concentrated according to Moebius, by a preliminary electrolytic process. Plates of the alloy are used as anodes, and sheets of copper as cathodes in an acidulated solution of cupric nitrate, or, if the alloy is poor in silver, a solution of cupric sulphate. By now passing a current of low electromotive force, the copper dissolves, and the silver, gold, platinum, etc., remain as a loose coating upon the anodes, and may be brushed off. This powder is melted and cast into anodes and treated by the ordinary Moebius process. The apparatus therein used consists, according to Gore and Maynard, of a mechanical arrangement of brushes or scrapers for continually keeping the cathodes free from loose crystals of electro-deposited silver, and of muslin bags stretched over a frame of wood covered with hard rubber and inclosing each pair of anodes to collect the separated insoluble substances. Underneath the electrodes, at the bottom of the vat or cell, are trays for catching the silver, and these are lifted out occasionally and the silver removed. Each tray has a perforated bottom covered with asbestos cloth and hinged to the tray on one side and kept in position on the other by movable pins. By means of a hoisting arrangement above the battery the electrodes, frames, bags, trays, and scrapers may be lifted so that the exciting fluid alone remains in the cells. The object of this arrangement is to facilitate the quick cleaning of the battery and the removal of the silver and gold precipitates. The vats, or cells, are made of wood, coated inside with rubber packing, are generally about two feet wide and deep, and may be arranged either in series or multiple arc. The electrolyte consists, according to Maynard, of a solution of copper and silver nitrate acidulated with nitric acid. The solution may be formed in the battery, if the process is started with a very dilute one per cent. nitric acid and adding more acid by degrees as the copper contents of the bullion may require it. Six doré bullion anodes, in the form of plates say half an inch thick and fourteen inches square, and four cathodes made of pure sheet silver slightly oiled to prevent adhesion of the deposited metal, are placed in each cell so that anodes face both sides of a cathode. By passage of a current of small electromotive force, the copper and silver dissolve and form a solution of nitrate of copper, nitrate of silver, and free dilute nitric acid; the silver alone is electro-deposited as powder and as crystals at the cathodes, leaving the less electro-negative copper in solution. These crystals of silver would rapidly grow over the anodes if they were not continuously scraped off and allowed to drop into the tray beneath. By reason of the scrapers, the electrodes can be brought very near to each other, thus diminishing the resistance and polarization of the cell. The gold, platinum, peroxide of lead, and other impurities separate at the anode and fall into the bags, which are saturated with coal oil, linseed oil, and paraffine to protect them from the acid, and are very little affected. No porous cells or partitions are employed. The current must have an electromotive force, according to Gore, of one to three volts to each vat. The copper is not deposited providing the liquid is sufficiently acidulated and not too poor in silver nor too rich in copper; if a little happens to be deposited, it falls into the trays with the

silver, and is then gradually dissolved by the liquid. The sediment, which contains all the gold from the anodes, is removed, dried, and melted; the peroxide of lead changes to lower oxide, the base metals are oxidized, the noble ones separate as metal. If platinum or iridium are present they are subsequently separated by means of bromine.

In course of time the electrolyte becomes too concentrated in copper and needs to be regenerated or replaced. In order to get back the nitric acid and copper contained in the solution, carbon anodes are substituted for the bullion ones, and a feeble current passed until all the silver is deposited. The silver cathodes are then removed and copper cathodes substituted. A powerful current is passed so as to deposit the copper rapidly as a loose powder, which falls into a copper box placed to receive it; and when so much acid is set free as to corrode the box and its contents the former is connected as a cathode. The liquid thus regenerated is used again, partly for making new electrolyte and partly for replacing water evaporated from the baths. According to the patentee's statements, the operation is continuous, and a large quantity of silver can be refined very rapidly at a low cost.

As Maynard states in his description of the Pinos Altos plant, where 4000 oz. of doré silver can be refined every day, the manual labor is very light, the assayer and his helper performing the duties. Every twenty-four hours the separated silver and gold are removed from the battery. By means of a lifting arrangement actuated by a crank the electrodes, conductors, trays containing the precipitated silver, and the bag frame containing the gold are raised up, leaving only the exciting liquid in the cells. A movable tank on casters, provided with a false or filtering bottom, and a chute extending under the silver trays, is pushed alongside the battery. By removing the pins holding the bottom of the trays, the silver precipitate drops on the chute and into the tank. After a superficial washing the silver is ready to be dried and melted into bars of 999 fine. The bag frames containing the gold are then removed and turned into a water tank provided with a filtering bottom. The gold is filtered (by drawing the water from the tank), dried, and melted, whereby the lead and other impurities go into the slag. The electric current employed is 170 ampères and about 8 volts, which corresponds to an expenditure of only 2½ horse-power, for parting 3500 to 4000 oz. per day. The plates weigh, on the average, about 100 oz., and as each of a seven-compartment tank contains six plates, it takes 42 plates, or about 4200 oz. of bullion, to fill such an apparatus at the start. The exciting liquid or stock solution needed contains less than 300 oz. of silver.

In the United States the Moebius process is claimed to be in successful operation at the works of the Pennsylvania Lead Company, near Pittsburg, where 30,000 to 40,000 oz. of doré bullion are parted daily, and at the works of the St. Louis Smelting and Refining Company. This process is also used by the Pinos Altos Company of Mexico, and by the Deutsche Gold und Silber Scheide Anstalt, at Frankfurt.

2. *Thofehrn's process* consists in a smelting of the slimes, or "base mud," followed by electrolysis and treatment of the slimes, now rich in silver, with concentrated sulphuric acid. After a sufficiently long exposure to the atmosphere the "base mud," which contains, say, 25% copper and from 1% to 6% silver, is

melted to get rid of the greater part of its metallic oxides other than those of copper and silver. For this purpose a little refining furnace is used, lined with magnesia bricks, which are neither attacked by the heat nor by the corrosive action of the slag. This fusion produces a matte containing 80% copper and 15% silver. The matte is cast into plates and submitted to electrolysis in special vats, in which the main refinery current and electrolyte is caused to circulate. The copper obtained is pure enough to be marketable, and the resulting slimes rich enough in silver for the treatment by concentrated sulphuric acid.

In connection with the above, Mr. Thofehrn informs the writer that he has succeeded in dissolving impurities, such as antimony, lead, and tin, in base copper slimes, with ferric chloride. He hangs the slimes contained in a straw cylinder basket in an electrolytic bath, and employs a very weak current of electricity. The Thofehrn process is used in the Pont de Cheruy and Eguilles copper refineries, in France.

3. The *Cabell-Whitehead process* consists in treating the mud with a certain quantity of silver sulphate and dilute sulphuric acid. A reaction takes place which results in the solution of the metallic copper in the mud, and the precipitation of an equivalent quantity of silver. The silver thus freed from metallic copper, and thoroughly washed to remove copper sulphate, is melted and cast into bars. This process is used with success at the Baltimore Smelting and Refining Company's works.

4. The *method of direct treatment with concentrated sulphuric acid* is now little used. By this process the dried mud is sifted to remove fragments of copper, and then treated directly, or after a melting operation, with hot concentrated sulphuric acid, whereby the copper and silver are dissolved, leaving the gold as residue. The silver in the solution is then precipitated on copper plates as cement silver, and the resulting copper solution is crystallized out as copper vitriol. A similar method is used by Dewey for refining "Russel sulphides." As the copper in the mud consists, to a large extent, of fine metallic particles broken from the anode, the hot concentrated sulphuric acid evolves considerable sulphurous acid. Partly to obviate this loss and reduce the quantity of acid necessary, and partly to save the expense of using concentrated sulphuric acid, Mr. Szontagh, at Anaconda, introduced the following improvement.

5. *Direct Treatment with Sulphuric Acid and Air.*—This improved method of refining slimes consists in treating the well-screened mud with dilute sulphuric acid, steam, and air, whereby the copper is completely dissolved; the resulting copper solution, which is again used as electrolyte, is then filtered and washed out from the silver and gold residue. The latter, which should now be entirely free from copper, is melted and cast into plates for parting. In carrying out this process a lead-lined tank is used, at the bottom of which a two or three inch perforated lead pipe is placed. This pipe is connected with a steam pipe and a Korting injector, having a short inner tube and an air opening. After the mud has been placed in the bottom of the vat and a certain amount of acid added, the steam is turned on, and sucks in air through the opening in the injector. As the steam in condensing itself dilutes the acid, it has been found best to add concentrated acid at the start, but in a very much smaller quantity than is used in any of the previously described processes. The reactions which take place are similar

to those in the Roessler converter. The hot concentrated acid in dissolving the metallic copper evolves sulphurous acid, which in turn combines with the oxgyen of the air and with the water present to form sulphuric acid anew; all of the acid being thereby utilized. The result is the oxidation of the metal copper and the dissolving of the same in the hot dilute acid as cupric sulphate. All of the copper is dissolved, and the mud is thereby purified and highly concentrated in precious values.

After the completion of the dissolving process, which can easily be determined by simple chemical tests, the supernatant solution is siphoned off and the highly concentrated mud thoroughly washed to remove all traces of copper. As the copper solution and the wash water carry suspended particles, they are filtered through canvas and asbestos cloth filters, and then added to the electrolyte in the copper refinery or otherwise utilized for their copper contents. The slimes, which are now practically free from copper, are dried (baked) and charged into a small reverberatory furnace. They are melted down into base bullion at a low heat, and with an oxidizing flame to volatilize any arsenic and antimony that may be present. Generally 1200 lbs. of bullion, assaying 980 and above fine, are obtained from 1500 lbs. purified and dried mud. The bullion obtained can now be easily parted in the usual way to separate the fine gold from the silver. This process, which is used at the Anaconda works, is probably the most efficient and cheapest method now in use for refining the slimes from electrolytic copper refineries.

THOFEHRN'S IMPROVED ELECTROLYTIC PROCESS.

BY HIPPOLYTE FONTAINE.

THE Thofehrn process, which during the last year has been improved in various respects, is rapidly finding its way into the metallurgical industry. On the completion of new plants now in course of construction, the daily output of copper produced by this process will amount to about 70 tons. The chief improvements in this process have been as follows: The volume of current has been increased to from 100 to 250 ampères per square meter of cathode surface, according to the quality of the copper treated. The quantity of copper undergoing treatment is correspondingly reduced from 60 tons to 12 tons per 1 ton of output. The cathodes are now produced by electrolysis in the refining vats as needed. The mechanical pumps, formerly used for the circulation of the electrolyte, which involved serious inconveniences, have been replaced by pneumatic siphons. By the introduction of secondary anodes, the quantity of copper held in the residue has been considerably reduced, and is now also sufficiently oxidized to allow of rapid treatment by the wet process for the extraction of its gold and silver. The secondary anode receives all the débris from the primary anodes, and keeps it subject to the electrolytic action, which gradually separates out almost all the copper contained. Oxide of copper is now used to maintain the electrolyte, the consequence being that the anodes last twice as long, and the item of labor in their manufacture is correspondingly reduced.

Oxide of copper is cheaply produced from matte of 50% or from black copper, in a patented water-jacketed converter, which works continuously. Matte is melted in a cupola; the molten material is poured in a continuous stream into the converter, where a hot blast under high pressure divides it into extremely fine particles which are immediately oxidized. The oxides are deposited in a large chamber of sheet iron, divided into several compartments. The light oxides are carried off with the fumes, and the heavier ones (of iron, copper, etc.) are deposited, according to density, in the various compartments. The bottom of the collecting chamber is inclined, and the deposits are discharged, through doors, directly into cars.

The converter deserves the attention of metallurgists, particularly for the treatment of nickel-bearing copper mattes, base bullion, etc.

In making the copper cathodes, a copper drum, covered on its surface with nickel, revolves slowly in a special tank. Pure copper solution is fed to this cylinder under pressure and thereby forms the cathode, anodes being placed at the bottom of the bath. With 250 ampères a beautiful deposit, very smooth and tenacious, is obtained. This deposit when it has reached the required thickness, about 0.4 mm., is removed from the cylinder, this latter remaining in circuit and in motion. A special preparation applied once a day to the cylinder facilitates this removal of the deposited film. To prevent the latter from assuming the form of a tube or ring, the cylindrical surface is broken by a streak of insulating paint. Each of these deposit-films sheets makes six cathodes.

The remainder of the work is still done as described in THE MINERAL INDUSTRY, Vol. I., 1892. All the anodes and cathodes required for one bath are suspended from a large framework, which is carried from the preparing to the electrolyte room by an electric crane, and which is lowered into and raised from the bath so as to receive simultaneous action on all the anodes and cathodes.

The cost of working by the Thofehrn process per ton of refined copper is as follows:

TREATING MATTES OF 50% TO 60% CU.	
Melting 2 tons @ $1.75	$3.50
Oxidizing 2 tons @ $2.20	4.40
Reducing to black copper and anode-casting 1 ton	5.50
Manufacture of cathodes	1.00
Labor at vats	1.50
Steam power	3.50
General mill expenses	1.35
Interest and sinking fund :	
Interest on real estate	.38
Interest on investment in plant	.90
Interest on copper for treatment	1.05
Interest on copper in stock	.75
Interest on various supplies in stock	.15
Interest on sinking fund	1.12
Total	$25.10

TREATING BLISTER COPPER OF 95% TO 98%.	
Manufacture of anodes	$2.50
Manufacture of cathodes	1.00
Manufacture of oxides	1.20
Labor at vats	1.50
Steam power	1.90
General mill expenses	.95
Interest and sinking fund :	
70% of those for matte treatment, or $4.35	3.05
Total	$12.10

CUPREOUS CHLORIDE PROCESS.

BY C. HOEPFNER.

IN the usual method of electro-refining copper we have to contend with a number of difficulties. The casting of the matte in such thin plates as are necessary for the anodes is not easily accomplished, and these anodes, after hanging for some time in the baths, become unevenly dissolved, and at last so soft that they often fall from their connection and then interrupt the process. Further, the electrolyte becomes, after a short time, so saturated with all kinds of impurities which exist in so concentrated an amount in the matte that, if great care is not taken, either the deposition of the copper is partly interrupted or else other metals are deposited with the copper, and consequently the latter deteriorates in quality. Besides, a large portion of the current is wasted by doing extra work, such as dissolving in the matte other metals that are not wanted. Again, there is a great loss of interest on the money invested, because of the large amount of copper which remains for months in the electrolytic vats, so that only financially well supported concerns are able to refine electrolytically by the usual method.

Partly in order to obviate these difficulties, and partly to reduce the cost of producing copper, I propose the introduction of my cupreous chloride process. This method of using a chloride solution is based on the following well-known facts:

Copper, silver, lead, and other metals are much more readily dissolved by a chloride than by a sulphate solution.

Chloride solutions are better conductors of the electric current.

They are also commercially cheaper.

A definite quantity of water will dissolve a much greater weight of any metal in a chloride state than this metal in any other combination.

Chloride solutions are also applicable to the extraction of gold.

They entirely prevent copper from becoming contaminated with sulphur or sulphates.

They allow the purification of the solution and the keeping of it perfectly free from iron, arsenic, antimony, bismuth, etc.

They will extract and allow an economic production of lead, zinc, silver, etc., and also of other valuable by-products.

The process is as follows:

The ore, ground to a fineness of about 90 meshes, is automatically conveyed to the leaching drums, which have a capacity of from 10,000 to 30,000 liters. Here it is mixed with a heated solution of cupric chloride, which contains before entering the drums 60 grams of copper to the liter, is saturated with common salt or chloride of calcium, and is left in contact with the ore from two to six hours, according to the nature of the treated mineral. Above the leaching drums is a tank filled with the necessary quantity of hot liquor to allow of continuous work.

The lixiviation takes place in two consecutive steps. At first, in one of the drums fresh cupric chloride solution is added to the ore that has been previously treated with the cupric chloride solution, to extract any remaining copper or other metals; then it is drawn off to another drum containing fresh ore. Here the cupric chloride solution is entirely reduced to cupreous chloride. After all the economic metals have been extracted from the ore the residue is taken out of the drums by means of a sand pump, transferred to filter presses, washed, and then dropped into cars and carried away. These tailings in careful work do not contain more than 0.2% of copper, and in many instances the percentage of copper remaining is even less than this.

The solution, after having been completely changed to the cupreous state in the drums, is drawn off into vats, allowed to clear, and then purified. Silver is precipitated by finely divided copper; lead, by the solution becoming cold; arsenic, antimony, bismuth, iron, etc., are precipitated either by oxide of copper or by lime.

The solution is now quite pure and contains 120 grams copper (as cupreous chloride) per liter, which is twice as much as its contents before extracting the copper from the ore.

The liquor now flows in two separate streams to the anodes and cathodes of the electrolytic baths. The one which passes along the cathodes deposits its copper on them in rose-colored crystals and flows at last from the baths wholly or partly freed from the copper. The other stream which passes the anodes retains its copper, but chlorine in the nascent state converts its cupreous chloride into cupric chloride. After it leaves the baths this stream is usually mixed in a suitable tank with the stream coming from the cathodes. Since the latter solution has lost its copper, while the former has kept its 120 grams per liter, the mixed solution therefore now contains again 60 grams per liter in a state of cupric chloride. The original state of things has been re-established; that is, the solution is pumped back to the tanks above the leaching drums, heated, and returned to the latter to perform its work anew. The transferring of the solution from tank to tank is conveniently accomplished either by means of a vacuum or compressed air machines. When the pure copper or cathode deposit is thick enough for removal the cathodes are taken out and replaced by new ones. The electromotive force required for the deposition of copper from a cupreous chloride or a ferrous sulphate solution by electrolysis is theoretically about 0.5 volt and practically 0.6 to 0.8 volt. From a copper sulphate solution one ampère precipitates per hour not more than 1.18 gram of copper, while from a cupreous chloride solution one ampère-hour precipitates twice the quantity, because one molecule of cupreous chloride contains double as much copper as one molecule of sulphate of copper. With 0.6 volt one horse-power produces per twenty-four hours as much as 60 kilograms, or 133 lbs., of copper. This is, of course, the case only when comparatively large cathode surfaces are used. These in European practice are generally about 1 sq. meter per 25 ampères, or about 1 sq. ft. per 3 ampères.

If steam-power should be very expensive, as it is in some parts of the United States, it is advisable to use large surfaces of cathodes and to electrolyze with low voltage. On the other hand, where power and fuel are cheap, it will be better to run with higher voltage and greater density of current and thereby save considerable in cost of plant. My process allows a tenfold density of the current which is generally used in Europe, and this not considering that with the cupric sulphate electrolyte only 1.18 gram of copper is precipitated per ampère, while with the cuprous chloride 2.36 grams per ampère are deposited. American refiners frequently run 10 ampères per square foot, instead of 2 to 3, as in Europe; but even compared with American practice this chloride process can precipitate five or six times the quantity per square foot. Another advantage is that it extracts the copper directly from the ores, or low grade of mattes. For lixiviation I make use of revolving drums constructed of wood or stone, analogous to the revolving roasting furnaces so largely used in the United States. Such drums do not require much power. The electrolytic baths consist of wood, stone, or any other suitable material. Their partition construction permits a perfect and independent circulation of the solution essential to this process. The anodes are insoluble, and of such composition and quality that they will last many years. Siemens & Halske, in their analogous sulphate process, claim that the depreciation of the carbon anodes does not amount to more than 10% a year. In a chloride of copper solution these anodes are even less liable to such a depreciation, owing to the fact that chlorine does not combine with carbon.

The residue is sometimes valuable on account of its gold contents or its free sulphur. In the former case the residue should be roasted alone, or with the addition of salt, and then lixiviated with a chloride solution containing free chlorine. Large quantities of limestone or iron carbonate in the ore interfere with the leaching process.

I do not believe that there is a better or cheaper electrolytic process than my own for all localities where fuel and labor are expensive and where it is desirable to produce pure copper directly from the ores or mattes. The following calculations show this: One horse-power in low voltage baths can produce up to 60 kilos of pure copper per day. Assume an ore containing 5% copper and a steam engine of 100 horse-power consuming 125 kilos of coal and evaporating 1000 kilos of water per hour. This is equivalent to 3 tons coal per twenty-four hours and $800 \times 24 = 19{,}200$ kilos of waste steam, which is certainly sufficient to heat the leaching solution. Assuming a daily production of 4000 kilos copper, then 70 tons of cupric chloride solution would be required for its extraction. For pumping and raising the solution, residue, mud, etc., not more than 6 horse-power per twenty-four hours will be required; the power necessary for driving the revolving drums for agitating the solution will be about 8 horse-power per twenty-four hours, or a total of 14 horse-power will be required for continuous lixiviation during twenty-four hours. Now there are 100 horse-power at our disposal, and we have left 86 horse-power for the electrolytic production of 4000 kilos or 4 metric tons of copper. As with 1 horse-power we can produce 60 kilos of copper per day, therefore with 86 horse-power we can deposit $86 \times 60 = 5160$ kilos, or certainly 4000 kilos. These figures prove that four tons of copper can be produced with three tons of coal, or, with a fair allowance, *one ton of copper from one ton of coal.*

From the above it will be seen that my process has the following merits and advantages:

In most cases, it does not require roasting, smelting, or concentrating of ores or mattes. It requires small quantities of fuel. It requires but little labor. It extracts all the economic metals from the ore or matte. It produces twice as much copper with the same quantity of current as does the sulphate solution. It enables the application of greater density of current, producing many times more copper per given surface of cathodes than with a sulphate solution, and thereby produces pure copper in a much shorter time. It does away with many difficulties of the usual electrolytical refining processes and preserves both the anodes and the purity of the electrolyte.

Present Practice in Copper Concentration and Extraction.

By Titus Ulke.

In treating of modern smelting methods a description will be given of those now practiced in Arizona, Colorado, Montana, Mansfeld (Germany), and Swansea (Wales), and of the wet methods of copper extraction employed at Argentine, Kan., and Rio Tinto, Spain.

In the Lake regions of Michigan the mechanical concentration of crushed ore has been carried on with the greatest financial economy. The ores of native copper are so lean (averaging from 0.5% to 5% copper) that in order to be profitable the treatment must be automatic and great quantities of ore handled. Hence large volumes of water are used to carry the crushed material through the grating of the steam stamps to the jigs, and to transport the intermediate and final products of the concentrators to their destination without handling. The steam stamp used is of the improved Ball pattern, and will crush daily from 275 to 325 tons of ore from a maximum size of 3 in. diameter down to a maximum of $\frac{3}{16}$ in. It consists of an 18 to 20 in. steam cylinder, with a 24 to 30 in. stroke, moving the reciprocating stamp head, and a mortar with four discharge gates, built on a rigid iron foundation. It occupies small space in proportion to the work it does, and its wearing parts can readily be replaced. The stamp discharges the ore through screens, with perforations $\frac{3}{16}$ in. diameter, to hydraulic separators, and thence to jigs and rotary slime tables. The only middlings produced are in re-jigging the overflow from the coarse jigs, which make the richest concentrates. The middling heads that are thus separated by re-jigging from waste tailings are sent back to the stamps for recrushing. The jig generally used is of the Collom type, characterized by the fact that the pistons of adjacent compartments receive a sharp stroke from a rocker and are returned to their position by the recoil of a spring. A triple deck rotary table is the accepted slime concentrator in the Lake Mills. At the mill two grades of concentrated products are made, carrying 23% and 84% of metallic copper, respectively. This copper (known as "mineral") is barreled and sent to the smelters at Torch Lake, Lake Linden, or Buffalo for further treatment.

The oxidized ores of copper are frequently sorted, but seldom concentrated. In Arizona, however, concentration of carbonate ores has been carried on for many years at both Clifton and Morenci. The concentrated product is rich, but the loss in tailings heavy. Leaching works have just been erected, primarily to treat these tailings by sulphuric acid, using pig iron to precipitate the copper from the resulting solution.

The Butte sulphide ores are concentrated at the Anaconda works in similar plants to those of Lake Superior. By passing the ore over "grizzlies," and thus screening out the smalls from that which is fed to the stamps, their capacity has been largely increased.

At the Parrott works the copper ores are concentrated with jigs (the coarsest size five-eighths of an inch on sieve, finer sizes through sieve) and Frue vanners from 3% to 12% copper up to nearly pure copper pyrites (34% copper). The tailings are quartz and granite.

Arizona.—The oxidized ores of Arizona consist of carbonates and oxides associated with more or less decomposed sulphides, and average between 7% and 12% copper. All the copper at the Arizona carbonate mines is made by one fusion in water-jacketed cupolas; the matte, which is produced simultaneously in greater or smaller quantity, is generally kiln or heap roasted and added to the ore charge. The products are bars of black copper (94% to 98% copper), slags (1.3% to 2.5% copper), and a small quantity of 60% matte. In some of the works the flue dust is bricked with screened clay ores and added to the charge. The pyritic ores of the Verde mines are heap roasted, matted, and concentrated in converters.

Mr. J. Douglas has prepared the following valuable article upon copper smelting in Arizona:

"The first copper smelting in Arizona was at the Longfellow (Clifton) mine, before the advent of the railroad. At this period the Messrs. Lazinski, who owned and worked the mine, employed brick furnaces, when bricks cost $1 apiece. An experiment at patching a burned-out furnace with a plate of copper proved successful, and then a furnace was built entirely of crude copper plates, cast on the spot, and when in position cooled by a spray of water.

"The next phase in the development was the introduction of clumsy cast-copper boxes, out of which a sectional furnace was built, after the manner of cast-iron water-jacketed lead furnaces. Wrought-iron jackets of a modern type were not introduced until lower freight rates were secured by the passage of the Southern Pacific Railroad through the Territory. Up to that date also, charcoal, brought a distance of nearly 100 miles from the Burro Mountains, was the fuel used. The Longfellow copper was at one period carted a distance of 700 miles to the nearest railroad terminus. From the arrival of the railroad, in 1880, dates the real beginning of extensive copper mining and smelting operations in the Territory. The Copper Queen mine was opened in July of that year. The Detroit company at Clifton commenced producing in the following year. Copper smelting at Globe also dates back to 1881. The Verde mines had been discovered and opened, but their great distance (180 miles) from the nearest railroad prevented their being worked economically.

"The Copper Queen commenced operations with one small 36-in. jacketed furnace, using English coke, imported *via* San Francisco, and smelting a surface ore of such extraordinary richness that for more than six months the furnace yield averaged over 20%. As the mine has attained greater depth and extension the average of the ore has declined, and simultaneously the cost of treatment has declined so as to permit the economical handling of an 8% ore. The metallurgical treatment and appliances have remained unchanged, the only alteration being in the increased size of some of the furnaces. Owing to the exposure of large quantities of sulphureted ore, a modification in the treatment is in contemplation, and a Bessemer plant will probably be added to the direct process plant now in operation.

"This method of making black copper direct is, with very slight modifications, practiced by all the copper companies in southern Arizona, all of whom have yet reserves of oxidized ores to draw upon. The ores as they come from the mine, consisting of carbonates, oxides, and silicates of copper in a gangue carrying more or less oxidized iron and manganese, silica, and alumina, are smelted with coke. The product is a black copper running from 94% to 98%, and a slag carrying from 1.5% to 2.5% of copper. Although settling wells are interposed between the slag tap and the slag pot, the metal in a minutely divided state is carried over and escapes, occasioning in every case a heavy loss. All the establishments make more or less matte, which is tapped with the copper bullion and removed from the pigs after cooling. Where the quantity is sufficiently great, the matte is roasted in stalls and returned to the black copper furnaces.

"The shape of the furnaces in use has been modified at one time and another, but a furnace with sloping sides, round or oval, and without a bosh, is the form which meets general acceptance. At the furnaces of the Old Dominion Company, at Globe, a hot blast is obtained by causing the air to circulate around the crucible in a jacketed compartment, resulting in a notable saving in fuel consumption. The Old Dominion furnaces are also constructed with large square hoods in which the draft is arrested and the dust settles. The Copper Queen and Clifton ores are much more friable and carry a larger proportion of light fines, necessitating the adoption of a more intricate system of dust catchers. At the 'Queen' the larger quantity of fine ore screened from the lump and added to the furnace dust is bricked in a hard brick press, dried, and added to the furnace charge.

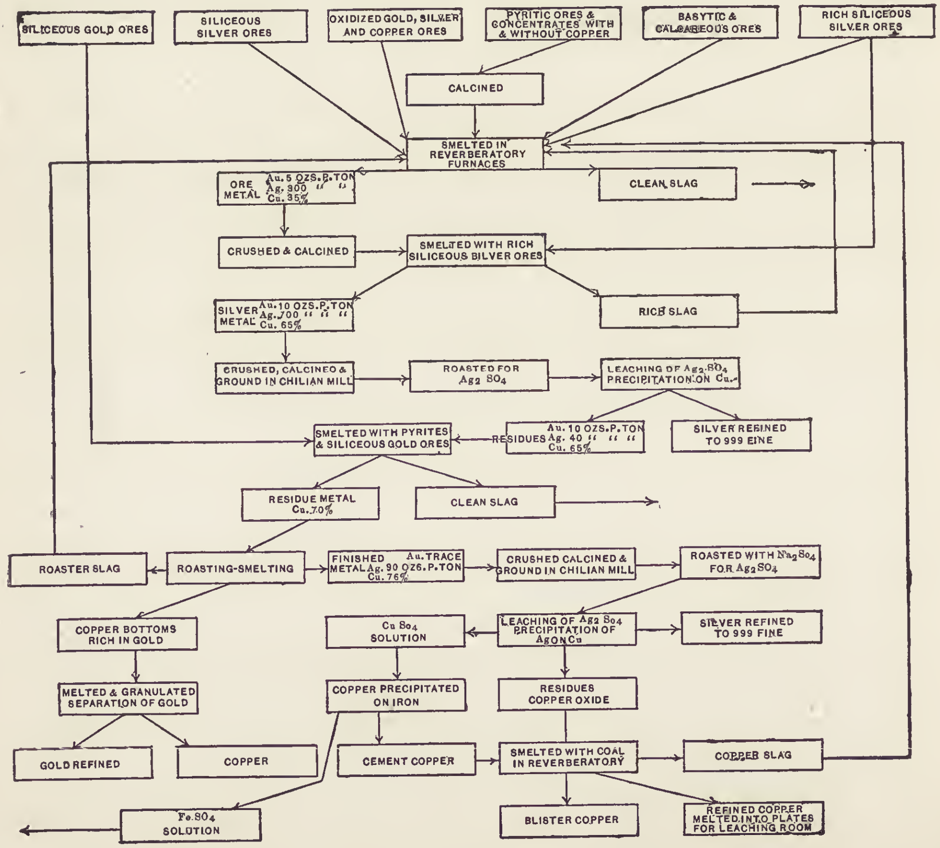
"The fuel used at the several establishments is determined by the condition prevailing at each. The Copper Queen furnaces being in direct communication with a standard-gauge railway and using basic ores, a friable coke high in ash can be used if cheap. The more silicious ores of the Clifton district make high ash undesirable, while the long wagon haul of 140 miles from Wilcox, on the Southern Pacific, to Globe, prohibits the use of any but the strongest and purest cokes. Among the higher grades of coke the choice seems to lie among those of Connellsville and West Virginia, which are used altogether at Globe and generally at Clifton, while the impure and friable cokes of Colorado and New Mexico have found a market in Bisbee because of their cheapness.

"The coke consumption is generally high, seldom falling below 1 of coke to 7 of ore. At the Copper Queen works no flux is added to the charge, silicious and basic ores being available for mixture in proper proportions, but the high percentage of alumina in the furnace charge not only makes the charge refractory, but the slags impure. Both at Globe and Clifton, the ores being silicious, from 15% to 30% of lime and iron have to be added to the furnace charge. From the very diverse conditions under which the mines are operated,—those of the Copper Queen being coupled with the standard-gauge railroad system of the country, those of Clifton connected with the standard gauge by a narrow-gauge railroad, and those of Globe subjected to the heavy cost of 140 miles of haulage,—it follows that the percentage of the ore which can be treated profitably at the different establishments varies greatly, and affords no criterion of what the actual average of the mines is, nor yet of the grade to which the ores could be selected.

"During the past year the Arizona Copper Company has erected works to leach the tailings from its jigs. Concentration of carbonate ores has been carried on for many years at both Clifton and Morenci, and while the concentrated product is rich the loss in the tailings is heavy. The leaching works have been erected primarily to treat these tailings at the rate of 100 tons per day, but sooner or later leaching will be applied to the treatment of the very large quantity of low-grade silicious ores which abound in Clifton and other copper districts in the southwestern part of the Territory. At Clifton acid is made from the sulphureted copper ores of the district in a plant with a capacity of 10 tons of pure sulphuric acid per day. The precipitant for the leached copper is pig iron. The only large copper producer in either the middle or northern section of the Territory continues to be the Verde mines, where during the past year there has been erected a Bessemer plant.

"In 1893 the only notable event in the copper industry in Arizona has been the introduction of this leaching plant at Clifton, which is applied to extracting copper from the tailings of the concentrator. The result of concentrating the carbonates of Arizona is a high concentrate and very rich tailings, which, being crushed, are admirably suited for the wet process. A Bessemer plant has been ordered for Bisbee, not because the carbonate ores show any signs of exhaustion, but in order to handle the large reserves of sulphureted ores which have been exposed of late years."

Colorado.—The Boston and Colorado Smelting Company has kindly furnished the following diagram showing the sequence of operations employed at its Argo works :



In the Argo process the residues from the Ziervogel leaching contain considerable silver (50 oz.) and are resmelted with auriferous pyrites (Gilpen County tailings) for gold bottoms.

In "bottom smelting," according to Professor Sadtler, all the gold and part of the silver is concentrated from 20 tons of matte (or 400 tons of ore) into one ton of bottoms. The matte in this process is first roasted, then melted, and just enough Gilpin pyrites (50% S) added to matte or saturate nineteen-twentieths of the copper present. The bath is then stirred vigorously and puddled. The impurities, such as lead, and all the gold, settle to the bottom with the metallic copper, and the supernatant matte is roasted with sodium sulphate and leached for silver. Part of the residue, desilverized black oxide of copper, is made into copper bars, and part is used in the form of powder to refine and remove the odor from petroleum. The method employed for the extraction of the gold from the copper bottoms is still a secret.

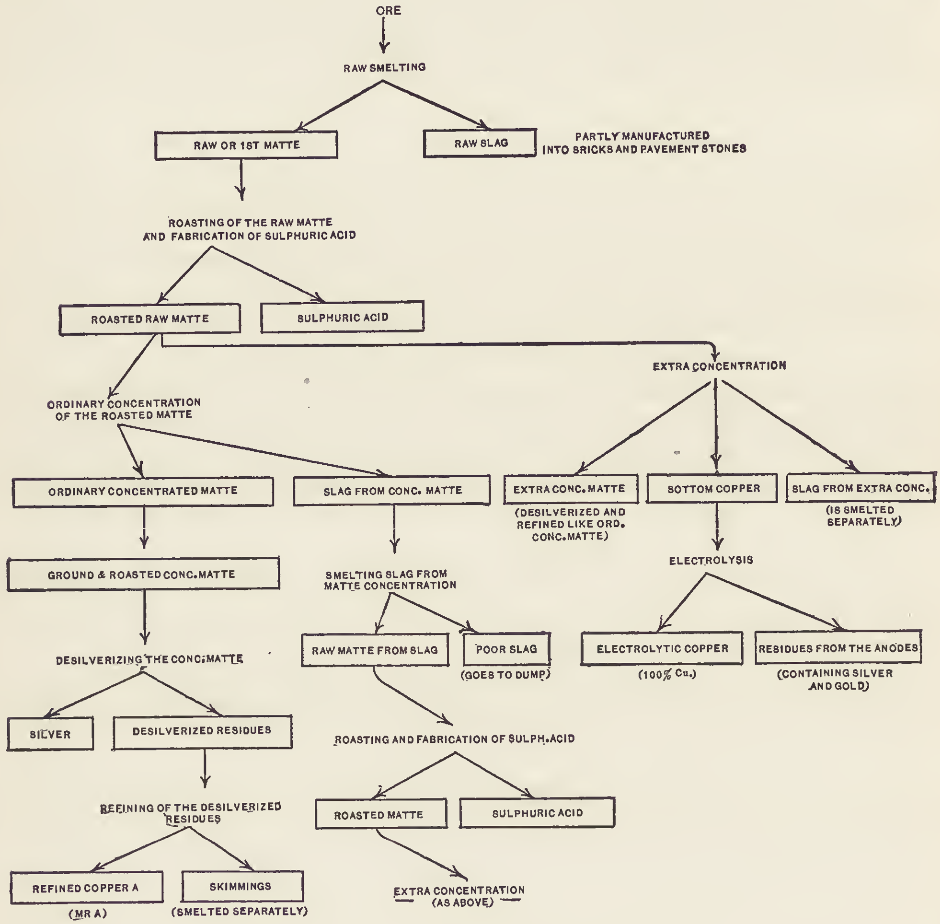
At the Pueblo Smelting Company's copper works in Colorado a method for desilverizing matte, patented by John Crook,has been carried into practice. The steps of Crook's method, according to Prof. J. Douglas, are as follows : 1. The ground matte is repeatedly immersed in a bath of lead maintained at a temperature below the fusing point of the matte, which dissolves a very large percentage of the precious metals. 2. The matte is skimmed from the lead bath and submitted to so-called scorification on the hearth of a reverberatory. The excess of lead flows off, and the volatile constituents of the matte are so thoroughly driven off that from a very arsenical, antimonial matte excellent copper is made, and with the iron is reduced to a sponge. 3. This sponge is fused with silica, and copper separates.

About two years ago the Pueblo Smelting and Refining Company was using four furnaces, and about two tons of concentrated matte, averaging from 50% to 60% copper, were added to 20 tons of molten lead. Most of the silver was taken out in the first furnace and then the matte was taken off and passed to the second furnace, where it was still further desilverized and treated. When the bullion in the first furnace assayed high enough, it was tapped. The matte from the fourth furnace was desilverized down to two ounces silver per ton.

Mansfeld.—The Mansfeld Copper Company works a bituminous shale or slate, carrying finely disseminated copper and silver ore, that forms a regular bedded deposit underlying a large part of central Germany. Profitable mining, however, is possible only in those regions where the copper slate carries sufficient silver besides the average of 2% to 3% copper, as in the vicinity of Eisleben. There the copper slate mined is only four inches from floor to roof, and carries about 3% copper and 0.018% (5.2 oz. per ton) silver. It is heap roasted, and then smelted down to matte in blast furnaces, of which there are twenty-four.

The further treatment takes place in kilns and roasting furnaces, of which the company has 128 and 23, respectively. The different steps in the process are made clear by the annexed diagram, which was prepared from one in the German metallurgical exhibit of the Chicago Exposition. The analyses were obtained from the same official source.

Montana.—At the Parrott Company's works at Butte the ores are roasted in stalls and hearths from 38% to 40% down to 5%s. Spence furnaces of large capacity, improved by Mr. H. Keller, the superintendent, are now being erected, and will probably effect a saving in the cost of roasting over the old pattern furnaces. Ores with but 10% to 12% copper are seldom roasted. The coarse ore is smelted in Rachette furnaces with twelve tuyères (in which very little lime and 7.5% to 8% of fuel are added to the charge), and the fine ore in English reverberatories, in which silicious ores are used to slag off the iron.



ANALYSES OF ORE AND SMELTING PRODUCTS.

Copper Slate.		First, or Raw, Matte.		Ordinary Concentrated Matte.	Extra Concentrated Matte.
Copper	2.90	Copper	40.550	74.600	78.200
Silver	0 016	Silver	0.252	0.465	0.472
Silica	33.15	Lead	0.735	0.580	0.381
Lime	14.39	Iron	25.698	2.323	0.476
Magnesia	2.32	Manganese	0.755	0.018	0.010
Alumina	12.90	Zinc	4.260	0.625	0.273
Iron	3 31	Nickel	0.330	0.442	0.348
Sulphur	2.15	Cobalt	0.210	0.108	0.058
Carbonic acid	10.47	Sulphur	26.053	20.773	19.677
Bitumen	9.89				

Refined Copper : Copper, 99.75% to 99.80%; silver, 0.026% = 8 oz. per ton. Production in 1891 : 15,366 tons (1000 kilograms) copper, 80,512 kilograms fine silver, and 18,275 tons sulphuric acid of 50° B.

At the Parrott works there are six converters. The diameter inside the new lining is 24 to 30 in., and 18 tuyère openings are provided. The capacity of each converter at first is 0.8 ton, but increases as the lining wears off to about 4 tons of 55% matte. Each one lasts from seventeen to twenty-four hours. Matte from 45% to 65% copper (averaging about 55%) from the blast furnace and reverberatories is first remelted in cupolas and then run into the converter. The wind is turned on from half to three-quarters of an hour, the slag skimmed off, the converter heated again, and its contents poured into ingot molds. This concentrates the matte from 55% to 98% or 99.5% copper, which is shipped to the refinery at Bridgeport, Conn.

At the Butte and Boston smelter Rachette furnaces are employed. No. 1 puts through 80 to 85 tons in twenty-four hours, collects the matte in the furnace, and, it is claimed, makes a higher grade matte as the tuyères blow on it. No. 2, a large furnace, puts through 100 to 140 tons and collects the matte in a forehearth, from which it is tapped. The calcining is done in eight Allen-O'Hara roasting furnaces, which handle 30 to 40 tons in twenty-four hours, from 38% to 40% sulphur down to 6%. One stack is provided for two or three furnaces. Automatic rakes, which run on two or three tracks, are used. Wood is used for fuel.

Maryland.—The Baltimore Copper Smelting and Rolling Company works Anaconda mattes, copper carbonate ore from Arizona, glance sulphide from Texas and Montana, and sulphurets from Vermont, producing the following products: Copper matte (60% copper) from Anaconda, Mont.; copper slag (8% copper), resulting from smelting this matte; "rigole" (80% copper), resulting from smelting roasted Anaconda matte; blister copper (98% copper), resulting from smelting rigole; low-grade matte (45% to 50% copper), resulting from cupola-smelting slags produced during all the matte-refining operations; cupola slag, resulting from smelting slags produced during all the operations of refining copper mattes (this slag is thrown away).

Copper matte from the Anaconda works, averaging 60% copper and 22% sulphur, is pulverized and roasted in a one-hearth reverberatory, in which 6% to 8% of the sulphur is driven off, the charge being six tons every twelve hours. It is then sent to another reverberatory, where it is made into regulus or rigole copper (averaging 82% copper). Generally 150 lbs. of oyster shells, which are the cheapest form of lime obtainable at the works, are added to the charge. The product (rigole) is now charged in the form of pig to another reverberatory, melted slowly so that the copper dripping down may be freed from sulphur by the oxidizing blast, and the iron silicate skimmed off as slag. The product of this furnace is 96% to 98% blister copper. This was formerly refined and poled in reverberatories and 99.8% copper, containing 60 oz. silver per ton, obtained as the product. A 30-ton cupola furnace with eight tuyères is used to work up the slag, the charge being 5% lime (oyster shells), 8% pyrites of copper or iron, and 10% coke.

All the blister copper now produced is either dissolved in dilute sulphuric acid, so as to leave the gold and silver in the residue, or is refined electrolytically. In the former case the molten copper is poured into warm water to hollow-granulate it, that best adapted for the purpose containing less than 99% copper and a certain percentage of impurities. The silver mud settles from the copper vitriol solution and is refined separately.

In the electrolytic process the anodes are cast of blister copper 1¼ in. thick and supported by lugs of phosphor-bronze. The cathodes are thin skins of pure copper, obtained by electro-deposition, and are hung on copper rods resting on heavy 2-in. copper conductors. The electrolyte, which must be kept in circulation, is fed near the bottom of the tank and overflows at the top. The tank itself is constructed of wood, lined with lead, which is itself protected from injury by wooden boards soaked in paraffine. Slate tanks are also used, but are very expensive. The solution, when it becomes too impure, is delivered to the blue vitriol works, where the copper in it is extracted and its acid utilized.

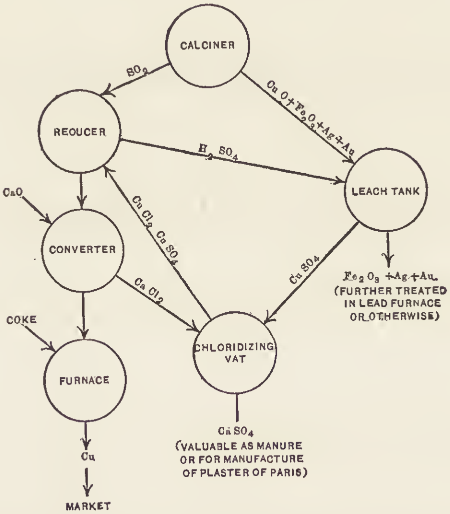
The silver mud, which carries much metallic copper, is treated by the Whitehead process, consisting in adding a certain quantity of silver sulphate and dilute sulphuric acid to the slimes, when a reaction takes place which results in the solution of metallic copper and the precipitation of an equivalent quantity of silver. The latter is then thoroughly washed to free it from copper sulphate, melted, and cast into bars for parting.

Swansea.—As stated by Mr. Roberts-Austin, the smelting methods in use at Swansea, the chief center of the copper industry of the United Kingdom, have undergone considerable modification in recent years, mainly because the importation of copper in the form of ore has to a great extent been replaced by copper regulus, which is frequently highly argentiferous. The changes introduced consist in a diminution of the number of fusions and "calcinations," combined with a mixed cupola-reverberatory treatment. The cupolas have in many instances external "wells" in which the regulus and slag resulting from the fusion of the charge are able to separate completely from each other before the former is finally tapped. In another modification of the ordinary Welsh process, rapidity of output has been secured by a method in which low-grade regulus is concentrated by fusion with a portion of the same regulus which had been previously roasted or "calcined." The slags produced in this method are added to the cuploa charge.

The collection of the silver contained in the regulus has in recent years been effected mainly by electrolytic methods, though the ordinary Augustine and Ziervogel processes are still in use in South Wales. In the electrolytic process either the whole of the coarse copper is refined direct or else auriferous and argentiferous "bottoms" are produced, which are subsequently refined electrolytically. Another process for the treatment of these "bottoms," for the manufacture of copper sulphate, consists in dissolving them in sulphuric acid, with the aid of steam, the gold and silver remaining undissolved in the resulting mud, as in the electrolytic process. At another works the bottoms are hollow-granulated, roasted to oxide, and then treated by a mixed Ziervogel-Augustine process, the auriferous residues remaining after leaching being returned again to the copper-smelting furnaces until they are sufficiently rich in gold to pay for the extraction of that metal.

Wet Extraction of Copper: The Hunt-Douglas Process.—The Kansas City Smelting and Refining Company is extracting copper from silver-lead mattes by the Hunt-Douglas method. The company prefers to work matte of at least 25% to 30% copper, not more than 15% lead, and not over 300 oz. in silver and gold. The finely pulverized matte is roasted at a very low temperature, so that copper sulphate and copper oxide result without forming silver sulphate. The roasted matte, still containing from 8% to 12% sulphur, is leached with a solution of 10% of sulphuric acid, and the resulting copper sulphate filtered from the insoluble lead, silver, and gold of the matte. The further treatment, according to Professor Douglas, depends on the action of sulphurous acid on copper sulphate, in solution with sufficient chlorine to produce cuprous chloride. The "chloridizing" by which cupric chloride is formed is at present effected by means of common salt, but it is intended to use the calcium chloride resulting in the course of a subsequent process.

Cuprous chloride, insoluble except in a strong chloride solution, readily separates on the injection of sulphurous acid gas from a roasting furnace. If the gas be not diluted by too much air, acid is generated in excess of the equivalent quantity due to the unavoidable, and in this case desirable, presence of some free oxygen in the gases. The subchloride is reduced by milk of lime to suboxide, and the chlorine recovered as chloride of calcium. The precious metals which remain with the iron oxide in the matte residues are best treated in a lead furnace. The following diagram, prepared from data furnished by Professor Douglas, illustrates these processes and the reactions which take place.



Rio Tinto.—At Rio Tinto, Spain, the combined wet and dry processes for treatment of low-grade copper ore which contains very small quantities of silver is employed.

The ores of Rio Tinto are sorted into six classes: 1. Rich coarse ore. 2. Poor coarse ore. 3. Fines. 4. Export ore. (About one-third of the product of the mines.) 5. Smelting ore. (Containing from 7% to 8% copper. This is smelted in blast furnaces and the matte is shipped to Swansea.) 6. Ore containing considerable quantities of copper, lead, and silver.

The rich ore is first sorted and part sent to the blast furnaces to be worked into matte and shipped, while the rest is roasted in open piles or "tileras," with the addition of 2% salt. This salt-roasted ore is then subjected to a leaching process, the result of which is a residue still containing about 25% of the copper in the original ore (subsequently treated in "torreras"), and a solution called "brown liquor," which, after the copper has been separated from it by iron, is again used to dissolve copper from the fine ores.

The fine ore was until recently treated by Doetsch's process. The ore, mixed with one-half of one per cent. of common salt and a like quantity of persulphate of iron, was built up into large heaps and a solution of perchloride of iron run in a continuous stream upon it. The solution, passing off at the foot of the heap, contained chloride of copper and protochloride of iron. After precipitation of the copper with scrap iron, the solution of protochloride of iron was run down a brick tower, packed with firebrick, and perchloridized by an ascending current of chlorine generated from a mixture of common salt and persulphate of iron in a furnace. The solution was now used over again. The fines treated by this process contained about 2.6% copper, 50% of which dissolved out in four months and 80% in two years. The iron pyrites remained unacted upon, and the sulphur contents of the leached ore was not sensibly decreased. This method was very slow and much chlorine was lost as oxychloride.

At the present time the fine ore is treated in large leaching tanks with the "brown liquor." According to H. M. Howe the following reactions take place : $Fe_2Cl_6 + CuS = 2FeCl_2 + CuCl_2 + S$; $Fe_2Cl_6 + Cu_2S = 2FeCl_2 + Cu_2Cl_2 + S$.

The copper in the resulting liquors is precipitated with scrap iron and the final liquor thrown away. The residue, still containing copper owing to imperfect extraction by the previous leaching, is taken to the "torreras" and built up with the poor coarse ore.

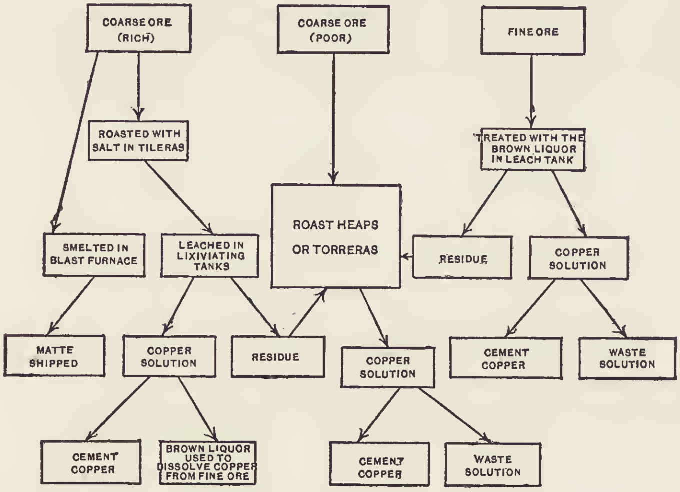
These "torreras" are a prominent feature of the ore treatment at Rio Tinto. The poor coarse ore is built up into the form of large cones 10 to 15 ft. in height and about 20 to 30 ft. apart. A fire is then lighted in each of these and the mixed lump and fine ore filled in between them. The gas produced by combustion mixes with the steam generated by heating the moistened mass and permeates the whole heap of ore, amounting to some 4,000,000 tons. After burning from four to six months, water is turned on the "torreras," dissolving out the copper sulphate. This percolating process continues for about five years; the liquor being caught below in dams, or large reservoirs built of masonry, and the copper precipitated by scrap iron.

When the liquors become too poor in copper, the piles are torn down and again built into "torreras" at the lower works (about five miles distant from the mines and upper works), where it is slowly leached for an indefinite number of years. At the present time at both works there are upward of 10,000,000 tons under treatment.

The cement copper obtained from all the previous operations is washed and concentrated on buddles and classified according to the percentage in copper and arsenic, the higher grades being shipped to England and run down with mattes, while the lower are smelted at the mines with first-class ore.

The annexed diagram has been prepared from data furnished by Mr. W. Douglas, and illustrates graphically the above described steps in the Rio Tinto ore treatment.

The Henderson-Claudet process, largely used in Great Britain for handling Rio Tinto ore and cinder, consists in chloridizing the copper and silver by roasting with common salt, dissolving the chlorides out with hot water, precipitating the silver as iodide and then the copper with metallic iron. There are five different stages in the process, namely: 1. Crushing the ore and mixing with salt. 2. Calcining or roasting. 3. Leaching. 4. Precipitating the silver from the argentiferous copper liquors. 5. Precipitating copper from the desilverized liquors.



The roasted ore (cinder) is mixed with 13% to 20% of salt and the mixture calcined in muffle furnaces. The muffle is connected with a condensing tower, built of firebrick and packed with bricks and coke, over which a stream of water is kept running to condense the acid gases evolved from the furnace mixture. The acid solution, running off at the bottom of the tower, is used to dissolve the oxide of copper out of roasted ore, as described later. The object in the calcination is to oxidize sulphur and chloridize the silver and copper (or rather to render all the copper soluble with the least possible expenditure of acid in leaching). About 77% of the calcined ore is soluble in water (*i. e.*, the copper present as protochloride and a little subchloride), 20% in dilute acid (the copper present as oxide), and the remainder, 3%, is unchanged copper sulphide. The heat of the furnace is not allowed to exceed a dull red, or else the protochloride is decomposed.

The calcined ore, while still quite hot, is taken to the leaching tanks. These are built of wood, and about 10 ft. square and 5½ ft. deep. Each tank holds 20 tons of calcined ore, which rests on a false bottom, on which a rough sort of filter is formed of screened furnace ashes. The ore is first washed with weak liquors from a previous operation, then with the acid solution from the condensing tower, and finally with hot water. Only the first (strong) liquors are run to the Claudet tanks, the weak liquors being used as first washings for another tank of ore. The residual ore is thrown out of the leaching tanks, and after draining is ready for shipping as purple iron ore, used as a fix in puddling furnaces.

The Claudet process of precipitating silver consists in first ascertaining the amount contained in the copper liquor (it averages 3 to 6 grains of silver per gallon and from 0.2 to 0.7 lb. of copper) and passing it, together with a slight excess of an iodode of zinc solution, into the "Claudet tanks," which are usually circular and of about 3500 gallons' capacity. The zinc iodide is of such strength that 1 gallon precipitates 500 grains silver. The reaction is $2AgCl + ZnI_2 = 2AgI + ZnCl_2$. The liquor is allowed to settle for forty-eight hours, and, being desilverized, is run off into the copper precipitating tank.

The precipitated iodide of silver accumulates in the Claudet tank for about a month, at the end of which time it is swept into another vat, and, after washing with dilute acid and water, is digested with scrap zinc, when the following reaction occurs: $2AgI + Zn = ZnI_2 + 2Ag$. The iodide of zinc thus regenerated is dissolved out and used again for precipitating silver from fresh liquors. The silver residue, consisting of metallic silver mixed with a little gold and considerable sulphate of lead, etc., is sold to silver refiners.

The desilverized copper liquors are precipitated with scrap iron, in wooden vats, the solution being kept at a temperature of from 150° to 170° F. by the use of steam. The copper in the first liquor admitted is precipitated in three or four hours, each subsequent liquor taking a longer time. When the iron is so enveloped in copper that about twenty-four hours are required to throw down the copper from a fresh liquor, the tank is cleaned out. When dried the precipitate contains 75%, or more, of metallic copper. The iron required for precipitating is about 110% of the copper.

Comparison of the Wet Process with Smelting.—The cost of the whole wet process, Mr. Martyn states, is about $7 per short ton of cinder, containing 4% copper. The cost of smelting a similar grade of cinder (assuming it to be silicious enough to flux itself) and producing a 75% matte will not exceed $2.25 per ton, but the amount of copper recovered by smelting will only be about 3.1%, against 3.7% by the wet process, and the silver (amounting to, say, $1, or even more, per ton) which is recovered in the wet process has smaller commercial value in the matte. The value of the purple ore obtained in the wet process must also be taken into account. On the other hand, the cost of a wet-extraction plant is fully four times as great as a smelting plant, and requires four times as much ground space. But a silicious cinder cannot be advantageously treated by the wet process unless it contains about 3 oz. silver per ton, nor a highly basic cinder by the dry process unless a cheap flux is at hand. W. Roberts-Austen states that there is still required a satisfactory modification of the above wet method, admitting the collection of more gold than is now extracted from the roasted pyrites residues.

COPPERAS.

Copperas, or green vitriol ($FeSO_4+7H_2O$), is met with in the trade in the form of green crystals, which have an astringent taste and on exposure to the air effloresce, being gradually converted into a yellow powder, basic sulphate of iron. The pure crystallized copperas contains 26.1% ferrous oxide, 29.90% sulphuric acid, and 44% water. It is frequently found native, resulting from the oxidation of pyrites, and often forms deposits of considerable extent analogous to the alum clays. Such occurrences are numerous in the far West, especially in California, where the mineral has been found in abundance at Sulphur Bank, in Lake County, and in the vicinity of Santa Cruz, in the county of the same name. The opinion has been expressed * that copperas might be recovered industrially from both these places, but as there would be no profit in this at the existing prices for the substance and under the high transportation rates which now prevail in California, no enterprise of the kind has yet been undertaken.

The copperas of commerce is entirely an artificial product. It was formerly made in some works as a principal product, but the competition of those making it as a by-product drove most of the others out of business years ago, only one concern (the Steubenville Copperas Works of Ohio), which has cheap fuel and pure pyrites, being engaged in the manufacture by oxidizing pyrites.

Copperas is saved as a by-product chiefly in sulphuric acid works, alum works, and wire and galvanizing works, etc., where sulphuric acid is used. In some sulphuric acid works the chamber acid is freed from the arsenic which it may contain as an impurity by precipitation with sulphureted hydrogen, the gas being obtained by decomposing pyrites with sulphuric acid. The solution of ferrous sulphate drained from the generators is neutralized with scrap iron and evaporated until the salt begins to crystallize. No copperas is made in the United States in this manner.

The alum schists, or clays, which are used for the manufacture of alum, generally contain pyrite (FeS_2) or basic ferric sulphate, which are partly converted into ferrous sulphate in the treatment of the material and dissolved with the alum. The green vitriol or copperas is obtained by evaporating the mother liquor containing iron and leaving it to crystallize. No copperas is won in this country, however, by this method.

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* *Sixth Annual Report California State Mineralogist*, 1885–86, p. 104.

In wire-drawing the metal becomes covered by a coat of oxide in the annealing, and this has to be removed before further drawing. To effect this the wire is pickled in dilute sulphuric acid, one to three parts acid (60°B.) to 100 parts water, for thirty-five or forty minutes at 38° C. (101° F.), from 47.6 to 65 lbs. of acid being consumed per ton of wire.* The waste acid is neutralized with scrap iron and the ferrous sulphate is recovered by crystallization, while the mother liquors are sometimes evaporated and the residue roasted, yielding colcothar (ferric oxide). The waste acid from galvanizing and tin-plate mills is utilized in the same manner. In many small works, however, the waste solution of ferrous sulphate is allowed to escape, as the cost of recovering it in very small quantities would not pay.

Copperas is used as a disinfectant; as a mordant in dyeing and calico printing for various black and brown shades; for the preparation of ink, prussian blue, and painters' colors; for the precipitation of gold from its solutions; for the preparation of fuming (Nordhausen) sulphuric acid; and for a host of other purposes.

About 25% of the whole make is employed for the preparation of venetian red, of which 4205 tons (2000 lbs.), valued at $89,335, were made in 1892, and 3830 tons, valued at $81,475, in 1893. The entire copperas product of one of the largest makers is used for this purpose. The production of copperas in 1892 was 13,250 tons (2000 lbs.), valued at $107,772, against 16,000 tons, valued at $95,440, in 1893. The increase in make was due chiefly to one new concern which engaged in the business in 1893. The average price of copperas in 1893 was about 60c. per cwt., or $12 per ton.

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* *Stahl und Eisen*, VI., p. 182, 1886; p. 14, 1886. *Howe's Metallurgy of Steel*, 1890, p. 221.

CRYOLITE.

Cryolite is a light mineral of vitreous luster, sometimes appearing slightly pearly on certain crystal planes. In color it is usually snow-white, but occasionally it is reddish or brownish-white, possibly brick red, and even black. It is subtransparent or translucent, the transparency being increased by immersion in water. Chemically it is a double fluoride of sodium and aluminum ($6NaF + Al_2F_6$), containing 13% aluminum, 32.8% sodium, and 54.2% fluorine. It is fusible in the flame of a candle. It is readily distinguished from other minerals by its extreme fusibility, and also by the fact that when heated in the open tube before the blow-pipe it gives off hydrofluoric acid, etching the glass.

Cryolite is found at only a few places in the world, and in most of these the occurrence is solely of mineralogical interest, its single commercial source being the mine at Ivigtûk, in South Greenland. Comparatively small quantities have been found at Miask, in the Ural Mountains, between Russia and Siberia, but their remoteness from the great centers of the chemical industry would limit their importance even if the supply of mineral were abundant. No workable deposits of cryolite have yet been discovered in the United States, though small veins have been found at and near Pike's Peak, in Colorado, and one of these was exploited to a small extent several years ago by the Home Mining Company, which owned the property. It was proved, however, that the vein was of no economic importance, and, like the others in the neighborhood, was only of interest mineralogically.

The great deposit at Ivigtûk has long been known, having been originally discovered by the Esquimaux. The name cryolite indeed is derived from two Greek words signifying ice-stone, and was given it on account of its resemblance to ice, the Esquimaux, who showed it, stating that they had found a kind of ice which would not melt in summer. Up to 1849, however, the mineral was found only in scientific collections, but in that year Prof. Julius Thomsen of Copenhagen showed its applicability to the manufacture of soda, and in 1854 obtained an exclusive right for thirty years to mine and use it in Denmark, this concession being subsequently acquired by a company, which erected a factory at Copenhagen in 1857, and later a larger one, still in existence, at Oeresund. In 1865 the Pennsylvania Salt Manufacturing Company, with works at Natrona, on the Western Pennsylvania Railroad, a short distance east of Pittsburg, obtained the right to two-thirds of all the mineral produced. Since that time the cryolite-soda industry has been in the hands of the Oeresund works in Denmark and the Natrona works in the United States.

The Ivigtûk deposit occurs in latitude 61° 13′ and longitude 48° 10′ W., on the west coast of Greenland, between the two principal Danish colonies of Julianshaab and Frederickhaab, on the Arksuk Fiord—one of the deep, rocky, winding inlets which cut into this dismal coast. The shore rises from the water's edge almost perpendicularly to the height of 1000 ft., and then recedes, forming a plateau, until it rises again to form the mountain chains of the interior. The coast is so precipitous that vessels fastened to the land by the bow have scarcely soundings at the stern, the anchorage being almost entirely by making fast to rings in the granite rocks of the shore. The mine or quarry is situated so near the shore that the mineral is loaded directly into vessels.

During the winter months the fiord is frozen over, and shipments are necessarily interrupted. From the last months of spring, however, until October, the climate of this part of Greenland is generally pleasant, the temperature sometimes rising to 80° F., and, the seas being comparatively open, vessels do not usually have difficulty in entering the fiord.

The cryolite occurs in a great bed, overlain by granite, dipping under the sea, and is worked as a pit or quarry, which is now about 600 ft. long and 200 ft. wide.* More than a year ago the pit had reached a depth of 185 ft. The method of mining the cryolite was described in THE MINERAL INDUSTRY, Vol. I., p. 166, to which the reader is referred.

The mineral occurs in great snow-white masses, partially transparent and of a vitreous luster. It has a hardness of 2.5, a sp. gr. of 3, and cleaves in three directions. The associated minerals, which reduce its commercial purity to from 80% to 90%, consist chiefly of spathic iron, traces of iron and copper pyrites, galena, and several interesting minerals found only in connection with cryolite, such as pachnolite, thomsenolite, arksudite, geoarksudite, and hagemanite. The contract requires that 90% of all the material shipped shall be cryolite, and some sorting is necessary in order to bring the product to this grade.

Cryolite is used for the preparation of soda salts, the manufacture of certain kinds of porcelain and glass, and as a flux in the electrolytic aluminum processes. Alum, or sulphate of aluminum, is also recovered as a by-product in the manufacture of soda, for which purpose most of the cryolite is consumed.

The method of decomposing the crude mineral is sustantially the same at the Danish and the Pennsylvania works. The mineral having been finely ground, it is mixed with the proper proportion of lime and heated to redness in reverberatory furnaces, with frequent stirring, whereby the double fluoride of sodium and aluminum is decomposed into aluminate of sodium and fluoride of calcium, according to the following reaction:

$$Na_6Al_2Fl_{12}+6CaO=Na_6Al_2O_6+6CaFl_2.$$

Upon being withdrawn from the furnace the charge is allowed to cool, and then as "cryolite ash" is leached in iron vats with hot water. The fluoride of

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* These figures, together with much of the data in this article concerning the occurrence of cryolite in Greenland, are taken from a pamphlet published by the Pennsylvania Salt Manufacturing Company.

calcium being insoluble, it remains as a residue while the aluminate of soda, together with any sodium carbonate or caustic soda which may have been formed, is taken into solution.

The concentrated solution from the vats, which should have a strength from 35° to 40° B., is treated with carbonic acid, obtained by burning lime, or by any other suitable method, whereby the aluminate of sodium is converted into carbonate of sodium, while hydrate of aluminum is precipitated, the reaction being thus expressed:

$$Na_6Al_2O_6+3CO_2+3H_2O=3Na_2CO_3+H_2Al_2O_6.$$

The solution of carbonate of soda is drained into evaporating pans, where it is concentrated to 32° or 36° B., when it is drawn off into vats, where the soda is crystallized out.

There are two by-products obtained in the process. The first is calcium fluoride, which forms the residue remaining from the lixiviation of the cryolite ash. This is sold to smelters, for whom it is valuable as a flux. It is also used in the manufacture of glass for green bottles, increasing its strength and fusibility. The hydrate of alumina, precipitated by the carbonic acid, is washed to remove soda salts, of which, however, it can never be entirely free. The washed hydrate is used for the manufacture of alum, for which purpose it is treated with sulphuric acid in the well-known manner.

In the works at Oeresund the cryolite is crushed so as to pass a sieve with 60 holes per sq. in. (9 holes per sq. centimeter) and mixed with chalk of the same fineness, 1.5 part of chalk being used for one part of cryolite, though of course the proportion varies according to the grade of the mineral. The decomposition is effected at a red heat on hearths 5 meters long and 2.7 meters wide. A charge remains in the furnace for about two hours, and each furnace treats 8000 kilograms per twenty-four hours. The lixiviation is effected in cylindrical iron tubs 2.5 meters high and 1.6 meter in diameter, three of which have a capacity for 3600 kilograms of cryolite in twenty-four hours. These works treat 2000 metric tons of crude mineral (averaging 85% to 90% pure cryolite) per annum, and produce about 3500 metric tons of crystallized sodium carbonate and 300 tons of aluminum hydrate.*

The works of the Pennsylvania Salt Manufacturing Company at Natrona have 12 decomposition furnaces, of about the same size as those at Oeresund. The leaching is carried out in 32 vats. The carbonic acid for converting the soda is obtained by burning lime in kilns, whence it is conducted through 15-inch pipes to a cooler, and is then pumped up through a coke tower 25 ft. high against a descending stream of water, to remove impurities. The soda solution is carbonized in cylinders 60 ft. long and 5 ft. in diameter, lying horizontally with a shaft bearing a number of paddles, or agitators, running through them lengthwise. The soda solution is pumped from the cisterns into these cylinders, and the carbonic acid gas from the tower is forced into them, the liquor being kept in agitation all the while. The gas passes from one cylinder to another until it is entirely absorbed, and the process is continued as long as there is a trace of alumina in the solution. The soda salts made from cryolite are excep-

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* *Berg- und Hüttenmännische Zeitung*, March 3, 1893, Vol. LII., No. 9, p. 69.

tionally pure; the alum obtained as a by-product is also of very high quality, being absolutely free from iron.

A peculiar and beautiful opaque glass, resembling French porcelain, is made from cryolite at a cost far below that of any other method. The process consists in mixing one part of cryolite and two parts of quartz sand with half as much oxide of zinc, which may be of the most impure quality. The resulting ware is extremely hard, and so tough that it may be handled with violence without fear of breaking.

The use of cryolite in the manufacture of aluminum is fully described in the article on that subject in THE MINERAL INDUSTRY, Vol. I., to which the reader is referred. All the cryolite brought into the United States is imported by the Pennsylvania Salt Manufacturing Company, to whose courtesy we are indebted for the following statement of the amount entered for consumption:

Year.	Tons.*	Year.	Tons.*	Year.	Tons.*	Year.	Tons.*	Year.	Tons.*
1877........	9,465	1881..........	7,932	1885..........	9,172	1889..........	9,085	1893........	10,560
1878........	7,070	1882..........	7,089	1886..........	9,190	1890..........	8,062		
1879........	7,172	1883..........	8,113	1887..........	11,534	1891..........	9,783		
1880........	7,690	1884..........	8,810	1888..........	8,180	1892..........	8,081		

* Short tons (2000 lbs.).

FELDSPAR.

By Heinrich Ries.

Commercial feldspar is orthoclase, or common potash feldspar ($KAlSi_3O_8$). Although this is an abundant and widely distributed mineral, it is only in a few localities that it is found of the proper quality, and in sufficient quantity to be of industrial value. In these cases it is usually obtained from veins in granite or pegmatite, which are sometimes due probably to hydrothermal action, and sometimes seem to be of igneous origin. The minerals associated with feldspar are chiefly quartz and mica, while tourmaline and topaz also occur commonly.

The chief sources of feldspar in the United States are quarries at South Glastonbury, Conn., at Brandywine Summit and vicinity in Pennsylvania, and the neighborhood of Newcastle, Del. Important quarries were formerly worked on the Kennebec River near Bath, Me., and at Edgecombe, Lincoln County, in the same State; also at Haddam and Middletown, Conn., and at Peekskill and Bedford Centre, N. Y., but these have not been operated during the past year. A new quarry has recently been opened, however, at Portland, Conn.

Feldspar is employed to a limited extent in the manufacture of glass, but the chief use for it is as a china-glaze and as a glass-forming ingredient in the body of the porcelain. It is prepared for the latter purpose by grinding, together with Cornish-stone and flint, in mills of peculiar construction, and calcining the pulp; ball-clay is then added to the mixture to give it plasticity, after which it is molded and burned. China which is influxed by feldspar is termed "spar-china," and has a yellowish color, like transmitted light. In "bone-china" the feldspar is partly replaced by bone-ash.

When used as a glaze the feldspar is mixed with silicate of lead (PbO_1SiO_2) and carbonate of lime. These are mixed in the grinding vat with a thin slip of pure clay, and the ware is dipped in them, the object of the clay-slip being to keep the heavier substances from settling out. Borax also is sometimes used as an ingredient of the glaze.

The chief centers of the pottery industry in the United States are Trenton, N. J., and East Liverpool, Ohio, whither practically the whole product of feldspar is shipped. The annual consumption of feldspar by the pottery works varies from 15,000 to 20,000 short tons per annum, the value of the mineral being from $5 to $7 per ton delivered on the railroad cars at Trenton.

Ground feldspar in Connecticut and Pennsylvania is worth in large lots $5 to $7 per short ton at mill. Lump varies from $2 to $3, depending upon its purity.

Feldspar is practically the source from which all of the kaolins and fine china clays have been derived. Under the influence of water and carbonic acid with changes of temperature it is decomposed, potassium silicate being leached out, leaving essentially a silicate of aluminum or kaolin. In many places this transition is shown in its various stages, and can be commonly observed in the decomposition of granite or gneiss. Under the subject head "Clay" will be found an exhaustive article treating on this and also upon the use of feldspar as a glaze in the manufacture of porcelain.

The varieties of feldspar known as labradorite and moonstone, which were at one time used to a considerable extent for jewelry, have now little sale other than to mineral collectors.

FLUORSPAR.

By P. L. Fearn.

The fluorspar industry of the United States, which is practically confined to a group of deposits in Hardin County, Illinois, will show for the year 1893, notwithstanding the industrial depression of its last few months, a substantial increase in production, in demand, and in the average price obtained for the product. While fluorspar is found, more or less mixed with other gangue matter, in various parts of the Southern States, in Arizona, New Mexico, Colorado, and California, its economic extraction has been in the past, and probably will be in the future, limited to the large deposits in the vicinity of Rosiclare, Ill. There is little to be said in regard to the geology of this region that has not already been said in the excellent paper on the subject by Mr. S. F. Emmons read at the Baltimore meeting of the American Institute of Mining Engineers in February, 1892, except to add that the views expressed there have to a great extent been confirmed by subsequent work and exploration, both as to the extent and continuity of the veins and the nature of the vein filling. At present the larger part of the marketable fluorspar is taken out quite near the surface. When this is exhausted it is probable that some difficulty will be experienced in obtaining a supply of pure fluorspar, as the percentage of galena, blende, etc., which may be considered as impurities, so far as the fluorspar is concerned, seems to increase sensibly with depth, and these minerals are also more disseminated throughout the vein matter; nor does the utilization of the fluorspar product of the jigs, which also contains more or less sulphides, appear to solve this difficulty. There is, however, a sufficient quantity of pure fluorspar, notably in the practically untouched Blue Diggings, to last for many years, and the presence of the lead sulphide is not considered a detriment, but, on the contrary, a source of additional revenue to the companies operating the mines.

The system of working the fluorspar mines in Hardin County has not been either efficient or economical, and in a number of cases consists of mere makeshifts, rendered necessary by the lack of capital. The vein matter is mined in drifts and open cuts, little attempt at systematic stoping having yet been made. It is brought to the surface in buckets, in many cases lifted by whims or whips. It is sorted by hand into three classes after having been more or less thoroughly washed by playing a hose on it.

The pure spar is used for grinding, and is selected for its white color and freedom from impurities. It is ground usually in a buhr-stone mill, and is used by glass makers, chemical manufacturers, and others. The price of the ground product varies slightly according to its fineness and color. It is difficult to grind, and requires considerable care and skill to produce a uniform grade and prevent clogging. It is probable that experiments would show a more efficient means of grinding than the buhr-stone mill, and it has recently been found that an emery mill gave a much better result as to capacity, but slightly discolored the fluorspar.

The second class of spar, containing more or less galena, blende, calcspar, and limestone country rock, is shipped in barrels or bulk, and used by smelters and foundries as a flux, but has also a number of other uses. Care is taken to keep the percentage of sulphides as low as possible, one per cent. of these impurities very much impairing its value as a flux, and rendering the iron or steel white, hard, and brittle.

The third-class mineral or lead ore is crushed at the mill and run over jigs, where the galena is separated. This is sold to smelters, and forms a considerable portion of the revenue derived from the mines. The proportion of galena, which is now about five per cent. of the whole vein matter, increases as depth is gained on the vein, as has been previously stated, and it is very likely that these mines may in time figure as large lead producers, though their history has thus far been that the lead alone would not pay for the cost of production, and it was not until the fluorspar gangue became marketable that any degree of success in their working was obtained.

The crushed fluorspar that comes over the jigs is marketed at the same price as the second-class spar from the mines. There does not appear to be as clean a separation made as there should be with two minerals of so different specific gravities, but it is very likely that this can be remedied by a little more skill and care on the part of the jigmen.

The production of fluorspar in the United States since 1880 is shown in the following table. The figures for the years previous to 1891 are from the *Mineral Resources of the United States;* those for the last three years are compiled from returns from the producers.

Year.	Amount, Tons of 2000 Lbs.	Value.	Year.	Amount, Tons of 2000 Lbs.	Value.
1880........	4,000	$16,000	1887.........	5,000	$20,000
1881........	4,000	16,000	1888.........	6,000	30,000
1882........	4,000	20,000	1889.........	9,500	45,835
1883.......	4,000	20,000	1890.........	8,250	55,328
1884	4,000	20,000	1891.........	6,320	38,000
1885........	5,000	22,500	1892.........	9,000	54,000
1886........	5,000	22,000	1893.........	9,700	63,050

These figures show a steady increase in both the production and the value of the product. It is probable that the consumption has increased to a still greater extent, the difference being made up by the increase in the importation. While the unequaled magnitude of the deposits renders it possible to mine fluorspar at

Rosiclare probably cheaper than at any other place in the world, this advantage may be offset and even overcome by the difference between the ocean freight rates and those by rail from the mines to the seaboard.

There is a steadily increasing consumption of lump fluorspar as a flux in cupolas for melting pig iron, and it is used for this purpose by some of the largest foundries in the country. It is not probable that it will ever replace limestone, the greater cheapness of which more than offsets any advantages that fluorspar may have, but melters of iron, pipe foundries, and many others who use but a small amount of flux find it very advantageous, as it is undoubtedly cleaner, more effective, and tends to produce a better iron than limestone. Its use in the manufacture of glass is also increasing, and it appears to be here an indispensable article, though its precise use and effects are difficult to obtain, being more or less trade secrets. It is the basis for the manufacture of hydrofluoric acid, and has a number of other miscellaneous uses in the arts.

The different properties at Rosiclare are now being operated by one company, which is making extensive improvements and putting in new machinery. With the introduction of capital and good management it is likely that the coming year will show a considerable increase in the industry.

Notes on the Fluorspar Deposits of Kentucky.

By C. J. Norwood.

In that portion of the fluorspar district lying in the counties of Livingston, Crittenden, and Caldwell operations have amounted to little more than prospecting. The total shipments of the spar from the beginning have not exceeded a few thousand tons. This has been due in large part to the lack of transportation facilities, but chiefly to the fact that, as in the earlier days of Rosiclare, the search has been for lead rather than for fluorspar.

At only two points within the district have considerable efforts at mining on the fluorspar veins been made, namely, on the Latrobe vein, at the Royal mines, on the Cumberland River, in Livingston County, and at the Columbia mines, on the Columbia, Memphis, and Beck veins, in Crittenden County.* In each case galena was the mineral sought, and the fluorite was cast aside. The vein proving poor in lead, the Royal mines were soon abandoned. Later on, some shipments were made from the Columbia mines, the product being hauled by wagon to the Ohio River, a distance of about fifteen miles. This length of haulage, aside from other considerations, based on dissensions among those interested in the properties, necessitated stoppage of the work. At present transportation may be obtained by rail within a distance of about eight miles. With transportation facilities extended to the Columbia mines, other, and probably richer, fluorite veins to the northwest will become available. During the past year considerable work was done by Mr. W. H. B. Ward and associates of Pittsburg, on what is known as the Tabb vein, in the southern part of Crittenden County. This vein, which was worked for lead, carries some galena, but at the top consists principally of fluor-

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*Descriptions of these and other "mines" may be found in the present writer's "Report of a Reconnoissance in the Lead Region of Livingston, Crittenden, and Caldwell Counties," Part VII., Vol. I., *Kentucky Geological Survey Reports*, N. S. Shaler, Director, 1875.

spar and zinc. So far as proven, it is poor in galena and is not promising in other respects. Work was stopped on account of a very large influx of water, and the place was abandoned. Messrs. Barnett & Crotser are preparing to mine for fluorspar in the coming spring at Carrsville, Livingston County, on the Kentucky section of the Fairview lode of Illinois.

It is not necessary to enter far into the geology of the veins. Much that has been said by Professor Emmons concerning the fluorspar deposits of Illinois will, while admitting, perhaps, of more elaboration, apply to those in Kentucky.* It may be proper to suggest, however, that the veins of Pope and Hardin counties, Illinois, are rather to be considered as extensions from Kentucky than as the source whence the fissures developed there proceed.

As in Illinois, the veins (fifteen or more) bearing fluorspar † occupy fissures following lines of faulting in the Carboniferous rocks, the faults reaching into the coal measures, and the fluorite extending through the entire Genevieve group—unless the upper Chester must be excepted. The principal deposits are found at the horizon of the St. Louis series. They usually have a limestone wall on at least one side, but occasionally both walls are sandstone. Usually Chester sandstone (quartzose) or sandy shale ("Chester slates") forms one wall, and St. Louis limestone the other. Sometimes both walls are of St. Louis limestone; in rare cases, the walls on either side belong to the Chester series.

The faults, as a rule, trend toward the dip of the uplifted coal measures in Union County (which joins Crittenden on the east), the strike of the latter being about N. 73° to 69° W., while the trends of the master fluorspar faults, with two or three exceptions, range from N. 30° E. to N. 55° E.‡ The exceptions are the Fairview lode (N. 28° W.) and the Rosiclare, or Anderson Well, lode, which trends about N. 5° to 10° W. They also trend against, and not with, the first considerable fault found in the coal measures on the east. They do not seem to reach far, if at all, into the coal field, as at present outlined. It is possible that they are more recent than the faults of the present coal field; but this question, as well as the one arising from the presence of a dike of mica-peridotite in Crittenden County, is reserved for discussion elsewhere.§

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* "Fluorspar Deposits of Southern Illinois," by S. F. Emmons, *Transactions American Institute of Mining Engineers*, Vol. XXI., p. 31.

† There are many faults and breaks that, so far as known, carry no mineral.

‡ A number of cross-faults and minor breaks, some of them bearing fluorspar, trend northwardly or a few degrees west of north; a few breaks bear nearly east.

§ This dike was discovered by R. M. Flannary in a search for silver. The rock was identified by J. S. Diller (United States Geological Survey) and described by him in the *American Journal of Science*, October, 1892. The linear extent of the dike is short, but Dr. R. H. Loughridge, late assistant on the Kentucky Survey, notes in a manuscript report that the fault in which it occurs extends through Livingston County.

GOLD AND SILVER.

For the silver-mining industry the year 1893 was one which in history will rank with 1873. The demonetization of silver, begun in the latter year, was finally completed in 1893 by the repeal of the Sherman law in the United States, which withdrew the last of the great nations of the world from the futile attempt to uphold the price of the metal, while furthermore the Indian mints were closed to the coinage of silver. At the present time, therefore, the only countries which are on a silver basis, wholly or partially, are Mexico, some of the South American nations, and the East. The future of the metal now deprived of the cheap coinage demand is extremely gloomy, but since the industrial prosperity of many countries depends upon maintaining the value of silver, their sole standard, it becomes probable that some international agreement may provide for the continued use of silver in coinage. The industrial uses of the metal, dependant upon its physical properties, cannot command a price that will secure its large production.

At the beginning of 1893 bar silver was quoted in New York at 82.5c. per oz., at which figure it had been for some time previous. The year opened with restored confidence in the belief that the decline in the value of the metal had been checked, owing to the demand from the East, where large amounts of silver were readily absorbed at current rates. Throughout the month the market was firm, the price rising to 84c. toward the close, and during the next five months it fluctuated between 84c. and 82c., declining to 81.25c. on June 21, on account of weakness in the East. A report from the Herschell committee on the Indian coinage was then expected, but there was not the slightest suspicion as to what it was likely to be. This report, closing the Indian mints for private coinage of rupees, which was published on June 26, fell on the market like a thunderbolt, and the price of silver declined that day to 77c.; on the 27th it was quoted at 73c., on the 28th at 69c., and on the 29th at 62c., at which point the bottom was reached. The reaction began on July 1, when the quotation was 70c., against 63c. on the previous day, and immediately afterward it rose to 75c., falling back again on July 8 to 70c. During the remainder of the year the price of the metal varied from 68c. to 76c., standing for the most part about 71c. Contrary to expectation, the repeal of the Sherman law had very little effect on the price of silver, the decline from Oct. 24 (when the unconditional repeal of the law was assured) to Oct. 31 being only from 73⅜c. to 68c. Subsequently there was a recovery to 70c. on the continued large purchases in the East, but the year closed with silver at 68c., the average for the year was 78.2c.

The first effect of the sudden drop in the price of silver at the end of June was to close down many of the smelting works and mines; the former did not wish to buy ores while the market for the metal was still fluctuating wildly, and for the same reason the large producers did not care to sell. When the price became steady again most of the mines which could still be worked at a profit resumed operations; those at which the cost of production was high remained idle. Many men were thrown out of work by these changes, and during the summer months much distress was occasioned thereby. The bad effect of the decline in silver was heightened, moreover, by its own reflex action. The uncertainty of the repeal of the Sherman law, which was felt in most parts of the country to be bringing our finances to grief, caused a disastrous panic, which was followed by a period of industrial depression, and the prices for all the common metals fell to a very low point. The producers of silver-lead and silver-copper ores, who might otherwise have disregarded the depreciation in the value of silver, suffered seriously. This was especially the case among the silver-lead mines of the Cœur d'Alêne and Wood River districts in Idaho and the Bingham Cañon in Utah, most of which were forced to close down. The output of lead in the United States in 1893 was smaller in consequence; but, owing to the unnatural conditions which have prevailed so far, it is impossible yet to foretell what will be the final effect of the changes in the silver-mining industry upon the production and price of lead.

Two results of the new order of things, however, have already become fixed, viz.: a reduction in the disproportionately high wages paid for labor in the Rocky Mountains, and an increase in the production of gold. The readjustment of the rate of wages, which became necessary through the less profits of the silver-lead, silver-copper, and silver-gold mines, has not yet been completed, owing to the expected resistance of the miners and the disinclination of the employers to bring on a general struggle. Nevertheless, small reductions have been made nearly everywhere, and with this beginning it is likely that wages will soon settle to a reasonable basis. The effect of the fall in silver upon gold mining has been more decisive, the less profits to be realized in the production of silver immediately diverting attention to gold mining. Men thrown out of work by the closing down of the silver mines engaged in rewashing the gravel of old placers in order to earn their living, while capitalists reopened old or low-grade gold mines which had been neglected for many years in consequence of the greater possibilities in silver mining. Prospecting for gold was also stimulated, and some important new discoveries were made. There was, of course, a falling off in the production of gold from the silver mines which had closed down, but this was more than offset by the new yield from the other directions mentioned, and the net result was an increase of about three million dollars in the total output of the United States, the total nearly reaching $36,000,000.

The production of silver in the United States in 1893 was not so much smaller than the previous year as might have been expected from the general closing down of the mines, but this was due to the fact that all the smelting works had large stocks of ore, which they smelted after the output of many of the mines had ceased. It was not, therefore, until August or September that there began to be a perceptible reduction in the outturn of silver, but in the autumn many of the works, including all those at Leadville, blew out their furnaces for lack of ore.

PRODUCTION OF GOLD AND SILVER IN THE UNITED STATES, BY STATES.
(From the Mint Reports.)

	1890.		1891.		1892.*		1893.†	
	Gold, vals.	Silver, ozs.	Gold, vals.	Silver, ozs.	Gold, vals.	Silver, ozs.	Gold, vals.	Silver, ozs.
Alaska	$762,500	7,500	$900,000	7,996	$1,000,000	8,000	$1,010,100	9,600
Arizona..............	1.000,000	1,000,022	975.000	1,480,033	1,070,000	1,062.000	1,184,200	2,985,700
California...........	12,500,000	900,020	12,600,000	750,017	12,000,000	400,000	12,080.000	470,100
Colorado.............	4,150,000	18,800,425	4,600,000	21,160,480	5,300,000	26,350,000	7,525,000	26,000,000
Dakota...............	3,200,000	100,002	3,550,000	100,002	3,700,000	100,000	4,005.400	140,400
Georgia..............	100,000	399	80,000	399	94.374	....	97,200	500
Idaho................	1,850,000	3,700,083	1,680,000	4,035,091	1,721,364	4,500,000	1,646,900	3,910,700
Michigan.............	90,000	55,001	75,000	73,002	70,000	75.000	42,000	43,500
Montana..............	3,300,000	15,750,279	2,890,000	16,350,370	2,891,386	18,500,000	3,575,000	17,000.000
Nevada...............	2,800,000	4,450,101	2,050,000	3,520,080	1,571,500	2,500.000	958,500	1,700.000
New Mexico...........	850,000	1,300,029	905,000	1,325,030	950,000	1,250,000	913,100	458,400
North Carolina.......	118,500	5,995	95,000	5,000	78,560	9,000	53,600	13,400
Oregon...............	1,100,000	75,001	1,640,000	230,005	1,400,000	100,000	1,644,300	11,800
South Carolina.......	100,000	399	125,000	499	123,365	....	124,000	500
Texas................	....	300,006	....	375,008	....	350,000	....	349,400
Utah.................	680,000	8,000,181	650,000	8,750,198	660,175	8,970,000	853,600	7,252,600
Virginia.............	....	....	....	....	....	....	....	....
Washington...........	204,000	70,002	335,000	165,004	373,561	150,000	222.100	152,700
Other States.........	40,000	1,995	25,000	3,100	†10,336	676,000	‡24,599	700
Total..........	$32,845,000	54,517,440	$33,175,000	58,331,314	$33,014,981	65,000,000	$35,959,599	60,500,000

* The figures of the Director of the Mint for the production of silver in the United States in 1892 have been discredited. and consequently are not reproduced here. † The statistics of gold and silver production in 1893 was collected for this work, but we are indebted to the Director of the United States Mint for the approximate distribution by States, and for the use of his estimates, which for gold have been used here. ‡ Including Virginia.

PRODUCTION OF GOLD AND SILVER IN THE UNITED STATES.

The estimates for 1792–1873 are by Dr. R. W. Raymond, United States Mining Commissioner; since 1873 by the Director of the Mint, except the production of silver in 1892, for which THE MINERAL INDUSTRY report is used, the estimate of the Director of the Mint having been discredited by competent statistical authorities.

Years.	Gold.		Silver.		Years.	Gold.		Silver.	
	Ounces.	Value.	Ounces.	Value.		Ounces.	Value.	Ounces.	Value.
1792–1834.	677.310	$14,000,000	....	$(*a*)	1869......	2,394,775	$49,500,000	9,281,520	$12,000,000
1834–44...	362,844	7,500,000	193,365	250,900	1870	2,418,965	50,000,000	12,375,360	16,000,000
1845......	48,782	1,008,327	38,673	50.000	1871.....	2,104,899	43.500,000	17,789,465	23,000,000
1846......	55,121	1.139,357	38,673	50,000	1872.	1,741,654	36,000,000	22,254,002	28,750,000
1847	43,013	889.085	38,673	50,000	1873.... .	1,741,654	36.000,000	27,665,712	35,750.000
1848	483,793	10,000,000	38,673	50.000	1874......	1,620,706	33,500,000	28,865,418	37,300,000
1849......	1,935,172	40,000,000	38.673	50,000	1875......	1.615,868	33,400,000	24,533,993	31.700,000
1850	2,418,965	50,000,000	38,673	50,000	1876......	1,930,333	39.900,000	30,010,054	38.800.000
1851......	2,660,861	55.000,000	38,673	50,000	1877......	2,268 988	46,900,000	30,783,509	39,800,000
1852......	2,902,758	60,000,000	38,673	50,000	1878......	2,476,800	51,200,000	34,960,000	45,200,000
1853	3,144,654	65,000,000	38,673	50,000	1879.....	1,881,787	38,900,000	31,550,000	40,800,000
1854......	2,902,758	60,000,000	38,673	50,000	1880......	1,741,500	36.000,000	30,320,000	39,206.000
1855......	2,660,861	55,000,000	38,673	50,000	1881.....	1,678,612	34,700,000	33,260,000	43,000,000
1856	2,660,861	55,000,000	38,673	50,000	1882......	1,572,187	32,500,000	36,200,000	46,800,000
1857	2,660.861	55,000,000	38,673	50,000	1883......	1,451,250	30,000,000	35,730,000	46,200,000
1858......	2,418,965	50,000,000	386,730	500,000	1884......	1,489,950	30,800,000	37,800,000	48,800.000
1859.	2,418,965	50,000,000	77,356	100,000	1885......	1,538,325	31,800,000	39,910,000	51,600,000
1860......	2,225,447	46,000,000	116,019	150,000	1886......	1,693,125	35,000,000	39,685,513	51.000,000
1861	2,080,309	43.000,000	1,546,920	2,000,000	1887......	1 596,375	33,000,000	41,721,592	53,350,000
1862......	1,896,468	39,200,000	3.480,547	4.500.000	1888.. ...	1,604,841	33,175,000	45,792,682	59,195,000
1863......	1,935,172	40.000.000	6,574,867	8,500,000	1889(*b*)....	1,590,868	32,886,744	51,354,839	66,396,988
1864......	2.225,447	46,100.000	8,508,060	11,000.000	1890... ..	1,588,880	32,845,000	54,517,440	70,461 474
1865......	2.574,897	53,225,000	8,701,369	11.250,000	1891... ..	1,604,840	33,175,000	58,331,314	75,417,699
1866......	2.588,292	53,500,000	7,734,600	10,000.000	1892......	1,597,098	33,014,981	65,000,000	84,038,500
1867......	2,502,419	51,725,000	10,441,643	13,500,000	1893......	1,739,700	35,959,599	60,500,000	78,220,450
1868......	2,322,206	48,000,000	9,281,520	12,000,000					

(*a*) Insignificant. (*b*) The figures for 1889 are those compiled for the Eleventh Census. The estimate of the Director of the Mint for the same year is: Gold, $32,800,000; silver, $64,646,000—total, $97,446,000.

NOTE.—The silver is calculated at the United States coining value = $1.2929 per oz.; gold $1 = 23 grains fine.

UNITED STATES: IMPORTS AND EXPORTS OF GOLD AND SILVER IN ORES.*

Year.	Gold.		Silver.	
	Imports.	Exports.	Imports.	Exports.
1887......	$14,028	$87,604	$4,228,107	$924,105
1888......	71,168	125,153	5,684,093	837,766
1889......	56,888	14,813	7,580,196	629,000
1890......	149,366	32,094	8,356,412	1,126,697
1891......	233,269	100,918	9,717,443	1,090,514
1892	714,110	9,262	9,726,704	1,592,931
1893......	518,186	....	9,490,892	....

* The imports of gold and silver given in the above tables are taken from official sources. The exports are only approximately correct. The Bureau of Statistics reports only the value of "silver ores" exported, but a much larger amount of silver leaves the country in copper matte, which is classified as "copper ore," and no record is kept of its silver contents. In the above table the value of the silver in copper matte, so far as could be obtained from the reports of the Director of the Mint, has been added to the value of silver ores, values being calculated at the commercial rates each year. The gold in copper matte exported is not included in the exports of gold given in the above table.

UNITED STATES: IMPORTS AND EXPORTS OF GOLD AND SILVER IN COIN AND BULLION.

Year.	Gold.		Silver.		Year.	Gold.		Silver.	
	Exports.	Imports.	Exports.	Imports.		Exports.	Imports.	Exports.	Imports.
1870..	$53,103,745	$10,430,561	$27,846,083	$15,259,199	1882..	$38,721,079	$13,402,528	$17,317,055	$9,098,385
1871..	44,915,975	5,841,948	32,524,495	10,962,467	1883..	6,048,770	22,055,961	25,794,670	15,153,357
1872..	68,638,125	11,113,290	32,048,799	10,068,714	1884..	40,948,246	27,957,657	29,563,748	15.504,777
1873..	25,496.118	20.537,254	38,076,207	9,212,185	1885..	11,417,207	23,642,826	33,280,542	17,771.241
1874..	43,149,091	7,422,806	29,577,984	7,830,998	1886..	41,281,276	41,309.181	27,040,290	17.221,465
1875 .	53,413,947	14,348,781	25,889,567	8,547,367	1887..	9,144,426	44,889,299	27,644,988	16,772,614
1876..	31,231,739	23,676,096	25,122,736	10,795,238	1888..	34,526.449	10,960,773	29,880,403	15,907,969
1877	18,982,638	11,629,655	29,336,929	12,141,560	1889..	50,933,460	12,004,632	40,694,230	19.219.262
1878..	8.655,948	10,477,859	18,209,252	18,389.884	1890..	24,063,074	20,230,090	26,539,789	22,426,119
1879..	4,115,446	78,767,941	21,701,552	14,425,017	1891..	79,086,581	44,970,110	27,692,879	18,192.750
1880..	3,062.459	73,644,698	12,983,442	11,631,025	1892..	76,532,056	17,450,946	35,975.834	21,726,252
1881..	2,603,543	60,398,620	17,063,274	8,595,645	1893..	79,767,354	72,762,389	46,230,439	18,274,804

COINAGE OF THE MINTS OF THE UNITED STATES.

Years.	Gold.	Silver.	Years.	Gold.	Silver.	Years.	Gold.	Silver.
1793–1795...	$71,485 00	$370,683 80	1828....	$140,145 00	$1,575,600 00	1861....	$83,395,530 00	$3,783,740 00
1796........	77,960 00	77,118 50	1829....	295,717 50	1,994.578 00	1862 ...	20,875,997 50	1,252,516 50
1797........	128,190 00	14,550 45	1830....	643,105 00	2,495,400 00	1863....	22,445,482 00	809,267 80
1798	205,610 00	330,291 00	1831....	714,270 00	3,175,600 00	1864....	20,081,415 00	609,917 10
1799........	213,285 00	423,515 00	1832....	798,435 00	2,579,000 00	1865....	28,295,107 50	691,005 00
1800........	317,760 00	224,296 00	1833....	978,550 00	2,759,000 00	1866 ...	31,435,945 00	982,409 25
1801........	422,570 00	74,758 00	1834....	3,954,270 00	3,415,002 00	1867....	23,828,625 00	908,876 25
1802........	423,310 00	58,343 00	1835....	2,186,175 00	3,443,003 00	1868 .	19,371,387 50	1,074,343 00
1803........	258,377 50	87,118 00	1836....	4,135,700 00	3,606,100 00	1869...	17,582,987 50	1,266,143 00
1804	258,642 50	100,340 50	1837....	1,148,305 00	2,096,010 00	1870....	23,198.787 50	1,378,255 50
1805........	170,367 50	149,388 50	1838....	1,809.765 00	2,333,243 40	1871....	21,032,685 00	3,104,038 30
1806........	324,505 00	471,319 00	1839....	1,376,847 50	2,209,778 20	1872....	21,812,645 00	2,504,488 50
1807........	437,495 00	597,448 75	1840....	1,675,482 50	1,726,703 00	1873....	57,022,747 50	4,024,747 60
1808........	284,665 00	684,300 00	1841....	1,091,857 50	1,132,750 00	1874....	35,254,630 00	6,851,776 70
1809........	169,375 00	707,376 00	1842 ...	1,829,407 50	2,332,750 00	1875....	32,951,940 00	15,347,893 00
1810........	501,435 00	638,773 50	1843....	8,108,797 50	3,834,750 00	1876....	46,579,452 50	24,503,307 50
1811........	497,905 00	608,340 00	1844 ...	5,427,670 00	2,235,550 00	1877....	43,999,864 00	28,393,045 50
1812........	290,435 00	814,029 50	1845....	3,756,447 50	1,873,200 00	1878....	49,786,052 00	28,518,850 00
1813........	477,140 00	620,951 50	1846....	4,034,177 50	2,558.580 00	1879....	39,080,080 00	27,569,776 00
1814...... ..	77,270 00	561,687 50	1847....	20,202,325 00	2,374,450 00	1880....	62,308,279 00	27,411,693 75
1815........	3,175 00	17,308 00	1848....	3,775,512 50	2,040,050 00	1881. .	96,850.890 00	27,940,163 75
1816........	....	28,575 75	1849....	9,007,761 50	2,114,950 00	1882....	65,887,685 00	27,973,132 00
1817........	....	607,783 50	1850....	31,981,738 50	1,866.100 00	1883....	29,241,990 00	29,246,958 45
1818...... ..	242,940 00	1,070,454 50	1851....	62,614,492 50	774,397 00	1884...	23,991,756 50	28,534,866 15
1819........	258,615 00	1,140,000 00	1852....	56,846,187 50	999,410 00	1885....	27,773,012 50	28,962,176 20
1820........	1,319,030 00	501,680 70	1853....	39,377,909 00	9,077,571 00	1886....	28,945,542 00	32,086,709 90
1821	189,325 00	825,762 45	1854....	25,915,962 50	8,619,270 00	1887....	23,972,383 00	35,191,081 40
1822........	88,980 00	805,806 50	1855....	29,387,968 00	3,501,245 00	1888...	31,380,808 00	33,025,606 45
1823........	72,425 00	895,550 00	1856....	36,857,768 50	5,142,240 00	1889 ...	21,413,931 00	35,496,683 15
1824........	93,200 00	1,752,477 00	1857 ...	32,214,040 00	5,478,760 00	1890....	20,467,183 00	39,202,908 00
1825........	156,385 00	1,564,583 00	1858....	22,938,413 50	8,495,370 00	1891 ...	29,222,005 00	27,518,857 00
1826........	92,245 00	2,002,090 00	1859....	14,780,570 00	3,284,450 00	1892 ...	34,787,222 50	12,641,078 00
1827........	131,565 00	2,869,200 00	1860....	23,473,654 00	2,259,390 00	1893....	57,102,020 00	8,837,797 30

PRODUCTION OF GOLD AND SILVER IN OTHER COUNTRIES.

Africa.—The Witwatersrand mines produced 1,478,477 oz. of gold in 1893, against 1,210,867 oz. in 1892. The Johannesburg Chamber of Mines estimates the output at the rate of £3 10s. per oz. The great increase from these mines was due to the greater quantity of ore worked, the grade not having increased; but there was an important addition to the stamping capacity of the mills, and a more general adoption of the cyanide process for the treatment of tailings, which has been very successful at these mines. A development of great importance in the Witwatersrand was the proof of the auriferous beds at a great depth by means of the diamond drill. In July the borings which were begun in October, 1892, cut the Main Reef at a depth of about 2400 ft. at a point 4000 ft. distant horizontally from its outcrop. The reef as cut was found to be dipping at an angle of only 16°, which indicates that the strata are flattening, and possibly nearing the bottom of a synclinal basin. The vein matter brought up in the core assayed well in gold. The amount of stoping ground that is added to the reserve of the district by this development cannot yet be foretold; it is, however, undoubtedly immense, and probably assures the future of the district for a very long time.

The production of the Witwatersrand mines by months since the beginning is given in the following table:

Months.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.
January	....	7,328	25,506	35,007	53,205	84,560	108,374
February	....	12,180	22,457	36,887	50,079	86,649	93,252
March	....	11,976	27,919	37,780	52,949	93,245	111,474
April	....	14,146	27,029	38,697	56,372	95,562	112,053
May	887	13,397	35,028	38,836	54,673	99,436	116,911
June	734	12,773	30,878	37,419	55,863	103,252	122,907
July	240	16,687	31,091	39,457	54,924	101,279	126,169
August	1,409	18,616	30,520	42,864	59,070	102,322	136,069
September	1,936	20,242	34,143	45,486	65,602	107,852	129,585
October	4,029	27,165	32,214	45,249	72,793	112.167	136,682
November	5,463	26.827	33,722	46,783	73,394	106,795	138.640
December	8,457	26,784	39,050	50,352	80,323	117,748	146.357
Total	23,155	208,122	369,557	494,817	729,238	1,210,867	1,478,473

The production of the principal mines on the Witwatersrand is given in the following table (gold is valued at £3, 10s. for mill and £3 for cyanite):

TOTAL PRODUCTION OF LEADING MINES.

Mines.	1889.	1890.	1891.	1892.	1893.
	Oz.	Oz.	Oz.	Oz.	Oz.
Robinson	75,038	71,828	94,059	170,140	161,138
Langlaagte Estate	61,755	56.750	51,462	88.981	104,910
New Primrose	3,626	12,795	23,080	56.475	83,779
Crown Reef	18,364	37,500	39,841	70,212	82.089
Durban-Roodepoort	14,539	16,017	23,155	30.932	60,634
Ferreira	....	....	44,561	48,233	55.674
City and Suburban	18,814	13,073	12,409	29.125	46,811
Nigel	3,698	13,600	18,145	50,287	46,008
Jumpers	21,778	30,230	16,818	20,946	43.392
Simmer and Jack	12,551	21,262	38,409	38,146	39,670
New Rietfontein	....	....	....	11,555	35.318
Meyer and Charlton	4,970	15.586	20,620	22,332	34,182
Jubilee	6,510	12,332	9,285	17,319	30.064
Randfontein	....	....	....	6,586	29,935
Block B	....	....	14,689	24,368	26,592
Wolhuter	1,548	6,846	....	11,093	25.951
May Consolidated	9,948	13,089	27,400	28,385	24.945
Wemmer	8,384	7,017	13,960	16.522	24.922
Salisbury	9,303	8,508	12,397	20,825	24,857

Mr. W. Y. Campbell of the South African Trust and Finance Co., Johannesburg, has kindly furnished the following figures concerning the Transvaal mines:

TRANSVAAL MINING COMPANIES—RAND CIRCLE.

Company.	Nominal Capital.	Paid-up Capital.	Value of Compa'y on Face Value of Shares Issued.	Value of Comp'y on Market Value, Dec. 1893.	No. of Stamps Mining, Dec. 1893.	Dividends Paid, 1893.	Total Output, 1893.			
							Tons.	Plates.	Concen.	Tailings.
Aurora	65,000	65,000	65,000	35,750	30	....	34,484	9,109. 8	....	....
Bothas Reef	150,000	105,000	105,000	78,750	15	....	5,187	2,041.19	....	....
Banket	300,000	198,000	198,000	9,900	20	....	3,981	1,347.15	....	....
Britannic	50,000	50,000	50,000	Liquid'n	40	....	3,124	1,093.12	....	....
Champ d'Or	135,000	120,000	120,000	30,000	40	....	17,896	5,722. 7	....	1,787.17
City and Suburban	85,000	85,000	85,000	935,000	50	100%	49,805	37,777.14	....	9,034. 3
Crown Reef	120,000	120,000	120,000	1,125,000	90	50%	118,244	51,688. 0	723. 2	29,679.14
Con. Anglo Tharsis	80,000	67,000	67,000	16,750	30	....	9,726	2,635.11	....	....
Durban-Roodepoort	135,000	125,000	125,000	593,750	70	45%	78,651	37,883. 6	....	22,751. 0
Evelyn	80,000	66,000	66,000	16,500	....	....	....	....	....	2,545.19
East Roodepoort	30,000	30,000	30,000	7,500	15	....	4,671	1,188.17	....	....
Ferreira	45,000	45,000	45,000	371,250	40	100%	47,376	43,978. 1	....	11,697.19
Geldenhuis Estate	175,000	175,000	175,000	787,500	80	25%	83,048	47,434. 6	....	....
Geldenhuis Main Reef	150,000	150,000	150,000	56,250	10	....	9,495	3,417. 7	....	372.17
George Goch, Amalg'ted	100,000	100,000	100,000	80,000	50	....	21,856	7,180.14	....	....
Gipsy	45,000	45,000	45,000	36,000	15	....	3,931	1,563. 6	....	712.14
Glencairn	200,000	200,000	200,000	215,000	50	....	38,937	15,913.14	....	....
Henry Nourse	100,000	100,000	100,000	185,000	25	....	19,749	15,329.18	....	6,893. 3
J. H. Burg, Pioneer	21,000	21,000	21,000	91,875	20	50%	17,606	9,073. 0	....	1,120. 4
Jumpers	100,000	100,000	100,000	300,000	100	25%	89,527	38,635. 2	....	....
Jubilee	30,000	30,000	30,000	195,000	35	120%	43,673	24,774.10	36. 0	5,254.16
Langlaagte Estate	500,000	470,000	470,000	1,645,000	160	30%	222,732	65,812.12	9,047.11	30,050.15
" Block B	632,500	546,326	546,326	109,205	55	....	64,066	19,621. 4	100. 0	6,869.19
" Royal	150,000	140,000	140,000	143,500	30	5%	40,478	16,476.16	....	....
" Western	(Amalg	amatedN	ew Crœs	us.)	20	....	6,915	2,061. 0	....	....
" United	100,000	100,000	100,000	47,500	40	....	35,920	10,621. 6	....	....
Luipaarde Vlei Estate	350,000	325,000	325,000	121,875	10	....	4,069	1,452.18	....	....
" West Battery Mine.	(Private	Syndicat	e.)		20	....	3,021	602. 0	....	....
Marai's Reef	275,000	249,184	249,184	24,918	15	....	935	937. 5	....	419.10
Lindum	20,000	16,000	16,000	16,000	10	....	3,390	1,290. 8	....	....
May Consolidated	450,000	430,000	430,000	204,250	50	....	60,298	24,957. 4	....	2,875. 0
Main Reef	300,000	300,000	300,000	60,000	30	....	8,031	2,588.17	....	....
Metropolitan	100,000	75,000	75,000	60,000	20	....	1,670	402. 0	....	....
Meyer & Charlton	75,000	71,700	71,700	358,500	50	60%	34,197	27,328.12	....	6,854. 2
Meyer & Leeb	15,000	15,000	15,000	6,750	15	10%	15,326	3,970.19	....	....
Mida's Battery	70,000	62,000	62,000	15,500	15	....	2,289	300. 1	....	....
Modderfontein	200,000	200,000	200,000	65,000	20	....	5,328	2,996.14	....	....
May Deep Level	170,000	146,000	146,000	56,575	30	....	14,124	5,391.16	....	....
New Heriot	85,000	85,000	85,000	280,500	40	10%	21,455	14,089. 2	....	8,689.18
New Chimes	70,000	70,000	70,000	84,000	40	....	33,641	14,510. 9	....	7,296.16
New Aurora West	80,000	80,000	80,000	40,000	25	5%	36,845	10,350.18	....	....
New Primrose	240,000	218,000	218,000	795,700	100	40%	141,464	57,574. 8	....	23,203.18
New Rietfontein Estate	160,000	160,000	160,000	440,000	25	25%	24,048	28,168.12	79.18	6,957.15
New Spec Bona	150,000	120,000	120,000	120,000	10	....	22,289	8,784. 5	....	1,040. 0
New Unified	170,000	140,000	140,000	29,750	60	....	74,331	16,484.10	....	....
New Black-Reef	80,000	76,000	76,000	36,100	20	....	10,307	3,205. 4	....	....
New Kleinfontein	175,000	150,000	150,000	48,750	35	...	9,941	4,779. 4	....	....
New Crœsus	225,000	195,000	195,000	214,500	10	....	989	419. 0	....	....
Nigel	160,000	160,000	160,000	432,000	25	50%	22,273	25,455. 0	3,516. 2	17,026. 8
Oriel	150,000	150,000	150,000	2,500	10	....	360	86. 0	....	....
Orion	30,000	30,000	30,000	37,500	40	....	34,657	8,318. 3	....	9,677.15
Paarl Central	170,000	138,750	138,750	83,250	Tgs	....	....	....	....	957.15
Princess Estate	80,000	72,046	72,046	46,829	30	....	2,472	756. 7	....	....
Randfontein	2,000,000	1,966,500	1,966,500	835,762	40	....	54,652	23,310.16	....	6,623.14
Robinson	2,750,000	2,718,750	2,718,750	2,446,875	60	8%	94,842	104,222.17	10,659.18	17,921. 4
Roodepoort Kimberley	122,000	99,000	99,000	37,125	40	....	4,487	981. 9	....	....
Salisbury	100,000	93,000	93,000	213,900	20	10%	24,786	19,268.18	....	5,587. 6
Simmer & Jack	85,000	85,000	85,000	314,500	100	40%	103,798	38,904.12	....	767. 0
Stanhope	35,000	34,000	34,000	42,500	20	50%	22,858	10,790. 8	....	3,873.16
Star	100,000	94,000	94,000	9,400	30	....	17,747	4,234. 8	....	....
Teutonia	100,000	96,000	96,000	4,800	20	....	2,330	615. 2	....	....
Treasury	40,000	36,000	36,000	32,400	15	25%	12,429	7,587.12	....	4,284.16
United Main Reef	130,000	120,000	120,000	168,000	30	....	25,917	9,928.10	....	....
Van Ryn Estate	125,000	100,000	100,000	70,000	30	....	40,211	13,440. 0	....	....
New Moss Rose	(Amalg	amated	withNew	Primr'se)	....	....	....	220. 0	....	....
Village Main Reef	132,000	132,000	132,000	415,800	40	....	11,607	6,143.17	....	1,996. 8
Vesta	50,000	40,000	40,000	8,000	10	....	750	170.15	....	....
Vulcan	95,000	90,000	90,000	11,250	15	....	2,766	764. 5	....	50. 0
Wemmer	55,000	55,000	55,000	247,500	40	....	27,654	22,705.13	....	3,063. 8
Worcester	100,000	90,727	90,727	149,700	20	15%	24,241	17,121.15	....	....
Witwatersrand	250,000	250,000	250,000	212,500	40	....	34,081	12,441.13	....	7,882.18
Wolhuter	130,000	120,000	120,000	264,000	55	....	53,859	25,949. 9	....	....
Vogelstruisfontein	45,000	41,800	41,800	6,270	Al.	5%	....	....	....	....
Customs Works	....	....	....	....	....	....	....	....	38,574. 0	35,669. 2
Total	....	13,249,783	13,249,783	16,283,069	2505	....	2,217,843	1,056,383. 0	62,736.11	304,498. 9

TRANSVAAL MINING COMPANIES—RAND CIRCLE—*Continued.*

Companies Mining but not Milling.	Nominal Capital.	Paid-up Capital.	Market Value of Company, Dec. 1893.
Agnes Munro	100,000	93,000	18,600
Alexandra Estate	250,000	225,000	33,750
Cinderella	100,000	100,000	17,500
Cornucopia	100,000	100,000	3,750
Champ d'Or, D. L.	200,000	200,000	50,000
Driefontein	130,000	120,000	24,000
Fern	30,000	30,000	2,250
Gordon Estate	175.000	160,000	8,000
New Blue Sky	150.000	150,000	30,000
New Comet	100,000	75,000	33,750
Leeuwpoort	100,000	95,000	7,125
Steyn Estate	140,000	125,000	25,000
Ginsberg	150,000	130,000	78,000
Total	1,725,000	1,603,000	331,725

Companies Dormant.	Nominal Capital.	Paid-up Capital.	Market Value of Company, Dec. 1883.
Amazon	100,000	100,000	5,000
Bohemian	131,000	131,000	6,550
Bantges	95,000	95,000	42,750
Balmoral	170,000	160,000	16,000
Emma	150,000	135,000	13,500
Gardner, M. R.	60,000	47,000	4,700
Great Britain	170,000	170,000	6,375
Henry Nourse, D. L.	125,000	111,310	55,655
Langlaagte	75.000	75,000	9,375
Mulder's Farm Block B. D. L.	200,000	164,000	16,400
Nabob	75,000	71,500	10,725
New Florida	125,000	105,000	7,875
New Grahamstown	150,000	150,000	56,250
Palmiel Estate	250,000	248,250	6,206
Ruby	30,000	23,114	34,671
Wemmer, F.&W., D. L.	100,000	90,000	135,000
Total	2,006,000	1,876,174	427,032

RAND CIRCLE—*Continued.* SUMMARY OF DIVIDENDS IN 1893.

Company.	Issued Capital.	Divide'ds Declared.	Amount Paid.
City and Suburban	85,000	100%	85,000
Crown Reef	120,000	50%	60,000
Durban-Roodepoort	125,000	45%	56,250
Ferreira	45,000	100%	45,000
Geldenhuis Estate	175,000	25%	43,750
Johannesburg Pioneer	21.000	50%	10,500
Jumpers	100,000	25%	25,000
Jubilee	30.000	120%	36,000
Langlaagte Estate	470,000	30%	141,000
" Royal	140,000	5%	7,000
Meyer & Charlton	71,700	60%	43,020
Meyer & Leeb	15,000	10%	1,500
New Heriot	85,000	10%	8,500

Company.	Issued Capital.	Divide'ds Declared.	Amount Paid.
New Aurora West	80,000	5%	4,000
New Primrose	218,000	40%	78,374
New Rietfontein Estate	160.000	25%	40.000
Nigel	160,000	50%	80,000
Robinson	2,718,750	8%	217,500
Salisbury	93,000	10%	9,300
Simmer & Jack	85,000	40%	34,000
Stanhope	34,000	50%	17,000
Treasury	36,000	25%	9,000
Worcester	90,727	15%	13.609
Vogelstruisfontein	41,800	5%	2,090
Total	5,199,977	....	1,067,393

RAND CIRCLE CUSTOMS WORKS, 1893.

African Gold Recovery.		Rand Central Ore Reduction Co.		Robinson Co.		Total.	
Concen.	Tailings.	Concen.	Tailings.	Concen.	Tailings.	Concen.	Tailings.
463.18	4,130.6	9,774.7	31,538.16	28.335.15	....	38,574.0	35,669.2

LOW COUNTRY DISTRICT, 1893.

Company.	Output.
	Oz. Dwt.
Birthday	2,595.0
Ellerton	1,681.0
Letaba and Sundries	1,000.0
Total	5.276.0

DE KAAP DISTRICT, 1893.

Company.	Output.
	Oz. Dwt.
Albion Gold Mine	1,218. 7
Barrett's G. M. Co.	1,873. 1
Coetzeestrom Estate	412. 0
Central Montrose	724. 3
Edwin Bray	417. 8
Forbes Reef	2,888. 7
Ives' Luck	1,861. 4
Moodie's Pioneer	2,126. 7
New Consort	1,696.12
Sheba	40,463.11
United Ivy	4,918.15
Mines on tribute	9,929.15
Alluvial	1,118.6
Other sources	29.12
African Gold Recov'y	708. 7
Total	70,385.15

LYDENBURG DISTRICT, 1893.

Company.	Output, Oz.
Frankfort	....
Lisbon	....
Novitgedacht	....
Clewer Estate	....
Spitzkop	....
Graskop	....
Ross Hill	....
Sherwell	....
Alluvial	....
Transvaal Ex	....
Total, estimated	31,500.0

KLERKSDORP DISTRICT, 1893.

Company.	Output, Oz.
Africander	2,865¾
" Cyanide Syndicate	2.933
Ariston Syndicate	591¼
Buffelsdoorn	4.253
" Cyanide	6,732
Klerksdorp Estate	753¼
Eastleigh	3,189
" Cyanide	2,851½
Monte Cristo	223
Wilkinson	15
Total, estimated	24,407.0

NOTE.—The total Transvaal output for 1893 was as follows: Witwatersrand (conglomerate), 1,478,477 oz. 3 dwt.; De Kaap (quartz), 70,385 oz. 15 dwt.; Low Country (quartz), 5,276 oz.; Lydenburg (deposit), 31,500 oz.; Klerksdorp (conglomerate), 24,407 oz. The average quality of bullion was 900 fine gold.

PRODUCTION OF GOLD IN AUSTRALASIA.

Year.	New South Wales.		Victoria.		New Zealand.		Queensland.		Tasmania.		South Australia.		Western Australia.		Total Production.		Total Value.
	Ounces.	Value.	Ounces.	Value.	Ounces.	Value.	Ounces.	Value.	Ounces	Value.	Ounces	Value.	Ounces	Value.	Ounces.	Kilos.	
1851........	144,120	£468,336	212,899	£851,596	....	....	....	....	....	....	....	....	....	....	356,919	11,119	$6,414,869
1852........	818,751	2,660,946	2,286,535	9,146.140	....	....	....	....	....	....	....	....	....	....	3,105.286	96,738	57,382.438
1853........	548,052	1,781,172	2,744,098	10,976,392	....	....	....	....	....	....	....	....	....	....	3,292.150	102,559	62,001.761
1854........	237,910	773,209	2,218.483	8,873,532	....	....	....	....	....	....	....	....	....	....	2,456,393	76,521	45,083,161
1855........	171,367	654,594	2,819,288	11,277,152	....	....	....	....	....	....	....	....	....	....	2,990,655	93,166	58,474,289
1856........	184,600	689,174	3,053,744	12,214,976	....	....	....	....	....	....	....	....	....	....	3,238,344	100,889	50,722,169
1857........	175,949	674,477	2,830.213	11,320,852	10.437	£40,422	....	....	....	....	....	....	....	....	3,016,599	93,975	58,493.750
1858........	286,798	1,104,175	2,596,230	10,384,924	13,534	52,464	....	....	....	....	....	....	....	....	2,896,563	90,235	56,091,996
1859........	329,363	1,259,127	2,348.703	9,394,812	7.336	28,427	....	....	....	....	....	....	....	....	2,685.402	83,657	51,916,299
1860........	384,053	1,465,373	2,224,069	8,896,276	4.538	17,585	....	....	....	....	....	....	....	....	2,612,660	81,391	50,443,077
1861........	465,685	1,806,172	2,035,173	8,140,692	194.031	751,873	....	....	....	....	....	....	....	....	2,694,889	83,953	51,995.862
1862........	640,622	2.467,780	1,730.201	6,920,804	410,862	1.591,389	....	....	....	....	....	....	....	....	2,781,685	86,656	53,362,669
1863........	466,411	1,796,170	1,694,819	6,779,276	628.450	2,431,723	....	....	....	....	....	....	....	....	2,789.380	86,896	53,494,839
1864........	340,267	1,304,926	1,622,447	6,489,788	480.171	1,856.837	....	....	....	....	....	....	....	....	2,442,885	76.102	46,905,566
1865........	320,316	1,231.243	1,611,554	6,446,216	574,574	2,226.474	....	....	....	....	....	....	....	....	2,506,444	78,082	48,133,114
1866........	290,014	1,116,404	1,546,948	6,187,792	735.376	2,844,517	....	....	843	£2,708	....	....	....	....	2,573.181	80,146	49,336,090
1867........	271,886	1,053,578	1,501,446	6,005,784	686,905	2,698,862	....	....	1,363	4,382	....	....	....	....	2,461,600	76,685	47,456,224
1868........	255,662	994,665	1,684,918	6,739,672	637.474	2,504,326	....	....	692	2,536	....	....	....	....	2,578,746	80,334	49,772,195
1869........	251,491	974,149	1.544,756	6,179,024	614.281	2 362,995	....	....	137	514	....	....	....	....	2,410,685	75,099	46,251,070
1870........	240,858	931,016	1,304,304	5,217,216	544.880	2,157,585	....	....	964	3.666	....	....	....	....	2,091,006	65,140	40,384,061
1871........	323,609	1,250,485	1.368,942	5,475,768	730,029	2.787,520	....	....	6,005	23,467	....	....	....	....	2,428,585	75,657	46,448.109
1872........	425,129	1,643,582	1,331,377	5.325,508	445.370	1,731.261	....	....	6,969	27,314	2,404	£8,729	....	......	2,211,339	68,889	42,478,796
1873........	361,784	1,395,175	1,170.397	4,681,588	505,337	1.987,425	....	....	4,661	18,390	98	343	....	....	2,042,277	63,622	39.282,960
1874........	270,823	1,040,329	1,097,643	4,390,572	376.388	1,505,331	....	....	4,651	18,491	8.351	29,229	....	....	1,757,856	54,761	33,941,991
1875........	230,882	877,694	1,068,417	4,273,668	355.322	1,407,770	....	....	3,010	11,982	13,742	48,097	....	....	1,671,373	52,067	32,169,357
1876........	167,411	613,190	963.760	3,855,040	322.016	1,284,328	....	....	11.107	44,923	9,857	34,500	....	....	1,474,151	45,923	28,341,553
1877........	124,110	471,418	809,653	3,238,612	371,685	1,496,080	2,646.916	£9,624,206	5,777	23,289	11,811	41,339	....	....	3,969,952	123,674	70,639,928
1878........	119,665	430,033	758,040	3,032,160	310,486	1,240,079	310,247	1,085,864	25,249	100,000	10,745	37,608	....	....	1,534,432	47,801	28,798,957
1879........	109,649	407,219	758,947	3,035,788	287,464	1,148,108	288,556	1,009,946	60.155	230,895	14,250	49,875	....	....	1,519,021	47,321	28,584.337
1880........	118,600	441,543	829,121	3,316,484	305.248	1,227,252	267,136	934,976	52,595	201,297	13.245	46,358	....	....	1,585.945	49,406	29.974,771
1881........	149,627	566,513	833,378	3,333,512	270.561	1,080,790	270,945	948,308	56,693	216,901	16,975	59,413	....	....	1,598,179	49,787	30,167,042
1882........	140,469	526,522	864,610	3,458,440	251,204	1,002,720	224,893	787,125	49.122	187,337	15,668	54,838	....	....	1,545,966	48,161	28,761,251
1883........	123,805	458,509	780,253	3,121,012	248.374	993,352	212,783	744,741	46,578	176,442	15,938	55,783	....	....	1,427,931	44,413	26,970,836
1884........	107,198	395,292	778,618	3,114,472	229,946	921,797	307,804	1,077,314	42,340	160,404	21,454	75,089	....	....	1,487,360	46,262	27,916,333
1885........	103,736	378.665	735,218	2,940,872	237,371	948,615	310,941	1,088,293	41,241	155,309	18.327	64,145	....	....	1,446.834	45,002	27.089.898
1886........	101,416	366,294	665,196	2,660,784	227,079	903,569	340,998	1,193.493	31,015	117,250	21,115	73.903	....	£4,207	1,386,819	43,135	25,837,406
1887........	110,288	394,579	617,751	2,471,004	203,869	811,100	425,923	1,490,731	42,609	158,533	31.745	111,108	4,873	19,492	1,437,058	44,697	26,523,171
1888........	87,503	317.100	625,026	2,500,104	201,219	801,066	481,643	1,685,750	39,611	147,154	16,763	58,671	3,493	13.098	1,454,658	45.245	26,839,923
1889........	119,759	434,070	614,838	2,459,352	203,211	808,549	739,103	2,586,861	32,333	119,703	20,000	70,000	15,492	58.871	1,744,736	54,267	31,770.044
1890........	127,760	460,285	588,560	2,354,240	193,193	773,438	610,587	2,137,054	20,510	75,888	26,086	91,301	22,806	86,664	1,589,502	49,439	29,054,800
1891........	153,336	558,306	576,399	2,305,596	251,996	1,007,448	576,439	2,017,537	38,789	145.459	28.700	100,450	30,311	115,182	1,455,970	45,286	30,365,988
1892........	156,870	569,17[illegible]	654,456	2,617,824	238,079	954,744	615,558	2,154,453	45,110	174,070	a28,700	100,450	59,548	226,284	1,798,341	55,935	33,985,015
1893........	c171,097	618,07[illegible]	671,126	2,684,504	226,811	913,138	600,327	2,101,114	b35,012	130,735	....	......	....	....	....	....	....

NOTE.—The values of the annual gold product of New South Wales, New Zealand, Tasmania, and Western Australia are taken from the blue books of the mining departments of these colonies. The mines departments of Queensland and Victoria state amounts only in their returns. The values of the yearly products of these colonies have, therefore, together with those of South Australia, been calculated at £4 per oz. for Victoria and £3.10 per oz. for Queensland and South Australia. The Queensland returns have been compiled annually since 1877 only. The figures for this colony for the year 1877, and for Tasmania in 1866, represent the product of the gold mines from the beginning to the end of the years mentioned. There are no reliable statistics of the production of gold in South Australia, and the figures given represent only the amount of gold from that colony received at the Melbourne mint. (*a*) Estimated. (*b*) Last quarter estimated. (*c*) Mint returns.

British Columbia.—Mr. S. S. Fowler estimates that the production of gold in this province in 1893 amounted to $379,534.

Nova Scotia.—According to Mr. J. E. Hardman the production of gold in Nova Scotia in 1893 was 19,900 oz., valued at $18 per ounce.

India.—The production of gold in the Colar field of Mysore in 1893 was 207,135 oz., against 163,140 oz. in 1892, the output of this district being valued usually at £3 17s. 6d. per oz. There is every reason to believe that the present large output will be maintained.

China.—We are indebted to G. James Morrison, Esq., of Shanghai for the information that the exports of gold from that port in 1893 were 450,000 fine ounces, of which 60% was in the form of dust. This was a great increase over 1892.

Mexico.—Mr. Richard E. Chism contributes the following data concerning the production of gold and silver in Mexico in 1893: "It has been unusually difficult to obtain a statement of the output of precious metals during the past year. Ordinarily the mint reports are published monthly in the *Diario Oficial*, but in 1893 this was not done. I have obtained, however, the following table showing the exports of gold and silver from Mexico during the fiscal year 1892–93, which are almost an exact measure of the production of these metals in the country, since only a small part of the silver is consumed at home:

PRODUCTION OF GOLD AND SILVER IN MEXICO, 1872–93.*

Years Ending—	Silver.		Gold.		Years Ending—	Silver.		Gold.	
	Kilos.	Value.	Kilos.	Value.		Kilos.	Value.	Kilos.	Value.
1872–73.......	548,211	$21,441,000	1,515	$975,000	1883–84.......	810,427	$31,695,000	1,639	$1,055,000
1873–74.......	519,421	20.314,000	2,104	1,354,000	1884–85.......	849,574	33,226,000	1,420	914,000
1874–75.......	544,989	21,314,000	1,643	1,057,000	1885–86.......	872,229	34,112,000	1,594	1,026,000
1875–76.......	555,575	21,728,000	1,689	1,087,000	1886–87.......	884,707	34,600,000	1,627	1,047,000
1876–77.......	605,717	23,689,000	1,513	974,000	1887–88.......	892,684	34,912,000	1,602	1,031,000
1877–78.......	635,071	24,837,000	1,161	747,000	1888–89.......	1,040,834	40,706,000	1,626	1,040,000
1878–79.......	642,435	25,125,000	1,369	881,000	1889–90.......	1,061,136	41,500,000	1,709	1,100,000
1879–80.......	685,264	26,800,000	1,464	942,000	1890–91.......	1,099,491	43,000,000	1,787	1,150,000
1880–81.......	747,505	29,234,000	1,574	1,013,000	1891–92.......	1,169,807	45,750,000	1,981	1,275,000
1881–82.......	747,628	29,239,000	1,456	937,000	1892–93.......	1,240,124	48,500,000	2,175	1,400,000
1882–83.......	756,066	29,569,000	1,485	956,000					

* The values in the above table are taken from the annual report of Wells, Fargo & Co. The amounts are calculated from the values taken on the mintage basis, *i. e.*, one kilogram of fine gold equals $643.529, and one kilogram of fine silver, $39.109. In the table given in THE MINERAL INDUSTRY, Vol. I. (1892), p. 202, these amounts were incorrectly calculated.

EXPORTS OF SILVER FROM MEXICO IN 1892–93.

Substance.	July 1 to Dec. 31, 1892.	Jan. 1 to July 1, 1893.	Total.	Substance.	July 1 to Dec. 31, 1892.	Jan. 1 to July 1, 1893.	Total.
Argentif. copper ore..	$1,600	$480	$2,080	Coined gold (Mexican)....	$60,087	$53,877	$113,964
Silver ore............	5,008,265	5,932.485	10,940,750	Gold bars................	169.204	188,683	357,887
Coined silver.........	16,456,496	10,714,369	27,170,865	Gold with silver..........	177,810	226,753	404,563
Slags	1,292	18,000	19,292	Gold ore.................	86,806	58,979	145,785
Silver bars...........	2,506,642	2,641,957	5,148,599				
Silver with gold......	1,339,356	1,638,638	2,977,994	Total................	493,907	528,292	1,022,199
Sulphide of silver....	743,982	840,220	1,584,202				
Argentiferous lead...	3.184,082	4,218,559	7.402,641				
Total product silver	....	....	$55.246,423				

"To the above official figures the following additions should be made in order to arrive at the approximate production: 15% of the total for clandestine exports; 0.5% used in the arts in Mexico; 1% retained in banks; 2% in circulation—total, 18.5%. The total value of the gold and silver exported from Mexico during the fiscal year 1892–93 is reported officially as $56,268,522. Increasing this by 18.5% gives a total of $65,228,522. In estimating the production for the calendar year 1893 I base my calculations upon the increase or decrease of the two semesters of the last fiscal year, and find that the exportation of the precious metals during 1893 may be put down fairly as follows: Silver in all forms, $49,273,000; gold in all forms, $1,114,864. Increasing these figures by 18.5%, the results are $58,388,505 and $1,321,114, respectively.

"Of course the addition of 18.5% to the exports is largely a matter of conjecture. The amount exported clandestinely is usually estimated at about 10%, and sometimes at 12%. I put it at 15%, however, because from private information I am convinced that more gold and silver was smuggled out in 1893 than ever before, and also because I have always considered the usual estimate of 10% much too low. Of course the actual amount of coined silver in the banks and in circulation is much more than 3% of the total product, which I have set down; this figure, however, is supposed to represent only the part of the annual product applied to the increase of the circulating medium of the country.

"The value bases used in the official reports are given in the mint regulations of May 13, 1893, Article 27, as follows: For export pure silver, $40.915 per kilogram, and pure gold, $675.416 per kilogram. For coinage silver is valued at $39.109 and gold at $643.529 per kilogram, which includes the coinage fees.

"The amount of gold brought to the mints during the fiscal year 1892–93 was $1,902,296, including that for coinage and that assayed and taxed for exportation. The total exports of Mexican gold coins, gold in bars, and gold alloyed with silver during the same period, however, amounted to only $876,314, so that 55% of the gold presented at the mints must have remained in the country if both sets of figures are correct. Silver was coined or assayed at the mints during the fiscal year 1892–93 to the amount of $30,383,428. The exports of coined silver, silver bars, and doré bars during the same period reached $36,297,456, so that part of the exports must have been the accumulations of previous years, assuming that both sets of figures are correct. Since, however, the silver exports are probably computed at the export rate, the mint or coinage value of the same would be about $34,200,000.

"The above figures are from the official reports of Señor Javier Stavoli, the statistician of the Mexican Treasury Department."

Russia.—No detailed reports of the production of gold in Russia in 1893 have yet been published, but indications are for an increase over 1892. The production of fine gold in Russia in 1890 and 1891 was 35,309 kilos and 32,993 kilos, respectively. The output of crude gold in 1892 was 43,138 kilos, which estimated as 860 fine (about the average of Russian crude gold in recent years) would give a fine equivalent of 37,099 kilos, valued at $24,655,955. The latest Russian statistics are given in the following table:

PRODUCTION OF UNREFINED GOLD IN RUSSIA.*

Year.	Cabinet of his Imperial Majesty.	East Siberia.	West Siberia.	Ural.	Finland.	Total.
	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.
1883	1,654	23,883	2,113	8,075	8.2	35,733.2
1884	1,491	24,048	2,031	7,961	....	35,531.0
1885	999	21,245	2,064	8,698	12.2	33,018.2
1886	1,687	20,525	2,047	9,172	5.5	33,436.5
1887	1,556	20,426	2,227	10,647	5.5	34,861.5
1888	1,409	20,508	2,326	10,909	12.2	35,164.2
1889	1,736	22,441	2,539	10,516	24.6	37,256.6
1890	1,867	24,530	2,432	10,524	16.4	39,369.4
1891	....	20,377	7,101	11,532	....	39,010.0
1892	1,818	22,130	7,265	11,925	....	43,138.0
1893	....	....	....	....	....	....

* From Catalogue of the Russian Section at the Chicago Exposition, p. 139.

Spain.—The production of silver in Spain in 1892, according to reports received by Señor Roman Oriol, amounted to 85,500 kilograms; in 1893 it was 90,000 kilograms.

United Kingdom.—The United Kingdom has not generally been considered among gold-producing nations; nevertheless it is a fact that as early as the 15th century gold was obtained from placer mines in the vicinity of Kildonan in Sutherlandshire, Scotland. Of the extent of these workings and of the quantity of gold taken from them at that early date no record now exists. It is known, that some of this gold was coined, and there is historical mention of ornaments made Scottish gold which constituted royal gifts. During the past ten years several attempts have been made to follow up the ancient workings, but the Duke of Sutherland, the owner of the property, has forbidden all working of the kind on his estate. A few months ago the County Council of Sutherlandshire passed resolutions requesting that the placers be opened and permission given to mine.

In North Wales also gold mines have existed for a number of years, though not on a scale sufficient to attract general attention. Recently, in answer to a question from Mr. Molloy, M. P., the Chancellor of the Exchequer stated in the House of Commons that during the past twenty years there have been extracted from the North Wales mines 43,600 tons of ore, from which 23,716 ounces of gold had been extracted, the average yield being therefore about 11 dwts. per ton. During 1893 there were 4,300 tons of ore taken out, but the result in gold was not yet known. He stated also that the government was willing to grant all possible facilities for working these Welsh fields and would withdraw the obstacles in the way of royalties, etc., which have heretofore prevented an extension of mining.

A syndicate was recently formed to work gold mines on the Fernhill property which is in Devonshire, near the line between that county and Cornwall. On this property it is said that explorations, which have as yet been carried only to a moderate depth, show the probable existence of three veins, and numerous assays of the outcroppings have given an average of about 3 dwts. of gold to the ton.

The London Market.

The following review of the foreign market for gold and silver in 1893 is from the Annual Circular of Messrs. Pixley & Abell of London:

Gold.—The demand, which had slightly slackened toward the close of 1892, became decidedly more active during the opening months of this year, and although fluctuations in the premium naturally occurred, all arrivals were exported, chiefly to Paris and Berlin. It was not until early in May that prices fell sufficiently to allow of the Bank of England receiving any of the imports. About this time the Australian crisis came to a head, and very large withdrawals for these parts were made by the larger Australian banks to strengthen their branches. For nearly two months the Bank of England received all open-market arrivals, but toward the end of June an intermittent demand again arose. In July the Continent required no gold, but large sums were exported to New York from London. The bulk of these was in eagles, and came from the bank. Caused by temporary scarcity of gold coin in the States, and a heavy premium to attract United States gold, the demand did not continue. The Continent then became buyer, exports being for Berlin, to replace gold loaned Hungary and Russia.

Silver.—From January until the 23d of June the changes in silver were comparatively unimportant, and, although many rumors were current as to probable action on the part of the Indian Government to place exchange on a more permanent basis, prices ranged between $37\frac{9}{16}$d. and $38\frac{9}{16}$d. During this period the India Council was selling its bills and transfers at from 1s. 2⅝d. to 1s. $2\frac{29}{32}$d., the sales usually showing a slow but regular improvement. On the 26th of June it became known in London that the Indian mints were to be closed to the free coinage of silver, and this was immediately followed by complete panic, and extreme pressure to sell at any price came from all parts, but more particularly from America. On the 30th of June business was done at 29½d., 29⅞d., and 30d. Accompanying the news of the closing of the mints, it was also announced that exchange would be fixed at ¼ per rupee, with the result that Indian rates at once nearly touched this figure, and on the 28th of June the rate was actually ¼. India buyers thought that no offers under the fixed rate would be entertained by the Indian Council, but on 1s. 3⅞d. being accepted, exchange rates at once fell away again.

A rapid recovery ensued in silver, and for the first time China became an important buyer of bar silver, and continued to take large sums until late in the year. Between July and October the question of the repeal of the Sherman act by the Senate was much discussed. The opponents of silver ultimately gained a complete victory. The silver market of course fell to pieces, and 31½d. was speedily touched. During this period hardly an application was made for Council drafts, but a fresh minimum was fixed at 1s. 3¼d., and some unimportant sales were made at this rate. As this seems likely to be adhered to, exchange has since approximated to the same figure. Good inquiry for both India and China caused silver to rise to 32d.@32½d., at which rates the banks became so independent of the usual Council remittances that it became likely that an import duty would be imposed on silver entering India. Toward the end of November, China ceased buying, but then large shipments were sent to India merely as merchandise, and, aided by extensive speculative buying, prices remained fairly steady. Many of the later shipments to China were diverted to India, the import duty being regarded as imminent. It is noteworthy that the highest and lowest prices of the year were on June 19 (38¾d.) and June 30 (30½d.), within eleven days of each other. The average price for the year was 35⅝d.

EXPORT OF SILVER TO INDIA, CHINA, AND THE STRAITS.

Year.	From London.				From Venice.	From Marseilles.
	India.	China.	Straits.	Total.		
1884	£5,357,836	£1,031,278	£1,671,858	£8,060,972	£27,000	£331,250
1885	6,352,341	649,402	638.682	7,640,425	150,000	220,500
1886	4,348,010	363,593	594,280	5,305,883	....	197,654
1887	4,068,289	293,266	568,570	4,930,125	....	971,053
1888	4,348,529	319,121	661,527	5,329,177	....	....
1889	5,834,334	355,874	1,681,114	7,871,332	....	....
1890	7,330,356	263,947	912,606	8,506,909	....	....
1891	4,462,754	241,985	2.209,966	6,914,705	....	....
1892	7,229,199	147,882	3,826,739	11,203,820	....	....
1893	7,052,271	2,390,969	1,612,513	11,055,753	....	....

COMMERCIAL RATIO OF SILVER TO GOLD EACH YEAR SINCE 1687.

(From 1687 to 1832 the ratios are taken from Dr. A. Soetbeer; from 1833 to 1878 from Pixley and Abell's tables; and for subsequent years from daily cablegrams from London to the Bureau of the Mint.)

Year.	Ratio.	Year.	Ratio.	Year.	Ratio.	Year.	Ratio.	Year.	Ratio.	Year.	Ratio.
1687	14.94	1722	15.17	1757	14.87	1792	15.17	1827	15.74	1862	15.35
1688	14.94	1723	15.20	1758	14.85	1793	15.00	1828	15.78	1863	15.37
1689	15.02	1724	15.11	1759	14.15	1794	15.37	1829	15.78	1864	15.37
1690	15.02	1725	15.11	1760	14.14	1795	15.55	1830	15.82	1865	15.44
1691	14.98	1726	15.15	1761	14.54	1796	15.65	1831	15.72	1866	15.43
1692	14.92	1727	15.24	1762	15.27	1797	15.41	1832	15.73	1867	15.57
1693	14.83	1728	15.11	1763	14.99	1798	15.59	1833	15.93	1868	15.59
1694	14.87	1729	14.92	1764	14.70	1799	15.74	1834	15.73	1869	15.60
1695	15.02	1730	14.81	1765	14.83	1800	15.68	1835	15.80	1870	15.57
1696	15.00	1731	14.94	1766	14.80	1801	15.46	1836	15.72	1871	15.57
1697	15.20	1732	15.09	1767	14.85	1802	15.26	1837	15.83	1872	15.63
1698	15.07	1733	15.18	1768	14.80	1803	15.41	1838	15.85	1873	15.92
1699	14.94	1734	15.39	1769	14.72	1804	15.41	1839	15.62	1874	16.17
1700	14.81	1735	15.41	1770	14.62	1805	15.79	1840	15.62	1875	16.59
1701	15.07	1736	15.18	1771	14.66	1806	15.52	1841	15.70	1876	17.88
1702	15.52	1737	15.02	1772	14.52	1807	15.43	1842	15.87	1877	17.22
1703	15.17	1738	14.91	1773	14.62	1808	16.08	1843	15.93	1878	17.94
1704	15.22	1739	14.91	1774	14.62	1809	15.96	1844	15.85	1879	18.40
1705	15.11	1740	14.94	1775	14.72	1810	15.77	1845	15.92	1880	18.05
1706	15.27	1741	14.92	1776	14.55	1811	15.53	1846	15.90	1881	18.16
1707	15.44	1742	14.85	1777	14.54	1812	16.11	1847	15.80	1882	18.19
1708	15.41	1743	14.85	1778	14.68	1813	16.25	1848	15.85	1883	18.64
1709	15.31	1744	14.87	1779	14.80	1814	15.04	1849	15.78	1884	18.57
1710	15.22	1745	14.98	1780	14.72	1815	15.26	1850	15.70	1885	19.41
1711	15.29	1746	15.13	1781	14.78	1816	15.28	1851	15.46	1886	20.78
1712	15.31	1747	15.26	1782	14.42	1817	15.11	1852	15.59	1887	21.13
1713	15.24	1748	15.11	1783	14.48	1818	15.35	1853	15.33	1888	21.99
1714	15.13	1749	14.80	1784	14.70	1819	15.33	1854	15.33	1889	22.10
1715	15.11	1750	14.55	1785	14.92	1820	15.62	1855	15.38	1890	19.76
1716	15.09	1751	14.39	1786	14.96	1821	15.95	1856	15.38	1891	20.92
1717	15.13	1752	14.54	1787	14.92	1822	15.80	1857	15.27	1892	23.73
1718	15.11	1753	14.54	1788	14.65	1823	15.84	1858	15.38	1893	26.43
1719	15.09	1754	14.48	1789	14.75	1824	15.82	1859	15.19		
1720	15.04	1755	14.68	1790	15.04	1825	15.70	1860	15.29		
1721	15.05	1756	14.94	1791	15.05	1826	15.76	1861	15.50		

HIGHEST, LOWEST, AND AVERAGE PRICE OF BAR-SILVER IN LONDON.

[Per ounce British standard (0.925), since 1833, and the equivalent in United States gold coin of an ounce 1000 fine, taken at the average price.]

Years.	Lowest.	Highest.	Average.	Average.	Years.	Lowest.	Highest.	Average.	Average.
	Pence.	Pence.	Pence.			Pence.	Pence.	Pence.	
1833	58.750	59.875	59.188	$1.297	1863	61.000	61.750	61.375	$1.345
1834	59.750	60.750	59.938	1.313	1864	60.625	62.500	61.375	1.345
1835	59.250	60.000	59.688	1.308	1865	60.500	61.625	61.063	1.338
1836	59.625	60.375	60.000	1.315	1866	60.375	62.250	61.125	1.339
1837	59.000	60.375	59.563	1.305	1867	60.375	61.250	60.563	1.328
1838	59.500	60.125	59.500	1.304	1868	60.125	61.125	60.500	1.326
1839	60.000	60.625	60.375	1.323	1869	60.000	61.000	60.438	1.325
1840	60.125	60.750	60.375	1.323	1870	60.250	60.750	60.563	1.328
1841	59.750	60.375	60.063	1.316	1871	60.188	61.000	60.500	1.326
1842	59.250	60.000	59.438	1.303	1872	59.250	61.125	60.313	1.322
1843	59.000	59.625	59.188	1.297	1873	57.875	59.938	59.250	1.298
1844	59.250	59.750	59.500	1.304	1874	57.250	59.500	58.313	1.278
1845	58.875	59.875	59.250	1.298	1875	55.500	57.625	56.875	1.246
1846	59.000	60.125	59.313	1.300	1876	46.750	58.500	52.750	1.156
1847	58.875	60.375	59.688	1.308	1877	53.250	58.250	54.813	1.201
1848	58.500	60.000	59.500	1.304	1878	49.500	55.250	52.563	1.152
1849	59.500	60.000	59.750	1.309	1879	48.875	53.750	51.250	1.123
1850	59.500	61.500	61.063	1.316	1880	51.625	52.875	52.250	1.145
1851	60.000	61.625	61.000	1.337	1881	50.875	52.875	51.938	1.138
1852	59.875	61.875	60.500	1.326	1882	50.000	52.375	51.813	1.136
1853	60.625	61.875	61.500	1.348	1883	50.000	51.188	50.625	1.110
1854	60.875	61.875	61.500	1.348	1884	49.500	51.375	50.750	1.113
1855	60.000	61.625	61.313	1.344	1885	46.875	50.000	48.563	1.065
1856	60.500	62.250	61.313	1.344	1886	42.000	47.000	45.375	0.995
1857	61.000	62.375	61.750	1.353	1887	43.250	47.125	44.625	0.978
1858	60.750	61.875	61.313	1.344	1888	41.625	44.563	42.875	0.940
1859	61.750	62.750	62.063	1.360	1889	42.000	44.375	42.688	0.936
1860	61.250	62.375	61.688	1.352	1890	43.625	54.625	47.750	1.046
1861	60.125	61.375	60.813	1.333	1891	43.500	48.750	45.063	0.988
1862	61.000	62.125	61.438	1.346	1892	37.875	43.750	39.813	0.876
					1893	30.500	38.750	35.625	0.782

The future value of the metal is extremely uncertain, and can be maintained only by an international agreement for bimetallism. The enormous interests involved in the destruction of the only money of the greater part of the human race, and more particularly the heavy losses this would inevitably bring cannot fail to awaken the most astute commercial people in the world to the dangers involved in these independent experiments with the world's money.

We doubt not that before long public opinion in Great Britain will demand that the money of the world shall be placed under the intelligent control of an international monetary commission or clearing house which will adopt a universal standard—gold, no doubt—and will provide for a flexible ratio between gold and silver, that will prevent blind experiments with the world's money and the wild fluctuations in values which have already caused losses far beyond the entire value of all the silver money in existence.

A plan for such a solution of this momentous question was proposed in the *Engineering and Mining Journal* by the editor of this work and has since been published in pamphlet form under the title, *Universal Bimetallism and an International Monetary Clearing House.*

Until the adoption of universal bimetallism, the price of silver must continue to decline, and this may at any time cause a panic in India which would probably extend to all other countries and bring immeasurable disaster on the great manufacturing, exporting, and money-lending countries. The United States, secure in its large production of gold and in its certain exports of breadstuffs and raw materials to gold-basis countries, would be affected the least of all nations, and consequently can await in perfect patience the awakening of Europe to the dangers of the situation, some such international control of the world's money without there may at any moment come a demand for gold that the production and stocks of that metal would be wholly inadequate to supply, and, like everything else that is not obtainable in the quantity demanded, its value, as measured by its purchasing power, would increase suddenly and perhaps enormously. This danger, so frightful in its possible consequences, must profoundly alarm every one who gives it thoughtful consideration.

The Bank of England and the other London banks which united in averting the impending panic due to the Baring failure; the banks in the New York Clearing House, which united succeeded in preventing a disastrous financial crisis in 1893—would be wholly unable to stem the panic which a rapidly appreciating value for gold would cause. Nothing short of a universal bimetallism and world's monetary clearing house could do that.

The danger is too real and too near to be dismissed with a suggestion that blind experiment and ignorant self-confidence will work out a way of salvation. The age of miracles and of charlatanism has passed, and the business affairs of the world can be safely conducted only through the intelligent study of the statistics of the past. A question which affects the rights and prosperity of the whole world cannot and should not be settled by one interest without regard to the rights of others.

The Gold Resources of Colorado.

By T. A. Rickard.

From 1859, when gold mining in Colorado first began, to 1893 is a long interval, yet it is not too much to say that even at this late date the extent and distribution of the gold resources of Colorado are not easy to determine. The great chain of the main divide traverses the State from north to south, a distance of 280 miles. For this entire length these mountains contain deposits of the precious metals. The width of the existing mining belt is greatest in the south, where it extends for 150 miles from east to west. The immense territory included within these limits covers a portion of the earth's exterior which for lavishness of mineral wealth is almost unequaled.

The Archæan granite and gneiss of the Front Range inclose the familiar vein structures of Boulder, Gilpin, and Clear Creek counties. To the west and southwest there are the extensive bodies of later eruptive rocks which of recent years have been found to be important depositories of the precious metals. In this area are the silver mines of Creede, the gold and silver lodes of Lake City, Marshall Basin, Red Mountain, and Ouray, and also the gold veins of newly discovered Cripple Creek, Hartsel, Balfour, etc. Farther west, toward the center of the State and extending southward, is the sweeping horseshoe curve of the Carboniferous limestone series which holds the treasures of Leadville, Battle Mountain, and Aspen, together with several patches farther south, the most important of which is that at Rico. Of these mining districts in the limestone Aspen is at present the only one which does not produce a notable proportion of gold. To generalize upon the geological distribution of the gold ores of Colorado would be dangerous, for modern experience has shown the miner one fact above all others—that gold is confined to the rocks of no one age or formation. In Colorado gold ores are found alike in the Archæan granite foundations which uphold the hills and in the Eocene lava flows which cap the mountains, while there is an unending diversity of lode types, from the best defined, clear-cut, almost vertical fissures to the most irregular, ill-defined, almost horizontal bedded deposits.

A reference to statistics shows that out of the $5,539,021 of gold credited to Colorado in 1892 the following counties were the chief contributors: Gilpin, $1,419,409; Boulder, $1,027,320; San Miguel, $725,484; El Paso, $583,010; Clear Creek, $328,205; Lake, $262,629; scattered, $1,192,964. It is generally considered that the figures for 1892 as given by the Director of the Mint are too high, and that, instead of $5,539,021, the total really was under rather than over $5,000,000. During 1893 there was a marked increase in the production. The total yield is estimated at from $7,250,000 to $7,500,000. All the gold-mining districts exhibit an increase. El Paso County, because of Cripple Creek, produced nearly $2,000,000; Lake County, owing to new discoveries on Breece Hill, Leadville, nearly trebled its gold output; while San Miguel showed a noteworthy and Gilpin a slight advance. The gold output of Boulder and Clear Creek counties suffered through the partial suspension of work at mines which produce gold in combination with silver-bearing ores. Therefore, notwithstanding the stimulus given to the production of the gold-mining parts of these counties, more particularly in the last quarter of the year, their output exhibits no such increase as would otherwise be expected. The same is true of the various parts of the San Juan region, whose output is counted under the heading "scattered," for at Red Mountain, Rico, Ouray, Silverton, and other districts much of the gold comes from silver-bearing ores. The gold output, therefore, suffered by the inactivity of many of the largest mines during the few months following the collapse in silver. At the present moment, however, matters are adjusting themselves, and mines which are essentially gold producing are being reopened and developed to such an extent as to much more than offset the diminished gold product from silver-bearing ores.

The first gold vein discovered in Colorado was the Gregory, at Black Hawk (May 6, 1859), in Gilpin County, which has from the beginning been the leading gold-mining section of the State, and although often considered "worked out," it is to-day as prosperous and productive as at any time since 1860. The deepest mines of the State are in this district, the California shaft having attained 2290 ft. on the lode and 2040 ft. in vertical depth. The characteristic lodes of Gilpin are fissure veins in granitoid gneiss. Though the ores carry a large percentage of pyrites, they are successfully treated by the 525 stamps in the mills around Black Hawk. Low freights enable the miners to benefit by the cheap rates offered by Denver smelters, so that there are large shipments of concentrates from the mills and of hand-picked, high-grade ores from the mines. The yield for 1893 was probably larger than that of 1892, which was previously the best on record. At the present time several of the most important and formerly most productive mines, such as the Gunnel, California, Prize, etc., are, owing to different causes, idle. Their temporary inactivity has, however, been more than offset by the younger producers, such as are yet in the windlass and whim stage of mining. This speaks well for the continued prosperity of the region, and in the same connection it is well to draw attention to the fact that during the past year the known productive area has been extended outside the old ground, around Black Hawk, Central City, and Nevadaville, by the discoveries which have been made at Yankee Hill, Pine Creek, and Elk Park.

A belt of the basement rocks of Colorado—the Archæan granite and gneiss—stretches through Boulder, Gilpin, and Clear Creek counties, and the similarity of the rock formation was the immediate cause of their early development. Though the gold belt of Gilpin passes through Boulder and contains certain veins, such as those of Copper Rock, which have the characteristics of those found in the pioneer county, yet on the whole Boulder County has a lode structure and mineral association which distinguishes it from any other district in Colorado, or indeed in the United States. Boulder is to the Rockies what Transylvania is to the Carpathians. It is the region of telluride ores of great variety and complexity. The mines are not so large nor so deep as those of Gilpin, because the veins which they contain are smaller and richer. The output is a steady one, the yield for 1893 showing no marked difference from that of the previous year. The silver product of this district at present is one-quarter of the gold yield, but the proportion will continue to diminish during the next few years, because the prospecting being done at the present time is entirely directed to the search for gold veins. An impetus has in this way been given to exploratory work in the Ward, Jamestown, Sunshine, Magnolia, and other well-known portions of the county, which will make its effects apparent in the yield for 1894.

On the other side of Gilpin is Clear Creek County, the most important producer of silver before Leadville and the San Juan were known. The gold output of this county for 1892 was about one-seventh its silver production, but during the past year the yield of the white metal has seriously diminished, while that from the gold mines has increased. In 1894 the same tendency will become more marked. The rock formation of the mountains encircling Empire, Georgetown, Silver Plume, and Idaho Springs is almost identical in character with that of Gilpin. The granitoid gneiss is seamed in more than one direction by systems of fissures of varying size and mineral contents. In the western part of the county they are mostly silver and lead bearing; in the northeastern, bordering upon Gilpin, they are mainly gold-bearing. There are, it is true, some mines near Georgetown which contribute to the gold output, but such output is mainly incidental to the working of silver ores, most of the gold of the county coming from the hillslopes surrounding Idaho Springs and from the mountains above Empire. The bold outcrops of the lodes often appear above the granitic surface. In the early days the soft and weathered portions of many of these croppings were treated as placer material and were washed in sluices. But now they suggest the beginnings of low-grade gold-milling propositions which merit careful examination and intelligent exploration.

In 1892 Lake County produced $250,000 in gold and $7,750,000 in silver. During 1893 the gold output was nearly trebled, while the silver yield largely diminished. In 1894 it is likely that the value of the gold produced will exceed that of the silver. It was gold placer-mining which caused the beginning of the development of Leadville, and after the fall in silver its miners woke up to the fact that the district still had gold resources, and attention was again directed to them. During the last three months of 1893 the rapid opening of the gold deposits of Ball Mountain and Breece Hill led to a production of 510 tons of ore per day, carrying an equal number of ounces of gold, equivalent to an annual output of no less than $3,000,000. There is no doubt that the rich placers formerly worked in Evans and California gulches were fed by the degradation of the lodes which are now being exploited in the Little Johnnie, Lilian, Antioch, and neighboring mines. This same gold-bearing belt extends across the range (the Park or Mosquito) and enriched the gravel deposits of Alma and Fair Play on the eastern slope.

The geological formation of Breece Hill and its vicinity is not unlike that of the main silver-producing belt of Leadville, the gold being in most cases found in the limestone between bodies of prophyry.* Sometimes, as at the Antioch, the dikes of porphyry which cut through the limestone series are themselves sufficiently gold-bearing to be economically valuable. These conditions of ore occurrence are familiar to the Leadville mining engineer, and the experience which he has obtained on Iron Hill, Carbonate Hill, and the other portions of the silver-producing area will be of great assistance in systematically developing this formerly neglected portion of the district.

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* Quartz felsite.

Across the valley of the Arkansas the granite formation of the Saguache Range is seamed with many gold veins. On the steep slopes of the mountains near Twin Lakes have been found small bodies of ore of remarkable richness. In the valleys below are placers of known value, and on the hillslopes opposite, behind Granite, many gold lodes are known to exist. There is ample room and plenty of evidence for the discovery in this wide territory of further important depositories of gold ore.

El Paso County made a gold output of $2000 in 1891; in 1892 it was $583,010, and in 1893 it is estimated to have reached nearly $2,000,000. This increase is due entirely to the mines of Cripple Creek, at the back of Pike's Peak. To-day the new camp has a productive area of over twenty square miles, a population of 8000, and a production of gold which is at the rate of $4,000,000 per annum. One of the most remarkable features of the new camp is the rapid extension of the proved gold-bearing area; and though the geological formation is in some respects unfamiliar to the miner from Leadville or Gilpin, yet, as it is becoming better understood, the work of development is proving the existence of well-defined lode channels traversing the later igneous rocks which lie upon and against the basal granite. Few mining districts afford so many varied types of vein structure. Nor is the mineralogical composition of the ore itself less diversified. That diversity has been a stumbling block in the way of successful milling; but as the preliminary blunders incidental to most new districts have now been made, there is reason to expect that the question of the ore treatment will be placed upon a sound and secure basis.

Cripple Creek has already brought "second Cripple Creeks" into existence. The miner who has prospected in the new camp has remembered a similar formation elsewhere, and active search for gold ores in other parts of the great masses of igneous rock in this section of Colorado has led to the finding of further deposits at Hartsel, Howbert, Balfour, and other localities in the adjoining portions of Park County.

San Miguel is part of the great southwestern mining region of Colorado. In 1891 its gold production was $670,602; in 1892, $725,484. During 1893 there was a notable increase in the yield, traceable in part to the larger output of the consolidated Smuggler-Union-Sheridan-Mendota mines at Marshall Basin. These, forming probably the largest mining property now under one management in the State, yielded nearly $400,000 in gold and 500,000 oz. of silver. The Cimmaron mine has been producing very steadily, and the erection of a 120-stamp mill by the San Miguel Consolidated Gold Mining Company has been one of the noteworthy events of the year. The gravel deposits of the San Miguel River, which in times past have been very extensively worked, now yield only an insignificant part of the gold production. Their place has been more than filled by the development of the strong and continuous veins traversing the enormous bodies of andesitic breccia which characterize the geology of this county. How successful vein-mining under these conditions can be made has been illustrated by the exploitation of the Smuggler-Union lode, which has been worked continuously for over a mile in length and for a vertical depth exceeding 1000 ft. This part of Colorado offers a fair field for large mining enterprises of a sound description.

In the foregoing paragraphs brief reference has been made to six counties out of the nineteen which in 1892 contributed to the gold yield of the State, but Pitkin, which holds the Aspen district, was the only county which in that year produced silver alone. Among the counties which have not been particularized there occur notable gold deposits which are destined to increased productiveness. The "silvery San Juan," embracing Ouray, San Juan, San Miguel, Dolores, and La Plata counties, is a mining territory whose diversified topographical and geological structure is identified with depositories of gold ores having a variety far beyond the attempt at any generalization.

GOLD AND SILVER MINING IN SOUTH AMERICA.[*]

BY COURTENAY DE KALB.

Bolivia.—The total exportation of silver from Bolivia in 1890 was 1,200,000 marcs[†] and in 1891 1,403,345 marcs, of which 792,279 were from the Huanchaca mines and 157,234 from the mines of the Compagñie Aullagas. In 1892 the Compañia Huanchaca de Bolivia shipped a total of 901,041 marcs, of which 616,315 were in the form of ore and 284,726 in refined bars. The gross value in Bolivianos of the production of this mine since 1877 has been:

1877........	1,565,784	1882........	6,034,282	1887........	5,183,341	1892......	7,453,935
1878........	2,189,749	1883........	5,136,788	1888........	5.549,398	1893......	....
1879........	2,215,882	1884........	4,934.439	1889	6,977,005		
1880........	2,489,143	1885........	4,858,989	1890........	7,698,326		
1881........	3,191,630	1886........	6,258,320	1891........	7,440,085		

Carefully detailed estimates of the ore available, but unmined, in this company's property, show a future production of 4,009,699 marcs of silver, or 1010 tons avoirdupois. The Royal Silver Mines of Potosi has been producing steadily at an average rate of about 27,000 oz. of silver per month.

Brazil.—The Ouro Preto Gold Mines of Brazil, Limited, which recently went into liquidation, has reorganized under the same title, with a capital of £80,000. The new company acquires all the rights of the old company, and is to receive £1000 per annum and a percentage of the profits. The output of these mines for four months of 1893 was 3600 oz. of gold, with considerable bismuth. The sales of gold and bismuth for two additional months are reported as realizing, gross, £6684. The total value of the product of the Ouro Preto mines for 1891 was £58,127, and for 1892, £44,894. The São João d'el Rei Mining Company has been doing extensive development work, and has erected a 40-stamp mill. The reports at hand for one month only announce a remittance of gold valued at £3340. No reports of output are available from the Dom Pedro mine, but important development work has been done and improvements have been made in the plant, among others the installation of Pelton wheels, which are reported as proving satisfactory. The Santa Barbara Gold Mining Company, Limited, issues

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[*] The author desires to express acknowledgments to Messrs. E. E. Olcott, A. D. Hodges, Jr., and Charles Bullman for assistance in the preparation of this article.

[†] The marc = .5065 lb. avoirdupois, or 7.3854 troy oz.

this statement of output for three years ending Dec. 31, 1892: Tons ore stamped, 8970; bullion produced, 3181 oz.; value, £11,124. The figures for the previous years were 12,050 tons, 4775 oz., and £16,566.

Colombia.—A number of the mines in this republic have been closed by order of the Government, pending the adjustment of difficulties with various municipalities over the contamination of streams resulting from the operation of the mines. The Colombian Hydraulic was producing gold to the value of about $5000 a month until stopped by an injunction in August. The Frontino and Bolivia mine produced ore to the value of £54,725 during the first six months of 1893, as against £53,632 in thc latter half of 1892. Extensive development work is in progress on this property, as a result of which the output is expected to be largely increased in the future. The Gravel Gold mines were producing up to July, 1893, at the rate of $1000 a month. Small returns were also reported from the Loma, Oritá, and Tesoro mines, but no reliable data concerning them are at hand. The production of the Frias (Tolima) mines has been very regular, averaging about 220 tons of concentrates per month, worth about $260 a ton. The production from this property from 1872 to 1877 averaged 17 tons of concentrates per month, carrying about 300 oz. of silver per ton. From 1877 to 1880 the output increased to 40 tons per month. Since then it has varied considerably until it has reached the present figure of 220 tons. Extensive developments are being made on this property to increase the product.

Ecuador.—There has been considerable increase of popular interest in mining in Ecuador, due to the operations which are being entered upon in this republic by several foreign companies. As one result of this the mining law has been revised, and all minerals of whatever sort, wherever found, including coal, are declared the property of the State, save where the mineral occurs loose on the surface. Any mine may be "denounced" by the finder, who may obtain a concession by the payment of 8 sucres. Nothing further is required to hold a concession than an annual payment of 8 sucres, and during the first twenty-five years of the life of the concession the property is exempt from all fiscal or municipal dues, royalties, or duties on mines or their products. This also applies to all plant and tools. The mining claims allowed by law measure 600 by 200 meters, except in the case of placer deposits, when the claim allowed is 50,000 square meters, the only restriction as to shape being that the minimum width shall be 50 meters. Also in coal or petroleum fields the claims granted are 200 meters in width by 1 kilometer in length. It is allowable for one person to "denounce" 20 contiguous claims. Extensive development work is being done on the Zaruma mines, and the output, on very irregular work, for five months, ending in July, 1893, reached 575 oz. of gold. The ore ranges from 6 dwt. to 1 oz. 14 dwt. per ton. Much interest has centered in the operations of the gold placers known as the Plaga de Oro and contiguous properties which are now being developed by American companies. Mr. Charles E. Russell and others have reported on these properties, giving most flattering acounts of the gravel, its richness, extent, and facility for the introduction of the American system of hydraulic mining. While large amounts of capital are being expended in this work, there has been no production as yet, but good returns are promised.

British Guiana.—Through the courtesy of Mr. W. Van Esveld, President of the Surinaamsche Bank, Paramaribo, Dutch Guiana, the following notes and information have been furnished as to the production of gold in British Guiana:

During 1893 the Kanimapoo Gold Mining Company, Limited, was floated with a capital of $250,000 in $5 shares. The Marima Gold Mining Company, Limited, capital $300,000 in $5 shares, was started, the purpose being to acquire mining and placer claims on the Arakaka Creek, Barima River. On July 5 a prospectus of the Arakaka Placer Gold Mining Company was issued, capital $250,000 in $5 shares, promoted for the purpose of acquiring a placer previously worked under the name of Barima Vale. During the last semester the following syndicates have been formed: Gold Fields of British Guiana, capital $95,000; Barima Development Syndicate, capital $30,000; Arakaka Development Syndicate, capital $50,000; Warimba Development Syndicate, capital $30,000; Manicura Development Syndicate, capital $30,000; and the Bartley Syndicate, capital unknown. Mr. Winter, the vender of the Kanimapoo claims, recently located another mining concession on the Demerara River opposite his firm's grant, named Appaparu, which he has sold to London capitalists. The Kanimapoo placer ordered a 20-stamp mill, which is now being erected. In the course of the year there were in British Guiana several deplorable catastrophes in placer and mining enterprises.

The production of gold in 1893 in British Guiana (Demerara) has been the largest on record. The yearly output since 1884 was as follows:

Year.	Kilos.	Value.	Year.	Kilos.	Value.	Year.	Kilos.	Value.
1884	7.775	$4,894	1888	453.127	$266,719	1892	4,031.027	$2,303,163
1885	22.983	15,596	1889	879.570	524,323	1893	4,440.707	2,542,996
1886	202.810	112,042	1890	1,947.327	1,124,760			
1887	370.277	213,252	1891	3,150.368	1,801,389			

Dutch Guiana.—Mr. W. Van Esveld has also furnished the following figures showing the exports of gold from Surinam, Dutch Guiana. From 1876 to 1891, inclusive, the figures are those published officially by the Minister of Colonies of the Netherlands, and those for 1892 and 1893 are furnished by Mr. Van Esveld's bank. It is estimated that nearly as much more is smuggled out of the country to escape the export duty of 2.8c. per kilogram.

Year.	Kilos.	Value.	Year.	Kilos.	Value.	Year.	Kilos.	Value.
1876	....	$20,060	1882	589.970	$315,460	1888	1,029.777	$567,140
1877	....	117,939	1883	679.621	363.385	1889	894.333	492,545
1878	....	163,638	1884	967.271	524,891	1890	952.023	524,319
1879	....	273,355	1885	983.039	535,373	1891	820.983	452,158
1880	680.156	369,306	1886	753.845	415,188	1892	944.000	627,025
1881	638.627	341,473	1887	1,006.904	554,562	1893	1,097.650	729,059

French Guiana.—The production of gold in French Guiana, which had shown signs of falling off in 1892, has again increased, and has exceeded the output of previous years up to the date of latest advices. The shipments for the first six months aggregated 26,856 oz., an average of 4476 oz. per month. The chief producing mine is the Enfin, which yields an average of 740 oz. per month, and this is closely followed by the Sainte Elie. The Sinnamary Mining Company has gone into voluntary liquidation. The following table shows the output of gold from French Guiana since 1878:

Year.	Kilos.	Year.	Kilos.	Year.	Kilos.	Year.	Kilos.
1878	1,605	1882	1,780	1886	1,594	1890	1,342
1879	1,516	1883	1,894	1887	1,785	1891	1,511
1880	1,304	1884	1,952	1888	2,032	1892	1,482
1881	1,650	1885	1,654	1888	1,496	1893	*2,000

* Estimated.

Peru.—The latest complete reports of the silver production of Peru are for the year 1891, when the exports of ore and bar reached a value of 2,201,895 soles. In the same year there was exported silver as specie to the amount of 1,479,456 soles. The Caylloma Silver Mining Company, Limited, in the year ending June 30, 1893, produced bullion of a gross value of £49,424. The net profit for the year was £13,428. During the same period £11,333 was expended on the company's plant. From June 30 to Oct. 31, 1893, the output was 45,856 oz. of bullion. In addition, the company exports its richer ores, which average about 685 oz. of silver and 2 oz. 7 dwt. of gold per ton. The Backus & Johnston smelter at Casapalca is now turning out from three to four tons of matte per day, varying from 600 to 225 oz. of silver, and carrying 25% of copper and 25% of lead. This firm is adding to its plant so as to increase its capacity to an output of about 1000 tons per month. The Central (Lima to Oroya) Railroad is now open as far as Oroya, but owing to the fall in the price of silver it has failed to greatly stimulate the mining industry up to the present time. The production of the Cerro de Pasco silver mines fell below 1,000,000 oz. in 1893, which is lower than for many years. The Central Railroad will be extended to these mines, and will communicate with the Valley of Pancartambo, in the Montaña, where the Peruvian Corporation is now establishing colonists.

Mr. A. D. Hodges, Jr., kindly furnishes the following report of the silver bars melted at the Government assay office at Cerro de Pasco: In 1879, 1,353,480 Spanish ounces; 1880, 1,043,096; 1881, 844,120; 1882, 835,760; 1883, 958,624; 1884, 1,007,408; 1885, 1,051,976; 1886, 1,171,956. Mr. Hodges also gives the following estimates of the total production of Cerro de Pasco: From 1630–1784 (154 years), 300,000,000 Spanish ounces; 1784–1886 (98 years), 200,000,000—total for 252 years, 500,000,000 Spanish ounces, equivalent to 462,250,000 troy ounces, or an annual rate of 1,833,888 troy ounces. These do not differ widely, roughly speaking, from the figures given in THE MINERAL INDUSTRY, Vol. I., p. 563, but they are valuable because Mr. Hodges' estimates are undoubtedly the most accurate that have been made. They are based upon (1) the official returns of silver bars melted at the Government assay office at Cerro de Pasco from 1784 to 1886, inclusive; (2) estimates of Fr. Castelnan of the production from 1630 to 1784; and (3) the estimate of the amounts of silver smuggled out of Cerro de Pasco,—not passing through the Government office, where it was taxed,—in part to evade the tax, in part because it was stolen, this estimate being based on the published writings of those who have reported on the mines, and upon the results of Mr. Hodges' own investigations at Cerro de Pasco.

Uruguay.—The production of gold from the gold fields of Uruguay, from official reports of the company, for five months of 1893, was valued at $13,750. The total output of gold in Uruguay in 1891 was 218.97 kilos, from 40,300 tons of ore crushed; in 1892 it was 131.88 kilos, from 16,500 tons of ore crushed.

Venezuela.—El Callao produced a little more in 1893 than in 1892, according to the reports of six months' working, which show a return of 17,441 oz. of gold from 25,212 tons of ore. The product of this mine during the last nine years has been as follows:

Year.	Ounces.	Year.	Ounces.	Year.	Ounces.
1884	177,055	1888	52,598	1892	31,931
1885	114,500	1889	52,973	1893	34,537
1886	181,300	1890	49,432		
1887	73,872	1891	44,774		

The Columbia mine, the ore from which is treated in El Callao mill, yielded 2328 oz. of gold in four months of 1893, the average grade of the ore being a little less than 14 dwt. per ton. An exhaustive examination of the tailings of the Caratal mine by Mr. Skertchley shows that there are 102,000 tons, with an aggregate value of $455,000. By a special decree of the Government all supplies for mines in Venezuela will henceforth be admitted free of duty. A new mining code has also gone into effect, full details of which will be found in the United States Consular Report for July, 1893.

PRODUCTION OF GOLD AND SILVER IN THE WORLD. (*a*)

(Kilogram of fine gold, $664.60; kilogram of fine silver, $41.56, coining rate in United States silver dollars.)

Country.	1891.				1892.			
	Gold.		Silver.		Gold.		Silver.	
	Kilos.	Dollars.	Kilos.	Dollars. (*b*)	Kilos.	Dollars.	Kilos.	Dollars. (*b*)
United States	49,917	33,175,000	1,814,642	75,416,500	49,654	33,000,000	*c*2,018,616	83,893,675
Australasia	47,245	31,399,000	311,100	12,929,300	50,964	33,870,800	418,087	17,375,677
Mexico	1,505	1,000,000	1,275,265	53,000,000	1,699	1,147,500	1,419,634	59,000,000
Russia	32,993	21,927,148	13,859	576,000	37,099	24,655,995	13,234	550,000
Germany	....	....	*d*190,600	7,921,336	....	....	*d*190,600	7,921,336
Austria-Hungary	2,106	1,399,648	52,020	2,161,951	2,264	1,504,654	55,082	2,289,208
Sweden	110	73,100	5,748	238,886	88	58,485	5,211	216,569
Norway	....	....	5,665	235,400	....	....	*e*5,665	235,400
Italy	242	161,000	27,583	1,146,370	297	197,419	29,753	1,236,551
Spain	....	....	*e*51,502	*e*2,140,400	....	....	*g*85,500	3,553,380
Turkey	*e*10	*e*7,000	1,323	55,000	*e*10	7,000	*e*1,323	55,000
France	206	136,872	71,303	2,963,353	206	136,872	71,303	2,963,353
Great Britain	101	67,000	8,673	360,450	100	66,600	6,156	255,650
Canada	1,392	925,000	9,797	407,100	*e*1,392	925,000	9,792	407,100
Argentina	*e*123	82,000	14,918	620,000	*e*123	82,000	*e*14,918	620,000
Colombia	5,224	3,472,000	31,232	1,298,000	*e*5,234	3,472,000	*e*31,232	1,298,000
Bolivia	*e*101	67,000	372,666	15,488,000	*e*101	67,000	*e*372,666	15,488,000
Chile	*e*2,162	1,436,600	70,794	2,942,000	*e*2,162	1,436,600	*e*70,794	2,942,000
Brazil	659	438,000	....	....	*e*659	438,000	....	....
Venezuela	1,504	1,000.000	....	....	*e*1,504	1,000,000	....	....
Guiana (British)	2,708	1,800,000	....	....	3,465	2,303.163	....	....
Guiana (Dutch)	816	542,000	....	....	1,079	717,535	....	....
Guiana (French)	1,502	998,229	....	....	1,482	984,937	....	....
Peru	113	75,000	74,879	3,112,000	*e*113	75,000	*e*74,879	3,112,000
Uruguay	219	145,547	....	....	132	87,727	....	....
Central America	246	163,492	48,123	2,000,000	*e*246	163,492	*e*48,123	2,000,000
Japan	*e*765	508,400	43,282	1,798,800	*e*765	508,400	*e*43,282	1,798,800
Africa	21,366	14,199,600	....	....	34,507	22,933,566	....	....
India (British)	3,754	2,495,000	....	....	4,600	3,057,900	....	....
Corea	*e*1,128	750,000	....	....	*e*1,128	750,000	....	....
China	*f*6,668	4,431,600	....	....	*f*11,694	7,771,920	....	....
Total	184,885	122,875,236	4,494,974	186,810,846	212,767	141,419,565	4,985,855	207,211,699

(*a*) This table is made up from the data reported by the Director of the Mint, except where there have been later official returns, in which cases the latter have been used. (*b*) Values are estimated at the United States coinage rate, wherein one kilogram of fine silver is worth $41.56. (*c*) Production as reported in THE MINERAL INDUSTRY, Vol. I., the figures for the production of silver in 1892 in the United States given by the Director of the Mint having been discredited by competent statistical authorities. (*d*) Amount estimated by the Director of the Mint as the product of German mines: the reason for using these figures and not those officially reported has been fully explained in recent Mint reports. (*e*) Estimated. (*f*) Net exports. (*g*) Reported by Señor Romon Oriol.

WORLD'S PRODUCTION OF GOLD AND SILVER.

Period.	Mean Annual Product, Kilos.		Ratio of Silver to Gold, Weight.	Ratio of Gold to Silver, Value.	Period.	Mean Annual Product, Kilos.		Ratio of Silver to Gold, Weight.	Ratio of Gold to Silver, Value.
	Gold.	Silver.				Gold.	Silver.		
1493–1520...	5,800	47,000	8.1	(*a*)10.75	1856–1860..	201,750	904,990	4.5	15.29
1521–1544...	7,160	90,200	12.6	(*b*)11.25	1861–1865..	185,057	1,101,150	5.9	15.41
1545–1560...	8,510	311,600	36.6	(*c*)11.30	1866–1870..	195,026	1,339.085	6.9	15.56
1561–1580...	6,840	299,500	43.8	11.50	1871–1875..	173,904	1,969,425	11.3	15.98
1581–1600...	7,380	418,900	56.8	11.80	1876.....	165,956	2,323.779	14.0	17.88
1601–1620...	8,520	422,900	49.6	12.25	1877....	179.445	2,388,612	13.3	17.22
1621–1640...	8,300	393,600	47.4	14.00	1878.....	185,847	2,551,364	13.7	17.94
1641–1660...	8,770	366,300	41.8	14.50	1879.....	167,307	2,507,507	15.0	18.40
1661–1680...	9,260	337,000	36.4	15.00	1880.....	163.515	2,479,998	15.2	18.05
1681–1700...	10,765	341,900	31.8	14.97	1881.. ..	158,864	2,592,639	16.3	18.16
1701–1720...	12,820	355,600	27.7	15.21	1882.....	148,475	2,769,065	18.6	18.19
1721–1740...	19,080	431,200	22.6	15.08	1883.....	144,727	2,746,123	19.0	18.64
1741–1760...	24,610	533,145	21.7	14.75	1884.....	153,193	2,788,727	18.2	18.57
1761–1780...	20,705	652,740	31.5	14.73	1885.....	159,289	2,993,805	18.8	19.41
1781–1800...	17,790	879,060	49.4	15.09	1886. ...	159,741	2,902,471	18.2	20.78
1801–1810...	17,778	894,150	50.3	15.61	1887....	159,155	2,990.398	18.8	21.13
1811–1820...	11,445	540,770	47.2	15.51	1888.....	159,809	3,385,606	21.2	21.99
1821–1830...	14,216	460,560	32.4	15.80	1889.....	185,809	3,901,809	21.0	22.09
1831–1840...	20,289	596,450	29.4	15.75	1890.....	181,256	4,180,532	23.1	19.76
1841–1850...	54,759	780,415	14.3	15.83	1891.....	189,824	4,479,649	23.6	20.92
1851–1855...	199,388	886,115	4.4	15.41	1892.....	220,133	4,757,955	21.6	23.72

(*a*) For the period 1501–20; (*b*) 1521–40; (*c*) 1541–60.

NOTE.—The figures from 1493–1882, both years inclusive, are Soetbeer's; those for 1882–92 are from the reports of the Director of the Mint, except United States silver for 1892, which is from direct returns of U. S. refiners, etc.

VARIOUS ESTIMATES OF THE WORLD'S PRODUCTION OF GOLD AND SILVER.

Years.	Gold. (Millions of Dollars.)				Silver. (Millions of Dollars.)			
	Soetbeer.	Sir Hector Hay.	Mint Report, 1889.	Most Probable.	Soetbeer. (*a*).	Sir Hector Hay. (*c*)	Mint Report, 1889.	Most Probable. (*e*)
1849........	....	....	27.1	....	....	....	39.0	....
1850........	....	....	44.5	....	....	....	39.0	....
1851........	....	....	67.6	....	....	....	40.0	....
1852........	....	182.5	132.8	....	....	40.5	40.6	....
1853........	(*b*)132.5	155.0	155.5	....	(*b*)36.8	40.5	40.6	....
1854........	....	127.0	127.5	....	....	40.5	40.6	....
1855........	....	135.0	135.1	(*b*)132.5	....	40.5	40.6	....
1856........	....	149.5	147.6	134.0	....	41.0	40.7	....
1857........	....	133.3	133.3	134.0	....	41.0	40.7	....
1858........	(*b*)134.1	124.0	124.7	133.0	(*b*)37.7	41.0	40.7	....
1859........	....	124.5	124.9	130.0	....	41.0	40.8	....
1860........	....	119.0	119.3	127.0	....	41.5	40.8	(*d*)40.0
1861........	....	114.0	113.8	122.0	....	43.0	44.7	45.0
1862........	....	107.0	107.8	119.0	....	45.5	45.2	46.0
1863........	(*b*)123.0	106.5	107.0	119.0	(*b*)45.8	49.5	49.2	49.0
1864........	....	113.0	113.0	122.0	....	52.0	51.7	52.0
1865........	....	120.0	120.2	126.0	....	52.5	52.0	52.0
1866........	....	121.0	121.1	127.0	....	52.0	50.8	52.0
1867........	....	116.0	104.0	127.0	....	50.5	54.2	54.0
1868........	(*b*)129.6	120.0	109.7	126.0	(*b*)55.7	49.0	50.2	57.0
1869........	....	121.0	106.2	125.0	....	49.0	47.5	61.0
1870........	....	119.0	106.9	123.0	....	55.5	51.6	64.0
1871........	....	116.5	107.0	119.0	....	59.0	61.1	68.0
1872........	....	110.0	99.6	113.0	....	58.5	65.3	71.0
1873........	(*b*)115.6	111.5	96.2	112.0	(*b*)81.9	64.0	81.8	75.0
1874........	....	107.5	90.8	111.0	....	68.0	71.5	79.0
1875........	....	110.5	97.5	111.0	....	69.0	80.5	82.0
1876........	110.3	111.5	103.7	111.0	96.6	77.0	87.6	88.0
1877........	119.3	117.0	114.0	116.0	99.3	87.0	81.0	93.0
1878........	123.5	110.5	119.0	120.0	106.1	80.5	95.0	97.0
1879........	119.2	104.0	109.0	114.0	104.2	79.0	96.0	99.0
1880........	108.7	106.0	106.5	108.0	103.1	87.5	96.7	101.0
1881........	105.6	103.0	103.0	104.0	107.8	94.0	102.0	106.0
1882........	98.7	101.0	102.0	100.0	115.1	102.5	111.8	111.0
1883........	96.1	98.0	95.4	97.0	120.4	103.0	115.3	115.0
1884........	97.1	95.5	101.7	100.0	122.9	104.0	105.3	120.0
1885........	102.7	97.5	108.4	106.0	132.0	106.5	118.5	125.0
1886........	107.3	....	106.0	106.0	134.6	....	120.6	130.0
1887........	106.3	....	105.8	106.0	141.9	....	124.3	136.0
1888........	106.3	....	110.2	110.0	151.2	....	140.7	146.0
1889........	....	....	121.0	120.0	....	....	158.8	159.0

(*a*) Figured from kilograms at United States coining value. (*b*) Average for five preceding years. (*c*) Subsequent to 1873 the figures in this column represent the product of silver calculated at its commercial value. (*d*) Average for preceding ten years. (*e*) Based on United States coining value, $1.2929 per oz.

GRAPHITE.

Graphite, or plumbago, is one of the allotropic forms of carbon, occurring commonly in imbedded, foliated, or granular masses, and, rarely, in globular concretions. It is a black, shining mineral of metallic luster and greasy feel. Its hardness varies from 1 to 2, and its sp. gr. from 2.09 to 2.229. It makes a black mark on paper, whereby it is easily distinguished from molybdenite, which resembles it in many respects, but gives a grayish-green streak. The two minerals can be otherwise distinguished by roasting or heating in the closed tube. when molybdenite (sulphide of molybdenum) gives off sulphurous fumes, while graphite remains unaltered.

Graphite is a widely distributed mineral. Ceylon is its most important source, while it is found in deposits of commercial value in Austria, Germany, Italy, Russia, Japan, Canada, and the United States. It is produced in small quantities in several other countries, and is found mineralogically in many localities.

PRODUCTION OF GRAPHITE. (IN METRIC TONS.)

Year.	Austria.	Canada.	Ceylon.	Germany.	Italy.	Japan.	United States.*b*
1880	13,718		10,453	1,450	1,327	....	*c*....
1881	13,379	..	.....	1,510	3,443	49	181
1882	15,577	....	13.217	2,161	4,147	10	193
1883	17,566	....	13,350	2,945	4,200	2	261
1884	17,249	....	9,268	1,925	4,000	2	*c*....
1885	16,051	....	9,978	3,359	4,000	4,231	149
1886	17,267	454	12,283	2,906	4,000	3,837	188
1887	19,796	272	12,122	2,960	1,572	1,084	189
1888	19,646	136	11,343	3,353	1,390	5,211	181
1889	22,336	218	28,988	3,327	1,531	4,123	*c*....
1890	23,728	159	32,225	4,355	1,735	4,601	272
1891	21,346	236	20,349	3,824	2,415	*a*2,479	707
1892	20,978	151	.....	4,036	1,645	....	634

(*a*) Fiscal year 1891-92. (*b*) Refined graphite. (*c*) No statistics.

OCCURRENCE.

Austria.—Graphite is mined in Bohemia, Moravia, Styria, and Lower Austria. There is also one mine in Carinthia, but it is not at present in operation. The relative importance of these provinces is shown in the following table:

PRODUCTION OF GRAPHITE IN AUSTRIA IN 1892.

Division.	Number of Mines.		Employees.	Production.	Value.*	
					Total Value.	Per Ton.
	Total.	In Operation.		Metric Tons.	Florins.	Florins.
Bohemia	14	5	827	10,849	456,557	42.1
Lower Austria	11	5	39	824	14,391	17.5
Moravia	11	9	216	6,284	96,170	15.3
Syria	14	10	73	3,021	69,894	23.1
Carinthia	1	0	1	......	....	....
Total in 1892	51	29	1156	20,978	637,012	30.3
Total in 1891	51	26	1179	21,346	693,327	32.5

* Value per metric ton at place of production.

The chief producers of graphite in Bohemia are Prince Adolf Josef zu Schwarzenberg, at Schwarzbach, and the firm Krumauer Graphitwerke Brüder Poràk, the former having made an output of 7210 tons in 1892 and the latter 2782, the total for the kingdom having been 10,849 tons.

These mines are situated in the southern part of Bohemia, in the vicinity of Przinitz and Eggetschlag, extending over an area of fourteen miles (22.5 kilometers) long and ten miles (16 kilometers) wide. The mineral occurs in parallel beds in gneiss, six beds having been opened at Schwarzbach. The most important of these has been explored for a length of more than 600 yards (549 meters) and to a maximum depth of 262 ft. (80 meters).[*] The soft graphite is brought from the mine in three classes. The first and second are hand-picked, dried, and packed in barrels for the market. The third class and hard mineral are crushed with an excess of water and dressed by allowing the heavy gangue to settle in depositing tanks. The graphite slime is then transferred to a stirring tank, whence it is pumped into large filter-presses, which yield tubular cakes of graphite, containing 20% moisture. These are dried and shipped to market.[†]

The graphite region of Styria extends from Leoben to St. Lorenzen, a distance of twenty-five miles (40 kilometers), with occasional interruptions. The most important deposit is that of the Kaiserberg, at St. Michel, where five parallel beds occur in grayish-black graphite schist. They are known for a length of 220 meters, and vary in thickness from a few centimeters to six meters. The mineral, which is of a deep black color and high luster, is prepared for market by screening, without further dressing, the finished product containing from 73.8% to 88.5% graphite.[‡] Messrs. F. Korb and T. Turner report the following analysis:[§] Carbon, 77.95%; silica, 13.04%; alumina, 6.12%; ferric oxide, 0.44%; lime, 0.08%; magnesia, 0.07%; potash, 0.43%; soda, 0.15%; sulphur, trace; phosphoric acid (P_2O_5), 0.01%; water, 1.95%; total, 100.24%. The output of the Kaiserberg is limited, owing to the high cost of transportation. As silica is the chief impurity of the mineral, it is very refractory and is used for the manufacture of crucibles.

The graphite of Lower Austria and Moravia is for the most part extremely impure, occurring in association with granular limestone in gneiss. It is usually amorphous and friable. The deposits, although numerous, are mostly unworked owing to their impurity.

Canada.—Graphite occurs in Canada in most of the stratified rocks of the Laurentian system, sometimes disseminated through the rock and sometimes as thin seams of pure mineral. The most important deposits are at Buckingham and Lochaber, in Ottawa County, and Grenville, in Argenteuil County, Quebec. It is also found at Burgess, Lanark County, and at Loughborough and Bedford, Frontenac County, Ontario; French Vale and Glendale, N. S.; in the vicinity of St. John, N. B.; and at Alkou Harbor, Dean's Canal, in British Columbia. The deposits near St. John, N. B., and at Buckingham, Quebec, are the only ones that have been exploited during the past two or three years.

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[*] A. Pallausch, *Berg- und Hüttenmännisches Jahrbuch der K. K. Bergakademien*, 1889, p. 95; *Journal of the Iron and Steel Institute*, 1890, II., p. 740.

[†] A. Pallausch, *loc. cit.*

[‡] T. Andrée, *Jernkontorets Annaler*, 1890, Part II.; *Journal of the Iron and Steel Institute*, 1890, Part II., p. 739.

[§] *Iron*, Vol. XXXV., p. 72.

The deposits of graphite in Quebec occur in the rocks of the Laurentian series in two distinct forms: (1) as veins or seams from a few inches to two or three feet in thickness, and (2) in the disseminated state in the gneiss and calcites, in the proportion of from 10% to 50%, these deposits affecting the stratified form and varying from a few feet to 25 ft. (7.62 meters) in thickness.

The deposits of the first class are neither extensive nor common, only a few veins having been found at Buckingham and Grenville. On one lot in the former township there is a series of fifteen veins, each two or three inches thick on the surface, but they are said to widen occasionally underground to as much as two feet. Some of them have been opened to a limited extent, and a small amount of mineral has been won from them. The mineral is of excellent quality, as shown by the following analyses taken from the report of the Geological Survey of Canada:

Carbon	99.675%	97.626%	99.815%	99.757%
Ash	0.142	1.780	0.076	0.135
Volatile matter	0.178	0.594	0.109	0.108
Total	99.995	100.000	100.000	100.000

The deposits of graphite disseminated in limestone have been found extensive enough to induce exploitation, but it has been difficult to separate the two minerals. Furthermore, some of the richest deposits contain iron pyrites, which is, of course, a very objectionable impurity. The graphite disseminated in gneiss, however, occurs with neither pyrite nor calcite intermixed, or at the worst, only a very small percentage of the former. Deposits of this class exist in great abundance,* and have been worked at Buckingham, where there are beds from 2 to 25 ft. (0.6 to 7.62 meters) thick, following the stratification of the gneiss. The graphite in the mass varies from 10% to 70%. The following analyses, taken from the reports of the Geological Survey of Canada, represent the average:

Graphite	27.518%	22.385%	23.798%	30.516%
Soluble in HCl	17.539	19.467	21.285	2.475
Insoluble	54.899	56.408	53.741	66.874
Hygroscopic water	0.044	1.740	1.176	0.135
Total	100.000	100.000	100.000	100.000

Graphite mining was begun in Quebec about 1860, and has been carried on by the following companies:

Lochaber Plumbago Company	Grenville	1860
	Lochaber	1866
	Buckingham	1866
Canada Plumbago Company, afterward Montreal Plumbago Company	Buckingham	1867
Dominion of Canada Plumbago Company. W. H. Walker, Ottawa	Buckingham	1875
Ste. Marie mine	Buckingham	....
St. Louis mine	Buckingham	....
Graphite Lubricating Company. Jacob Weart	Buckingham	1891

All of the above concerns have been idle since 1875 with the exception of the Dominion of Canada Plumbago Company and the Graphite Lubricating Company. The former acquired the Walker mines at Buckingham in 1875, but in 1879 resold them to their former owner, Mr. W. H. Walker of Ottawa. Concentrating works were erected, abandoned, and started again in 1888; operation

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* J. Obalski, *Mines and Minerals of the Province of Quebec*, 1889-90, p. 86.

were then carried on regularly until 1891, when financial difficulties interrupted the work.

The concentrating works at the Walker mines have a capacity of 20 tons of ore per twenty-four hours, and running on 25% ore they should give a product of about 3 tons per day (estimating a salvage of 60%).

The Graphite Lubricating Company of Jersey City acquired a mine near Plumbago Lake, in Buckingham Township, in 1891, since which time it has been operated to supply the raw material to the company, which manufactures Weart's patent self-lubricating bushings. The graphite is separated from the gangue by the Napenberger process. The ore is burned in a kiln, passed through a Blake crusher, reduced to a fine powder, and concentrated pneumatically. The graphite thus obtained is said to be of excellent quality for lubricating purposes, being very pure, fine, and tenacious, surpassing the Ceylon graphite, which is too soft and friable.

Ceylon.—This island is the most important producer of graphite in the world, for although the output of the Austrian mines during the last ten years has been larger, the Ceylon mineral is far superior to any other in quality. Graphite is found in Ceylon chiefly in the western and northwestern provinces, but it occurs also in the southern and central provinces. The industry of graphite mining on the island has been and is still a very profitable one. It is entirely in the hands of natives. The total number of pits and mines is said to exceed 700.* The ore as shipped after treatment at Colombo is worth about 10 rupees per cwt.; *i. e.*, about $3.20 (13s. 4d.) per 112 lbs. About one-half the output (which is all exported) goes to Europe and the remainder comes to the United States.

According to J. Walther, who describes a mine a mile and a half from Kaltura, the mineral occurs in a series of veins in gneiss, which has become converted to a depth of twelve yards (10.97 meters) into a mass resembling laterite.† He considers that the veins must not be regarded as seams or beds originally deposited horizontally, but as true veins, in which the carbon was probably deposited from carbureted vapors, citing in support of this theory the facts that hydrocarbons are widely distributed throughout the earth, and that sublimed carbon has been found in gas-works.

The method of mining in Ceylon is exceedingly primitive, objection being made to the introduction of machinery and more improved methods on the ground that as at present conducted the work is profitable, while with new conditions not thoroughly understood losses might be incurred. A shaft is usually sunk until stopped by water, a depth of more than 200 ft. (60.96 meters) having been gained in some instances, though most of the mining is done less than 40 ft. (12.19 meters) below the surface. Drifts are driven out from the bottom of the shaft until the lamps will no longer burn. The ground overhead is then stoped upward, waste being dropped behind and the shaft filled. In some cases the veins are followed by open works and galleries. The mineral is hoisted by windlass and bucket, or is passed out by hand. The openings underground are roughly timbered and powder is used in breaking the rock.

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* *Imperial Institute Year Book*, 1893, p. 478.

† *Zeitschrift der deutschen geologischen Gesellschaft*, XLI., pp. 359-364; *Journal of the Iron and Steel Institute*, 1890, II., p. 740.

The graphite of Ceylon is famous for its purity. Its composition is shown by the following analyses :

Carbon	99.792%	99.679%	98.817%	99.284%
Ash	0.050	0.213	0.283	0.415
Volatile matter	0.158	0.108	0.900	0.301
Total	100.000	100.000	100.000	100.000

The first sample was columnar mineral of 2.2671 sp. gr.; the second was foliated, of 2.2664 sp. gr. A specimen of the columnar variety examined by Dr. E. J. Ball in the metallurgical laboratory of the Royal College of Science showed only 0.04% ash.* Pitchblende and pyrrhotite, are said sometimes to occur with the graphite of Ceylon †

England.—Graphite has been mined at Borrowdale, in Cumberland, by the Borrowdale Plumbago Mines Manufacturing Company, Limited, but no production has been reported for a number of years. The mineral occurs at Borrowdale in veins traversing diabase and diorite under very interesting geological conditions. Mr. J. Postlethwaite finds similarities between the containing rocks in Borrowdale and the diamond-bearing rocks of Kimberley, South Africa, and considers that the conditions under which the graphite was formed in the former locality approached more closely those which gave rise to the diamonds of the latter than those which originated the graphite deposits of North America.‡

Germany.—The only workable deposit of graphite in Germany is that at Passau, in Bavaria, which has been exploited for centuries.§ The mineral occurs there in a bed of variable thickness (attaining as much as 16 ft.—4.88 meters) in feldspathic gneiss, in which also graphite occurs in the form of small grayish-black scales, partly taking the place of mica. The mineral is amorphous and of poor quality. It is dressed in a crude manner and with great loss. The graphite as brought from the mine is separated, according to its hardness and purity, into several sorts. The softer varieties are ground in an ordinary mill with horizontal stones, while the harder are first crushed in a stamp battery. During the grinding the elastic, very thin and soft scales of graphite arrange themselves parallel with the surface of the mill-stones, and so preserve their flat forms, while the hard, brittle pieces are pulverized. The ground product is then passed over a fine silk-gauze sieve on which the scales of graphite remain, while the fine flour, or waste, passes through. The best raw material contains 53.8% graphite, the dressed product 89.2%, and the waste from 22.3% to 36.8%. The Passau graphite is used exclusively for the manufacture of crucibles. Herr H. Putz, in the *Jahresberichte des Naturhistorischen Vereins Passau*, 1886, gives the following analyses of the crude mineral :

	I.	II.	III.	IV.	V.	VI.
Water	3.28%	5.02%	3.45%	3.66%	2.88%	2.70%
Carbon	53.78	31.72	34.54	54.49	36.22	45.25
Ash	42.95	63.26	62.01	41.85	61.80	52.05

I., graphite from Pfaffenreuth; II., flinty grains from Kropfmühle, III., brown earth from Germanusdorf; IV., selected earth from Kropfmühle; V., brown earth from Kropfmühle; VI., black earth from Stierweide, near Germanusdorf.

Japan.—Graphite is produced in five provinces in Japan, but the amount is insignificant in all but Hida, where the Kawai-mura mine, in the prefecture of

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* J. Ferguson, *London Mining Journal*, LXII., p. 703. † *Engineering*, LII., p. 576

‡ *Quarterly Journal of the Geographical Society*, Vol. XLVI., p. 124.

§ *Journal of the Iron and Steel Institute, London*, 1890, II., p. 739; *idem*, 1891, II., p. 166; *Berg- und Hüttenmannische Zeitung*, LII., p. 245.

Gifu, makes a considerable output. In 1890 this was 75,773 piculs (4582 metric tons) out of a total of 76,085 piculs (4601 metric tons).

New South Wales.—A vein of graphite six feet (1.83 meter) wide was discovered near Undercliff, in the New England district, in 1889, but systematic exploitation of it has not yet been undertaken.

New Zealand.—Plumbago occurs in many localities in this colony, but not pure enough or in sufficient quantity to be permanently worked. Prior to 1865 seven tons of the manufactured article were exported from Parkawau, near Collingwood (Nelson), but nothing has since been done to continue the trade. In addition to this locality graphite has been found in Wellington Province, and also at several places in Canterbury, Otago, and Westland.*

Russia.—Deposits of graphite are known in various parts of Russia, European and Asiatic, but the mineral has as yet been exploited only in the Kirghiz steppes, in Eastern Siberia, and in Finland. The deposits of Eastern Siberia are especially worthy of attention. In 1856 a Finnish merchant, named Aliber, began to work graphite in the Government of Irkutsk, where there is a bed of the highest quality. At one time this graphite was supplied to the well-known pencil makers Faber, but at present it is worked only to satisfy the wants of the Irkutsk gold melting house, for the manufacture of crucibles. Large deposits of graphite of excellent quality were discovered in 1860 by a merchant named Sidorov, in the north of the Government of Yenissei, along the rivers Nizhni-Toungouska and Koureika. The high grade of this mineral was certified at the Perm gun factory, and in St. Petersburg, and also in London, whither a parcel of it was sent. The situation of these deposits in a distant desert and unpopulated district is the cause of their not being worked.† In general the production of graphite in Russia is subject to considerable fluctuations, and sometimes it is not mined at all for several years. The largest output was made in 1875, when 18,500 poods (303 metric tons) were turned out. In 1892 the product was 164 tons.

United States.—Graphite is widely distributed in the United States, but there seem to be few deposits sufficiently large and sufficiently pure to be profitably worked. At the present time the only mines in operation are those of the American Graphite Company (Jos. Dixon Crucible Co.), at Graphite, Warren County, N. Y. (about twelve miles from Ticonderoga), and those of the New England Mining Company, at Cranston, R. I., where a very impure graphite is found in conjunction with the peculiar anthracite coal of that district. Graphite was formerly mined at Byers, Chester County, and in the Pickering Valley, Pennsylvania, but the exploitation of the deposits existing there was not successful, and for many years they have been allowed to lie idle, although from time to time there have been rumors of a resumption of work. Graphite has also been mined in northern New Jersey.

In the Rocky Mountains veins of graphite of considerable size have been found in Albany County, Wyoming; in Gunnison County, Colorado, where it occurs in beds two feet thick, but very impure; in the coal measures of New Mexico;

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* George V. Binns, *Transactions of the Federated Institution of Mining Engineers*, Vol. IV., Part I., Jan. 20, 1893, p. 75.

† A. Keppen, *The Industries of Russia, Mining and Metallurgy*, Vol. IV., p. 92.

in Humboldt County, Nevada ; in Beaver County, Utah ; and in the Black Hills of South Dakota. None of these deposits has yet been productive.

The occurrence of graphite on the Pacific coast seems to be quite extensive, deposits being known at Sonora, Tuolumne County; near Summit City, Alpine County ; on the border of Tomales Bay, Marin County ; near Fort Tejon, Kern County ; at Tejunga, Los Angeles County ; at Boser Hill, Fresno County ; and at several places in Sierra, Plumas, Marin, and Sonoma counties. It is found in Washington, in Lewis County, and elsewhere. Attempts have been made from time to time to work these deposits, the first having been made at Sonora as early as 1863, when 1000 tons of mineral were extracted, most of it being shipped to England, France, and Germany, where it brought about $100 per ton, a price that afforded the shippers some profit. The impossibility of securing any large quantity of mineral sufficiently pure for commercial purposes, however, put an end to the enterprise, the labor of concentrating the crude material, which was largely mixed with slate and other foreign matter, having been expensive. There is no record of any production of graphite on the Pacific coast since that time. A new discovery was made in 1893 in Lewis County, Washington, about 40 miles from Chehalis, and the Olympic Graphite Company was organized at Olympia, Washington, to develop it. Operations will be begun in 1894. The graphite found at this place is an impure, massive, amorphous kind.

Uses of Graphite.

Graphite is used for making refractory crucibles, for stove polish, paints, lead pencils, and as a lubricant. By far the most part is employed in the manufacture of crucibles, after which comes the consumption for stove polish, for which an inferior grade of mineral suffices. The amount of mineral used for lead pencils is comparatively small, but the best quality is required. The use of graphite as a lubricant, likewise requiring a high quality of mineral, is rapidly increasing ; so also is the consumption of graphite paint, which is used on smokestacks, boilers, iron roofs, and for other purposes where a very durable covering is required.

The Jos. Dixon Crucible Co. uses for the manufacture of crucibles 50% of graphite, 33% of air-dried clay, and 17% of sand. Ceylon graphite is generally employed, the laminated or fibrous varieties being preferred, as they bind the clay firmly. The mineral is ground to pass screens from 40 to 100 mesh. If too coarse, the crucible will be porous ; if too fine, it will be too dense and apt to crack. The clay should be refractory ; the sand is sifted through a 40-mesh screen. The clay is made into a thin paste with water, the sand and graphite are mixed in, and the dough is then passed several times through a pug-mill, after which it is tempered for several weeks in a damp place. Weighed lumps of the tempered dough are then kneaded and molded on a wheel, which is considered to be better than simple pressing, as the graphite flakes are arranged tangentially and bind the mass better. The crucibles are placed in plaster molds and left for three hours, during which time the plaster absorbs part of the moisture ; they are then dried for a week at a temperature of 70° to 80° F. and burned in a common pottery kiln, which is first fired with anthracite coal and afterward with long flaming wood. The burning takes a week, the temperature reaching about 1350° C.

In judging the value of graphite for crucible purposes, H. Putz* lays the greatest stress upon the incombustibility of the carbon, regarding the fusibility of the ash as of secondary importance. A series of comparative tests on graphite of the same size of grain gave the following results :

Number.	Analysis.			Percentage Loss upon Ignition of the Graphite Freed from Volatile Matter, calculated on Equal Weights of Carbon.				Hours before attaining Constant Weight of Ash.
	H_2O.	C.	Ash.	1 Hour.	2 Hours.	3 Hours.	4 Hours.	
I.	0.0%	97.5%	2.5%	89.74	96.16	100.00	100.00	3
II.	7.5	83.5	9.0	71.85	85.50	93.85	99.68	8
III.	5.0	62.5	32.5	61.58	71.00	80.83	90.94	14
IV.	0.0	85.0	15.0	69.41	80.58	87.50	88.24	10
V.	0.0	100.0	trace	94.50	97.50	100.00	.....	3

I., Ceylon graphite of excellent quality; II., Ceylon graphite of best quality; III., Ceylon graphite of ordinary quality; IV., Bavarian (Pfaffenreuth), purified; V., Pfaffenreuth, freed from ash by means of hydrofluoric acid.

It appears from the above that the Bavarian graphite is more refractory than that of Ceylon, and that the combustibility of the graphitic carbon is diminished by the impurities (ash) mixed with it.

***Jahresberichte des Naturhistorischen Verein Passau*, 1886 ; *Journal of Iron and Steel Institute*, 1888, I., p. 286.

GYPSUM.

GYPSUM is a hydrous sulphate of lime containing when pure 20.9% water. The color varies according to its purity from white to gray, red, yellow, blue, brown, and even black. Upon calcining at a temperature below 260° C. the water is driven off, and in this condition it is known as plaster of paris, which has a wide application in the arts. Gypsum occurs transparent and crystallized as selenite, fibrous as satin spar, massive and fine grained as alabaster, but generally is a massive, dull-colored rock, often mixed with clay, lime, and anhydrite.

Geologically, gypsum forms extensive beds, sometimes 600 ft. thick, interstratified with limestone and clay, occurring in the Silurian, Subcarboniferous and Cretaceous formations. It is characteristic of Triassic of the Rocky Mountain region, and is widely distributed throughout the country, being mined and quarried in Michigan, Kansas, New York, Iowa, Virginia, Ohio, Utah, Colorado, California, Wyoming, South Dakota, and Texas. The first six mentioned States comprise the most important gypsum-producing localities of this country.

Producers either market their gypsum as crude, grind it for fertilizer or land plaster, calcine it into plaster of paris, or sell it in all three of these conditions. In Kansas a portion of the product is a "gypsum clay" utilized in the manufacture of wall plaster. One of the principal uses of gypsum is as a fertilizer or land plaster, which forms a valuable top dressing for clover, potatoes, wheat, and similar plants.

The chief use of gypsum, however, is in making plaster of paris, which is employed for making molds, pressed and embossed ware of various kinds, taking casts of statues, medals, and various things, and for producing a hard finish on walls. It is also used in the manufacture of artificial marble, and, indeed, for many other purposes. "Keen's cement" is made by mixing calcined gypsum with one part of alum and twelve parts of hot water. It is said to differ from the ordinary plaster in being much firmer and slower in setting and not liable to crack or become dull. "Parisian cement plaster" is made by adding to the calcined gypsum water containing 10% borax. Stucco plaster, obtained by adding glue to gypsum, is largely used, among other purposes, for making imitation meerschaum.

The price of crude gypsum in New York ranges from $2.50 to $3 per ton.

The following table shows the production of gypsum in the United States since 1888. The imports into this country will be found in the general table in another part of this volume.

PRODUCTION OF GYPSUM IN THE UNITED STATES.

(In tons of 2000 lbs.)

Year.	Product.	Value.	Year.	Product.	Value.	Year.	Product.	Value.	Year.	Product.	Value.
1880......	90,000	$400,000	1884....	90,000	$390,000	1888....	110,000	$550,000	1892....	256,259	$695,492
1881......	85,000	350,000	1885....	90,405	405,000	1889....	267,769	764,118	1893....	253,615	696,615
1882......	100,000	450,000	1886....	95,250	428,625	1890....	182,995	574,523			
1883......	90,000	420,000	1887....	95,000	425,000	1891....	208,126	628,051			

Year.	Michigan.		Kansas.		New York.		Iowa.		Virginia.	
1888..........	....	....	....	....	....	....	....	....	....	....
1889..........	131,767	$373,740	17,332	$94,235	52,608	$79,476	21,789	$55,250	6,838	$20,336
1890..........	74,877	192,099	20,250	72.457	32,903	73,093	20,900	47,350	6,350	20,782
1891..........	79,700	223,725	40,217	161,322	30,135	58,571	31,385	58,095	5,959	22,574
1892..........	139,557	306,527	41,016	195,197	32,394	61,100	....	....	6,991	28,207

Year.	South Dakota.		Colorado.		Other States (a)		Total.	
1888..................	....	....	....	....	....	....	110,000	$550,000
1889..................	320	$2,650	7,700	$28,940	b29,420	$109,491	267,769	764,118
1890..................	2,900	7,750	4,580	22,050	20,235	138,942	182,995	574,523
1891..................	3,615	9,618	....	....	17,115	94,146	208,126	628,051
1892..................	....	....	....	....	31,301	104,461	256,259	695,492

(a) Includes California, Ohio, Utah, and Wyoming. (b) In 1889 Ohio produced 9920 short tons, valued at $51,491; California 3000 tons, valued at $30,000; and Utah 16,000 tons, valued at $25,000, according to *Mineral Resources of the United States*, 1889 and 1890.

IODINE.

Iodine, which is an element of the chlorine group, is a grayish-black, crystalline substance, with a metallic luster somewhat resembling that of graphite. Its sp. gr. is 4.94. It fuses at 115° C. and boils at about 200° C., giving off vapor of a violet hue, which when concentrated is purple. Iodine is slightly soluble in water, and readily so in alcohol, ether, chloroform, benzol, carbon disulphide, and solutions of sulphurous acid, sodium thiosulphate, and potassium iodide.

The iodine of commerce usually contains traces of chlorine and from 10% to 20% of water. It is sometimes adulterated, moreover, with pulverized charcoal or graphite, but this may be detected easily by treating a sample with alcohol, in which the iodine is soluble.

Iodine is found usually in combination with sodium or potassium, either as an iodide or an iodate, traces of the former being detected in the brine of many salt springs, as in those of Ohio and West Virginia (which are also rich in bromides), in the United States. Free iodine and bromine have been found in the serpentine rocks at Point Lobos, San Francisco, Cal.*

The iodine of commerce is obtained from three sources, viz.: from the ashes of sea-weed, in which it exists as iodides of the alkaline metals; from the niter of Chile, which contains 0.059% to 0.175% in the form of sodium iodate; and from the phosphorites of the French departments of Lot, Tarn, and Garonne, whence it is obtained, as a by-product, at Lille, in the manufacture of superphosphate.†

The production of iodine on the commercial scale was begun by Tissier at Cherbourg in 1824,‡ and the industry was undertaken in Scotland in 1845, in which year four small works engaged in the business, the number being increased to twenty in the following year. In the period between 1873 and 1875, however, there were only three works in operation in Glasgow, the others having gradually withdrawn on account of the unsatisfactory condition of the industry.

The existence of sodium iodate in the South American *caliche* (crude sodium nitrate) was noticed as early as 1865, and in 1874 iodine from that source was

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* J. B. Trask, *Report on the Geology of the Coast Mountains*, etc., 1854, pp. 26, 92.

† The presence of iodine has been detected in the phosphorites of Amberg, in Bavaria, and Diez on the Lahn, besides the departments mentioned in France. It is said that 1000 kilos of the French phosphorites contain ½ kilo of iodine.

‡ Iodine was discovered in 1811 by Courtois in a lye obtained from sea-weeds.

offered on the London market for 10½@11d. per oz., against 13d. for the Scotch product. The result of this new competition was active warfare, during which the price of iodine fell to 5¾d. per oz. (1876), the Scotch producers being able to continue the fight only by virtue of revolutionary improvements in methods of manufacture, which they were forced to make. In March, 1877, however, a combination was effected between the European and South American producers, whereby the price was fixed at 10½d. per oz., and the war was ended temporarily. The trade gained a great impetus during the next three years, but in 1880 the combination was broken and prices fell again, reaching 3¾d. per oz. in 1884. In the latter part of the year, however, a new combination was formed, and the price rose to 9d., at which figure it has since ruled, except during short breaks in the agreement between the producers, indicated by the accompanying table.

At present there are 12 iodine works in Glasgow, 2 in Ireland, and 10 or 12 in the Department of Finisterre, France. In South America there are numerous works in the Province of Tarapaca, formerly a part of Peru, but now belonging to Chile, and at Antofagasta, Bolivia.

The sea-weeds which are thrown upon the coasts of Ireland, Scotland, France, and Scandinavia are collected in large quantities for the preparation of iodine, which element exists in minute traces in the water of the ocean, whence it is abstracted by the algæ, particularly those growing at great depths.* In recovering the iodine from sea-weeds they are first burned, and their fused ashes, termed kelp, are lixiviated with water, whereby 60% or 70% of their weight, consisting chiefly of alkaline carbonates, together with the iodides, iodates, etc., is dissolved. The solution is evaporated and cooled to remove the sulphates and chlorides of sodium and potassium which may be present, and the mother liquor is treated in shallow open vessels with dilute sulphuric acid, from which there is a strong evolution of sulphureted hydrogen and carbonic acid, and the formation of sulphur, the last being saved as a by-product. The liquor is treated with more acid after the evolution of gas has ceased, manganese is added, and iodine distilled from the mixture into earthenware receivers.

At Cherbourg iodine is made, according to Barrull's plan, by passing chlorine gas into the mother liquor, when the following reaction takes place:

$$MgI_2 + Cl_2 = MgCl_2 + I_2.$$

Another plan is to distill the mother liquor with ferric chloride, according to the following reaction:

$$2NaI + Fe_2Cl_6 = 2I + 2NaCl + 2FeCl_2.$$

The iodine is carried over with the steam and deposited at the bottom of the receiver in the form of a black powder.

There are various processes in use besides the above mentioned, among the more important being those of Allary & Pellieux, Vitali, and Stanford.

The crude iodine obtained by these methods is refined by sublimation. One ton of kelp is said to yield an average of 4.07 kilos of iodine.

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* Although the percentage of iodine in sea water is minute, the total amount may be immense. Sonstadt (*Chemical News*, 1872, p. 242) found, as a result of six experiments, that a cubic mile of sea water contains about 17,000 tons of iodate of calcium, or 11,072 tons of iodine. T. A. Rickard, in a paper on the "Origin of Gold-bearing Quartz of Bendigo Reefs" (*Trans. Amer. Inst. Mining Engineers*, August, 1893), calculates that the entire ocean contains 4,428,800,000,000 tons of iodine, using Sonstadt's figures.

Iodine is recovered from the crude niter of South America by precipitation with sodium bisulphite from the mother liquors left in refining the niter, which may contain as much as 22% of sodium iodate. The iodine precipitated settles to the bottom of the vats, whence it is removed, washed, pressed into cakes, and purified by distillation.

Iodine is also recovered in South America as iodide of copper by precipitation with a mixture of sodium bisulphite and copper sulphate, in which form it is sent into the trade.

Iodine is used largely in medicine, in photography, and in the preparation of some of the aniline colors.

Herr O. Meinecke, in *Zeitschrift für Analytische Chemie*, XXXII., p. 462, gives the following notes on the preparation of pure iodine and some of its properties :

Perfectly pure iodine, in which foreign constituents can no longer be detected, may be obtained by precipitating a concentrated solution of iodine in potassium iodine with water, or by precipitation with sulphuric acid from a solution containing potassium iodide and iodine. According to the first method, a solution of potassium iodide in two parts of water is saturated with powdered iodine, and water is then added until a small portion of the iodine is deposited. After twenty-four hours it is decanted, and water again added to the clear solution. The precipitates are thoroughly washed and dried over calcium nitrate. In the second method, a solution containing 25 grams potassium iodate and the same weight of potassium iodide is directly precipitated with dilute sulphuric acid ; the precipitate is washed until the filtrate ceases to react with sulphuric acid, and dried over sulphuric acid. The iodine obtained according to each method is sublimed twice with, and twice without, barium oxide. The second method yields a pure product even in the presence of bromine, chlorine, and cyanogen ; while in the first method, to avoid contamination with cyanogen, it is advantageous to add a little hydrochloric or sulphuric acid.

Musset's process for the purification of impure iodine consists in melting it in a concentrated solution of potassium iodide, from which it must be separated by repeated sublimation. Instead of the solution of potassium iodide, Meinecke uses a solution of calcium chloride of sp. gr. 1.37, adding to this liquid a few grams of potassium iodide and a little hydrochloric acid, so that the liquid has a brown color. The mixture is heated to the melting point of iodine, and kept at this temperature for five minutes. The iodine is washed out and sublimed once alone and once with barium oxide, when it is nearly pure. The removal of cyanogen is complete, that of bromine and chlorine less so. The quantity of the latter is so slight that a single sublimation suffices for its entire removal.

Meinecke has also made careful experiments on the hygroscopic character of iodine. Freshly sublimed iodine was placed, while still hot, in tightly fitting glass jars, and preserved for use over sulphuric acid. During some hours no change from absorption of moisture was perceptible, and during five days the proportion of water increased only by 0.06%. Even pulverized iodine, under the most favorable circumstances, takes up at most 0.1%. Specimens kept for four months over sulphuric acid, and opened once or twice every week, showed no change.

For determining the moisture in iodine, Meinecke superstratifies a weighed quantity of iodine in a glass tube (which is closed with a glass stopper) with a weighed quantity of silver powder, four to five times the weight of the iodine, and weighs again. If a rise of temperature occurs, owing to the reaction of the two elements, the weighing is deferred until complete cooling. The tube is then placed in a small beaker standing on an asbestos plate, which is heated moderately, so that the formation of silver iodide takes place gradually. The upper stratum of silver must remain unchanged. During the absorption of the iodine, the water condenses in the upper part of the tube, whence it is driven off by a stronger heat. When the tube is perfectly cold it is weighed again, when the water is found as loss.

PRICE OF IODINE FROM 1841 TO 1883.[*]

Year.	Price per Lb.	Year.	Price per Lb.	Year.	Price per Lb.	Year.	Price per Lb.	Year.	Price per Lb.
1841..........	$1.20	1851...	$2.08	1861..........	$1.68	1871........	$3.44	1878..... .	$4.00*c*
1842..........	1.12	1852..........	3.64	1862..........	1.36	1872........	8.16	1879........	4.48*c*
1843..........	1.44	1853..........	3.72	1863...... .	1.20	1873.......	5.12	1880........	1.92*d*
1844..........	2.88	1854..........	2.88	1864..........	2.00	1874........	3.52*a*	1881...	2.00*d*
1845..........	7.46	1855..........	3.20	1865..........	1.84		2.94*b*	1882........	1.60*d*
1846...... ...	5.34	1856........	3.28	1866	2.40	1875........	2.44*a*	1883........	1.28*d*
1847..........	2.64	1857	2.96	1867..........	2 88		2.25*b*	....	....
1848..........	2.64	1858..........	2.52	1868	3.04	1876........	1.92*a*	....	....
1849..........	2 64	1859.....	2 32	1869..........	3.12		1.87*b*	....	....
1850..........	2.58	1860.......	2.04	1870..........	3.04	1877......	3.28*c*	....	....

PRICE OF CRUDE IODINE PER LB. IN ENGLAND AND THE UNITED STATES SINCE 1883.[†]

Date.	England. s. d.	U. S. Dollars.	Date.	England. s. d.	U. S. Dollars.
1884—Jan. 1	5 4	1.75	1888—Jan. 1	12 0	....
Feb. 1	5 0	1.65	May 1	....	3.60
Oct. 1	5 4	1.60	July 1	....	3.55
Nov. 8	10 8	....	Dec. 31	12 0	3.50
Dec. 1	12 0	3.50	1889—Jan. 1	12 0	3.50
1885—Jan. 1	12 0	....	June 1	....	3.50
Dec. 31	12 0	....	Aug. 1	9 4	2.70
1886—Jan. 1	10 8	....	Aug. 17	5 4	1.80
Oct. 1	10 8	3.35	Sept. 14	12 0	3.50
Nov. 1	8 8	3 00	1890—Jan. 1	12 0	3.50
1887—Jan. 1	12 0	2.75	Mar. 29	8 0	2.50
Feb. 1	10 8	3.65	May 10	12 0	3.50
July 9	10 8	....	1891—Jan. 1	12 0	3.50
Aug. 20	12 0	....	Dec. 31	12 0	3.50
			1892-Jan. 1	12 0	3.50
			Dec. 31	12 0	3.50
			1893—Jan. 1	12 0	3.50
			Nov. 1	12 0	3.50

EXPORTS OF IODINE FROM CHILE.

(In metric tons.)

Year.	*Amount.*	*Value.*	*Year.*	*Amount.*	*Value.*
1879	77.35	$1,160,205	1886	175.68	$1,756,860
1880	83.86	1,236,981	1887	77.20	771,960
1881	200.06	2,953,628	1888	91.37	913,750
1882	263.98	3,963,240	1889	201.39	2,013,950
1883	220.92	2,987,491	1890	419.74	4,197,420
1884	218.19	2,181,947	1891	424.02	4,240,190
1885	256.80	2,567,960	1892	441.96	4,419,600

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[*] From *Mineral Resources of the United States*, 1885, p. 855. (*a*) Scotch. (*b*) Peruvian. (*c*) Combination. (*d*) Combination broken.

[†] From data kindly furnished by Messrs. Powers & Weightman, Philadelphia.

IRON AND STEEL.

By H. S. Fleming.

(Unless specially stated to the contrary, the ton used in this article is of 2240 lbs.)

The tables used in the following review of the iron trade are taken from a valuable and exhaustive article by Dr. William B. Phillips upon iron and steel, which was presented in Vol. I. of The Mineral Industry.

The year 1893 will long be remembered in the iron trade as the one in which there was the greatest decline yet witnessed in the production of pig iron in the United States. At the beginning of the year there were 253 furnaces in blast, and on Dec. 31 only 137, showing that 116, or 45.8%, had been shut down. In 1892 the total production of the country was 9,157,000 gross tons and in 1893 only 7,124,502 tons, a decline of 22.1%, which was distributed as follows: Decline in the production of anthracite iron 25%, coke iron 20.9%, and charcoal iron 28%. In the first six months of the year the total production was 4,562,918 tons and in the last six months 2,561,584 tons, a decrease of 2,001,334 tons, or 43.8%. In 1892 the production of Bessemer pig was 4,444,041 tons and in 1893 only 3,568,598 tons, a decline of 875,443 tons, or 19.7%. In the first half of 1893 the production of Bessemer pig was 2,374,890 tons, the greatest in its history, and in the last half of the year only 1,193,708 tons, a decline of 1,181,182 tons, or 49.7%. The production of spiegeleisen and ferromanganese shows an even greater reduction, from 179,131 tons in 1892 to 81,118 tons in 1893, a decrease of 98,013 tons, or 54.7%.

The decline in the production of Bessemer steel was from 4,168,435 tons in 1892 to 3,123,524 tons in 1893, a falling off of 1,044,911 tons, or 25%. The production for the first six months of 1893 was 2,092,057 tons as against 2,109,507 tons in the last half of 1892, a decline of only 17,450 tons, or eight-tenths of one per cent. In the latter half of 1893 the production fell to 1,031,467 tons, a decline of 1,060,590 tons, or 50.6%, corresponding almost exactly with the decline in the production of Bessemer pig. The production of Bessemer steel rails in 1893 was 1,036,353 tons as against 1,458,732 tons in 1892, a decline of 422,379 tons, or 28.8%. During the first half of the year 704,240 tons were produced, and in the latter half 332,113 tons, a decline in the last six months of 372,127 tons, or 52.8%. In railroad building there has been a similar decline, from 4428 miles in 1892 to 2629 miles in 1893, a decrease of 1799 miles, or 40.6%.

The following tables give the pig-iron production, imports, exports, stocks, and total and per-capita consumption in the United States since 1889, and the production of all kinds of iron by States. Tables showing production, imports, and exports from the beginning of the industry to 1892 will be found in The Mineral Industry, Vol. I.

TOTAL PIG-IRON PRODUCTION IN THE UNITED STATES: IMPORTS, EXPORTS, STOCKS, AND TOTAL AND PER-CAPITA CONSUMPTION.

Year.	Production.						Stocks.					Consumption.		Estimated Population.
	Anthracite	Coke & Bituminous.	Charcoal.	Total.	Imports.	Exports	Anthracite.	Coke & Bituminous	Charcoal.	Total.	Supply.	Total.	Per Capita in Lbs.	
1889	1,714,600	5,313,772	575,268	7,603,640	148,759	13,573	69,198	77,475	101,706	248,379	8,038,960	7,790,581	273.25	61.4
1890	2,186,411	6,388,146	628,145	9,202,702	134,955	16,341	146,697	304,734	157,489	608,920	9,569,695	8,960,775	320.49	62.6
1891	1,866,108	5,836,798	576,964	8,279,870	67,179	14,945	124,369	258,678	213,374	596,421	8,941,024	8,341,603	292.76	63.9
1892	1,797,113	6,822,266	537,621	9,157,000	70,125	15,427	119,015	213,615	173,486	506,116	9,823,546	9,302,003	320.06	65.1
1893	1,347,529	5,390,184	386,789	7,124,502	54,394	24,570	166,359	288,528	207,181	662,068	7,685,012	6,998,374	236.8	66.2

PRODUCTION OF SPIEGELEISEN AND FERROMANGANESE IN THE UNITED STATES.

Years.	Tons.	Years.	Tons.	Years.	Tons.	Years.	Tons.
1875........	7,000	1880........	17,502	1885........	30,956	1890.....	133,180
1876........	5,907	1881........	18,827	1886........	42,841	1891......	127,766
1877........	7,900	1882........	19,610	1887........	42,480	1892......	179,131
1878........	9,530	1883........	21,941	1888........	48,[illegible]01	1893......	81,118
1879........	12,438	1884........	30,261	1889........	76,627		

CONDITION OF BLAST FURNACES IN THE UNITED STATES.

Year Ending Dec. 31.	Anthracite.			Bituminous and Coke.			Charcoal.			Total.		Grand Total.	Average Output per Furnace. Tons of 2240 Lbs.			
													By Fuel.			By No. in Blast.
	In Blast.	Out of Blast.	Total.	In Blast.	Out of Blast.	Total.	In Blast.	Out of Blast.	Total.	In Blast.	Out of Blast.		Anthracite.	Bituminous and Coke.	Charcoal.	
1889..	104	71	175	169	56	225	59	77	136	333	203	536	16,486	31,442	9,750	22,833
1890..	101	72	173	143	100	243	59	76	135	303	248	551	21,647	44,672	10,646	30,372
1891..	94	66	160	164	88	252	48	73	121	306	227	533	20,000	35,590	12,020	27,058
1892..	72	87	159	141	130	271	40	94	134	253	311	564	24,959	43,384	13,440	36,193
1893..	34	107	141	84	175	259	19	99	118	137	381	518	39,633	64,168	20,357	52,003

An examination of these tables shows that in the year 1893 the total production of pig iron decreased 22.1%, the product of anthracite furnaces falling off 25%, of coke 20.9%, and of charcoal 28%. Our imports decreased 22.4% and exports increased 59.2%. Total stocks increased 30.8% and the consumption per capita decreased 26%. The second table shows a decrease of 54.7% in the production of spiegeleisen and ferromanganese. In the third table the average output of pig iron per furnace in blast is shown. By comparison in the statistics of previous years given in Vol. I. of THE MINERAL INDUSTRY, it will be seen that in 1881, where there were 455 furnaces in blast in this country, the greatest number there has ever been, the average output per furnace per annum was 9108 tons. In 1884 the minimum number of furnaces were in blast, 236 in all, and the average output per furnace was 17,364 tons per annum. The average output per year has risen steadily, amounting to 36,193 tons per furnace in 1892, but in 1893 it reached the unprecedented figure of 52,003 tons, an increase of over 43%. A part of this increase is due to the fact that a number of furnaces operating during part of the year are not counted while their product is included, but the greater part is because the larger plants continued when smaller furnaces were blown out, and also because of better furnace practice in some sections. A further examination of the table shows that during 1892 there were 72 anthracite furnaces in blast as against 34 in 1893, a reduction of 52.7%. In coke furnaces there was a reduction of 40.4%, and in charcoal furnaces of 52.5%.

The following table shows the production of pig iron, by States, since 1884:

PRODUCTION OF PIG IRON IN THE UNITED STATES BY STATES.

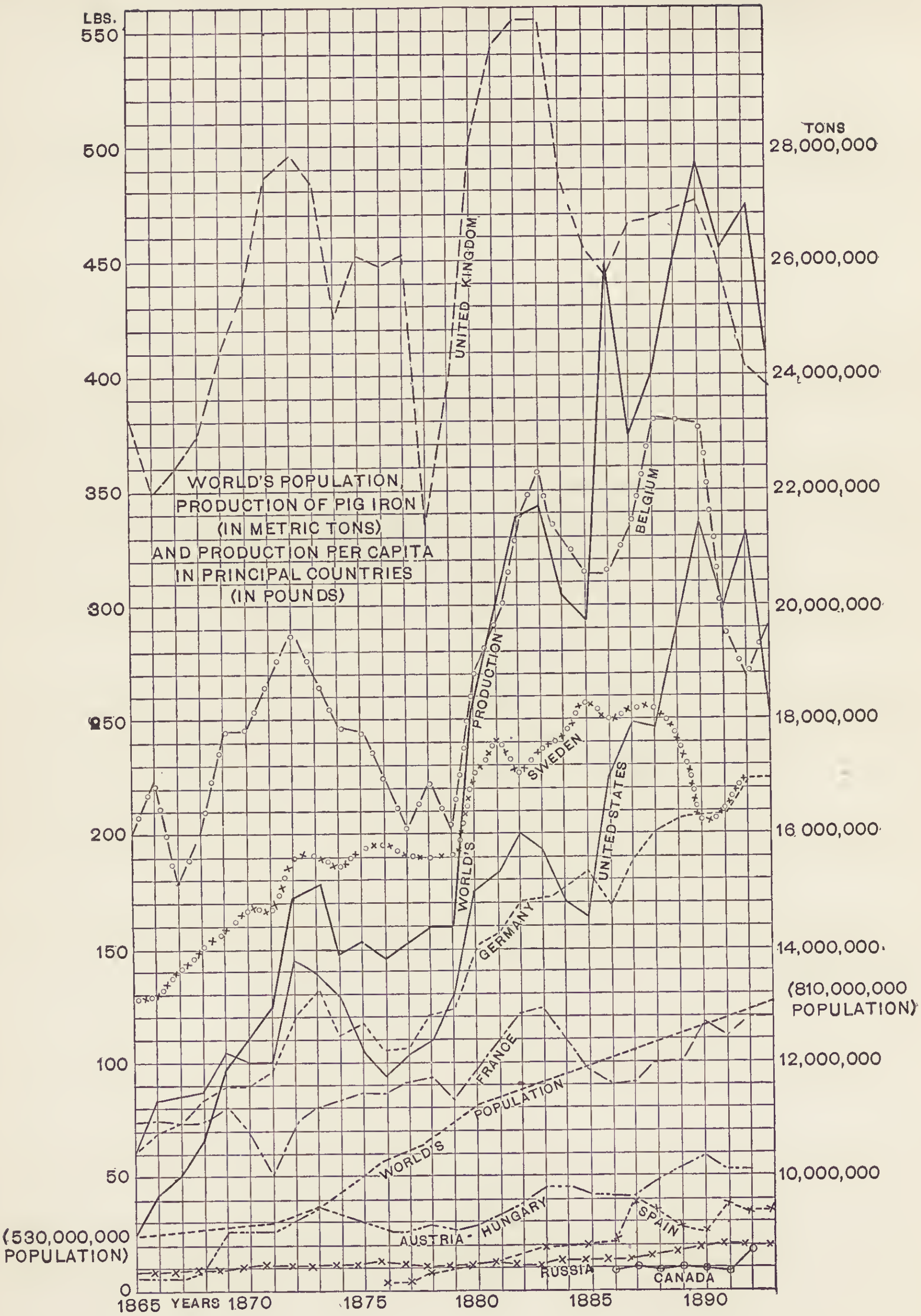
States.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Alabama..........	169,342	203,069	253,445	261,394	401,330	706,629	816,911	795,673	915,296	726,888
California.........	1,926	....	1,562	....	....	....	....	....	....	....
Colorado..........	14,140	4,894	9,331	22,581	18,640	2.391	21,061	18,116	32,441	45,555
Connecticut.......	12,655	15,625	17,312	19,411	19,325	22,556	20,135	21,811	17,107	12,478
Georgia...........	38,085	29,396	41,508	36,559	35,176	24,606	29,185	49,858	9,950	39,675
Indiana...........	2,292	5,924	14,875	11,797	13,625	8,785	14,641	7,729	7,700	5,567
Illinois............	292,471	292,838	448.031	504,868	517,238	536.638	701,107	669,202	949,450	405,261
Kentucky.........	40,225	33,530	48,968	37,419	50,705	37,961	47,860	44,844	56,548	47,501
Maine.............	....	393	4,518	3,925	4,977	4.643	1,072	....	....	....
Maryland.........	24,409	15,445	27,248	33,416	15,719	30,220	147,820	123,398	99,131	151,773
Massachusetts....	4,378	775	7,253	9,924	11,828	6,920	4,938	8,990	7,946	7,853
Michigan	154,316	127,787	170,298	190,663	190,403	191,389	230,768	213,145	184,421	117,538
Minnesota.........	....	....	....	....	....	....	....	1,226	14.071	10,373
Missouri..........	53,610	45,900	66,538	123,789	81,949	76,955	89,777	29,229	57,020	32,360
New Jersey.......	74,048	65,774	140,969	154,067	90,961	112,225	158,740	92.490	87,975	74,305
New York.........	213,828	142,997	208,587	264,796	229,624	265,398	329,806	315.112	310,395	191,115
North Carolina...	388	1,598	1,964	3,250	2,143	2,588	2,840	3,217	2,908	2,843
Ohio..............	506,351	494,647	810,797	871,017	985,553	1,085,332	1,240,330	1,035,013	1,221,913	875,265
Oregon	3,250	3,421	....	....	2,240	8,416	10,987	9,295	7,628	4,739
Pennsylvania.....	2,129,823	2,183,478	2,940,437	3,289,837	3,204,632	3,733,251	4,415,329	3,952,387	4,193,805	3,643,022
Tennessee	120,176	143,927	177,829	223,521	239,224	263,086	267,625	291,738	300,081	207,915
Texas.............	4,588	1,645	2,902	3,913	5,881	4,057	9,700	18,662	8,613	6,257
Utah..............	....	....	....	....	....	....	....	....	....	....
Virginia	140,612	146,233	139,508	156,888	176,246	224,424	292,778	295,292	342,847	302,856
Vermont..........	....	....	....	....	....	....	....	....	....	....
West Virginia....	49,313	61,613	88,052	73,492	85,053	105,268	129,438	86,283	154,793	81,591
Washington.......	482	1,658	2,537	1,416	3.654	9,250	....	....	....	....
Wisconsin.........	47,161	21,957	58,857	119,213	103,607	141,643	219,854	197,160	174,961	131,772
Total	4,097,869	4,044,524	5,683,326	6,417,156	6,489,738	7,603,640	9,202,702	8,279,870	9,157,000	7,124,502

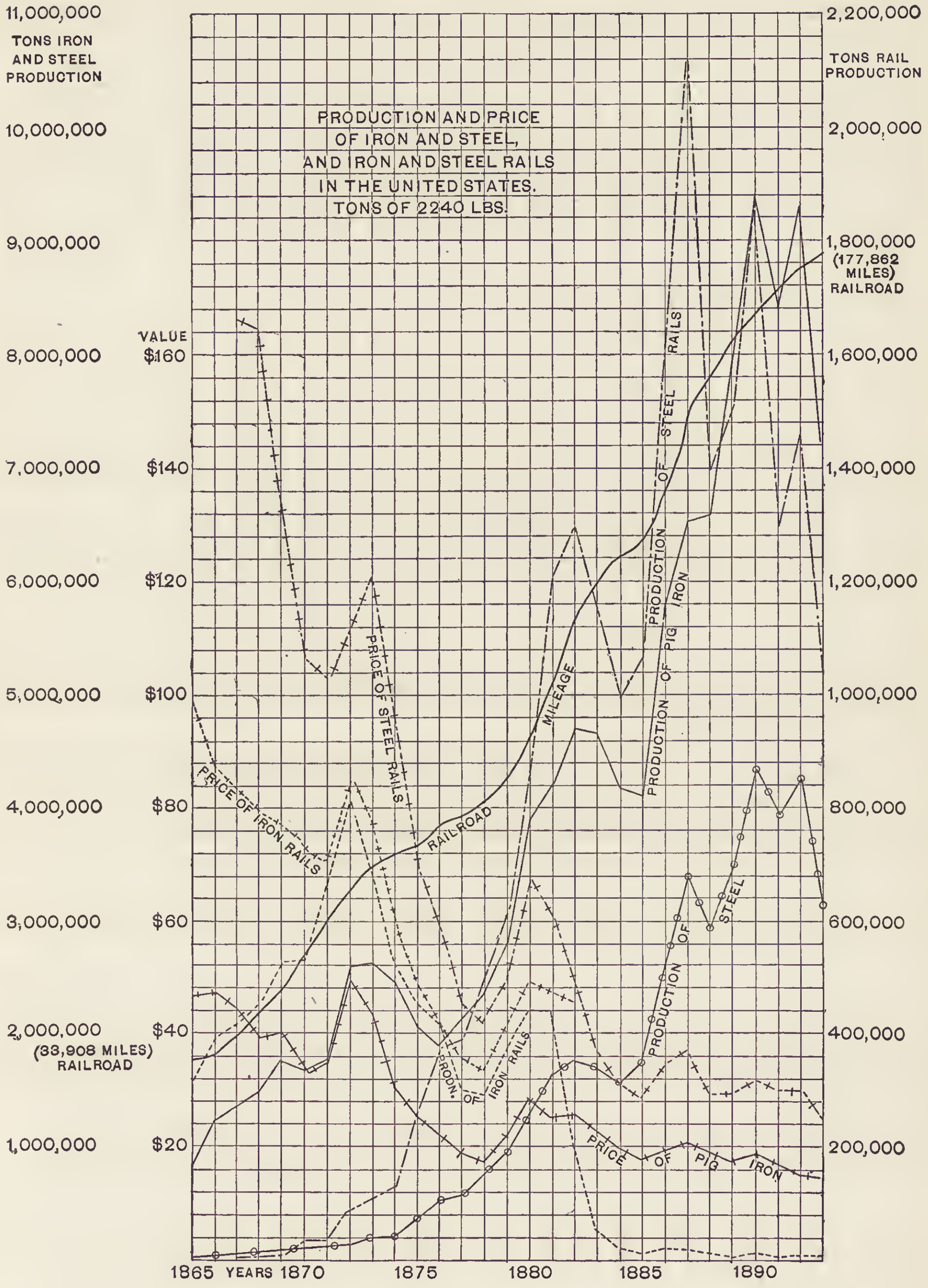
The following table shows the world's production of iron and steel, in metric tons, from 1865 to the close of 1893. Where figures are preceded by a * there are no official records of the production, and estimates have been made, based upon authoritative figures. The table is interesting in showing the relative progress in iron and steel production during the past twenty-nine years.

PRODUCTION OF PIG IRON AND STEEL IN THE PRINCIPAL COUNTRIES.

(In metric tons.)

Year.	Austria-Hungary.		Belgium.		Canada.	France.		Germany.		Italy.		Russia.	
	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.
1865......	101,403	5,000	470,767	650	....	1,203,710	40,574	988,191	97,752	......	....	299,438	*3,871
1866......	106,720	12,000	482,304	1,050	....	1,260,348	37,764	1,046,954	114,434	......	.......,	290,000	*3,932
1867......	104,048	15,000	423,069	1,575	....	1,229,044	46,467	1,113,606	122,591	......	....	*300,000	*6,271
1868......	112,575	20,000	435,754	1,928	....	1,235,307	80.564	1,264,347	122,837	......	....	*335,000	*9,327
1869......	405,082	30,000	534,319	2,940	....	1,380,965	110,227	1,413,029	161,319	......	....	*350,000	*7,200
1870......	402,953	40,000	565,234	4,321	....	1,178.113	94,386	1,391,123	169,951	......	....	*359,531	*8,647
1871......	424,606	52,000	609,230	7,453	....	859,641	86,125	1,563,682	250,947	......	....	*399,273	*7,132
1872......	459,399	67,500	655,565	15,079	....	1,217,838	141,704	1,988,395	312,247	......	....	*378,387	*8,254
1873......	534,508	25,000	607,373	21,657	....	1,381,626	150,529	2,240,574	302,647	......	....	387,940	*8,807
1874......	494,057	37,000	532,790	37,683	....	1,415,807	208,787	1,901,263	354,256	......	....	379,060	*9,511
1875......	463,063	45,000	541,805	54,420	....	1,448,272	256,393	2,029,389	370,655	......	....	427,187	*14,252
1876......	400,425	70,000	490,508	76,524	....	1,435,212	241,842	1,846,345	390,434	......	....	441,914	*19,749
1877......	387,630	97,470	470,488	104.182	....	1,506,827	269,181	1,932,726	495,000	......	....	400,054	*48,793
1878......	434,250	129,478	518,646	124,195	....	1,521,274	312,921	2,147,641	570,328	......	....	417,632	*104,766
1879......	404,162	125,000	453,371	111,275	....	1,400,206	333,265	2,216,587	500,900	......	....	432,997	*233,471
1880......	464,234	129,007	608,084	132,052	....	1,725,293	388,894	2,792,038	660,591	......	....	448,596	*295,568
1881......	543,641	130,000	624,736	141,640	....	1,886,350	422.416	2,913,009	897,425	27,800	3,630	470,052	293,323
1882......	611,739	150,000	726,946	182,627	....	2,039,067	458,238	3,380,806	1,074,806	24,778	3,450	463,087	247,670
1883......	698,857	271,733	783,433	179,489	....	2,069,430	521,820	3,469,718	1,060,591	......	....	482,274	222,183
1884......	734,346	225,752	750,812	187,066	....	1,871,537	502,908	3,608,618	1,200,000	18,405	4,645	510,132	206,965
1885......	714,787	278,803	712,876	155,012	....	1,630,648	553,839	3,687,434	1,202,990	15,991	6,370	528,170	192,895
1886......	719,980	256,023	701,677	164,045	*20,138	1,516,574	427,589	3,528,658	1,360,620	12,291	23,760	532,744	241,791
1887......	704,530	276,670	755,781	229,321	22,529	1,567,622	493,294	4,023,953	1,685,406	12,265	73,262	613,184	225,480
1888......	790,227	355,038	826,850	243,647	19,781	1.683,349	517,294	4,337,121	1,862,000	12.538	117,785	667,737	222,288
1889......	855,813	398,156	832,226	261,397	23,522	1,734,000	....	4,524.558	2,022,472	13,473	157,899	740,957	258,734
1890......	965,382	499,600	787,836	245,566	....	1,962,196	581,998	4,658,451	2,161,821	14,346	107,676	927,585	378,424
1891......	921,846	*475,000	684,126	243,913	21,697	1,897,387	638,530	4,631,218	2,562,549	11,930	75,925	1,004,745	433,487
1892......	940,284	*480,000	753,268	260,037	38,514	2,022,989	*650,000	4,937,461	*2,600,000	12,729	56,543	*919,614	*305,003
1893......	....	....	760,296	273,058	....	....	....	4,953,148	....	......	....	....	....


WORLD'S POPULATION, PRODUCTION OF PIG IRON (IN METRIC TONS) AND PRODUCTION PER CAPITA IN PRINCIPAL COUNTRIES (IN POUNDS)
LBS.
550
500
450
400
350
300
250
200
150
100
50
0
(530,000,000 POPULATION)
TONS
28,000,000
26,000,000
24,000,000
22,000,000
20,000,000
18,000,000
16,000,000
14,000,000
(810,000,000 POPULATION)
12,000,000
10,000,000
1865
YEARS
1870
1875
1880
1885
1890
UNITED KINGDOM
BELGIUM
WORLD'S PRODUCTION
SWEDEN
UNITED-STATES
GERMANY
FRANCE
WORLD'S POPULATION
AUSTRIA - HUNGARY
SPAIN
RUSSIA
CANADA


PRODUCTION AND PRICE
OF IRON AND STEEL,
AND IRON AND STEEL RAILS
IN THE UNITED STATES.
TONS OF 2240 LBS.
11,000,000
TONS IRON AND STEEL PRODUCTION
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
(33,908 MILES) RAILROAD
1,000,000
VALUE
$160
$140
$120
$100
$80
$60
$40
$20
2,200,000
TONS RAIL PRODUCTION
2,000,000
1,800,000
(177,862 MILES) RAILROAD
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
1865
YEARS
1870
1875
1880
1885
1890
PRICE OF IRON RAILS
PRICE OF STEEL RAILS
RAILROAD
MILEAGE
PRODUCTION OF STEEL RAILS
PRODUCTION OF PIG IRON
PRODUCTION OF STEEL
PROD. OF IRON RAILS
PRICE OF PIG IRON

PRODUCTION OF PIG IRON AND STEEL IN THE PRINCIPAL COUNTRIES—*Continued.*

Year.	Spain.		Sweden.		United Kingdom.		United States.		All Other Countries.		Total.	
	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.
1865...	....	......	226,619	*5,000	4,897,971	225,000	843,410	13,848	68,037	28,135	9,099,666	419,830
1866...	....	......	230,173	*7,000	4,697,636	235,000	1,222,480	17,216	318,865	30,580	9,655,480	458,976
1867...	....	......	253,538	*9,000	4,828,627	245,000	1,326,450	19,963	483,724	29,055	10,062,106	494,922
1868...	....	......	263,089	*15,500	5,051,220	260,000	1,454,272	27,223	553,891	29,072	10,705,455	564,451
1869...	....	......	292,134	*13,150	5,534,522	275,000	1,739,232	31,760	300,485	38,559	11,949,768	661,153
1870. .	....	......	300,338	*12,193	6,060,720	286,797	1,692,378	68,057	309,520	8,881	12,259,910	703,333
1871...	....	217	298,761	*8,551	6,735,302	410,585	1,730,800	74,710	281,578	27,016	12,902,873	924,736
1872...	....	272	339,409	*15,876	6,851,822	497,987	2,590,360	143,289	412,614	14,043	14,893,789	1,218,241
1873...	....	216	345,720	16,986	6,673,484	588,437	2,602,750	202,075	368,200	28,865	15,142,175	1,345,219
1874...	....	171	327,852	22,948	6,089,067	643,317	2,440,470	219,250	367,763	30,795	13,952,729	1,563,718
1875...	....	149	350,539	21,387	6,469,219	723,605	2,056,750	396,165	316,078	17,998	14,102,222	1,900,024
1876...	44,491	......	352,466	24,069	6,602,859	851,659	1,899,480	541,900	304,695	10,814	13,878,395	2,226,991
1877...	46,919	......	344,536	21,352	6,716,385	904,507	2,100,380	578,921	184,381	18,073	14,090,326	2,519,406
1878...	66,763	......	340,857	25,918	6,485,062	1,117,930	2,338,790	743,931	99,534	49,392	14,370,449	3,178,859
1879...	68,742	......	342,547	27,631	6,093,060	1,029,522	2.786,650	950,550	198,880	55,850	14,397,282	3,367,464
1880...	85,939	......	405,713	37,454	7,875,545	1,320,561	3,897,840	1,267,700	306,946	42,091	18,547,228	4,273,918
1881...	114,394	......	430,042	49,712	8,513,915	1,808,728	4,211,980	1,614,258	302,354	334,029	20.038,273	5,576,869
1882...	120,064	......	398,945	58,730	8,631,727	2,245,666	4,698,790	1,765,070	665,178	2,113	21,461,127	6,186,257
1883...	139,920	......	422,627	65,814	8,628,614	2,041,624	4,670,570	1,708,865	341,729	*120,000	21,707,172	6,184,119
1884...	124,363	373	430,534	67,386	7,651,688	1.891,985	4,164,800	1,576,210	283,633	124,530	20,140,868	5,988,620
1885...	159,225	361	464,737	77,172	7,368,842	2,020,450	4,110,600	1,739,883	398,583	119,201	19,791,893	6,276,076
1886...	57,728	20,261	442,457	78,231	7,124,012	2,403,214	5,776,168	2,604,355	*350,000	211,756	25,862,289	7,791,645
1887...	288,634	......	456,625	111,565	7,682,738	3,196,778	6,521,973	3,393,640	*350,000	123,847	22,977,305	9,809,263
1888...	252,116	......	457,052	114,537	8,129,047	3,774,670	6,595,735	2,933,260	264,136	100,576	24,015,908	10,241,088
1889...	197,874	49,124	420,665	137,821	8,458,486	3,605,346	7,871,509	3,441,037	380,418	242,670	26,029,980	10,574,652
1890...	170,782	75,255	456,103	169,287	8,033,052	3,637,381	9,353,020	4,346,932	301,959	*250,000	27,630,712	12,450,940
1891...	278,462	69,972	490,913	172,774	7,525,301	3,207,994	8,413,176	3,968,010	*350,000	*250,000	26,230,081	12,097,434
1892...	247,329	56,490	485,664	158,978	6,817,274	2,966,522	9,304,428	4,235,541	*350,000	*250,000	26,859,554	12,019,114
1893...	260,450	71,200	....	....	....	....	7,239,206	3,173,813	....	....	....	....

The following table shows the movement of iron in the warrant yards since their commencement:

MOVEMENT OF PIG IRON IN YARDS OF THE AMERICAN PIG IRON STORAGE-WARRANT COMPANY FROM ITS ORGANIZATION, IN 1889, TO THE CLOSE OF 1892.

Year.	Received.	Delivered.	In Yard.	Year.	Received.	Delivered.	In Yard.
1889....	36,500	300	36,200	1892....	105,900	26,200	79,700
1890....	83,000	18,800	64,200	1893....	36,500	30,500	85,700
1891....	90,500	38,600	51,900				

Steel.—The following tables give the production of iron and steel and their products in the United States since 1889, and the imports and exports and their values since 1889:

PRODUCTION OF IRON AND STEEL AND THEIR PRODUCTS IN THE UNITED STATES.

Year.	IRON.					STEEL.							No. of Kegs Cut Nails and Spikes.
						Rails.		Ingots.					
	Pig.	Spiegel and Ferro-manganese	Blooms.	Rolled.	Rails.	Bessemer.	Open-hearth.	Bessemer.	Open-hearth.	Crucible.	Miscellaneous	Total.	
1889..	7,603,640	76,628	32,375	*a*3,714,723	9,159	1,510,057	2,988	2,930,204	374,543	75,865	5,119	3,385,731	5,810,758
1890..	9,202,702	133,180	27,485	*a*4,137,567	13,882	1,867,837	3,588	3,688,870	513,232	71,175	3,793	4,277,070	5,640,946
1891..	8,279,870	127,766	26,088	*a*4,083,787	8,240	1,293,053	5,883	3,247,417	579,753	72,587	4,484	3,904,241	5,002,176
1892..	9,157,000	179,131	25,000	*a*4,613,970	10,437	1,537,588	3,819	4,168,435	669,889	84,709	4,548	4,927,581	4,507,819
1893..	7,124,502	81,118	......	....	......	1,036,353	......	3,215,686	....	......	......	....	....

(*a*) Includes rolled steel.

UNITED STATES IMPORTS OF IRON AND STEEL, TIN PLATE, ETC.

Year.	Pig, Scrap (Iron and Steel), Spiegel, and Ferromanganese.		Bar Iron.		Castings, Boiler Iron, Band, Hoop, Cotton Ties, Scroll, Sheet, and Taggers' Iron.		Steel Ingots, Billets, Blooms, Slabs, Sheets, etc.		Tin and Terne Plates.		Rails.	
	Am't.	Value.	Am't.	Value.	Am't.	Value.	Am't.	Value.	Am't.	Value.	Am't.	Value.
1889..	180,388	$3,344,593	29,570	$1,097,132	*a*41,867	*a*$1,858,852	72,808	$1,989,837	323,274	$21,726,707	6,217	$163,339
1890..	191,232	4,535,526	24,034	1,002,480	*a*30,218	*a*1,515,225	28,636	1,578,286	329,435	23,670,158	204	5,035
1891..	67,179	1,432,455	18,099	770,858	*a*12,753	*a*781,557	34,685	1,673,214	327,868	25,900,305	253	8,405
1892..	99,348	2,023,428	19,281	776,927	*a*71,756	*a*3,195,684	30,586	1,591,092	268,472	*b*17,102,487	347	10,607
1893..	61,667	1,321,899	14,896	603,985	*a*76,647	*a*3,276,537	26,868	1,293,834	253,485	*b*15,559,423	2,888	57,584

(*a*) Includes sheet steel. (*b*) Includes taggers' iron.

EXPORTS OF IRON, STEEL, ETC., FROM THE UNITED STATES.

(In short tons.)

Year.	Pig Iron.		Bar Iron.		Boiler, Band, Hoop, Scroll, and Sheet Iron.		Steel Ingots, Bars, Sheets, and Wire.		Rails.		Total Value.*
	Amount.	Value.	Amount.	Value.	Amount.	Value.	Am't.	Value.	Am't.	Value.	
1889....	13,573	$227,048	778	$52,341	339	$29,540	8,738	$689,784	9,325	$309,825	$23,712,814
1890....	16,341	266,107	1,068	97,317	609	48,168	10,721	886,214	16,948	577,916	27,000,134
1891....	14,945	258,000	1,341	85,382	506	34,019	12,516	940,375	11,239	363,488	30,736,442
1892....	15,427	282,290	963	60,463	31	1,762	15,291	1,027,541	7,982	256,325	27,900,862
1893....	24,570	379,254	1,842	94,219	255	10,487	17,079	1,033,757	20,876	595,988	30,159,150

* Includes all manufactures of iron and steel as classified by Census Bureau.

The following tables give the production, imports, and exports of iron and steel rails since 1889, and also the increase in railroad mileage:

IRON AND STEEL RAILS: PRODUCTION, IMPORTS, AND EXPORTS, AND CONSUMPTION IN THE UNITED STATES.

Year.	Rails in Tons of 2240 Lbs.										Railroads, Miles.	
	Home Production.			Imports.			Exports.			Consumption.	Annual Increase.	Total Mileage
	Iron.	Steel.	Total.	Iron.	Steel.	Total.	Iron.	Steel.	Total.			
1889..	9.195	1,513,045	1.522,240	6,217		6,217	1,082	8,243	9,325	1,519,132	5,184	161,353
1890..	13,882	1,871,425	1,885,307	204		204	104	16,844	16,948	1,868,563	5,353	166,706
1891..	8,240	1,298,936	1,307,176	253		253	160	11,079	11,239	1,296,190	4,089	170.795
1892..	10,437	1,541,407	1,551.844	347		347	486	7,496	7,982	1,544,209	4,409	175,204
1893..	....	1.130,368	....	2,888		2,888	164	19,712	19,876	....	2,549	177,753

Iron Ore.—The following table shows the tons and percentages of red and brown hematites, magnetites, and carbonate ores mined in the United States, and also the imports from foreign countries:

Year.	Red Hematite.		Brown Hematite.		Magnetite.		Carbonate.		Total.	Imports.		Total.
	Tons.	Per Cent.	Tons.	Per Cent.	Tons.	Per Cent.	Tons.	Per Cent.	Tons.	Tons.	Per Cent.	Tons.
1889..	9,056,288	62.3	2,523,087	17.4	2,506,415	17.2	432,251	3.0	14,518,041	853,573	5.5	15,371.614
1890..	10,527,650	65.6	2,559,938	15.9	2,570,838	16.0	377,617	2.3	16,036,043	1,246.830	7.2	17,282,873
1891..	9,327,398	63.9	2,757,564	18.8	2,317,108	15.8	189,108	1.3	14,591,178	912,864	5.9	15,504,042
1892..	11,646,619	71.4	2,485,101	15.2	1,971,965	12.1	192,981	1.2	16,296,666	806,585	4.7	17,103,251
1893*	8,000,000	......	1,900,000	......	1,000,000	......	100,000	......	11,000,000	526,951	......	11,526,951

* Estimated.

The following table shows the production of iron ore in this country in 1879, and from 1889 to 1893, inclusive:

States.	1879, 10th Census.	1889, 11th Census.	1890. (*a*)	1891. (*a*)	1892. (*a*)	1893. (*a*)
Alabama	171,139	1,570,319	1,897,815	1,986,830	2,312,071	1,742,410
Colorado	....	109,136	114,275	110,942	141,769	171,670
Connecticut and Massachusetts	92,549	88,251	61,492	78,425	76,265	40,752
Georgia	84,584	258,145	244,088	250,755	185,054	(*b*)186,015
Kentucky	57,865	77,487	77,685	65,089	50,523	36,714
Maryland	127,102	29,380	35,657	37,379	40,171	13,830
Michigan	1,640,814	5,856,169	7,141,656	6,127,001	7,543,544	4,668,324
Minnesota	....	864,508	891,910	945,105	1,255,465	1,499,927
Missouri	344,819	265,718	181,690	106.949	118,494	77,863
Montana	....	24,072	....	....	7,070	(*c*)38,716
New Jersey	676.225	415,510	495,808	525,612	465,455	356,150
New Mexico and Utah	....	36,050	81,632	51,776	26,302	....
New York	1,126,899	1,247,537	1,253,393	1,017,216	891,099	534,122
North Carolina	....	....	22,873	19,210	25,379	....
Ohio	488,753	254,294	169,088	104,487	95,768	68,147
Oregon	6,225	26,283	....	29,018	11,503	....
Pennsylvania	1,951,496	1,560,234	1,361,622	1,272,928	1,084,047	697,985
Tennessee	93,272	473,294	465,695	543,923	406,578	372,996
Texas	3,214	13,000	22,000	51,000	22,903	25,620
Virginia and	217,448	511,255	543,853	658,916	741,027	612,465
West Virginia			25,116	6,200	6,000	4,500
Wisconsin	37,000	837,399	948,963	549,481	790,179	439,429
Total	7,120,362	14,518,041	16,036,043	14,591,178	16,296,666	11,587,629

(*a*) From report by John Birkinbine in the *Mineral Resources of the United States.* (*b*) The estimated output for 1893 is: Alabama, 1,818,000 tons; Colorado, 150,000 tons; Maryland, 30,000 tons; Michigan, 4,114,700 tons; Minnesota, 1,434,300 tons; New Jersey, 343,840 tons (correct figure); New York, 500,000 tons; Virginia, 650,000 tons; Wisconsin, 510,000 tons; other States, 1,979,160 tons—total, 11,000,000 tons. (*b*) Including North Carolina. (*c*) Including New Mexico, Idaho, Utah and Oregon.

SHIPMENTS OF LAKE ORE BY PORTS.

Year.	Escanaba.	Marquette.	Ashland.	Two Harbors.	Gladstone.	Superior.	Duluth.	Total Lake.	Total Rail.	Total Shipment.
1890	3,714,662	1,307,395	2,123,556	826,063	91,091	....	....	8,063,767	940,634	9,003,401
1891	3,058.590	1,056,027	1,261,688	890,299	177,866	....	....	6,444,440	651,541	7,094,981
1892	4,010,085	1,026,338	2,223,683	1,165,076	115,886	4,245	....	8,545,313	528,930	9,074,243
1893	2,048,981	1,086,934	1,117,524	903,329	203,585	80,273	440,292	5,880,918	178,037	6,058,955

PRODUCTION OF LAKE SUPERIOR IRON ORE MINES FOR THE LAST TEN YEARS, AND TOTAL SINCE COMMENCEMENT OF MINING.

Range.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Gogebic	....	1,022	119,860	747,589	1,303,267	1,424,699	2,016,391	2,847,786	1,825,599	2,973,993	1,329,464
Marquette	1,305,425	1,548,034	1,480,422	1,627,380	1,851,414	1,918,750	2,634,816	2,993,664	2,512,242	2,666,856	1,829,053
Menominee	1,047,415	895,634	690,435	880,006	1,193,343	1,191,101	1,796,755	2,282,237	1,824,619	2,261,499	1,466,197
Mesaba	....	....	....	....	....	....	....	....	....	4,245	613,620
Vermilion	....	62,124	225,484	304,396	394,252	511,953	844,682	880,014	894,618	1,167,650	820,621
Total	2,352,840	2,506,814	2,516,201	3,559,371	4,472,276	5,046,503	7,292,644	9,003,701	7,057,078	9,074,243	6,058,955

The total production of Lake Superior iron ore mines, as given in the preceding table, is: Gogebic, 14,576,686 tons; Marquette, 39,749,610 tons; Menominee, 18,245,547 tons; Mesaba, 617,865 tons; Vermilion, 6,105,794 tons—a total of 75,295,502 tons.

During 1892 there were 163,444 tons of ore obtained by magnetic separation from 436,238 tons of crude material, and also 93,627 tons of jigged ore from 291,611 tons crude material. This shows an average of 2.67 tons raw ore to one ton concentrates, and 3.11 tons lean ore to one ton jigged ore. A little over 9000 tons of ore which had been hand-sorted was marketed as such.

Canada.—The full extent of the iron ore deposits in Canada has never been ascertained, but explorations by both the Geological Survey and private companies have shown the presence of numerous bodies of ore in various parts of the Dominion, and their occurrence and general features favor the opinion that there are many more of which nothing as yet is known. Some of these deposits have been worked for many years, one of the earliest being in Quebec, near St. Maurice, where forges were operating in 1737.

Probably the best known, and certainly the most fully developed, ore deposits are those in Nova Scotia, as owing to their proximity to coal they have been worked to supply the furnaces operating in that province. Regarding these deposits, Mr. Edwin Gilpin, mine inspector, gives the following information: The iron ore deposits of Nova Scotia are widespread and abundant. In Cape Breton magnetites and hematites occur, and valuable beds of specular and red hematite are found at Arisaig and Guysborough. No work has been done on these other than testing the outcrop. In Pictou County brown, red, and specular hematites occur. At Londonderry, in Colchester County, brown hematite has been worked for many years to supply the furnaces, and at Torbrook, Nictaux, and Clemensport, in Annapolis County, extensive bodies of both magnetite and hematite are found. At many other points deposits of ore occur, but have received little attention.

In the second report issued by the Bureau of Mines considerable information is given concerning the occurrence of iron ores in Ontario. Referring to the Ottawa Valley, it is said that extensive deposits of magnetic and specular ores are found, and at Hull, on the Quebec side of the river, a bed of magnetic ore occurs. In Bedford, Bastard, Sherbrooke, and McNab townships, Ontario, large beds of ore have been found. Near the Rideau Canal and at both North and South Crosby, as well as in the Hastings and Frontenac districts, magnetic and specular ores appear. In Seymour and north of Crow Lake specular and red hematites occur. In eastern Ontario the Kingston and Pembroke Railway gave access to the ore districts of Frontenac and Lanark, consisting mostly of magnetites. In Lavant township, at the Mississippi mines, and at Coe Hill in Wallaston, large deposits of magnetite occur. In the Nipigon and Michipicoten River districts extensive bodies of both magnetites and red hematites are found, and explorations have shown the presence of large bodies of ore along the Mattawan River and near Land Lake. A district which is regarded as promising well is in the Antik-okau range, lying along the Labawe and Antik-okau rivers. Many of the largest of the ore properties in this district are owned by residents of the United States, but as yet no important work has been carried out. It is estimated that these ores can be mined for $1 per ton; railroad freights to Port Arthur or Fort Williams $1 per ton, lake freights to Cleveland or other ports about the same as charged from Ashland or Two Harbors. The figures are given by Mr. W. W. Russell of Port Arthur.

The iron industry of Canada has been but little developed, notwithstanding its extensive ore deposits and the bounty granted upon pig iron. At present there are but four furnaces in the Dominion which may be accounted producers. These are at Londonderry, Ferrona, and Bridgeville in Nova Scotia, and at Radnor Forge in Quebec. Mr. J. T. Donald of Montreal states that the Pictou

Charcoal Iron Company, which erected a charcoal furnace at Bridgeville, had the plant in operation for a few months in the latter part of 1892 and early in 1893, producing during the latter year 445 tons charcoal iron. Additional capital has been secured and the furnace is expected to blow in again during 1894. The New Glasgow Iron, Coal and Railway Company, which built a furnace at Ferrona, near Pictou, blew in Aug. 25, 1892, and is producing an average of 2000 tons per month. In the Province of Quebec the only producing furnace is at Radnor Forge, nine miles from Three Rivers. This has a daily output of 20 to 25 tons. The production of pig iron in Canada during the fiscal year ending June 30, 1893, is stated to be 51,000 tons, of which Nova Scotia produced 40,926 tons.

The following figures of production of iron ore in Canada have been furnished by Mr. J. T. Donald.

The production of iron ore in Canada for the years 1886 to 1893 is given in the following table. The great increase of 1892 over the previous year is due to the operations of the new blast furnace at Ferrona, already referred to.

Year.	Tons.	Value.	Year.	Tons.	Value.	Year.	Tons.	Value.
1886........	69,708	$126,982	1889..........	84,181	$151,640	1892........	110,240	$212,674
1887........	76,330	146,197	1890..........	76,511	155,380	1893........	*124,562	245,278
1888........	78,587	152,068	1891..........	68,979	142,005			

* Possibly a few hundred additional tons of ore have been raised in British Columbia, but at present no definite information is to be had.

Of the total product in 1893 Nova Scotia contributed 105,181 tons and Quebec province 19,381 tons. The Quebec production was principally bog ores for the furnaces at Radnor and Drummondville. In 1893 Nova Scotia produced 46,335 tons of pig iron and Quebec 8219 tons.

Great Britain.—The English iron trade has suffered greatly from the depression of the past year, though because of the Durham strike in 1892, which reduced the output, it does not show so markedly in the production of 1893. During the first half of 1893 there were produced 3,665,537 tons of pig iron, against 2,790,918 tons in the corresponding half of 1892, and 3,712,118 tons in 1891. This shows an increase of 874,619 tons over the output of 1892, and a decline of 46,619 tons from the production of 1891. Since June, however, owing both to the coal miners' strike and the diminished demand, many furnaces have gone out of blast; so while the production for the first half year was at the rate of 7,330,000 tons per annum, by September this had fallen to a rate of 5,800,000 tons per year. The total production for the year is given as 6,800,000 tons.

The Scotch iron trade suffered more in proportion than the furnaces of England, the total production for the year being 783,867 tons, or 19,346 tons less than 1892, while the total number of furnaces in blast was but 53 as against 76 in 1892. During the first half of the year there were produced in Great Britain 656,774 tons of acid Bessemer and 127,938 tons of basic Bessemer steel, a total of 134,896 tons more than the production for the corresponding period in 1892. During the latter half of the year the output declined, the total for the year, of both kinds of steel, being given as 1,300,000 tons. The production of Bessemer steel rails during the first half of the year was 317,395 tons, or 105,511 tons more than in the corresponding period of 1892. During the latter half of the year the output declined, the total for the year being given as 550,000 tons.

The exports of iron and steel from Great Britain in 1893 amounted to 2,884,279 gross tons, an increase of 144,062 tons, or 5.3% over 1892. The exports were made up as follows: Pig iron, 839,869 tons; rails, 558,826 tons; hoops, sheets, and plates, 195,370 tons; bars, angles, and rods, 148,931 tons; iron, cast or wrought, 280,578 tons; steel, unwrought, 169,764 tons; tin plates, 379,233 tons; wire, 37,137 tons; old iron, 118,551 tons; manufactures of iron and steel, 18,531 tons. Imports of iron and steel in 1893 were 297,773 tons, a decrease of 3,584 tons, or 1.1%, from 1892. The imports of iron ore in 1893 were 4,065,863 tons, being 287,210 tons, or 7.6%, greater than in 1892.

Spain.—The production of iron ore, iron, and steel, and also exports of ore, are shown in the following table. In another part of this volume complete statistical tables of this country are given.

PRODUCTION OF IRON ORE, PIG IRON, WROUGHT IRON, AND STEEL, AND EXPORTS OF IRON ORE.

(In metric tons.)

Year.	Production.				Exports, Iron Ore.
	Iron Ore.	Pig Iron.	Wrought Iron.	Steel.	
1890.......	5,788,743	179,433	63,933	63,011	4,696,944
1891.......	4,822,089	278,462	59,910	69,892	3,625,665
1892.......	5,405,142	247,329	122,295	56,490	4,240,130
1893.......	5,497,540	260,450	121,340	71,200	4,331,621

Cuba.—The Juragua Iron Company, Limited, has courteously furnished the following interesting figures, showing the output of its mines near Santiago de Cuba and the importations of this ore into the United States for the calendar years 1884 to 1893, inclusive.

STATEMENT SHOWING OUTPUT OF THE JURAGUA IRON MINES, NEAR SANTIAGO DE CUBA, AND IMPORTATIONS OF ORE INTO THE UNITED STATES FROM THESE MINES, FOR THE CALENDAR YEARS 1884 TO 1893, INCLUSIVE.

Calendar Year.	Output, Tons.	Importations, Tons.
1884....................	35,722	21,798
1885....................	74,913	81,106
1886....................	109,540	111,710
1887....................	97,192	97,711
1888....................	201,966	198,048
1889....................	261,112	256,278
1890....................	364,502	362,068
1891....................	266,139	266,377
1892......................	335,521	322,527
1893......................	336,202	348,663
Total to Dec. 31, 1893....	2,082,809	2,066,286
Lost at sea...............		10,131
On hand in Cuba and in transit Dec. 31, 1893....		6,392
Total		2,082,809

THOMAS-GILCHRIST STEEL.

The following information regarding this process and the production of basic steel has been supplied through the courtesy of Mr. Percy Gilchrist:

The use of the process is being considerably extended in Belgium by the erection of fresh works. In Germany the make of each works is somewhat increasing; in England the make (excluding the effect of the Midland strike) is stationary.

The basic process itself is being worked much as it has been from the first; viz., the lining and bottoms are still made of shrunk dolomite, crushed and mixed with boiled tar. The shrunk dolomite is mostly made in basic-lined cupolas, but in some few works the original method of grinding the limestone or dolomite and mixing it, if necessary, with sufficient fluxing material, and making it into bricks and then shrinking the bricks in kilns, is still followed. In a few works shrunk magnesia is used for the hearth of the open-hearth furnace. The bottoms in most works are made by mechanically ramming the material around metal pins; in some the material is rammed around fire-clay tuyères; the additions are of ordinary well-shrunk lime. The after-blow is still a necessity.

The slag, most finely ground, has been for several years of great value as a fertilizer, and the price obtained for it is a considerable factor in determining the cost of the basic ingot.

At one time there was a considerable difficulty in producing steel with over 0.2% of carbon; but this has been quite overcome by the use of the Phœnix-Darby-Meyer process of carburizing. The works that use this process produce almost as much steel with over 0.17% of carbon as with under 0.17%; while those works that do not use the process produce almost entirely steel with under 0.17% carbon.

Some works employ the Massenez-Hoerde process for reducing the percentage of sulphur in the pig iron. This process also undoubtedly enables the pig iron to be used to the best advantage when it is taken direct from the blast furnace.

There is only one works—Witkowitz—that refines in the acid converter and then completes the conversion into steel in a basic Siemens furnace. All the other works find it more economical to make the pig iron in the blast furnace with low enough silicon to enable it to be treated at once in either a basic-lined converter or an open-hearth furnace.

During 1893 the total make of steel and ingot-iron from phosphoric pig-iron amounted to 3,638,556 tons, being an increase over the make for the previous twelve months of 435,916 tons. Of this, the basic bessemer was 2,808,241 tons, and the basic open hearth, 830,315 tons. Of the steel containing under 0.17 per cent. of carbon, the basic bessemer produced 2,304,881 tons, and the basic open hearth, 596,716 tons.

PRODUCTION OF THOMAS STEEL.

(In metric tons.)

Years.	England.	Germany and Luxembourg.	Austria.	France.	Belgium.	Russia.	United States.	Total.
1878	20	....	....	....	....	....	....	20
1879	1,150	1,782	....	....	....	....	....	2,982
1880	10,000	18,180	13,754	4,771	3,295	....	....	50,000
1881	46,120	200,000	54,700	10,480	14,200	10,500	....	336,000
1882	109,364	235,132	64,214	12,306	16,672	12,312	....	450,000
1883	122,380	328,909	85,593	38,229	27,399	31,863	....	634,373
1884	179,000	440,000	80,300	113,000	31,700	20,000	....	864,000
1885	145,707	548,252	69,262	130,582	21,056	30,458	....	945,317
1886	258,466	784,212	99,647	122,711	27,938	20,657	....	1,313,631
1887	435,046	1,167,702	142,409	210,301	50,777	17,836	....	2,024,071
1888	408,594	1,137,632	138,438	222,333	31,937	14,300	....	1,953,234
1889	493,919	1,305,887	175,755	222,392	47,037	29,562	....	2,274,552
1890	503,400	1,493,157	202,315	240,638	46,445	39,349	....	2,603,083
1891	436,261	1,779,779	221,212	255,401	38,793	38,973	77.779	2,880,535
1892	406,839	2,013,484	288,122	287,528	56,274	58,664	110,116	3,202,640
1893	358,036	2,344,754	314,992	363,017	....	257,757	91,729	3,638,556

NOTE.—With the above there were produced in 1893 some 876,894 tons of slag, containing about 36% of phosphate of lime; and nearly the whole of this was finely ground and used as a fertilizer.

PITTSBURG MARKET IN 1893.

(From our Special Correspondent.)

THE year 1893 will long be remembered by the iron and steel interests and all connected therewith. Prices on all grades of these products reached during the year the lowest mark ever recorded. In January, 1889, Bessemer pig sold at $24.50; the present price is $10.90@$11, a decline of $13.50 per ton. The same year gray forge sold at $19, and steel billets at $37.50 per ton. The year's sales in 1893 reached 1,639,226 tons, a very liberal amount considering the great depression in trade generally and the iron and steel business in particular, being only 431,997 tons below the previous year. The sales of iron ore amount to 4,011,000 tons, being 1,742,000 tons below the previous year. One very noticeable feature of the year was the strides soft steel made in taking the place of iron. Steel at present is cheaper than iron. Take, for instance, skelp iron, wide grooved, which is sold at $1.30 per 100 lbs.; skelp steel, wide grooved, is $1.15, the difference making a good profit.

During the year sales of blooms, billets, and slabs were large and showed a wide range of prices. In 1892 January opened at $25@$26 per ton, but the figures were maintained only a short time. In February a syndicate was formed to hold the price at $25, but it soon fell to $23@$24. In 1893 prices reached the lowest point ever known in the history of the trade, the year opening at $21.75 @$22.25 and closing at $16.70, a decline of $5.65 per ton.

In Bessemer pig prices ranged in January, 1892, from $15.75 to $16 and closed the same year at $13.70, the year's decline being $2.30 per ton. In 1893 the market opened at $13.65@$13.75 and closed at $10.82@$11, the decline for the year being $2.75@$2.83 per ton, and the present prices the lowest on record. Gray forge iron has shown a steady decline in values from $12.25@$12.50 in January to $10 in December, a decline of $2.25 to $2.50 per ton.

CASH PRICE OF IRON AND STEEL IN PITTSBURG, LAST WEEK OF DECEMBER.

Year.	Pig Iron.													
	Bessemer	Coke, Foundry.							Charcoal Iron.				Ferro-Mang., 80%.	Spiegel, 20%.
		No. 1.	No. 2.	No. 3.	Gray Forge.	Mottled	White.	Silvery.	No. 1.	No. 2.	Cold Blast.	Warm Blast.		
1889	$24.50	$20.25	$19.50	$19.00	$17.75	$16.25	$17.25	$21.00	$24.00	$22.50	$27.00	$25.00	$105.00	$36.00
1890	16.50	17.25	16.25	14.75	14.25	14.25	14.25	16.50	24.00	22.50	26.00	24.50	65.50	30.00
1891	15.75	16.00	15.25	13.65	13.25	13.25	13.25	17.00	22.50	20.50	26.50	19.50	63.00	27.00
1892	13.75	14.25	13.25	12.60	12.50	12.00	12.00	16.00	20.00	19.00	25.00	19.00	61.00	28.50
1893	11.00	12.25	11.25	10.00	10.00	10.25	10.60	15.50	18.50	18.00	25.00	18.00	52.50	23.75

Year.	Steel.							Wrought Iron.						Coke at Furnace.
	Billets.	Rail Ends.	Bloom Ends.	New Rails.	Old Rails.	Steel Nails.	Wire Nails.	Muck Bar.	Old Rails.	No. 1 Scrap.	No. 2 Scrap.	Bar Iron.	Iron Nails.	
1889	$37.25	$26.50	$26.50	$36.00	$24.50	$2.50	$3.00	$31.75	$28.00	$24.00	$20.00	$1.95	$2.50	$1.75
1890	26.00	17.75	17.50	29.00	18.50	1.90	2.10	29.50	26.00	22.00	18.00	1.85	1.90	2.15
1891	24.50	17.25	17.25	30.00	17.50	1.60	1.70	26.00	23.25	24.00	17.50	1.65	1.60	1.90
1892	22.50	15.50	16.00	30.00	14.50	1.55	1.55	24.50	20.50	20.50	15.00	1.60	1.55	1.90
1893	16.75	11.50	11.50	24.00	10.50	1.10	1.20	21.00	14.50	7.25	6.00	1.45	1.10	1.15

MONTHLY SALES OF RAW IRON AND STEEL AT PITTSBURG FROM 1888–93.
(Tons of 2240 lbs.)

Month.	1888.	1889.	1890.	1891.	1892.	1893.
January	40,265	66,213	147,270	85,062	203,247	122,915
February	54,530	63,057	82,870	158,365	117,245	183,675
March	57,925	113,038	105,777	125,749	243,019	267,556
April	73,656	61,060	84,325	167,216	115,875	200,470
May	68,770	123,640	139,495	180,640	148,323	220,215
June	111,240	125,945	181,640	269,595	139,670	117,550
July	126,030	188,365	121,360	229,090	137,000	52,250
August	123,675	206,545	159,235	124,436	132,690	43,325
September	123,940	155,903	174,940	194,210	180,953	57,500
October	134,915	377,095	187,020	185,735	242,340	84,050
November	120,125	201,405	141,055	261,861	244,714	108,925
December	93,965	239,775	88,705	186,500	119,310	113,260
Total	1,129,036	1,922,041	1,613,692	2,168,459	2,024,386	1,591,691

MONTHLY PRICES OF PIG IRON AT PITTSBURG, 1888–93.

Month.	1888.		1889.		1890.		1891.		1892.		1893.	
	Gray Forge.	Bessemer.	Gray Forge.	Bessemer.	Gray Forge.	Bessemer.	Gray Forge.	Bessemer.	Gray Forge.	Bessemer.	Gray Forge.	Bessemer.
January	$16.50	$19.00	$15.50	$16.65	$18.25	$24.00	$14.25	$16.25	$13.50	$15.70	$12.30	$13.50
February	16.25	18.50	14.50	16.50	18.00	23.00	14.50	16.50	13.30	15.20	12.25	13.50
March	16.00	18.32	14.75	16.75	17.00	20.00	15.00	16.50	12.90	14.70	12.25	13.75
April	15.50	18.25	14.25	16.50	15.25	18.25	14.25	16.50	12.95	14.50	12.25	13.85
May	15.00	17.00	14.00	16.65	15.50	18.25	14.12	16.50	12.90	14.40	12.20	13.50
June	14.30	17.00	14.00	16.00	15.75	19.25	14.15	16.25	12.80	14.10	12.15	13.50
July	14.25	17.00	14.00	16.65	15.50	19.30	14.10	15.80	12.75	14.00	12.10	13.30
August	14.25	17.25	14.50	16.85	15.50	18.75	14.00	15.80	12.60	14.00	11.75	12.90
September	16.25	18.00	15.65	18.00	15.25	18.50	14.10	15.62	12.50	13.90	11.50	12.25
October	16.50	18.00	16.25	19.00	15.25	17.75	13.87	15.40	12.50	13.90	10.80	11.65
November	16.00	18.00	16.75	21.50	15.00	17.50	13.60	15.18	12.50	14.05	10.50	11.30
December	15.50	17.25	19.00	24.00	14.75	16.75	13.50	15.25	12.50	13.90	10.30	11.00

REVIEW OF THE CHICAGO MARKET FOR 1893.

The year 1893 will be remembered as one of the worst years in the history of the iron and steel industries in the West. The two more prominent features of the trade were the almost uniform and steady decrease in prices of crude and manufactured material—from which there has been little or no recovery—and the number of prominent concerns in the West which have succumbed to the financial stringency. During the earlier months of the year there was a fair volume of business done in crude and finished iron, but since April there has been a marked falling off each month. So many firms were compelled by the general liquidations going on to watch their lines of credit so closely that practically a cash basis was established in place of the usual two, three, or four months' time.

Substitution of steel for iron has made remarkable progress in all lines of industries in which they are component parts. In July the stagnation in the iron ore market caused some late boats to tie up and forced others into grain and coal carrying. The months of July, August, and September were exceptionally dull—in some lines the dullest on record. Nearly all the mills in this vicinity were shut down for months, some of which have resumed only in part. Toward the close of the year conservatism prevailed among all manufacturing consumers of iron and steel. In November came the break in steel rails, the price dropping from the Association figures of $29 to $24. It was expected that the reduction would stimulate business from railroads, but little response was noted up to the end of the year. The fall in the price of rails had a depressing effect on steel billets and soft steels generally.

Pig Iron.—In pig iron the chief characteristic of the market has been the decline in prices of local as well as Southern. Another feature has been the substitution of certain grades of coke iron for Lake Superior charcoal iron in the manufacture of car wheels, malleables, etc. To such an extent has this been carried that there are now only a few furnaces making the latter grade. The enforced economies and conservative management which have prevailed at all the coke furnaces in this district have in a measure placed them in a safe position. There is not a blast furnace in operation, nor will there be until early in 1894, and then conditionally on the price of fuel and ore. Most of the larger implement makers have taken much less raw material than last year. The general foundry trade was fair for the early part of the year, and there was little revival until the last quarter, and then only in a moderate degree. The fall in price has been from $1.50 to $2 per ton on all grades. In December Southern furnaces endeavored to force prices 25c. to 50c. a ton, but the effort was unsuccessful. Production has been much restricted, but is still in excess of consumption.

Structural Iron and Steel.—In these products only about one-third of the new enterprises which had been projected in the fall of 1892 were carried forward to completion. Structural material, excepting that required for the World's Fair, has been in light demand, particularly bridge and viaduct work. In the latter, public opinion, being in favor of elevated railroads, has acted as a deterrent. Since January values have receded $5@$6 per ton.

Steel Billets and Rods.—The demand for these materials has been exceedingly light, and especially so since June 1, and prices on both have dropped $5@$6 per ton. January quotations for billets were $24.50; December, $19.25; rods, $32.50@$26.50.

Plates.—During the early part of the year there was a moderate demand for plates, the only heavy business being from the Pacific coast, some large orders being placed from time to time for irrigation and hydraulic purposes, some of these contracts for steel plates being made at extremely low prices.

Bar Iron.—Early in the year car orders took a considerable tonnage, but when the stringency in the money market came in May business began to decline, and after the annual shut-down of mills in July few order books were sufficiently filled to resume until September, and some not until October. From first to last there has been no strength to the market, which in January was $1.60; in December $1.25 base was quoted by local mills.

Block and Galvanized Sheets.—There has been a steady growth of the iron roofing and building cornice industries, so the demand has been almost uniformly steady and prices have held up remarkably well, showing only a slight drop throughout the twelve months.

Nails.—One feature of the nail trade is noteworthy; the larger centers and distributing points sell more steel-cut than wire nails to local consumers, while the smaller towns in the interior use a greater proportion of wire nails. During the first half year the demand was well sustained, but the latter part shows a material falling off. Wire nails show a decline of 35c., and steel-cut about the same.

Steel Rails.—The demand up to April was fair in small lots; early in May a number of contracts for larger quantities were closed. The Union Works, part of the plants of the Illinois Steel Company, have been closed throughout the year, and but few rails were made at the Joilet Works. In September the South Chicago Works closed down and at the close of the year not a standard section of steel rails was being rolled west of the Alleghenies. In November occurred the break in steel rails, which dropped from $30 to $25.

Old Material and Scrap.—In old material and scrap prices have steadily retrograded during the year. Old iron rails in January were selling at $18.50; in December sales were reported at $12. Steel rails were $12@$14, and are now $7@10. Old wheels have receded from $14.50 to 12.50.

German Iron Market in 1893.

The year 1893 must be termed decidedly unfavorable for both iron makers and consumers. The depression which prevailed in almost all departments of the iron trade was due rather to the combined decrease in quotations, and consequently reduced gain, than to want of demand in general. To this was added the almost total absence of orders from Russia, which for some years past has been steadily decreasing, partly because of the extension and improvement of Russian works, and partly to the new tariff. The German iron masters have tried to make up for this loss by an increasing export to England, Belgium, and other countries. Heavy sacrifices had, of course, to be made to obtain these foreign orders. The prices at which Breslau dealers sold were: Jan. 1—Bars, 14.25 marks; sheets, 16 marks; plates, 15 marks. Dec. 31—Bars, 12.35 marks; sheets, 14 marks; plates, 14 marks. In Rheinland-Westphalia the average prices for 1893 were: Forge pig, 45 marks (50@51 marks); bessemer, 52 marks (58 marks); bars and girders, 87@115 marks (88@120 marks); hardware, 128@129 marks (134@135 marks). The figures in parentheses are the average prices for 1892. The general decrease in prices has led to a reduction in wages.

AVERAGE YEARLY PRICE OF IRON AT THE PRINCIPAL MARKETS IN GERMANY.*

(Price in marks per 1000 kilos. 1 mark = 23.8 cents.)

Year.	German Pig.							English Pig.				Lübeck.
	Breslau, at Works.		Dortmund, at Works, from Ruhr District.			Düsseldorf, at Works.		Berlin, Free on Shore.		Hamburg, Duty Paid from Store.		
	Puddle.	Foundry.	Bessemer Pig.	Westphalian Puddle.	Thomas Pig.	Best German Puddle.	Best German Fond'y.	Best Scottish Fond'y No. 1, Langloan.	English, (Middlesbrough), No. 3.	Scotch, No. 1.	Middlesbrough, No. 1.	Rod Iron, A1 Stockholm, at 3 Months.
1879	51.67	56.75	64.18	53.23	....	56.08	62.55	74.42	55.58	64.59	53.51	201.88
1880	66.75	72.88	78.67	68.67	....	....	....	87.29	71.06	74.59	61.12	256.88
1881	55.88	62.25	69.25	57.42	....	59.04	73.25	81.67	64.85	66.06	52.09	229.92
1882	66.08	69.50	70.08	65.00	....	64.58	75.04	83.75	67.33	72.89	59.18	228.67
1883	57.79	63.58	60.63	57.63	48.84	57.58	72.88	82.54	62.94	70.17	55.33	227.17
1884	54.48	60.29	53.08	50.38	43.86	50.04	65.67	75.08	58.50	65.98	50.33	224.50
1885	48.31	56.54	45.77	44.17	41.25	44.52	58.42	69.83	53.43	61.50	48.92	222.13
1886	43.54	51.33	42.58	41.07	38.95	40.88	51.88	67.04	50.90	55.94	42.19	215.54
1887	49.54	54.17	48.96	46.63	43.20	46.71	54.88	73.63	57.04	59.20	44.43	212.25
1888	52.00	58.00	52.71	50.46	45.29	50.85	57.42	72.00	56.29	57.20	45.09	199.67
1889	58.54	65.04	65.92	64.54	54.79	65.29	70.83	82.98	66.26	80.21	66.38	193.75
1890	66.60	74.44	79.83	70.00	60.96	77.50	83.63	93.02	71.79	89.14	70.82	227.67
1891	48.21	54.79	62.08	52.08	49.50	52.83	71.17	81.99	61.52	80.53	62.41	208.54
1892	48.88	52.58	57.83	50.54	49.33	51.38	65.50	73.46	58.69	70.31	60.04	206.46
1893	50.21	52.46	52.00	46.71	45.54	46.25	62.00	74.83	54.98	68.52	55.92	206.67

* From *Vierteljahrshefte zur Statistik des Deutschen Reichs*, 1894, Part I.

SKETCH OF CERTAIN ADVANCES IN IRON AND STEEL METALLURGY IN 1893.

BY HENRY M. HOWE.

At the blast furnace important steps have been taken toward lessening the labor both of preparing the charge for the furnace and of handling the product.

It is somewhat humiliating that the 100,000,000 tons, more or less, of ore, coke, and flux which enter the blast furnaces of the world each year must, after arriving at the stockyard of the furnace, be all shoveled by men's hands, and that of the 26,000,000 tons of pig iron made each year by far the greater part must be lifted out of the molds by the ache of men's backs and broken by the sheer force of men's arms. It is humiliating, too, that, though these manipulations, through their simplicity and the enormous scale on which they are conducted, should lend themselves readily to mechanical treatment, no suitable mechanical means for such treatment has been installed until very lately.

The usual way of getting ore to the furnace is to run a barrow or buggy to one of the piles of ore, shovel the ore into it, and run it back to the furnace, all by hand. One late improvement is to carry these buggies to and from the ore-piles on cars which are run by power. Another, which promises far-reaching results, has lately been adopted, and I hope to describe it later.

The pig iron is cast usually in molds rammed up in sand by hand, though more rarely in iron molds, and, after solidifying, the individual pigs are broken apart by hand, lifted by hand from their molds, carried by hand and thus loaded on cars, thence broken by hand, and piled by hand. To get to the cupola furnace in which they are to be remelted they have to be handled at least once more, and often several times. Lately important methods have been devised and installed by which the iron is picked up in lots of many tons each by an overhead traveling crane, which delivers it to a breaking machine, which in turn breaks it into pieces of a size convenient for handling, and discharges it upon the platform of a railroad car. Methods are even projected for carrying this mechanical handling much farther. In both cases the results are to be looked for with great interest.

The iron foundries are fast waking up to the fact that there is some sort of connection between the composition of cast iron and its properties, and also to the important rôle which silicon plays—a sad day for the makers of charcoal pig iron.

Direct Processes.—In the days of abundant natural gas two direct processes attracted much attention in Pittsburg—the "Carbon" process and the "Adams-Blair" process. With the decline of the natural gas supply the use of these processes has been suspended, but only temporarily it is believed by those interested.

The Bessemer Process.—Perhaps the most important recent step in Bessemer procedure is the introduction and spread of the "car-casting" method. The old and still usual method of procedure is to cast the steel in ingot molds which stand in the converting room (the room in which the Bessemer converters stand), in a pit of such depth that their tops are a little above the general floor level. After the metal has solidified, the molds are removed or "stripped" from the ingots, and stored either within or, as in later works, outside the converting house. The ingots are then raised from the pit, loaded on cars and carried away to the blooming mill for further treatment. We have thus three steps: (1) conversion, (2) casting, (3) stripping and removal.

Under these conditions the casting, stripping, and removal of the ingots is the most laborious matter connected with the Bessemer process, and the plan I have thus outlined has serious inconveniences. To appreciate this, consider that the output of the converting department is limited, not only by the rapidity with which the Bessemer converters can convert cast iron into steel, but also by the rate at which the steel so made can be cast into ingots, and at which these ingots can be removed for further treatment. Now, under this old plan this laborious handling of the ingots and molds had to be done in the hot converting room, in a limited space, and hence with extreme alacrity. This alacrity and discomfort had to be paid for roundly.

The labor of handling the ingots might, indeed, be lessened by casting the steel in only a few very large ingots, but this implies extra expense in rolling these large ingots down to the finished size—an expense which, in the judgment of many competent men, leads to no compensating improvement in the quality of the product. Next this procedure made the converting room—at best an uncomfortable place—almost unbearably hot in warm weather, for the hot molds had to remain in place till the ingots had solidified enough to be stripped safely. After stripping the molds from the ingots, some minutes would elapse before the scorching red-hot ingots were removed from the converting house, and during this interval they radiated heat in enormous quantities. This may at first seem a slight thing, but to have ten tons of bright red-hot steel ingots standing naked in the converting room for, say, three minutes at a time, and to have this repeated every ten minutes, day in and day out, during July weather, is no laughing matter. Finally, not a few ingots would stick to their molds. To loosen them by sledging was laborious and expensive; to force them out in the converting house was inconvenient and not altogether safe, for it had to be done quickly so as to clear the casting place for the next heat of steel, and it might easily break the thin skin of the merely externally solidified ingots.

Stripping ingots and setting molds in the converting house was thus clearly a nuisance. Why not abate it? This question, to my personal knowledge, was under discussion twenty-three years ago, and it has been at frequent intervals, if not continuously, ever since.

At some European Bessemer works it was attempted to abate it by casting the steel into ingots in a special room away from the converting department. But this did not really meet the most serious difficulty; for, after all, what was most objectionable was having to set the molds and strip and handle the ingots in the limited casting-pit at full speed; and the mere fact of having the casting-pit in the converting house was simply an annoying aggravation of a trouble in itself extremely serious. Any delay in stripping or removing the ingots held the casting back, and this in turn immediately held the converters back. There was no "play," no elasticity between the conversion and the removal of the ingots.

But at Sparrows Point they really did abate this nuisance by casting the ingots in molds which stood on cars (hence "car casting"), and, as soon as the molds had received the steel, running the cars away to a convenient outside point, where stripping could go on in a temperate, leisurely, and therefore economical way. If the molds stripped readily, well and good; if the ingots stuck to the molds, they could be forced out. If any delay occurred in stripping the ingots, those of the succeeding heat simply stood so much the longer on their car awaiting their turn, and the room which they thus took up was not specially needed for anything else. Delay here did not hold back either the casting or the conversion. As wise precautions had been taken to fully protect not only the track but also the running gear of the mold-bearing cars from the spattering of any mispoured steel, which otherwise might have cemented the cars to the track, this scheme succeeded and was adopted elsewhere.

So great an economy did it effect that the managers of the old-fashioned Bessemer mills were put to their trumps, with the result that they devised not only many minor inexpensive improvements, greatly lessening the labor of removing the ingots from the casting pit and converting house, but what promises to be a very important improvement in the way in which sticking ingots are extracted from their molds.

Pig-Mixers.—At the "direct-metal" Bessemer works—*i. e.*, those in which the cast iron direct from the blast furnace is run while still molten into the Bessemer converter, as distinguished from those where the cast iron is run into pigs which are subsequently remelted before conversion into steel—the pig-mixer has further shown its value. It is a great brick-lined reservoir, mounted so as to rock or tip, into which the cast iron from the several blast furnaces is poured, so as to dilute the variations in its composition. The mixing is promoted by the rocking of the mixer, and by thrusting into the molten metal a wooden pole which, thus destructively distilled, gives off gas copiously, stirring up the mass. To push this farther, a colossal mixer is projected, with a capacity of 200 or even 250 tons.

Actual experience shows that the chief advantages of the mixer are that it leads to greater regularity in the composition of the steel, and that it greatly lessens the production of scrap iron and steel.

The Bessemer process cannot be accurately controlled so as to yield steel of the desired composition unless its final temperature lie within certain rather narrow limits. Now the proportion of silicon, the heat-giving element of this process, varies very rapidly and widely in the cast iron from successive casts of any given blast furnace, and in order to prevent its variations from throwing the temperature of the Bessemer process outside of the proper limits, that temperature is regulated as the process goes on by throwing into the converter more or less cold scrap iron. As this scrap iron is so much more material added to the charge, variations in the quantity added vary correspondingly the weight of the steel made. Economy requires that the steel should be cast into a relatively small number of large ingots, each of a closely predetermined weight; so that, in effect, the scrap iron which is thrown in to regulate the temperature causes an excess in the steel made. This excess will not usually yield an ingot of useful size, but will form a short or "butt" ingot, a thick lump of metal hard to utilize. The mixer, then, by regulating the silicon-content of the cast iron regulates the temperature of the blow, and thus lessens the addition of cold scrap, and hence the production of "butts."

The molten cast iron now is brought to the Bessemer mill, not as fast as the converters will take it, but as fast as the blast furnaces make it; and if it simply stands in the ladle in which it comes from the blast furnace awaiting its turn for conversion, it solidifies rapidly, causing a heavy formation of "skulls," which, instead of being good cast iron, are worth only about as much as iron ore, for they have to be remelted in the blast furnace. If there is any stoppage in the converting operation, as often happens, these ladles, full of molten cast iron, accumulate in a long line awaiting conversion, and the amount of "skulling" becomes very serious.

With a mixer, however, this is nearly done away with. As fast as the cast iron is made at the blast furnace it is brought to the mixer, which should stand close to the converters. It is there kept hot, if need be by burning a little fuel within the mixer, and it is drawn thence only as fast as the converters are ready to receive it. Moreover, if the converters are to be stopped for any length of time, before this occurs the metal in the mixer is purposely allowed to run rather low, so that during the stoppage the cast iron coming from the blast furnaces may have room to accumulate.

Desulphurizing in the Mixer.—Metal thus accumulated in a great deep reservoir cools very slowly: here, then, is an opportunity to submit it to any treatment which calls simply for exposure to high temperature. It has been known for some years that manganese, when introduced into sulphur-bearing molten iron, removed its sulphur. This fact has now been taken advantage of by Hilgenstock, who runs into the same mixer a sulphurous cast iron and also a manganiferous one. Under these conditions much of the sulphur is removed, and it is reduced, it is said, from 0.50% to 0.05%.

The Saniter process of desulphurizing molten cast iron or steel by means of a mixture of chloride of lime with lime or limestone gave such valuable results that it was adopted on a commercial scale at Wigan about a year ago.

The Open-Hearth Process.—Among the advances in open-hearth practice is the construction of enormous tipping furnaces at Steelton. Six gigantic furnaces, each with a nominal capacity of 50 tons, are to be grouped about a single deep, rectangular casting pit, commanded by a traveling crane. Some of them have already been running regularly and satisfactorily, with an actual capacity decidedly greater than 50 tons. Judging from their performance, it is not unlikely that the output of this single pit will reach 15,000 tons a month. Thus the reproach of the open-hearth process, its small output, is to disappear. These furnaces certainly effect a large saving in labor, and probably in fuel and repairs.

Each furnace has a single great port at each end, through which both gas and air enter; and the furnace, in tipping, rotates about its longer axis, or, to speak more accurately, about a horizontal line which runs through the center of these two ports. To permit this, the furnace rests on rollers which travel in circular supports concentric with this axis of rotation; and it is moved, and held in position, by a powerful horizontal hydraulic cylinder. Thus the ports are always in position, and can always supply heat, no matter at what angle the furnace stands.

The rotary motion of these furnaces avoids all the difficulties and annoyances connected with tapping. During the heat the tap-hole is kept above the level of the metal, so that a "break-out" of the molten charge is impossible. When ready to tap, the loose filling of the tap-hole can be leisurely dug out, and the furnace tipped down so as to run out the metal. By tipping the furnace much while pouring, the slag is kept well above tap-hole and thus prevented from mixing with the steel and getting into the ingots. Should a stopper leak or anything go wrong, the steel can be poured back into the furnace almost as if one were pouring sherry.

Handling the output of one of these monsters is no easy task. A Bessemer plant turning out this same quantity of steel daily delivers it in relatively small lots of 10 or even 15 tons, which may readily be cast separately into ingots of moderate size. Not so, however, with a 50 or 70 ton heat. Were we to try to cast this separately into 50 one-ton ingots from a single ladle, even if the metal did not chill, the stopper would melt off. The manner in which this difficulty is met is worthy of the heroic scale on which operations are here conducted. But probably the greatest advantage of the tipping arrangement is with regard to a new and somewhat revolutionary step in open-hearth practice, not now spoken of.

The whole heat of steel is poured into a single ladle, and thence through a 4-in. nozzle into a distributing funnel, whence finally it runs simultaneously into a group of three or four separate 10-ton ingot molds standing beneath. After standing in gas-fired soaking pits till their temperature is nearly equalized, the ingots are rolled into slabs in a great universal mill, with a pair of main or horizontal rolls 26 in. in diameter and 5 ft. long, and a single pair of vertical rolls 20 in. by 4 ft. The main rolls are driven by a pair of 42 by 50 in. engines, and the vertical rolls by an independent pair of 26 by 30 in. engines. Unlike the vertical rolls of the common universal mills, which do little more than to keep the edges of the plate true and sound, these vertical rolls actually have a very considerable draft; a piece 32 in. thick (deep) is reduced horizontally about one inch at a pass by these vertical rolls.

As compared with the usual plan of rolling small ingots directly into plates, this general scheme of rolling immense ingots down into slabs, which are later rolled into plates, has very great advantages to offset the extra expense of having two rollings instead of one. Among these advantages are a great saving in scrap and crop ends, and the fact that after the preliminary rolling into slabs, during which whatever cracks or mechanical defects are to develop will have appeared, we have an opportunity not only to chip out these defects in such a way that the further rolling will eliminate them, but also to inspect the metal carefully, and, should this inspection make it desirable, to change its destination. Finally, whatever our views of the effect of work as such on the quality of steel, we must admit that the greater reduction which these larger ingots undergo in rolling into plates will more effectively close blow-holes.

Other large open-hearth furnaces are two at Bethlehem with a nominal capacity of 40 tons each, and a group at the Carbon Iron Company's works with a nominal capacity of 30 tons each.

The substitution of open-hearth steel for crucible steel, for purposes where the latter was formerly thought indispensable, continues.

In the crucible process an important step is Wittgenstein's apparently successful substitution of basic open-hearth and basic Bessemer steel scrap for the more expensive materials which have been used. We have always been told that good crucible steel could not be made regularly out of Bessemer or open-hearth steel, no matter of how excellent composition. Yet we are now told that the Poldi Hütte of Austria makes its crucible steel chiefly from this material, and disinterested Austrians assure me that the St. Egyde tools, made from the steel of this establishment, maintain their reputation for excellence.

Duplex Process.—The treatment of gray and hence siliciferous pig iron by either of the great dephosphorizing processes, the basic Bessemer and the basic open-hearth, presents grave difficulties, because in either process the silicon of the cast iron is converted into silica, which corrodes the basic lining of the apparatus and lessens the basicity of the slag; and these processes cannot remove phosphorus unless the slag present be highly basic. The most obvious way to turn the difficulty is by the "duplex" process; *i. e.*, by first treating the metal in a Bessemer converter with a silicious lining, thus removing its silicon, and then finishing the conversion by removing the phosphorus in a basic-lined Bessemer converter or open-hearth furnace.

This subsequent dephosphorization in the Bessemer converter has not been found economical, if indeed practicable, because in this process the combustion of the metal itself and of the foreign elements it contains is the sole source of heat, and because the heat thus obtained was insufficient under the conditions which existed in the trials. But in the basic open-hearth process this difficulty does not arise, for in it we get all the heat we need by burning producer or other gas. One of the important papers of the year describes the use of this duplex process at Witkowitz.

But it is generally felt that the converter and the open-hearth furnace are an ill-matched team. To be economical the converter must run rapidly, at a pace which the open-hearth furnace cannot keep. The converter turns out its product at very short intervals, the open-hearth furnace can take its charge only at long ones. Hence there is much doubt as to the general applicability of the duplex process.

For our Southern States the problem is a serious one. Most of the Southern pig irons contain so much phosphorus that they cannot be treated by the acid Bessemer or the acid open-hearth process; yet very few have enough phosphorus to be treated by the basic Bessemer process, and they would often have too much silicon to permit easy treatment by the basic open-hearth process. In the European steel-making centers, and those of our Northern States, scrap iron is to be had in great quantities, and with this the silicon of the pig iron may be so diluted as to offer no very serious trouble, but in the South scrap iron is not yet abundant.

Talbot's Process.—In this connection Talbot's process, which has been carried out experimentally, but not on a commercial scale, is of decided interest. Before treating his cast iron in the basic open-hearth furnace, he removes its silicon by mixing it while molten with the still molten slag from the last preceding charge of that furnace.

The iron oxide of the slag rapidly oxidizes the silicon of the pig iron, and is thereby itself deoxidized; the resulting silica unites with the slag; and the resulting metallic iron unites with the cast iron under treatment and is thus recovered.

Cranes.—In our steel works the overhead traveling crane has encroached rapidly on the field formerly held by the hydraulic swing-crane. This movement has been hastened by the electric motor, for the square shaft by which the traveling cranes were formerly driven had grave inconveniences, especially in dusty places.

Furnaces.—The custom of heating ingots on end, instead of on their sides, so as to concentrate the internal cavity, or "pipe," at the top of the ingot, where it can readily be cut or cropped off, instead of spreading it along the whole of one side, has increased. Yet in some important new ingot-heating furnaces the ingots are to lie instead of standing.

In the older Siemens furnaces the different parts were huddled as closely together as possible, so that the hot gases might lose but little heat in their passage either way between the combustion chamber and the regenerators. The tendency of late years has been to separate these parts, with a probable slight sacrifice of thermal efficiency and a great gain in simplicity of construction and ease of repair. The days of natural gas, when the quantity of fuel used was relatively unimportant, gave an impulse to this movement. The constructions of the past year have shown the same tendency toward simplicity of construction and facility of repair. The old-fashioned regenerator, a stumpy block which lost little heat by radiation while the furnace was in commission, but cooled off exasperatingly slowly when it was to be repaired; which was so close to the furnace proper that little heat indeed was lost in transit between them, but was half ruined in case the steel broke through the bottom of the furnace—this promises soon to be a thing of the past. To-day regenerators are rather spacious flues leading from beside (not beneath) the furnace to the chimney, quick to cool, and easy to mend.

Properties of Steel.—A very important group of papers on the physics of steel, presented at the Chicago meeting of the American Institute of Mining Engineers, told of valuable advances in our knowledge of the relations between the properties of the metal on the one hand, and its composition, microstructure, and its treatment, both thermal and mechanical, on the other.

John Fritz's great ordnance plant at Bethlehem has advanced an important step toward its final completion in the successful starting of his gigantic 14,000-ton armor-plate press, with its 7000 lbs. of hydraulic pressure per square inch and its 16,000 horse-power pumps. What numbers! The older 5000-ton forging press and the 7000-ton press for liquid compression themselves seemed inconceivably immense. With the 2000-ton forging press, the machine shop 1250 ft. long, and the 125-ton hammer, they are the worthy progeny of that great and good man, "Unser Fritz."

After the character and intelligence which lighted the faces of that enormous throng, and after the "Court of Honor," I found nothing at Chicago more impressive than the great hollow forgings and armor plate of Bethlehem. Two of these forgings are of surpassing interest, the jacket for the 66-ton gun, and the 67-ft. shaft. The former is a hollow-forged tube, weighing 56,800 lbs., 17 ft. 6 in. long and 38.25 in. in diameter, with an interior diameter of 2 ft. Three bands turned by a lathe in the skin of this jacket show the remarkable accuracy of the forging. From an examination of these I inferred that this great mass had been forged so accurately that there was not more than $\frac{1}{16}$ in. eccentricity at any of these three bands, nor more than $\frac{1}{8}$ in. difference in diameter. As the jacket had been forged on a mandrel, this concentricity implies corresponding accuracy in the thickness of the walls. Its wonderfully accurate length was not less suggestive. Judging from a lathe-cut taken near each end, the difference in length between the longer and shorter side was 2.5 in. at one end and 3.06 in. at the other end. Was this done by some trick ? Was the jacket forged nearly to its final dimensions, its ends then turned accurately to shape in a lathe, and forging then completed ? Evidently not ; for so testified the rounding or bulging of the ends.

The other of this impressive pair is a hollow shaft 66 ft. 11 in. long, 20 in. in diameter outside and $8\frac{1}{4}$ in. inside, weighing 24.6 tons. He who has felt the difficulty of keeping a little red-hot glass tube true and straight as he draws it out in the laboratory can begin to guess the appalling difficulties in the way of forging this long tube, straight as an arrow and with a bore forged almost as if it had been bored in a lathe. Conceive the task of handling so long a tube, much of it red hot, plastic, and bending; of manipulating within it a long, slender mandrel, which not only must not stick in the tube, but, though within this red-hot mass, must be cool enough and stiff enough to hold it true, and to withstand the titanic squeeze of the hydraulic forging press. It is not like trying to conceive the place where the stars stop, but it is not so much easier.

Bethlehem's ventilator for the Puritan, which stood alongside these at Chicago, appears to an outsider to be a most difficult forging. It is a great cylinder forged hollow, with an outside diameter of 7 ft., with walls 6 in. thick, 4 ft. 1 in. high, and weighing 20,388 lbs.

Many other iron and steel products of great size were shown at Chicago. There was the Krupp boiler-plate 65.5 ft. long, 10.82 ft. wide, 1.26 in. thick, and weighing 15.94 tons ; the Pottstown plate, rolled on a universal mill and 150 ft. by 20 in. by $\frac{7}{16}$ in., which weighs about two tons; and the Wittgenstein plate, 162 ft. 2 in. long, 3 ft. 3 in. wide, $\frac{1}{12}$ in. thick, and weighing 1672 lbs. It is especially interesting for being made on the Wittgenstein mill, which is a sort of continuous mill, suggesting the famous Bedson wire-rod mills. Behind a stand of Lauth three-high plate rolls stands a series of five pairs of two-high plate rolls with axes parallel, behind each other in column, and so near together that the plate is at one time in all five pairs of rolls simultaneously ; for its forward end reaches the last pair of rolls before its rear end has passed through the first pair. The circumferential velocity of these five pairs of rolls of course varies to compensate for the progressively diminishing thickness, and hence increasing velocity, of the plate as it passes from pair to pair.

Still longer is the Sandviken hot-rolled steel band, which is 12 in. wide, of No. 9 gauge, and 182.5 ft. long; it weighs 1142 lbs. This is rolled cold into bands 650 ft. long, 12 in. wide, and of No. 25 gauge, which weigh 528 lbs. each.

Next in length is a strip made by the Trenton Iron Company about $\frac{1}{16}$ in. thick, 1 in. wide, and 1100 ft. long, rolled at one heat in seventeen passes from a 4-in. square billet.

Finally there is a wire rod one mile long, rolled in one heat from a 4-in. billet of Otis steel on the Morgan rod mill of the American Wire Company. It is of about No. 9 gauge, and weighs 390 lbs. So far as I know, this is the longest piece of hot-rolled metal ever made.

Speaking of long rolled pieces, the superb Stumm exhibit at Chicago, full of interesting things, had I-beams from 4 to 12 in. in height, each 82 ft. long, and a rail of large section 177 ft. long. The Lowmoor exhibit had an iron wire of 42 gauge nine miles long.

Then there are the great Krupp armor plates, of which the largest are a 15.7-in. compound plate 11.8 ft. long, 8.3 ft. wide, and weighing 27.55 tons, and a nickel-steel plate of the same weight and thickness, 12 ft. by 8 ft.

The compound plate, with its face of hard steel welded to a back of very soft steel or wrought iron, is especially interesting on account of the thoroughness of the weld between its two layers. Welding two such great masses of unlike composition together is, of course, very difficult, and when the whole is bent by the impact of a projectile there is a strong tendency to part at the weld. But, though a 12-in. shell had got its nose through the plate, and had made a crack from front to rear, gaping open 1⅛ in. in front and ¾ in. behind, there was no clear indication of yielding at the weld

Still slightly greater is the Bethlehem nickel-steel barbette plate for the Indiana, 12 ft. 1 in. high, 8 ft. 4 in. wide, 17 in. thick, and weighing 31 tons. It is one of thirteen plates which form the complete barbette. This will, therefore, reach the enormous weight of 400 tons, if all thirteen are of the same weight. Then there is the 39-ton shaft made by Bethlehem for the Old Colony Steamboat Company, 39 ft. 5 in. long, 2 ft. 3 in. in diameter, with a 9-in. longitudinal hole.

For mere weight these are pigmies beside the great Krupp 61-ton plate, 27 ft. long, 10.26 ft. wide, and 1.01 ft. thick, and the 50-ton shaft of the Ferris Wheel, one of Bethlehem's hollow forgings, 33 in. in diameter, 45 ft. 6 in. long, with a 16-in. bore forged in it.

Other great forgings of Krupp demand attention. There is a hollow shaft weighing 11.81 tons, 82 ft. long, 11.81 in. in diameter, and with a hole 4.32 in. in diameter, bored from end to end on a lathe which has a bed 111 ft. 6 in. long. But the shorter 65-ft. Bethlehem shaft is a greater triumph, because forged hollow; while this one was forged solid and later bored out. Then there is a 20-ton forged steel pinion for an armor-plate rolling-mill; and the screw, thrust and crank shafts of a fast passenger steamer, which weigh collectively 103 tons after being bored from end to end.

Armor.—The resistance of armor to penetration has been greatly increased by the adoption of nickel-steel, and of the special processes of treatment, which, like the Harvey process, probably consist mainly in very deep case-hardening or carburization. Bethlehem's 10.5-in. Harveyized nickel-steel plate broke up five Holtzer 8-in. armor-piercing shells, with a total energy of 25,040 foot-tons, and was itself but slightly cracked. On a par with this stands Krupp's 10.23-in. specially treated nickel-steel plate. It broke up three 5.9-in. and two 8.26-in. Krupp armor-piercing shells, with a total energy of 20,957 foot-tons.

The chief merit of nickel-steel lies not in greater resistance to penetration, but in non-fissibility, *i. e.*, in having little tendency to crack. It resists penetration admirably: but if struck with force enough, it lets the projectile through, but suffers relatively little harm itself, beyond thus having a clean hole punched through it.

In tube making there have been interesting developments. First, we saw at Chicago most wonderful products of the Mannesman process, which by an ingenious method makes a tube as it were by rolling a central longitudinal hole the whole length of an initially solid rod. Besides tubes of common shape and of common and uncommon thickness, there were tubes with regularly varying cross-section—for instance, conical and pyramidal ones suitable for wagon poles; tubes with abrupt changes in cross-section, suitable for trolley poles for electric railroads; tubes forming double cones, base to base, suitable for whiffletrees; and other wonders. Moreover, Mr. Mannesman assures us that his process is now making tubes of usual sizes in open competition with common lap-welded and cast-iron piping, and at like prices.

Ellwood Ivins showed at Chicago marvelously small tubes made by a secret process. One of these was so small that I could not see its bore even in broad daylight, though I could detect it with a knife-point, and we are informed that he makes tubes with walls as thin as thin paper, of about 36 gauge (say 0.004-in.), and accurate both within and without to 0.001-in.

Erhardt has a most astonishing method of making tubes, by forcing a cylindrical mandrel lengthwise through and along the axis of a solid square red-hot iron or steel rod, which stands in a round matrix; the sum of the areas of the spandril-spaces between the square rod and the round matrix equals the area of the mandrel which is forced through the rod; the tube is thus made cylindrical within and without. He now withdraws the mandrel and immediately draws the still hot tube in the usual way through circular dies, one, two, or even three drafts.

This reminds us of a Swedish method of making tubes by punching a longitudinal hole in a round cold steel bloom or slightly hammered ingot, and opening it out by cold drifting till it has a diameter of about 4 in.

Finally we have the Swedish method shown at Chicago of casting round ingots in molds hanging on trunnions, and of pouring out the molten interior as soon as the walls of the ingot have by solidification grown thick enough. The tubular ingot is then lengthened by rolling.

Of the special steels two only have been made prominent this year, nickel-steel and manganese-steel. I have already spoken of the wonderful resistance to penetration which Harveyized nickel-steel armor-plates have shown. It is believed that all the new United States Government contracts for armor plate will call for nickel-steel, and that this will be Harveyized wherever practicable.

Manganese-Steel.—My personal interest must not prevent my recording the important advance which this year has seen in the manufacture and use of this stiff-necked and stubborn material. Passing by the many purposes for which it has been tried this year with success, and the previously established uses,—such as for dredging and crushing machinery,—its employment for mine-car wheels, the endurance of which is most remarkable, has this year become firmly established in this country, and the very great difficulties in the manufacture of railway wheels of this material seem at last to have been mastered.

Steel Castings.—The warship's stem which Krupp showed at Chicago, and of which the middle section weighed 15.05 tons, and the 15-ton stern-post, of which Jessop there showed a photograph, were certainly great, but they have been surpassed in weight by the 22-ton stern-post cast successfully by the Standard Steel Casting Company of Thurlow early in 1893. So far as mere weight is concerned these fall behind the 25-ton 42-in. cylinder made at Homestead in 1888, and the great 30-ton steel-cast anvil-block made by the Otis Company in 1887. But this was a relatively compact solid mass easy to cast. The Midvale Company advertised in 1891 its readiness to make steel castings up to 45 tons in weight, and as long ago as 1884 Cambria could, with very slight alterations, make as heavy ones. The Standard Company made a 30-ton casting in 1893 for Cramps.

Jessop had at Chicago photographs of a steel-cast prow, keel-piece, and ram weighing 40.5 tons and 44 ft. long, but I understand that this was not a single casting.

But these castings which I have mentioned yield in interest to the steel-cast cylinder cover shown by Creusot at Chicago, on the whole the most remarkable casting of which I know. Nine ft. 10 in. in outside diameter, and weighing 4.3 tons, it is neither wonderfully large nor unusually heavy, but for combined size, weight, difficulty of shape, and marvelous solidity I do not know its equal. With enormous cores, and with but slender ribs for crushing them, this great polished curved plate shows a freedom from defects and cavities which is simply marvelous.

As judged by their tensile tests, the castings enumerated in the following table have the best physical properties which I have met this year. Judged by their combination of extraordinary toughness with file-destroying hardness, the manganese-steel cast railway car wheels of the Taylor Iron and Steel Company are certainly most extraordinary; while for its combination of great toughness with perfect solidity, the dished cast locomotive driving-wheel center, which Krupp showed at Chicago, certainly excels.

SOME TENSILE TESTS OF STEEL CASTINGS REPORTED IN 1893.

Description.	Maker.	Tensile Strength, Lbs. per Square Inch.	Elastic Limit, Lbs. per Square Inch.	Elongation.		Contraction of Area.
				Per Cent.	Inches.	
	Solid Steel Company	106,138	......	17	2	.....
	Solid Steel Company	76,413	......	27.5	2	.. ..
Piston....	Skoda	73,958	......	22	8	51.3%
Rudder frame.....	Skoda	68,500	......	26 5	8	40.8
	Hadfield	68,320	35,840	30 95	2	34 86
	Solid Steel Company	66 224	......	31	2	.....
Wheel for tender	Skoda	64,570	......	30	4	49 5
Stem of war vessel.	Jessop	64.288	......	36	2	47
	Solid Steel Company	61,092	......	34.25	2	.....
Wheel center......	Krupp	58,889	28,873	32.8	4	51.7

These Hadfield manganese steel car wheels, though so hard that they cannot readily be machined, are extraordinarily tough. They had, without breaking, undergone drop tests incomparably more severe than any composite wheel could endure, and were finally pounded far out of shape before actual rupture.

The dished Krupp wheel center is a steel casting 55.5 in. in diameter, with spokes 3.25 in. thick. It has been bent or dished under a hydraulic press, so as to throw its edges some 13 in. out of their original position. Owing to the shape of the piece this greatly distorts the spokes, yet neither crack nor check can be found in it, though it is machined all over.

IMPROVEMENTS IN ALABAMA FURNACE PRACTICE.

The great improvement which has taken place in furnace practice during the past few years has nowhere been more marked than in Virginia, Tennessee, and especially in Alabama. In 1886–87 furnaces were operated in what might now be called a haphazard fashion. The raw material underwent no preparation except at some of the charcoal furnaces. Coal as delivered to the coke ovens contained sufficient slate to produce 15% to 18% ash in the coke, which was friable, high in sulphur, and exceedingly unsatisfactory as a fuel. The fossil ores were divided into hard and soft, but the form was so irregular in its lime contents that only a small portion could be used with safety. The brown hematite ores were but imperfectly separated from accompanying rock or clay. The entire operation of the furnace was uncertain, and no manager ever felt sure what kind of iron was coming until it had been cast. Such irregular work naturally affected the output, and there were very few furnaces in the State which could show an output of over 700 tons a week for any considerable period, and, as a rule, the iron was of irregular quality, varying from silvery to gray in an apparently unaccountable fashion.

As the price of pig iron declined, furnace-men endeavored to increase the output of their plants, and in order to do this they found that they must improve the quality of the stock. Gradually ore washers were introduced to clean the brown hematites; more care was taken in mining hard and soft red ores, and within the past two years an important improvement, that of washing the coal, has been carried out at the principal works. As a result of better stock, furnaces which formerly yielded 90 tons per day are now producing 150, and pig iron which in the days of the "boom" cost $10 and $11 per ton is now produced for a little over $7. In the quality of the product the improvement has been as marked as in other features. The characteristic of Southern pig in 1886, and for some years after, was a light color and rounded feel to the grain, and not much strength over the block. At some few furnaces the product was above this average. At present the greater part of the coke iron produced in the South ranks equally with Northern irons, though, as they are unlike in character, one cannot replace the other.

Improvements in Southern plants have been made in the methods and appliances used in and about the works and mines; in reducing labor cost; and, indeed, in every detail of blast furnace and mining practice. Experiments are now being carried on in Birmingham looking toward the magnetization of the lean, soft fossil hematites and their subsequent concentration by electro-magnets. The experimental work has succeeded so well that a large plant is under construction. If this process is a success it will solve the question of producing pig iron in Alabama suitable for steel manufacture, and will, furthermore, make a market for vast bodies of the leaner ores which cannot now be profitably worked.

The Open-Hearth Work at Steelton.

By H. H. Campbell.

Up to within a few years the great bulk of the open-hearth steel made in the United States was melted in small open-hearth plants whose product was rolled into plates directly from the ingot at the works where produced. Each establishment had built up a trade resting rather upon some real or fancied character of its product than upon the ability to produce at the minimum of cost. In former days the making of a certain grade of steel was looked upon as a trick possessed by a chosen few, and these few guarded their knowledge with a watchfulness which only ignorant jealousy can create.

The system of rolling direct from the ingot is being superseded by the method of making a larger ingot and putting this through a preliminary roughing. The extra cost of this double work is warranted by certain practical considerations. Prominent among them is the matter of defective plates. All other things being equal, it is evident that fewer bad plates will be made from already worked slabs than from the untreated ingot. This difficulty has been overcome in a measure in the casting by long practice, great skill, and at no little expense. A more serious matter, however, is the larger percentage of scrap produced in direct rolling. The practice varies much in different works, but it may be roughly stated that whereas an ingot must weigh 30% more than the sheared plate, it is not necessary when using slabs to have an excess of over 20%.

There are other incidental, but not at all important, advantages in the preliminary slabbing arising from the capacity to cut each slab to a different weight, so as to economically fill a mixed and special order. It is also clear that on account of the work done in the roughing mill the slab is in a better physical condition than an ingot, so that the plate mill can start with a thinner piece and even less risk of breakage.

These conditions have developed the slabbing mill, one of the most unique products of modern invention. The Pennsylvania Steel Company has bloomed all its open-hearth steel for plates since 1885. Following its lead, the Homestead Steel Works erected a massive roughing mill which breaks down ten-ton ingots for its plate train. The Carbon Steel Company has joined the ranks, and the Pennsylvania Steel Company has again pushed up to the front by its new mill started in 1893. This is of the same general type as the Homestead mill, both of them working the ingot sidewise and flatwise by two separate engines driving independent sets of rolls. At Steelton we roll ingots of ten tons and reduce sidewise from 38 in. to 18 in. without turning the piece, and in thickness from 32 in. to 4 in.

The great advances in very recent years have not been caused entirely by a desire to improve the old ways of manufacture, but by the phenomenal increase in the use of steel as a structural material. With the dispelling of ignorance and prejudice among engineers it is rapidly replacing iron in all construction. Moreover, the more intelligent users are calling every day for a better material; specifying also that it shall be made in the open hearth, and requiring that phosphorus shall be below a certain percentage. Not only in plates and angles, but in all the multitudinous byways of industry, there is a demand for more, for better, and for softer steels.

This demand has been met by the building of large open-hearth plants fitted with both acid and basic furnaces, superintended by educated men, guided by chemistry and the testing machine. All raw materials and all products are thoroughly tested, and the reports of the chemist go into the hands of every melter and roller.

The entire open-hearth plant at Steelton numbers twelve furnaces, with a capacity of 18,000 tons per month ; six of these constitute an establishment by itself. This was built and put in operation in 1893. The furnaces are of the tilting type, tapping 100,000 lbs. of ingots each cast, and all are commanded by a seventy-five-ton electro-hydraulic crane. The ingots are cast at one end of the building and are handled by a twenty-five-ton electric traveler. The furnaces can be lined either acid or basic, and have been successfully operated under both systems.

The tilting furnace is not entirely new at this works, for two of them with a basic lining have been used with great success since 1890. The ability to remove the slag in such a furnace renders possible the use of an impure stock, and charges have been successfully handled which contained .28% of sulphur, while others have had 3% of phosphorus. For the most common work it may suffice if the phosphorus and sulphur are both brought below .10%, but this by no means represents the regular practice. The charges in the basic furnaces generally average from 0.25 to 0.50 in phosphorus, and from 0.07 to 0.12 in sulphur. This is reduced to a content from .005 to .04 phosphorus, according to requirements, and from .015 to .06 sulphur in the steel.

The large steel castings are made from one of these tilting furnaces, and by careful selection acid metal of .015 phosphorus has been produced. The smaller castings are made from a five-ton acid furnace, and contain from .025 to .04 phosphorus. This pure metal gives steel which will compare with the products of any of the celebrated foreign manufactories.

The steel business is becoming more complicated and precise every day. Where once there were three or four or five grades, there are now a hundred, varying in carbon, in manganese, in phosphorus, and in sulphur, and graded by tensile strength, by elastic limit, by elongation, and by reduction of area. Each engineer has his own opinions or fancies as to the requirements of his special field of work, and it is the province of the open-hearth plant of to-day to make anything that is required. We have tried to make a plant at Steelton capable of producing anything that can be reasonably asked for by the engineer or manufacturer, but we reserve the privilege of making suggestions concerning the quality, founded on the experience of many years.

LEAD.

THE total production of lead from ores smelted in the United States in 1893 was 195,948 short tons, against 209,411 short tons in the previous year. The amount of lead in imported ores brought into the United States for reduction in 1892 was 26,734 tons; in 1893 it was 29,270 tons. The net production of lead from ores mined in this country was, therefore, 166,678 tons in 1893, against 182,677 tons in 1892. The imported lead ores came chiefly from Mexico, but a small amount was derived from British Columbia, which was smelted at works in the Northwest. There were also imported 35,000 tons of Mexican bullion, which was refined in bond at works on the Atlantic coast and re-exported. There was a great increase in this as compared with the previous year, when only 12,874 tons of imported bullion were treated in that manner.

The falling off in the domestic production of lead, amounting to 15,999 tons, was expected on account of the financial troubles beginning in the early summer, which interrupted the course of all industry in the United States. The actual decrease, indeed, was undoubtedly greater than is shown by these statistics, which are for the production of lead turned out in a marketable form, *i.e.*, chiefly refined together with a small amount of hard or antimonial lead. These figures do not, consequently, represent the actual output of the mines, because the smelting works and refining works always carry large stocks of ores, between products and base bullion, which may enable them to run at full capacity for some time after the original supply of ore has been cut off, and these stocks were worked down in 1893.

After the great fall in the value of silver, precipitated by the action of the Indian Council on June 26, a large number of the silver-lead mines of the Rocky Mountains were closed, and while some resumed operations later, it is doubtful if any were producing at full capacity at the close of the year. It was not until August or September, however, that the smelting works used up their stocks of ore and began blowing out. Hence the production of neither silver nor lead in marketable form shows so large a falling off as might have been expected.

The method adopted for the compilation of the statistics of the production of lead in the United States in 1893 should be here explained for a complete understanding of what they represent. Returns are received direct from every one of the refining works, who report their output of desilverized and antimonial lead, also stating from what States the base bullion and ores were derived; the base bullion is then followed back to the works whence it came, from which reports are also received, and the distribution is carried further according to them. The reports for 1893 and 1892 were so itemized that it has been possible to make this distribution with, we believe, a high degree of accuracy. In previous years it has been practicable to make it only approximately correct, notwithstanding the numerous reports at hand to serve as a basis for the division. It is impossible, therefore, to draw exact conclusions concerning the production of lead in the various districts of the United States by a comparison of the figures for 1893 and 1892 and those for previous years, although this may be done in a general way.

Of the important lead-producing districts of the country, it appears that there was a great falling off in the output of Colorado, which apparently decreased from 61,500 tons in 1892 to 43,698 tons in 1893. It should be noted, however, that there were many thousand tons of base bullion produced there during the year which had not been refined at the close, and consequently do not appear in our statistics. The large falling off in the lead product of Colorado is to be attributed, for the most part, to the exhaustion of the mines at Leadville, which formerly produced rich and desirable lead ores.

In Idaho, according to our returns, the lead product was 32,263 tons in 1893, against 33,000 tons in the previous year. There was undoubtedly a much larger decrease in the output of this State, since the mines of the Cœur d'Alêne district were unproductive for several months. The fact that no greater decrease is shown in the statistics is to be attributed to the smelting and refining of Idaho ore and bullion carried in stock by the smelters and refiners. In Utah there was an apparent increase from 22,000 tons to 26,454, which is to be explained in the same manner.

The production of lead in the Mississippi Valley, which is derived chiefly from Kansas and Missouri, with a small amount from Wisconsin, is reported as 38,241 tons, against 37,000 tons in 1892. Nearly 7000 tons of this ore were reduced by the silver-lead smelters of the Central States, and the bullion derived from it figures with the desilverized product. The production of soft lead in the United States in 1893 was 31,369 tons, of which a small amount came from Virginia, and the remainder from the Mississippi Valley.

The stock of refined or marketable soft lead has remained very insignificant during the year, and the stock of base bullion has declined. It is probable that the entire stock of lead in every form, base and refined, in the country, if it were available, would not supply current consumption for more than six or eight weeks.

Year.	Stock of Refined, Jan. 1.	Produced from U. S. Ores.				Smelted from Foreign Ores.	Total Smelt'd	Imported in Bullion Pigs or Bars.	Total Supply.	Con-sumed.	Export-ed in Bullion, Pigs or Bars.	Stock of Refined, Dec. 31.
		Desilver-ized.	Soft.	Anti-monial.	Total.							
1890	8,000	106,066	31,103	4,896	142,065	18,124	182,967	9,975	200,942	190,942	....	10,000
1891	10,000	138,749	32,897	5,105	176,751	21,162	197,113	4,615	211,728	200,028	2,700	9,000
1892	9,000	145,217	31,655	5,805	182,677	26,734	209,411	14,149	231.285	212,911	12,874	5,500
1893	5,500	130,026	31,369	5,283	166,678	29,270	195,948	35,000	236,448	195,457	35,000	5,991

The Distribution and Production of Lead.

By Walter Renton Ingalls.

With the exception of iron and copper there is none of the useful metals so widely distributed throughout the world as lead, and iron is the only one of which there is more produced. In this article it is proposed to describe briefly the principle lead mining-districts of the world, the character and grade of their ores, their present output, and the probability of production in the future. In compiling the statistics of production an attempt has been made to begin with the earliest consecutive records, and to trace the output as nearly to the mines as possible. Since railways have been built into formerly inaccessible regions and steamships have begun running to all parts of the world, offering so cheap freight rates that comparatively low-grade ores are sent to European smelting works from the antipodes, it has become more and more difficult to trace the production of the industrial metals to their true source, and confusion has arisen in many series of statistics, especially in those of silver and lead, through differences in the methods of compilation, which have exposed statisticians to the danger of counting the product of certain countries twice.

The most satisfactory method of arriving at the total production of lead in the world would be by reports from each country of the lead contents of ore mined therein, with proper allowance for loss in smelting, which is the plan adopted by the English statisticians in determining the lead product of the United Kingdom. If this method were generally followed it would enable us to trace the world's output of lead to the actual source, *i. e.*, the country in which mined, which it is desirable to know. It would be important, also, to have statistics of the outturn of the metallurgical works in each country, in order to know where the metal was put in marketable form. If either of these plans was uniformly followed, however, there would be no difficulty in arriving at the world's total product, but unfortunately some countries use one and some the other. Germany, for example, reports the output of the smelting works within its limits, and also the yield of domestic ore, but does not give the lead tenor of the latter; while the English blue-books give the lead tenor of domestic ore, but do not report the outturn of the smelting works. In any statistical compilation, therefore, it is necessary to use some figures which are not official in order to include all the metal actually produced.

In making up the statistics for this article the plan has been to trace the production of lead back to the producers of silver-lead bullion, which represents approximately the production of the mines, unless, as in the case of Mexico, there are data which make it safe to go further back. The lead ore produced in Mexico is partly smelted in that country and partly exported to the United States, a small amount also being shipped to Germany. The returns from American lead smelters state the amount of lead derived by them from Mexican ores, and it is, therefore, right to deduct that from the total American make and credit it to Mexico, the country which actually produced it. In the case of New South Wales it is difficult to arrive at the true figures, the exports from that colony being reported as "silver-lead bullion and ores,"* the lead tenor of the latter not

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* Harrie Wood, Esq., Under Secretary for Mines, New South Wales, states in a private communication that the actual production of lead in that colony is probably 10% more than the reported exports of silver-lead bullion.

being stated. It is only possible, consequently, to credit New South Wales with its production of bullion; while the lead contained in its ores, going to England, Belgium, and Germany for reduction, is accounted for in the returns of those countries. It may be assumed, therefore, that the statistics given in the following table understate the actual production of Mexico, Australia, France,* Spain, Greece, and other countries, whence lead ores are exported; they represent the true production of the American, British, and Russian mines, whose entire product is smelted at home; while the production of Germany, Italy, and Belgium (importing ores) is overstated, notably in the case of Belgium, which itself produces only an insignificant amount of lead ore, but is credited with an output of 9000 to 10,000 metric tons of metal per annum on account of its metallurgical works.†

LEAD PRODUCTION OF THE WORLD.‡

(In metric tons.)

Year.	Austria.	Belgium.	Canada.	France.	Germany.	Greece.	Hungary.	Italy.	Japan.	Mexico.	New South Wales.	Russia.	Spain.	Sweden.	Un. Kingd'm		United States.	Total.
															Foreign Ores.	Native Ores.		
1867	......	10,518	...	.....	49,346	....	2,003	2,257	....	....	......	.....	....	410	....	69,562	13,789	....
1868	......	11,279	...	.....	53,818	....	1,619	4,642	....	....	......	.....	....	393	....	72,181	14,878	....
1869	......	10,799	...	.....	69,851	....	2,071	4,416	....	....	......	.....	....	513	....	74,460	15,876	....
1870	......	10,034	...	.....	63,980	....	1,495	3,851	....	....	......	1,649	....	374	....	74,623	16,175	....
1871	......	9,287	...	.....	57,092	....	1,962	4,250	....	....	......	.....	92,017	89	....	70,188	18,144	....
1872	......	6,535	...	.....	57,943	....	1,950	4,583	....	....	......	.....	101,548	43	....	61,411	23,478	....
1873	......	6,387	...	.....	63,874	....	1,589	5,036	....	....	......	944	99,712	24	....	55,127	38,592	....
1874	6,264	8,020	...	.....	69,071	....	1,636	4,401	....	....	......	1,330	106,258	56	....	59,740	47,247	....
1875	6,515	7,459	...	.....	69,237	....	1,895	6,018	....	....	......	1,083	119,652	55	....	58,376	54,015	....
1876	6,881	7,275	...	.....	74,771	....	2,381	4,784	....	....	......	1,169	127,495	43	....	59,612	58,124	....
1877	8,116	7,753	...	.....	79,692	....	2,302	6,179	....	....	......	1,204	80,822	32	....	62,410	74,400	....
1878	8,445	8,141	...	.....	83,519	....	2,064	8,709	....	....	......	1,397	89,567	44	....	58,971	82,882	....
1879	8,542	7,961	...	.....	86,046	....	2,113	8,757	....	....	......	1,357	90,117	44	....	52,481	84,170	....
1880	8,517	8,204	...	.....	89,066	....	2,071	10,665	....	....	......	1,146	79,808	197	....	57,882	88,747	....
1881	8,783	7,651	...	7,078	90,340	11,892	2,171	11,773	261	....	......	986	90,672	382	....	49,383	106,220	....
1882	11,113	8,805	...	8,140	96,137	6,645	1,843	13,237	235	....	......	573	88,339	243	....	51.153	120,558	407,021
1883	11,134	8.391	...	7,816	94,965	9,612	2,227	13,551	293	*e*15,000	......	542	99,312	91	*e*15,870	39,821	130,591	449,216
1884	12,111	7,751	...	6,371	98,743	*e*9,000	1,945	15,000	90	*e*15,000	......	631	83,304	364	*e*19.268	40,732	126,914	437,224
1885	11,170	8,656	...	4,894	96,483	*e*9,000	4,130	16,461	90	17,500	193	714	88,615	267	21,195	38,405	117,402	435,175
1886	10,515	8,665	...	3,977	95,621	*e*10,000	2,425	19,508	238	16,000	......	776	105,942	197	*e*10,871	40,129	123,042	447,906
1887	10,095	10,044	93	6,022	98,478	12,922	1,965	17,795	390	18,100	......	988	187,707	282	*e*11,489	38,511	131,735	546,606
1888	10,151	10,921	306	6.509	100,652	14.543	2,101	17,481	400	30,100	18,393	798	234,838	328	*e*11,806	38,194	137,820	685,341
1889	10,060	9,421	75	5,390	103.740	13,567	2,549	18,165	650	28,400	35,667	577	176,822	254	11.613	36,187	142,789	595,926
1890	9,827	9,617	51	4,578	104,958	14,208	1,424	17,768	769	22,339	42,113	836	177,953	344	15,655	34,140	128,880	586,603
1891	9,397	12,698	267	6,680	98,114	13,242	2,454	18,500	*e*800	30,186	56,482	558	*s*165.978	316	16,681	32,733	160,347	626,686
1892	9,268	10,146	547	6,655	100,710	14.426	2,941	22,000	*e*800	47,532	46,660	*e*600	175,124	801	14,921	30,014	186,548	645,435
1893	......	......	...	.....	....	....	.....	......	....	60,525	......	.....	188,500	...	....	......	175,931	....

(*e*) Estimated. (*s*) Fiscal year 1891–92.

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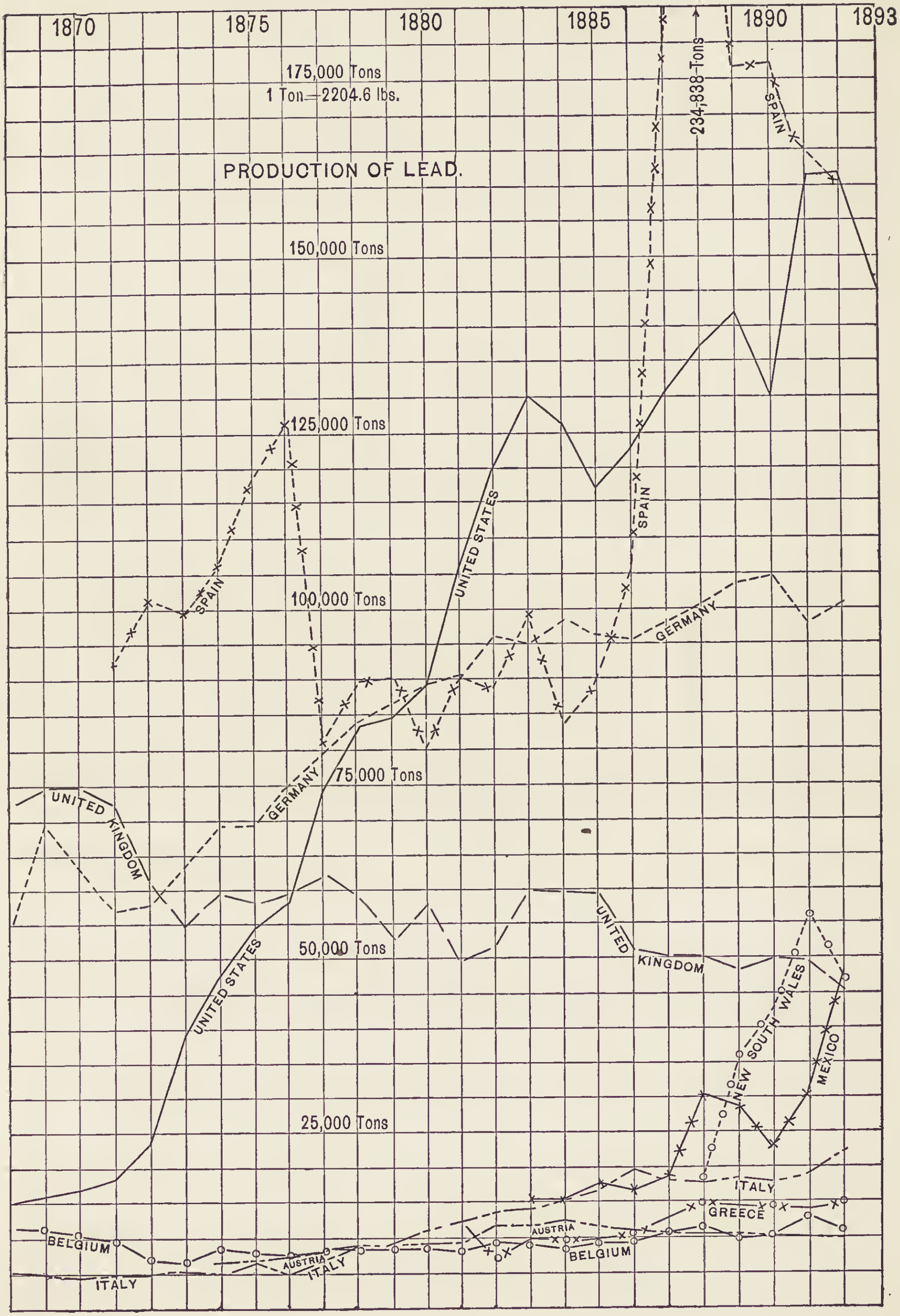
*Some foreign ore is smelted in France, but more domestic ore is exported, large quantities going from Algeria to England.

†In this article the figures in the text and special tables relating to the United States are given in short tons (2000 lbs.); those for England and Australia are in long tons (2240 lbs.); the statistics for all other countries are stated in metric tons, as are also those of all countries in all the general tables of production, etc.

‡The figures for Germany for the years 1871–92, both inclusive, have been calculated by adding to the production of lead reported in the official statistics the lead contents of the litharge produced, which have been taken at 80% of the litharge. The figures for 1867–70 include the litharge production taken at full tonnage as reported in the official statistics.

The production of lead in the United Kingdom is given in two columns. One gives the amount of lead derived from domestic ores, the yield of which is calculated at 95%, as reported in the official blue books. The other column gives the production of lead in the United Kingdom from foreign ores smelted there. These figures, which are not reported in the official blue books, are obtained by deducting the production of British lead from the total ouput of the lead smelters of the United Kingdom as stated in the *Statistische Zusammenstellungen über Blei, Kupfer, Zink, und Zinn* of the Metallgesellschaft Frankfurt am Main, 1893. The lead ore from which this additional amount of metal is derived is brought into England chiefly from France, Algeria, Australia, and Chile. The importations from France in 1892 amounted to 1054 long tons (2240 lbs.), while 9669, 1084, and 1787 long tons were imported from Algeria, Australia, and Chile, respectively.


1870
1875
1880
1885
1890
1893
175,000 Tons
1 Ton=2204.6 lbs.
234,838 Tons
PRODUCTION OF LEAD.
150,000 Tons
125,000 Tons
100,000 Tons
75,000 Tons
50,000 Tons
25,000 Tons
SPAIN
UNITED STATES
GERMANY
UNITED KINGDOM
NEW SOUTH WALES
MEXICO
ITALY
GREECE
AUSTRIA
BELGIUM

The principal ores of lead are galena (lead sulphide, PbS), cerussite (lead carbonate, $PbCo_3$), and anglesite (lead sulphate, $PbSo_4$), which rank in importance in the order named. Lead ores are associated almost always with the ores of other metals, galena occurring commonly with zincblende and iron pyrites, less frequently with copper pyrites, while lead carbonate is found generally with the oxides of iron and manganese. Lead ores are furthermore almost invariably silver-bearing, even the mineral ordinarily called non-argentiferous having usually a trace of the precious metal. The terms argentiferous and non-argentiferous, indeed, as commonly used with respect to lead ores, are merely relative, and it would not be easy to draw the dividing line between the two classes, unless at the point at which it pays to extract the silver, which of course varies in different places. The ores commercially classed as argentiferous, however (*i.e.*, those whose silver contents form an important, perhaps the more important, part of their value), furnish nearly two-thirds of the world's supply of lead. On the other hand, a constantly increasing amount of silver has been coming from the silver-lead smelters during the past ten years, so that the silver-milling processes —like amalgamation and lixiviation—which belong to the metallurgy of silver alone have fallen in relative importance, and probably more than one-half of the total output of silver in the world now comes from the lead desilverizers. The mining and metallurgy of the two metals silver and lead, and the industrial conditions affecting their production, are so closely woven together, indeed, that it is difficult to consider either of them alone.

* At various times, especially when the mines of Leadville were at their best, large parts of the world's supply of lead have been derived from carbonate ores,

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The figures for Mexico, previous to 1893, are from the *Statistische Zusammenstellungen über Blei, Kupfer Zink, und Zinn* of the Metallgesellschaft Frankfurt am Main, 1893. The figures for 1883 and 1884 are estimated. Those for subsequent years are compiled by adding the imports of Mexican lead into Europe (including the bullion refined in the United States in bond and re-exported) to the lead smelted in the United States from Mexican ores. This does not take into account the consumption of lead in Mexico, as pointed out in the part of this article relating to that country, and the statistics of its production are therefore somewhat too low.

The figures for Italy for the years 1867–77, both inclusive, give only the production of the Pertusola works, which are the largest and most important in the kingdom. The total production of Italy for this period would be only a trifle larger than that here reported.

The figures for Austria and Hungary include the lead contents of litharge, calculated at 80%.

The figures for New South Wales are obtained by adding together the exports of silver-lead bullion from the colony and the small amount of soft lead produced at home; there is much lead exported from the colony in silver-lead ores, which is accounted for in the production of the country (Belgium, France, Germany, or England) where smelted.

The figures for Spain are obtained by adding together the production of argentiferous and non-argentiferous lead as reported in the official statistics of the kingdom. The production reported for 1892 is as reported by Señor Don Roman Oriol.

The above table does not include the lead smelted in Asia Minor, European Turkey, South America, and the Australian colonies other than New South Wales, where small amounts of metal are produced. Taking in account the small output of each of these countries, and the underestimates for Mexico, and some other countries, as previously pointed out, it is probable that the actual production of lead in the world for the past five years, at least, has been between 5000 and 10,000 tons greater than here reported. It is always certain, moreover, that statistics compiled from official sources, and not based on mere estimates, understate the actual production.

* In bringing out the first edition of THE MINERAL INDUSTRY, Vol. II., for 1893, after the plates had been prepared it became necessary to insert hastily a page in this article in order to complete a form, and the author being then absent from the country this was done by the editor. The author has now supplied the following matter to take the place of that inserted in the first, and the substitution has been made in accordance with his desire.

but galena has been always the most important source of the metal, and at present the Mexican mines are the only ones furnishing large quantities of carbonate ore. The metallurgical treatment of the latter is very simple, involving only a reduction of the oxide of the metal, and it is therefore comparatively inexpensive. Such ores, when obtainable, however, are seldom smelted alone, but are usually mixed with more refractory ores in order to reduce the general average cost.

Galena ores are treated by one of three methods, viz.: (1) Roast-reaction, (2) roast-reduction and (3) precipitation, or (4) a combination of 2 and 3, these being carried out ordinarily in reverberatory or blast furnaces, and occasionally on shallow hearths which are of a more primitive type. The roast-reaction method in reverberatory furnaces is used in North Wales (where it is known as the Flintshire process), at Couëron, Loire Inférieure, France, at Bleiberg, Carinthia, and in the south of Spain, where a form of furnace known as the "boliche" is employed. By far the more part of the galena ore of the world is treated, however, by the roast-reduction or iron-precipitation methods, or a combination of the two, in shaft furnaces, which are either of circular or rectangular cross-section, the latter form being the more modern. In the development of this system of lead smelting, which has been very rapid during the last twenty years, the way has been led by American metallurgists, and the practice in this country is now conceded to be the best in the world.

The American practice in lead smelting, and the Mexican and Australian, which have followed the American model, are characterized especially by the general use of rectangular water-jacket furnaces of great size, instead of the circular brick furnaces of small capacity, which are still employed in Europe, and the reduction of the cost of smelting to a very low figure by the great increase in tonnage treated, notwithstanding the comparatively high cost of supplies, labor and freight. At the same time the salvage of valuable metals in the ores reduced has been kept up to the highest standards. At the present time mixed ores made up into neutral charges averaging about 10% lead are smelted in Denver and Pueblo, Colo., at a cost of $4.50 per ton (not including roasting), and with losses in lead and silver not to exceed 6% and 5% respectively, the bullion produced assaying 300 ozs. silver per ton of 2000 lbs. and the slag carrying not more than 0.8 ozs. silver per ton and 0.75% lead. It should be noted in addition that labor at those points costs from $1.75 to $2.25 per day, limestone $1.00 per ton, and coal and coke $2.00 and $6.00 respectively.*

Lead in the United States.

The lead-producing regions of the United States may be classified as being of the Atlantic coast, Mississippi Valley, Rocky Mountains, and Pacific slope, the last including the mines in the Coast Range in Washington and California, which are not, however, of much consequence as yet. The Rocky Mountain region, including the States and Territories of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, South Dakota, and Utah, is by far the most important,

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* This is the cost of El Moro coke in Denver, but the Crested Butte and Jerome Park products command from $8.00 to $9.00 per ton. The value given for coal is an average; slack sells for $1.50 and run of mine for $2.50.

producing about 80% of the total make of lead in the United States at the present time, all of this coming from argentiferous ores. The remaining 20% is derived chiefly from the non-argentiferous ores of the three lead districts of the Mississippi Valley.

PRODUCTION OF LEAD IN THE UNITED STATES.

(In short tons—2000 lbs.)

Year.	Arizona and California.	Colorado.	Idaho.	Mississippi Valley.	Montana.	New Mexico.	Nevada.	Utah.	Other States.	Total American Production.	Produced from Mexican Ore	Total Production Smelti'g Works.
1873......	....	56	....	22,381	....	....	....	15,000	5,103	42,540	....	42,540
1874......	....	312	....	e23,000	....	....	....	20,000	8,768	52,080	....	52,080
1875......	....	818	....	24,730	....	....	....	19,000	14,992	59,540	....	59,540
1876......	....	667	....	26,421	....	....	....	25,000	11,982	64,070	....	64,070
1877......	....	897	....	31,152	....	....	19,724	27,000	3,127	81,900	....	81,900
1878......	....	6,669	....	26.770	....	....	31,063	21,000	5,858	91,360	....	91,360
1879......	....	23,674	....	28,130	....	....	22,805	14,000	4,171	92,780	....	92,780
1880......	....	35,674	....	27,690	....	....	16,659	15,000	2,802	97,825	....	97,825
1881......	....	40,547	800	30,770	....	....	12,826	24,000	8,142	117,085	....	117,085
1882......	....	55,000	e4,100	29,019	4.100	....	8,590	30,000	2,081	132,890	....	132,890
1883......	3,200	70,557	6,100	21,800	4.900	2,400	6,000	29,000	....	143,957	....	143,957
1884......	4,300	63,165	7,600	19,932	6.900	6,000	4,000	28,000	....	139,897	....	139,897
1885......	4,000	55,000	10,000	21,975	e6.000	5,000	3,500	23,000	937	129,412	....	129,412
1886......	e3,500	59,000	16,500	20,800	e5,500	5,000	3,400	e21,500	429	135,629	....	135,629
1887......	e3,300	63,000	20,000	25,148	7.000	e4,500	3,400	e18,700	164	145,212	15,488	160,700
1888......	e2,500	e65,500	21,500	29,090	e8,500	e4,500	2,400	e17,500	429	151,919	28,636	180,555
1889......	3,200	68,000	23,172	29,258	10,000	4,764	1,950	16,500	553	157,397	25,570	182,967
1890......	1,500	52,500	e24,000	31,351	e10,000	5,910	e1,500	e15,000	304	142,065	18,124	160,189
1891......	2,000	64.000	38,181	34,000	14.127	5,330	2,500	e16,000	613	176,751	†21,162	197,113
1892......	2.500	61.500	33,000	37,000	12,858	5,895	3,000	e22,000	4,924	182,677	†26,734	209,411
1893......	2,405	43,698	32,263	38,241	8,348	6,869	3,041	26,454	5,359	166,678	†29,270	195,948

(*e*) Estimated. † Does not include Mexican lead refined in bond, which in 1891 amounted to 2700 tons; in 1892, to 12,874 tons, and in 1893 to 35,000 tons.

Atlantic Coast.—The production of lead on the Atlantic coast, which was never large, has now become insignificant, and reference to the localities where ores have been mined is chiefly of historical interest. Veins of lead ore have been worked at Lubeck and elsewhere in Maine, and at various places in New Hampshire and Vermont. At Byfield, Essex County, Mass., a gash-vein of rich silver-lead ore was productive in 1873, but was soon exhausted. Mines near Northampton, Mass., and Middletown, Conn., were formerly well known, as was also the Ancram mine in Columbia County, New York. More productive were the mines near Rossie, in St. Lawrence County, N. Y., which were opened on veins in Archæan gneiss, carrying galena in a gangue of calcite. There are mines in southeastern Pennsylvania, but none of them have been worked in recent years. In Virginia (Wythe County), in the region west of Roanoke, there are important zinc mines, of which the Bertha is the best known, which produce a small amount of lead, but they are far more important as sources of zinc. Lead also occurs in Tennessee, and the Blue Springs Mining Company has a smelting furnace at Blue Springs Station, in Bradley County. In North Carolina there are small mines at Silver Valley and elsewhere in Davison County, which produce argentiferous ores. The North Carolina Smelting Company at Thomasville smelts these ores, but it does not run regularly, the supply being so small. The total production of lead on the Atlantic coast probably does not exceed 1000 tons per annum.

Mississippi Valley.—The lead-producing districts of the Mississippi Valley are divided naturally into three groups, viz.: Southeastern Missouri, southwestern

Missouri (including the southeastern corner of Kansas), and Wisconsin-Iowa (including the northwestern corner of Illinois). Lead is also found in the Rosiclare district in southern Illinois, and across the river in Kentucky, but these desposits are quite insignificant.* The lead produced in the Mississippi Valley is entirely non-argentiferous, and previous to the discovery of the richer mines of the Rocky Mountains it constituted the chief American supply. The southeastern Missouri district is still very important, but the mines of southwestern Missouri and Wisconsin-Iowa are now exploited chiefly for their zinc ores. Arthur Winslow, State Geologist, gives in the following table the production of lead in Missouri from 1720:

PRODUCTION OF LEAD IN MISSOURI.
(In short tons.)

Years.	Tons.	Years.	Tons.	Years.	Tons.	Years.	Tons.
1720 1803	16,095	1847 1854	50,400	1875	16,480	1885	20,916
				1876	22,550	1886	22,780
1804 1819	5,590	1855 1868	45,560	1877	24,680	1887	16,720
				1878	23,112	1888	22,610
1820 1832	3,900	1869	6,480	1879	22,386	1889	31,590
		1870	7,060	1880	24,850	1890	28,840
1833 1845	31,200	1871	6,840	1881	25,630	1891	31,000
		1872	10,220	1882	23,870	1892	32,260
1846	4,500	1873	13,840	1883	18,390	1893	....
		1874	15,160	1884	14,330		

It will be noted that the product reported for Missouri in the preceding table is in a few cases greater than that stated for the Mississippi Valley in the general table of production of lead in the United States. More or less of the Missouri ore is shipped to silver-lead smelters, by whom it is reported as "desilverized," and it is not credited to the States producing it, except since 1890, when the reports made by the smelters to THE MINERAL INDUSTRY have been divided so that the production could be traced to its true source.

Southeastern Missouri.—The lead mines at Bonne Terre, Doe Run, and Mine la Motte, in southeastern Missouri, 25 miles west of the Mississippi River and 40 to 100 miles south of St. Louis, are the oldest in the United States, the Mine la Motte having been opened in the early part of the eighteenth century.‡ They are still the largest producers of non-argentiferous lead in the country, furnishing over 60% of the make of that class of metal. The most important mines of the district are those of the St. Joseph Lead Company, at Bonne Terre; the Desloge Consolidated Mining Company, at Doe Run; and the Mine la Motte, at the place of the same name.

A brownish-black magnesian limestone, perhaps of Upper Cambrian (Potsdam) age,§ forms the ore-horizon. The thickness of the lead-bearing formation at Bonne Terre is 220 ft.; at Mine la Motte it is locally much reduced by denudation, attaining 150 ft. as a maximum. The ore is galena, scattered through the limestone in crystalline grains from $\frac{1}{16}$ to $\frac{1}{2}$ in. (1.6 to 12.7 mm.) in diameter, and also occurring in flat, irregular, thin sheets in the shaly partings between the

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* For information concerning the occurrence of lead at Rosiclare see paper on "Fluorspar Deposits of Southern Illinois," by S. F. Emmons, in *Trans. Amer. Inst. Min. Eng.*, Vol. XXI., and the article on "Fluorspar" in this volume.

† From the *Geology and Mineral Products of Missouri*, by Arthur Winslow, State Geologist.

‡ This mine is said to have been discovered in 1702.

§ Walter P. Jenney, "Lead and Zinc Deposits of the Mississippi Valley," *Trans. Amer. Inst. Min. Eng.*, 1893 layers of the rock. Iron pyrites, carrying nickel and cobalt, are associated with the galena, but there is no zincblende. The ore deposits are of great size. At Bonne Terre there is a stope nearly 3000 ft. long, 100 to 200 ft. wide, and 25 to 60 ft. high.* At Bonne Terre the mineralized beds occur at a depth of 50 to 225 ft.; at Mine la Motte they outcrop at the surface.

The ore of this district has to be dressed, and the works for this purpose at Bonne Terre and Doe Run rank among the best in the United States, the mill of the St. Joseph Lead Company, at Bonne Terre, being of 800 tons capacity per twenty-four hours. The average grade of the ore at Bonne Terre is about 8% galena (equivalent to 6% lead), of which 70% to 75% is recovered in dressing, which costs less than 40c. per ton. The ore contains about four ounces of silver per ton of lead. The concentrates, which average about 70% lead, are smelted in small shaft furnaces at the mines, and the lead is shipped to St. Louis.

Southwestern Missouri.—The lead and zinc mining region of southwestern Missouri, commonly known as the Joplin district. extends into the adjoining corners of Kansas, Arkansas, and the Indian Territory. These ore deposits were discovered in 1851, since which time they have been worked continuously, with the exception of an interruption during the civil war, when some of the smelting works were destroyed. In 1872 the zinc ore associated with the lead in these mines began to attract attention, and finally became more important than the lead ore, which now is won merely as a by-product. At the present time the production of blende in Joplin and vicinity is ten times more than that of galena.

The ore deposits of the Joplin district occur near the surface in a formation (Subcarboniferous) 185 to 220 ft. in thickness, which is made up of beds of limestone irregularly interstratified with layers of chert. The ore is found in mineralized zones of brecciated chert, which are very irregular in shape and often of remarkable size. In the vicinity of Webb City and Joplin, Mo., and Galena, Kan., there are stopes 75 to 150 ft. wide, 40 to 80 ft. high, and 200 to 400 ft. long, from which all the extracted material has been milled. In one instance a run of ore was traced by connected workings for nearly 1000 ft.†

Only in exceptional cases are the ores of the Joplin district sufficiently free from gangue to allow them to be shipped without dressing. The proportion of concentrates obtained from the crude ore varies from 1:2 to 1:20. As a rule the ore is free from pyrites, though in some mines that mineral is found mixed with the blende and galena.

Where blende and galena occur in the same ore body, the former usually predominates in the lower and outer portions, while the galena is found in the top and center. The fact that the surface deposits of the region are now mostly worked out explains the decrease in the lead production of this region in recent years.

Wisconsin-Iowa.—Lead mines have been worked for many years in the vicinity of Shullsburg and Benton, Wis., Dubuque, Iowa, and Galena, Ill., the district covering the corners of three States. The ore occurs in runs chiefly in limestones of the Trenton and Galena formations, aggregating 300 ft. in thickness. The ores are galena and blende, associated with calamine, pyrite, and marcasite.

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* W. P. Jenney, *op. cit.* † *Ibid.*

As in the Joplin district, the zinc ore is now the more important product, the lead ore forming only 6% of the total shipments from Wisconsin in 1892. The old mines at Dubuque, Iowa, and Galena, Ill., have been of little importance for many years.

ROCKY MOUNTAINS.—At the present time most of the lead produced in the United States comes from the argentiferous ores of the Rocky Mountains, where the lead-mining industry began with the opening of the great ore deposits at Eureka, Nev., in 1869. Lead ores had been mined and smelted previously at Argenta, Mont., but the work there was carried out on a small scale only and was without much significance. Soon after the establishment of the lead-smelting industry at Eureka important discoveries were made in Bingham and Cottonwood cañons, near Salt Lake City, and furnaces were erected there also. For ten years Nevada and Utah were the largest lead-producing districts; Colorado then took the first place through the discovery of the mines at Leadville; and though the latter are now approaching exhaustion, the output of the State is still the largest of any in the Rocky Mountain group.

COLORADO.—This State at present furnishes about one-third of the total domestic supply of lead. It also contains the principal lead-smelting centers of the United States, and the quantity of ore reduced within its borders is much larger than the production of its own mines. There are two smelting works in regular operation at Denver, three at Pueblo, four at Leadville,* one at Durango, and one at Rico. A part of the silver-lead bullion produced at these points is desilverized in Colorado, but by far the more part is shipped to the refiners at Omaha, Argentine, St. Louis, Chicago, and Mansfield.

The principal lead-producing district of Colorado, now as formerly, is Leadville, after which the most lead-bearing ore comes probably from Aspen (Pitkin County), although only a few of its mines have a significant amount of lead in their ores. These two districts still furnish about one-half of Colorado's lead product, although the yield of Leadville is decreasing rapidly. The remainder comes from small camps in various parts of the State, among which should be mentioned Monarch, Lake City, Ten Mile, Georgetown, Rosita, Decatur, and the San Juan region.

The following table gives the production of lead in the State of Colorado and in Leadville since 1876. The totals for the State for the years previous to 1888 are taken as published in THE MINERAL INDUSTRY, Vol. I.; the amount reported for 1888 is estimated, and that for 1889 is based on the figures of the Eleventh Census; the figures for the years since 1889 are compiled from returns received directly by the *Engineering and Mining Journal* and THE MINERAL INDUSTRY from every smelting company in the United States. With respect to the production of Leadville it is very difficult to arrange the data, much of which is incomplete and inexact, and the figures here reported cannot be claimed to be more than approximate. Those for the years 1877–82, both inclusive, are based on the reports in the Leadville *Herald-Democrat*, estimating the lead contents of the ore shipped from Leadville to valley smelters. The figures for 1883 and 1884 arrived at in this manner were obviously incorrect, and these years have been estimated

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* All of these works closed down in the autumn of 1893, and only two of them—the Elgin and Arkansas Valley—have started up again. The Harrison works will not be reopened.

by comparison of the output in other districts of the State with the total. The figures for 1885 are from the *Herald-Democrat*, while those for 1886 are taken from the *Mineral Resources of the United States* for that year, and those for 1887 and 1888 are based on the Mint reports. The figures for 1889 are those of the Eleventh Census, and seem to be too high. There are no reliable figures for 1890 and 1891, and the output for these years has been estimated. The figures for 1892 are compiled from returns furnished by the smelters, who separated the lead derived from Leadville ore and that bought in ores from other districts. It is probable that the output of lead reported for Leadville in the years 1883–88, both inclusive, comprises some lead smelted there from Aspen, Red Cliff, and Ten Mile ores.

Until 1882 Leadville was the only large producing district in Colorado. The mines of Red Cliff then began to make a considerable output, and in 1883 and 1884 turned out as much as 3500 tons of lead per annum. The Monarch district also began to produce in 1883, and in 1885 yielded a trifle over 10,000 tons of lead, but after that time the output gradually fell off, amounting to 7600 tons in 1887 and 5700 tons in 1888. Aspen also began to ship considerable quantities of lead ore in 1884. It yielded 3200 tons of lead in 1885, 6000 in 1887, 8000 in 1888, and 7100 in 1889.

PRODUCTION OF LEAD IN LEADVILLE AND THE STATE OF COLORADO.

Year.	Leadville.	Colorado.	Year.	Leadville.	Colorado.
1877	835	897	1886	48,500	59,000
1878	6,000	6,669	1887	47,000	63,000
1879	22,500	23,674	1888	45,500	*65,500
1880	34,000	35,674	1889	50,500	68,000
1881	39,000	40,547	1890	*35,000	*52,500
1882	45,000	55,000	1891	*32,000	64,000
1883	*60,000	70,557	1892	22,211	62,500
1884	*53,000	63,165	1893	....	42,698
1885	36,100	55,000			

Aspen, in Pitkin County, situated in the valley of the Roaring Fork River, on the western slope of the Continental Divide, is at present the largest producer of silver in Colorado. Much of the ore is "dry," but there are also silver-lead ores, and although none of them are very rich in lead, the aggregate amount of metal obtained is important. These ores, which are for the most part oxidized and are usually associated with lime and baryta, are found chiefly at the contact between a bed of blue Lower Carboniferous limestone and underlying brown dolomite of the same age; and also in fissures and less regular deposits in these and older limestones. The blue limestone is very pure; the dolomite contains from 20% to 28% of carbonate of magnesium. The average grade of the Aspen ore is shown by the following analyses:[†]

$BaSO_4$	0.5%	24.2%	26.0%	29.5%
SiO_2	6.5	17.3	40.0	14.3
CaO	7.6	13.7	3.0	7.8
Fe	9.0	1.5	9.4	2.5
Pb	19.3	4.7	8.0	16.0
H_2O	9.8	5.0	9.0	3.0
Ag	7.5	31.0	25.0	69.0

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[*] Estimated. [†] Hofman, *Metallurgy of Lead*, 1892, p. 39.

The chief producers of lead at Aspen are the Aspen Mining and Smelting Company, the Aspen Contact Mining Company, the Smuggler Mining Company, and the Durant Mining Company.

The geological structure of the Aspen district is very complicated, the formations being much contorted, broken by faults, and disturbed by intrusions of igneous rock. The same formation extends over a large area in the neighborhood of Aspen, and promising mines have been opened at other points in the same region.

Custer County.—The mines in the vicinity of Silver Cliff, in this county, have been at times large producers of lead, the Terrible, at Ilse, and the Bull-Domingo and Bassick having been the most important. The Terrible mine was opened in a porphyry dike 127 ft. wide, which traverses granite country rock for a considerable distance, 87 ft. being impregnated with crystals of cerussite. The ore raised averaged from 10% to 12% lead and 1 oz. silver per ton. It was dressed to a product assaying 70% lead and 1.5 oz. silver per ton. The mine is owned and operated by the Omaha & Grant Smelting Company, to which it formerly furnished a large supply of lead, but its output is no longer important. The Bassick and Bull-Domingo mines were opened on similar chimneys, but their ore was richer in silver, especially that of the former. The Bassick was once a famous producer and paid large dividends, but it has not been exploited on an important scale for several years, though it is reported that dressing works are to be erected and that the mine is to be worked for its low-grade ore. The Bull-Domingo mine, which is situated about five miles from the Bassick, is now the largest lead producer of this district. It is opened to a depth of 800 ft. The ore, which is galena, is dressed in a mill of 150 tons capacity per twenty-four hours, situated on Grape Creek, two and one-half miles from the mine. The concentrates produced average 70% lead and 14 oz. silver per ton. At present they are shipped up the mountains to a smelting works at Leadville, which is illustrative of the extent to which the desirable smelting ores of Leadville have been exhausted.

Leadville.—This district, one of the most famous in the world, was discovered in 1874, but no shipments of ore were made until 1876. In 1878 the mines became large producers, and their yield increased rapidly during the five years following, the maximum output having been made in 1883, and until 1891 the camp held its position as the premier lead-producing district of the United States.

Leadville, in Lake County, is situated at the head of the Arkansas River, on the western slope of the Park, or Mosquito, Range of mountains. The altitude of the camp above sea level is 10,200 to 10,500 ft. The ore deposits occur at the contact of a formation of Carboniferous limestone with an overlying sheet of white porphyry, and in channels in the limestone itself. The ore-bearing area is extensive, but by far the most of the mineral has come out of a section less than two miles square.

The country rock is much folded and faulted, and disturbed by intrusions (dikes and sheets) of gray porphyry of later age than the white porphyry. The porphyry-limestone contact dips east at a moderate angle, and is exposed at the surface by the upthrow of the two great fault series—the Carbonate and the Iron. The point of attack on the ore bodies was doubled by these breaks, which gave two long outcrops. The ore occurs in chutes or channels of great size and remarkable continuity, of which a large number, nearly parallel and connected with one another by arms or branches, have been opened.

From the surface to water-level the ore was lead carbonate (cerussite) and lead sulphate (anglesite), imbedded in a great body of manganiferous limonite; below water-level the ore consists of a mixture of blende, galena, and pyrite, which in one case (Stone-Minnie-Moyer chute) passes into low-grade copper-bearing pyrites. In the Henriette-Maid of Erin mines, also, copper sulphide ore was found below the lead carbonate.

The more part of the lead mined in Leadville in recent years has been obtained from the Morning Star, Henriette-Maid of Erin, and Adams mines, all of which have been controlled by the Henriette & Maid Consolidated Mining Company.* This ore (carbonate) averaged about 30% lead, 4 oz. silver per ton, and was basic in character, being very desirable for the smelters, by whom it was eagerly sought, and paid for at a high price. The great ore chute, which was in many places 30 ft. thick and 200 ft., or more, wide, was practically exhausted of its lead carbonate ore in 1892.

Ore of the same class has been discovered on the west slope of Carbonate Hill, west of the Carbonate fault in the continuation of the Morning Star ore chutes on the down-throw side of the fault, and the Wolcott Mining Company has produced a large amount of it since 1890, but a great flow of water is encountered as the contact is approached, and the exploitation of these mines has been difficult and costly; nor have the results been indicative of the existence of any such large and rich deposits of ore as were worked on the other side of the fault.

The largest producers of lead sulphide ore have been the mines of Iron Hill, especially the A. Y. and the Minnie, the Silver Cord and the Colonel Sellers, though the Agassiz and Mahala mines, on the east side of Carbonate Hill, have also made a large output. The ore chute extending through the Stone, A. Y., Minnie, Colonel Sellers, and Moyer mines is one of the largest ever opened in the United States. In the A. Y. and Minnie territory, where the carbonate ore changes to sulphide, its width is 400 ft., and it is nearly 70 ft. deep. It has been proved, however, that less than 25% of the sulphide ore of Iron Hill is of sufficiently high grade to be mined at a profit. The low-grade ore, consisting of a mixture of blende, pyrite, and galena, among which minerals the silver is more or less erratically distributed, with less than 5% gangue, has not been dressed very successfully, and these mines are now for the more part idle, or are being worked only in a small way.

Monarch.—The Monarch district, situated at the head of a branch of the South Arkansas River, in Chaffee County, formerly made a large output of lead ore, but within the past two or three years it has become comparatively unimportant. The Madonna, Eclipse, and Silent Friend mines were the chief producers. The ore occurred in chambers in limestone, the age of which has not been accurately determined; it was found near the surface and was easily mined. Some of the chambers were of great size; in 1884 there was a stope in the

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* The shares of this company were taken over by the Maid of Erin Silver Mines, Limited, an English corporation, in 1891, but the issue failed, and the American stockholders repurchased the shares that had been sold in London.

Madonna mine, which was then making a large output, nearly 300 ft. long, 60 ft. wide, and 40 ft. high.

The Monarch ores consist, for the most part, of carbonate of lead (cerussite), much of it being in the form of sand, colored by ferric oxide. Occasionally unaltered galena is found, and occasionally also sulphate of lead (anglesite). The average grade is represented by that of the Madonna mine, in which the silver varied from 5 to 12 oz. per ton, and the lead from 20% to 45%. The following analysis by Mr. Robert Sticht is typical of the ore: Sesquioxide of iron, 32.99%; sesquioxide of manganese, 0.93%; alumina, 2.99%; oxide of zinc, 4.17%; lime, 1.78%; lead sulphate, 12.47%; lead carbonate, 32.35%; silica, 4.24%; sulphuric anhydride, 3.30%; carbon dioxide, 6.73%; water, 6.68%; silver, 0.023%=6.8 oz. per ton.*

Red Cliff.—There are deposits of galena and its oxidized products at the contact of Carboniferous limestone and quartzite or porphyry at Red Cliff, on the Eagle River, in Eagle County, which formerly produced as much as 3300 tons of lead per annum, but are now comparatively unimportant. The Iron Mask mine was the principal producer.

Ten Mile.—Immense bodies of argentiferous galena, pyrites, and zincblende are found at Robinson and Kokomo, two adjoining towns on Ten Mile Creek, in Summit County. These mines were discovered in 1880, and for a few years a large amount of development work was done in the district, several smelting works being erected there. The mines proved disappointing, however, and they were soon, for the most part, abandoned. The ore occurs in contact deposits between beds of Upper Carboniferous limestone and an overlying micaceous sandstone, or at the contact of the limestone with sheets and dikes of porphyry. The Ten Mile deposits are, therefore, situated at a higher geological horizon than those of Leadville, which are less than twenty miles distant. The sedimentary rocks of this district are much disturbed by dikes and instrusive sheets of porphyry and broken by faults.

The ore bodies of Ten Mile are of enormous extent, but are extremely low grade and refractory; hence the failure of most of the mines which were opened in them. The character of the ore varies much throughout the district. The more part is an intimate mixture of galena, pyrites, and zincblende, all of which are silver-bearing (like the Leadville sulphides), but in places large bodies of nearly pure pyrites are found. Streaks and pockets of rich galena occur in the great mass of mixed ore. The Ten Mile vein outcropped at the surface, and was easily opened, dipping at a gentle angle, but was oxidized to a much less depth than that of Leadville. The most important silver-lead mines were the White Quail, Aftermath, and Colonel Sellers, on Elk Mountain, and a group on Sheep Mountain. In recent years the only mine on which any extensive work has been done is the White Quail. This was opened about four years ago by a long crosscut tunnel, and the low-grade ore brought out through that is dressed somewhat successfully in a works built at its mouth.

IDAHO.—The principal lead-producing region in this State is the Cœur d'Alêne, which has become the most important in the United States since the exhaustion

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* *United States National Museum Bulletin*, No. 42, p. 45.

of the Leadville mines. The Wood River district, in the southwestern part of the State, also makes a large output. Formerly the Viola mine, at Nicholia, in Lemhi County, turned out much bullion, but it has been non-productive for several years past. Exploration work has been carried on during this time, but results do not seem to be promising.

The following table, giving the production of lead in Idaho and the principal districts of the State, is compiled as to early years from data scattered through the various volumes of the Mint reports upon the *Production of Gold and Silver in the United States*, and those of the Geological Survey. The figures for 1889 are those of the Eleventh Census. It should be noted, furthermore, that the large amounts of lead credited to "other districts" in this table for the years 1885-88, both inclusive, are due almost wholly to the Viola mine. This mine began to produce largely in 1885, during which year 6000 tons of ore, averaging 62% lead, were shipped, according to the prospectus of the Viola Mining and Smelting Company. In 1886 the company is said to have produced 7000 tons of lead, while the output of Lemhi County (practically the output of the Viola mine) in 1887 and 1888 was 6500 and 7500 tons, respectively, according to the Mint reports. The Viola mine has produced nothing since 1888, and the small amount of lead shipped from districts other than Wood River and the Cœur d'Alêne comes chiefly from small mines in Custer County.

PRODUCTION OF LEAD IN IDAHO.

Year.	Cœur d'Alêne District.	Wood River District.	Other Districts.	Total for State.
	Tons.	Tons.	Tons.	Tons.
1881..........	....	710	90	800
1882..........	....	*a*4,000	*a*100	*a*4,100
1883..........	....	6,000	100	6,100
1884..........	....	7,500	100	7,600
1885..........	....	6,422	3,578	10,000
1886..........	1,500	8,232	6,768	16,500
1887..........	5,980	7,100	6,920	20,000
1888..........	8,000	5,500	8,000	21,500
1889..........	18,564	3,970	638	23,172
1890..........	*a*19,800	4,500	700	*a*25,000
1891..........	33,000	5,000	563	38,563
1892..........	*a*27,839	4,500	661	*a*33,000
1893..........	*a*29,563	*a*2,000	*a*700	32,263

(*a*) Estimated.

Cœur d'Alêne.—This district is situated in Shoshone County, in the northern part of the State, extending over an area about 10 by 22 miles. The first discoveries of silver-lead ore were made near the eastern limit of the district in 1884; in the following year mines were opened in the western part. Production increased very rapidly, as is shown by the preceding table. In 1891 there were 40 developed mines in the district, of which 26 were classed as producers.*

The country rock of the Cœur d'Alêne region consists of quartzite and thin beds of schist, much folded along east and west axes. In this way they became faulted and shattered, and gave the ore a chance to deposit. The ore is found in zones of crushed, brecciated quartzite, lying on well-marked foot-walls of the

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* *Production of Gold and Silver in the United States*, 1891, p. 193.

same rock.* These mineralized zones, or veins, are strong and wide, eight feet of ore often being stoped. Several of the mines have been opened to a depth of 900 ft. without showing any falling off in amount or grade of ore. The reserves in these mines are very large, and they promise to be productive for many years.

The ore of the Cœur d'Alêne is galena (silver-bearing), with a small amount of blende, and a gangue of spathic iron (siderite) and quartz. It is mostly of low grade, averaging about 6% to 10% lead and 3 to 9 oz. silver per ton, and is dressed at the mines before shipment. In 1891 there were in operation 13 dressing-works, with an aggregate capacity of 2000 tons of ore per day. The largest works then were those of the Bunker Hill & Sullivan Mining and Concentrating Company, which dressed 450 tons per day, but in 1892 the same company completed an addition to its mill, which gave it a total capacity of 750 tons.

The Cœur d'Alêne concentrates average 60% lead and 30 oz. silver per ton, about five tons of ore being reduced to one ton of concentrates. About 75% of the value of the crude ore is saved. The cost of dressing in 1891 at the old mill of the Bunker Hill & Sullivan Company (450 tons per day) was 44c. per ton; in the mill of the Helena & Frisco Mining Company (170 tons per day) it cost 45.6c. per ton. These mills are driven by water power, but the results are by no means unfavorable in view of the high cost of labor in the district (at that time $3.50 per day).

The Cœur d'Alêne mines are easily worked, most of them being entered by tunnels. The Poorman mine (Cœur d'Alêne Silver-Lead Mining Company), at Burke, is opened by shafts to a depth of 800 ft., and is the only one in the district in which pumping is necessary. Water power is abundant, and serves for driving many of the dressing works. Timber is plentiful and cheap. At the Helena & Frisco mines in 1891 the cost of mining 51,604 tons of ore was $2.45½ per ton, according to the official report of the company; at the Bunker Hill & Sullivan mines it is higher, the cost of mining and dressing amounting to $4.55 per ton.†

The concentrates are shipped principally to the smelting works at Denver and Omaha. There are two railway lines into the district—a branch of the Northern Pacific connecting with the main line at Missoula, Mont., and a branch of the Union Pacific, which leaves the Pendleton-Spokane branch at Tekoa, Washington. The freight rate on concentrates to the principal smelting points, according to the schedule of March 20, 1892, was as follows:

Point.	II.	I.	Point.	II.	I.
Omaha	$12	$16	Pueblo	$11.25	$15.28
Kansas City	12	16	Tacoma	7.00	8.00
Denver	10	14	Helena	6.00	8.00

I. First-class concentrates, containing more than 40% lead. II. Second-class concentrates, containing less than 40% lead.

Smelting charges vary from $9 to $12 per ton; so the total cost of treatment is from $25 to $28 per ton. In March, 1892, it cost the Bunker Hill & Sulli-

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* J. E. Clayton, "The Cœur d'Alêne Silver-Lead Mines," *Engineering and Mining Journal*, Feb. 11, 1888, p. 108.

† *Engineering and Mining Journal*, March 18, 1893.

van Company $25.50; in March, 1891, the cost was $28. A reduction in freight rates was made in September, 1893, after the general closing down of the mines, but smelting charges were increased, so there was no net saving.

The great drawback in the Cœur d'Alêne region hitherto has been the disproportionately high wages demanded by the miners' unions, labor difficulties, and excessive freight charges by the railway companies on ore shipments. Until the spring of 1892 miners were paid $3.50 per day, and trammers, shovelers, and surface men received the same amount. A reduction to $3 per day was then made in the wages of all but the miners. A general strike followed, which was accompanied by many acts of lawlessness by the men. The striking miners eventually returned to work on the terms offered by the companies. The steady decline in the prices of silver and lead, however, reduced the profits of the mines very much, and when finally silver fell to 70c. it became impossible to operate them longer under the existing conditions. Every mine in the district was closed, therefore, while an offer was made to the men to reopen if a $2.50 per day wage rate would be accepted; this the men did not agree to. When the prices of silver and lead rose to 74c. per oz. and 3.80c. per lb., respectively, however, orkw was resumed in some of the mines at the old rate of wages ($3.50 per day).

Wood River.—This district, which was first discovered in 1880, is one of the important lead producers in the United States at the present time, although its output is not so large as it was seven or eight years ago. The mines are situated in the neighborhood of the three small towns, Bellevue, Hailey, and Ketchum, on the Wood River. The ore, which is chiefly a silver-bearing galena, is found in veins and irregular deposits in limestone of undetermined age. Although there are large areas of igneous rocks in southwestern Idaho, none seem to be immediately associated with the ore deposits of this district.*

The chief producers in the Wood River district are the Minnie Moore, Idahoan, Queen of the Hills, Red Elephant, and White Elephant mines. The ore produced by them is mostly dressed before shipment, the concentrates, which average 40% to 70% lead and 15 to 60 oz. silver per ton, being of excellent quality and much sought by the lead smelters. A great drawback to mining in the Wood River district, as in the Cœur d'Alêne, has been the high freight rates charged by the railway companies, in this case the Union Pacific Railway, which is the only one tapping the district.

There are several small smelting works at Ketchum, Hailey, and Bellevue, which have been operated at times, but, with the exception of the plant of the Philadelphia Company at Ketchum, have been idle since the centralization in the lead-smelting industry of the United States.

Veins of silver-bearing galena were known to exist in the Wood River district as early as 1873, and in 1874 Callahan Brothers made locations in the lower valley and worked there until driven out by the Bannack Indians. Prospecting parties went into the district in 1876 and 1877, but did not stay long enough to do more than the locating and staking of some claims; then the Nez Perces and Bannack wars, from 1877 to 1879, put an end to all prospecting. In the autumn of 1879 prospectors returning from the Salmon River Valley discovered and

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* J. F. Kemp, *Ore Deposits of the United States*, p. 191.

located about a dozen veins at the head of Wood River, in the vicinity of the present town of Galena, but it was so late in the season that nothing was done until the next year, when hundreds of miners rushed into the district.

MONTANA.—The silver-lead smelting industry of the United States originated in Montana, furnaces having been erected at Argenta in 1867, although it did not begin to be of much importance until the mines of Eureka, Nev., were opened. The lead production of Montana has never been large, however, and it is only within the past five or six years that it has been of much consequence, due largely to the inaccessibility of many of the lead-mining camps.

The principal lead-producing districts of Montana are Glendale (Beaverhead County), Wickes (Jefferson County), Barker, and Castle (Meagher County). There are small lead-smelting works at several of these places, and a great plant, belonging to the United Smelting Company, at Great Falls.

Castle.—This district, in Meagher County, has been regarded as one of the most promising producers of lead in the State, but recent developments have been unfavorable. The ore occurs as chimneys in limestone, and at the contact of the limestone with igneous rocks. The ore, which is lead carbonate, and sulphate, with oxide of iron, and a gangue of silica, is oxidized to an unusual depth. The most important mines are the Cumberland and Yellowstone, the former being owned by the Cumberland Mining and Smelting Company, which has smelting works at Castle and has paid small dividends in the past. The high cost of transportation to Livingston (nearly 75 miles away), which is the nearest railway point, has retarded the development of the district. In 1892 Mr. J. Kennedy Tod of New York invested in the Cumberland mine, and plans were made to build a railroad to Castle, but the ore reserves were found to be smaller than expected, and operations were suspended early in 1893, after the expenditure of a large amount of money.

Glendale.—Deposits of argentiferous galena mixed with zincblende, copper, and iron pyrites are found lying parallel with the bedding planes of a bluish limestone of undetermined age at Glendale, in Beaverhead County, in the southwestern part of the State. So far as known, they are not associated with igneous rocks, and in some respects resemble the ore deposits of southeast Missouri.* The average grade of the ore of these mines in 1892 was given in the twelfth annual report of the Hecla Consolidated Mining Company, which controls the more important, as follows: First-class ore, 36% silica, 23.35% lead, and 45.61 oz. silver per ton; low-grade ore, 7.2% lead and 16.7 oz. silver per ton, which was dressed to 14.34% silica, 33.85% lead, and 50.2 oz. silver per ton. This ore is smelted at the works of the company in Glendale. The Hecla mines have been steady producers for many years, having yielded a profit of $1,897,622,† in the twelve years 1881–92, but at the present time they show evidence of exhaustion. The production of lead during this period is given in the following table:

Year.	Lead, Tons.	Year.	Lead, Tons.	Year.	Lead, Tons.	Year.	Lead, Tons.
1881	2,422	1885	2,764	1889	3,069	1893	987
1882	2,492	1886	2,051	1890	2,149		
1883	2,602	1887	2,332	1891	2,015		
1884	2,295	1888	3,442	1892	1,652		

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* J. F. Kemp, *Ore Deposits of the United States*, p. 191.

† According to an official statement of the company.

Neihart.—This district, in Meagher County, has some promising silver-lead mines, and being connected with Great Falls by railway there is now an easy market for the ore. The latter consists chiefly of galena, with a gangue of quartz and barytes, occurring in fissure veins four or five feet wide. The Queen of the Hills is one of the prominent mines of the district. There are also silver-lead mines at Barker, in the same county.

Wickes.—This district, which is just south of Helena, in Jefferson County, was one of the first opened in the State, and is still one of the most important producers of lead. The ore, which is galena mixed with zincblende and pyrites in a gangue of quartz, occurs in fissure veins (from 1 to 10 ft. wide) near the contact of granite and liparite (Cretaceous or Tertiary), but cutting both rocks. The Helena Mining and Reduction Company (Alta Montana mine) and the Gregory mine are the chief producers.

NEVADA.—Nevada was the first State in the Rocky Mountains to become a large producer of lead, its output beginning in 1869 with the development of the Eureka district, which had been discovered five years previously. Mines at Pioche and elsewhere in the State subsequently became producers of lead also, but none of them were of any consequence in comparison with those of Eureka, and when the output of the latter began to fall off the total for the whole State declined correspondingly.

Eureka.—The lead deposits of Eureka occur in a zone of much faulted and crushed limestone of Cambrian age, which dips at a steep angle and lies between formations of shale and quartzite. Crossing these stratified rocks are dikes and intrusive masses of quartz-porphyry and rhyolite, which were influential in the deposition of the ore. The latter is found in fissures, crevices, and caves in the crushed limestone. The ore was oxidized to a depth of about 1000 ft., below which sulphides appeared.

The chief producers of lead in Eureka were the Eureka Consolidated Mining Company and the Richmond Consolidated Mining Company, both of which paid large dividends. Their ore was smelted at works in Eureka, and the base bullion was refined there also. The furnaces of the Eureka Company make brief campaigns now, but the output of the district has become insignificant, though a good strike in the Diamond mine two years ago helped to maintain it. There is not much prospect, however, that Eureka will again be a large producer of lead.

NEW MEXICO.—The most important lead-mining districts of New Mexico are Cook's Peak, Lake Valley, and the Magdalena Mountains. The total production of the Territory has averaged recently about 4500 tons per annum.

Cook's Peak.—This district, which has been an important producer of lead ore during the past few years, is situated in Grant County, about nine miles north of Florida, on the Atchison, Topeka & Santa Fé Railroad. The property of the Cook's Peak Mining Company has made the largest output. This mine is opened on a fissure vein in porphyry, which has been developed by five levels, the lowest being 525 ft. deep. The ore, which is galena, is divided into two classes, the second of which is dressed. The average grade of the ore shipped from Cook's Peak during the past two years has been 43% lead, 61.6 oz. silver, and 0.08 oz. gold.*

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* *Engineering and Mining Journal*, Jan. 6, 1894, p. 15.

Lake Valley.—The mines of Lake Valley, in Doña Aña County, are opened on deposits of silver-lead ore in the bedding planes of limestone, probably of Subcarboniferous age, and at the contact between it and various igneous rocks.* Carbonate of iron is associated with the ores. The mines are owned chiefly by the Silver Mining Company of Lake Valley, a Philadelphia corporation, which has paid $310,000 in dividends since 1887.

Magdalena Mountains.—There are bodies of oxidized lead ores forming a contact deposit between slates and porphyries in the Magdalena Mountains, 30 miles west of Socorro, which have supplied the smelting works at that place. The ore of this district averages 25% lead and 8 oz. silver per ton.†

UTAH.—Utah has numerous lead mines, and follows Colorado and Idaho as the most important lead-producing region of the Rocky Mountains. The most productive mines of the Territory are situated in Bingham and the Cottonwood cañons and the adjacent districts in Salt Lake County. The famous Horn Silver mine, in Beaver County, maintains a large output, and a considerable amount of lead ore and concentrates is obtained from the great silver veins at Park City. The ore of the Tintic district, Juab County, contains a small amount of lead, but it is of a refractory character, and is not important as a source of supply to the smelters. Utah has a great lead-smelting industry, which is centered at Salt Lake City, the small works scattered through the State at isolated points, of which there were a great number in the early days, having experienced the same fate as those similarly situated in other parts of the Rocky Mountains. It is not easy to arrive at the statistics of the output of lead in Utah during recent years, since the smelters of the Territory reduce much ore from Nevada and Idaho, which is not credited to those States in their bullion statements. The figures for Utah in the general table accompanying this article, therefore, are largely estimated.

Bingham.—The Bingham district of Utah, including the mines of Bingham and Big and Little Cottonwood cañons, is the most important lead-producing area of that Territory, the smelters of Salt Lake City and vicinity being primarily dependent upon it for their lead supply. These mines are situated in cañons leading into the Oquirrh and Wasatch mountains, a short distance to the southwest and southeast of Salt Lake City, in Salt Lake County. The rock formations of this region are much broken by great faults and intrusions of igneous rock. The ore occurs in bed-veins in Carboniferous limestone, or at the contact of the limestone and the underlying quartzite, in belts which are often of considerable extent, with here and there enormously rich bonanzas like those worked in the Emma, Flagstaff, and other mines famous twenty years ago. These have been long since exhausted, however, and the output of the district is now made from small bodies of low-grade ore, much of which requires a preliminary dressing before shipment.

The ores of the Bingham district were oxidized silver-lead ores above the water-level, changing to galena and pyrite with depth. The production of the district during the past year (1893) has been about 100 tons per day, the average grade of the whole being 25% lead and 12 oz. silver per ton. The Old Jordan

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* J. F. Kemp, *op. cit.*, p. 181. † Hofman, *Metallurgy of Lead*, p. 40.

and Galena Mining Company ships two-thirds of the entire output. The other principal producers are the Old Telegraph mine (owned by the Société Anonyme des Mines de Lexington), the Niagara Mining and Smelting Company, the York, Brooklyn Group, Petro, Sampson, and Yosemite No. 2. Many of these closed down when silver dropped in the middle of the year, and have not since resumed operations. Others have worked intermittently, starting up with a rise in the value of lead, and closing down again when the market took an unfavorable turn.

Frisco.—The Horn Silver mine at Frisco, in Beaver County, is opened on a great contact vein between rhyolite (hanging wall) and limestone, which is known to extend for two miles, but is valuable only within the Horn Silver lines. The vein strikes north and south and dips 70° east. It varies in width from 20 to 60 ft., but has pinched twice in going down. The mine has now been opened to a depth of 1100 ft. and on the 700 level for a distance of 1500 ft. along the strike of the vein. The ore is chiefly a silver-bearing anglesite with considerable barytes, averaging at present about 25 oz. silver per ton and 30% lead. The Carbonate mine, two and a half miles northeast of Frisco, opened on a vein in hornblende andesite, and the Cave mine, which has irregular pockets of lead-bearing limonite (containing from 5% to 7% lead) in limestone, have been small producers.

The Horn Silver Mining Company is now (January, 1894) building dressing works of the estimated capacity of 100 tons per twenty-four hours, which are nearly completed. They will treat the low-grade ore of the mine, averaging 10 oz. silver per ton and 15% lead, of which there are large reserves.

Park City.—The great veins of Park City, in Summit County, carry silver-bearing galena ores together with the silver-milling ores, and in the Ontario and Daly mines the two classes are separated by sorting, the lead ores being shipped directly to the smelting works. The Crescent, Anchor, Woodside, and other veins in Park City have silicious lead ores which are dressed, the galena concentrates being shipped to the lead smelters. The average grade of the lead ore produced in Park City, including the concentrates and the selected ores, is about 30% lead; the total production of lead in the district is about 4000 tons per annum.

Stockton.—Bed veins of oxidized silver-lead ores are found in the Carboniferous limestone, or between it and the underlying quartzite, near Stockton, in Tooele County. These deposits occur in Ophir and Dry cañons, on the west side of the Oquirrh Range, just over the divide from the Bingham district. The principal mine is the Honorine, which was formerly a large producer, paying dividends, but is no longer of much consequence.

LEAD IN FOREIGN COUNTRIES.

AUSTRALIA.—Lead is found in all the colonies of Australia, but only the silver-bearing ores are worked. In Western Australia there are immense lodes of lead sulphide and carbonate ore, very rich in lead but low grade in silver. Attempts have been made to work them, the Government having offered a bonus of £10,000 for the first 10,000 tons of lead smelted in the colony, but so far these have been unsuccessful. The most promising mines of the colony are situated in the Northampton district, between Geraldton and Murchison. In Tasmania silver-lead ores are found in the western part of the island, in the Mount Zeehan and Dundas districts, which are now beginning to be productive, their inaccessibility having checked their development hitherto. Northern Queensland has some silver-lead mines, but their output is insignificant. The great lead-producing colony of Australia is New South Wales, where is situated the famous Broken Hill district, besides which there are less important mines at Silverton and Leadville.

Broken Hill.—This is at present the largest lead-producing district of the world, its output alone exceeding the total yield of any other country, with the exception of Spain, the United States, Germany, and Mexico. The great lode was first discovered in September, 1883, but owing to the poverty of the outcrop and the difficulty of transportation, the mines being 300 miles distant from Adelaide, South Australia, it was not until 1886 that they began to be productive. In less than five years, however, their annual output exceeded 50,000 long tons.

The Broken Hill ore deposits occur in an immense vein in crystalline schists.* The lode makes a slight angle with the dip of the country rock, but apparently agrees with it in strike. The schist, which forms the country rock, is for the most part fine grained but is sometimes gneissose in character, and at other times is silicified to a quartzite; garnetiferous sandstone also occurs. The walls of the lode are irregular, though the foot is the better. Included portions of the country rock are common, and at one point the lode is split by the schist. This has led to the suggestion that the lode is a "saddle reef."

Above the water level the Broken Hill ore is principally lead carbonate, assaying high in silver, and mixed with manganiferous iron-stone, which makes it an easy smelting ore. Ores of other kinds, however, like the curious kaolin ore, which contains no lead but is often extremely rich in silver chloride, are found in the lode. Below the water level the ore changes in character to a mixed sulphide of lead and zinc, carrying silver, in which a distinct mineral can only be detected with difficulty by the naked eye. The sulphide ores are of comparatively low grade and of very refractory character, containing for the most part only from 16 to 18 oz. silver per ton, and 20% to 25% lead, with 15% to 20% blende. Their treatment has been a problem on which metallurgists in all parts of the world have been engaged, but no satisfactory method has yet been devised.

The principal producer at Broken Hill is the Broken Hill Proprietary Company, Limited, whose property originally consisted of seven 40-acre blocks, numbered from 10 to 16, inclusive. When its value had been proved, Blocks 15 and 16 were sold in London to the British Broken Hill Company, the parent company receiving £576,000 in cash and £400,000 in full-paid shares. The British Broken Hill Company has also been a large producer. Other parts of the property were sold to the Block 10 Mining Company, Block 14 Mining Company, etc. At the present time the ten most important companies operating in the field are the Broken Hill Proprietary, British Broken Hill, Broken Hill Consolidated, Block 10, Block 14, British, Central, Junction, Junction North, South Broken Hill, and Australian Broken Hill Consols. Five of these companies produced more

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*T. A. Rickard, *Engineering and Mining Journal*, Nov. 7, 1891, p. 530.

than 2000 long tons (2240 lbs.) each of lead in 1892, and four of them made a silver product greater than 1,000,000 oz.

Austria-Hungary.—The principal lead-producing districts of Austria are situated in the Kingdom of Bohemia and the Province of Carinthia, the mines of Przibram being the most important in the former, and those at Raibl and Bleiberg in the latter. Most of the lead produced in Hungary comes from the mines of Schemnitz.

Carinthia.—The ore deposits of Raibl and Bleiberg, near Villach, are bed-veins in Triassic limestone, the ores occurring in channels of considerable continuity and extent in the vicinity of slates, which are bedded with the limestone. The ores are galena associated with lead carbonate, calamine, and blende. It is considered probable by Professor Posepny, who first explained truly the geological structure of these veins, that the ore-channels will be found at the slate-limestone contact when greater depth is gained. The mines stretch along the valley of the Nötsch, between Bleiberg and Kreuth, a distance of about fifteen miles. The chief producers of lead in Carinthia are the Bleiberg Bergwerks-Union, Count Henckel von Donnersmark, and the State, which operates both mines and smelting works. The production of lead ore in the province in 1892 was about 7500 tons, the yield of metal being 4965 tons. The crude ore of Bleiberg averages 8% lead, and is dressed to a product assaying 71%.

Przibram.—The mines of Przibram are situated southwest of Prague, in the interior of Bohemia. The country rock of the region is greywack slate of lower Silurian age, resting on granite and overlain by sandstone, slate, and sandstone, in the order named. The country is intersected longitudinally by dikes of diabase of great extent, which cut through the first sandstone and the second slate. It has been demonstrated by the Austrian geologists that these dikes have had an important bearing in the deposition of the ore in the fissures in the sandstone in their vicinity. The total number of veins which have been worked at Przibram is 40, but only a few of them have been important. The richest is the Adalbert, which is known to extend 1300 meters on its strike and 1050 meters on its dip, the maximum width having been 8 meters.

The filling of the Przibram veins consists of silver-bearing galena, zincblende, siderite, quartz, and calcite. The crude lead ore averages about 20% lead, and is dressed to a product assaying 37% to 38% lead and 75 oz. silver per ton. The total output of dressed lead ore in Bohemia (chiefly Przibram) in 1892 was 2106 tons, the production of lead being 1442 tons.

It should be noted that the mines of Przibram are the deepest in the world. The Maria shaft is down 1129 meters (3704 ft.), while the Adalbert is over 3600 ft. deep. The Franz Joseph shaft when completed will be 1295 meters (4294 ft.) deep. According to the records these mines have been worked since 1330, but it is thought that they were opened as early as the ninth century. They are operated by the State.

Belgium.—Lead ore was formerly produced in considerable quantity in Belgium at the Nouvelle Montagne, near Verviers, where galena mixed with blende and calamine occurred in pear-shaped bodies in a fissured zone in Carboniferous limestone. Formerly 10,000 or 12,000 tons of lead ore were produced from this district annually, but during the past ten years the output has been decreasing steadily, until at present it is insignificant. The production of lead which is credited to Belgium in the statistical tables is derived chiefly from foreign ores, which are reduced at the great smelting works at Hoboken, near Antwerp.

France.—Lead has been mined in France at Savoy, at Bretagne (where many remains of old silver-lead mines are found), at Poullaouen and Huelgoat in Vendée, and at other places, but the only mines of consequence at the present time are those of Pontgibaud and Pontpéan, in the Puy-de-Dôme. The ores mined at these points are smelted chiefly at Cöueron, but imported ores are also treated there. A good deal of Spanish, Italian, and Grecian base bullion is brought into France for desilverization, but this is not included in the statistics of production, which give only the yield of silver-lead bullion from ores smelted in the republic.

Pontgibaud.—The Pontgibaud district is situated on the left bank of the Sioule, about 12 miles west of Clermont, and extends 8 or 9 miles in a north and south direction. The country rock is chiefly mica-schist and gneiss, covered in many places by extensive flows of basalt, and traversed by many veins of granulite, and a few of porphyrite, in addition to the lodes. The principal mines of the district are those at Pranal in the north, La Brousse in the center, and Rosier and Roure in the south, the last being the most productive.

In the Pranal mines the work carried on at present is on the St. Mathieu lode, which has been worked to a depth of 360 ft. and has been productive over a length of 3000 ft. The vein-filling in the productive parts averages from 5% to 6% lead; the lead yields 80½ oz. silver per ton. The ore is galena mixed with blende; the percentage of the latter mineral appears to increase with depth. The Brousse lode, opened to a depth of 800 ft. and for a length of 3000 ft., has been one of the most productive in the Pontgibaud district. South of La Brousse are the Mioche, La Grange, and St. Denis mines, which have been abandoned, and the Rosier mine, opened on a continuation of the Mioche-Grange lode, which extends into the Roure mine, where it is known as La Agnès.

The Roure mine has been worked almost entirely during the last forty years. Its works extend 5500 ft. north and south, cover a breadth of 1600 ft., and attain a depth of 800 ft. below the adit level. The principal lodes are the Agnès, to the west, and Virginie, to the east, which dip toward each other and should meet at a depth of 1600 to 2000 ft. There are several branch lodes, which are in many cases very productive. The filling of the Virginie lode averages 6% to 8% lead and 96½ oz. silver per ton of lead. This deposit is in places 100 ft. thick; it is practically unexplored from the 325 to 725 ft. level, but at the latter it is poor. The Agnès lode was continuously productive over a length of 1600 ft., but only to a depth of about 200 ft. The vein matter was 10 to 13 ft. thick, and yielded an average of 10% lead, but it was not so rich in silver as the Virginie.*

Germany.—Germany, which was formerly the chief source of the world's supply of lead, and at present ranks third among the countries producing it, maintains a steady output of about 100,000 tons per annum, this being the product of the smelting works and including the metal brought into the empire in the foreign ores, which are reduced principally at Stolberg, Freiberg, and in the

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* Lodin, "Études sur les Gîtes Métallifères de Pontgibaud," *Annales des Mines*, 1892.

Harz. Lead ores are imported chiefly from Austria-Hungary, Belgium, France, Sweden and Spain, while some rich silver ore comes from South America, Mexico, and Australia. The chief lead-producing districts of Germany are Mechernich, the Upper and Lower Harz, Freiberg, Upper Silesia, the Lahnthal, and the Prussian frontier in the vicinity of Aachen, whence the ores are taken to Stolberg for treatment.

PRODUCTION OF LEAD ORE IN GERMANY.

(In metric tons; values in thousands of dollars, converted from marks at the rate of $1=4 marks.)

Year.	Silesia.		Harz Mountains.		Rhineland.		Total.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.	Amount.	Value.
1872	13,905	$688	20,725	$952	41,969	$1,443	94,037	$3,758
1873	13,709	749	23,472	1,054	46,968	1,829	101,270	4,435
1874	16,287	990	20.708	892	47,839	1,771	104,088	4,569
1875	16,428	1,091	25,950	1,151	48,629	1,817	113,808	5,260
1876	17,844	946	28,880	1,082	50,470	1,915	120,603	5,097
1877	18,198	938	34,135	1,041	64,283	2,435	147,012	5,681
1878	17,390	739	33.435	995	67,078	2,366	152,843	5,266
1879	16,187	497	36,824	1,013	61,983	1,881	149,055	4,461
1880	17,766	643	41,344	958	61,352	1,903	159,726	4,780
1881	21,084	773	42,787	994	65,952	1,976	164,771	4,810
1882	24,256	876	45.812	998	70,811	2,123	177,656	5,155
1883	24,821	826	45,118	870	63,826	1,779	169,754	4,523
1884	25,860	773	42,977	770	56,670	1,437	162,772	3,935
1885	26,319	762	43,626	729	55,761	1,415	157,869	3,773
1886	29.316	912	46,425	768	53,102	1,471	158,505	3,980
1887	28,697	892	44,638	748	57,040	1,564	157,570	3,981
1888	29,223	838	43,310	747	59,147	1,741	161,777	4,171
1889	32,116	915	45,888	737	61,230	1,862	169,569	4,432
1890	32,504	926	47,787	766	60,083	1,851	168,234	4,524
1891	27,616	743	46,347	695	57,550	1,798	159,215	4,164
1892	27,878	661	48,032	528	56,720	1,570	163,372	3,672
1893	....	....	....	....	....	....	....	....

PRODUCTION OF LEAD IN GERMANY.

(In metric tons.)

Year.	Westphalia. Rhineland.	Nassau.	Harz.	Upper Silesia.	Saxony.	Total.
1880	47,882	8,464	10,159	13,596	6,107	89,066
1881	49,156	8,493	9,852	14,279	4,494	90,340
1882	52,165	8,979	11,026	15,793	5,990	96,137
1883	50,972	8,414	10,348	16,269	5,742	94,965
1884	51,998	9,373	10,809	18,173	5,923	98,743
1885	49,517	8,509	12,099	20,169	4,525	96,483
1886	45,819	*a*9,000	*a*12,500	22,870	4,780	95,621
1887	45,946	9,866	13,264	24,582	4,573	98,478
1888	47,360	11,562	13,723	22,133	5,783	100,652
1889	49,045	11,402	12,942	21,081	6,572	103,740
1890	47,876	12,240	13,941	21,673	6,583	104,958
1891	43,745	13,455	13,564	20,010	5,731	98,114
1892	45,084	14,113	13,054	20,158	7,162	100,710
1893	....	....	....	....	....	....

The figures for Rhineland and Westphalia in the above table are from the reports of the *Verein für die Berg- und Hüttenmännischen Interessen im Aachener Industrie-Bezirk*, and those for Upper Silesia are from the *Oberschlesische Berg- und Hüttenmännische Verein*. The Saxon figures are from the *Jährbüche für das Hüttenwesen im Königreich Sachsen*, and include the sales of lead and all lead products. Litharge, calculated at 80%, is also included in the Silesian figures. The latter do not, however, include a few hundred tons of lead won annually as a by-product at the zinc works. The totals are from the official statistics of the German Empire as calculated in the table on the second page of this article. The figures marked (*a*) are estimated.

Freiberg.—The Erzgebirge in Saxony forms one of the classic regions in the history of the mining industry. Its mines, which are grouped in the neighborhood of Freiberg, are important producers of lead, their annual output amounting to between 5000 and 7000 metric tons per annum.* The mines are opened on

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* Product of the smelting works, which exceeds that of the mines on account of the foreign ore smelted.

veins in gneiss, which are more than 900 in number. These veins are divided into groups, one of which, containing between 300 and 400 veins, is known as the "Precious Lead Group," in which the ore consists of galena rich in silver, together with blende, pyrite, and arsenopyrite, spathic iron, and a gangue of quartz. The ore hoisted is chiefly low grade and has to undergo a preliminary dressing, which is carried out with a degree of skill that has made the Freiberg practice famous the world over. In 1890 a new central dressing works was built at the Himmelfahrt mine, and now most of the ore is concentrated there.

The mineral treated in the Himmelfahrt works averages 2.75% lead, 0.275% zinc, and 230 grams of silver per ton of ore, with 0.5% arsenic, 0.01% copper, and 5% sulphur. The galena concentrates contain as much as 85% lead and 3000 grams of silver per ton; the blende concentrates assay 40% zinc and 300 grams silver per ton; while the pyritous concentrates have 40% sulphur and 500 grams of silver per ton. The loss in dressing amounts to 21% of the silver, 38% of the lead, and 60% of the sulphur. The cost of dressing is $2.33 per ton of crude ore.*

The lead concentrates are smelted in Pilz furnaces at the great Halsbrücker and Muldner works near Freiberg, the silver-lead bullion produced being desilverized at the same works. There are also connected with the works a rolling mill and a pipe and shot factory, so that some of the lead produced is marketed as finished products. In addition to the domestic ores mineral is imported from foreign countries, even from Chile and Australia, and smelted at these works, the lead production of which consequently is higher than that of the mines of Freiberg proper. Both the mines and the works are operated by the Saxon Government.

Freihung.—The mines of Friehung, in the upper Palatinate of Bavaria, are opened in a deposit which Von Cotta considered analogous to that of Mechernich. There is a bed of sandstone, dipping steeply, impregnated with cerussite and galena. These mines were formerly operated by an English corporation, the Bavarian Lead-Mining Company, Limited, but the enterprise failed, and after one reconstruction went into liquidation.

Lower Harz.—The lead produced in the Lower Harz is derived chiefly from the famous Rammelsberg mine, near Goslar, which was first opened in the tenth century, and has been worked more or less continously since that time. The mine is opened on a great body of ore lying in a bedding place of the clay slates, which form the country rock. The channel of ore was 1900 ft. wide and 150 ft. thick at its maximum development. At a depth of 800 ft. the width was 750 ft. and the thickness 20 ft. The ore is a mixture of zincblende, galena, copper-bearing pyrites, and heavy spar. It is sorted at the mine into two classes: (1) copper ore, averaging from 8% to 10% copper, and (2) lead-zinc ore, averaging about 12% lead and 25% zinc. The copper ore is shipped to the smelting works at Oker for reduction, while the lead-zinc ore goes to the Sophienhütte at Langelsheim and the Juliushütte at Astfeld. The lead-zinc ore shipped to these works has the following composition:† Blende, 36%; pyrite, 24%; barite, 16%; galenite, 14%; chalcopyrite, 1.5%; gangue, 8.5%—total, 100%. It is roasted in

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* M. Bellom, "Préparation Mécanique des Minerais dans la Saxe, le Hartz, et la Prusse Rhénane," *Annales des Mines*, 1891, 4, pp. 81, 91.

† H. O. Hofman, *Engineering and Mining Journal*, Oct. 21, 1893.

heaps and then leached with water in revolving wooden barrels to extract the zinc sulphate. The latter, as obtained, has the following composition: ZnO, 25.45%; MnO, 2.32%; FeO, 0.47%; SO_3, 29.54%; H_2O, 41.67%; CuO, trace—total, 99.45%. The leached ore, containing 9% PbO, 25% ZnO, 25% Fe_2O_3, 5% S, 20% $BaSO_4$, 0.75% Cu, and 0.015% Ag, is smelted in blast furnaces. The slag produced in this operation has a very peculiar composition, as is shown by the following analysis: SiO_2, 16.90%; FeO, 35.05%; ZnO, 19.64%; $BaSO_4$, 10.24% (8.13% BaS); Al_2O_3, 6.31%; CaO, 6.0%; Pb, 0.50% to 0.75%.

Mechernich.—This district, situated on the north edge of the Eiffel Mountains, embraces a zone about 4¼ miles (7 kilometers) long, extending through Call, Keldenick, Mechernich, and Strempt. The ore occurs in a bed of sandstone, somewhat porous, which is impregnated with small concretions of galena (*knoten*). This bed of sandstone (*knotensandstein*) lies on a layer of conglomerate, which separates it from the Devonian rocks below, and is covered by another layer of conglomerate, the *Wackendeckel*, above which is barren red sandstone. Several layers of conglomerate are intercalated with the ore-bearing sandstone; the layers of the latter are united, however, in the Meinerzhagen grant, where they form a bed 72 ft. (22 m.) thick.

The ore-bearing sandstone contains from 0.5% to 3% lead and 0.03 to 0.18 oz. silver (1 to 6 grams) per metric ton. In 1889, according to the official report of the Mechernicher Bergwerksverein, the ore averaged 2.371% lead, while in 1890 the average was 2.318%, and in 1891 it fell to 2.210%. The ore is dressed to a product assaying about 70% lead and 235 grams silver per ton. In 1890 the concentrates produced amounted to 36,245 metric tons, and yielded 24,083 tons of lead, or 66.4%, together with 8.195 kilograms (216,824 oz.) of silver, which was equivalent to 226 grams per ton of concentrates, or 340 grams per ton of lead. The output of concentrates in 1891 was 32,526 tons, yielding 21,550 tons of lead and 27,061 kilograms of silver, while 32,771 tons of concentrates were produced in 1892, from which 22,010 tons of lead and 33,459 kilograms of silver were obtained. In 1893 the production of lead ore was 35,365 tons, lead 20,250 tons, and silver 14,550 kilograms. The Mechernich Company smelts some foreign silver and lead ore, having reduced 11,819 tons, valued at 343 marks ($86) per ton, in 1892, and 7871 tons, valued at 153.5 marks ($38.40), in 1893.

The mines of the Mechernicher Bergwerksverein are worked through two shafts, the Virginia and the Schafsberg, and at times also by open cast. The open-cast working was discontinued in 1882, but was resumed in 1887; in the autumn of 1891 it was restricted on account of the great cost of removing the overlying earth, and in 1892 was discontinued again, the low price of lead having made it unprofitable. At the smelting works of the company 14 roasting furnaces and 7 blast furnaces are usually in operation. Formerly an average of 3000 men was regularly employed, but within the last two years the number has been reduced. At the beginning of 1891 there were 3048 men on the pay-roll, while at the end there were only 2827, the average number for the year being 2960; at the end of 1892 the number had been reduced to 2557, the average for the year being 2605.

The decline in the value of lead, together with the decrease in the lead tenor of its ore and the increased cost of working, has affected the Mechernich company very seriously. The increasing competition of foreign lead, moreover, especially that of Australia, has made it almost impossible for it to sell in France, Belgium, and Holland, which formerly took about one-third of its production. At the same time the importations of foreign lead into Germany have been increasing rapidly.

The reports of the Mechernicher Bergwerksverein contain interesting data, from which figures as to its cost of production may be deduced. In 1889 the wages paid amounted to 2,071,348 marks ($492,981), while in 1890 and 1891 the amounts were 2,095,816 ($498,804) and 2,140,118 marks ($509,348), respectively. The profits of the company in 1890 were 2,057,906 marks ($489,782). After writing off 475,009 marks ($113,052) the net profits were 1,582,806 marks ($376,708), out of which donations to the workmen's relief funds, etc., were paid and a dividend of 1,440,000 marks ($342,720), or 15% on the capital stock of the company (9,600,000 marks, or $2,284,800), was declared. In 1891 the net profits were only 842,610 marks ($200,541), and the dividend declared was only 8%, amounting to 768,000 marks ($182,784).

Besides the works of the Mechernicher Bergwerksverein there are in the Eiffel those of A. Poensgen & Söhne, at Call, which employ 140 men and produce about 4600 tons of lead per annum.

Nassau.—There is an important lead-producing district in the valley of the Lahn, Duchy of Nassau, where a series of remarkably strong lead-bearing veins are found in a graywacke, belonging to the lower Devonian formation. There are two great veins on which a number of mines are opened. One of these extends from a point near St. Goar, on the west bank of the Rhine, to Holzappel, on the Lahn, at which point the vein is richest, a distance of nearly eight miles.* Another, the Ems vein, extends from Braubach, on the Rhine, across the valley of the Lahn to Deerbach, near Montabaur. The most important mines are those situated at Holzappel belonging to the Rheinisch-Nassauische Bergwerks- und Hüttenactiengesellschaft, those near Ems owned by the Emser Blei und Silberwerke, and the mine of the Silber und Bleibergwerk "Friedrichssegen" at Friedrichssegen. The mines at the first mentioned place have been worked since 1785. They are opened by a cross-cut tunnel 1600 meters (5248 ft.) long, which, then changing its course, follows the vein for 3500 meters (11,480 ft.) more.

The ore of the Lahnthal veins is a complicated mixture of silver-bearing galena, zincblende, and spathic iron, with a gangue of quartz, calcite, and heavy spar. It is concentrated, before shipment, in the dressing works at Laurenberg, Silberau, and Friedrichssegen, which are among the largest of their kind in Germany, the works at Silberau, near Ems, being especially noteworthy. The ore dressed at these works contains 4% lead, 2.5% zinc, and 54 grams silver per metric ton. The galena is concentrated to 36% lead, with 300 grams silver per metric ton, and the blende to 44.5% zinc; the blende does not carry silver. The loss in dressing is 8% for silver, 6% for lead, and 34% for zinc. The cost of dressing is about 85c. per metric ton of crude ore.† The concentrates produced in the Lahnthal are smelted partly at the works of Remy Hoffman near Ems, and

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*John W. Meier, *Engineering and Mining Journal*, Oct. 29, 1892, p. 414.

†M. Bellom, "Préparation Mécanique des Minerais dans la Saxe, le Hartz, et la Prusse Rhénane," *Annales des Mines*, 1891, 4, pp. 82, 91.

S. B. Goldschmidt at Braubach am Rhein (the former producing about 5500 metric tons of bullion per annum, and the latter a trifle over 8000 tons), and are partly shipped to Stolberg for reduction.

Upper Harz.—The most important mines of this district are at Clausthal, Lautenthal, and Grund. The ore occurs in veins in zones of crushed slate, 65 to 262 meters (20 to 80 ft.) wide and extending about 9 miles (15 kilometers) longitudinally, in which the ore bodies are irregularly distributed. The rocks of the ore zones are called vein-clay-slates (*gangthonschiefer*), to distinguish them from the ordinary slates (*culmschiefer*) of the district. Recent investigations have shown, however, that their composition is practically identical,* the former having been derived from the latter, for the most part, by mechanical alteration due to the action of the great faults which traversed the district.

All the ore of the Harz is dressed before smelting, the crude ore from the mines averaging about 9% lead. The dressing works in this district are famous for their completeness in design and thoroughness in detail. Those at Clausthal are the largest in Germany. The concentrates produced contain from 55% to 50% lead and 23 to 30 oz. silver per ton. They are smelted chiefly at Silberhütte, near Clausthal, at Lautenthal, and at Altenau. An average sample of all the ore smelted at Clausthal in 1889 showed the following composition: Galenite, 74.09% (Pb 64.13%, S 9.91%); argentite, 0.10% (Ag 0.085%, S 0.015%); stibnite, 0.80% (Sb 0.58%, S 0.22%); chalcopyrite, 1.15% (Cu 0.40%, Fe 0.35%, S 0.40%); sphalerite, 7.46% (Zn 5.00%, S 2.46%); pyrite, 0.60% (Fe 0.28%, S 0.32%); siderite, 2.27% (FeO 2.41%, CO_2 0.86%); rhodochrosite, 0.48% (MnO 0.30%, CO_2 0.18%); magnesite, 0.35% (MgO 0.17%, CO_2 0.18%); calcite, 1.71% (CaO 0.96%, CO_2 0.75%); gypsum, 1.92% (CaO 0.62%, SO_3 0.90%, H_2O 0.40%); barite, 0.00%; alumina, 1.32%; silica, 8.57%—total, 100.77%.† The ore is smelted raw in circular and oblong blast furnaces 12½ ft. high from center of tuyères to charging door and 3½ ft. wide at the tuyère level, with a pressure of 1 in. quicksilver. Water-jackets are not used as yet. The production of concentrates in the Upper Harz in 1892 amounted to 11,053 tons of galena and 8492 tons of blende, against 13,260 tons of galena and 9405 tons of blende in the previous year. Out of this there were produced 7690 tons of lead in 1892 and 8209 tons in 1891. The Harz lead is famous in Germany for its purity. The blende concentrates are shipped to the zinc works of Westphalia for reduction.

Upper Silesia.—The country in the neighborhood of Beuthen is the second largest lead-producing district of Germany. The lead ore is found in connection with the vast deposits of calamine and blende on which the great zinc industry of the province is based. There are two bed-veins, of great strength, in dolomite of the Muschelkalk formation, dipping at a gentle angle. The vertical distance between the two varies from 12 to 25 meters. Zinc ores are obtained chiefly from the lower, but streaks of galena are scattered through the blende and calamine. The upper bed, which is known as the lead vein, contains a layer of lead ore varying from 0.05 to 0.3 meter in thickness, but sometimes reaching as much as 2 meters. The ore is galena and cerussite, lying on low-grade red calamine and limonite. It is rich in lead and zinc, but low grade in silver, and is smelted in

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* Posepny, "The Genesis of Ore Deposits," *Trans. Amer. Inst. Min. Engineers*, Vol. XXII., 1893.

† H. O. Hofman, *Engineering and Mining Journal*, Oct. 21, 1893.

reverberatory furnaces, by the well-known Tarnowitz process, for base bullion and a rich residue. The latter is then treated in blast furnaces together with ore not suited for the reverberatory furnaces. There are two lead-smelting works in Upper Silesia—the Friedrichshütte at Tarnowitz, and the Walther-Croneckhütte at Rosdzin. A small amount of lead, less than 1000 tons per annum, is recovered as a by-product by the zinc smelters. The total production of lead in Upper Silesia amounts to 18,000 or 20,000 metric tons per annum.

PRODUCTION OF LEAD IN UPPER SILESIA.
(In metric tons.)

Year.	Lead.	*Lead in Litharge.	Total.	Year.	Lead.	*Lead in Litharge.	Total.	Year.	Lead.	*Lead in Litharge.	Total.
1861..	1,414	1,000	2,414	1872..	7,663	1,001	8,664	1883..	14,715	1,554	16,269
1862..	2,972	774	3,746	1873..	7,901	1,061	8,962	1884..	16,755	1,418	18,173
1863..	2,905	739	3,644	1874..	9,107	1,278	10,385	1885..	18,558	1,611	20,169
1864..	3,143	796	3,939	1875..	10,469	1,514	11,983	1886..	20,879	1,991	22,870
1865..	5,513	505	6,018	1876..	12,891	1,295	14,186	1887..	22,279	2,303	24,582
1866..	5,628	576	6,204	1877..	12,287	1,190	13,477	1888..	20,073	2,060	22,133
1867..	5,071	662	5,633	1878..	11,905	1,678	13,583	1889..	19,520	1,561	21,081
1868..	5,583	613	6,196	1879..	11,586	1,190	12,776	1890..	19,622	2,051	21,673
1869..	5,852	1,156	7,008	1880..	12,694	902	13,596	1891..	18,429	1,581	20,010
1870..	7,404	1,207	8,611	1881..	13,939	1,340	15,479	1892..	18,346	1,815	20,161
1871..	7,698	1,270	8,958	1882..	14,541	1,252	15,793	1893..	....	....	....

*Reckoned as 80% of the production of litharge.

GREECE.—The only important lead mines in Greece are those at Laurium, which were first opened thirty centuries ago. In 1860, after seventeen centuries of neglect, they were reopened by a French company, which had obtained a concession for their exploitation from the Grecian Government. The successor of this company—the Société des Usines du Laurium—and the Compagnie Française des Mines du Laurium, also a French concern, are the chief operators at Laurium at the present time.

The geological formation of the Laurium region consists of alternate sheets of mica-schist and limestone, at the contact of which the ore occurs in beds. The surface rock is limestone, below which come mica-schist, limestone, mica-schist, limestone, mica-schist, and limestone, in the order named, the last being of unknown thickness. There are four contact veins, the lowest being from ½ meter to 12 meters thick. The limestone between the contact veins is frequently impregnated with mineral, and sometimes contains irregular ore bodies.

The lead of Laurium occurs in the form of galena and cerussite, the former associated with blende and pyrites, and the latter with the oxides of iron and manganese. The ore is argentiferous, its silver contents averaging from 1.5 to 4 kilograms per ton of lead.

The ores worked at present are of two classes: (1) Ancient slags and refuse, rejected or imperfectly treated by the ancients, and (2) new ores. The amount of refuse ore belonging to the Société des Usines du Laurium has been estimated, by M. André Cordella, director-general of the company, to be 105,000,000 metric tons, containing from 4% to 8% lead and 1000 to 1300 grams of silver per ton of lead, but it is understood that hardly one-tenth of this can be extracted without great care. The old slags are reckoned to amount to about 2,500,000 tons, containing 10.5 lead.* Part of the old slag that is worked by the company

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* A. Cordella, *The Mining and Metallurgical Industries of the Laurium*, for the exhibition at Chicago.

is obtained by dredging in the adjacent sea, about 40,000 metric tons per annum being won in this manner at a cost of 7 drachmas ($1.35) per ton.

The low-grade ore of the Société des Usines du Laurium is dressed at Ergasteria (near Laurium) in a new mill completed during the past year (1893). This is the largest dressing works in Europe, its capacity being from 1000 to 1200 tons per day. Ore assaying from 3.5% to 4% lead is concentrated to a product assaying 20% to 23% lead.

The concentrates are smelted in Pilz furnaces, of which there are fourteen, treating about 130,000 tons per annum, and producing 10,000 to 10,500 tons of lead. Most of the bullion of this company is exported for desilverization, but a small refinery connected with the works turns out from 500 to 1000 tons of soft lead annually for domestic use.

The second largest producer of lead in Greece is the French company of Laurium, which controls the entire central area of the district (54,000 acres) and employs 3500 to 3800 men. The main business of this company is zinc mining, but it also produces lead and manganese. The lead smelter, situated at Cypriano, adjoining Laurium, has 9 furnaces and produces about 5000 tons of bullion per annum. A small quantity of high-grade galena ore is exported for reduction.

ANALYSES OF PRODUCTS SMELTED AT LAURIUM.*

No.	Products.	Pb %	Ag Ozs. p. t.	Fe %	SiO_2 %	Zn %	CaO %	Al_2O_3 %	As %	Sb %	Cu %	Mn %
1	Ancient land slags from Barbaliaki..	10.70	17.78	11.90	33.80	5.40	13.80	3.90	....	......	......	......
2	Sea slags from Brysakia............	11.50	13.12	12.30	26.50	5.60	14.70	3.60	....	......	......	......
3	Sea slags conglomerated	8.50	13.99	10.30	27.00	4.80	14.50	3.40	....	......	......	......
4	Sea slags with lead and litharge.....	13.50	11.37	10.50	32.00	5.00	13.00	3.80	....	......	......	......
5	Slags with laurionite	10.00	11.23	10.50	30.00	5.00	15.00	3.80	....	......	......	......
6	Litharge............................	65.00	3.59	......	......	......	......	......	....	......	......	......
7	Old slimes	10.30	53.90	10.55	42.50	5.95	6.30	4.50	....	......	......	......
8	Yellow ecvolades	7.30	43.19	15.75	36.50	3.20	5.30	1.70	....	......	......	......
9	Ecvolades Souriza..................	3.60	98.17	3.50	15.00	6.50	25.00	......	....	......	......	......
10	Coarse sand.. Products of modern concentration works............	31.65	126.70	5.55	21.50	7.20	18.10	......	....	......	......	......
11	Fine sand....	32.65	82.63	7.05	11.00	7.20	17.30	......	....	......	......	......
12	Fine slime ...	5.25	52.41	9.64	42.20	4.30	8.00	6.70	....	......	......	......
13	Prepared bricks	10.20	72.91	10.35	20.00	4.30	15.50	3.00	....	......	......	......
14	Unroasted arsenical fumes..........	38.50	3.83	......	......	......	......	......	....	......	......	......
15	Roasted fumes......................	50.00	3.00	......	......	......	......	......	35.00	3.50	......	......
16	Iron ore for smelting	6.50	65.18	29.50	6.00	1.40	5.30	......	....	......	......	12.25
17	Base bullion	......	73.50	0.014	......	......	......	......	0.374	0.713	0.31	......
18	Speise	4.00	91.43	56.00	......	......	......	......	24.00	......	5.00	......
19	Refined lead	......	0.58	0.049	......	......	......	......	0.0236	0.250	0.0079	......

The ancient land slags (No.1) go straight into the modern blast furnaces; the sea slags (No. 2), worked in the same way, are recovered by means of steam dredges from the sea; often they form a loose conglomerate with limestone (No. 3) and contain lead and litharge (No. 4); in some cases a new mineral, laurionite $PbCl_2$, $Pb(OH)_2$ (No. 5), has been formed by the action of the sea water on the metallic lead in the slag. The old slimes (No. 7), which are so rich in silver, show that the ancients were not aware of the great losses of silver that are likely to take place in washing carbonate ores. Yellow ecvolades (No. 8), from dumps of ancient mines, and ecvolades Souriza (No. 9), from the dumps of the ancient dressing works, are passed through the new dressing works, of which Nos. 10 to 12 are the products. No. 13 represents bricked slimes ready to be charged into the furnaces.

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*A. Cordella, *op. cit.*

The mineral area of Greece is small, and its reserves have been drained for thirty centuries, more or less. The work of the present companies has been chiefly in treating the waste material of ancient times, and mining the bodies of low-grade ore left standing by the original miners as unprofitable to extract by their methods. The life of the district, therefore, is not indefinite, and this has been realized by the managements of the companies, which have reached out into other parts of the Levant, acquiring mines in Macedonia and Asia Minor, with a view of utilizing the smelting works of Laurium for the reduction of their ores. The great drawback to Laurium as a metallurgical center, however, is the lack of good fuel, there being no coal mined in Greece. The smelting works use lignite from Oropus and elsewhere, which costs 19 drachmas (about $3.80) per ton delivered, but large quantities of coal and coke have to be imported from England.

ITALY.—Italy is one of the most important lead-producing countries of Europe, its output being exceeded only by that of Germany and England. The chief mines are in the island of Sardinia, though there are also workings in the districts of Milan, Bergamo, Florence, and elsewhere. These are, however, insignificant in comparison with those of Sardinia. The great lead deposits of Sardinia are the Montevecchio and the Monteponi. The former is a great quartz lode traversing Silurian slate, and striking almost parallel to the contact of the slate with a formation of granite. The outcrop of the vein has been traced in a straight line for a distance of nearly six miles. The width of the lode varies from 75 to 100 ft.; the ore consists of galena mixed with blende, iron pyrites, heavy spar, spathic iron, and copper pyrites. The Monteponi mines are opened on a series of chimneys of galena, occurring mostly at the contact of a clayey limestone with dolomite.

Most of the ore produced in Sardinia is reduced at the works of the Societa di Pertusola (formerly G. Henfrey & Co.), at Pertusola, on the Gulf of Spezia, near Sargana, which is one of the great metallurgical establishments of Europe. About 80% of the ore reduced at these works comes from Sardina; the remainder is imported, some coming from countries as distant as Tasmania.

MEXICO.—Since the discovery of the Sierra Mojada mines, in 1878, Mexico has been increasing steadily in importance as a lead-producing country. At first the ores were brought into the United States for reduction, two of the large American smelting companies having acquired control of the principal mines. The ores being rich in lead, oxidized, and basic in character, formed a very desirable class of material for the lead smelters, and were brought to the United States in large quantities until importations were partially restricted by the McKinley tariff of 1890. Immediately afterward large silver-lead smelting works were erected in Mexico, and a great smelting industry has now been built up there. At present there are two works at Monterey, one at San Luis Potosi, and one at Pedriseña (built in 1893), all of which are owned and operated by American companies. Some ore is still shipped into the United States to be smelted, because certain American smelters are obliged to have it, and a large part of the Mexican base bullion is brought here, principally to Newark, to be refined in bond, while a smaller part is exported from Mexico to European refineries.

The manner in which the production of lead in Mexico is reckoned in the accompanying statistics does not take into account the consumption in the country itself. The amount of lead used in plumbing, etc., in the City of Mexico (not including that manufactured into ammunition) is about 1200 metric tons per annum, and 4000 tons per annum would probably cover the total consumption of lead in the republic.* Since the statistics previously given are based on the exports of lead in ore and bullion from the country, its actual production is, therefore, probably about 4000 tons greater than reported.

The two most important lead-mining districts of Mexico are Sierra Mojada and Velardeña, but noteworthy deposits exist at many other places in the republic, and there are scattered through the Sierras numerous small smelteries, some with native furnaces and some with water-jackets, which turn out a considerable quantity of lead. This is partly exported and partly goes into domestic consumption, but in many cases, where transportation is costly, is cupeled for its silver contents only, the litharge being used again in a subsequent smelting of silicious ore.

Sierra Mojada.—Sierra Mojada has been, since the exhaustion of the deposits of Leadville, Colo., the largest producer of silver-bearing lead carbonate ore in the world. These mines were first discovered in 1878, upon a hill called La Blanca, which forms a buttress to the Sierra Mojada at the point of its highest elevation. There was, however, little activity in the district until about the year 1886, when the Mexican Ore Company (an American concern) began to open the mines and export the product to the United States. Since that time there has been a steady increase in the output of the district.

The country rock of the Sierra Mojada district is a magnesian limestone, of which there is a formation about 2000 ft. thick, including some beds of calcareous sandstone, and one horizon (near the bottom of the series) of calcareous conglomerate. The geological age of this formation is uncertain, but the few fossils that have been found have been classified by Mexican paleontologists as Cretaceous, and they have, therefore, assigned it to that period. The ore deposits of Sierra Mojada are found in a bed-vein consisting of a sheet of decomposed country rock, impregnated with iron and silver-lead minerals in which occur chambers or chimneys of ore of great size and extent. The vein which dips to the southwest extends along the north flank of the Sierra Mojada for a distance of about four miles, showing a distinct outcrop the whole way. The mineral belt has now been explored for about three miles from west to east. The vein is found to be more distinctly defined toward the west than toward the east, and the character of the ore differs somewhat in the two portions, that on the east being the richer in lead, containing from 20% to 50%, while toward the west the lead tenor decreases to 10% or 20%, though the percentage of silver increases slightly.†

The lead of Sierra Mojada occurs chiefly in the form of carbonate, although lead sulphate and undecomposed lead sulphide are also found. Associated with the lead ore are oxidized iron and manganese ores, the occurrence being similar to

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* W. R. Boggs, Jr., in a private communication.

† Besides the great deposits of lead ore at Sierra Mojada, above described, there is a vein of copper ore which outcrops near the lead vein but dips in the opposite direction. This vein carries carbonate of copper (azurite) ore, rich in silver, but little exploration work has yet been done on it.

the ore deposits of Leadville, Colo. As in Leadville also, the lead carbonate is found as "sand" and as "hard carbonate." The average grade of the ore shipped from Sierra Mojada is about 30% lead and 35 oz. silver per ton. The percentage of silica in the ore does not exceed 5, while the tenor in iron averages about 15%. The gangue of the ore is chiefly magnesian limestone.

The most important mine of the Sierra Mojada district is the San Salvador, after which follow, in the order of the tonnage output, the Encantada, Esmeralda, San José, Vita Rica, Fortuna, and Volcan. The San Salvador and the Esmeralda have been opened to a considerable extent laterally, but the greatest depth yet gained in the district is 550 ft., where massive iron ore forms the vein filling and the lead ore is of lower grade, or plays out entirely.

The average cost of mining and loading a ton of ore on board the railway cars in Sierra Mojada is about $5.80 in Mexican silver. The miners employed are almost all Mexicans, who are paid from 75c. to $1.25 per day in Mexican silver. The timbermen and mechanics are mostly Americans, who receive from $3.50 to $4 per day in United States currency.*

One of the difficulties of mining in Sierra Mojada is the lack of water, which was formerly a very serious drawback, the people of the district being forced to leave it temporarily during some of the long droughts. This difficulty has been partly overcome, however, by the construction of large reservoirs to store the water which falls abundantly during the rainy season. The water thus secured is usually sufficient, with proper economy, for the present needs during the remainder of the year. In case of an exhaustion of the supply, however, water can now be brought into the camp by the railways.

Previous to July, 1891, ore was shipped from Sierra Mojada by mule teams, the traffic engaging from 8000 to 10,000 mules, but in that month the Mexican Northern Railroad was built into the camp. This railroad runs from Escalon on the Mexican Central, which is 67 miles distant in a direct line, but is 78 miles by the route taken. The Mexican International Railway Company built a branch from Monclova, on its main line, to Sierra Mojada, a distance of 155 miles, in 1892, and during the past year the Monterey and Mexican Gulf Railroad Company began the construction of a line to Sierra Mojada from Treviño, where it connects with the Mexican International. The British Mexican Railway Company had previously commenced a line from Jimenez, on the Mexican Central, to Sierra Mojada, 120 miles east.† Eventually, therefore, there will be four railways running into the district.

The mines of Sierra Mojada are controlled principally by the Mexican Ore Company (a branch of the Consolidated Kansas City Smelting and Refining Company), which engaged in their development in 1886. The ore was at first reduced by the Esmeralda Smelting Company, which had furnaces at Sierra Mojada, but it was found more profitable to ship it out of the district, and it was exported to the United States in large quantities previous to the passage of the McKinley tariff act. Under the former tariff silver-lead ores could be brought

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* These figures are from a report by Mr. Eugene O. Fechet, consul of the United States at Piedras Negras, written under date of Oct. 24, 1892, and published in *Consular Reports*, January, 1893, No. 148, pp. 73–79.

† Work on this road was suspended temporarily in September, 1893, about 60 kilometers having been completed at that time.

into the United States duty free when the value of their silver contents exceeded that of their lead; the Sierra Mojada ores consequently were classified as silver ores. Under the McKinley tariff silver-lead ores have had to pay a duty of one cent per pound upon the lead contained in them when the value of the silver exceeded that of the lead; otherwise the duty was levied on gross tonnage at the rate of $30 per ton. Sierra Mojada ore, averaging 30% lead, or 600 lbs. lead per ton, therefore had to pay 1½c. per lb. on the lead.

Velardeña.—The lead mines of Velardeña are situated nine kilometers from Pedriseña, a station on the Mexican International Railway, in the State of Durango, about 75 kilometers southwest of Torreon. The ores are of low grade, and it was impossible to exploit the mines extensively until railway communication was established, but since the completion of the Durango extension of the Mexican International Railway, which has built a branch to the mines, operations have been begun on a large scale.

According to Richard E. Chism,* the ore deposits at Velardeña occur at the contact of porphyry and limestone in well-defined bodies, which in some places are 100 ft. thick. Openings have been made on the vein, which dips vertically or at a steep angle, for a distance of 6000 ft. The ore is a carbonate, high in lead and low grade in silver, with an excess of iron over silica. The limestone country rock, which is not magnesian, furnishes the lime flux for smelting, and silicious ores rich in silver are obtained in the immediate vicinity and in other parts of Durango; hence in all respects except fuel Velardeña seems to be well adapted for silver-lead smelting. The mines are owned and operated by the Compañia Minera de la Velardeña, which has erected smelting works of six furnaces, and employs about 750 men. The first furnace was blown in Nov. 1, 1893, and was followed by four more in December.

RUSSIA.—All the lead smelted in Russia is obtained from the argentiferous lead ores of the Caucasus and Siberia. In the Caucasus the ore is mined at the Alagirsk Government Works, and in Siberia at the Altai and Nerchinsk mining districts of the Imperial Cabinet, and also in the Kirghis steppes, where the exploitation is carried on by private individuals. Besides this, argentiferous lead ores are known to exist on the Mourman coast in the Government of Archangel, and a private company has recently been formed for working these deposits, which were only fully surveyed in 1890. Private individuals are also endeavoring to make a detailed survey of the argentiferous lead deposits of the Government of Ekaterinoslav, and to start the smelting of these metals there.†

Caucasus.—In the north of the Caucasus, in the Kouban Basin, Batalpaschinsk military district, on the lands of the native commune of Kara-Tchai,‡ large deposits of argentiferous lead ore have been discovered within the past two or three years. The mineral-bearing area is 35 kilometers long and 4 to 5 wide. In it 44 veins had been found up to 1892, and 11 of them had been examined in detail by M. A. D. Kondratieff, who reported an average lead tenor of 47.90%, with 0.5345% of silver in the lead. The veins are large and favorably situated for exploitation; many of them can be attacked by tunnels. Materials of

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* *Engineering and Mining Journal*, June 3, 1893.

† A. Keppen, *The Industries of Russia*, Vol. IV., "Mining and Metallurgy," p. 27.

‡ In the north of the Caucasus certain communes are inhabited by Cossacks and others by natives.

construction, wood, clay, and limestone, abound at Kara-Tchai, and fuel is easily obtained. The river Kouban affords water-power in winter as well as in summer.[*]

Southern Russia.—Deposits of lead ore, which it is thought will prove important, have been discovered recently in the Donetz Basin, between the villages of Jouzowka and Grouschevka, 110 kilometers from the Sea of Azov and 8 kilometers from the Donetz railway. A large number of veins have been found, but only three have been yet determined to be exploitable.[†] These, however, are very favorably situated. The ores are sulphides, and are of good grade in lead. It is probable that these mines will soon be opened.

SPAIN.—The principal lead-producing districts of Spain are situated in the provinces of Jaen, Murcia, and Almería. Some of these mines were worked by the Romans and were described by Pliny. They were worked actively by the Moors, and were exploited from time to time with more or less success after their expulsion. It was not, however, until the issue of a royal decree by Ferdinand, after the Peninsular war, opening the mines of Spain to the people of all nations, that the industry was established on a substantial basis.[‡]

New deposits of lead ore are constantly being discovered in Spain, and there is no doubt that the country can increase its output very largely with satisfactory prices for the metal. The lead-mining industry has been affected unfavorably, however, by the decline in the value of silver, probably one-third of the total output of the metal coming from argentiferous ores, while the tax of two per cent. on the gross product of the mines, which was imposed by the Government on July 1, 1892, has been a heavy burden. The more part of the lead ore produced in Spain is smelted in the country itself, there being large works at Linares, at Peñarroya, and at Mazarron.

Almería.—The important lead mines of this province are situated in its northeastern portion, in the Sierra de Almagrera, which forms a range about 1000 ft. high and 15 miles long on the coast of the Mediterranean. The country rock, which consists chiefly of mica-schists passing into clay slate, is traversed by numerous veins, the most remarkable of which is the Jaroso. This great lode, which attains a maximum width of 20 ft., carries ore consisting of a mixture of argentiferous galena, iron and copper pyrites with a gangue of heavy spar, spathic iron, calcspar, and quartz. The percentage of silver in the ore decreased with depth.

The production of lead in the Sierra de Almagrera has fallen off during recent years, owing to the flow of water encountered in the mines as depth was gained. As the water seeps from each mine into the others it is impossible for any single concern to undertake to contend with it, combined action being necessary. A contract to unwater the mines has finally been made by a syndicate of the mining companies with a firm of engineers, who are to collect a royalty on the product of each to pay for the same, and the work will doubtless be undertaken in 1894. According to a report prepared for the Government by a corps of engineers under Inspector-General Don Pablo Garcia Martino, the problem of unwatering these

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[*] Levitzky, *Revue Universelle des Mines, de la Métallurgie*, XX., 3, p. 362, December, 1892.

[†] *Revue Universelle des Mines, de la Métallurgie*, etc., XXI., 3, p. 332, March, 1893.

[‡] Davies, *Metalliferous Minerals and Mining*, p. 196.

mines is not a very serious one, involving only the raising of a maxium of 7000 metric tons per twenty-four hours to a height of 163 meters.

Jaen.—The chief lead mines of this province occur in the Linares district, which covers a large area, lying north of the town of Linares, and south of the main highway from Madrid to Seville. The country rock is a bed of sandstone of Triassic age, lying nearly horizontal, and seldom exceeding 35 ft. in thickness. This bed of sandstone lies directly upon granite. Both the sandstone and the granite are traversed by two distinct systems of lead-bearing veins, which are marked by projecting outcrops of ferruginous quartz, and generally become productive at an inconsiderable depth. They vary in width from one foot to 12 ft., and so far as they have yet been opened show no decrease in width. The ore, which occurs in chimneys in the veins, was lead carbonate down to the water level, where it changed to galena (poor in silver), mixed with iron pyrites, and a gangue of quartz, calcspar, and heavy spar. These mines have been opened only to a moderate depth so far, and are capable of making a very large output. The chief producers are the Linares Lead-Mining Company (an English corporation), and the Fortuna, Alamillos, and La Cruz companies.

Murcia.—Important lead deposits are found in the vicinity of Almazarron, some distance west of Cartagena, in the Sierra de Cartagena, which is composed of Silurian slates and limestone, penetrated by trachyte and other igneous rocks, and surrounded at the base by rocks of Tertiary age. Both the Silurian rocks and the trachyte are traversed by a series of veins of which the dip is almost vertical, carrying galena mixed with iron and copper pyrites and a gangue of calcite, heavy spar, and quartz. In the stratified rocks ore is found also in bed veins, which are sometimes of much extent and thickness.

PRODUCTION OF LEAD IN SPAIN ACCORDING TO PROVINCES.

(In metric tons).

Year.	Almeria.	Badajoz.	Cuidad-Real.	Cordoba.	Guipuzcoa.	Jaen.	Malaga.	Murcia.	Total.
1881	19,067	932	35	10,812	8,308	4,940	3,731	42,798	90,672
1882	17,391	963	1,786	14,776	8,680	4,977	3,340	36,426	88,339
1883	20,991	1,368	2,480	25,730	8,050	5,447	2,550	32,688	99,304
1884	15,444	1,203	3,723	16,179	7,500	....	2,844	36,411	83,304
1885	10,857	1,003	3,088	12,656	7,042	17,661	2,956	33,352	88,615
1886	8,013	650	3,372	16,897	7,196	27,798	3,610	38,406	105,942
1887–88	14,028	270	2,589	35,720	8,520	32,558	3,354	48,394	145,433
1888–89	11,333	279	....	20,610	7,267	25,550	2,873	63,546	131,460
1889–90	19,611	....	....	17,616	6,385	28,361	2,314	116,895	191,182
1892*	18,000	....	2,000	18,600	5,500	35,000	....	96,024	175,124
1893*	21,000	....	2,500	19,000	5,500	40,000	....	100,500	188,500

* Reported by Señor Don Roman Oriol.

United Kingdom.—There are many lead-producing districts in the United Kingdom, but that of the North of England, including the counties of Cumberland, Westmoreland, Northumberland, and Durham, is the most important. The mines of Derbyshire in the Midlands, Flintshire and Denbighshire in North Wales, and Foxdale and Laxey in the Isle of Man make a large output, while there are productive mines in Cardiganshire, Montgomeryshire, Shropshire, and in Scotland in the adjoining counties, Lanarkshire and Dumfriesshire. The mines of Wicklow, in Ireland, are no longer worked on a large scale.

During the past fifteen years the production of lead in the United Kingdom has been declining, and unless prices rise it is likely that there will be a further falling off, since none of the large companies can operate at much profit when the market for lead hangs about £10 per ton (2240 lbs). This is certain from the fact that all of the chief lead-mining companies, with the exception of the Isle of Man, passed their dividends in 1893, while the report of the latter company, which has an ore richer in silver than the others, indicates that it will be obliged to discontinue payments to its shareholders if the price of lead does not improve. It is not said that there has been a decrease in the reserves of the British mines, but the increasing supply of cheap Spanish and Australian lead has forced the market price down to the cost of production in Great Britain.

Derbyshire.—The lead mines of this county are very ancient, having been worked prior to 1289, when they were the only ones in operation in the United Kingdom. The mining district lies between the towns of Buxton and Castleton on the north and Cromford and Wirksworth on the south, covering an area about 30 miles long by 12 miles wide, of which the eastern half is the more productive. The geology is similar to that of the North of England, but is more complicated in structure, being much broken by faults and disturbed by intrusive sheets of eruptive rocks, which run irregularly through the beds and pinch the lodes as they pass through them, or cut them off altogether. The ore occurs as pipe-veins, which are elongated vertical pockets, and as "rake-veins" and "flats" similar to those at Alston Moor. The ore of Derbyshire is galena, with a gangue of calcite, fluorite, and barite. The entire product is dressed, the concentrates, which are non-argentiferous, assaying about 75% lead.

Isle of Man.—The lead mines of the Isle of Man are opened on veins cutting through slates, sandstones, and shales of Cambro-Silurian age, like those of Shropshire and Wales. There are at present five productive mines on the island, the most important being the Foxdale at the place of the same name, which turns out about 3500 tons of metal per annum. The Great Laxey mine, at Laxey Glen, also makes a considerable output. The ore (galena) produced by these mines is dressed so as to assay from 76% to 80% lead. It carries more silver than any lead ore produced elsewhere in the United Kingdom, the concentrates of the Foxdale mine averaging about 15 oz. silver per ton, while those of the Great Laxey mine go over 40 oz. per ton. These mines have been very profitable, paying dividends regularly over a long series of years, but both were affected seriously by the low price for lead in 1892 and 1893, the Isle of Man Mining Company, which owns the Foxdale mine, making a smaller distribution than usual during the past year (1893), while the Great Laxey Mining Company passed its dividend altogether, although there was no falling off in the output of either company.

Cardiganshire.—The lead district of this county extends from the southwest boundary of Montgomeryshire southwestward to Cardigan Bay. It consists of four or five mineral zones, roughly parallel to each other, the geology of which is similar to that of the mineral district of Shropshire, the ore occurring in veins in slates and shales of Cambro-Silurian age. As in Shropshire also, the lodes are most productive in the compact slate and poorest in the softer shales, or gritty mines in operation in this county in 1892, none of them making a large output. The ore is dressed to assay from 78% to 80% lead, and the concentrates contain 8 or 9 oz. silver per ton. This district extends into Montgomeryshire, and mines have been worked around the village of Llangynog, in the northwest corner of that county, but their production is now insignificant.

Shropshire.—The lead-mining district of this county lies in the southwest corner, on the Montgomeryshire border. It is of small extent, lying between the Stiper Stone Hills on the southeast and the road from Minsterley to Bishop's Castle on the northwest. The ore occurs in simple fissures in stratified slates, shales, and sandstones of Cambro-Silurian age, which are traversed by dikes of igneous rock. The veins are most productive in the hard slates, becoming poor in the soft shale. The ore, which is a mixture of galena and blende, with a gangue of heavy spar, calcspar, and quartz, together with fragments of the country rock, occurs in runs or channels in the vein. There were six mines which produced ore in this county in 1892, the most important being the Roman Gravels and Snailbeach, both at Minsterley, which turned out 744 and 794 long tons of lead, respectively. The Shropshire ore is dressed up to about 80% lead. It does not contain silver.

North of England.—The North of England is the chief lead-producing region of the United Kingdom, the most important mines lying in the neighborhood of Alston Moor, where the three counties of Northumberland, Durham, and Cumberland meet. They were known by the Romans and were worked by them, traces of their ancient smelteries still existing. The ore occurs in a formation of Carboniferous limestone in true lodes ("rake-veins") and in flat-veins.* The former are the more important. They are not always regular, but often descend in a zigzag course, the inclined parts of the vein being connected by horizontal deposits. The mineral of the North of England is galena, occurring in a gangue of fluorspar, calcspar, or quartz, the average grade of the crude ore being about 8.5% lead. Blende and pyrite are sometimes associated with the galena. All the ore raised is dressed, the concentrates produced assaying from 70% to 82% lead and a few ounces of silver per ton, the Northumberland mineral averaging 1 oz. silver per ton, and that of the other counties about 5 oz. silver per ton, or 7.5 oz. per ton of lead. The largest producers of lead in the North are the London Lead Company, operating at Teesdale, and the Weardale Lead Company at Weardale, both in Durham. These companies turn out 90% of the whole output of lead in that county. The product of Cumberland and Northumberland comes from a large number of small producers.

The mining districts of Yorkshire and Westmoreland, lying south of Alston Moor, resemble the latter in their geological features. The Swaledale district, which extends from Richmond on the east to Westmoreland on the west and from Wensleydale on the south to Teesdale on the north, in the North Riding of Yorkshire, is the most important in that county. There were in this district five producing mines in 1892. In the West Riding there were five producing mines at Pateley Bridge in the same year. The Yorkshire mineral is not silver-bearing. The entire output of Westmoreland, at present amounting to about

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* J. A. Phillips, *Ore Deposits.*

sandstone-beds. The ore is chiefly galena mixed with blende. There were 14 1000 long tons of lead per annum, is derived from the Greenside mines, at Patterdale.

North Wales.—After the North of England this is at present the most important lead-producing district in the United Kingdom. Its geological structure is like that of Derbyshire and the North of England, the limestone bed of the latter dipping westward under the Coal Measures, Permian, and New Red Sandstone formations, and rising again in Flintshire and Denbighshire. The mineral zone runs from Llangollen on the south to Flint, Holywell, and Prestatyn on the north. The ore occurs in veins which have a general east and west direction, but there are also flats, which form at the contact of the limestone with sandstone beds. The ore is galena, associated with blende. Some of the mines, indeed, as the Minera and New Minera, at Wrexham, are now far more important as zinc mines than as lead mines. The two mines mentioned produced 6400 long tons of dressed zinc ore in 1892, and only 1400 tons of lead ore. The most important mine in North Wales is the Halkyn, at Holywell, Flintshire, which produces about 3000 long tons of lead per annum; at the same time it turned out about 800 tons of dressed zinc ore. All of the Denbighshire and Flintshire ore is silver-bearing, that of the Halkyn mine containing 5 or 6 oz. silver per ton. The lead ore of these two counties is dressed very cleanly, the concentrates averaging nearly 82% lead.

Scotland.—Lead is mined at Lead Hills, Abington, Lanarkshire, and at Queensbury, Wanlockhead, Abington, Dumfriesshire. The ore at both places is galena, and carries a trifling amount of silver.

PRODUCTION OF LEAD IN THE UNITED KINGDOM.

(In long tons of 2240 lbs.)

Year.	North of England.	Derbyshire.	North Wales.	Mid-Wales, including Shropshire.	Isle of Man.	Scotland.	Ireland.	Elsewhere.	Total Long Tons.	Total Metric Tons.
1872	22.426	4,191	5,187	17,550	2,639	2,331	726	5,404	60,455	61,411
1873	20.359	3,116	3,712	16,990	3,131	2,125	885	3,915	54,235	55,127
1874	21,701	3,572	5,816	18,061	3,185	2,073	1,313	3,053	58,777	59,740
1875	22,131	2,090	4,169	18,799	3,158	3.078	1,387	2,619	57,435	58,376
1876	22,992	2,149	4,479	18,956	3,086	2,936	1,368	2.699	58,667	59,612
1877	26,115	3,300	4,897	18,164	3,342	2,105	1,241	2,238	61,403	62,410
1878	20,673	4,257	6,381	18,200	2,995	2,743	1.263	1,504	58.020	58,971
1879	17.245	4,079	5,629	16,788	3,267	2,770	911	944	51,635	52,481
1880	23,831	3,601	4,749	16,394	3,886	2,848	931	706	56,949	57,882
1881	18,754	2,875	4,490	14,249	4,183	2,839	636	557	48,586	49,383
1882	19,316	4,205	4,756	10,381	4,263	3,377	734	3,296	50,328	51,153
1883	11.274	2,638	3,755	12,279	4,546	3,613	358	722	39,189	39,821
1884	16,376	2,744	3,349	9,076	4,439	3,219	341	531	40,075	40,732
1885	17,144	3,407	2,580	5,970	5,094	3,243	88	161	37,687	38,405
1886	18,246	3,505	2,783	6,534	4,629	3,433	177	175	39,482	40,129
1887	17,223	3,244	3,182	6,317	4,864	2,821	230	9	37,890	38,511
1888	16,351	3,375	4,095	5,614	4,733	3,143	196	71	37,578	38,194
1889	13,740	3,866	4,600	5,321	4,753	3,163	160	....	35,604	36,187
1890	13,149	3,020	5,074	4,851	4,530	2,881	5	80	33,590	34,140
1891	11,531	3,157	4,909	4,434	4,926	3.198	7	33	32,205	32,733
1892	9,786	2,836	5,232	3,589	4,930	3,064	31	72	29,540	30,014
1893	11,173	3,236	4,806	2,004	4,734	2,665	41	1,039	29,698	30,176

This table is compiled from statistics in the British blue books, which make no distribution of the product for the years 1858–71, both inclusive. The column "North of England" includes the production of Northumberland, Cumberland, Westmoreland, Durham, and Yorkshire; "North Wales" includes Flintshire and Denbighshire; while Cardiganshire, Montgomeryshire, and the English county of Salop (Shropshire) are grouped under the caption "Mid-Wales." In all the English statistics the production of lead is estimated from the output of dressed mineral reported by the mines, the amount of metal obtainable by smelting being reckoned at 95% of the dry assay value of the mineral.

PRODUCTION, IMPORTS, EXPORTS, AND CONSUMPTION OF LEAD IN THE CHIEF COUNTRIES OF THE WORLD.* (IN METRIC TONS.)

	Austria H'gary.	Bel-gium.	France.	Ger-many.	Great Bri'n(*a*)	Italy.	Russia.	Spain.	Switz-erland.	United States.
Production	11,251	9,617	4,578	104,958	49,795	17,768	836	177,953	....	146,966
Imports	3,471	35,985	67,418	13,477	161,187	2,484	17,824	....	2,853	9,049
Total	14,722	45,602	71,996	118,435	210,982	20,252	18,660	177,953	2,853	156,015
Exports	1,075	27,370	9,653	33,981	51,200	518	....	140,660	*100	....
1890-Consumption, pig lead.	13,647	18,232	62,343	84,454	159,782	19,734	18,660	37,293	2,753	156,015
Imports of sheet lead, manufactures and lead products	353	....	3,329	1,462	....	297	3,414	....	900	....
Exports of same	538	....	5,674	20,796	21,194	1,607	....	....	....	....
Grand total consump.	13,462	18,232	59,998	65,120	138,588	18,424	22,074	37,293	3,653	156,015
Production	11,851	12,698	6,680	98,114	49,414	18,500	558	165,978	....	180,800
Imports	4,576	34,093	74,502	o8,374	172,439	4,594	16,370	....	1,867	1,737
Total	16,427	46,791	81,182	116,488	221,853	23,094	16,928	165,978	1,867	182,537
Exports	1,002	24,073	10,518	26,668	46,018	542	....	140,000	129	....
1891-Consumption, pig lead.	15,425	22,718	70,664	89,820	175,835	22,552	16,928	25,978	1,738	182,537
Imports of sheet lead. manufactures and lead products	451	....	3,644	1,224	....	209	2,400	....	933	....
Exports of same	545	....	5,794	20,302	19,284	2,030	....	....	....	....
Grand total consump.	15,331	22,718	68,514	70,742	156,551	20,731	19,328	25,978	2,671	182,537
Production	12,209	10,146	6,655	100,710	44,935	22,000	600	160,000	....	186,548
Imports	7,375	31,054	73,720	18,477	185,707	2,166	18,646	....	2,036	....
Total	19,584	41,290	80,375	119,187	230,642	24,166	19,246	160,000	2,036	186,548
Exports	1,278	24,709	8,999	27,684	55,668	1,377	....	153,859	114	....
1892-Consumption, pig lead.	18,306	16,491	71,376	91,503	174,974	22,789	19,246	6,141	1,922	186,548
Imports of sheet lead, manufactures and lead products	756	....	2,569	1,113	....	230	2,400	....	984	....
Exports of same	596	....	6,120	22,096	19,288	1,640	....	....	....	....
Grand total consump.	18,466	16,491	67,825	70,520	155,686	21,379	21,646	6,141	2,906	186,548
Production	....	....	....	....	....	....	....	....	....	....
Imports	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	....	....	....
Exports	....	....	....	....	....	....	....	....	....	....
1893-Consumption, pig lead.	....	....	....	....	....	....	....	....	....	....
Imports of sheet lead, manufactures and lead products	....	....	....	....	....	....	....	....	....	....
Exports of same	....	....	....	....	....	....	....	....	....	....
Grand total consump.	....	....	....	....	....	....	....	....	....	....

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* The statistics of production in the above table are derived from official sources, as are also the imports and exports of the United States, Spain, and Belgium. The imports and exports of other countries are taken as reported by the *Metallgesellschaft*, Frankfurt-am-Main. In the statistics of production litharge is calculated as containing 80% lead.

(*a*) In the imports and exports for Great Britain the chemical products are not taken into consideration.

The American Lead Market.

If anybody considers that all other metals than lead have fluctuated considerably, there certainly will be found none to dispute the assertion that, with the possible exception of silver, lead has been the most erratic as to price. In fact, it may be said that a revolution has taken place in the lead business during 1893. The uncertainty regarding the future of silver, as well as the continual decline in the value thereof, of course had considerable influence upon the lead market, as the baser metal is, in the main, produced in conjunction with the more precious.

A year ago we pointed out that as the lead production from domestic ores was 178,138 tons in 1891 and but 178,892 tons in 1892, a stop had been put to the increase in production, which had regularly increased from year to year, the only check having occurred in 1890, when exceptional conditions prevailed. And this stop to the regular increase has been in spite of the country's rapidly increasing population, and the consequent greater demand for all commodities. The figures for the year now about closed, show that there has been a quite important falling off in the output, which, however, is not astonishing in view of the great depreciation in the value of both silver and lead.

During the first few months of the year consumption for all purposes was very good; in fact, so good that a scarcity of refined lead was apparent, as is clearly shown by the prices ruling during the period just mentioned. In January 3.85c. ruled, and there was a gradual advance until 4c. was marked up by the middle of February, when a decline set in and 3⅞c. soon ruled. Then came another advance, steadily continuing during March, in which month the price was first 4c. and then 4⅛c., reaching the top notch by the middle of April, when 4¼c. was recorded. This price made it almost possible to import foreign lead, and, realizing this, smelters showed themselves anxious to sell considerable quantities. The pressure thus put upon the market caused a gradual decline, 4c. ruling by the end of April and 3⅞c. throughout the month of May. By the middle of June 3.70c. was reached, principally because of the stringency of the money market, and we had thus to quote the lowest price known for years. Then came the closing of the Indian mints to silver, which did not help matters, although under ordinary circumstances it would have meant a strong upward movement in lead because of the closing down, to await developments, of a considerable number of silver-lead ore producing mines. Some of the mines which shut down have since reopened and are endeavoring to struggle along, but the majority are still closed.

The tremendous falling off in consumption, especially for white and sheet lead purposes, and the extreme difficulty of financing, more than offset the shutting down of the mines and the consequent curtailment of supplies, and prices kept dropping until by the end of June 3.40c. was the market value. Then came a temporary advance, only to be followed by another downward turn, caused by the reopening of some of the mines that had been closed. Throughout July there was the same downward tendency, and we find, on looking back, that when the middle of August arrived 3.20c. at New York and 3c. at St. Louis were the ruling prices. As practically no lead was to be had at these figures, while there were many who thought it would be a good thing to take in some lead at these abnormally low prices, the natural result was a reaction in tendency, resulting in prices advancing to 3⅞c. by the first week in September, more or less of a scarcity of lead being apparent for a while, but disappearing when the price last mentioned was reached, the smelters then coming out as free sellers.

During the entire period of depression it was noticed that while the low prices had the natural effect of shutting up many mines here, they caused an increase in the importations of lead and silver ores from Mexico, where, of course, wages are low and payable in silver.

Meanwhile Congress had been convened in extra session to consider the silver question, the result being the passage of a bill discontinuing the purchases of bullion, which for a long time had been made in accordance with the provisions of unwise legislation, which was thus put an end to, but not until after it had involved the country in one of the severest panics ever known and brought the national finances almost to the verge of bankruptcy. Immediately after the passage of the silver purchase repeal bill, Congress adjourned, and the Ways and Means Committee of the House commenced work upon the bill revising downward the famous McKinley tariff.

All the occurrences related above should have steadied prices for lead, but quite the contrary was the case, as values declined continually until by the end of October the lowest level established during the panic—3.20c. at New York and 3c. at St. Louis—was again reached, and although values afterward improved somewhat, they never advanced beyond 3.45c. at New York, which figure ruled during all of November and the early part of December. By the middle of the latter month a price of 3.10c. at New York had been established, the market price in St. Louis being at the same time easily maintained at 3c., and at the close of the month the prices were 3.20c. at New York and 3.07½c. at St. Louis. Why such figures should rule was a puzzle to the trade at large, especially as some of the most prominent refiners were evidently instrumental in keeping values down. For a long time it was thought their action was due to a desire to make favorable contracts for supplies for a long period, but even yet it is not known whether this is the correct solution of the problem.

At the end of November the proposed tariff bill was made public, and it was found that the duty on pig lead was reduced to 1c. per lb., as against the present ruling rate of 2c. per lb.; that silver-lead ores were placed on the free list, while the duty on straight lead ores was reduced to 15% ad valorem, and that similar reductions had been made in the rates of duty on manufactures of lead. Changes were made, however, and it is now proposed to make sheet lead, lead pipe, and shot pay 1¼c. per lb., and red and white lead 1½c. per lb. During the month of December nothing new developed: transactions were few, and prices ranged between 3¼ and 3.20, or at about the lowest point touched during the whole year.

Considering that in the markets of the world the price of lead in the pig has long ruled at something less than 2c. per lb., or say 2@2⅛c. at New York, it stands to reason that with a duty of 1c. per lb. prices here cannot rule at much above 3⅛c., as otherwise foreign pig lead could and would be imported in large quantities. However, the chances of lead and silver-lead ores coming in to a greater extent are more threatening, and while such heavier importations would result detrimentally to our smelting industry, that would suffer very little in comparison with the mining industry. The bulk of the lead produced in this country comes from west of Colorado, and thus a haul in almost all cases by an all-rail route of several thousand miles with its higher charges than by shipment by water is necessary to get the lead to the point of consumption.

If we rightly understand the situation the production in Germany, Spain, and Greece is likely to suffer, but any decrease there will be offset by the continually growing production in Australia and Mexico. Nevertheless, as soon as trade here and abroad is in a better condition than it has been during the last six to eight months, it seems as if we should again see permanently higher prices than those now ruling for this metal.

AVERAGE MONTHLY PRICES OF LEAD IN NEW YORK, IN CENTS PER POUND.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1870..	6.25	6.21	6.15	6.20	6.22	6.22	6.25	6.35	6.33	6.31	6.30	6.30	6.25
1871..	6.22	6.22	6.17	6.15	6.14	6.13	6.12	6.06	6.05	5.93	5.95	5.87	6.08
1872..	5.95	5.93	5.93	6.00	6.43	6.50	6.50	6.45	6.40	6.51	6.55	6.51	6.30
1873..	6.32	6.45	6.37	6.37	6.50	6.33	6.06	6.12	6.50	6.50	6.25	6.06	6.32
1874..	5.95	6.12	6.18	6.07	5.87	5.81	5.71	5.72	5.87	6.22	6.37	6.26	6.01
1875..	6.10	5.87	5.68	5.83	5.92	5.82	5.97	5.91	5.78	5.62	5.76	5.90	5.85
1876..	5.93	6.17	6.45	6.26	6.30	6.37	6.27	6.32	6.12	5.90	5.75	5.67	6.13
1877..	6.12	6.30	6.62	6.37	5.77	5.65	5.50	5.00	4.80	4.55	4.62	4.55	5.49
1878..	4.17	3.75	3.75	3.62	3.37	3.30	3.43	3.35	3.35	3.48	3.77	3.95	3.61
1879..	4.25	4.50	3.87	3.06	3.00	3.46	4.00	4.02	3.87	4.75	5.30	5.55	4.14
1880..	5.80	5.93	5.62	5.57	4.82	4.62	4.50	4.65	4.85	4 76	4.80	4.50	5.04
1881..	4.65	4.95	4.75	4.60	4.47	4.37	4.70	4.85	5.16	5 06	5.07	5.12	4.81
1882..	5.05	5.10	5.00	4.95	4.72	4.72	5.02	5.02	5.05	5.00	4.70	4.62	4.91
1883..	4.65	4.55	4.57	4.50	4.47	4.42	4.35	4.25	4.31	4.22	3.85	3.67	4.32
1884..	4.12	3.90	4.12	3.84	3.63	3.61	3.62	3.61	3.65	3.67	3.46	3.62	3.74
1885..	3.65	3.65	3.65	3.65	3.65	3.75	4.00	4.25	4.25	4.20	4.10	4.55	3.95
1886..	4.55	4.75	4.90	4.78	4.70	4.75	4.87	4.75	4.65	4.22	4.35	4.32	4.63
1887..	4.31	4.37	4.32	4.27	4.52	4.65	4.55	4.58	4.50	4.25	4.40	5.12	4.50
1888..	4.90	4.95	5.15	4.75	4.25	3.90	3.97	4.45	5.00	4.50	3.67	3.75	4.42
1889..	4.84	3.73	3.72	3.68	3.78	3.96	3.88	3.86	4.00	3.86	3.84	3.89	3.93
1890..	3.86	3.85	3.95	4.05	4.20	4.42	4.62	4.60	5.11	5.87	5.02	4.24	4.48
1891..	4.38	4.31	4.35	4.25	4.28	4.48	4.42	4.42	4.52	4.39	4.12	4.25	4.35
1892..	4.20	4.12	4.21	4.15	4.22	4.16	4.13	4.11	4.11	4.02	3.84	3.80	4.09
1893..	3 87	4.22	3.96	4.08	3.89	3.77	3.58	3.41	3.80	3.51	3.41	3.27	3.73

The production of lead in this country which is, as we have said above, considerably affected by the price and production of silver, does not appear likely to increase at present. The further fall in silver which has recently taken place on account of the failure of the Indian Government to maintain the price of the rupee, and the imposition of a duty on silver imported into India, has brought the price of silver to a lower point than ever before. Under these circumstances it is probable that the silver-lead mines already closed will remain in that condition and that others will shut down, thus reducing the output of lead. The Australian mines will be affected in the same way, and the present outlook is for a diminished production. That any considerable increase in lead prices will result may, however, be considered doubtful, since the mines which are worked for lead only, or for lead and other metals, not silver, can probably meet all the demand for consumption.

THE LONDON LEAD MARKET IN 1893.

The serious failure of important building societies in a large degree, and the severe frost in a lesser measure, had disorganized the building trades and depressed the lead market, which consequently opened dull, with a downward tendency. The value fell to £9 11s. 3d. in January, and this low level elicited rather more inquiry, though only a small proportion emanated from consumers. In February complaints of bad trade at home and of poor export business were rife, and in the absence of demand parcels of Spanish lead were arriving in the Thames unsold and had to be parted with as low as £9 5s. per ton. A natural reaction then set in, and very soon English lead was not obtainable under £9 15s. There was also a firm undercurrent induced by general efforts to buy, on the quiet, when prices were at their lowest. Early in March a large Government order for white lead assisted the market, and £9 17s. 6d. was paid for Figuerva and La Cruz lead. About the middle of the month there was a shade easier tendency, due to offers of American lead. Manufacturers, however, continued very busy, and were admittedly better off for orders than at the same period last year, while on the Continent a brisk trade was being done in white lead.

April brought no great change. Rollers continued well occupied at home but were feeling the effect of Australian competition in their Chinese market. The value of foreign was £9 13s. 9d.@£9 15s. The course of values during May was toward a lower level and fair sales were made at £9 12s. 6d. down to £9 7s. 6d., and this retrograde movement made further progress in June, the low limit of £9 3s. 9d. being eventually reached. At this figure consumers began nibbling and values improved, stimulated by a rather better export inquiry. £9 8s. 9d. was paid before June expired. July witnessed a rapid recovery of values, and when it was found that very little lead was obtainable, the firmness became accentuated and £9 15s. was paid. The scarcity growing more pronounced and it being expected that the fall of silver would lead to the closing of many silver-lead mines, the value of lead rose to £10, and many inquiries had to go unsatisfied. Spot was finally dealt in at £10 5s. and forward at £10 10s. Speculators realizing their holdings at this level and we had a recoil to £9 15s., but this was followed by a good business at prices up to £10 2s. 6d. and £10 5s.

In August there was a fair amount of demand at £10, though consumers, on the whole, were holding back. Smelters evinced more disposition to meet the market, which closed at about £9 15s.

In September there was a certain amount of inquiry for forward delivery and the market for foreign lead improved to £9 17s. 6d., £10 being paid for English. One circumstance in favor of the market was the falling off—owing to the long drought and to labor difficulties—in the shipments from Australia of Broken Hill lead, which for some three months past had averaged only about 75% of the usual quantity. Trade demand here had, however, now grown dull, and further speculative realizations sent values down to £9 13s. 9d. October was a period of lifelessness. Rollers were disinclined to buy, and when a slight demand arose it was readily filled by the smelters, who were eager sellers.

The transactions which were effected were chiefly at £9 10s. and £9 12s. 6d. Early in November £9 15s. was paid and then £9 16s. 3d., but toward the close it was difficult to sell even at £9 13s. 9d. As to the Broken Hill shipments, these began now to assume something nearer their normal proportions.

The market closed at £9 7s. 6d.@£9 10s. for soft foreign and £9 12s. 6d. for English. The imports, according to the Board of Trade returns, were 191,174 tons, against 182,782 tons in 1892; the exports in 1893 were 48,935 tons, and in 1892, 58,162 tons.

AVERAGE YEARLY PRICE OF ENGLISH LEAD FROM 1771 TO 1872.*

Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.
	£ s. d.		£ s. d.		£ s. d.		£ s. d.		£ s. d.		£ s. d.		£ s. d.
1771..	13 7 6	1782..	16 17 6	1798..	15 10 0	1809..	31 3 9	1825..	25 5 0	1844..	16 18 9	1857..	23 17 6
1772..	12 7 6	1783..	16 2 6	1799..	17 17 6	1812..	23 2 6	1826..	19 0 0	1846..	18 18 9	1858..	21 10 0
1773..	12 2 6	1784..	16 2 6	1800..	21 0 0	1813..	25 15 0	1828..	15 15 0	1849..	15 18 9	1860..	22 5 0
1775..	13 1 3	1785..	15 2 6	1801..	24 0 0	1814..	26 15 0	1830..	12 2 6	1850..	17 10 0	1862..	20 17 6
1776..	12 17 6	1788..	21 10 0	1803..	27 15 0	1816..	16 5 0	1832..	11 12 6	1851..	17 2 6	1863..	21 17 6
1777..	12 17 6	1790..	16 2 6	1804..	28 0 0	1818..	27 8 9	1835..	17 0 0	1852..	17 17 6	1864..	20 15 0
1778..	12 7 6	1792..	19 8 9	1805..	27 12 6	1820..	21 10 0	1836..	25 2 6	1853..	23 7 6	1865..	20 2 6
1779..	11 10 0	1793..	19 2 6	1806..	35 15 0	1821..	22 10 0	1837..	21 15 0	1854..	23 13 9	1866..	20 12 6
1780..	11 2 6	1794..	14 10 0	1807..	30 2 6	1823..	22 5 0	1840..	18 2 6	1855..	23 1 3	1871..	18 2 6
1781..	14 15 0	1796..	18 8 9	1808..	30 0 0	1824..	21 0 0	1841..	20 2 6	1856..	24 0 0	1872..	....

* From *Statistiche Zusammenstellungen von der Metallgesellschaft*, Frankfurt-am-Main.

MONTHLY AVERAGE PRICE OF COMMON PIG LEAD IN LONDON.*

(Per ton of 2240 lbs.)

Y'r	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1872	19 3 9	19 3 6	19 9 9	19 18 3	20 3 3	20 2 0	19 19 6	20	20 10 ..	20 12 0	20 17 0	21 17 0	20 3 0
1873	22 3 0	22 11 3	23 6 3	23 8 9	23 11 0	23 12 6	23 3 0	22 14 6	23 10 6	23 19 0	24	24 2 6	23 6 9
1874	23 17 9	22 16 0	21 13 9	20 17 6	20 10 6	21 2 0	21 3 6	21 7 6	21 13 0	22 17 0	23 13 9	24 0 0	22 2 9
1875	23 8 0	23 1 3	21 15 0	21 7 0	22 18 0	22 7 6	22 0 6	22 13 9	23 2 6	23 1 6	21 19 9	22 4 0	22 10 0
1876	**	....	....	....	....	....	....	....	....	....	....	....	21 13 9
1877	21 17 6	21 9 6	21 6 6	20 18 0	21 6 3	20 14 6	20 4 6	20 1 0	20 0 3	20 2 3	19 14 6	19 3 0	20 11 6
1878	19 2 3	18 9 6	17 17 0	17 3 0	16 16 6	16 15 3	16 18 0	16 10 0	16 0 0	15 9 9	14 17 0	14 13 9	16 14 3
1879	14 3 3	13 7 6	14 12 6	14 9 6	13 15 9	13 10 6	13 9 0	14 1 0	14 15 0	16 8 6	17 1 3	18 10 0	14 17 0
1880	19 5 0	18 18 9	14 15 0	16 11 6	15 5 6	14 16 3	15 13 0	16 5 0	15 15 0	15 5 0	15 7 3	15 3 9	16 6 9
1881	15 3 9	15 2 6	15 2 6	14 12 9	14 11 3	14 15 0	14 12 3	14 15 3	15 3 0	15 9 6	15 3 0	15 5 0	14 19 9
1882	14 18 0	14 17 0	14 9 9	14 10 4	14 6 3	14 12 0	14 8 0	14 10 0	14 3 9	14 0 8	14 0 8	13 17 9	14 7 3
1883	**	....	....	....	....	....	....	....	....	....	....	....	12 18 0
1884	12 5 0	11 19 6	11 12 6	11 10 6	11 8 9	11 2 9	10 11 6	11 1 0	11 1 0	10 0 3	10 18 9	11 0 8	11 6 0
1885	10 19 6	10 16 0	10 14 8	10 15 3	11 1 6	11 6 3	12 8 0	12 1 3	11 15 8	11 12 9	11 16 10	12 11 10	11 10 0
1886	12 15 3	13 1 6	13 13 0	13 13 6	13 5 6	13 8 3	13 9 9	13 6 3	13 5 0	12 19 9	12 18 0	13 0 0	13 4 9
1887	13 0 0	12 18 9	12 13 6	12 14 6	12 9 6	12 11 0	12 6 9	12 6 3	12 6 9	12 5 0	12 19 0	15 12 9	12 17 0
1888	15 2 6	14 16 3	14 16 6	14 5 3	13 2 6	12 11 6	13 3 11	13 8 5	14 6 9	14 0 7	14 0 0	13 5 0	13 18 3
1889	13 6 3	13 2 6	12 16 3	12 16 6	12 17 6	12 13 9	12 11 3	12 15 3	12 13 11	12 11 3	13 15 6	14 10 0	13 0 10
1890	14 2 9	12 17 6	12 13 1	12 15 11	13 1 9	13 7 6	13 1 10	13 2 9	13 16 3	14 14 0	13 19 4	13 1 3	13 7 10
1891	12 19 9	12 12 6	12 13 1	12 13 1	12 13 3	12 16 3	12 12 3	12 7 2	12 7 8	12 4 3	11 16 10	11 10 6	12 8 10
1892	11 4 8	11 0 7	11 2 6	10 19 3	10 16 7	10 19 4	10 15 0	10 11 3	10 8 6	10 13 1	10 8 5	10 1 10	10 15 1
1893	10 0 10	9 13 3	10 2 0	10 2 6	10 6 3	9 10 6	10 2 6	10 0 6	9 19 4	9 14 6	9 16 9	9 13 9	9 18 6

* From British blue books. ** The monthly prices are not given in the blue books for these years.

AVERAGE MONTHLY PRICE OF SPANISH LEAD IN LONDON.*

(Price per long ton, 2240 lbs.)

Y'r	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1883	....	....	....	....	....	....	....	....	....	....	....	....	12 11 3
1884	11 16 3	11 11 6	11 2 9	11 1 3	11 2 0	10 15 3	10 5 6	10 15 0	10 11 9	10 14 3	10 13 0	12 3 9	10 18 11
1885	10 14 6	10 10 4	10 7 4	10 10 6	10 17 8	11 1 3	12 6 3	11 14 4	11 6 6	11 4 6	11 11 0	11 4 0	11 4 2
1886	12 7 6	12 15 6	13 3 0	13 5 3	12 12 0	12 19 9	12 19 6	12 16 9	12 17 3	12 12 3	12 14 6	12 14 9	12 16 6
1887	12 15 3	12 12 9	12 11 3	12 9 0	12 1 9	12 6 3	11 19 0	11 19 3	11 19 6	12 2 3	12 12 9	15 7 0	12 11 4
1888	14 16 6	14 12 6	14 11 9	13 18 0	12 10 6	12 5 0	12 16 10	12 19 6	14 1 3	13 13 5	13 6 3	12 13 9	13 10 5
1889	12 19 8	12 13 9	12 10 3	12 12 10	12 11 3	12 9 1	12 6 10	12 12 3	12 11 3	12 8 5	13 11 0	14 2 10	12 15 9
1890	13 11 9	12 14 1	12 10 0	12 12 6	12 18 4	13 4 10	12 17 6	12 18 4	13 12 1	14 7 9	13 11 3	12 16 10	13 2 11
1891	12 14 4	12 9 8	12 9 6	12 10 0	12 8 9	12 13 11	12 7 6	12 2 9	12 4 3	12 0 7	11 12 2	11 6 9	12 5 0
1892	10 18 1	10 13 11	10 17 4	10 12 4	10 11 9	10 13 5	10 19 3	10 5 11	10 3 4	10 7 0	10 1 10	9 19 0	10 9 5
1893	9 15 9	9 11 2	9 16 5	9 14 10	9 12 6	9 7 2	9 19 8	9 19 0	9 15 9	9 12 4	9 14 6	9 12 0	9 14 3

* For years 1883–92, inclusive, from British blue books. For the year 1893, compiled from Vivian, Younger & Bond's Metal Price Current. The prices are for Spanish, soft, without silver, ex ship, 2½% discount for cash.

AVERAGE YEARLY PRICE OF LEAD IN THE PRINCIPAL MARKETS OF GERMANY.

(In marks per 100 kilos.)

Year.	Berlin, Saxonia, Tarnowitz, Refined Hartz.	Cologne, Rhenish, Soft, Double Refined, Rhenish brands 3 Months.	Frankfurt-am-Main, Rhenish Double Refined in Pigs at Works.	Halberstadt.		Hamburg, Hartz, Soft Pig Lead, Double Refined.
				Refined Hartz, Soft, 3 Months at Works.	Ref'd Silesian, Soft, 3 Months at Works.	
1879	30.67	29.55	30.29	....	....	30.57
1880	33.25	32.07	32.04	....	....	34.35
1881	30.85	29.03	28.72	....	....	30.67
1882	29.77	28.27	28.28	26.86	26.18	29.83
1883	26.88	25.03	25.15	23.91	23.22	27.13
1884	23.08	21.62	20.46	20.72	20.78	23.90
1885	23.35	22.34	21.40	21.50	21.37	25.10
1886	26.84	25.83	25.41	24.84	24.71	28.81
1887	25.67	25.13	24.87	24.35	24.09	27.47
1888	28.56	27.63	27.03	26.62	26.29	30.27
1889	27.25	26.43	25.88	25.21	25.42	28.02
1890	28.10	27.47	26.83	25.91	25.65	29.05
1891	26.23	25.56	25.34	24.74	24.72	27.15
1892	23.13	22.05	21.73	21.02	20.98	23.16
1893	21.25	20.46	20.10	19.52	19.70	21.73

RECENT IMPROVEMENTS IN THE TREATMENT OF ARGENTIFEROUS LEAD ORES.

By H. O. Hofman.

In the volume of The Mineral Industry for 1892, pp. 321–328, appeared a short general review of the present methods for the treatment of argentiferous lead ores. In these pages it is proposed to give a record of the progress that has been made during the year 1893. The information is drawn in part from papers which appeared in the technical periodicals, and from the list of patents granted by the United States Patent Office as published in the *Engineering and Mining Journal.* Some important facts have also been obtained from special communications of metallurgists in charge of various works, to whom I am greatly indebted. Although this review aims to be largely critical, it has seemed advisable with some improvements, and generally with the patents, simply to put them on record without any special comment. The arrangement of subjects is the same as that adopted by the writer in his *Metallurgy of Lead.* The following abbreviations of titles of periodicals consulted will be used:

A. M., Annales des Mines.
B. & H. Ztg., Berg-und Hüttenmannische Zeitung.
Ch. Ztg., Chemiker Zeitung.
Coll. Eng., Colliery Engineer.
Coll. Guard., Colliery Guardian.
Colo. S. S. M. Sc. Q., Colorado State School of Mines Scientific Quarterly.
D. P. J., Dingler Polytechnisches Journal.
E. & M. J., Engineering and Mining Journal.
I. A., Iron Age.
J. A. & A. Ch., Journal of Analytical and Applied Chemistry.
J. S'y Chem. I., Journal of the Society of Chemical Industry.
J. Fr. I., Journal of the Franklin Institute.
J. I. & St. I., Journal of the Iron and Steel Institute.
M. I., Mineral Industry.
M. S. P., Mining and Scientific Press.
O. J., Berg- und Hüttenmännisches Jahrbuch der K. K. Bergakademien, etc.
O. Z., Oesterreichische Zeitschrift für Berg- und Hüttenwesen.
Pr. Z., Zeitschrift für Berg-, Hütten- und Salinen-Wesen in Preussen.
Proc. Colo. S. S'y., Proceedings of the Colorado Scientific Society.
R. U., Revue Universelle des Mines, etc.
S. M. Q., Columbia School of Mines Quarterly.
St. & E., Stahl und Eisen.
Th. I. Z., Thonindustrie Zeitung.
T. Q., Technology Quarterly.
Tr. A. I. M. E., Transactions of the American Institute of Mining Engineers.
Z. Anorg. ch., Zeitschrift für Anorganische Chemie.
Z. Angew. ch., Zeitschrift für Angewandte Chemie.

Introductory.

Properties of Lead.—The behavior of commercial lead with acids has been the subject of considerable investigation, but the results obtained have been far from uniform, so that new experiments are always of interest. The researches of

Lunge and Schmid (Lunge: *E. & M. J.*, Jan. 7, 14, 21, 1893. Schmid, a thesis: *Ueber die Einwirkung von reiner, nitroser und rauchender Schwefelsäure und Saltpetersäure auf reines Blei und Legirungen von Blei mit Antimon und Kupfer*, Bâle, 1892. Lunge, Schmid: *Z. Anorg. Ch.*, 1892, Vol II., p. 451, and *Z. Angew. Ch.*, 1892, p. 642) into the action of sulphuric and nitric acids on lead of different degrees of purity give important information.

Sampling.—Wood (*S. M. Q.*, XIII., p. 367; *E. & M. J.*, Aug. 13, 1893) publishes some notes on the sampling of mines and of ores and products at smelting and refining works. They consist of a short outline of the customary operations. Ledoux (*M. I.*, I., p. 143) has an interesting paper on the sampling and assaying of copper ores and mattes which contains valuable data. Landis (*Tr. A. I. M. E.*, XX., p. 611) discusses a method of hand sampling for iron ores which corresponds approximately to the grab sample in common use with fluxes and fuels at lead smelting works. Clarkson's paper (*J. I. & St. I.*, 1893, II., *Coll. Guard.*, Oct. 13, 1893) is of a similar scope. The Bridgman laboratory sampler (*Tr. A. I. M. E.*, XX., p. 437) is no longer in the market. It has been replaced by a similar but simpler device.

The different valuations put upon the same ore arise from different methods of sampling and assaying (Dudley in *Iron*, Dec. 2, 1892; *I. A.*, Nov. 24, 1892; *E. & M. J.*, Dec. 24, 1892; editorial, *E. & M. J.*, April 23, 1893. Molin: *I. A.*, Dec. 1, 1892). As sampling has been very much improved lately, the discrepancies are much less frequent than they used to be. The tendency at present is to replace hand sampling by machine sampling, thus not only cheapening the work, but making the sample more uniform. To the two intermittent machines of Brunton and Bridgman, which have become standards, a third, that of Constant, made in New York City, has been added. This is a very desirable machine and has been adopted by many Eastern works.

In hand sampling the transportation of the rejected ore to the ore bed and of the sample to the sampling room is usually connected with considerable expense. This has been much reduced at the works of the Pueblo Smelting and Refining Company, Pueblo, Colo. (*Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 34), where the rejected ore is unloaded at one side of the track into a large bin discharging into a Hunt automatic dump-car, which runs down on an elevated inclined track over the ore-bedding floor, and can be discharged at any point desired. The empty car is run back by a counterpoise. The ore reserved for a sample is collected in a small bin on the opposite side opening into a tram-car running to the sampling mill.

Assaying.—Drawings of assay furnaces having two muffles and intended for burning soft coal have been published by Waring (*E. & M. J.*, Sept. 10, 1892) and by Wells (*Colo. S. S. M. Sc. Q.*, Vol. I., No. 4, p. 13). In most gas muffle furnaces it is difficult to obtain a heat high enough to make two or more scorification assays at the same time, and even a single scorifier must often be placed toward the back of the muffle and the front kept hot with charcoal if the assay is to be successful. Borchers (*B. & H. Ztg.*, 1893, 243) has built a gas muffle furnace with small regenerative chambers in which he superheats the air and thus attains a temperature high enough for the nickel and cobalt assay, which is far beyond what is required to scorify a silver ore with granulated lead.

The time needed to make a lead assay in an iron crucible is usually from ten to fifteen minutes (see PERCY: *Lead*, p. 107). LOWE (*J. S'y Chem. I.*, 1892, XI., p. 133; *O. Z.*, 1892, p. 252) obtains his best results by working at an increased temperature and shortening the time to five minutes. There is a tendency now in the laboratory to replace dry assays of lead ores by wet ones, especially with complex ores and intermediary products rich in sulphur, arsenic, copper, iron, and zinc. The following three methods have come into somewhat general use. They all aim to determine volumetrically the lead in the mixture of lead sulphate and insoluble residue obtained by treating the ore or by-product with hydrochloric or nitro-hydrochloric acid and sulphuric acid until sulphuric acid fumes are given off, then cooling and disintegrating with water, filtering and washing. They are the bichromate method (ALLER: *Colo. S. S. M. Sc. Q.*, Vol. I., No. 4, pp. 18,22; CROASDALE: *J. A. & A. Ch.*, VI., p. 678, *E. & M. J.*, Feb. 11, 1893), Knight's permanganate method (*Proc. Colo. S. S'y*, 1892; *E. & M. J.*, Dec. 10, 1892; *Colo. S. S. M. Sc. Q.*, Vol. I., No. 3, p. 21; *J. A. & A. Ch.*, VI., 61), and Alexander's molybdate method (*E. & M. J.*, April 1, 1893; *Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 60). In assaying metallic copper, copper ore, or matte for silver and gold the usual scorification gives, especially with small amounts of precious metal, results that are too low. Whitehead (*J. A. & A. Ch.*, VI., 292; *J. Fr. Inst.*, May 17, 1892; *Iron*, July 1, 1892; *S. M. Q.*, XIV., p. 65; *B. & H. Ztg.*, 1893, p. 201) has described a method which is similar to the one in common use at most copper works; full details are given.

The crucible assay which has long been used on the Pacific coast for silver and gold ores has been largely adopted by Colorado smelting works for the assay of gold ores. It is preferable to the scorification assay, as, on account of the greater amount of material taken, the weights of gold obtained are larger, and there is consequently less liability to error in weighing and calculating results. A table of crucible charges by Tilden and Furman is published in the *Colo. S. S. M. Sc. Q.*, Vol. I., No. 4, p. 8.

The usual method of determining manganese with potassium permanganate has been modified by Lowe (*Colo. S. S. M. Sc. Q.*, Vol. I., No. 4, p. 86; *J. A. A. Ch.*, VI., p. 663); the determination of baryta in slags is discussed by Croasdale (*E. & M. J.*, Feb. 11, March 11, 1893) and Trachsler (*E. & M. J.*, Feb. 18, 1893). The investigations made by the Colorado Scientific Society (*Proc. Colo. S. S'y*, 1892; *E. & M. J.*, Aug. 20, 1892; *Colo. S. S. M. Sc Q.*, Vol. I., No. 2, p. 44; *J. A. & A. Ch.*, VI., p. 488; *B. & H. Ztg.*, 1893, pp. 337, 347) on the different methods of determining zinc in ores proved that the results of Von Schulz and Lowe by their assay method were nearer the chemical analysis than those of any of their six competitors. Their method is now recognized as the standard in the West. Hinman (*S. M. Q.*, XIV., p. 40; *J. A. & A. Ch.*, VI., p. 682) found, however, that the mode of procedure had to be modified with not readily decomposable oxide zinc ores that are rich in iron.

SMELTING OF LEAD ORES.

In General.—Haunay (*E. & M. J.*, Aug. 5, 1893) proposes to treat lead ore in a Bessemer converter and produce either lead, litharge, or lead sulphate.

In the Reverberatory Furnace.—The old Corinthian furnace and the old method of treatment at Bleiberg have at last (*O. Z.*, 1893, p. 283) been given up. The Belgian reverberatory furnace is now in use and is worked by the Silesian method.

In the Ore Hearth.—The lead ores of Wisconsin, which were formerly locally smelted in the air furnace or ore hearth, are now (BLAKE: *Tr. A. I. M. E.*, XXII.) sold to refiners, who use them in their blast-furnace charges for working up copper-bearing drosses from base bullion.

In the Blast Furnace: Lead Slags.—Heberdey and Kroupa publish two analyses of crystallized lead slags (*O. Z.*, 1893, p. 138), a valuable contribution to the study of this important chapter.

Action of Fluxes.—Bretherton (*E. & M. J.*, March 4, 1893) states that at the American Smelter, Leadville, Colo., he has used for the last eight years burnt lime instead of limestone, with the result that the furnaces not only put through more ore with the same labor and fuel than with limestone, but that cleaner slags were produced and fewer wall-accretions formed. He answers (*E. & M. J.*, April 22, 1893) the criticism of the editor of the *Colorado State School of Mines Scientific Quarterly* (Vol. I., No. 4, p. 78) that burnt lime is too fine for the common fine-ore charges by saying that their lime, as taken from the car, measured about five inches—a good size for the blast furnace. Other persons who have been using burnt lime complain of its fineness. Burnt lime was used many years ago in the iron blast furnace. The supposed advantages were that more ore could be put through the furnace per unit of fuel in a given time (as 56 CaO charged are equivalent to 100 $CaCO_3$); that the heat consumed by driving off the 44 CO_2 in the blast furnace was saved; and that the partial reduction of the 44 CO_2 by means of carbon did not occur. Lang (*E. & M. J.*, April 8, 1893) again calls attention to this. Grüner (*A. M.*, 1871, XX., 325; *D. P. J.*, 1872, CCIV., p. 309) calculated a saving of 10% of fuel by the use of burnt lime, while Bell (*Chemical Phenomena of Iron Smelting*, London, 1872, p. 138) made it only 3.4%. The reason why burnt lime in the iron blast furnace has been given up is that it absorbs carbonic acid and water vapor from the furnace gases, a heat up to redness (Bell, *Manufacture of Iron and Steel*, London, 1884, p. 60) assisting the absorption of carbonic acid, and lime parting even less readily with the combined water than with carbonic acid. While the absorption generates the same amount of heat that the expulsion consumes, it occurs in the upper parts of the furnace, warming only the gases that are passing out; meanwhile the lower part is being cooled by the expulsion, and this has to be made up by an extra amount of fuel. If lime is to be used, the limestone must be burned in large pieces and the burning must be very complete and even carried to a fritting, if possible (*i. e.*, with impure limestone), so as to diminish the absorption of carbonic acid and water. The apparatus must be easy to regulate and manage, so as to supply just the amount of lime required by the blast furnace, as storage and transportation for any distance are out of the question. The fuel charged into the blast furnace must be dry, and the ore and iron flux not only dry, but free from carbonic acid. Finally, the height of the furnace may have to be increased to prevent the furnace gases from passing off at too high a temperature. The many difficulties in the way of using burnt lime have deterred the iron smelter from it, and special economic conditions must prevail to make it profitable to the lead smelter; as, for example, at Leadville and Salt Lake City. Le Chatelier (*Th. I. Z.*, 1886, p. 429) found that calcium carbonate under the pressure of one atmosphere is decomposed at 812° C.

Influence of Foreign Matter.—A contribution to the subject of the behavior of alumina in slags has been made by Kosmann (*St. & E.*, 1892, p. 270; *B. & H. Ztg.*, 1892, p. 177). The best manner of treating zinc-lead sulphides may be considered still an open question. Schnabel (*E. & M. J.*, Sept. 17, 24, 1892; *B. & H. Ztg.*, 1892, 428, 438) has reviewed the different methods, and criticisms upon special points in his paper have appeared by Bucherer (*E. & M. J.*, Oct. 1, 1892) and Kosmann (*B. & H. Ztg.*, 1892, 439). The same ground has been gone over by Emmens (*M. I.*, I., 416), who in his turn is taken up by Bartlett for one of his statements (see BARTLETT, *E. & M. J.*, July 1, Oct. 7, 1893; EMMENS, *E. & M. J.*, Sept. 16, 1893).

No improvements in the mechanical separation of blende and galena have yet been suggested. As to smelting the ores, new facts have been published about the Bartlett process at Cañon City, Colo. (BARTLETT: *Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 1; HAWKER, *E. & M. J.*, Dec. 9, 1893; HOFMAN: *E. & M. J.*, Oct. 28, 1893). At the Broken Hill Mines, New South Wales (GREENWAY: *E. & M. J.*, Nov. 11, 1893), some sulphide ores with 30% to 35% Pb, 18% to 25% Zn, 10% Fe, 10% gangue, and 26 to 30 oz. Ag per ton are dead-roasted and smelted with 25% carbonate ores, the slag formed having a peculiar composition: 24% SiO_2, 36% Fe (Mn)O, 16% ZnO, 16% CaO; other ores (HOWELL: *E. & M. J.*, Sept. 23, 1893) are concentrated. The heads with 60% Pb, 7% to 9% Zn, and 20 to 34 oz. Ag per ton are smelted, and the tailings rich in zinc, silica, and garnet and running 7 to 12 oz. Ag per ton are going to be treated by the Patera process. In this connection the experiments made by O. Hofmann (*E. & M. J.*, Feb. 9, 16, 23; March 9, 1889) on the treatment of blende and galena are of special interest.

All other modes of treatment are so far confined to the records of the Patent Office. Lumaghi has patented (No. 483,934, Oct. 4, 1892) improvements in connection with zinc retorts. James (Patent No. 483,962, Oct. 4, 1892) proposes to dead-roast two-thirds of a given quantity of ore, to mix it with the remaining unroasted third, and to smelt the mixture in a reverberatory furnace on a bath of lead which is to take up the lead and silver set free, while the zinc is to be volatilized and the rest scorified. Hunicke (*E. & M. J.*, Dec. 24, 1892; Patent No. 487,444, Dec. 6, 1892) suggests preheating in separate furnaces roasted zinc-lead ore and coke up to a temperature at which zinc oxide is reduced, and then charging in thin alternate layers into a blast furnace. Zinc and lead are reduced near the throat, the lead (silver) is collected in the crucible of the furnace, while the zinc is volatilized to be condensed in suitable chambers. As the volatilization takes place near the throat of the furnace, the zinc vapors and zinc oxide do not clog up the pores of the coke. Wetherill (Patent No. 484,269, Oct. 11, 1892) wishes to treat silver-bearing blende on the Wetherill grate for zinc oxide and residue, the former to be distilled in ordinary retorts for zinc and second residue, and this to be smelted with the first residue from the grate in a suitable apparatus. Chanute (Patent No. 501,559, July 18, 1893) intends to roast zinc ores with salt and to recover the volatilized chlorides by filtering through bags; they are to be dissolved in hydrochloric acid and the metals to be precipitated with zinc.

Roasting of Ores.—The Pearce turret furnace (Patent No. 488,797, Dec. 27, 1892; *Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 33; *E. & M. J.*, June 3, 1893). This is a mechanical reverberatory furnace, the hearth of which is circular or turret-shaped, and is heated by two or more exterior fireplaces. The ore, fed automatically through the roof, is turned over and moved along the hearth to the discharge by four sets of hollow rabble-blades attached to horizontal pipe-arms inserted radially in a central hollow column which is set in motion by gearing. Part of the air necessary for oxidation is drawn on to the hearth through the warm flues in the outer wall and part driven through the hollow horizontal arms and rabble-blades, whereby not only the air is warmed but the iron work also protected. This admission of air is automatically regulated (Patent No. 506,129, Oct. 3, 1893). The outer wall has a number of doors to permit work on the hearth. The inner wall supporting the arch is suspended from I-beams. These furnaces are used at Argo, Colo., and Butte City, Mont., where one 36 ft. in diameter, requiring 2½ horse-power, roasts 22 tons of copper ore in twenty-four hours, reducing the sulphur from 30% to 5% and 7%, or 9 tons of pyrite concentrates with 45% sulphur and 6% moisture, driving off all the sulphur. The merits of the furnace are discussed by Bellinger (*E. & M. J.*, July 22, 1893) and Pearce (*E. & M. J.*, Aug. 5, 1893). According to Furman (*E. & M. J.*, Sept. 9, 1893), a Pearce furnace with fuse-box attachment is being erected at Denver.

A furnace working on a similar plan is the one patented by Keller (Patent No. 506,511, Oct. 10, 1893). It is also ring-shaped, or rather horseshoe-shaped, the ring being open for about one-sixth of its circumference. To the right of the opening is the exterior fireplace, and to the left the flue, ending in the chimney. Working doors open from both sides on to the hearth. The ore, fed at the flue end, is moved toward the discharge by a set of radial arms attached to a ring revolving around the inner wall on the level of the hearth and protected from heat and fumes.

The Blake furnace (*Tr. A. I. M. E.*, XXI., 943, and XXII.) is an improved Brunton revolving calciner, the two principal new features being that the hearth, instead of having the form of a flat truncated cone, has a series of concentric terraced floors, and that superheated air, free from products of combustion, is admitted on to the hearth.

The O'Hara furnace, a mechanical two-story reverberatory roasting furnace, heated from exterior fireplaces, has lately been improved. In the original furnace the ore fed on the upper hearth is mechanically stirred over and moved on by several sets of plows attached at certain distances to an endless chain, which passes along the center of the hearth, and, leaving this, runs over revolving sheaves. From the upper hearth the ore is dropped through an opening on to the lower one, and is thence moved in the same manner by the returning chain in the opposite direction toward the discharge. In order to reduce the great wear caused by the chain being dragged along the floors of the two hearths through the hot ore, and also the amount of power required, Brown and Allen (*E. & M. J.*, May 20, 1893; *M. S. P.*, May 20, 1893) have replaced the central chain by two side-chains, which, resting on buggies in partly closed off side galleries and being connected with the stirrer carriages, pull these over the hearth. Thus the chains are protected from mechanical wear, heat, and chemical action, and the power required is reduced one-third. Minor details distinguish the furnaces as Brown-O'Hara and Allen-O'Hara. (BELLINGER: *E. & M. J.*, July 22, 1893; PEARCE: *E. & M. J.*, Aug. 5, 1893; BEADLE: *E. M. & J.*, Sept. 9, 1893; FURMAN: Sept. 9, 1893; BROWN'S Patent No. 489,143, July 3, 1893, illustrated in *Coll. Eng.*, XII., 267.)

The fuel used in roasting lead ores is commonly bituminous coal, burned on ordinary horizontal grates or step-grates. Gaseous fuel, generated in the Taylor producer, has lately been used to some extent in chloridizing silver ores (STETEFELDT: *E. & M. J.*, May 9, 1892, and *Tr. A. I. M. E.*, XXII.; MORSE: *Tr. A. I. M. E.*, XXI., 919, and *E. & M. J.*, Feb. 25, 1893), and promises to make its way also in the roasting of lead ores.

Davis shaft roasting furnace: The latest form is the Davis-Colby (*E. & M. J.*, Dec. 30, 1893; Patent No. 508,542, Nov. 14, 1893).

Heberdey and Kroupa (*O. Z.*, 1893, p. 138) published analyses of crystallized slag-roasted galena ore rich in zinc.

The collection of fumes from roasting furnaces has always been and still is a difficult matter. Sheedy and Iles (Patent No. 483,176, Sept. 27, 1892) propose to save them by filtering through matted fibrous material held in frames which are placed across the flue and can be easily exchanged when clogged or injured.

A most interesting paper on the relative cost of roasting ores in heaps, in the Pearce and O'Hara mechanical furnaces and the hand reverberatory furnaces, with and without fuse box, appeared in the *Engineering and Mining Journal* of Dec. 30, 1893, which will probably cause some discussion.

General Arrangement of Plant.—The plant of the Zeehan & Dundas Smelting Works, Tasmania, is described and illustrated in the *Engineering and Mining Journal*, Sept. 3, 1892, by Beardsley. It stands on a sloping hillside and has two furnaces, 136 by 40 in. at the tuyères, designated as 100-ton furnaces. The sides of these are placed toward the dump instead of the ends, which is the usual arrangement.

An illustrated description by Drake of the works of the Mount Stewart Lead and Silver Mining Company at Leadville, New South Wales, will be found in the *Transactions of the American Institute of Mining Engineers*, XXI., p. 874. The furnace is 11 by 4 ft. at the tuyères and faces the dump.

New Blast Furnaces.—The furnaces of the Zeehan & Dundas Smelting Works (BEARDSLEY: *Tr. A. I. M. E.*, XXI., p. 575) are of the same general type as those used in the American smelting works, but a few peculiarities require to be noticed. The crucible is inclosed with wrought-iron plates braced by heavy rails; the cast-iron jackets are held in place by screws turning in cast-iron plates attached to the I-beams and pillars and bearing against sockets in the water-feeders; the shaft consists of six wrought-iron jackets, with a three-inch space, separated by courses of firebrick. These top jackets are suspended from upper I-beams sustained by pillars resting upon the lower I-beams and pillars. The throat is surmounted by an iron hood having a horizontal flue which leads to the dust chamber; the hood is suspended and is independent of the flue, so that it can be removed for barring down the furnace.

The shaft of the new furnace of the Broken Hill Proprietary Company, New South Wales (*E. & M. J.*, Nov. 18, 1893), is also built of wrought-iron jackets. The use of water-cooled jackets instead of brickwork was tried many years ago at the La Plata works of Leadville, Colo., but was given up on account of the great loss of heat. The tendency to-day is to make the lower part of the brick shaft especially thick, as this lessens the amount of fuel used.

The furnace of the Mount Stewart Lead and Silver Mining Company, Leadville, New South Wales (*Tr. A. I. M. E.*, XXI., p. 874), 11 by 4 ft. at the tuyères, has high cast-iron jackets with water-inlet near the bottom, the main supply pipe being laid under ground. The jackets are closed at the top, near which are the water outlets, goosenecks discharging into troughs which convey the water to the hollow columns. These serve not only to support the shaft, but also to carry off the overflow water.

Details of the Blast Furnace.—A new method of supporting the shaft, and also the water jackets by the columns, and connecting these, has lately been patented by Nesmith (No. 507,031, Oct. 17, 1893). The drawing in the specification shows also small water jackets placed between the common cast-iron water jackets and the supports of the shaft. Iles patented (No. 476,275, June 7, 1892) some details in the construction of buckstaves with lugs through which pass the tie-rods that bind the shaft of the furnace.

In connection with the feed-holes of the furnace a not very recent paper by Hering (*D. P. J.*, 1886, CCLXI., p. 205) may be recalled, in which are reviewed the different methods in use for charging a blast furnace and drawing off the gases. Iles (Patent No. 484,018, Oct. 11, 1892) introduces the charges from the side of the furnace through two feeding doors closed by sliding curtains, and draws off the fumes from the top through a pyramidal funnel ending in a sheet-iron pipe having the form of an inverted V, which delivers the fumes in the roof of the dust chamber. He also made an improvement (Patent No. 501,188, July 11, 1893) in the cast-iron plates extending over the throat and around the feed-opening of a furnace charged from the top by reinforcing them with strips of steel or wrought iron riveted fast to hold in place the cast iron in case of breakage. To protect the sides of the furnace while the charge is being fed, Sheedy and Iles (Patent No. 505,538, Sept. 26, 1893) cover them with iron plates suspended from the throat by hooks. In the iron parts of the crucible a few changes have been made. Iles (Patent No. 484,020, Oct. 11, 1892) rivets a wrought-iron band to the crucible casting which has strengthening ribs and oblique flanges fastened by means of tie-bolts to corner plates with rectangular flanges. The object of the band is to hold together the castings in case of breakage. He also covers (Patent No. 481,950, Sept. 6, 1892) the brickwork of the crucible with iron plates held in place by anchors. The plates have depressed flanges on which rest the water jackets. The brickwork is thus protected, the jackets are secured in their position, and the replacing of them in case of accident is much facilitated.

At the Zeehan & Dundas Smelting Works, Tasmania (Beardsley: *Tr. A. I. M. E.*, XXI., 575), the crucible is, as already stated, inclosed by wrought-iron plates and braced by heavy rails. Water-cooling of the slag-spout (Hofman, *E. & M. J.*, Oct 14, 1893), used at several American works, has been introduced in Australia;

e.g., at the Broken Hill Proprietary Company's works (*E. & M. J.*, Nov. 18, 1893), where the lead spout is also cooled, and at the Mount Stewart Lead and Silver Mining Company's works (*Tr. A. I. M. E.*, XXI., 874).

The recent improvements made in lining the crucible and boshes of some iron blast furnaces with carbon bricks—*i.e.*, bricks made of coke and clay or coke and tar (BURGERS: *St. & E.*, 1890, p. 112; *I. A.*, March 6, 1890; *Coll. Guard.*, Sept. 6, 1892; KERL: *B. & H. Ztg.*, 1890, p. 73; KUPELWEISER: *O. Z.*, 1890, p. 195; KAIL: *O. Z.*, 1891, p. 277; GAYLEY: *Tr. A. I. M. E.*, XXI., p. 112; WIBORGH: *O. Z.*, 1893, p. 238)—suggest a similar use in the lead blast furnace, as the bricks stand the scouring of the charge, if sufficiently hard, and the action of heat and slag (the clay protecting the coke from combustion and the coke the clay from corrosion), are bad conductors of heat, and at least as impervious to lead as the ordinary firebrick. According to Kerl (*B. & H. Ztg.*, 1890, p. 73) air-dried coke bricks were used in 1857 in the lead furnaces of Clausthal, and according to Jung (*O. Z.*, 1893, p. 160; *J. I. & St. I.*, 1893, I., p. 291; *B. & H. Ztg.*, 1893, p. 204) in 1866 in those of Mechernich. They might prevent the adhesion of a crust to the walls of the crucible and cause a considerable saving of fuel, as the cooling water of the jackets carries away a large amount of heat.

In the separation of matte and slag many improvements have been made. These are of two classes, those within the furnace and those without (see later). To the former class belong the arrangements of Eurich, Mathewson, and Bretherton. As early as 1875 Hering (*B. & H. Ztg.*, 1875, p. 327) suggested the separate tapping of the matte from a furnace having Arents' siphon tap. This was carried out about 1878 at the Delaware Lead Works of Philadelphia (see also KIRCHHOFF: *B. & H. Ztg.*, 1878, p. 34, and HAHN: *B. & H. Ztg.*, 1878, p. 129). The improvement of Eurich (Patent No. 424,104, March 25, 1890; *B. & H. Ztg.*, 1892, pp. 143, 187) consists in using in connection with Arents' siphon tap a crucible that is partly internal and partly external, in replacing the usual tympstone by a water jacket, and in having in the fore-hearth two separate water-cooled taps for matte and slag. Mathewson's invention (Patents No. 483,936, Oct. 4, 1892, and No. 501,351, July 11, 1893; *Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 40) resembles in principle that of Eurich, but differs from it in details of construction. He has a separate cleaning-hole through which the rod can be introduced into the blast furnace; the slag runs off continuously, while the matte is only tapped periodically. In its latest form (Patent No. 511,090, Dec. 19, 1893) the fore-hearth with water-cooled tymp has been abandoned. The closed breast has three separate openings. The two lower ones, placed in a water-cooled tapping jacket, are small and serve as matte-taps and emergency slag-taps respectively. The upper one, which is large, has a water-cooled tube, fastened to the breast jacket, which extends into the furnace and downward to nearly the level of the matte, and thus traps the blast and permits a continuous discharge of clean slag, while the matte is tapped at intervals. In case of accident to the slag-discharging tube, the emergency tap comes into play. Bretherton finally at the American Smelter, Leadville, Colo. (*Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 41), discharges the matte from the blast furnace in a stream of from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter (how is not stated), and granulates it by means of water issuing from a flat nozzle. The bulk of it is sufficiently fine for roasting in the reverberatory furnace, and the coarser particles, amounting to one-quarter of the whole, are more readily crushed fine than if the matte had cooled slowly in a pot.

No change is to be recorded in the construction of water jackets. A note in the *Engineering and Mining Journal* for Nov. 15, 1890, on an improvement in repairing a crack in a cast-iron jacket may be of interest. The usual method is to bore a hole at either end of the crack, cut out a shallow mortise with receding sides along its length, and to close the holes by driving in copper pins and the mortise by calking with a stout copper wire. If the holes are not bored just where the rent ends, the crack will extend beyond them. The improvement is for doing this accurately. It consists in moistening the crack with coal oil, wiping it off and then rubbing it with chalk, when the oil previously taken up will exude and show the exact points where the crack ends.

The manner in which the jackets are held in place at the furnaces of the Zeehan & Dundas and the Broken Hill smelting works has already been referred to.

An important addition to the construction of tuyères is the Davies slag escape (Hofman: *E. & M. J.*, Oct. 14, 1893), which consists of an opening in the under side of a tuyère-pipe or box that is closed by a linen or paper diaphragm. Any slag flowing into the tuyère-pipe comes in contact with the diaphragm, and burning a hole makes itself noticed by the noise of the escaping blast. A few improvements are recorded for making a tight joint between the tuyère-pipe and jacket. A tuyère-elbow (Iles, Patent No. 497,072, May 9, 1893) with slag escape on lower side and turned-off facings is secured by means of lugs to the outside of the water jacket around the tuyère-hole. Another tuyère-elbow (Iles, Patents 505,549 and 505,550, Sept. 26, 1893) similar to the previous one, only with beveled facing, fits at the tuyère-hole into corresponding recesses on the outside of the water jacket and is held in place by a lever having a cam-shaped head.

Keller reviews in a well-illustrated article (*Tr. A. I. M. E.*, XXII.) the slag-pots commonly used at lead and copper works. He distinguishes three kinds, according to the form of the bowl and the manner of securing the axle—two deep ones, one of which has rounded sides, a pointed bottom, and the axles secured with set screws, which is recommended for dumping slag; the other, straight sides, a rounded bottom, the axles secured with wedges, for settling out matte, and a shallow one, the oldest form, with straight sides and a rounded bottom, the axles being of a somewhat complicated construction no longer in use. He also discusses some further details and calls attention to a new wheel patented by Cole, Gaylor, and himself (No. 470,340, Nov. 29, 1893). The spokes, threaded at one end, are screwed into the cast-iron hub and held in place by jam nuts; the opposite ends have flanges, on to the outer sides of which a strong wrought-iron tire is shrunk and then fastened by means of countersunk set-screws. Three new forms of pots for the disposal of waste slag have to be recorded. Föhr (*Ch. Ztg.*, 1892, XVI., p. 532) describes and illustrates the Leder slag-dumping car of the Anhalt Smelting Works, holding about one ton of slag. Iles patented (No. 483,152, Sept. 27, 1892) a dump car suited for a horizontal or an inclined track. The pot holding the clean slag is suspended by trunnions, and is automatically discharged by levers which extend downward and forward and are attached to the trunnions. They strike stops fastened to the track at any desired point, and thus tilt the pot. Another patent (Iles, No. 484,019, Oct. 11, 1892) concerns a slag-dumping car, similar to that of Nesmith (No. 388,708, Aug. 28, 1888; also Hofman: *Lead*, p. 202), for collecting slag from a number of ordinary catch-pots and discharging it at the edge of the dump, the tilting being done by hand. A number of devices have been patented to perfect the separation of matte and slag outside of the furnace. Pohle (Patent No. 484,570, Oct. 18, 1892) lets the molten slag and matte enter the slag-pot tangentially in proximity to the wall, thus not disturbing the matte that has once settled out. Keiper (Patent No. 484,659, Oct. 18, 1892) applies the principle of Arents' siphon tap for lead to the separation of matte and slag by conducting the melted mixture from the furnace into a covered conical cast-iron pot, both cover and pot being cooled by spiral water pipes. The clean slag overflows at the rim of the pot; the matte at the rim of the siphon, which is placed below the level of the slag-outlet spout. Iles (Patent No. 500,621, July 4, 1893) uses two or more overflow pots with removable spouts. He further (Patents No. 505,551 and 505,552, Sept. 26, 1893) granulates the slag from a couple of overflow pots in a stream of water, crushes fine, and removes the heavy particles by washing. Neill (Patent No. 505,904, Oct. 3, 1893) aims to settle out matte from slag in a slag-pot through the combined forces of gravity and magnetic attraction by bringing the bottom of the pot in contact with an electro-magnet. An arrangement which somewhat resembles the external crucible, so common with copper furnaces, is patented by Iles (Nos. 494,570 and 494,571, April 4, 1893; *Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 37). He runs the slag and matte from six large-sized blast furnaces through a covered trough into a reverberatory smelting furnace, where, after a complete separation, the clean products are removed at intervals. The products of combustion from the reverberatory furnace and the fumes from the slag and matte pass off together into a dust chamber. The covered troughs can be heated by oil jets to prevent any chilling. There does not appear any reason why there might not be a continuous flow of slag and matte in a lead furnace as there is in a copper furnace, the separation to take place in an external crucible and the lead to be collected in the usual way by Arents' siphon tap.

Calculation of Charge.—Methods in common use by engineers for calculating charges for iron and lead blast furnaces have been often described by recent writers, while formerly very little, if anything, was published on this subject. Furman (*S. M. Q.*, XIV., p. 314) discusses the calculation of a lead blast furnace charge in great detail. He begins with a general statement of what is required in a good lead slag, and gives six examples of typical slags and the several conditions to which they are best suited. He then considers the making-up of the charge with reference to the different kinds of ore in the market and to whether they can be smelted raw or have to be roasted, which may affect the percentage of lump and fine ore in the charge. Finally, the percentage of lead in the charge and the grade of bullion to be produced, the size of the charge and the percentage of fuel used, and the by-products which will result,—speise, matte, flue dust, etc.,—are passed in review before the calculation proper is taken up. This is carried through in detail, first in a purely algebraical form, and is then illustrated by four numerical examples.

Saint Dizier (*Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 50) gives two algebraical formulæ to find the amounts of iron ore and limestone required to form a typical slag from the slag components of 100 tons of ore.

Work on the Furnace Floor.—Experiments in automatic feeding with cup and cone have not given satisfactory results, as it was proved impossible to keep the top of the charge cool. Those with a furnace the throat of which is open, have, on the contrary, been successful. The charge is introduced, in the usual order, into a car having nearly the same sectional area as the throat of the furnace and a movable bottom; this is then run over the throat and the bottom dropped. Thus a number of furnaces can be fed by the same crew and the ore beds made up in the most convenient place, even if distant from the feed floor, because the hauling is mechanically done.

Work on the Dump.—Keller (*Tr. A. I. M. E.*, XXII.) speaks of the advisability of having tracks leading from the furnace building to near the edge of the dump for the slag carts to run on, and of keeping the dump smooth by means of slag squares.

Irregularities in Working.—Bretherton (*E. & M. J.*, March 4, 1893) states that after having used burnt lime for eight years in the blast furnace he can confidently assert that less wall accretions form with it than with unburnt lime, the lime having a decomposing action on the metallic sulphides which form the main constitutent of the accretions. Reasons against the use of burnt lime have already been given.

Furnace Products: Base Bullion.—Pattinson (*J. S'y Chem. I.*, 1892, XI., p. 321; *J. A. & A. Ch.*, VI., p. 387) suggests, as a method of sampling base bullion, sawing through the bars with a circular saw and using the "sawings" as sample. This method, of little value to the smelter who ships his bullion, will hardly recommend itself even to the refiner, as the bars, having to be sawed through at least in two places, on account of the uneven distribution of the silver, will be inconvenient to handle, and the finely divided sawings are too liable to cause losses while they are being collected and melted down.

Speise.—Hampe (*O. Z.*, 1893, p. 144; *B. & H. Ztg.*, 1893, p. 140) published an analysis of speise from Andreasberg.

Matte.—The stalls used for roasting matte are usually built of slag brick. Their manufacture at copper works is described by Egleston (*S. M. Q.*, XII., p. 189), Peters (*Modern American Copper Smelting*, New York, 1891, p. 93), and Klette (*Pr. Z.*, XL., p. 501; *B. & H. Ztg.*, 1893, p. 150). The roasting of lead matte in lump form in shaft furnaces has not been tried, probably on account of the low temperature at which it softens and fuses, although the Davies ore roaster, which is doing such excellent work in roasting iron ores, also promises well for lead matte, if this be not charged alone, but mixed with roasted matte to keep down the temperature.

The crushing of matte that is to be roasted in the reverberatory furnace is usually done by rolls, in some cases by the Sturtevant mill. Lately concentrated matte of lead works has been granulated (Bretherton, *Colo. S. S. M. Sc. Q.*, Vol. II., No. 1, p. 41), as had been previously done at copper works—*E. & M. J.*, 1893, Oct. 14 (Deering); Nov. 25 (Colquhoun); Dec. 2 (Thomson); Dec. 23

(Raht and Eustis)—and nickel works—*E. & M. J.*, 1893, Sept. 16; Oct. 28, (Browne).

Slag.—The principal methods of disposing of lead slags have already been considered in connection with slag-pots. In a few instances slag has been granulated in a similar manner to matte (see also TERHUNE: *E. & M. J.*, Dec. 9, 1893). Several attempts have been made to utilize the heat of waste slag: by Bretherton (*E. & M. J.*, June 12, 1886), Giroux (*M. S. P.*, July 15, 1893), and Howell & Ashcroft (Patent No. 510,395, Dec. 12, 1893; *E. & M. J.*, July 15, 1893), for raising steam; by Engelbach & Bretherton (Patent No. 496,250, April 25, 1893), for heating blast; and by Bell (*E. & M. J.*, March 8, 1890), for evaporating brine.

Hering (*O. Z.*, 1893, 238) discusses the loss of metal with the slag. He attributes it to incomplete reduction of metallic oxide, to re-oxidation of reduced metal, to incomplete separation of matte and slag, and to what he calls adhesion of precious metal or metallic compound to gangue or slag. The first loss is not uncommon; the second hardly ever occurs in the blast furnace; the third is often caused by the oxidizing action that some slags, especially if they contain particles of magnetic oxide of iron, have on shots of matte which, on account of the sulphurous acid that is set free and surrounds them, are prevented from settling out. The fourth loss refers first to that occurring in sweep-smelting, where, without a very intimate mixing of litharge and roasted sweep, the slags made are liable to be richer in gold than the base bullion produced, and secondly to the loss caused by fine particles of matte being held in solution or perhaps suspension by the slag, especially in the presence of zinc. Kroupa (*O. Z.*, 1892, 424) discusses the desilverization of slags not to be freed from silver by simply smelting. He refers to the work done by Keller (*Tr. A. I. M. E.*, XXI., p. 71) at Leadville, Colo., and to the similar method of treatment at the Freiberg Smelting Works (BROWN & PHILLIPS: *Notes on the Smelting Processes at Freiberg*, p. 18, Freiberg, Saxony, 1886.)

Flue Dust.—The dust flues built according to the Monier system in the Harz Mountains, Germany (*St. & E.*, 1892, pp. 867, 871; *B. & H. Ztg.*, 1893, p. 22), have proved very satisfactory; also those constructed of hollow bricks with air circulating in them to assist cooling (Omaha and Grant Works, Denver, Colo.). Filtering (Globe Smelting and Refining Company, Denver, Colo.) appears to give favorable results, to judge by the number of patents taken out referring to the details of the process (Iles, Patents No. 475,774, May 31, 1892; No. 477,759, June 28, 1892; Chanute & Iles, No. 479,489, July 26, 1892; Iles, No. 484,016 and 484,017, Oct. 11, 1892; No. 485,797, Nov. 8, 1892).

A new plan to assist the collecting of flue dust has been tried on a small scale with some success by Hempel (*B. & H. Ztg.*, 1893, p. 355). It consists of placing in a chamber a centrifugal fan, which sucks in the fumes at the center and discharges them with force against the walls, increasing the friction of dust-particles and thus assisting condensation. Two recent improvements ought to be mentioned in connection with the treatment of flue dust. The first is Edison's method of bricking fine iron ore. He bricks the ore (Patent No. 485,840, Nov. 8, 1892) by mixing it with lime slaked in hot water, allows the bricks to set, re-dampens them, and then dries them, the last two operations being uncommon with flue dust. The other is Iles' (Patent No. 500,580, July 4, 1893) for fusing the flue dust in a reverberatory furnace and collecting the fumes formed by filtering.

DESILVERIZATION OF BASE BULLION.

The Pattinson Process.—The melting points of several silver-lead alloys determined in 1859 by Tunner are published by Priwoznik, with additional remarks, in *O. Z.*, 1892, p. 480.

The Parkes Process.—Several additions have been made to the Parkes process. In softening and refining, oil has in a few instances replaced bituminous coal as fuel, and air jets have been found more economical as atomizers than steam jets.

The time required for desilverizing in the kettle has been shortened in some cases by having only two zincings instead of three when no separate gold crust is being made, each zincing lasting six hours. It can be done in this way by using larger additions of zinc, carefully regulating the temperatures and stirring in by hand. The last has come again into pretty general use, in preference to steam-stirring, which requires such a very nice adjustment of temperature as to be somewhat troublesome. Roessler & Edelmann use an alloy of zinc with half a per cent. of aluminum instead of pure zinc. This enables them to desilverize with a single zincing. A full set of samples of their process was exhibited at the World's Fair (HOFMAN: *E. & M. J.*, Oct. 21, 1893), and a few particulars about the mode of operating have been published since (*E. & M. J.*, Sept. 2 and Dec. 2, 1893). The details are still lacking. The process, or at least a part of it, has been used for some time in Belgium, and the inventors are now trying to introduce it here. The use of steel for desilverizing-kettles, and especially for those in which zinc crusts and desilverized leads are to be steamed, has not as yet found such general acceptance in German works (*B. & H. Ztg.*, 1893, p. 22) as was hoped, on account of the difficulties of steel casting. The common material is still cast iron, and Föhr (*Ch. Ztg.*, 1892, XVI., p. 503) calls attention to the fact that of two irons of the same chemical composition the one that is the denser will resist the action of heat and chemicals better than the coarser one, and that, therefore, the determination of the specific gravity forms an important auxiliary means of deciding on the kind of iron best suited not only for desilverizing kettles, but for any iron vessels that are to be used in metallurgical processes. The form of the kettles used remains the same with one exception. Honold (*B. & H. Ztg.*, 1893, pp. 21, 51; *O. Z.*, 1893, p. 388) has again altered the construction, by which he aims to make the process of desilverization a continuous one. To do this he lets an ascending current of zinc meet a descending one of softened base bullion, allowing the zinc crust to flow off from the surface and the desilverized lead from the bottom through a suitable aperture. The manner of conducting the operations in the ordinary kettle shows only one change, that belonging to the introduction of the Howard combined skimmer and sweater (Patent No. 502,122, July 25, 1893). It has already been in use for some time at the works of the Pueblo Smelting and Refining Company, Pueblo, Colo., and is simple and effective. It consists of two semicircular perforated iron plates, hinged together and folded up when introduced into the lead. They are then unfolded and raised slowly under the floating zinc crust until just covered by the lead, the heat of which sweats out any excess of lead in the crust. The plates are then lifted a little higher and kept there for a short time to drain off the lead before they are removed with the dried crust.

The form of the furnaces in which the retorting of the zinc crust is carried on has not changed, but the usual fuel (coke) has been replaced in most refineries by oil. The results obtained are very satisfactory as, in addition to its cheapness, all the conditions necessary for a good distillation are better fulfilled by oil than by coke. The air jet also proved more valuable than the steam jet for atomizing the oil. A peculiar form of retort has been constructed by Honold (*St. & E.*, 1892, p. 1061; *B. & H. Ztg.*, 1893, p. 10).

Cupellation.—The cupelling of retort bullion has been carried on in the usual way except for the occasional introduction of oil as fuel.

The Roessler-Edelmann Desilverizing Process.

This process, which has been in operation for some time at Hoboken, near Antwerp, Belgium, consists essentially in first desilverizing the lead by means of an alloy of zinc and about 0.5% aluminum, which gives refined lead and a homogeneous zinc-silver alloy, and second in working up this alloy to refined silver and zinc.

In carrying out the process the zinc-aluminum alloy is thrown upon the lead bath, when the latter has acquired the necessary temperature, which varies somewhat according to the contents in silver, but is about 400° to 500° C. Then the whole is stirred and afterward allowed to cool. As this latter proceeds the molten lead, which at a low temperature is no longer capable of holding the zinc, separates from it. The free zinc, having in the meantime alloyed with the silver, rises to the surface of the bath from which, together with some lead, it is removed. In order to expel the excess of lead this alloy is charged into a cast iron pot with an outlet at the bottom and slowly heated, thus liquidizing and drawing off the greater part. Subsequently the temperature is raised to a red heat for melting the zinc-silver alloy as well as for separating it from the remainder of the lead present, the former floating on top whence it is ladled off, care being taken not to touch the lead underneath. This zinc-silver alloy consists of 20 to 40% silver, according to the richness of the silver-lead treated; about 5% lead; 2 to 4% copper, and 60% to 70% zinc. It amounts to about 2% of the lead treated, while by the old process nearly 15% zinc scum, consisting of 4% to 6% silver, 70% to 80% lead, and 0.5% copper, with possibly 10% zinc was produced.

In order to work up the zinc-silver alloy two methods are adopted: The first is to treat the granulated alloy with hydrochloric or dilute sulphuric acid, thus securing the zinc as a soluble salt and silver as slime, and in the second way by electrolysis, which gives a very pure spelter. The electrolyte in the latter process consists of a solution of zinc chloride in chloride of magnesia. Its specific gravity being about 1.2 to 1.27. The cathodes are vertical, circular sheets of metallic zinc fixed upon a horizontal spindle which revolves just above the surface of the bath. The slime left as a residue after the zinc is removed consists of about 75% silver, and 12% lead. At the plant named about 200 kilos of silver slime are refined in eight hours, and it is possible to run through three charges in twenty-four hours. In place of the usual lengthy cupellation process there is required only the short refining process on the cupel. As there is a very small quantity of litharge produced nearly the whole of the silver-lead is worked at once into refined lead which requires no subsequent desilverization.

LIMESTONE, MARBLE, AND LIME.

By T. C. Hopkins.

Limestone consists essentially of the carbonate of lime, or, in the case of dolomite, of the double carbonate of lime and magnesia. The carbonate of lime ($CaCO_3$) is a chemical union of lime (CaO) and carbonic acid gas (CO_2).

Mineralogically, limestone consists essentially of one or more of three minerals —calcite ($CaCO_3$), aragonite ($CaCO_3$), and dolomite ($CaCO_3$, $MgCO_3$). Mineralogically, as well as chemically, limestone is always impure, and contains many associated minerals as well as earthy impurities. The more common associated minerals are quartz, pyrite, sphalerite, galenite, smithsonite, siderite, serpentine, graphite, gypsum, fluorite, petroleum, natural gas, etc.

Origin of Limestone.—Travertine, such as that deposited in caves, at hot springs, and along streams, is a chemical precipitate from limestone in solution in carbonated waters. Nearly all the great beds of limestone, however, were formed in the sea, and consist of remains of sea animals, such as mollusks, corals, etc. In some cases these remains are simply cemented together, and the rock plainly shows its origin ; more frequently they are ground to fragments by the waves and distributed over the ocean bottom by the currents in a fine granular mass, resulting in a compact limestone. Many extensive beds are formed of the remains of minute shells, and their organic origin is seen only by the aid of the microscope. Such are the chalk beds.

The dolomites are generally, if not always, formed by a change in the rock subsequent to deposition. This process, known as dolomitization, may take place by acidulated waters carrying away in solution lime from a slightly magnesian limestone or by deposition of magnesium carbonate, as the calcium carbonate is dissolved, or by the simultaneous action of both processes.

The varieties of limestone are almost innumerable, and are based on composition, color, structure, texture, origin, use, locality, geologic position, and appearance.

Uses of Limestone.—The uses of limestone are more varied than those of any other rock. It is one of the most useful of building stones. Its value varies with its durability, color, workability, and cost. The durability depends largely upon com position and texture, but is affected rather by the kind and manner of occurrence of the impurities than by their percentage. Thus magnesia, if it occurs in chemical union with the lime, forming dolomite, rather increases its durability. Yet a mixture of dolomite and calcite is less durable than either alone. Alumina or clay is one of the most injurious impurities in a building stone, especially when it occurs in layers or patches. Iron pyrites, a common and injurious impurity, is more destructive when in large patches or crystals than when it is disseminated in small crystals through the rock, and the red iron oxides are not necessarily injurious if they are diffused through the mass. All other forms of iron are subject to rapid change, to the injury of the stone. Bitumen, if not in too large quantities, increases rather than decreases its durability, but frequently mars its beauty by being drawn to the surface by the heat of the sun and making black streaks which catch the dust.

The texture of limestones for building purposes should be homogeneous and finely granular. The compact and highly silicious varieties are generally the more durable, but their "plucky" nature prohibits them from fine work. The coarse-grained are generally porous and weather badly.

One of the best and most popular building stones is the oölitic limestone of Lower Carboniferous age in the central Mississippi Valley. It is quarried so extensively near Bedford, Ind., that it is widely known as Bedford stone, but it occurs also in Illinois, Kentucky, Iowa, Missouri, and Arkansas. Its value lies in the homogeneity of composition, texture, and color; its elasticity, durability, and the ease with which it can be quarried, cut, and carved. It is used extensively in Chicago, Indianapolis, New York, and other cities.

A less widely known but probably not less valuable building stone is the dolomite or magnesian limestone (in some localities known as "cotton rock") of Lower Silurian age, which occurs in Arkansas, Missouri, Iowa, Minnesota, and in some of the Eastern States. It has a light-gray, cream, or drab color, and an even, fine-grained, homogeneous texture, is soft when quarried, hardening on exposure, dresses readily in all directions, and takes a very smooth finish.

The Niagara limestone of Upper Silurian age furnishes good building stone in New York, Ohio, Indiana, Illinois, and Arkansas, marbles occurring in Arkansas, while in the others the stone is adapted to bridge piers and heavy masonry, but not to fine carved work.

The Devonian limestones in New York, Iowa, and Minnesota, and beds of the Lower Carboniferous of the Mississippi Valley, the Carboniferous limestones of the Rocky Mountain region and the Tertiary Coquina limestone of Florida, the White limestone of Alabama and the Arbitoides limestone of the Southern States, all yield good building stone.

Limestone has an extensive use as a furnace flux, for which the purer varieties are desirable, but very impure ones are frequently employed on account of their proximity to the furnace. If the slag is to be used for the manufacture of cement, bricks, glass, or paving blocks, a comparatively pure, or at least a homogeneous, one is necessary. Magnesian limestones are said to remove phosphorus from iron to a certain degree, and are sometimes selected for flux because of this property.

Lime is commonly used in making glass, which is essentially a silicate of potash or soda and a heavier base, such as lime, alumina, or lead. The tendency of lime is to harden the glass; of alumina, to render it less fusible; and of lead, to to make it more brilliant. Any comparatively pure limestone is suitable for glassmaking, providing it is homogeneous in composition and contains no injurious elements, such as iron or other metallic oxides, which color the glass.

A good lithographic stone is one of the rarest and most valuable varieties of limestone. For information concerning its properties, uses, etc., the reader is referred to the article on "Lithographic Limestone," in another part of this book.

Limestone is one of the best and cheapest stones for railway ballast and for macadamizing. It is used extensively for curbstones, sewer caps, and flagstones, but it does not stand the wear of vehicles as well as granite.

Large quantities (commonly scrap marble) are used in the manufacture of carbonic acid gas for soda-water fountains and laboratory purposes, and calcined it is used very largely in making mortar, chloride of lime, and as a fertilizer.

Marble.—Marble is a name applied to any limestone, whether cystalline, granular, or compact, which is susceptible of a fine polish and desirable for ornamental purposes, and its value depends upon its color and the brilliancy of the polish it takes. Nearly every bed has peculiarities in color or texture that distinguish it from all others, and several varieties often occur in the same quarry. The most valuable forms known in the market are statuary marble and Mexican onyx marble, the former a pure white variety of a peculiar grain and texture and free from flaws, while the latter is a form of travertine.

Vermont continues to be the greatest marble-producing State in the Union, the product exceeding in value that of all the other States combined. The producing localities are Rutland, West Rutland, Proctor (formerly Sutherland Falls), Dorset, Wallingford, Manchester, Pittsford, Brandon, Middlebury, North Ferrisburg, and Swanton, the most extensive quarries being at West Rutland and Proctor. The Vermont marbles vary greatly in color and texture in different places, and in different layers in the same quarry. Following is a section of one of the West Rutland quarries, beginning at the top, which illustrates this variation: 1. Upper blue layer, 4 ft. 2. Upper white layer, 3.5 ft. 3. Gray limestone, 5 ft. 4. White statuary, 3 ft. 5. Striped, 1.6 ft. 6. New white layer, 4 ft. 7. Wedged white layer, 8 in. to 2.5 ft. 8. Muddy layer, 4 ft. 9. Striped green, 4 ft. 10. Camphor-gum, 3 ft. 11. White, 9 ft. 12. Blue, 3.5 ft.

The rarest and most valuable variety is the pure white statuary marble, the supply of which never equals the demand, though it is thought by some that the Vermont stone is too soft for statuary. A large part of the product of the quarries is sold for headstones, which may be seen in nearly every cemetery in the country. It also has an extensive use for decorative purposes in architecture.

The total thickness of the beds at Rutland varies from 50 to 110 ft., and has been followed on a dip of 25° to 85° to a depth of 220 ft., where the layers become more nearly horizontal. At Proctor the stone is massive, and the quarries, one of which is said to be the largest in the world, yield blocks of almost any dimensions. An excellent water power is utilized in quarrying and manufacturing the marble.

At Dorset the quarries are mostly upon the sides of Mount Eolus, or Dorset Mountain, where more than twenty different layers of marble have been recognized, from some of which beautifully mottled and clouded varieties are obtained and are used almost exclusively for monumental and decorative purposes.

New York contains, chiefly in the eastern and southeastern part of the State, a large number of quarries producing white and clouded marbles. The most extensive are at Gouverneur.

The following information concerning the Gouverneur marble has been courteously furnished by Prof. C. A. Waldo. For more than fifty years it has been used for building and monumental purposes. Something more than a decade ago taste in the color of monuments underwent a rapid change, and Gouverneur marble came to the front because it resembled the gray granites in appearance, took quite as good a polish, and could be worked more easily. The St. Lawrence Marble Company was organized. It has changed hands once, but has always done a thriving business. There are now six firms in existence, most of them actively. The output in 1893 was 13,400 short tons, valued at $338,618.

The St. Lawrence Marble Company alone sent out 5145 short tons, valued at $130,000. This company uses 150 horse-power for its 16-gang mill and 200 horse-power for its quarry, and has a capital stock of $150,000.

Gouverneur marble has a hard, crystalline structure, a compact, homogeneous texture, and takes a high polish. The best is of a rich dark blue color, finely mottled, and has a sparkling fracture which it does not lose in weathering. It is impervious to moisture and retains its freshness without disintegration. It has a crushing strength of 12,692 lbs. per sq. in., and weighs 170 lbs. per cu. ft. It is well established as a monumental stone, and has recently been used extensively for architectural purposes in Syracuse, Rochester, Cleveland, Detroit, Chicago, and St. Louis.

The "snowflake marble," quarried at Pleasantville, is one of the handsomest varieties in the State, being composed of large snow-white crystals, some of which are an inch or more in length. Professor Newberry says that the snowflake marble has no rival in the United States in strength, durability, purity of composition and color, and in the magnitude of the deposit. Large quantities of fine building marble are quarried at Tuckahoe, and several varieties are produced at Sing Sing.

Maryland produces numerous varieties of marble, a snow-white, coarsely crystalline variety being the one most extensively quarried. It occurs in the region north of Baltimore, and most of the quarries are in the vicinity of Cockeysville. The product is largely used for building in Baltimore, Washington, and Philadelphia.

The marble industry in Georgia is of comparatively recent date, but has been growing so rapidly that the State is now one of the leading producers of white and clouded marbles. It largely supplies the Southern and Southwestern trade, while some of the product goes North. The marbles occur in Pickens, Cherokee, Gilmer, and Fannin counties. Nearly all the stone taken out is quarried near Tate in Pickens Co.

The quarries in Pickens County, controlled by the Georgia Marble Company, produce highly and coarsely crystalline marbles in which the crystals are closely interlocked, so that the stone weathers well, has a smooth surface, and is remarkably strong. The principal varieties are the "Kenesaw," white, or white clouded, with occasional dark spots; "dark mottled creole," white, with nearly black spots; the "medium cloud creole," white and gray colored; the "Etowah," variously colored—pink, salmon, rose, and green.

There are white and clouded marble in different portions of California. The productive localities are Inyo and San Bernardino counties, Inyo producing several varieties, one a white and remarkably pure dolomite. Another handsome and unique variety has a white ground interspersed with blotches, streaks, and branching, feathery, fan-like markings of a dark-brown color with occasional patches of yellow. These are said to be the most promising marbles in the West. The most extensive quarries in the State at present are at Colton, San Bernardino County, where three varieties occur—one nearly pure white, one white colored with gray, and one grayish black, finely mottled with white. The Colton marble is used extensively throughout the State for building and decoration.

Clouded marbles occur among the Lower Silurian rocks in many places along the Great Valley in eastern and southeastern Pennsylvania. The productive quarries are those at King of Prussia and Henderson stations, in Montgomery County, the product of which is shipped mostly to Philadelphia and Baltimore.

White and clouded marble occurs, but is not quarried to any extent, at Calumet and Yule Creek, Colorado; near Frisco and in the Wasatch Mountains, Utah; in Virginia, Wyoming, Alaska, Connecticut, and Massachusetts. It was formerly quarried extensively in the two last mentioned States, but the quarries, except those at Lee, Mass., have been abandoned.

Among the colored marbles the red and reddish variegated are the most important in point of production, in which Tennessee ranks first among the States. The marble occurs in many of the counties in East Tennessee, but is quarried to an important extent in only four—Hawkins, Knox, Loudon, and Blount. It was first quarried in Hawkins County, but within the last few years the product of these quarries has been decreasing, while that from the Knox County quarries has been increasing. This is probably due to the better railway facilities in Knox County, as the Hawkins County marble is the handsomer and higher-priced stone. The quarries in Loudon and Blount counties are all recent. In color and texture there are many varieties of the Tennessee marbles, but a reddish chocolate is the prevailing color, and this is sometimes interspersed with gray patches and sometimes with fossil casts of white calcite, some of the latter variety being very handsome. These marbles are used largely for cabinet work and interior decoration, for which they are admirably suited.

Vermont produces handsome red variegated marble that has been used extensively for interior decoration. It is known as the "Winooski," or "Wakefield" marble, and occurs along the eastern shore of Lake Champlain, in the northwest part of the State. It resembles the Tennessee marbles somewhat in general color, but differs in the surface markings or variegation, and is harder.

Red marble is known to occur in Arkansas, Alabama, Missouri, Maryland, and New York, and is reported from Georgia, Colorado, North Carolina, and Wyoming, but is not quarried to any extent in any of them. A recent scientific investigation shows that there are large deposits of very handsome marbles in Arkansas,* valuable for building purposes and some well adapted for cabinet work and interior decoration. They are in thick beds in good position for quarrying, but unfortunately are remote from railways.

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* *Ann. Rep. Geol. Survey of Arkansas*, Vol. IV., 1890.

Black marble is quarried at Isle la Motte, in Vermont, and at Glens Falls and Willsborough, N. Y. That at Glens Falls is a dark, blue-black magnesian limestone, fine grained and compact, which when polished has a deep lustrous black color. Black marble occurs at Williamsport, Penn., in Inyo County, California, and in Independence, Searcy, and Marion counties, Arkansas. It is reported to occur in Colorado, Illinois, Tennessee, and West Virginia. As the supply of good black marble is not equal to the demand, it is to be hoped that some of the new localities will be developed.

The so-called onyx marbles, the handsomest in the market, are described elsewhere in this volume. Gray marbles valuable for building purposes occur in many places, notably New York, Virginia, Tennessee, and Arkansas. In Maryland there is a handsome marble known as the Potomac or Calico marble, which consists of rounded and angular fragments of quartz and magnesian limestone of red, white, gray, and other colors, imbedded in a calcareous matrix. It is a beautiful stone, but polishes with difficulty, owing to the difference in hardness between the quartz and the limestone. It is thought to be the only true conglomerate or breccia marble that has ever been utilized to any extent in the United States. The Madrepore marble, quarried near Charles City, Iowa, is a handsome and unique stone. The prevailing color is light drab, with fossils of all sizes, and varying from yellowish to mahogany-brown in color. The Iowa City or bird's-eye marble is a coral limestone of considerable beauty, but does not occur in large quantities.

PRODUCTION OF MARBLE IN THE UNITED STATES.

Year.	Cal.	Ga.	Maryland.	Mass.	New York.	Penn.	Tenn.	Vermont.	Other States and Territories.	Total.
1886	$4,000	$100,000	$137,000	......	....	....	$404,229	$1,500,000e	$254,771	$2,400,000
1887	5,000	150,000	160 000	....	$60,000	....	520,000	2,275,000	....	3,170,000
1888	5,000	125,000	175,000	....	50,000	....	225,000	2,200,000	...	2,810,000
1889	87,030	196,250	139,816	....	354,197	....	419,467	2,169,560	*a*121,850	3,448,170
1890	....	....	....	....	....	.....	....	....	....	.... .
1891	100,000	275,000	100,000	....	390,000	$45,000	400,000	2,200,000	100,000	3,610,000
1892	115,000	280,000	105,000	$100,000	380,000	50,000	350,000	2,275,000	50,000	3,705,000
1893	....	....	....	....	....	....	....	....	. ....	....

(*a*) Includes Pennsylvania, Massachusetts, Idaho, and Virginia.

IMPORTS OF MARBLE INTO THE UNITED STATES.

Years.*	Sawed, Dressed, etc., not over Two Inches in Thickness.	Sawed, Dressed, etc., over Two and not over Six Inches in Thickness.	Veined and All Other in Blocks, etc.	White Statuary, Brocatelle, etc.	Not Otherwise Specified.	Total.
1867	......	......	$192,514	$2,540	$51,978	$247,032
1868	......	......	309,750	4,403	85,783	399,936
1869	......	......	359,881	3,898	101,309	465,088
1870	......	......	332,839	3,713	142,785	479,337
1871	$5,973	$317	400,158	1,134	118,016	525,598
1872	3,499	1,841	475,718	4,017	54,539	539,624
1873	3,124	......	396,671	4,148	69,991	473,955
1874	1,837	......	474,680	2,863	51,699	531,079
1875	1,456	523	527,628	1,623	72,389	603,619
1876	595	416	529,126	1,151	60,596	591,884
1877	2,124	......	349,590	1,404	77,293	430,411
1878	198	19	376,936	592	43,915	421,660
1879	184	......	329,155	427	54,857	384,623
1880	......	......	531,908	7,239	62,715	601,862
1881	339	......	470,047	1,468	82,046	553,900
1882	655	......	486,331	3,582	84,577	575,145
1883	619	......	533,096	2,011	71,905	607,631

* Fiscal years ending June 30.

During the calendar years ending Dec. 31, from 1886 to 1893, and fiscal years ending June 30, for 1884 and 1885, the classification of marble was as follows:

	Marble in Blocks, Rough or Squared.	Veined Marble, Sawed, Dressed, or Otherwise.	Other Kinds.	Total.
1884	$511,287	$12,941	$67,829	$592.057
1885	429,186	43,923	54,772	527.881
1886	408,895	96,625	44,053	549,573
1887	355,648	142,405	31,880	529,933
1888	357,220	107.957	69,086	534,263
1889	498,274	115,909	61,231	675.415
1890	510,354	142,653	132,376	785,383
1891	492,894	83,416	119,787	696,097
1892	....	....	....	....
1893	....	....	....	....

Lime (quicklime, caustic lime, calcium oxide) is obtained for commercial purposes by heating limestone to a sufficient temperature to drive off the carbonic acid gas. It is not a stable compound in the presence of moisture, hence it never occurs as a native product. Yet, fortunately, as it is the most useful of all building materials, there is an abundant and widespread source of supply in the great limestone beds.

Lime, when pure, is snow-white and strongly alkaline, being one of the strongest bases. It has great affinity for water, and in contact with it evolves a great heat, sufficient in some instances to start a conflagration. Unless kept in a perfectly dry place, it will absorb moisture from the air, and then carbonic acid from the same source, finally becoming calcium carbonate. It is this property of returning to a solid and stable form which makes it valuble for masonry and similar purposes.

As the limestones, while consisting essentially of the carbonate of lime, rarely if ever occur pure, so the lime obtained from them will not be pure. It depends, however, on the kind of impurity and the use to which the lime is to be applied whether the impurity is injurious or not. Like the limestones, from which they are obtained, there are almost innumerable varieties of lime which for commercial purposes are grouped into classes, the classification commonly made being fourfold: (1) common or fat limes; (2) poor or meager limes; (3) hydraulic limes; (4) hydraulic cements.

Common, fat, or rich limes usually contain less than 10% of impurities. In slaking they evolve much heat and increase in volume from two and a half to three times their original mass. With the exception of some of the impurities, they are entirely soluble in water. In hardening they shrink so that they cannot be used for mortars without a large dose of sand. They are cheaper and more general in their use than the other varieties. The great bulk of the ordinary lime of commerce falls into this class. The superiority of lime from certain localities over that from others depends in large measure on its greater purity. The common lime is used more extensively in ordinary building than the cement on the score of economy, as it is more abundant, is more easily burned, gives increased volume in slaking, takes a larger dose of sand, and is therefore cheaper.

The poor, or meager, limes contain from 10% to 25% of impurities, sometimes ranging as high as 39%. They are less desirable than the preceding class and are rarely used in this country except in the absence of the rich lime, but are said to be preferred by some English artisans.

Hydraulic Lime.—The hydraulic limes are so called because of the property of hardening under water, which makes them valuable for certain kinds of masonry. . They are commonly divided into three classes: limes slightly hydraulic, in which the impurities form 10% to 20% of the whole; hydraulic limes, in which the impurities range from 17% to 24%; and limes eminently hydraulic, in which the impurities form 20% to 35%. The hydraulic property does not depend wholly on the amount of impurities, but on the kind and the manner in which they are diffused. They slake more slowly than meager limes, with but a slight elevation of temperature and a slight increase in volume. Practically the hydraulic limes are rarely used, the hydraulic cements being preferable in many ways.

The distinctions commonly made between hydraulic lime and hydraulic cement are: the lime will slake, but the cement does not; the lime requires sand to form mortar, while the cement does not, although sand is nearly always used because of economy; the cements set or harden much more quickly than the limes.

Hydraulic cement, which may be a natural or an artificial product, contains a lower percentage of lime than any of the other classes, although the proportion rarely falls below 29% of the whole. It can be used with or without sand, the amount required depending on the grade of the cement and the importance of the work. This substance is treated separately in another part of this book, to which the reader is referred.

Common lime when used for mortar is first slaked; that is, enough water is added to reduce it to a powder or a liquid paste. It is then mixed with a certain amount of sand, the amount depending upon the quality of the lime, forming mortar. The value of the mortar depends upon its property to harden or set, thus binding the separate stones or bricks of the masonry into a solid piece. The lime from which the carbonic acid was expelled in the kiln slowly absorbs the gas from the air, returning finally to its original stable form as carbonate. Some of the lime may form a silicate with part of the sand, and some may first solidify as the crystallized hydrate, but the final stable form is the carbonate.

The setting in hydraulic cement is a different process. While possibly some chemical changes take place which are not as yet clearly understood, the process in the main is as follows: In the manufacture the lime combines with the alumina and silica, and on contact with the water forms the crystallized hydrous aluminates and silicates of lime. Thus water which would dissolve and carry away the lime from common mortar is necessary for the hardening of cement. While the hardening of common mortar is a slow process, requiring many years for final completion, the hardening of cement is a shorter process, some of the quick-setting cements hardening in three or four minutes.

Lime has many other uses, some of them important in the arts, but none requiring such large quantities as are used in masonry. It is used in plastering, whitewashing, bleaching, and disinfecting. It is employed in tanning and glass-making. In chemical operations it is used for drying gases and liquids, in the preparation of the caustic alkalies, in the liberation of ammonia, in the manufacture of soda, in the analysis of organic compounds, and as lime water, both as a chemical reagent and in pharmacy. Lime has an important part in agriculture as a fertilizer. It is used in the lime light (calcium light or oxyhydrogen light). It is also employed to make crucibles for fusing highly refractory substances and as a mold for casting iron or steel, and it sometimes takes the place of raw limestone as a furnace flux.

The varied and important uses of lime show the necessity for a knowledge of the essential characteristic properties of the different varieties and the particulars in regard to at least the local source of supply.

PRODUCTION OF LIME IN THE UNITED STATES.

	For Building, etc.		For Iron Flux.	
Year.	Barrels.	Value.	Long Tons.	Value.
1880	28,000.000	$19,000,000	4 500,000	$3,800,000
1881	30,000,000	20,000,000	6,000,000	4.100,000
1882	31,000,000	21.700.000	3,850.000	2,310,000
1883	32,000,000	19,200,000	3,814,273	1,907,136
1884	37.000,000	18.500,000	3,401,930	1,700,965
1885	40,000,000	20.000,000	3,356.956	1,678.478
1886	42,500,000	21.250,000	4,717,163	2,830.297
1887	46,750,000	23.375,000	5,377,000	3,226.200
1888	49,087,000	24,543,000	5,438,000	2 719 000
1889	68,474,668	33,217,015	6,318,000	3,159,000
1890	60.000,000	35,000,000	5,521,622	2,760,811
1891	60,000,000	35.000,000	5,000,000	2,300 000
1892	70,000,000	38.500,000	4,560,000	2,097,600
1893	65,000,000	35,000,000	3,750,000	2,250,000

Lime in New Brunswick.

By L. W. Bailey.

Limestone is a very abundant mineral in New Brunswick, being found in many parts of the province, in several geological formations (Laurentian, Huronian, Silurian, Devonian, and Carboniferous), and often in beds of great extent and thickness. Of this, however, the only deposits used for other than purely local consumption are those outcropping near St. John, and mostly along the banks of the St. John River. The beds found there are very extensive, and, belonging to the old Laurentian system, are remarkable for their compactness and crystalline character, as well as for the varieties of texture and of color presented by them. Their situation for quarrying is unexcelled, being exposed in nearly vertical bluffs upon the side of the stream, whence they may be directly transferred, in some instances by gravity only, to the kilns, and thence, after burning, to the holds of vessels close at hand. The lime produced is also of excellent quality, in no way inferior to that of Rockland, Thomaston, and other places on the coast of Maine.

The existence of large deposits of limestone upon the banks of the St. John River was observed and described by Champlain and other French voyagers 300 years ago. Subsequently stone from these deposits was employed by Brouillon in rebuilding the fort at Port Royal (Annapolis) in 1701. Prior to the landing of the loyalists at St. John, some of the early settlers exported lime from these beds to Newburyport and other ports in New England in small sloops. It had even then a high reputation.

Numerous quarries have been opened on the lime-beds near St. John, and the aggregate amount of lime manufactured is large. The annual output has, however, fluctuated greatly, and it is difficult to obtain any reliable information relating thereto. Prior to the adoption of the McKinley tariff, the St. John lime industry experienced a great expansion, and for a time the demand was considerably in excess of the capacity of the kilns then existing; but just as preparations to meet this increasing call were under consideration, the imposition of the duty of about 13c. per barrel, in place of 3c. per barrel, curtailed the market.

The production of lime in New Brunswick began to assume considerable proportions about the year 1881, and from that time to 1892 the exportation has been as follows:

Year.	Barrels.	Value.	Year.	Barrels.	Value.	Year.	Barrels.	Value.
1881	3,644	$1,822	1885	9,850	$4,425	1890	286,584	$143,292
1882	6,804	3,402	1887	76,858	38,429	1891	203,668	101,834
1883	10,488	5,244	1888	183,680	91,840	1892	120,350	60,175
1884	6,840	3,420	1889	232,710	116,355	1893		

The marked decrease in 1892 was the result of the McKinley tariff, whereby a duty of 6c. per 100 lbs., including the weight of the barrel, was imposed on imports of lime into the United States, which was equivalent to 13⅝c. per barrel, or about 20% on the value of the product delivered in the United States markets. With the removal of this tax it is thought that the industry will not only recover its former status, but will rapidly assume far larger proportions.

There are about twenty-five draw-kilns for burning lime in the vicinity of St. John, and prior to the passage of the McKinley bill the total production was not less than 350,000 barrels a year, giving employment to about 300 men. As the result of the bill only eight draw-kilns were kept in blast, and the product was reduced to from 175,000 to 200,000 barrels. In the case of the larger companies every article used in the manufacture of a barrel of lime is made on the premises, excepting only hoops, which cost from $4.50 to $5 per thousand, or about 3c. for each barrel. For $100,000 worth of lime exported it is estimated that $91,000 is expended in labor.

The chief competitor of the St. John lime is that of Rockland, Me., and the vicinity, where there are about 100 kilns, with an output of from 2,500,000 to 3,000,000 barrels per year. As compared with Rockland, the St. John manufacturer has the disadvantage of higher freight charges to American markets, but this is more than made equal by the remarkably favorable situation of the quarries and the comparatively low cost of fuel, the latter consisting largely of refuse from adjacent lumber mills. At Rockland the cost of the limestone placed in the kilns is stated as 20c. per barrel, while at St. John it is but 10c.; the cost of kiln wood at Rockland is $3 per small cord, as against $2 at St. John. Cordwood burnt in a kiln at Rockland costs 15c. for each barrel of lime, while at St. John the cost for the same is but 10c. The Rockland producers estimate that their lime ready for shipment costs 72c. per barrel, and the freight to Boston is 13c., while the selling price is 85c., leaving no margin of profit. At St. John the cost is 45c. per barrel and the freight 18c., so that, even with a duty of 14c. per barrel, the cost delivered in Boston is only 77c. Rail freight to Boston is 20c. per barrel, and the cost laid down there about 80c. Analyses of St. John limestone, by Mr. A. E. McIntyre, show 97.38% lime, with less than 2% magnesia.

LITHOGRAPHIC LIMESTONE.

By George P. Merrill.

The invention of lithography, the art of printing from stone, is attributed to Alois Senefelder of Prague, who patented the process in Vienna, in 1802. The principles upon which the art depends are as follows: (1) The adhesion of an encaustic composition to a peculiar kind of limestone; (2) the power acquired by the parts covered with this compound to receive printing ink; (3) the power possessed of preventing the adhesion of the ink by the interposition of a film of water; and (4) the power of again removing the ink from the greased portion by simply pressing an absorbent paper into close contact.

The only stone yet found possessing the necessary qualifications for this work is a fine-grained homogeneous limestone, breaking with an imperfect shell-like or conchoidal fracture, and as a rule of a gray, drab, or yellowish color. A good stone must be sufficiently porous to absorb the greasy compound which holds the ink, soft enough to work readily under the engraver's tool, yet not too soft, and must be uniform in texture throughout and free from all veins and inequalities of any kind, in order that the various reagents used may act upon all exposed parts alike. It is evident, therefore, that the suitability of the stone for practical purposes depends more upon its physical than its chemical qualities. An actual test of the material by a practical lithographer is the only test of real value of stones of this nature. Nevertheless the analyses given below are not without interest as showing the variation in composition even in samples from the same locality.

	$CaCO_3$	$MgCO_3$	Al_2O_3	Fe_2O_3	Soluble Silica	Insoluble Silica	Organic Matter.	FO	H_2O	Spec. Gravity.	Authority.
Salenhofen, Bavaria.....	81.47	13.83	0.25		4.45		......	......	......	......	J. L. Howe.
" " (dark)..	90.934	3.571	0.584	0.236	0.520	2.00	0.720	0.13	0.40	2.95	C. W Volney.
" " (yellow)	89.539	4.380	0.101	0.321	0.02	1.893	0.132	0.003	1.379	2.84	" "
" "	96.24	6.21	2.02				......	......	......	......	Gmelin.
Kentucky (light gray)...	73.241	12.431		1.141		11.50	0.40	......	0.935	2.99	C. W. Volney.
Iowa (blue gray).........	82.20	4.327		1.076		6.795	3.30	......	0.24	2.82	" "
Missouri (light gray).....	77.03	14.27		2.143		4.30	1.83	......	0.341	2.75	" "
" (Ralls County)..	81.77	15.10	0.06		3.12		......	......	......	......	
Overton, Tenn...........	77.62	17.32	0.66		4.10		......	......	......	......	
Canada (light blue gray).	89.989	2.789		0.884		3.712	0.409	0.104	1.25	2.84	C. W. Volney.
" (dark blue gray).	88.034	2.50	0.577	0.359	0.49	3.60	1.29	0.41	1.360	2.89	" "

Stones possessing in a greater or less degree the proper qualities for lithographic purposes have from time to time been reported in various parts of the United States; from near Bath and Stony Stratford, England; Ireland; Department of Indre, France; Silesia; India; and the British American possessions. By far the best stone, and indeed the only stone which has as yet been found to fill satisfactorily all the requirements of the lithographer's art, and which is the one in general use to-day wherever the art is practiced, is found at Solenhofen, near Poppenheim, on the Danube, in Bavaria. These beds are of Upper Jurassic or Kimmeridgian age, and form a mass some 80 ft. in thickness, though not all portions are equally good or adapted to the same kind of work. The stone varies both in texture and in color in different parts of the quarry, but the prevailing tints are yellowish or drab.

In the United States materials partaking of the nature of lithographic stone have been reported from Yavapai County, Arizona; Talladega County, Alabama; Arkansas; Lawrence County, Indiana; near Thebes, Illinois; Jones and Van Buren counties, Iowa; Hardin, Estell, Kenton, Clinton, Rowan, and Wayne counties, Kentucky; near Saverton, Ralls County, Missouri; Clay and Overton counties, Tennessee; Burnet County, Texas; near Salt Lake City, Utah; and at Fincastle, Virginia. While, however, from nearly if not quite every one of these localities it was possible to get small pieces which served well for trial purposes, we believe that all have failed as a constant source of supply of the commercial article, and this for reasons mainly inherent in the stone itself, though it is very possible that ignorance as to proper methods of quarrying may have been a cause of failure in some cases.

The Arizona stone is one of the most recent discoveries, and according to first reports seems also the most promising. Samples submitted to the writer, as well as work done, seemed all that could be desired. We are informed by Mr. John F. Blandy that the quarries are situated on the east slope of the Verde Range, two miles south of Squaw Peak, 1200 ft. above the Verde Valley, and 40 miles by wagon road east of Prescott. Two quarries have thus far been opened in the same strata, about 1000 ft. apart, one showing two layers, or beds, 3 and 4 ft. in thickness, and the other three beds, 3, 10, and 8 ft. As at present exposed, the beds, which are of Carboniferous age, are broken by nearly vertical fissures into blocks rarely 4 or 5 ft. in length. Owing to the massive form of the beds and the conchoidal fracture, the stone cannot be split into thin slabs, but must be sawn. No satisfactory road yet exists for its transportation in blocks of any size, and such material as has thus far been produced has been in small slabs, which could be "packed." Those who have inspected the properties express themselves satisfied that blocks of good size and desirable quality can be had in quantity.

The Alabama stone examined by the writer is finely granular and too friable for satisfactory work. Qualitative tests showed it to be a siliceous magnesian limestone. It is, of course, possible that the single sample shown does not fairly represent the product. The Arkansas deposit is situated in Township 14 N., R. 15 W., of the 5th P. M., Sections 14, 23, and 24, Searcy County. The color is darker than that of the Bavarian stone, and the reports of those who have tested it are represented as being uniformly favorable. The Indiana stone is harder than the Bavarian, and samples examined were found not infrequently traversed by fine hard veins of calcite. The Illinois stone is darker, but to judge from the display made by Martin O'Neill in the Illinois Building at the Columbian Exposition, it is capable of doing good work, and can be had in large slabs. The Kentucky stone is hard and brittle, though that from Rowan County is said to have received a gold medal at the Exposition of 1876. It is fine-grained, homogeneous, and very pure, only a small flocculent residue of organic matter remaining insoluble in dilute hydrochloric acid. The stone from Saverton, Mo., is compact and fine-grained, with, however, fine streaks of calcite running through it. It leaves only a small, brownish residue when dissolved in dilute acid. This stone has been worked quite successfully on a small scale. The State Geologist in writing on the subject says: "Some of the beds of the St. Louis limestone (Subcarboniferous) have been successfully used for lithographic work. No bed is, however, uniformly of the requisite quality, and the cost of selection of available material would seem to preclude the development of an industry for the production of lithographic stone."* From the deposit at Overton, Tenn., it is said that slabs 40 by 60 by 3½ in. thick were obtained, though little, if anything, is now being done. An analysis of this stone is given in the preceding table. Large deposits of this stone are also found in McMinn County, which are said to equal the Bavarian. According to the State Geological Survey Report, the stone "lies between two beds of variegated marble. The stratum is thought to run entirely through the county, but some of the stone is too hard for lithographic purposes. The best is found eight miles east of Athens, on the farm of Robert Cochrane, and a quarry has been opened by a Cincinnati company, which pays a royalty of only $250 per annum. It is sold for nearly the same price as the Bavarian stone. It is a calcareous and argillaceous stone, formed of the finest sediment, of uniform texture, and possesses a pearl-gray tint. The best variety of this stone has a conchoidal fracture and is free from spots of all kinds."

A lithographic stone is described in the State Survey Reports of Texas as occurring at the base of the Carboniferous formations near Sulphur Springs, west of Lampasas, on the Colorado River, and to be traceable by its outcrops for a distance of several miles, the most favorable showing being near San Saba. The texture of the stone is good, but as it is filled with fine reticulating veins of calcite, and as, moreover, the lithographic layer itself is only six or eight inches in thickness, it is obvious that little can be expected from this source. The Texas Lithographic Stone Company, with headquarters at Burnet, has used the stone, it is said, in considerable quantities. A stone for which many points of excellence are claimed has for some years been known to exist in the Wasatch Range within a few miles of Salt Lake City, and several companies are or have been engaged in its exploitation. Among these may be mentioned the Newton American and Columbian Lithographic Stone companies. The writer has seen this stone only in small pieces, and can express no opinion as to its value. If only a small part of what is claimed for the deposit proves true, it is obvious that for many years to come the world need look no further for its supply. Very encouraging reports of beds, examined by men whose opinions should be conservative, come from Canadian sources, and it is possible that a considerable

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* *Bulletin No. 3 Geol. Survey of Missouri*, 1890, p. 38.

industry may yet be developed there, though little is being done at present. The descriptions as given in the Geological Reports are as follows: "The lithographic stones of the townships of Madoc and Marmora, and of the counties of Peterborough and Bruce, have been examined and practically tested by lithographers, and in several cases pronounced of good quality; they have also obtained medals at various exhibitions. They were obtained from the surface in small quarries, and possibly, when the quarries are more developed, better stones, free from 'specks' of quartz and calcite, will be available in large slabs.

"A very fine grained and compact limestone is required for the purposes of lithography, and beds having these characters are found in the Birdseye and Black River formation at the base of the Trenton group throughout a considerable part of its distribution, from Hungerford to Rama, on Lake Couchiching. In the township of Marmora there is a section of about 20 ft. of light-gray limestone which is compact, with a conchoidal fracture, and holds no organic remains. Some of the beds contain numerous small lenticular crystals of calcspar. . . . There is, however, a bed of two feet in thickness, which is extremely fine in its grain, and yields a lithographic stone of excellent quality. It has been repeatedly tried by lithographers, both in Canada and England, with most satisfactory results; but owing to the remoteness of the locality, no attempt has hitherto been made to work the stone. It is probable that equally good material for the purpose may be found in other parts of this band, which . . . may be traced for about 100 miles.

"Beds of a fine-grained, yellowish-gray stone, well fitted for lithographic purposes, have lately been found among the dolomites of the Onondaga formation in the township of Brant. They occur in the bed of a small stream (Brant) about half a mile south of Walkerton, where several strata of the stone from 2 to 11 in. in thickness occur in a section of 15 ft. The beds at this place are traversed by natural joints, which cause the rock to divide into somewhat narrow portions; but the stone is found to be well adapted for lithography, and larger slabs may probably be found elsewhere in the same formation. Equally good specimens of it were obtained from the Oxbow on the Saugeen River, on the third lot of the seventh range of Brant. The stone from this formation, being magnesian, is attacked by acids more gently, and with less effervescence than ordinary limestone. This peculiarity in the action of acids which are employed in the lithographic process is said to be an advantage." *

We are informed that during 1893 the output of the Madoc quarry was only some 1000 lbs., in samples, valued at 10c. per lb.

It should be stated, before closing, that in actual use the principal demand is for stones 22 or 28 by 40 in. The largest ones practically used are about 40 by 60 in., and 3 to 3½ in. thick. As the better grades bring as high as 22c. per lb., and as some 250 tons are annually imported for use, it will be readily perceived that the field for exploration is one offering great inducements.

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* *Geology of Canada*, 1863.

MAGNESITE.

MAGNESITE, carbonate of magnesium, $MgCO_3$, is a mineral corresponding chemically to calcium carbonate, or calcite. Between these two dolomite, which normally has the formula $(CaMg)CO_3$, but is better represented by $xCa(1 - x) MgO, CO_2$, where x is variable. Pure magnesite occurs in transparent rhombohedral crystals (bitter spar), and in massive form, compact or granular. Its color varies from white to brown, according to the amount of iron with which it is contaminated, the variety breunerite, which contains several per cent. of ferrous oxide (FeO), being of the darker shade, and often called brown spar. The hardness of magnesite varies from 3.5 to 4.5 ; the sp. gr. of the crystals is 3 to 3.08, that of the earthy variety 2.8, while the iron-bearing mineral ranges from 3 to 3.2. When pure, magnesite contains 47.6% of magnesia (MgO) and 52.4% of carbonic acid (CO_2). It is usually found in association with serpentine, talcose schist, and other magnesian rocks.

Artificial carbonate of magnesia is obtained as a by-product in the mother-liquor tanks of salt (sodium chloride) works, but the amount produced in this manner is insignificant.

Magnesite may be used for the preparation of magnesian salts by treatment after calcination with sulphuric or chlorhydric acid, in which the oxide of magnesium is readily soluble. It has been employed as a bleaching agent in the manufacture of paper from wood pulp, for which purpose it has been found cheaper and more effective than the chlorine heretofore used. It is chiefly employed, however, as a refractory material in the construction of fireproof buildings, and for basic hearths in steel furnaces, for which purpose it is much superior to dolomite. Magnesite to be used as refractory material should contain more than 90% magnesia (MgO) after calcination, and should not have more than 5% silica.

Crude magnesite must be burned at a high temperature to drive off the carbonic dioxide, in the course of which the mineral sinters, without actually fusing, the extent to which this occurs depending apparently upon the percentage of iron and alumina. Thus the Styrian magnesite sinters more than the Grecian, its color changing to a deep brown or even a blue-black in the furnace.

In burning magnesite there is formed at a dull red heat a magnesia which can be worked into shape at high pressures, being of a more or less binding character, and possessing marked hydraulic properties. If heated higher it diminishes largely in bulk and becomes hard and quite unmoldable. The sp. gr. of dead-burned magnesia may be as much as 3.8. In making magnesia bricks and in preparing basic-furnace hearths, therefore, it is necessary to use a binding material, such as anhydrous tar, soda, silica, vinegar, clay, milk of dolomite, and magnesium chloride, all of which have been tried. Advantage is taken also of the setting property of half-burned magnesia, previously referred to. The addition of clay decreases the infusibility of the magnesia, while substances which contain volatile compounds detract from the firmness of the burned material. When partially burned, or caustic, magnesia (possibly as much as 10%) is employed, it is customary to use a little silica in order to lower the melting-point slightly, and if it is a question of producing a very firm, compact material, a little ferric oxide or even, some silicate is added.* In shaping the bricks, high pressure must be used drying should be slow to prevent cracking, and before burning the bricks must be perfectly dry. The burning must be effected evenly and at a high temperature, and the cooling must be slow. The prime consideration, however, is care in selecting the raw material, and burning so as to produce both a binding and a sintered product.

Professor Wedding gives the following description of the method of preparing a basic hearth of magnesia: † Finely ground, sintered mineral is mixed with five parts by weight of clean, basic open-hearth slag, containing 10% to 15% silica, 2.5% to 3.5% alumina, and 18% to 30% lime, but some works use hammer or roll scale in place of this slag. Inclusive of the amount used in building the furnace, the consumption of magnesite per ton of steel is from 30 to 40 lbs., from 100 to 200 lbs. being used for repairs in each heat. It is stated that a well-rammed magnesia hearth will often outlast three Dinas roofs. The hearth may be made of brick, which must be of special shape, in order that the quantity of mortar used shall be as small as possible. The mortar consists of finely pulverized slag from the furnace, mixed with magnesia.

Professor Wedding summed up the disadvantages of chromite and dolomite for basic-furnace lining in comparison with magnesite in a paper read before the Society for the Promotion of Industry, at Berlin, Feb. 6, 1893:

"The use of chrome ore is limited by the exceedingly high price asked for it, which is increased by the cost of carriage, owing to its high specific gravity. There is also always uncertainty as to its composition and its sensibility to the change of temperature, which has caused the works which have tried it to cease using it. Although in France moderately satisfactory results have been obtained, it has never been a financial success in the long run, while even in Hungary, where cheap Bosnian ore has been available, its use has been discontinued, and its place taken by calcined magnesite.

"Magnesite is far superior to dolomite in the fact that the latter cannot be kept in stock on account of its property of attracting moisture from the atmosphere. A furnace lined with dolomite must be constantly kept under heat, else the lining will become useless owing to its moisture-attracting property, which of course makes it expensive if there is an interruption in the working of the furnace. The higher the tenor of a dolomite in line the more moisture it

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* C. Bischof, *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, XLI., 3, p. 27, Jan. 21, 1893; *Journal of the Iron and Steel Institute*, 1893, p. 213.

† *Stahl und Eisen*, XIII., 279-286.

absorbs. Another disadvantage of the dolomite is its fusibility in contact with silica bricks, which makes it especially troublesome in open-hearth furnaces at the point where the hearth and vault meet. Finally, dolomite once used has to be thrown away, while magnesite may be used over and over again."

Sources of Magnesite.

The chief sources of the magnesite of commerce at the present time are Veitsch, in Styria (Austria); near Frankenstein, in Silesia (Prussia); at Mantoudi, in the north of the island of Eubœa (Greece); and Child's Valley, near Rutherford, in California.

Austria.—The magnesite deposits of Styria occur at the foot of the Semmering, attaining their greatest development in the neighborhood of Veitsch. The formation is Silurian, consisting of argillaceous shales, quartzite, dolomite, and limestone, the last resting upon gneiss. The magnesite lies in beds conformable with the strata and is usually seamed with small stringers of calcite, dolomite, and quartz, with occasional segregations of dolomite crystals. It is necessary, therefore, to cob and pick the mineral.

The clean mineral, containing from 90% to 96% of magnesium carbonate, is calcined at a white heat in furnaces lined with magnesia brick at the part where the greatest heat is attained, this being to prevent the introduction of impurities into the material. The small amounts of silica and ferric oxide contained in the mineral do not slag, but only give rise to a sintering of the charge. The furnaces, which have an aggregate capacity of 80 tons of calcined mineral per day, are continuous in their action, the charges being drawn every six hours. The calcined product is delivered to a mechanical sorting plant, where the dust is sifted out, while quartz and other impurities are picked out by hand. The percentage of lime is reduced by the sifting, this substance slacking readily and forming a powder, which is removed.

The product from the sorting plant is crushed, and made into bricks in hard steel molds by a hydraulic press working at 300 atmospheres. The bricks are then burned, 3000 to 6000 at a time, in large kilns lined with magnesite brick.

The average composition of the Styrian magnesite from the valley of the Veitsch, according to Dr. Carl Bischof,* is magnesium carbonate, 90.0 to 96.0%; calcium carbonate, 0.5 to 2.0%; ferrous carbonate, 3.0 to 6.0%; silica, 0.0 to 1.0%; manganic oxide, 0.0 to 0.5%. The average yield of the sintered magnesia is about 50% of the raw material. Its composition, according to Professor Wedding,† is magnesia, 85.34%; silica, 3.40%; alumina, 0.82%; ferric oxide, 7.70%, and lime, 1.70%. Samples analyzed by Zyromski ‡ gave an average of magnesia, 77.6%; lime, 7.5%; silica, 1.2%; ferric oxide and alumina, 13.0%.

The first experiments in making bricks from Veitsch magnesite took place in 1884, and two German works engaged in the regular manufacture two years later. Brick-works were erected at Veitsch in 1890. Bricks are made there in all sizes up to 400 by 400 by 200 mm., and also in special shapes. The following are analyses of these bricks, as reported by the maker.

**Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, XLI., 3, p. 27, Jan. 21, 1893.

† *Stahl und Eisen*, XIII., 279-286.

‡ *Compt. Rend.*, 1886, p. 106.

	I. Per Cent.	II. Per Cent.	III. Per Cent.
Silica	2.70	4.70	4.48
Ferric oxide	7.84	9.05	9.10
Alumina	0.30		
Manganese peroxide	0.52	0.52	trace
Lime	1.69	trace	1 84
Magnesia	86.70	85.31	84.27

Three kinds of magnesite are found in the Styrian Alps, viz.: (1) pinolite, which on account of the high percentage of clay mixed with it can be used only as building material; (2) massive magnesite, mixed with serpentine, and therefore available only for the manufacture of artificial stone; and (3) magnesite spar. The last resembles spathic ironstone in appearance, being of a yellowish white to light yellow color, and is the only kind of mineral which is suitable for basic furnace lining.

The Veitsch magnesite mines are situated 985 meters above the sea level, about a mile from the railway station at Mitterdorf-Mürzthal, which is in direct railway communication with the ports of Fiume and Trieste. The works are about 450 meters below the mine, with which they are connected by a double gravity tramway, and are equipped with twenty-two furnaces and kilns. Altogether 342 persons are employed in the mines and works.

The following statement of the production of magnesite brick in the Veichsthal is taken from a pamphlet published by the owner of the works:

PRODUCTION OF MAGNESITE IN VEICHSTHAL, STYRIA.
(In metric tons.)

	Raw.	Burned.		Raw.	Burned.		Raw.	Burned.		Raw.	Burned.
1881	20	....	1884	911	....	1887	*a*	1,650	1890	4,920	5,825
1882	447	....	1885	2,251		1888	*a*	2,200	1891	5,330	8,310
1883	550	....	1886	2,622	128	1889	*a*	4,200	1892	3,690	9,020

a Not stated.

Canada.—The existence of magnesite at several points in the eastern townships of Quebec has been known, its occurrence having been noted in the early reports of the Canadian Geological Survey. A deposit in Bolton was said to have a width of 60 ft., a large portion being stained a light-green color by chromic oxide. Samples of the rock free from these stains gave magnesium carbonate, 83.35%; carbonate of iron, 9.02%; and silica, 8.03%. Two other analyses of rock from Bolton gave insoluble residue, 29.90% and 32.20%; magnesium carbonate, 59.72% and 59.13%; carbonate of iron, 10.31% and 8.32%. At Sutton there is a bed of magnesite one foot thick in mica schist, but this also is impure, the percentage of insoluble matter reaching as high as 76%.* It is evident, therefore, that the Canadian magnesite represented by these analyses is worthless for most of the purposes to which the purer mineral is put, the high percentage of iron and silica rendering it valueless as a refractory material. The official Canadian statistics do not report any production of magnesite in the Dominion. It is often very difficult to distinguish the magnesite of Quebec from the crystalline dolomite of the same region.

Germany.—Deposits of magnesite at Grochau and Baumgarten, near Frankenstein, in Silesia, are operated by the Deutsche Magnesit-Werke, which has works at Frankenstein.

The Silesian mineral was formerly made into bricks at Brieg, but this manu-

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* *Ann. Rep. Geol. and Nat. His. Survey of Canada* (new series), Vol. IV., 1888-89, p. 110, K.

facture has been discontinued, and now the calcined product is used in the preparation of other kinds of structural material, such as slabs for roofs and floors (pavements), wall linings, window seats, door jambs, etc., in buildings. Walls lined with this material are fireproof, and resist the weather well. The magnesite plates have the further advantage of being poor conductors of heat, and walls covered with them are said to be never damp.

The method of brick-making formerly used at Brieg was as follows: A portion of the magnesite, to serve as binding material, was burned at a low temperature, while the remainder was sintered at the highest temperature possible. The calcined mineral was then crushed, sifted, and mixed; a little magnesium chloride was added, and the mass was finally pressed into bricks by a machine working at a pressure of 110 atmospheres, the pressure exerted upon each brick being about 1000 centners. After drying for a week they were burned in a Mendeshein gas furnace, a kiln with a circular oven, of which the bed was lined with magnesite bricks.

The Deutsche Magnesit-Werke at Frankenstein reports that its annual production is about as follows: Crude magnesite, in lumps, 2000 metric tons; raw magnesite meal (sold to seltzer and soda-water manufacturers), 1500 tons; burned magnesite (for plates and structural material), about 1200 tons, equivalent to 2400 tons of the crude rock. The following analysis gives the composition of the Frankenstein coarse magnesite: Magnesia, 49.24%; carbonic acid, 50.25%; silica, 0.13%; alumina and ferric oxide, 0.13%; lime, 0.01%; water, 0.21%. Magnesite in small pieces and meal: Magnesia, 43.49%; carbonic acid, 47.34%; silica, 6.35%; alumina and ferric oxide, 1.45%; lime, 1.05%; water, 0.28%.*

Greece.—The magnesite mines of this country are near the village of Mantoudi, in the northern part of Eubœa. The mineral, which is of a cryptocrystalline texture, occurs in large veins in serpentine. Its tenor in magnesium carbonate is sometimes as high as 98%, but the average composition, according to Christomanos,† is as follows: Carbonate of magnesia, 94.46%; carbonate of lime, 4.40%; ferric oxide, 0.08%; silica, 0.52%; water, 0.54%. Four analyses of the calcined mineral showed a composition: Magnesia, 82.46 to 95.36%; lime, 0.83 to 10.92%; ferric oxide and alumina, 0.56 to 3.54%; and silica, 0.73 to 7.98%. The value of the mineral some years ago was only 25f. to 28f. ($4.83 to $5.40) per metric ton, but now it is higher; in the calcined state it is worth more than twice the raw. The whole amount of mineral raised is exported. The production during the past five years has been as follows:‡ 1888, 300 metric tons; 1889, 1200; 1890, 8734; 1891, 5223; 1892, 10,100; 1893, 8815.

The United States.—The only part of the United States in which magnesite has been commercially produced, or in which its existence in workable deposits has been mentioned, is California.

In 1885 the occurrence of magnesite in California had been noted at the following places:§ In the Mount Diablo Range, Alameda County; in Mariposa County, where "a heavy bed of magnesian rock, chiefly magnesite, charged with crystals of iron pyrites, accompanies the chief gold-bearing quartz vein of the

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* Analyses by Dr. Gustav Götting, Aug. 20, 1893, sent by the Deutsche Magnesit-Werke in a private communication.

† *Chemiker Zeitung*, 1886.

‡ *L'Industrie Minérale en Grèce. Rapport pour l'Exposition de Chicago; Ministère des Finances.*

§ *Sixth Ann. Rep. State Mineralogist of California*, Part I., p. 119, 1885-86.

county;[*] on Arroyo Seco, Monterey County, in a vein two feet wide; in Township No. 9 N., Range 5 W., Napa County, in large quantities; at Gold Run and Damascus, Placer County; at Port Harford, in San Luis Obispo County; a large deposit of excellent quality on Coyote Creek, about two miles from Madrone station (Southern Pacific Railway), in Santa Clara County; beds of hard, white, fine-grained mineral from one to six feet thick (interstratified with serpentine and talcose slates) near Visalia, below Four Creeks and Moore's Creek, in Tulare County; in Tuolumne County, associated with serpentine and gold-bearing quartz.

In Section 5, T. 13 S., R. 24 E., Fresno County, Cal., there is a large vein or deposit of magnesite, massive and of a white color. It crops to the surface, has an average width of about 10 ft., and can be seen extending for several hundred feet in length on its course north 10° east. It is encased in a hornblendic shale on the eastern side, and by a micaceous shale on the west.[†]

The magnesite found in the Mount Diablo Range, Alameda County, is of the hydrous variety and pulverizes easily. The mineral found near Visalia, in Tulare County, is white, hard, and fine grained, resembling unglazed porcelain in texture. It occurs in beds varying from one foot to six feet in thickness, which are interstratified with talcose slate and serpentine.

The most important of the California deposits appears to be that in Child's Valley, Napa County, where there is a well-defined lode from five to seven feet thick, with a regular hanging wall, dipping at an angle of about 70°. The lode has been uncovered for about a quarter of a mile. The mineral is white in color and of good quality. The Snow Flake mine, owned by H. G. Staab of San Francisco, has been opened on this vein and worked to a small extent by Stanley & Bartlett. The mine and the calcining works connected with it are ten miles from Rutherford and sixty-five miles from San Francisco. The crude mineral is worth $7 per ton at Rutherford, and the calcined $20 per ton. Freight from Rutherford to San Francisco is $2 per ton. The total output of this mine (which is the only producer on the Pacific Coast) since 1890 is given in the following table:

PRODUCTION OF MAGNESITE IN CALIFORNIA.

Year.	Crude.		Calcined.		Crude Equivalent of Calcined, Short Tons.	Total Crude.	
	Amount, Short Tons.	Value at Mine.	Amount, Short Tons.	Value at Works.		Amount, Short Tons.	Value.
1891	117	$819	322	$6,440	644	761	$5,397
1892	608	4,256	397	7,910	794	1402	9,814
1893	263	1,841	440	8,800	830	1143	8,000

The calcined mineral is shipped to the Willamette Pulp and Paper Company, at Oregon City, Ore., for the manufacture of wood pulp by the sulphite process.

Mr. Patrick Noble, superintendent of the Pacific Rolling Mill Company, informs us that his company used about 200 tons of calcined magnesite as a lining for its open-hearth furnace during the latter part of 1892 and the first part of 1893, with very satisfactory results. Mr. Noble also reports that magnesite may

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[*] It is interesting to note that this rock is stained green with nickel or chromium, like that at Bolton, Quebec.

[†] *Tenth Ann. Rep. Cal. State Mineralogist*, p. 185.

be obtained commercially from three counties adjoining San Francisco, and gives the following average analysis of the mineral used by his company: Silica, 2.76% ; carbonate of lime, 2.78% ; carbonate of iron, 0.40% ; carbonate of magnesia, 93.66%—total, 99.60%.

On Jan. 1, 1894, crude magnesite was quoted in New York at $14 per long ton (1015 kilograms); calcined magnesite was $22.75, and magnesite brick, $47.50; these prices being for Styrian mineral, c. i. f. at New York.

Russia.—Extensive deposits of magnesite were discovered in the Werchnenval district, on the Asiatic side of the Ural Mountains, in 1891. The mineral was said to be very pure, containing only insignificant quantities of lime, ferric oxide, and silica. We have not heard that these deposits have yet been exploited on an industrial scale.

MAGNESIUM.

THE chloride and bromide of magnesium occur in vast quantities in sea water and in carnallite (one of the Stassfurt salts), the sulphate in the minerals kieserite, schönite, and kainite, and the carbonate in magnesite and the dolomites; but the metal itself has become of industrial importance only within the last twenty years. It is soft, silver-white, of 1.743 sp. gr. On breaking, its fresh fracture appears slightly crystalline, finely granular, or even fibrous. It is about as hard as calc spar and becomes dull on exposure to the air. It melts at about the same temperature as zinc, and, having a strong affinity for oxygen, takes fire when heated slightly above its melting-point, burning to magnesia (MgO) with a dazzling white flame.

Magnesium was formerly produced in exactly the same way as aluminum, the chloride being decomposed by heating in contact with sodium. Now, however, all the metal used is produced by electrolysis, with which the sodium process cannot compete.

Magnesium was first prepared electrolytically from its chloride by Bunsen in 1852. The suitability of fused potassium-magnesium chloride (carnallite, $KMgCl_3$) for the electrolytic separation of magnesium, and the important fact that the metal formed could be kept from burning by the introduction of reducing gases, was shown by Rudolf von Wagner.* The process of reducing magnesium described by him is as follows:

The double chloride of magnesium and potassium is melted in a porcelain crucible, heated by a gas burner, in which there is a carbon rod, serving as the positive electrode, and an iron wire (5 millimeters in thickness), the lower end forming a ring round the carbon, which serves as the negative pole. The crucible is closed at the top by a tightly fitting asbestos cover, with tubes for the introduction of the reducing gas and the escape of chlorine. Graetzel has modified this process by using an iron crucible, which itself serves as the negative electrode. The metallic magnesium formed from the decomposition of the chloride melts and collects in the bottom of the crucible in balls about the size of a nut.

Magnesium, which now comes into the market in the form of plates, cubes, sticks, ribbon, wire, and powder, is used chiefly as an illuminant in photography and signaling. Recently it has been employed in refining metals to reduce metallic oxides contained therein, for which its great affinity for oxygen makes it a

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* *Chemical Technology*, p. 224. New York, 1892.

powerful agent.* Copper refined with magnesium is perfectly homogeneous and free from blow-holes, thereby forming the best material for the manufacture of fine brass. Equally favorable results are obtained with magnesium in the purification of alloys of copper, like German silver, brass, etc. It is also employed in the steel industry as a desulphurizing and dephosphorizing agent, magnesium combining with sulphur as MgS and with phosphorus as Mg_3P_2, which rise to the surface, whence they can easily be removed. In chemical technology magnesium has been used with advantage in dewatering oil, alcohol, and ether, while it has been recommended as a substitute for zinc in galvanotechnics on account of its purity, chemical strength, and electromotive power.

It is claimed that the addition of magnesium to copper imparts to it tenacity and hardness without altering its other properties, making it specially suitable for telegraph or telephone wires. Conductors made of magnesium copper are said to have great strength and offer the minimum of electrical resistance.

The chief use for magnesium, however, at the present time is as an illuminant. The properties which adapt it for this purpose have been summed up by Mr. F. J. Rogers as follows :† (1) The spectrum of burning magnesium approaches much more nearly that of sunlight than the spectrum of any other artificial illuminant. (2) The temperature of the magnesium flame, about 1340° C., lies between that of the Bunsen burner and that of the air-blast lamp, although the character of its spectrum is such as would correspond to a temperature of nearly 5,000° C. were its light due to ordinary incandescence. (3) The "radiant efficiency" is 13½%, a value higher than that for any other artificial illuminant, excepting, perhaps, the light of the electric discharge *in vacuo,* for which Dr. Staub of Zurlich has found an efficiency of about 34%. (4) The radiant energy emitted by burning magnesium is about 4630 calories per gram of the metal burned, or 75% of the total heat of combustion, as compared with 15% to 20% in the case of illuminating gas. (5) The total efficiency of the magnesium light is about 10%, as compared with 0.25% for illuminating gas. (6) Taking into consideration the greater average luminosity of the rays of the visible spectrum of the magnesium flame, it is certain that, per unit of energy expended, the light-giving power of burning magnesium is from fifty to sixty times greater than that of gas.

An alloy of magnesium, zinc, and iron has been proposed as a substitute for magnesium in pyrotechny and in photography, being equal to the latter in illuminating effect, and produced much more cheaply. This alloy, known as magnesium zinc, is produced either by the electrolysis of magnesium-sodium chloride in contact with zinc, or by the action of sodium upon that compound. In the first instance 10 or 12 lbs. of zinc are introduced into a plumbago crucible, through the bottom of which is inserted a carbon rod ; an excess of sodium-magnesium chloride is added, and a current of about 50 volts passed through the whole. The zinc speedily absorbs the magnesium thus set free, while chlorine escapes abundantly from the further electrode in contact with the magnesium chloride. When an alloy containing about 70% of magnesium has been obtained, the current is broken, and a small quantity of ferrous chloride introduced ; a further action is thus established, metallic iron being set free, which further

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* *Dingler's Polytechnische Journal,* 287, 10, p. 240.

† *Nature,* 1892.

alloys with both the zinc and the magnesium to the extent of about 12%. By this means a compound is obtained possessing so brittle a texture as to be readily reduced to the finest powder. In the second instance, a saturated alloy of sodium and zinc is caused to act upon a mixture of magnesium-sodium chloride; the sodium speedily changes place with the magnesium, forming the above-mentioned alloy, to which an equivalent portion of the iron is introduced by the action of ferrous chloride.*

The chief producers of magnesium are the Aluminum und Magnesium Fabrik of Hemelingen, near Bremen, Germany, and the Magnesium Metal Company of Patricroft, Manchester, England. A small amount is also made in Paris. In the United States there is no producer at the present time, the American Magnesium Company having abandoned the business. This company, operating in Boston, Mass., was organized in 1865, and continued to produce until 1889. It is impossible to gather any statistics concerning its make of metal, but the amount was small.

The Aluminum und Magnesium Fabrik of Hemelingen, Germany, which is the chief producer of the metal, quotes prices (Jan. 1, 1894) as follows: Ingots and cubes; $6.48 per kilogram; bars, $6.24; powder, $8.64; ribbon and wire, $9.12 per kilo. These prices are at the works and for orders of over 10 kilos; for less than 10 kilos 24c. per kilo must be added for ingots and bars, and 48c. for powder or wire.

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* H. N. Warren, *Iron*, XLI.

MANGANESE.*

BY R. A. F. PENROSE, JR.

THE production of manganese ore in the United States in 1893, exclusive of manganiferous iron ores, manganiferous silver ores, and manganiferous zinc ores, was 9[illegible]50 tons (2240 lbs.), or less than one-half the production of 1892. Like iron mining and most other industries, manganese mining was depressed; but while the dullness in iron mining was due directly to the small demand for pig iron, manganese mining was curtailed, not only by the small demand for ore from the iron and steel makers, but also on account of the steadily increasing imports of ore from Russia, Chile, and Cuba.

The total consumption of manganese ore in the United States in a year of ordinary prosperity is more than 60,000 tons, so that the output in 1893 was only about 10% of the average requirement. The remainder was imported chiefly from Russia, Chile, and Cuba, small amounts coming also from Canada and Greece. The falling off in the output of the United States was not due to any particular district, but to a general decrease in all. Minnesota was the only State figuring in 1893 as a new producer.

Arkansas.—The total production of manganese in Arkansas in 1893 was 2000 tons, the whole coming from the Batesville region, in the northern part of the State. In 1892 the production was 6708 tons.

Colorado.—The total production of this State in 1893 was 4700 tons, the whole of which came from Leadville; of this amount 4300 tons was derived from the Crescent and Catalpa mines, and averaged about 32% manganese, while the remaining 400 tons averaged about 27% manganese.

Georgia.—The production in 1893 was only about 500 tons, against 2000 tons in 1892. The manganese deposits of this State are situated in the northern part, mostly in Bartow County.

Minnesota.—A new mine, situated at Monticello, Wright County, on the Mississippi River thirty miles above Minneapolis, produced about 50 tons of ore in 1893, which was used for coloring bricks and in the manufacture of paints.

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* For a full account of the occurrence of manganese in the United States, its character, uses, etc., the reader is referred to THE MINERAL INDUSTRY, Vol. I., pp. 329-339.

This is the first year that any output of manganese has been recorded for this State.

Virginia.—The production of Virginia was only about 1500 tons in 1893, against 6079 tons in 1892. The falling off was due to the idleness of the Crimora mine part of the year. For a number of years previous to April 30, 1892, this mine was operated by the American Manganese Company, but on May 1, 1892, it passed into the hands of the Crimora Mining Company, which in March, 1893, abandoned it; since that time the mine has not figured to any important extent in the manganese market.

PRODUCTION OF MANGANESE ORES IN THE UNITED STATES SINCE 1889. (*a*)
(In Long Tons, 2240 Lbs.)

Year.	Arkansas.	Colorado.	Georgia.	Virginia.	Other States	Total.	Value.
1890	5339	*b*	749	12,699	6897	25,684	$219,050
1891	1650	*b*	3575	16,248	1943	23,416	239,129
1892	6708	4000	2000	6,079	350	19,117	129,586
1893	2000	4700	500	1,500	*c*450	9,150	60,000

(*a*) The production in previous years is given in THE MINERAL INDUSTRY, Vol. I., p. 330. (*b*) Included with "Other States." (*c*) California 400 tons, Minnesota 50 tons.

Canada.—The principal manganese deposits of Canada are in the Provinces of Nova Scotia and New Brunswick, mostly in the neighborhood of the Bay of Fundy. They occur in the marine limestone of the Lower Carboniferous series. Similar deposits also occur near Loch Lomond, in Cape Breton, while limited quantities of manganese ore were mined a number of years ago in rocks of Cambro-Silurian age at Tête-à-Gauche Falls, near Bathurst, in New Brunswick.

The manganese ores of the Bay of Fundy basin occur, as stated, in rock of Lower Carboniferous age. This is usually a limestone often containing shaly layers. The ore occurs in this rock in pockets, nests, and disconnected seams, varying from less than an inch to several feet in thickness. When mining in this region was first begun, considerable quantities of ore were obtained from a residual clay which had been formed by the decay of the ore-bearing limestone, and which overlay the uneven surface of that rock. Since the exhaustion of these surface deposits the production has steadily decreased, on account of the greater expense of mining the ore in the solid rock.

Chile.—The manganese deposits of Chile at present worked are mostly in the Provinces of Atacama and Coquimbo. The manganese region of the Province of Atacama is often known as the Carrizal district. The largest miner of manganese ore in Chile is the Chilean Manganese Mines Company, Limited, of England, which has mines in both of the above mentioned provinces. A smaller amount of ore is produced by Señor Naranjo in the Province of Coquimbo.

The principal manganese mines in the Province of Atacama are the Coquimbana, Porvenir, and Negra. These are about fifty miles east of the coast, and are connected by railroad with the port of Carrizal, from which the ore is shipped. The deposits in the Province of Coquimbo are also some fifty miles east of the coast, and about fifteen miles from the nearest railroad. The ore is conveyed by mule-back and wagons to the railroad, and shipped thence on cars to the ports of Coquimbo and La Serena, mostly to the former. The principal mines owned by the Chilean Manganese Mines Company in the Province of Coquimbo are in the districts of Corral Quemado, Arrayan, Romeral, and Las Faguas. The mines of Señor Naranjo, in the Province of Coquimbo, are mostly in the districts of Arrayan and Las Canas. The ore here is also conveyed to the railroad on mule-back or in wagons, and shipped thence to the ports of Coquimbo or La Serena.

Most of the production of Chile is shipped to England, though an important and constantly increasing proportion of it comes to the United States. The ore of the Chilean manganese mines is generally a mixture of one or more of the oxides, principally, however, psilomelane and pyrolosite in varying proportions, and possibly also some braunite. In some of the specimens examined by the writer the oxide ore was mixed with a grayish carbonate of manganese, which would suggest the possibility of some of the oxide ore having been derived from the carbonate by oxidation. The ore that is shipped averages nearly 50% manganese. In silica it ranges from 1% or 2% to 12% or 14%, averaging probably about 10%. In phosphorus it averages probably a little under 0.1%.

The ore in the Coquimbo district occurs as strata interbedded mostly with shales and sandstones, sometimes lying horizontally, sometimes dipping steeply. The beds vary from a few inches to five or six feet in thickness, and are remarkably continuous along their strike across country, though the ore in some places is much poorer than in others, and in some localities it is too low grade to ship profitably. The ore of the Carrizal district occurs in a silicious limestone following lines of stratification, as in the sandstones and shales of the Province of Coquimbo. The deposits, however, are much thicker than those in the latter region—sometimes measuring as much as 20 ft. in thickness. The limestone inclosing the ore dips at a high angle, sometimes almost vertically.

Russia.—The manganese deposits of Russia occur in the Province of Kutais, district of Sharopan, near the village of Chiatur, 26 miles north of the station of Kvirili, on the Trans-Caucasian Railway. They are found over an area of 13¼ square miles and within a radius of from one to three miles from the village of Chiatur. Until lately the ore has been carried from the mines to Kvirili on the backs of pack animals and in carts, thus adding considerably to the cost of the ore at the point of shipment; but recently the railroad has been extended from Kvirili to Chiatur, so that now the ore can go by rail direct from Chiatur to the coast of the Black Sea without any transportation by pack animal or wagon, except from the mines to the village of Chiatur. Most of the ore is shipped from Poti, though Batoum is the principal port for other shipping.

The manganese industry in the Trans-Caucasian region is of recent date. It was begun in 1879, when 871 tons were produced. This greatly increased from year to year, until in 1890, in spite of all the difficulties in the way of transporting ore, the production had increased to 182,468 tons, which is over twice as much as the production ever reached in any other manganese district in the world. It is stated by Mr. P. Stevens,* British consul at Batoum, that the exports for 1893 are expected to amount to 322,581 tons, though these figures are probably excessive.

The ore of the mines of the Trans-Caucasian region are oxides of manganese averaging in large shipments about 50% manganese and rarely over 0.16% phos-

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* *Report on the Manganese Ore Industry of Sharopan,* Foreign Office, Miscellaneous Series, 1893, No. 307.

phorus. The deposits occur in the valley of the river Kvirili, and are situated mostly on five hills known as Sedorgani-Rgani, Gwimewi, Darquetti, Shukrutti, and Perewissi. The ore crops out in the sides of these hills in an almost horizontal bed interstratified with chalk, sand, and other materials. It is mined in an exceedingly crude manner in small openings, and this, with the expensive means of transportation employed, has so enhanced the cost that the production, though far larger than that from any other manganese region in the world, has not yet reached anything like what the region is supposed to be capable of affording, but with the new railway facilities the production will doubtless be greatly increased.

Greece.—Greece annually produces considerable quantities of manganiferous iron ore from the Laurium mines and from the island of Seriphos. Manganese ore proper, however, is mined on the western end of the island of Chalaka

Other Countries.—Among the other regions which produce important quantities of manganese ore may be mentioned Cabesses, near St. Girons, France, and Merionethshire, Wales, while smaller quantities are produced in Sweden, Portugal, Spain, Turkey, Bosnia, New Zealand, New South Wales, and elsewhere.

MANGANESE ORE PRODUCTION OF THE WORLD. (IN METRIC TONS.)

Year.	Austria.	Belgium. (*a*)	Bosnia.	Canada.	Chile.	Cuba.	France.	Germany.	Great Britain.	Greece.
1881	9,108	770	....	....	....	....	13,708	13,642	2,931	....
1882	8,418	345	2,283	....	....	....	7,538	6,735	1,573	....
1883	9,382	820	4,003	....	....	....	6,573	6.488	1,308	....
1884	7,942	750	4.210	....	....	....	4,535	9,672	924	....
1885	6,158	....	4,406	....	4.106	....	3,424	16,628	1,716	....
1886	9,246	750	5,308	1,623	24,313	....	7,676	27.050	12,972	....
1887	9,311	12,750	5,202	1,130	48,286	....	12,000	38,385	14,000	500
1888	6,554	27,787	100	1,634	19,014	1,973	11,000	28,710	4,413	1,475
1889	3,926	20,905	1,000	1,320	29,145	715	10,000	45,167	8,997	10.660
1890	8,007	14,255	5,500	1,205	48,759	22,161	15,984	41,841	12,646	13,547
1891	5,279	18,498	8.847	231	35,017	22,341	15,343	40,335	9,632	13,453
1892	4,558	16,775	7,944	105	*c*50.000	18,000	*c*15,000	32,891	6,175	11,716
1893	....	....	7,403	....	*c*50,000	13,922	....	....	....	....

Year.	Hungary.	Italy.	Japan.	New S. Wales.	New Zealand.	Portugal.	Russia.	South Aust'lia.	Spain.	Sweden.	United States.
1881	2,832	8,767	1.5	....	1,291	9.906	11,238	....	8,207	1,659	4,974
1882	4,360	6,978	157	....	2,216	17,336	14,431	138	5,668	1,673	4.605
1883	2,846	11,384	152	....	390	....	17,052	338	4,182	4,043	6,254
1884	2,829	835	126	....	323	9,241	22,134	60	851	3,662	10,344
1885	2,757	1,802	124	....	112	7,103	60,532	132	4,045	6,091	23,632
1886	2.192	5.561	405	....	334	....	74,400	1,575	400	7,192	30,679
1887	963	4,434	313	....	310	6,812	58,207	....	1,460	8,659	35,080
1888	622	3,630	815	....	1,102	5,638	32,680	52	2,807	9,690	29,663
1889	98	2,203	948	....	1,097	5,893	78,031	1,622	8,187	8.645	24,586
1890	1,445	2,147	2,612	102	490	....	182,468	2,808	9.872	10,698	26,098
1891	128	2,429	*b*3,249	140	1,172	....	113,081	861	*b*9,002	9,079	23,793
1892	1,304	1,243	....	16	529	3 399	....	....	....	7,832	19,425
1893	....	....	....	....	....	....	....	....	....	....	9,297

(*a*) Ferro-manganese ore. (*b*) Fiscal year. (*c*) Estimated.

Value of Manganese Ore.—The schedule of prices paid for manganese ores delivered at Bessemer, Penn., by the Carnegie Steel Company, dated Jan. 1, 1894, was as follows :

	Prices per Unit.			Prices per Unit.	
Manganese.	Iron.	Mang'nese.	Manganese.	Iron.	Mang'nese.
Ore containing above 49%	6c.	28c.	Ore containing 43% to 46%	6c.	26c.
Ore containing 46% to 49%	6c.	27c.	Ore containing 40% to 43%	6c.	25c.

Prices are based on ores containing not more than 8% silica and not more than 0.10% phosphorus, and are subject to deductions as follows : For each 1% silica in excess of 8%, 15c. per ton ; for each 0.02% phosphorus in excess of 0.10%, 1c. per unit of manganese. Settlements are based on analysis made on samples dried at 212°, the percentage of moisture in samples as taken being deducted from the weight.

GREENSAND AND CALCAREOUS MARLS.

BY JOHN C. SMOCK.

Greensand Marls.—Greensand, or glauconite, characterizes a series of formations which occur in New Jersey, in a belt stretching from the Navesink Highlands to Salem, on the Delaware. The beds have a nearly uniform dip toward the southeast. The length of this belt is 100 miles and its breadth varies from 5 to 15 miles. There are three formations, known as the lower, middle, and upper marl beds, in which pits are dug or openings made to get the marl for use as a fertilizer. There are numerous marl pits or "marl banks," as they are called, the practice being to open them wherever there are outcrops, or where the covering of earthy beds is not so great as to make the extraction too expensive. Nearly every farm in the belt has its marl pits.

Besides the local use of marl on the farms where it occurs, it is carried by railways into the country on either side of the belt and sold as a commercial fertilizer.

There are large openings or pits at Farmingdale, in Monmouth County; at Birmingham, Vincentown, and Fostertown, in Burlington County; and near Wenonah, in Gloucester County, whence the marl is shipped by train loads to all parts of southern and southern-central New Jersey.

The amount of marl used as a fertilizer has greatly decreased within the last two decades, owing to the increased cost of digging and carting, as well as to the competition of artificial fertilizers. The latter, because of the quicker result from their use, appear to be more satisfactory than the marls, which are slower to act, but improve the soil more lastingly. Phosphate of lime, varying from ½% to 10%, carbonate of lime, and potash are the more valuable constituents of these marls, which also beneficially affect the physical texture of the soil.

The price ranges from 25c. to more than $1 per ton, only a comparatively small quantity selling at the maximum price. The quantity of marls used locally largely exceeds that sold by the marl companies. The output for 1890 was, in a low estimate, put at 153,000 tons; that for 1893 was about 110,000 tons, of which 11,500 tons were produced by the companies. It is difficult to estimate the output, and well nigh impossible to compile exact statistics of it, because of the large number of pits where a little marl is dug for home use only.

Greensand to some extent is used in the coloration of some of the more common kinds of green glass and in the manufacture of some of the commercial fertilizers.

Greensand marls occur in the States southwest of New Jersey to the Gulf of Mexico. In Delaware and Maryland a little is dug for use in agriculture. The deposits in North Carolina, Alabama, and Mississippi have been described in the State reports and their use has been advocated, but the results hitherto, so far as can be learned, have scarcely been sufficient to demonstrate the value of the marls.

Calcareous Marls.—Calcareous marls occur in shallow deposits in wet meadows and in lakes and ponds in the northern part of New Jersey. They have been used as fertilizers. Their high percentage of calcic carbonate and their fine earthy condition have suggested their use in the manufacture of Portland cement.

ANALYSES OF NEW JERSEY MARL FROM MONMOUTH AND MIDDLESEX COUNTIES.*

Formation.	Clay Marl.		Lower Marl.							Middle Marl.		Upper Marl.	
Number of Analysis.	1	2	3	4	5	6	7	8	9	10	11	12	13
	%	%	%	%	%	%	%	%	%	%	%	%	%
Phosphoric acid	1.15	0.58	1.51	1.14	2.18	0.84	0.38	1.14	1.20	0.19	0.50	6.87	3.73
Sulphuric acid	1.28	.....	2.40	0.14	......	0.12	0.20	0 31	.....	0.41	0.34	3.12	2.44
Silicic acid and sand	34.50	45.40	55.69	38.70	43.70	52.07	53.10	38.70	36.70	51.15	47.50	44.68	49.68
Potash	1.54	3.79	5.27	3.65	3.82	6.46	3.78	4.47	3.10	7.08	5.29	3.97	4.98
Lime	2.52	1.51	0.65	9.07	8.85	1.01	......	.....	1.56	0 49	0.56	4.97	4.14
Magnesia	2.15	2 20	0.79	1.50	2.33	1.53	0.70	1.21	2.60	2.02	2.70	2.97	0.47
Alumina	6.00	5.80	6.61	10 20	25.00	6.96	6.30	30.67	43.58	8 23	8.60	6.04	28.71
Oxide of iron	31.50	24.50	21.63	18.63		21.55	15.39			23.13	20 52	18 97	
Water	18.80	15.40	8.85	10.00	9.21	9.31	8.64	11.22	10.62	6.67	13.57	8.63	5.54
Carbonic acid	.....	.....	......	6.14	5.40	.....	......	......	.....	.....	.....	.....	.....
Carbonate of lime	.	.....	.....	.....	......	.....	12.10	13.91	.....	.....	.....	.....	.....
	99.44	99.18	103.40	99.17	100.49	99.85	100.59	101 63	99.36	99.37	99.58	100.22	99.69

* From *Report of New Jersey State Geologist*, 1892, p. 230.

MICA.

By J. T. Donald.

The name mica is used by the mineralogist in a generic sense, to include a number of distinct species. Those species which enter into commerce are similar in their physical characteristics, and are distinguished chiefly by their color. The micas are very complex silicates of alumina, together with other bases, notably potash, magnesia, iron, and soda. Three of them are of commercial importance, viz.: muscovite, or "white mica"; phlogopite, or "amber mica"; and to a limited extent biotite, or "black mica." Muscovite is sometimes spoken of as potash-mica, since, after alumina, potash is the predominant base, and for a similar reason phlogopite is known as magnesian mica, and biotite as magnesian-iron mica. These three varieties are found in largest quantities in the older rock, like those of the Appalachians and the northerly parts of Canada.

Muscovite occurs in greatest abundance in granites and gneisses, whereas phlogopite is more frequently associated with magnesian limestone and pyroxenic rocks. Both varieties occur in crystals, in detached masses, and in veins, which in many cases appear to be lenticular deposits connected by stringers.

A fear has frequently been expressed that mica deposits are mostly superficial, but so far as conclusions can be drawn from a study of the deepest workings yet made (over 200 ft. in Canada and 300 to 400 ft. in the United States), there does not appear to be any good grounds for attributing unusual shallowness to the mica veins.

In mica mining it has been found that hand drilling gives the best results. With power drills there is greater liability to destroy valuable crystals, and consequently but few are in use. The mineral is blasted out and the crystals of suitable size and quality are sorted from the waste. They are then taken to the dressing shop and split into sheets of the requisite thickness, which are then cut or punched into shapes or sizes as large as the crystals will yield. The dressed mineral is cleaned and then packed in paper in pound packages.

The amount of waste in mica mining is enormous. In the first place, only a fraction of the mica mined is suitable for dressing, and then the weight of dressed mica in general amounts to only from 4% to 10% of the block mica treated, although in some cases a higher percentage has been obtained.

Muscovite has been employed in the arts for many years, principally for panels of stoves and furnace doors. When it was first used in this connection, the stove panels were large, and correspondingly large sheets of mica were called for, and the latter was an important item in the cost of stoves. The result was a change to much smaller panels, for which smaller sheets of mica sufficed, the small sizes being much more abundant and cheaper than large ones. This change on the part of the stove manufacturers caused a rapid decline in mica mining, which had previously been a profitable business. Subsequently the mineral came into demand for the construction of electrical appliances, machines, and apparatus, and for this has again taken a position of importance in the mineral industry. For electrical purposes phlogopite is the variety chiefly used, although there is no objection to the biotite, which is less abundant, and muscovite, which is generally reserved for other uses. Phlogopite is usually of a bronze color, but is commonly known as "amber mica."

"Electrical mica" must be smooth, free from wrinkles and crevices, must split readily, and be so flexible that a piece .01 in. thick will bend to a curvature of about 3 in. diameter without crackage. Mica that has dark spots, or spots similar to rainbow colors, or what is known as smoky mica, is not at all suitable for electrical uses. It must also stand a high temperature without crumbling or disintegrating.

Some of the waste mica from the mines and the dressing-houses is ground and used for various purposes, but especially as an ingredient in lubricants for heavy bearings, and in certain insulating compounds. A certain amount of scrap mica is now, by a patent process, pieced into large sheets, which are claimed to have all the good qualities of entire sheets. The composite sheets are known under the trade name of "micanite."

The principal sources of mica are India, the United States, and Canada. The chief consumers are in the United States. The consumption, and consequently the production, of the mineral decreased to a marked extent in 1893, owing to the general financial depression, but the Canadian miners believe that the stocks of mica in the hands of consumers are very small and that so soon as the business of the world is again in normal activity the demand will revive.

The operations of the year were to a notable extent in the direction of development of properties and concentration of management, with a view to increased output when the expected increase in demand sets in, and to reduction of cost of production.

The principal mines producing electrical mica are situated in the counties of Perth and Renfrew, in Ontario, and in Ottawa County, Quebec. Muscovite and phlogopite are found in these counties, and there are also some good muscovite deposits along the lower St. Lawrence which are being worked with satisfactory results.

NICKEL.*

THE production of nickel in the United States in 1893 was much smaller than the previous year owing to the exhaustion of the Lancaster Gap mine, where exploration work failed to show new ore bodies. A small amount of ore was, however, derived from the old stopes.

The only other producers were the lead mines of southeastern Missouri, which turn out a small amount of nickel-cobalt speiss as a by-product. In 1893 this was exported to England for treatment.

The development of the Oregon and Nevada mines was continued during 1893, but although some ore was produced by them none was sent to market. The Oregon mines have been proved undoubtedly to contain an important supply of nickel, but their value at present is reduced on account of their comparative inaccessibility and the high cost of coal and material to put the ore in an easily transported form. Little information is given out concerning the Nevada mines, but it is understood that the National Nickel Company of New York, which owns the most promising of them, has concluded to erect matte-smelting works at the mines, which will be completed during the present year (1894).

Fine nickel was produced in the United States in 1893 by the American Nickel Works (Joseph Wharton, Jr.) at Camden, N. J., the Orford Copper Company at Constable Hook, N. J., and the Canadian Copper Company at Brooklyn, near Cleveland, Ohio. The first mentioned refined Lancaster Gap and Canadian matte, and the others Canadian alone, which was for the more part turned out in the form of nickel oxide. The production of metallic nickel in the United States in 1893 was 356,942 lbs.; fine nickel in oxide and sulphide, 2,520,827 lbs.; in other salts, 38,009 lbs.—total, 2,915,778 lbs. Of cobalt oxide 3893 lbs. were produced, against 8600 lbs. in 1892.

The nickel production of Ontario decreased in 1893, falling from 4,164,000 lbs. in 1892 to 3,284,000 lbs. We have not had figures for 1893 from New Caledonia, but the output from those mines was probably somewhat smaller than in the previous year (when about 40,000 metric tons of ore, averaging 7% nickel, were produced), owing to severe storms in the Spring, which did much damage to

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* The occurrence, distribution, and statistics of the production of nickel in the United States and Canada and metallurgy of nickel, etc., were described in THE MINERAL INDUSTRY, Vol. I. (1892), p. 343 *et seq.*, to which the reader is referred.

the mining plants on the island. The total production of nickel in the world in previous years is given in the following table:

THE WORLD'S PRODUCTION OF NICKEL.

(In kilograms.)

Year.	New Caledonia.	Canada.	United States.	Norway.	Sweden.	Total.
1889	1,381,482	309,701	98,731	88,500	…………	1,878,414
1890	1,633,214	651,239	90,870	70,500	8,050	2,454,873
1891	2.449,306	2,098,598	54,815	91,000	12,000	4,705,719
1892	*a*2,800,000	1,888,790	43,614	*a*90,000	…………	4,822,404
1893	*a*2,800,000	1,811,205	11,745	*a*90,000	…………	4,712,950

(*a*) Estimated.

An experimental plant for the operation of the Mond process of nickel winning was put in operation at Birmingham, England, in 1893, but metal therefrom has not yet been placed regularly on the market. The nickel resources of various countries, including the United States and Canada, were examined in this interest in 1893, and we are informed that an attempt is to be made to work by this process the ores of Frankenstein, Silesia, where there is said to be a large deposit of nickel-bearing pyrrhotite. A new dry process has also been put in operation by the Société Havraise de Nickel, at Havre, France, under the management M. David Levat, formerly director general of Le Nickel of New Caledonia, and a noteworthy output has been made thereby.

Experiments with nickel-steel for new uses were carried on during 1893, but none have yet reached final results. The most important of these are the application of the alloy to the manufacture of heavy guns, for which it is thought that its non-corrodibility and other physical characteristics, such as increased elasticity and extraordinary elongation, render it well adapted, especially for guns subjected to a high pressure with nitro-powders. A test gun which will be 304.5 in. long and will weigh 31,300 lbs. is now being made at the Washington works from forgings which contain 3.15% nickel. The minimum physical characteristics of the gun will be: For the tube, tensile strength, 85,000 lbs.; elastic limit, 42,000 lbs.; elongation, 20%. For the jackets, tensile strength, 90,000 lbs.; elastic limit, 45,000 lbs.; elongation, 13%. Nickel-steel is also to be tried for the barrels in the new small-bore rifles adopted by the Navy Department. The future for nickel-steel is considered very bright by those engaged in its manufacture.

It is, of course, the manufacture and use of nickel-steel to which the producers of nickel look for the great increase in the demand for that metal; but how great will that demand be? It is only within a few years that we have commenced to study the question of the alloys of steel, and although many useful ones have been invented and brought into use, we really know little about their properties. May not some cheaper alloy having all the advantages of nickel-steel be discovered in the near future?

The extent to which nickel is coming into use in Europe for small articles which have hitherto been only nickel-plated is worthy of note. Thus one may see in the shop windows scores of things, such as door-plates, oil-cans, settings for spirit-levels, and the like, made of solid nickel. It is now generally recognized that nickel-plating is not durable, and as the price of the metal declines we shall doubtless see a large increase in its consumption for such purposes as those named. The following account of investigations on the strength and properties of the metallic nickel of commerce was reported by Prof. H. Wedding in behalf of the iron-alloys committee of the Verein zur Beförderung des Gewerbefleisses.*

At the works of Herren Basee and Selve, Altona, three very pure commercial nickel bars, each weighing 30 kilograms, and of the following composition,† were cast:

Nickel	97.87%	97.90%	98.21%
Cobalt	1.45	1.25	1.19
Iron	0.45	0.50	0.25
Copper	0.10	0.07	0.07
Silicon	0.19	....	....
Silicic acid	....	0.19%	0.24%
Carbon	trace	trace	trace
Sulphur	0.05%	....	trace
Alkalies, lime, and alumina	....	trace	trace
Total	100.11	99.91	99.96

The molds, which were of cast iron, were given a coating of dry chalk and uniformly heated to 130°. The crucibles were of ordinary graphite, but in the interior were lined with a thin layer of chamotte, which was firmly burnt in. The furnace was heated with coke, and was made white hot before the insertion of the crucible, which was wholly embedded in the coke. The crucible, which during fusion was covered with a firmly closing lid, was lifted out after complete fusion of the nickel to a watery-fluid mass, the temperature having at that time reached a blue heat. There was a small quantity of viscid dark-green slag, which was removed by the graphite spade. Casting took place immediately after the crucible was taken out. The cast-nickel blocks were at once forged, and at the same heat at which they were cast. It was manifested that pure nickel without an addition of magnesium was porous and irregular in fracture—the fracture being yellowish-gray—and would not forge well. For the production of a useful nickel the addition of some magnesium at the end of fusion is necessary. To all the baths, therefore, shortly before lifting out the crucible, 42 grams of magnesium to 30 kilograms of nickel were added. Aluminum cannot be used instead of magnesium.

The literature of nickel was enriched to an unusual extent in 1893, the most noteworthy contributions having been made by Prof. J. H. L. Vogt of Christiania, Norway, and H. B. von Foullon of Vienna. The following list includes the most important papers:

J. H. L. Vogt, *Nikkelforekomster og Nikkelproduktion*, a monograph published by the Norges Geologiske Undersögelse, Christiania, 1892.

J. H. L. Vogt, "Bildung von Erzlagersttäten durch Differentiationsprocesse in basischen Eruptivmagmata," Part II. Sulphidische Ausscheidungen von Nickelsulphiderzen, namentlich nickelhaltigen Magnetkies, in Basischen Eruptivgesteinen, *Zeitschrift für Praktische Geologie*, April, 1893, pp. 125–143, and July, 1893, pp. 257–284.

H. B. von Foullon, "Ueber einige Nickelerzvorkommen," *Jahrbuch der K. K. Geologischen Reichsanstalt*, 1892, Vol. XLII., Part II., pp. 223–310.

F. Benoit, "Les Mines de Nickel de Nouvelle Calédonie," *Bulletin de la Société de l'Industrie Minérale*, 1892, pp. 753–804.

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* *Oesterreichische Zeitschrift für Berg- Hütten und Salinenwesen*, May 27, 1893.

† The analyses are by Pufahl and Von Knorre.

Fuchs et de Launay, *Traité des Gîtes Mineraux*, 1893, Tome II., pp. 48–72.

W. L. Austin, "Nickel: an Historical Sketch," *Proceedings of Colorado Scientific Society*, Dec. 4, 1893.

Philip Argall, "Nickel: Occurrence, Geological Distribution, and Genesis of its Ore Deposits," *Proceedings of Colorado Scientific Society*, Dec. 4, 1893.

Second Report of the Ontario Bureau of Mines (1892), pp. 129–170.

"Uebersicht der Nickelhüttenprocesse," *Berg- und Hüttenmännische Zeitung*, LII., 15, p. 121, April 14, 1893.

And although not included among the contributions to the literature of this metal in 1893 reference may be made again to the very excellent monograph by M. David Levat, entitled "Mémoire sur les Progrès de la Métallurgie du Nickel, et sur les Récentes Applications de ce Métal," which was published in the *Annales des Mines*, Tome I., 1892, and is one of the best treatises on the subject, especially with respect to nickel-mining from New Caledonian ores, in existence.

The following notes relating to the nickel mining industry in foreign countries are taken from some of the articles previously referred to.

*Nickel in Russia.**—Deposits of nickel ore are known in various parts of the Urals, and also in the Caucasus in the Province of Daghestan, the richest deposits being in the Revdin mining district of the Urals. These were first discovered in the fifties, and the Petrovsk mine was subsequently opened for working them. This is the only instance in Europe of a mine producing oxidized nickel ores almost free from sulphur and arsenic. The ore averages about two per cent. nickel. The supply is said to be large, and it is possible that Russia may become some time one of the chief sources of this metal.

Nickel Mining in New Caledonia is carried on by the usual methods of vein mining, and also by open cast work. Inclines are sunk on the veins and connected by levels, the ore being stoped from below toward the surface and the waste dropped behind. The miners include a few Englishmen, who are paid from 6 to 9f. ($1.20@$1.80) per day; Kanakas, who are given their board and 20f. ($4) per month; and Annamite and Tonkese prisoners, galley slaves and convicts, obtained by contract from the Government. The best workmen are the freed convicts, who earn from 5 to 6f. ($1 to $1.20) per day.

The cost of mining the New Caledonian nickel ore varies between 15 and 40f. ($3 and $8) per 1000 kilos, according to the position and condition of the mines and the cost of transporting the ore from the mine to the port of shipment, which varies from 0.5 to 10f. (10c.@$2) per ton. Ore containing 7.5% to 8.5% nickel is worth at shipping port 105f. ($21) per ton, and ore with 9.51% to 10.50% nickel, 125f. ($25) per ton. The freight from Nouméa to Havre is 40f. ($8) per ton of ore, having been 50f. ($10) before the company Le Nickel had its own ships.

There are two companies operating in New Caledonia—Le Nickel, and the Société d'Exploitation de Mines de Nickel, the latter working a few mines belonging to the former. Besides these there are several small ventures. Le Nickel has smelting works at Havre, and buys all the ore mined in New Caledonia. This company has acquired about 60,000 hectares of mineral land on the

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*A. Keppen, *The Industries of Russia; Mining and Metallurgy*, Vol. IV., p. 84.

island, but is only working 1000, from which it earns a net profit of more than 6,000,000f. ($1,200,000) yearly, with a capital stock of 12,720,000f.

The principal mining districts at present are Thio, Nakéty, Canala, and Kouaoua on the east coast, and Dumbea, Bourail, Paouéa, and Koniambo on the west coast. All the mines of Le Nickel lie in the Thio district. In 1890–91 the company extracted 32,000 and 33,000 tons of ore containing 7% nickel, and it was expected that the output would be 40,000 tons in 1892.*

The Nickel Industry of Scandinavia.†—From 1848 to the end of 1892 about 330,000 metric tons of nickel ore were hoisted in Norway. The maximum yearly output (42,550 tons) was made in 1876. Since that time the production has been only 5000 to 19,000 tons per annum. The average nickel contents of the ore have been as follows: 1851–60, 20 tons; 1861–72, 45 tons; 1873–76, 245 tons; 1876, 360 tons; 1877–80, 100 tons; 1881–85, 125 tons; 1886–92, 105 tons.

In some mines rich ore, although in small bodies, has been found, as, for example, at Beiern, ore with an average of 7% nickel (nickel-bearing pyrite and pyrrhotite), and in other places with an average of about 5.5% nickel. In the better mines first-class smelting ore with 3.5% to 4% nickel can often be sorted out, but the grade of the bulk of the ore is much lower. In 1870 miners were satisfied with a yield of 0.8% to 1.3% nickel from the smelting ore, the actual assay of which was 0.9% to 1.5%. In later years, when only the richer mines have been operated, and hand-sorting has been practiced with more care, the yield has increased, varying from 1.4% or 1.5% nickel, at least, to 2.5%, with an average of 2%.

In the best mines the cost of producing one ton of ore, assaying about 2% nickel, varies from $1.67 to $3.09, averaging $2.38. One kilogram of nickel in ore, therefore, costs 10.71@14.28c. (the small amount of copper contained in the ore being reckoned free), while in some mines operated on a large scale the cost may be as low as 7.14@9.52c. If modern metallurgical methods were introduced, the Norwegian nickel industry could doubtless attain considerable proportions.

The nickel contained in ores produced in Sweden from 1866 to 1875 averaged 65 to 70 tons per annum; since 1886, however, it has been only 10 to 15 tons per annum.

THE AMERICAN NICKEL MARKET IN 1893.

The nickel trade in 1893 differed considerably from preceding years, as consumers found no difficulty in getting what they needed, while before they had often been hard put to secure supplies, the question of price not considered. Then it was the custom to make contracts calling for deliveries a long time ahead, the terms of such contracts not being allowed to become generally known. This year it has not been so, as what was left over from the supplies contracted for 1892, together with what was readily obtainable, was amply sufficient to enable

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* F. Benoit, *Bull. de la Société de l'Industrie Minérale*, 1892, pp. 753–801.

† *Engineering and Mining Journal*, Nov. 25, 1893. Translated from the article by J. H. L. Vogt, on "Sulphidische Ausscheidungen von Nickelsulphiderzen, namentlich nickelhaltigen Magnetkies, in Basischen Eruptivgesteinen," in *Zeitschrift für Praktische Geologie*, April, 1893, p. 143.

the manufacturers to fill all demands for German silver, while the nickel-plating business, like many another, has been almost at a standstill.

In previous years almost all the nickel came from abroad, although there was one producer at home, in the interior, who now produces chiefly from Canadian ores, selling under the old-time brand. The new factor in the market has been the Canadian Copper Company, whose product being placed upon the market, to compete with any and all others, caused the foreign makers to reduce their prices, which, at the opening of the year, were about 60@62c., while at the close they are but 52@53c., American refined nickel being quoted at 45@47c.

Most of the nickel produced in this country from Canadian ores has been exported to Europe in the form of oxide of nickel, for which a ready market, notably among the iron and steel industries, has been found.

ONYX.

By George P. Merrill.

The stone to which the name "onyx"—or, more properly, "onyx marble"—is applied differs from marbles of the common type in being purely a chemical deposit, rather than resulting from the metamorphism of calcareous sediments thrown down on ancient sea bottoms. It is, in fact, either a stalagmitic deposit from the floor of caves, or a travertine. All the finer grades of onyx in this country, so far as now known, are travertines—that is to say, spring deposits. They have resulted from the leaching out, by carbonated waters, of the lime constituents of preëxisting rocks, and the subsequent deposition of this lime as carbonate upon the surface of the ground, when the water evaporated or lost its excess of carbonic acid.

Formed in this way, it is not difficult to understand that the beds are far less extensive and regular in their arrangement than are the ordinary stratified limestones and marbles. Spring action is more or less intermittent, and the place of discharge, as well as the character of the deposit, is variable. The latter usually takes the form of a comparatively thin crust, conforming to the contours of the surface on which it lies, though sometimes it is in vein-like and irregular nodular masses. The various layers thicken and thin out irregularly, and are often lenticular in cross-section. Layers of uniformly sound material of more than 20 in. thickness are not common. Where two or more layers occur, they are, as a rule, separated by intervening layers of tufaceous matter, or by foreign débris. Both color and textural qualities of the stone are liable to abrupt changes, and not infrequently the character of the output is so uncertain that it is impossible to make contracts for blocks of any specified size or color in advance of actual quarrying.

A marked and very beautiful feature of the stone is the fine, wavy banding shown upon a cross-section, which is, of course, due to its mode of origin through successive depositions upon the surface. The stone owes its value for decorative purposes to its translucency, fine veination, and color. In many instances the original hues have been enhanced by oxidation, and through the development of reticulating veins of small size, due to incipient fracture, into which percolating waters have introduced new coloring solutions or locally oxidized the iron carbonate which seems to form the chief coloring constituent. Mineralogically, it should be stated, the onyx marbles consist almost exclusively of calcite, and not aragonite, as has been commonly supposed. Their average hardness is about 3.5 of Dana's scale, which is a trifle greater than that of ordinary calcite, though not harder than many compact marbles. The average sp. gr. is 2.75, which is equivalent to a weight of 173 lbs. per cu. ft.

Prior to 1876 the chief commercial supply of this material—at least so far as America was concerned—was the Province of Oran, in Algeria, the stone being wrought in Paris and sent to this country in the form of clocks, turned columns, and the tops of small stands. A considerable amount is still imported from this source, both in the rough and in the manufactured form. The exhibit made by the Mexican Government at the Exposition of 1876 at Philadelphia first called public attention to the wonderful resources of its country, and since that date, down to within a few years, a large proportion of our entire supply has come from a few comparatively insignificant deposits southeast of the City of Mexico, in the State of Puebla. Later yet, deposits of similar material were discovered in the Santa Lucia Mountains, near the town of Musick, in San Luis Obispo County, California. This was followed by like discoveries in Yavapai County, Arizona, and lastly, by that of material of exceptionally high grade on the peninsula of Lower California, some 150 miles southeast of San Diego. Various smaller or less accessible deposits have likewise been found, but have as yet proved of little or no commercial value. Spasmodic and often sadly misguided attempts have frequently been made to work the numerous cave deposits of the southern Appalachian regions, but so far without success.

Mexico.—According to a writer in the *Engineering and Mining Journal*,* the onyx in the Mexican quarries occurs mostly in the form of boulders, or detached masses, ranging in size from a few inches up to 10 or 12 cu. ft. Larger sizes are occasionally found, but so rarely that the event is a notable one, while the value per cubic foot is correspondingly increased. Thus the value of a piece containing only one or two cubic feet would be estimated, ordinarily, as $3 a cu. ft. in Mexican money; but were the piece to contain 25 to 30 cu. ft., it would be worth $15 per cu. ft. This is for ordinary stock; with green and the other finer grades the price is still more variable. The smallness of available sizes is one of the principal drawbacks to the stone.

According to the authority above quoted, the material in which the onyx marble of Mexico is found is a tough reddish or dark-brown clay, overlying a closely cemented conglomerate. This is the usual form, but in one instance—that of the Antigua Salines, on the Rancho del Carmen—it is found in a hard, flint-like country rock which appears more like a "bastard jasper" than anything else. In this particular instance the onyx occurs as small veins varying from 1 in. to 12 in. in width.

All the Mexican quarries are small. The most famous—La Pedrara, in the district of Tecali, 21 miles from the city of Puebla—does not cover more than three acres, while the average depth is not above seven feet. The value of the onyx taken from this small area is, however, hard to realize. The high reputation of the stone is recognized the world over, but it is

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* Dec. 26, 1891.

very doubtful if one-tenth of what has been sold as "La Pedrara" during the last quarter of a century ever came from there. At present no attempt is made to work the quarry, and in fact no indication of onyx in place is to be seen; the only effort made to obtain onyx from it being by sorting over the old dumps or refuse places which have accumulated during its active exploitation. From these is taken every piece of onyx that will square six inches or over. The process is slow, and the yield is seemingly very small in return for the labor. The onyx obtained is of a fine quality of green, ranging from a very light to a very dark tint, and, as a rule, showing a slight dash of red or pink. Occasional pieces of variegated colors are found which are very fine, while the texture is good.

Next in importance to La Pedrara is Antigua Salines, in the district of Tehaucan, which has already been briefly mentioned on account of its peculiar geological formation. The quarry covers an area not exceeding two acres, and forms the face of a hill about 250 ft. high. In working it, the system has been simply a process of gouging out the onyx and the rock which incases it, until into the side of the hill there has been excavated a hole 100 ft. in width by 50 ft. in height and 60 ft. deep, looking much as if an immense shovelful had been taken out. The onyx is variegated in color, and is ranked next to that of La Pedrara. On account of the cost of taking out the marble very little has yet been quarried, although the property has been considered one of the finest in Mexico.

Ranking third probably in importance is La Sopresa, which covers an area of about five acres, and is situated thirty-five miles west of Antigua Salines, in the same district. The onyx from this quarry is semi-translucent, white, and totally devoid of colors, save where an occasional mass of green is found. The quarry has been worked for the last fifteen years only, and is at present the largest producer of onyx in Mexico. Sizes ranging as large as from two to three feet square can be obtained, which is something extraordinary in Mexican onyx deposits, and the supply "in sight" seems to be sufficient for several years. The total absence of any color to set off the pure white is to be regretted, but as it is, the demand for the stone is sufficient to tax the quarry to its utmost to supply it.

Directly east from Sopresa about four miles is the quarry of La Mesa, lying, as its name indicates, on a level table-topped mountain. The quarry shows quite extensive working, the product being a variegated onyx, which, however, lacks the brilliancy shown in the stone of Antigua Salines. It covers an area of nearly thirty acres, and is the largest quarry in Mexico. Occasionally quite large pieces are obtained, but the average sizes prepared for shipment will not exceed 15 by 10 by 6 in., while pieces as small as 10 by 6 by 10 in. are also shipped, both to Europe and America. This, however, is the case with all the quarries, and it is the exception when pieces larger than the first named are exported.

In addition to the quarries here mentioned there are many others of less importance, either by reason of their small output or from having been worked out. Among these the most interesting, on account of historical associations or past records, are those known as El Mogote, Lajas, Agua Esconda, Desamparo, Mehauntepec, Tepeyac, Tecoluco, La Paoma, and La Reforma.

Arizona.—Two workable deposits are known within the Territory, both in Yavapai County—one at Meyers Station, 25 or 30 miles southeast of Prescott, and the other in the extreme southern part of the county, near the Maricopa

County line. The first named occurs in a country of crystalline schists and older eruptives, and is well exposed at the stage station on the banks of Big Bug Creek. The stone occurs as a surface deposit and interbedded with a coarse breccia formed of schistose and dioritic fragments imbedded in a sandy and calcareous matrix, the entire formation occupying a series of low hills or rounded knolls, of which an area of 200 acres is estimated to comprise all the quarriable material. At the shallow openings that had been made at the time of the writer's visit (1891) the onyx occurred in irregular, somewhat concentric layers, from the fraction of an inch to two feet or more in thickness. These were in a few instances quite uniformly green in color throughout, but as a rule were traversed parallel with the plane of deposition by wavy bands of color, in all shades of amber, white, ocher yellow, brown and deep ocherous red. The sound layers of stone were, as a rule, separated from one another by porous, cellular layers, so that slabs of large size were obtainable only by cutting parallel with the plane of deposition. No two of the openings show material of exactly the same nature as to color and markings, or as to size and thickness of the blocks. In all, the stone lies in readily separable layers, which thicken and thin out irregularly, so that the same layer cannot be relied upon for any distance. The more highly colored varieties carry, as shown by analysis, some five per cent. of carbonate of iron. Through the oxidizing effect of permeating solutions this carbonate has in many instances been converted into a more or less hydrated sesquioxide whereby the green is changed to red, brown, or ocher-yellow colors in all shades. This oxidation has naturally followed along the lines of jointing and penetrated the more porous layers, so that blocks of homogeneous green are now surrounded by a crust of varying thickness of this oxidation product. All stages of this process are to be seen at the various openings, from those in which the green stone is covered with a mere crust, and scarcely sufficiently veined to give a desirable variety, to those in which hardly a trace of the original green remains, but the entire block is of a red brown color. At times the oxidation has been accompanied by the removal of so large a proportion of the lime carbonate that the close texture is destroyed, and the stone becomes cellular and spongy, and is no longer susceptible of a good polish. In other cases the stone still retains its compact structure, though necessarily losing its translucency, becoming quite opaque. Such blocks, when properly cut, are capable of yielding slabs at once unique and beautiful, and which, in consideration of the peculiar surface configuration, I have ventured to call "tapestry onyx."

So far as can be determined from surface exposures, there are here three beds of the onyx alternating with the beds of breccia above noted.

During 1893 but little stone seems to have been shipped from this source, though it is stated that a great deal of development work was done. The actual output is placed at 550 cu. ft., valued at $7500. The stone is of high grade, and it is stated that from one block shipped to Chicago a slab 9 by 3½ by 2½ ft. was sawn.

The Cave Creek quarries have lain idle throughout the year. The stone thus far shipped was obtained mainly from loose masses dug from the tufaceous soil. The quarry lies near the Maricopa County line and is accessible from Phœnix—the nearest shipping point—over fifty miles of roadway so rough and hilly as to make the cost of transportation no inconsiderable item. The main ledge of stone lies on the western slope of a low basalt-capped hill, the country rock being mainly slaty schists with dikes of acid eruptives and diorite. The ledge, as exposed in August, 1892, was some 200 yds. in length and 10 ft. in greatest thickness, but showed evidence of having been shattered by earth movements. The prevailing colors here are the same as at Big Bug (Meyers Station).

California.—Several deposits have been described from time to time in the reports of the State Mining Bureau, though but one has been systematically worked. This is the San Luis Obispo deposit, near the town of Musick, in the Santa Lucia Mountains. The inclosing rock is here a sandstone, the ledges standing nearly on edge and showing a total thickness of onyx of some 16 ft. The prevailing colors are white with veins and clouds of red. Unique slabs are occasionally obtained in which a smoky black coloring material injected along the lines of bedding gives most wonderful landscape and cloud-like effects. Visitors to the California pavilion of the Mines Building during the World's Fair of 1893 will recall the slabs of this nature exhibited by Kesseler Brothers of San Francisco. It is stated that blocks of the ordinary type 10 ft. square can be had if desired. The material is hauled by wagon to Musick and thence by rail to San Francisco, where it is worked up. Systematic quarrying was begun in 1890. Resinous travertines of good quality, but limited in quantity, have been obtained at Suisun, in Solano County, and at Sulphur Creek, in Colusa County. A light-brown variety is also said to occur in the quarries of the Colton Marble Company in San Bernardino County, and a fine emerald-green variety below Sisson, in Siskiyou County.

Other Localities.—Other occurrences within the limits of the United States which should be mentioned, but which have not as yet become regular sources of supply, are noted below. Near Lehi, Utah, is found a singular orange and chrome-yellow variety, beautifully translucent, and which is reported as occurring in the form of a vein some four feet in width, in limestone. Near Rio Puerco Station, Valencia County, N. M., a deposit of dull variegated stone, with pronounced fibrous and concretionary structure and silky luster, is being operated by the Aztec Onyx Company. Somewhat similar occurrences have been reported near El Paso, Texas, but so far as the writer has information, these have turned out little, if any, material. The onyx recently reported from Garfield County, in the State of Washington, proves on examination to be an impure, yellowish-green variety of opal.

Lower California.—One other deposit remains to be mentioned, which has come into prominence only during the past year. This lies on the Peninsula of Lower California, some 150 miles south of San Diego, and well over toward the gulf coast. The main body of the onyx lies in the open desert, a region of mesas and low rolling hills and shallow valleys. The country rock is a soft and friable sandstone, of presumably late Tertiary age. The onyx is found upon the immediate surface. To what depth it extends has not yet been determined, but the work done is sufficient to indicate three or more distinct beds, from 20 to 50 in. in thickness. The remarkable features shown are the almost entire freedom from small holes and other defects so common in stones of this class. Sound blocks containing upwards of 100 sq. ft. in superficial dimensions and from 10 to 30 in. thick occur, lying upon the immediate surface. The stone presents the usual varieties in color, but is unique in beautiful rose tints, quite unlike the stone of Mexico proper. Indeed, the colors as a rule are of more delicate shadings than the prevailing types from other localities, while the "muddiness," or dull opacity, so common is scarcely ever met with. It is a satisfaction to know that for almost the first time in the history of the onyx industry it is possible to obtain the material in quantity and in sizes sufficient to meet all probable demands. The deposits are being worked by the New Pedrara Onyx Company, with headquarters in New York.

As above noted, various ineffectual attempts have been made toward working the cave deposits of the southern Appalachians, and also those of the Ozark Mountain region. These attempts have almost uniformly resulted in failure, in part owing to the gross ignorance of those in control regarding the nature of the material they handled, and in part because the properties have been stocked for an amount beyond all possibility of reasonable profit. The main difficulty encountered lies in the fact that the true nature of the deposits is not recognized. The stone differs greatly in color from those described under the name of travertine, and is far from being as desirable. Statements such as appear in the reports of the Missouri Survey, to the effect that the onyx of that State "is of the variety known as Mexican, and is aragonite," are quite misleading. From the very nature of the deposition it follows that it cannot be relied upon, and the sooner investors become convinced of this the better. Properly worked, the deposits undoubtedly can be made of value, and capable of producing a small amount of desirable material at a fair profit. Too much has been expected from them, and disaster has resulted as a necessary consequence. They never can compete with the onyx marbles formed by spring action, like those of Mexico, Arizona, and California.

Among the numerous companies that have from time to time been formed to work these cave deposits may be mentioned the Ozark Onyx Company of St. Louis; the Virginia Onyx Company of New York; the Eureka Onyx Company of Eureka Springs, Ark.; and the Merrimac Onyx Company of Boston. None of these have as yet produced any appreciable amount of stone, and it is safe to say that some of them never will, if indeed they have not already gone out of existence.

The production of onyx in the United States in 1893 amounted to 2175 cu. ft., valued at $28,750, which was a considerable falling off from the previous year, when the output was 3500 cu. ft., worth $40,000 at the quarries. The decrease was due chiefly to the Big Bug quarries of Arizona, which produced only 550 cu. ft. of stone in 1893, against 2550 cu. ft. in the previous year, and the Cave Creek (Arizona) quarries, which produced about 450 cu. ft. in 1892 and were idle in 1893, although part of the stone quarried in the former year was shipped. There was one new producer in Utah, and the Virginia Onyx Company of Virginia marketed a small amount of stone, for the first time.

OZOKERITE.

By J. Wallace.

Very much has been written on the origin of ozokerite, and the exact niche in which it should be placed is a difficult matter for the various scientific authorities to agree upon. However, it certainly belongs to the series of hydrocarbon compounds which includes marsh gas, petroleum, etc. It is found in many localities, varying in purity, the principal source of supply at present being Boryslaw, in the Province of Galicia, Austria. In color it ranges from light yellow to brown and black, with a melting point from 136° to 208° F. This mineral wax, or natural paraffine, possesses properties peculiarly its own and distinct from the paraffine of commerce recovered from petroleum by destructive distillation.

The deposit of ozokerite at Boryslaw covers an area of about 150 acres. It has been worked steadily since 1859, and has yielded enormous quantities of the mineral, the total value of which is estimated as upward of $50,000,000. The system of mining has been extremely crude, as the holdings are largely among small owners, each working his own little mine. There are also smaller deposits of ozokerite at or near the towns of Wolanke, Dizwiniacz, Starunia, and Tuskawisc, also in Galicia, but none of these is of much importance.

The only known occurrence of true ozokerite in America is in Wasatch County, Utah, about 100 miles east of Salt Lake, which is owned by the Ozokerite Mining Company of New York. The working of these deposits has been mostly for exploration and development, and although a large quantity of ozokerite has been produced, the utmost capabilities of the mines have not yet been determined. There has been much to contend with in opening this property; and while it has been proved that the mineral exists in an important quantity in the Utah field, it has now a too strong competition in the foreign product, which comes in free of duty, to exploit it extensively. The rate of wages in Galicia is about 40c. per day, while in Utah it is $2.50. Transportation from Galicia to the seaboard is only about $19 per ton; from Utah it is $27. It has been frequently reported of late that the Boryslaw field is becoming exhausted, but some new finds have evidently been made; for while the production has fallen off, there is yet enough to supply the market at a slightly increased price. The Utah field, however, contains the store to which all will sooner or later have to come for this valuable mineral.

In prospecting for ozokerite Prof. R. J. Kroupa, who has examined the deposits at Boryslaw and has been in charge of the developments in Utah, writes as follows: "The first thing necessary is to find the correct geological formation—viz., clay, salt, and sandstone. The presence of oil in connection with these rocks is sufficient to make the existence of ozokerite probable. Deposits of ozokerite are to be looked for in a country of which the geological structure is made up of broken rock-strata and saddle formations. The origin of the wax is due to the infiltration of heavy oils into these saddles and crevices; and through the action of pressure, heat, and general decomposition, a gradual solidification has occurred, as is evident from the fact that all the clay that is mixed in and surrounding the ozokerite is thoroughly saturated with oil, giving evidence of its having absorbed a large part of the liquid, volatile, and gaseous matter."

Refined ozokerite, or ceresin, is used in the manufacture of waxed paper, the lining of wooden vessels, and the manufacture of varnish and blacking; for adulterating beeswax, calking ships, making liniments, plasters, salves, shoemakers' wax, wax ornaments, dolls, and toy figures; in the manufacture of heavy lubricants, where body is requisite; and for any of the thousand or more uses to which beeswax is applicable. Inasmuch as nature has succeeded in eliminating all the lighter products of the lower paraffines, without destroying its structure it is endowed with plasticity without softness, and with hardness and capability of receiving high polish without brittleness—which make it very desirable in its natural state for insulating and electrical purposes.

PEAT.

Occurrence.—Peat is a natural product arising from the decomposition of certain forms of vegetation under special conditions of moisture and heat. Occurring in nearly every country outside of the tropics, it has furnished a cheap and convenient source of fuel from the earliest days, and is now an important factor as a sanitary agent when properly prepared, and is used as a fertilizer in agriculture, and for many other purposes in which its value is just becoming known.

The plants of which it is formed are different in various localities and altitudes. In Great Britain, and generally throughout Europe, the moss *Sphagnum palustre* is the principal constituent, in America a number of aquatic plants, particularly the *Polygonums* and some varieties of water-lilies, and in Asia the wild rice, *Oryza Sylvestris*, are its principal sources. Peat occurs either in swamps continually under water, in lowlands subject to frequent overflow, or in high land where mist and rain serve to keep the bog in a condition favorable to the production of the material. The process of formation is merely the natural growth and decay of the plants, those of one season dying while over them grows fresh vegetation which in its turn adds to the accumulating bed of peat beneath. Consequently in all bogs of any depth, which are still in the process of formation, every stage of transition from the green plants to the relatively hard, compact, and black peat beneath may be observed. In older bogs which have been covered with accumulations of clays and now lie buried at greater or less depths, these stages are not so distinguishable, but there is, as a rule, a marked difference even in the oldest bogs between the upper and lower strata. In practical work three distinct layers are recognized in a peat bed—the top, consisting of the green sod; the middle layer, composed of the semi-solid brown, matted, and but partly decomposed roots and stems of the plant still retaining their identity; and the lower layer, which will include possibly two-thirds the depth of the bed, dark in color, sometimes of a pitchy luster, compact, and showing little trace of the organism of the plant.

The rate of growth of these peat bogs varies considerably, depending upon the plant and climatic influences. It is estimated that the average growth in low land will be from 2 to 4 in. per year, though an instance is mentioned by Percy* when a bed 15 ft. thick was formed in thirty years, an average growth of 6 in. per annum.

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* *Fuel*, p. 201.

In the United Kingdom peat is found in many localities, Ireland alone being estimated as containing 1,576,000 acres of flat bog, and 1,254,000 acres mountain bog, a total of 2,830,000 acres, or nearly one-seventh of the entire island. Russia is estimated as having about 67,000 square miles of peat bogs. In Norway and Sweden there are several million acres of peat bogs, the largest being in Dalecarlia, Vermland, Halland, Smaland, and North Scania. Bogs covering many square miles and from 3 ft. to nearly 40 ft. deep occur in Upper Noorland and Lapland. In Holland the peat deposits are extensive, some of them being in very low ground. In France peat is widely distributed, occurring near Brest, Cherbourg, Lyons, Calais, and many other places. Very extensive bogs are found throughout Germany, especially in northern Prussia and the Grand Duchy of Oldenburg.

In America peat beds occur in various parts of the United States and Canada. In the former, while the peat bogs are not so large as those in parts of Europe, they are found in nearly all of the Northern States and at some places in the South. In New York and Pennsylvania there are numerous peat deposits, some of those in the latter State being of considerable depth, notably one crossed by the Lehigh Valley Railroad, which caused considerable trouble and expense because of the roadbed sinking in it. In Michigan, Wisconsin, and Minnesota similar deposits are of frequent occurrence. In the South, along the Mississippi Valley, the Gulf, and Atlantic coast, beds of peat occur, one of the largest lying in the Dismal Swamp in Virgina and North Carolina.

In Canada the peat bogs cover an extensive area, in nearly all of the provinces. Attention was called to these by the Geological Survey in 1845–46, and afterward in 1863 and 1878. In 1875 a considerable amount of work was done in preparing peat for fuel by the Hodges process, near St. John, and also at St. Hubert, Quebec. Some 13,000 tons were produced in the year named, most of it being used on the Grand Trunk Railway. About the same time a small quantity of prepared peat was produced near Port Lewis and at Newtonville, Ontario. Mr. E. B. Borron estimates that 10,000 square miles of peat bog from 6 to 20 ft. thick exist in the Hudson Bay slope, and smaller areas of from 1000 to 5000 acres are widely scattered through the provinces of Ontario and Quebec.

Composition.—The appearance and composition of peat vary from the light, spongy material on top to the black, heavy, and compact substance found at the bottom of the beds. The following analyses by Kane, made in 1851, serve to show the comparison between surface and bottom peat:

	Specific Gravity.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Surface peat, Phillipstown	0.405	57.53	6.83	32.23	1.42	1.99
Bottom peat, Phillipstown	0.669	58.48	5.90	31.47	0.85	3.30
Surface peat, Wood of Allen	0.335	58.27	6.43	31.33	1.23	2.74
Bottom peat, Wood of Allen	0.655	56.20	5.31	29.84	0.75	7.90

These may be taken as good typical analyses, though the percentage of ash varies greatly not only in different localities but in various parts of the same bog. In some cases it exceeds 30%, though this is rare; but the precentage of ash is found invariably to increase with the depth from which the sample is taken.

As peat is formed from the matted roots and stems of plants, its structure is necessarily porous and retains a large proportion of water, this varying with its density. Fibrous, spongy peat, fresh from the upper part of a bog, may contain as much as 90% of water, while the heavy and compact variety retains about 30%, about one-third of which may be removed by air-drying.

Preparation.—The removal of peat from bogs is a very simple process. In most places the surface moss is taken off and the underlying peat cut into blocks or thick sods with a spade and these removed and stacked up to dry, or taken to machines for further manipulation. In Ireland a special tool called a "slane" is generally used in cutting the sod. This is shaped like a spade, but with a blade turned out at right angles to the main cutting face, so that in pressing it down two sides of the sod are cut. In Holland, where the peat is too spongy to be removed in this manner, it is scooped up by peculiar shaped shovels and placed on a suitable platform to allow the water to drain off. When the mass has reached a certain consistency it is tramped by men having flat boards on their feet, and finally, when compacted so that a footstep leaves no impression, is beaten, cut into blocks, and stacked up to dry. In a number of countries machines are used to cut the peat, but while they perform the work satisfactorily, it is said that but little saving in labor has been observed.

It is evident that the fuel value of peat depends upon its density, dryness, coherence, and proportion of ash contained. As it comes from the bog it contains too much moisture to burn, and therefore must be dried, either by exposure to the air or by some artificial means. When air-dried the fuel will still contain about 30% of water, and while it burns more or less freely in a fireplace or furnace, it is too tender to stand the rough handling of transportation or the forced draft in furnaces requiring high temperatures. Moreover, it is so bulky in proportion to its fuel value as to be exceedingly costly to carry, or to handle in metallurgical or manufacturing operations in a country where coal is reasonably cheap.

To overcome these difficulties various processes have been tried to condense the raw peat or air-dried peat by compression, with or without heat, or by pulping, molding, and drying, with or without heat and compression. The elasticity of the fibers offers a great difficulty in handling peat by these methods, for when pressure is released the block expands, and, if exposed to much moisture, re-absorbs nearly as much as it had lost. Neither rolls nor presses have proved satisfactory. The process introduced by Mr. C. M. Williams at Cappoge, Ireland, consisted in breaking down the fresh peat between rolls and then placing in cloths and submitting to powerful pressure. The resultant material occupied about one-third the bulk and three-fifths the weight of the raw peat. It was estimated that this fuel could be delivered for 5s. ($1.20) per ton; but as the price of ordinary air-dried peat was but 3s. 6d. (84c.), the process was not a commercial success. The best work has been done by the pulping process, in which some of the sand, clay, and other impurities may be removed and the fiber completely destroyed, permitting greater coherence after drying or compression.

In Germany, at the Haspelmoor bogs, between Munich and Augsburg, the Exter process was followed for a long time. This consisted in first air-drying the peat, then breaking it up and passing through sieves, and finally heating it and compressing under powerful presses. The cost of production was placed at about $2.16 per ton, and an analysis of the fuel showed: Water 16.74%, coke 36.30%, ash 6.90%. However, nearly all of the peat fuel now used is removed by hand and air-dried. In the Grand Duchy of Oldenburg it is estimated that 150,000 tons per annum are prepared in this manner and used for households, brick kilns, and ovens. At Carolinenhorst the dried sods sell at auction for from $3.36 to $1.92 for a lot of 1200, the price depending upon quality. On the moor at this place nearly 500 men and women are employed, the former receiving about $1 per day and the latter 7c. per cubic meter of sods stacked. In Holland about 280,000 tons of peat, valued at $638,000, are used annually. Most of this is prepared in blocks in the manner already described, but a considerable quantity is worked up by machines, three systems being used—the Koch & Manhardt, disintegrating and pressing; the Challeton, disintegrating, pulping, and air-drying; and the Versmann, disintegrating and forcing into shapes. In France the use of peat as fuel has been declining for some years past and but little is now manufactured for that purpose. A considerable quantity is used in Denmark, but is cut and air-dried by the people for their own use. In Russia large bogs are worked in Moscow, Vladimir, Nijni-Novgorod, Ord, Kharkoff, Kieff, Esthonia, and St. Petersburg. With the exception of works at Perst and New Woidonia, where some German machines are employed to compress blocks, all the fuel used is simply hand-dried, and in this condition serves for manufactories, sugar works, and other industries, and at one time was used on locomotives. In Norway and Sweden there are a few factories in the south manufacturing peat fuel, but as a rule such as is used in the country is merely air-dried. At some metallurgical establishments where peat is used in connection with other fuels, it is dried in an oven heated by the waste gases from the furnace.

A process patented in Canada in 1864 by Mr. Hodges consists in placing upon a floating scow the machinery necessary to cut the peat and convert it into pulp, which is flowed over a space of drained bog alongside the canal excavated by the machine. The pulp solidifies and is then cut into blocks and stacked to dry.

Mr. A. A. Dickson of Canada has perfected a process in which the peat is pulped and then submitted to powerful compression. The blocks made in this manner retain about 10% of water and are calculated to cost about $1.50 per ton. In a test of this fuel, made at the John Abell engine works in Toronto, Mr. Dickson states that 457½ lbs. of compressed peat kept steam steadily at 85 lbs. for exactly two hours, and an equal weight of anthracite kept up the same pressure for six and one-half minutes longer. Another process being tried in Canada is that of Mr. Hally, who disintegrates, pulps, and air-dries the fuel.

Heating Effect.—Extended experiments have been made as to the heating effect of raw and prepared peat as compared with coal. Berthier gives the following as the pounds of water heated by one pound of peat from 0° to 100° C.:

Source of Peat.	Lbs. Water.
Troyes	18.1
Department de la Somme	27.9
" " "	29.2
" " "	34.9
" " "	34.6
Ireland, Bog of Allen, upper peat	62.7
" " " lower peat	56.6
" " " pressed peat	28.0

Winkler gives 26.9 as the evaporative power of the poorest and 42.6 the best peat from the Erzgebirge in Saxony. Crooks and Röhrig state that the absolute heating power of the best air-dried turf is a little inferior to that of kiln-dried wood, but kiln-dried turf is superior to kiln-dried wood. The specific heating power of the best turf is equal to air-dried wood and sometimes surpasses it. In practice it has been observed on Dublin steamers that 51 lbs. good turf evaporated 1 cu. ft. water, and 7.61 lbs. replaced 1 lb. of coke, but the general results obtained by various authorities show that the average caloric power of dry turf is about half that of coal. This power, however, decreases rapidly as the peat becomes moist. These values practically would preclude the direct use of peat for manufacturing purposes except in localities where the price of coal is so high as to counterbalance the lower caloric effect; but since it is well adapted for use in making producer gas, a use in which Siemens said he would prefer it to coal, its value as a metallurgical and manufacturing fuel is by no means insignificant. The relatively large proportion of water contained in it does not in this case prove a serious drawback, since the greater part can be condensed and removed from the gas before it reaches the combustion chamber. The uses of producer gas are steadily increasing, and the application of peat to make this fuel would secure its full calorific value.

In England and at some places on the Continent peat gas has been applied to house and town lighting and is said to be excellently suited for the purpose, the gas having a higher candle power than that ordinarily obtained from coal. The greatest use for peat as a fuel seems to be the form of producer gas and in the household, where its inferiority to coal is not so marked and the primary low price is a consideration.

By-Products.—Interesting experiments have been made on the products secured where peat is subjected to destructive distillation. Kane and Sullivan give the following as the commercial products in percentages, from an average of seven analyses, the samples all being typical Irish peats: Ammonia 0.268, corresponding to 1.037 sulphate of ammonia; acetic acid 0.191, corresponding to 0.280 acetate of lime; pyroxylic spirit, or naphtha, 0.146; paraffine 0.134; volatile oils, 0.790; and fixed oils 0.550. An average from the same samples gave the following: Water, 31.37%; tar, 2.78%; charcoal, 29.22%; and gas, 36.61%. The average amount of ash was 3.43%.

Charcoal.—Peat charcoal has long been used for various industrial purposes. In 1560 it was used in Saxony for metallurgical work, and probably long before that served as fuel in the crude processes used to reduce ores. In 1620 Sir William St. John, Sir Giles Mompesson, and others in England were granted a patent for the exclusive right "to charke or otherwise convert into charkcole" every kind of coal, peat, or other material, wood only being excepted. In 1726 Mr. William King, in a paper presented to the Royal Society of Dublin, says he has seen turf "coaled," and that it serves for bloomery or iron-work, making a very pure fire, and to burn in a chamber is unusually "sweet and wholesome." In Sweden, France, and indeed in nearly all European countries, the charcoal has been used for forge and other purposes. In some places it has been employed in small blast furnaces as a mixture with other fuels, and in Sweden is quite largely used in metallurgical work. To coke the peat various forms of kilns have been employed, from the simple heap to the more complex forms with regenerative chambers arranged to distribute the heat more evenly throughout the mass. As a rule the old-fashioned meiler is most largely used, and where ovens are employed they are generally of some simple form. At Oberndorf, in Würtemberg, an oven which has given satisfactory service is of a circular form, 5½ ft. in circumference and 9 ft. high. In the wall near the bottom of the kiln a number of pipes are inserted to furnish air, and in front a large door is provided for withdrawing the charcoal. The peat is shaped in more or less regular lumps or bricks, air-dried, and charged through the top. In Holland it is usually coaled in heaps, or a special oven shaped like the ordinary meiler.

The principal objection to peat charcoal is that it is exceedingly friable, even when made from compressed bricks. A process invented by Mr. R. Nelson Boyd of London is said to have shown very fair results in this respect, the charcoal made from compressed blocks being quite compact. The peat blocks made by this process are said to cost about 5s. ($1.20) per ton, and to contain carbon 33%, volatile gases 54%, moisture 10%, and ash 3%. The sp. gr. is from 0.860 to 0.963. Sir Robert Kane, in his extended report on Irish peats, gives an average yield of 36.35% carbon in air-dried peats containing 17.58% moisture and 3.98% ash. Percy speaks of a 36-ft. blast furnace at Josefstadt which used half peat charcoal and half wood charcoal, and states that the service obtained from the peat was about equal to that from soft wood charcoal.* A disadvantage which peat charcoal has, when made from peat containing a considerable amount of ash, is the relatively high proportion of this material which will be present. The peat blocks used by Mr. Boyd contain 3% ash, but the charcoal would contain 7.6%.

Other Uses.—Within recent years an exceedingly important and extensive industry has sprung up in manufacturing from peat what is known as "moss litter." This has a variety of uses, one of the principal being stable bedding for horses. Owing to its porous nature when in certain stages of decomposition, peat possesses to a great degree the power of absorbing fluids, and in addition to this is a well-known antiseptic. In consequence it is exceedingly valuable for bedding in stables, forming a soft and dry bed which is afterward valuable as a fertilizer. Throughout Europe this material is being manufactured on a large scale and considerable quantities are exported annually to England and the United States.

The best material for the production of moss litter is found on the upper strata of the bogs, as in it the decomposition is incomplete and the substance exceedingly porous and elastic. Upon drying, it contracts but little, and consequently retains these qualities, and with them the important ones of softness and toughness. Hollman's system of making moss litter, as used at Carolinenhurst, is essentially as follows: The peat is cut from the bogs in autumn and early winter, so as to allow it to freeze before drying, and thrown up in stacks which are allowed to remain until dry enough for the factory. About 6½ acres cut 58 in. deep yields 3000 tons of litter. When dry the mass is taken to the works and placed in a machine which tears the fibers apart, from this it passes through a sieve to separate the dust, and then into a large press where it is made into bales. The general experience with moss litter in stables appears to have been quite

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* *Fuel*, p. 514.

satisfactory, a report upon its use by a Prussian regiment of Uhlans showing that it provided dry beds and dry air free from ammonia. The ceiling, walls, and leather trappings remained free from moisture and mold and the material absorbed eight times its weight of fluids, while straw took up but half as much. The litter was in short and broken fibers, so the wet portion could be readily removed, though care was taken to carefully shake up and fork over the bed. This gave the animals a dry and elastic bed and they were more easily kept clean and their skin in healthy condition. Harness and saddles, as well as the soldiers' boots, were better preserved, and from a veterinary point of view catarrh was less frequent and wounds healed quicker, while in contagious diseases it was regarded as an excellent disinfectant. In Denmark equally satisfactory results were obtained by the Copenhagen Milk Supply Company, which kept fifty horses at an average cost of $9.60 per year each for bedding, while the material which had been used was a valuable fertilizer.

In some reports recently made by its foreign consuls to the British Government, much valuable information appears concerning the peat industry in various European countries. From these it is learned that in Norway and Sweden the manufacture of moss litter has become an extensive industry, some twenty large and a number of small factories being engaged in it. The bales are about 100 by 75 by 50 centimeters in size, weighing from 100 to 120 kilograms and worth from 40 to 50c. per bale, depending upon quality. Both here and in France and Germany factories are engaged in making mattresses, a variety of felt, blankets, carpets, rugs, materials for surgical purposes, disinfectants, paper, and a number of other articles. In France the works of M. Beraud, known as La Beraudine, supplies the Government with mattresses, blankets, saddle cloths, and other materials made from peat. In Germany these materials and moss litter are made in East Prussia, Pomerania, Posen, Silesia, Hanover, Oldenburg, Würtemburg, Saxony, and Bavaria. One of the largest establishments is that of Herr Rottbarth, at Gifhorn, in Hanover, who manufactures peat fuel, charcoal, and a variety of textile and chemical products. At these works the dust separated from the moss litter is ground to a fine powder and sells for about 30c. per cwt., serving as a disinfectant, to make antiseptic bandages, in absorbing lye resulting from treatment of molasses with strontium in sugar factories, as an admixture in chemical manures, and for packing perishable goods. An important and rapidly extending use for moss litter is in absorbing sewage. In Holland and some other countries this is being done, a mixture of equal parts of the two producing a dark, dry, and earthy substance free from odor and valuable as a manure.

As yet the employment of peat in various branches of industry is only in its infancy. It is likely that machinery will be made by which it can be made into an economical fuel, and there is always the wide field of use in producers. In the manufacture of moss litter and the numerous other products already named there is an almost unlimited field, and each year new uses are found. Mixed with rubber and sulphur it has been found to make a useful insulating material for submarine cables; porous bricks have been made by mixing peat dust with the clay; pure peat charcoal has been employed in the manufacture of gunpowder, and the fibers have been used to make strong paper.

Undoubtedly one of the most important uses to which peat may be applied is in the disposal of municipal sewage. Either as manure in its semi-solid state or as poudrette, as it is termed in Sweden, it has been found a valuable fertilizing agent. An ingenious machine for producing the latter substance is in operation near Gothenburg. This takes the mixed peat and sewage and burns it in a large rotating vessel. The gases and flame pass through a second furnace where the former are completely consumed, so that there is no odor from the products of combustion. The poudrette remaining in the rotating furnace is collected, packed in bags, and sold as a fertilizer. Experiments carried on near Stockholm from 1887 to 1890, comparing the value of turf poudrette with other manures, showed that unmanured land which produced 1900 kilos barley ear and 2340 kilos of straw per hectare, when manured with poudrette gave 3170 kilos ear and 3410 kilos straw. With ordinary farmyard manure the same land yielded 1970 kilos ear and 2690 kilos straw, with Peruvian guano 3470 kilos ear and 3790 kilos straw, and with fish guano 2540 kilos ear and 4350 kilos straw. The same proportionate effect was shown when using this fertilizer on clover, potatoes, and mixed crops.

During the past year experiments have been tried by H. Ekelund of Jonkoping, Sweden, on a new process for coking peat. In the plant constructed at Omberg, near Motala, the furnace is built of firebrick and divided into four chambers 32 ft. high and 20 ft. square. The peat is conveyed into the upper chamber, where it is dried. It then passes successively through the other two, in which it is coked, and finally into the fourth, where it is cooled. The gases produced during the process are utilized to heat the chambers, which have a capacity of about 10,000 cu. ft. of peat, or 48 tons coke, in twenty-four hours. The coke produced is used either as it comes from the oven, or is compressed, with the addition of some form of agglutinant.

PETROLEUM.*

History.—Petroleum, in the form of bitumen, seems to have been known from the earliest periods of history. It was used in the walls of Babylon and Nineveh, and Strabo, in the first century before Christ, refers to that brought from the region of the Dead Sea and sold to Egyptians for embalming. This is confirmed by Diodorus Siculus, who describes this asphalt and the commerce in it with Egypt. The holy fires of Baku, on the Caspian, the home of the fire god, were known and worshiped for at least twenty-five centuries, and six hundred years before Christ this spot was the goal of pilgrimages even from India.

Perhaps the first mention of the use of petroleum for illuminating purposes is the "Sicilian oil" described by Pliny, obtained near Agrigentum, which was burned in lamps as early as the beginning of the Christian era. In America the Indians collected what was known as "Seneca oil" from petroleum springs; and the indications are that, long before them, the mound builders, who worked the copper mines of Lake Superior, the lead mines of Kentucky, and the mica mines of North Carolina, not only gathered the oil that flowed from natural springs and appeared on streams, but even dug numerous wells in Pennsylvania, Ohio, and Canada, and dipped up the petroleum that flowed into them.

GEOLOGICAL OCCURRENCE.

Origin of Petroleum.—The question as to the genesis of petroleum is far from being settled. The oil-bearing sands are undoubtedly of sedimentary origin; but how, when, and where was formed the petroleum which they contain? Is it indigenous to the rock in which it is found, or has it been condensed in this rock, having come up in the form of gas or vapor from deeper strata? In either case,

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* In the preparation of this article the valuable report by Mr. H. C. Folger on *The Pennsylvania Petroleum Industry* has furnished much information. Data regarding the Russian naphtha industry was obtained from Prof. D. I. Mendeléeff's article in the *Industries of Russia*, prepared for the World's Columbian Exposition, 1893. Other sources of information were as follows: *Geological Survey of Canada*, Vol. V., 1891 and 1892; THE MINERAL INDUSTRY for 1892; *Mineral Oil Exports*, United States Customs Office, 1893; and Stowell's *Petroleum Reporter*, January, 1894.

is it the result of chemical reaction or of distillation by heat? If the latter, is it the result of destructive or fractional distillation? And finally, is the oil of animal or vegetable origin, or of both?

The theory of the chemical origin of petroleum as advanced by Mendeléeff is based upon the action of water upon metallic carbides at an elevated temperature and under high pressure. As a result metallic oxides and saturated hydrocarbons are formed, which, being transported by aqueous vapor, have reached those strata where they would easily condense and impregnate beds of sandstone, which have the property of absorbing great quantities of mineral oil. Another theory, which also looks upon petroleum as condensed from gas, claims that the gas has been previously distilled—at least in Pennsylvania—from the great black shale formations (the Marcellus and Genesee).

J. P. Lesley, in criticising both of these theories, states that they must face the objections that such a process ought to have distributed the oil everywhere, and permanently blackened and turned into bituminous shales the entire thickness of this part of the earth's crust for several thousand feet. It fails to explain the petroleum obtainable from the cannel coals and from roof shales of bituminous coal beds, and it fails also to give reasons for the entire absence of petroleum from immense areas of not only shales, but also sand and gravel rocks, equally underlaid by the Marcellus and Genesee formations. Professor Peckham claims that there is overwhelming proof that the Pennsylvania oils are of vegetable origin, in the fact that an examination of the petroleum demonstrates that the lighter portion consists of a certain series of hydrocarbons identical with those obtained in the destructive distillation of coal, bituminous shales, and wood, when the operation is conducted at low temperatures. Lesley inclines to the belief that primordial animals, as well as submarine plants, are the basis of petroleum. It can hardly be disputed that it is in some way connected with the vastly abundant accumulations of Palæozoic seaweeds, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations lying several thousand feet beneath the Venango oil sand group. But the exact process of its manufacture, of its transfer, and of its storage in gravel beds is utterly unknown. That it ascended rather than descended into them seems indicated by the fact that the lowest sand holds oil when those above do not, and that upper sands hold oil where they extend beyond or overhang the lower.

A question of great practical importance is the possible limitation to the production of petroleum. It seems at first difficult to comprehend how a stratum of rock, as compact in its formation as many of the oil sands appear to be, can hold such enormous quantities of liquid. In fact, in the early days of the industry it was generally supposed that the oil was collected, if not in streams, at least in pools in subterranean caverns, or crevices, as they were technically termed, and all paying wells were believed to start from such fissures in the rock. That these fissures occur is undoubtedly true, for they often annoy the well-drillers by throwing the tools out of plumb and starting a "crooked hole," but that they are not a necessary adjunct to a paying well has been clearly shown by Carll. He says: "Experiments made on a number of pieces of oil rock proved quite conclusively that it is capable of absorbing and holding from one-fifteenth to one-tenth of its own bulk of water or oil; this, too, when the pores of the rock are more or less clogged with residuum from the oil previously held by it, and without its being charged under pressure.” He then makes a calculation to show how easily it can be proved that even a flowing well need not depend upon a crevice for its supply. With a bed 5 or 10 ft. thick, and a strong pressure behind the oil, it is clear that the sand could readily yield several thousand barrels of oil per day. ‘The diameter of an ordinary well being $5\frac{1}{2}$ in., the circumference of the circle is therefore $17\frac{28}{100}$ in., and the area of its cross-section $23\frac{76}{100}$ sq. in. Suppose the interspaces of the oil rock to amount, in proportion to its whole bulk, to only one-seventeenth, instead of one-fifteenth or one-tenth, as we have ascertained it to be in some cases; then for every inch of depth drilled in an oil sand, by which $17\frac{28}{100}$ sq. in. of its surface is laid bare, not including the area in the bottom, we shall have at least one square inch of oil ducts opening into the well. A depth then of $23\frac{76}{100}$ in. would give $23\frac{76}{100}$ sq. in. as the combined area of the inflowing oil leads, and this equals the full capacity of the $5\frac{1}{2}$-in. hole. In other words, the aggregate sum of the pores or interspaces of a sand rock of this kind, as exposed in the walls of a well of $5\frac{1}{2}$ in. diameter, is equivalent to the area of an open crevice one inch wide, extending from top to bottom of the gravel bed, whatever its thickness may be.” This calculation will serve to account for the enormous yield of certain wells and districts, and explain the possibilities of the porous sandstone acting as a sponge to store the oil.

An idea is obtained of the enormous quantities a given territory can yield when one considers that much of the sand holds probably one-eighth or more of its bulk of oil, and that the latter is under pressure. This means $1\frac{1}{2}$ in. of oil to every vertical foot of sand, equal to 1000 barrels per acre. Carll states that the oil rock of the Venango is from 30 to 50 ft. thick in the third sand, and from 15 to 30 ft. in the other sands. Assuming only 15 ft. of good rock means 15,000 barrels per acre, or nearly 10,000,000 barrels per sq. mile.

Many facts support the theory that the oil-producing sands lie in pockets or patches surrounded by impervious rock, so that each pool forms a separate, and, to a very large extent, an independent reservoir of oil.

Occurrence.—While petroleum has been found in all the geological formations from the Silurian up to the Tertiary, it occurs principally in the rocks of the Silurian and Devonian ages, and to a less extent in the Cretaceous and Tertiary. The great deposits of western Pennsylvania, eastern Ohio, and West Virginia are in the Devonian sandstones, although small amounts have been found in the Carboniferous. In striking contrast to this is the oil horizon of western Ohio, Kentucky, and of Indiana in the Trenton limestone of the Silurian age, which at present is by far the most important single source of petroleum in the United States. All the oil produced in the new fields of Ohio and Indiana is from this single horizon, while the oil produced in Pennsylvania is from several distinct strata of sandstone distributed through several thousand feet of the Devonian and, to a small extent, Carboniferous formations.

The horizon in which the heavy lubricating oils of Kansas and Texas are found has not been determined. According to the latest investigations, the chief oil-bearing formation in the Florence field of Colorado is the Montana group of the Cretaceous. The oils of California, according to Professor Peckham, are found in the Miocene of the Tertiary. It may be of interest to note that the Russian

(Baku) petroleum also occurs in the Tertiary, although not in the Miocene, but in the Oligocene division, and that the Russian crude occupies, in chemical composition, an intermediate position between the Californian oil, in which the "base" is largely asphalt, and the Pennsylvanian oil, in which paraffine is the "base." The petroleum of Canada occurs in two distinct horizons; the one in the limestones of the Trenton group of the Silurian, and the other in those of the Corniferous formation of the Devonian. The Peruvian petroleum, like the Californian, probably occurs in the Tertiary formation.

Methods of Mining Crude Petroleum.

The petroleum industry has undoubtedly reached its highest development in Pennsylvania, and the methods adopted in that State are typical of good practice.

Oil Wells and Tools.—The derrick, which is the most conspicuous feature of an oil well, consists of a tall pyramidal wooden skeleton about 12 ft. square at the base and 75 ft. high, tapering to about 3½ ft. square on top. The framework is held together by girths and braced by diagonals at frequent intervals. At the foot of the derrick is the bull wheel, and at the top the crown pulley, used for raising and lowering the tools during the drilling, and for handling the tubing and sucker rods after the drilling is finished. There is also, near the top, another pulley for lowering and raising the sand pump, and a separate reel at the base of the derrick for winding up the sand-pump rope. Motion or power for drilling is communicated from the engine to the band-wheel, and by the latter to a walking beam for drilling and pumping. The walking beam is supported by the "Samson" post, set in the derrick foundation.

For a complete well there is also needed a boiler and engine properly housed or protected. Often a single engine, located centrally, pumps as many as 30 or 40 wells, by means of stiffened rods made of strips of wood nailed together, suspended by cords from posts at proper intervals, or supported on light frames that swing easily as the rods move forward and back. The power required is reduced to a minimum by a skillful balancing of the upstroke of the pump by means of weights placed at the end of the walking beam, the engine furnishing power to produce the down stroke only. The same result is accomplished at other points by balancing the wells in pairs, so that the pump rods of one go down as those of the other come up. By means of rocking levels, knuckle-joints, elbows, and tees, the lines are carried up and down hill, and are made to turn at any desired angle. Several wells are sometimes connected and worked by means of an endless wire rope, or furnished with power from an engine supplied with steam from a centrally located boiler.

In 1890 the cost of a "rig," as the structure put up by the carpenters is called, averaged from $200 to $275, and the rig irons, such as bolts, pulleys, hooks, etc., from $70 to $80 additional. With the rig, boiler, and engine set up, sinking the bore-hole, or well proper, can be commenced. The first section of a well from the surface of the ground to the first solid rock consists of a driven pipe 8 in. or larger in diameter. This is necessary to keep the earth from caving and choking the well, or the surface water from seeping into it and giving trouble. The drive pipe is put down in exactly the same way as piles are driven, the derrick serving as support for the pipe and as guide for the heavy maul as it goes down. This pipe has to be cleaned out in the same manner as the bore that is afterward carried down through the rock.

The hole through the rock is then begun. If the driven pipe is long enough, the work is started and carried on regularly; but frequently there is not room enough to start off with a full string of tools, as they require at least 60 ft. depth. In such cases the upper part of the bore has to be made by "spudding," the auger or drill being suspended on a rope running over the pulley at the top of the derrick and raised or lowered by the skillful manipulation of the rope end by the driller, it having been first carried around the bull wheel, moved by the engine. This is continued until the regular string of drilling tools can be used. Such a string consists of the bit, the auger stem, 30 or 40 ft. long, the "jars," and the sinker bar, 15 ft. long, which in turn is fastened to the drilling rope. Together these tools are more than 60 ft. long, and weigh very nearly a ton.

The "jar" is a clever device, by means of which a sudden blow can be given either on the upward or downward movement of the tools. They give a blow to the auger stem on the upward stroke, to loosen the bit in case it becomes wedged in the rock, as would frequently happen if it were fastened directly to the cable, since the stretch of the rope would admit motion in the walking beam without moving the drill. Suppose the tools to have been just run to the bottom of the well: the jars are closed and the cable is slack. The men now take hold of the bull wheels and draw up the slack until the sinker bar rises, the "play" of the jars allowing it to come up, say, 13 in. without disturbing the auger stem. They watch for the coming together of the crossheads, which will be plainly indicated by a tremulous motion communicated to the cable and by the additional weight of the auger stem. When the jars come together they slack back about four inches, and the cable is in position to be clamped in the temper screw. If now the vertical movement of the walking beam be 24 in. when it starts on the up stroke the sinker bar first moves, it rises 4 in., the crossheads come together with a sharp blow, and the auger stem is picked up and lifted 20 in. On the down stroke the auger stem falls 20 in., while the sinker bar goes down 24 in. to telescope the jars for the next blow coming up. This is the theory of the movement, but of course in practice the spring of the cable in deep wells and the weight of the tools may make many modifications necessary.

The cable holding the string of tools runs up over the pulley at the top of the derrick down to the large wheel at its foot. Upon this wheel it can be coiled to draw the tools out of the well whenever desirable. This cable is fastened at the end of the walking beam by the temper screw, which lowers the tools a little at every stroke. The pulverized rock formed by the impact of the tool is held in suspension by water poured into the well from the top until there is sufficient to impede the progress of the work. The tools are then withdrawn and a sand pump lowered, which, on being withdrawn, brings with it the accumulation of broken rock and sand. There are various kinds of sand pumps, but in general they consist of a cylinder with a valve in the bottom.

Many minor appliances, principally fishing tools, are found serviceable in well drilling. These tools are of all kinds, from the delicate grab designed to pick up a small piece of valve leather or a broken sucker-rod rivet from the pump chamber, to the ponderous string of "pole tools" containing tons of iron, which at a depth of 1500 ft. or more can unscrew a set of "stuck tools" and bring them up piece by piece, or cut a thread upon the broken end of a sinker bar or auger stem, so that it can be caught and unscrewed by the use of "whisky jacks" at the surface.

The wells first put down consisted of a four-inch hole bored wet—that is, full of water until completed and pumped out—down to the producing sand. In this four-inch hole two-inch tubing extended to the bottom, with a seed bag at what was thought to be the proper place. The seed bag was bagging of some sort placed on the tubing to fill up the space between it and the rock through which the well was bored so as to prevent the water in the bed-rock from flowing into the well. When wells were bored wet, or full of water, it was a matter of guesswork where to place the seed bag, and a great step forward was taken when it was found practicable to drill wells dry, for it was then possible to decide, as the well progressed, how far down it would be necessary to provide for the flow of water from the strata through which the hole was bored. If a well starts with an eight-inch drive, pipe that size bore is carried down beyond the veins of water, and then gradually made to taper by using smaller drilling tools, to a five and a half inch hole. A five and five-eighths inch casing is then put down inside the eight-inch drive-pipe, and below it, until it strikes the point where the hole is reduced in size, forming at that point a tight joint with the rock and shutting off all water from above. The five and a half inch hole is continued to the producing sand, and inside of this a two-inch tubing is placed, extending to the bottom of the well, terminating in what is called the "anchor," a perforated casing, which admits into the pipe oil from the surrounding rocks. There are then down to the bed-rock three pipes, one inside the other—the outer eight-inch or drive pipe, then a five and five-eighths inch casing, and inside of the two a two-inch tubing for pumping the oil. The two latter extend to where the hole is reduced to five and a half inches, when the outer one of the two, the casing, terminates, and the oil tubing extends alone to the bottom of the well. On this two-inch pipe, which is in the five and a half inch hole, a water bag is placed somewhere below the point where the casing terminates—generally at the top of the oil sand, filling the hole between the rock and the pipe. It serves a double purpose, keeping out any water that may have leaked through the casing and preventing the gas from the oil stratum from reaching the surface of the ground by any other channel than the oil tube. This puts a pressure on the oil in the tube, relieving to an extent the force required for pumping, and in many cases forcing the oil to the surface without any pumping whatever.

Cost of Wells.—Carll, in his report for 1880, makes the following statement of the cost of a productive well drilled at Bradford in 1878: "Carpenter's rig complete, $350; belt, bull-rope, engine, 'telegraph,' water pipes, steam pipes and fittings to connect boiler and engine, $100; boiler (20 horse-power) and engine (15 horse-power) on ground, $750; contract for drilling, contractor to furnish fuel, tools, cable, sand pump, line, etc., at 65c. per ft., say 1500 ft., $975; casing, say 300 ft., at 80c. per ft., $240; tubing, say 1600 ft., at 20c. per ft., $320; torpedo (almost universally used before tubing), $100; packer, $25; working barrel, $8 ; casing head, $3 ; tees and elbows to make tank connections, $5 ; one twenty-five barrel tank, $25 ; one two hundred and fifty barrel tank, $110 ; tankhouse, $25 ; expense of tubing and packing well, $20 ; expense for hauling, tubing, materials, etc., say $50—total cost of well, flowing, $3106.

"In the above well no 'drive pipe' was used, a short wooden conductor set by the rig builder being all that was required. In localities where from 100 ft. to 280 ft. of drive-pipe casing, costing $1.80 per ft., is required, the cost of a well is increased accordingly.

"If the well is to be pumped, the following items are to be added : 1500 ft. of sucker rods at 5½c., $82.50 ; valves for working barrel, $7 ; polished rod, $2.50 ; stuffing box, $1.50 ; adjuster, $5 ; tees and elbows, etc., say, $2 ; total, $100.50.

"The necessary tools and implements for handling the tubing and sucker rods are : Large pulley block, $11 ; tubing elevators, $9 ; three pairs of tubing tongs, $10 ; tubing cable, $25 ; sucker rod rope, $11 ; sucker rod wrenches and elevators, $3.50."

In 1890 the cost was probably about as follows : Rigs per well, $300 ; labor drilling, $500 ; boiler and engine, $500 ; pulleys, ropes, etc., $75 ; casing and tubing, $400—total, $1775.

Torpedoes.—Col. E. A. Roberts in 1862 discovered that the production of oil wells could be greatly increased by discharging an explosive in them. Roberts' method, which was patented and successfully employed in the oil regions, consists in sinking to the bottom of the well, or to that portion of it which passes through the oil-bearing rock, a water-tight flask containing an explosive material, the flask being a little less in diameter than the hole, to enable it to slide down easily. This torpedo, or flask, is so constructed that its contents may be ignited either by percussion caps or by fulminating powder, so placed that it may be exploded by a movable wire, electricity, or other means. When the flask had been sunk to the desired position, the well was filled in with water, thus confining the effects of the explosion to the rock in its immediate vicinity. The contents of the flask were then exploded by the means above mentioned, and, as the evidence showed, with the result in most cases of increasing the flow of oil. The theory of the inventor was that petroleum was contained in seams or crevices in the rock. These being of different dimensions and irregularly located, a well sunk through the oil-bearing rock may not touch any of them, and thus may obtain no oil, though it may pass very near the crevices ; or it may in its passage downward touch only small seams or make small apertures into the neighboring crevices containing oil ; in either of which cases the seams or apertures are liable to become clogged by substances in the well or oil. The torpedo breaks through these obstructions and permits the oil to reach the well.

Concerning this Professor Peckham says : "While not disputing that in some instances Colonel Roberts' theory of the action of torpedoes may explain such action, I am forced to the conclusion that when a torpedo is exploded in such a rock as the Bradford oil-sand the crushing effect of the explosion is comparatively limited. The generation of such an enormous volume of gas in a limited area, the walls of which are already under a very high gas pressure, and which is held down by a motionless column of air of 2000 ft. (the use of water tamping has been abandoned), must be followed by an expansion into the porous rock that drives both oil and gas before it until a point of maximum tension is reached. The resistance then becomes greatest within the rock, and, reaction taking place, oil and gas are driven out of the rock and out of the well, until the expansive forces originally generated by the explosion are expended. By this reaction the pores of the rock are completely cleared of obstructions, and the pressure of the gas within the oil-rock continues to force the oil to the surface until it is no longer sufficient for that purpose."

The success of the use of the explosives was complete from the first. Henry states that the first 39 wells showed an increase in production of 2227 barrels, or an average of 57 barrels per day per well, six of the wells showing an increase of from 125 to 200 barrels each.

In the early trials gunpowder was used, but now nitroglycerine is employed, and the charge has been increased to enormous quantities, in some cases as much as 100 quarts, this amount equaling in effect one ton of gunpowder. The explosive is lowered through the well bore in sections, one can resting on another at the bottom of the hole. A cap is adjusted on top of the last section, and upon it a weight is dropped from the surface. A few seconds after the explosion a fountain of oil, water, mud, and pebbles shoots up through the well-mouth to the top of the derrick and above it, saturating it with oil and scattering a shower of broken stones in every direction. The job of shutting in the petroleum flow that often follows is sometimes very difficult. The packer for the oil-saver is tied on the bull-wheel shaft, the tools placed over the hole and run in. However, the pressure of the solid stream of oil is sometimes so great that even the suspended weight of the 2000 lb. tools is insufficient and 1000 lbs. or more additional weight must be added before the cap can be fitted and the well closed. The well is then connected with the receiving tank by a pipe.

Flooding.—Assuming that the oil-charged rocks lie in beds surrounded by harder impervious formations, so that each bed forms practically an independent reservoir saturated with oil and gas under great pressure, which is supposed to be at times as much as 300 lbs. to the square inch, it will be clear that as an outlet is given for the oil and gas, the pressure will be gradually reduced. There is good proof of this in the fact that the wells first drilled in a pool or section of oil-bearing rock yield best, even though they be only on the outskirts of the deposit; and wells put down later into the center of the bed do not yield so much, and always reduce the output of the first wells. So long as the pressure continues, all force is exerted outward and upward from the rock below, extending back from the sand immediately surrounding the bore farther and farther as the pressure is gradually relieved by the escape of the oil and gas up through the well. By natural law an equilibrium is being established, and is finally established when the well ceases to flow. If it is now pumped, a partial vacuum is formed. It is then that flooding, or filling the oil rock with water to replace the oil and gas, may occur. Producers try to guard against this. It is the practice, when wells have ceased to yield oil in remunerative quantities, to draw the iron casing out of them for use in other wells. Through carelessness these abandoned wells are sometimes left unplugged; that is, the hole is left open instead of being filled with earth. Surface water is thus allowed to run down to the oil-bearing strata, and spread itself indefinitely until it reaches other wells in the same strata, and they begin to pump oil and water mixed, and perhaps water only. This is so important a matter to the general welfare of the oil-producing region that a law has been enacted making it a misdemeanor for an owner to abandon a well and leave it unplugged. The penalty is $200 for each offense, one-half to go to the informer and one-half to be turned into the fund for the use of schools in the district where the well is situated.

Plugging for the purpose of excluding fresh water from the oil-bearing rock must be performed as follows : The owner or operator must, before drawing the casing, fill up the well with sand or rock sediment to a depth of at least 20 ft. above the third sand or oil-bearing rock, and drive a round, seasoned, wooden plug at least 2 ft. in length, equal in diameter to the well below the casing, to a point at least 5 ft. below the bottom of the casing, and immediately after drawing the casing must drive a round wooden plug into the well at the point just below where the lower end of the casing rested, the plug to be at least 3 ft. in length, tapering in form, and of the same diameter, at the distance of 18 in. from the smaller end, as the diameter of the well below the point at which it is to be driven. After it has been properly driven the well is filled with sand or rock sediment to the depth of at least 5 ft. above the plug.

The first intimation of flooding in a district is given by an increased production from the wells. Old wells, without any observable cause, improve gradually, running up from 5 barrels per day to 10, 20, or even 50. After pumping in this way for some time the oil quickly fails, and the wells yield only a few barrels of salt or brackish water. As the wave moves on, the wells in advance, one after another, are affected in the same way. In some districts the movement is quite rapid and wells are invaded and "watered out" in quick succession; in others it is so slow that large quantities of oil are obtained from those which are favorably situated to receive a "benefit." Flooding a well is sometimes a very profitable way of closing its career, inasmuch as it thus yields more in a few months than it otherwise would in years; so when the water reaches it the owner knows at once that further operations are useless, thus saving the time and money often expended in fruitless efforts to reclaim wells failing through natural decline.

GEOGRAPHICAL DISTRIBUTION.

California.—Petroleum is found in many localities in California, but most abundantly in the southern part, especially in Ventura and Los Angeles counties. The occurrence of petroleum and asphalt in California is intimately connected, according to A. S. Cooper, with carbonaceous shales. From these by chemical heat, steam, etc., the petroleum has very probably been distilled, frequently leaving the shales red and vitrified.

The petroleum industry has now reached considerable proportions in this State, the amount produced in 1893 being estimated as 600,000 barrels (of 42 gallons each), valued at point of production at $1,050,000. Owing to the high cost of coal there is an active demand for crude petroleum for fuel purposes.

The knowledge of the existence of petroleum in California dates back many years ; even as early as 1851 it was being distilled on a small scale, and in 1857 a comparatively large plant was erected in Santa Barbara County. In 1865 there were 65 companies, with a nominal capital of $45,000,000, engaged in the industry.* Crude oil from Pico Cañon, in the San Fernando Mountains, Los Angeles County, which is at present the most productive field in the State, is thick and dark green in color, with a sp. gr. of 0.8414 at 15° C. The oil contains paraffines, naphthenes, and benzene-homologues, and is apparently intermediate in composition between the Pennsylvania and Russian petroleums.

Colorado.—All of the oil produced in Colorado is from what is known as the Florence oil field. The following description of the district is extracted from an article by S. H. Eldridge : †

The Florence oil field lies in Fremont County, along the valley of the Arkansas River in close proximity to the eastern base of the Rocky Mountains. Its present center of production is near the town of Florence, thirty miles west-northwest from Pueblo, and eight miles below Cañon City. The first active prospecting was begun by a Mr. Cassidy in 1862, about six miles northeast of Cañon City. He sank several shallow wells, found oil in the strata near the surface, and crudely refined and sold it in Denver at a price ranging from $1.25 to $5 per gallon. Companies were soon formed to prospect the region, among them the Arkansas Valley Company, the Colorado Oil Company, and the Cañon City Oil Company. They explored the strata of the Montana group (Pierre and Fox Hills) of the Cretaceous formation that affords the yield of to-day. The companies at present in the field are, in order of magnitude : The United, Florence, Rocky Mountain, and Triumph ; the first two having been established about 1887, and the others more recently.

The Pierre formation and its included oil-bearing zone are chiefly made up of argillaceous shales with occasional local developments of sandy strata of various degrees of coarseness. In the Florence field the coarser varieties of sand are wanting, but there often exists an extremely fine arenaceous matter intimately mixed with the clay. These arenaceous beds frequently pass into clays, and are found irregularly distributed both in the vertical and lateral range of the formation. The more sandy varieties of shale are said to yield the oil. The thickness of the oil-bearing zone is probably 2000 ft. The lowest geological horizon at which oil has been observed in Colorado is near the base of the Jurassic shales. Asphalt occurs in the Dakota in several localities in the West, and in many places in Wyoming this formation is also oil-bearing, though as yet undeveloped. It would seem probable, however, according to Eldridge, that both the source and reservoir of the oil lie within the Pierre formation itself, since shales are in many regions the recognized place of origin of oil, and the distribution of the materials of the Pierre would permit the accumulation of the entire product in the more open porous, sandy bodies inclosed within the argillaceous portions.

In the examination of the well records of the Florence field, two points of interest appear in connection with the flows : first, that there are certain horizons in which oil has been found more frequently than in other parts of the vertical scale ; second, that wells yielding petroleum from depths of 400 or 500 ft. below the summit of the oil-bearing zone occur to the west of wells in which no

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* *Fourth Annual Report of the California State Mineralogist.*

† *Trans. Am. Inst. Min. Eng.*, Vol. XX .

flows are encountered at these depths, and that, too, notwithstanding the continuation of their productive horizons considerably beyond the easternmost wells. In explanation of the latter point, it is possible that the requisite sedimentary conditions for an oil-bearing rock do not exist over this portion of the field, but from an inspection of the sections and from the fact that oil is rarely found at a depth less than 800 or 900 ft. beneath the surface, it would seem that some other cause, such as evaporation, may have had an influence toward this result. The vertical succession of oil-bearing strata in individual wells suggests another argument in favor of the origin of oil within the Pierre formation itself. In the event of its having been derived from a lower formation it would have been largely taken up by the lower bodies of sands. The yields of the several horizons of a single well afford no evidence of this condition, large flows occurring with equal frequency from either upper or lower oil-bearing strata, or from both.

No connection exists for the field in general between flows of the same horizon. Only within the narrow group limits has this been recognized, and here, between wells in close proximity to one another. Of the total number of wells drilled up to Nov. 1, 1890, 57½% had been successful.

When a productive well is struck in the Florence field, it shows an abnormal rise, due to expansion of the gas contained in the oil, the latter ascending the well 50 to 1000 ft., but upon being pumped it settles to the normal level of flow. The yield of the wells ranges between 5 and 150 barrels per day. Among them there are some that have maintained a constant flow during their entire existence to date, while in a few instances actual increases to two or three times the original yield have occurred. The use of torpedoes has been tried in three instances, without success. Caving of the walls has resulted in each case, while within the range of action of the torpedo it is believed that, on account of the clayey nature of the strata, there has resulted a packing of material which is the reverse of the desired effect.

The crude product of the field is of a light yellowish-green color, varies but slightly from an average gravity of 31° B., and is remarkably free from sand and other impurities, which, in a month's constant run, amount to but about a gallon per still. The present production of the field is considerably under its capacity, being about 2000 barrels per day, which yields upon distillation, approximately, one-third refined or illuminating oil, a small amount only of lubricating oil, and a residuum, which is stored. The production, however, is varied according to the market demand. From about 300 lbs. of crude oil are manufactured about 100 lbs. of illuminating oil and 5 lbs. of lubricating oil.

The treatment of the crude oil as practiced by the United Oil Company, in the process of distillation, is practically the same as ordinarily employed elsewhere. It passes from the wells to storage-tanks, and thence to the stills in charges of 400 lbs. for the larger and 100 lbs. for the smaller. The run of the former is of 26 hours' duration, of the latter 20 hours'. The yield from these is 40% illuminating oil, the gravity of the distillate being 44½° B., and that of the residuum 22° B. From the stills the cooled distillate passes to storage-tanks and thence to the agitators, where it is subjected to chemical treatment consisting of agitation with sulphuric acid (66° B.) and subsequent washing with a solution of caustic soda and water. Upon completion of the agitation it is run to the bleachers, settled, and thence distributed to the warehouse for packing or direct to the tank cars. The percentage of naphtha in the oil is insignificant. The burning point is 130° F.

The lubricating oil is derived from the residuum by passing the latter through a retort and removing the paraffine. This "stock" is compounded with neutral oil from the stills, which results in a product having a cold test from 0° to 30° F., a flash test of 350° F., and a gravity from 24° to 28° B. The residuum chills at 60° F.

The quality of both illuminating and lubricating oils derived from Florence petroleum is said to be excellent; but for the latter product there is at present only a slight demand, owing to Eastern competition and high freight rates. The residuum from the manufacture of the above two classes of oil is stored in open reservoirs about the field, except such portion of it as is required beneath the stills and boilers of the refineries and wells. As a fuel, from 1200 to 1300 lbs. (3 to 4 barrels) are estimated to be equivalent to 2000 lbs. of coal worth from $1.43 to $2 per ton at the mines. The tanks for the storage of the various products of the Florence field range in size from 5000 to 35,000 barrels.

In 1893 the Florence Oil Company completed its second refinery at a cost of $75,000, with a capacity of 1000 barrels a day, and will soon put it in operation. The United Oil Company made some costly additions to its refining machinery for the manufacture of fireproof oils for use in railroad cars, steamboats, etc., an investment, it is stated, of over $100,000 having been made.

The progress of petroleum development in Colorado during the past year may be summarized as follows: New wells, 12; new refineries, 2; number of men employed, 300; monthly payroll (Colorado) $15,000; cash value of annual output of oil, $1,000,000; present daily output of oil 2000 barrels, or at the rate of 730,000 barrels per year.

Indiana.—Judged by percentages, no State in the Union made the progress in the production of petroleum in 1893 that was made by Indiana, the production being 2,332,303 barrels, as compared with 698,068 barrels in 1892, an increase of over 234%. This puts Indiana the fifth in the list of producing States, Pennsylvania being first, Ohio second, West Virginia third, and New York fourth. With the exception of a small amount of oil produced near Terre Haute, Vigo County, all oil produced in the State is from an extension of the Lima field of Ohio. The wells are included in the counties of Blackford, Jay, Wells, Adams, and Grant.

The following petroleum statistics of Indiana are furnished by Hon. S. S. Gorby, State Geologist: Wells producing Dec. 31, 1892, 251; wells completed in 1893, 557—total, 808. Unprofitable wells, 56; abandoned wells, 70—total, 126. Number of wells producing Dec. 31, 1893, 682. The wells are located as follows: Jay County, 279; Wells County, 270; Adams County, 85; Blackford County, 45; Grant County, 3—total, 682. The number of wells drilling on Dec. 31, 1893, was 43. The total production in 1893 was 2,332,303 barrels, or 3⅓ times as much as the production of the previous year.

Ohio.—The oil-producing districts of Ohio, omitting the little important Mecca-Belden Field, may be divided into the Lima or Northwestern, which extends from Lima as a center in a southwesterly direction into Indiana, and the Eastern Ohio district, which is really an extension of the West Virginia field.

The former is possibly the most remarkable oil district ever opened in this country. Its development has been exceedingly rapid, since it did not begin to assume prominence until 1885, yet in 1892 it furnished nearly one-third of all the oil produced in the United States.

The oil of the Lima district is found in the Trenton limestone, and its mode of occurrence is therefore very different from that of the Pennsylvania oils. The limestone lies as near a level terrace as an area of this sort ever becomes, and carries oil at a depth of 1300 ft. The oil is dark or black and rather heavy, and, like the oils of Canada and Tennessee, contains sulphur compounds. Until quite recently all the oil produced in the Lima district was classed as fuel oil, and but little of it had been refined prior to 1889. The chief obstacle was the difficulty of removing the sulphur compounds present and the small percentage of illuminating oil which could be produced. It was even believed that the Lima crude, because of its peculiar character, could not be used for illuminating purposes. Yet to-day Lima furnishes most of the illuminating oil in the United States. This remarkable result has been due chiefly to the fact that the refineries have succeeded in removing the sulphur compounds by means of copper oxide.

Although the percentage yield of the Lima oils in illuminants is still considerably less than that of the Appalachian oils, still, as now refined, they are considered better than the latter. The Lima crude, in actual practice, is said to yield 22% in illuminating oils and 15% of naphtha.

The Eastern Ohio district includes the wells along the extreme eastern boundary of Ohio contiguous to Pennsylvania and West Virginia. It occurs in grit and sandstone similar to the Pennsylvania fields. The oil from the Mecca-Belden field is entirely a lubricant, derived from the "Berea grit." Although the production of petroleum in Ohio in 1892 was 1,400,000 barrels less than in 1891, the value was $700,000 more. Of the total production nearly 93% came from the Lima district.

Pennsylvania, New York, and West Virginia.—In boring wells for brine in West Virginia, soon after the opening of the present century, it was noticed that oil appeared in many of them. This fact was a source of considerable annoyance to the salt men, who did not dream of the value of these indications, and the wonderful petroleum resources remained practically unknown until late in the fifties.

The first oil company organized in the United States was the Pennsylvania Rock Oil Company, incorporated with a nominal capital of $500,000 in 1854, which purchased 105 acres of "Watson's flats," near Titusville, Penn., and obtained crude petroleum in limited quantities by means of surface pits and trenches. The Seneca Oil Company succeeded the Pennsylvania Rock Oil Company in 1857, with the plan of seeking for oil by drilling, and Col. E. L. Drake was sent to Titusville the following year to carry out this project. At first he tried to dig down to the rock at which to begin drilling, but the hole soon filled with water and quicksand. It then occurred to him to drive a pipe through the sand and clay, a plan afterward generally adopted, not only in oil-well boring but in all artesian drilling. At a depth of only 70 ft. below surface, in the first sand, the drillers "struck" petroleum, Aug. 27, 1858. When the pump was started a few days later, Drake's well produced at the rate of 25 barrels per day, at that time an enormous quantity. The success of this attempt led to a period of almost unparalleled excitement, surpassed only by the gold fever of California. Western Pennsylvania, in 1859 and the next few years, was the scene of indescribable activity and speculation. Wells were sunk in great numbers along Oil Creek, French Creek, and the Alleghany River. Adventurers flocked thither from all parts of the country, and what was soon known as the "oil region" was transformed from an almost unbroken forest into camps and towns.

Up to this time all of the oil secured had been lifted from the wells by pumps. The first flowing well was struck in February, 1861, on the McElhenny farm, yielding 300 barrels per day, and flowed for fifteen months. This surprise had not spent itself when the largest flowing well ever operated in America, the Phillips, was struck, shooting forth 3000 barrels per day. These "gushers" stimulated prospecting and increased the production, and as a natural consequence prices declined rapidly. In 1862 it was found that productive territory need not necessarily underlie the valleys and river bottoms, but that the high lands also covered the hidden treasure. Then the drillers tested the high plateaus of Clarion, Butler, Armstrong, McKean, and Warren counties. The new wells gave a beautiful amber-colored product, in contrast with the dark green and black Venango oils. The Butler-Clarion belt was discovered in 1870, opening up the Lower or Southern field, which even to-day stands, in quantity of oil produced, second only to the great Bradford district.

In December, 1874, a well was struck on the Buchanan farm, near Bradford, which in 1875 yielded 25,000 barrels. This in 1878 had increased to 6,500,000 barrels, or as much in a day as was produced in a year in 1875, and further increased in 1881 to 23,000,000 barrels, making the Bradford production six-sevenths that of Pennsylvania. The Bradford wells are very deep, some going down considerably more than 2000 ft.

In 1876 the Beaver district of Clarion County became prominent, and in 1879 the Richburg field in Allegany County, New York. The first well in the latter district was put down as a "wildcat" or test well, and produced at the rate of four barrels per day, hardly foreshadowing the enormous output soon to follow, which in 1882 reached 6,450,000 barrels. In 1884 the Thorn Creek oil was secured, and in 1885 and 1886 that of Washington and Greene counties.

The accumulated stocks of "crude" became very large in 1887, and depressed prices, occasioning general alarm among producers.

An agreement was drawn up and signed by the members of the Petroleum Producers' Association, looking to curtailing for a time the output of the oil fields. The agreement was to stop cleaning out and torpedoing all wells for one year and to "shut in" a certain part of the production. The movement proved a success, and resulted in bringing up the average price of crude from 66⅝c. per barrel in 1887 to 87c. in 1888. In 1889 production was again resumed. The year 1890 shows the largest number of wells ever completed in any one year, a total of 6358. The McDonald field was opened in 1891, and because of the extraordinary average output of the wells, the production and stocks increased over 5,000,000 barrels.

The McDonald field began to decline in 1891, and in 1892 the Sisterville field took its place, but the low prices prevailing have not encouraged the search for new fields in Pennsylvania.

At one time an effort was made to classify the oils from these States according to the sands from which they came, namely, first sand, second sand, third sand, and crude, meaning by this nomenclature the geological rock stratum from which the oil was drawn. This plan was soon found to be impracticable. Not only was it difficult to determine from which sand different wells were obtaining their supply, owing to the lack of intelligence and care on the part of those sinking them, but other sands than those thus numbered in the early days appeared in the later borings. It soon became clear that a geographical classification was more satisfactory than the geological. The common classification adopted in Pennsylvania recognizes the following principal divisions: Bradford, Middle, Lower, and Southwestern or Washington districts.

The *Bradford* field includes the detached basins of oil rock of Allegany and Cattaraugus counties, New York, separated by several miles from the main producing territory of McKean County, Pennsylvania, in which Bradford lies. The oil of this field is dark amber green to black, and of heavier gravity than that of the other fields.

Middle.—This includes particularly the production of Warren and Forest counties. The crude is generally of an amber shade, but varies greatly in different parts of the field, both in color and gravity.

Lower.—This embraces all the production of Venango, Clarion, Butler, Beaver, and Lawrence counties. The oils are green to black in color and generally of light gravity.

Washington, or Southwestern.—This includes the production of southwestern Pennsylvania, particularly in Allegheny, Washington, and Greene counties. The Turkey Foot and other oils of West Virginia and the Macksburg production of southwestern Ohio are also included in this general field in statistics prepared to show the total production of what is termed "Pennsylvania crude," in distinction from the crude oil of Ohio. These oils are a reddish amber in color and of light gravity.

With reference to the geological location of petroleum, Professor Peckham concludes that the oil-bearing formations in western Pennsylvania belong to the Chemung and perhaps later groups of the Upper Devonian, consisting of shales and marls interstratified with sandstones. The sandstone varies in character from a coarse-grained uncemented sandstone to a pebble conglomerate, composed of worn pebbles of white or slightly opaque quartz overlaid by marls and slates, and forming very hard and impervious crusts.

Between these beds of oil-bearing sandstone or conglomerate, which are quite uniform in structure over wide areas, are beds of shale, often of great thickness, and containing thin strata of sand and shells. The Pennsylvania crude occurs, according to Peckham, saturating the porous portions of formations or deposits that lie conformably with the inclosing rocks and slope gently to the southwest. The Bradford field in particular resembles a sheet of coarse-grained sandstone 100 sq. miles in extent by 20 to 80 ft. deep, lying with its southwest edge deepest and submerged in salt water, and its northeast edge highest and filled with gas under an extremely high pressure. From whatever source the petroleum may have originally issued, it now saturates porous strata not of any particular geological age, but runs through a vast accumulation of sediments from the oldest to the newest rocks in Pennsylvania and West Virginia, embracing all the rocks between the Lower Devonian and the Upper Carboniferous.

John F. Carll concludes that the whole oil field of western Pennsylvania, from Pittsburg to Lake Erie, constitutes a group of oil sands 300 to 380 ft. thick, above which lie 300 or 400 ft. of soft formation everywhere, and below which there is another mass of soft shale. This he designates as the Venango group. It does not include the Warren or Bradford oil sands, which are older and therefore deeper.

Canada.—Although petroleum has been found in Quebec, Nova Scotia, and Alberta, nearly the whole of the present production comes from Ontario. Attention was first drawn to this province in 1860 or 1861 by a Mr. Tripp, who owned a farm where now stands the village of Oil Springs. The first flowing well was struck on Feb. 19, 1862, when Mr. James Shaw of Oil Springs found oil at a depth of 160 ft. in what is now known as the "upper vein." Following closely upon this discovery was a rush to the new oil field, and the business passed through the various stages of speculation and finally settled on a solid basis in 1867.

The only oil-producing territories in Canada during 1893 were, as in previous years, the Petrolia and Oil Springs fields, Lambton County, Ontario. These large oil-producing districts lie at the point of the peninsula between Lake Erie and Lake Huron, the oil being obtained at a depth of from 400 to 500 ft. No new developments are reported from these fields, nor have they been much extended, though drilling operations are constantly being carried on. An important discovery was made during the previous year in the South Kootenay Pass, in Alberta and British Columbia, where oil was found occurring in natural springs, but in what quantity is not yet known.

According to Stowell's *Petroleum Reporter*, the shipments of petroleum from Petrolia, Canada, for the past two years were as follows:

1892.			1893.		
Crude.	Refined.	Equivalent.	Crude.	Refined.	Equivalent.
198,409	308,910	1,007,271	224,763	225,572	1,066,155

India and Burma.—According to R. D. Oldham (*Journal of Society of Arts*, No. 2149, Vol. XLII., p. 145 *et seq.*), the Indian petroleum fields at Kattan, British Beloochistan, and Mogalkot, near the Sulaiman Hills, are not very promising, while those in Upper Assam (Digboi and Makum) give evidence of becoming established among the productive oil fields of the world. At present the only productive oil field of the Indian Empire is in the newly acquired province of Upper Burma. The petroleum industry in Burma is of considerable age. Until 1887 the only means of working the oil in use were square shafts rudely lined with timber, in the bottom of which the crude oil collected and was drawn up in earthen vessels by ropes. The greater part of the oil is still produced in this laborious and primitive manner. Many deep borings, however, are fitted with steam pumps. The Burma oil fields are at Yenangyaung (Stinking Water Creek), Yenangyat, and at Minbu on the Irawadi River. (No oil is produced at Rangoon, Rangoon oil being merely a commercial name.) In geological structure these oil fields are very simple. The formation, especially at Yenangyaung, is a well marked anticlinal, at the crest of which the beds lie horizontal. The oil-bearing strata consist of beds of sand, separated by clays and shales, lenticular in form, and coalescing with each other irregularly. In area the oil territory of Yenangyaung is $3\frac{1}{2}$ miles long by $\frac{1}{2}$ mile wide. The oil field of Yenangyat is 54 miles north-northwest of Yenangyaung, but, like Minbu, is as yet a small producer. The near future will probably see a considerable increase in the production of petroleum in Burma and Assam, an increase which will enable these provinces to provide for their own consumption and in part for that of the rest of the empire, though there seems no reason for expecting that India will ever rank with America and Russia among the great petroleum exporting countries of the world. The oil imported into India and Burma in 1892–93 was 67 and $2\frac{4}{10}$ million gallons, respectively, and the amount of petroleum manufactured in Burma was $2\frac{2}{10}$ million gallons, or less than half the total consumption of the province.

Peru.—Petroleum was discovered in Peru about 1860 in the asphaltum beds of Mancora and Zorritos, in the Department of Piura. Later on expensive works were established at Negritos to refine the oil. This attempt failed, as did one started about 1865. In 1876 a well 500 ft. deep was sunk at Tumbez, and obtained a good supply of oil. In 1880 Mr. Piaggio acquired control of the Hacienda de Mancora and established there refining works. In 1887 Mr. Herbert W. C. Tweddle purchased the hacienda of Pariñas, and established at Talara very large refining works, now owned by the London and Pacific Petroleum Company.

The petroleum beds of Peru have an area of about 16,000 sq. miles. The oil is found in slate at a depth of 200 to 500 ft., the overlying materials being at the surface a layer of sand from 0.25 to 4 meters thick, the white sandstone from 0.3 to 2 meters thick, and a layer of wet sand from 8 to 10 meters thick. Following this is a conglomerate of sea shells from 5 to 10 meters thick. The oil is similar to that of Pennsylvania, except that it contains little or no paraffine. On the west coast of South America it has entirely replaced American kerosene, and its use is rapidly extending. The crude oil has been tried on the Oroya Railway, and, according to a report by Mr. F. Moreno, the Peruvian Corporation has made contracts for a regular supply for its railways.

Russia.—The presence of petroleum in Russia has long been known, and as early as 1745 a merchant named Nabatoo had works for treating crude petroleum in the Pechirsk district, at the mouth of the river Okhta. The production only attained commercial importance at the beginning of the present century. By a treaty signed between Russia and Persia at Hulestan on Oct. 12, 1813, the Khanates of Baku, Kouban, and Derbent were united to the empire, and from that time Russia became the possessor of the rich petroleum sources of the Apsheron peninsula, which, as the Arab writer Massoundi states, had been worked since the ninth century B. C. At first, however, the oil industry of the Caucasus developed very slowly, and up to 1860 the yearly yield did not exceed 30,000 barrels. This petroleum was exclusively employed in the crude state, either for fuel or as a coarse lubricant, thus accounting for its small demand and production, but the success of the kerosene (photogene) production in Germany gave an impetus to the Caucasian petroleum industry, and in 1860 a refinery was started at Sourakhany. In 1864 the Baku works were constructed, and from that time until the present, and especially after 1872, the production of petroleum in Russia has rapidly increased, and is now very large.

The extraction of crude petroleum in Russia is chiefly conducted near Baku, on the Apsheron peninsula, western coast of the Caspian Sea, although it is also carried on, but to a less extent, on the Cuban, Province Tersk, Caucasus, and in other localities. In the Baku district, which produces over 99% of the Russian output, the petroleum occurs in an area of only 6.4 sq. kilometers, and in sands belonging to the Tertiary formation. The Apsheron peninsula presents an uneven and in general but little elevated surface, intersected here and there by shallow and wide valleys. It is chiefly covered with sand, and partially by salt marshes, salt lakes, and "mud volcanoes." In its geological structure the peninsula is exclusively made up of Post-Tertiary and Tertiary formations, the oldest of which are marls and schists of the Upper Eocene period. The stratification of all these formations is broken, the dislocations appearing in two predominating directions northwest and northeast. In the majority of cases the natural outflow of oil appears on the sides or crusts of anticlinal ridges, or in narrow and deep anticlinal valleys of rupture. The oil lies in the Oligocene formation, and is chiefly concentrated in sands and friable sandstone. The total thickness of the oil-bearing tier of Oligocene is not less than 6000 to 7000 ft., and the thickness of the oil-bearing sands and sandstone extend to 1000 ft. The majority of the wells are situated northwest of Baku. The crude oil has a sp. gr. of 0.86 to 0.88, and is called "green" owing to its fluorescent appearance, although by transmitted light it is brown. Smaller quantities of a light "white" petroleum of sp. gr. 0.78 are obtained, and a "black" heavy crude of 0.9 sp. gr. and over.

The total number of wells in the Baku district in 1891 was only 641, of which 458 were worked. The wells are nearly all of shallow depth and large capacity as compared with those of Pennsylvania. The great advantage of these conditions may be seen from the fact that tens of thousands of wells are under exploitation in the United States to obtain the same quantity of oil that the 500 wells at Baku yield. The only ones worked are the rich wells, giving over 50 barrels per day, whose crude is not too thick and heavy to flow easily. The field is exploited, as elsewhere, by drilling. Rigid rods with free-falling tools are generally used, as local conditions are said to be unfavorable to the rope system of boring.

The crude oil of the Apsheron peninsula is chiefly obtained from the wells by one of two methods—by means of buckets, or by fountains. The bucket system consists in lowering on a cable, by means of mechanical appliances, such as windlasses or steam haulage, a deep bucket or cylinder having a valve at the bottom, by which the crude oil and water are raised and emptied into a gutter on the surface. The dimensions of the buckets vary, but they are always large, lifting as much as 164 kilos at a time. Three men per shift are necessary to work this system, and by it more than four-fifths of the crude oil is extracted.

Fountains form an ordinary, if not a regular, phenomenon in sinking wells in the neighborhood of Baku, some of them having given several hundred thousand poods of naphtha per day. They are always accompanied by the evolution of gas, and often throw up water, sand, and sometimes stones, together with the petroleum, to a height of even 400 ft. The duration of the action depends upon the pressure of the dissolved gases, the quantity of the crude flowing, the depth of the well, and local conditions. In general, the deeper the well the more powerful the fountain. The crude oil thrown up is collected by forcing helmets or stopcocks into the ends of the tubes lining the holes, and by this means directing the naphtha into reservoirs or pits. After a certain period of activity the fountains cease flowing, and then recourse has to be had to the bucket system. The diameter of the tubes in the wells varies from 6 to 22 in., but is generally 10 to 15 in. The average depth of all the wells worked in 1891 was 715 ft., and in 1890 the average was 94 ft., showing that the depth which is the most profitable for exploitation increases every year. The highest average yield was from one of the deepest wells—1000 ft.

The cost of boring, including the cost of steam power, erection of derricks, and lining with tubes, is now on the average from 170 to 200 rubles per sagene (7 ft.). At present the cost of production per pood of crude is 1⅔ to 2 kopecks, and the market price at the wells 2½ kopecks. The cost of pumping the crude through the pipe lines to the refineries, situated five to ten miles away, is about half a kopeck per pood. Statistics of the production of petroleum in Russia are given in the statistical table for that country at the end of this volume.

Italy.—There are three petroliferous districts in this country—one between Voghera and Smola, in Emilia; another in the valley of Pescara; and the third in the Siri Valley, near San Giovanni, Tucarico. A fourth basin has lately been discovered at Vallega, near Piacenza, where there are about 40 wells in active working. Italy's consumption of petroleum now amounts to 80,000 tons, while the national production in 1892 was about 1000 tons, or little more than one per cent. of her consumption.

Other Countries.—Besides the countries previously mentioned, petroleum is obtained in Tegernsee, Bavaria and Hanover, Prussia, Germany; Parma, Sicily; Japan; Galicia; Rangoon, Burmah; Mexico; and Venezuela. Of these only Germany and Japan are important producers.

TRANSPORTATION OF CRUDE PETROLEUM.

Early Methods.—The market for crude petroleum being the refineries that had been constructed particularly at the seaboard, the Pennsylvania oil producer had early to face the problem of cheap transportation. Hauling by trucks (carrying oil in barrels) to the nearest shipping station was replaced, wherever practicable, by water transportation on oil barges. But many of the streams, like Oil Creek, were shallow during most of the year, and a novel but dangerous plan of slack-water navigation known as "pond freshet" was resorted to. This consisted in damming the water in streams tributary to Oil Creek, and then, at a fixed hour, releasing it so as to flood the main stream, on which the oil barges could then be carried to their destination. Losses were frequent from collisions and other accidents. As railroads were built into the oil region, the development of the tank car followed. But the magnitude of the petroleum industry made it necessary to find some mode of transportation even cheaper than the railroad, and the result was the invention and introduction of the pipe lines. The cost of transportation was thereby so much reduced that the many little refining works that had meanwhile filled the country around Pittsburg and Oil City were replaced by a few very large plants built at the seaboard and on the shores of Lake Erie and Lake Michigan.

Samuel Van Syckle of Titusville was the first to put down a working pipe line. This was four miles long, and, although making an ascent of nearly 500 ft., delivered oil at the farther end practically without loss. The owners and drivers of oil wagons saw that this mode of transportation must soon deprive them of occupation, and they did all they could to retard the progress of the work, but eventually they had to yield, and to-day the total length of lines transporting Pennsylvania crude oil is probably 25,000 miles.

The lines are usually laid under ground, with bends at intervals to allow for expansion or contraction. The pipe for the trunk lines is made of wrought iron, lap welded, in length of 18 ft. and 4 to 8 in. in diameter. On each end coarse and sharp taper threads are cut, and the lengths connected with long sleeve couplings. The pipe is tested to stand a pressure of 2000 lbs. per sq. in. The necessity for this can be appreciated from the fact that, in addition to overcoming the friction of the oil on the line, the large body of liquid is made to move with great speed. It was found that the friction on the 108 miles of 6-in. pipe between Rixford and Williamsport, Penn., was equal to a column of oil 700 ft. high.

Where the New York trunk line passes under the Hudson River it is double—that is, one pipe is placed inside of another with tight-fitting sleeve joints. The jacket pipe has its ends separated by a space of 12 in. to permit the inclosed pipe to be screwed home. The sleeve is then pushed over the 12-in. gap, and the whole space between the two is filled with melted lead. The line is held in place on the bottom of the river by two sets of heavy chains parallel with the pipe and about 25 ft. from it, one on each side. Every 300 ft. a guide chain connects the pipe with these lateral chains, and beyond each one of these connections an anchor, weighing over a ton, keeps the whole in place. The line crossing the salt marshes approaching the river is laid in a rectangular wooden box, filled with hydraulic cement to withstand corrosion.

Stations, which are placed at intervals of 28 to 30 miles on the pipe lines, each have two or more storage tanks of from 30,000 to 35,000 barrels capacity. The oil is received from the preceding station into one of the tanks while the pump is emptying another. In this way the movement of oil through the trunk lines is made continuous. Most of the stations are also provided with duplicate pumping machinery and engines for high and low duty.

A station equipped with a high-service pump has seven or eight horizontal tubular boilers, 80 to 100 horse-power each. Six of the boilers are fired at once. They are placed in a boiler-house 40 ft. square, built of brick and covered with a corrugated iron roof. The pumps are in a separate brick building, being separated for greater safety from fire. The stations are connected with one another and with the main offices of the pipe lines by independent telegraph lines. When a producer's tank is measured and accepted by a gauger and the oil passed into the pipe line, a report is telegraphed to the central station of that section of the field. A complete record of the capacity of each tank in the field is here kept, by which the feet and inches of the oil indicated by the dispatch are at once converted into barrels and placed to the credit of the producer on the books of the pipe line. When a producer wishes to deliver oil from his tank he notifies a representative of the pipe line, who measures the oil and gives a voucher for it, running it into the line. The oil thus received is treated the same as a deposit in a bank. Against it certificates are issued in lots of 1000 barrels each at the request of the owner. It is in these that the oil exchanges deal.

All crude petroleum contains more or less amorphous or uncrystallized paraffine or wax. Water mixed with crude oil forms an emulsion or soapy deposit. The paraffine is known in the oil region as "sucker-rod wax," because it collects on the rods used for pumping wells. The emulsion is locally known as "B. S." These two sediments, together with the impurities naturally incident to the mining of petroleum and its transfer from point to point, gradually choke the pipe lines, particularly in colder weather. To clean them, a curious instrument called a "go-devil" is sent through the pipe. This is a spindle with a ball and socket joint near its center so that it can follow the bends in the pipe. It is fitted with steel blades set radially, and is kept in position in the pipe by three arms both in front and rear, with a guide wheel on the end of each arm. Oblique vanes put in motion by the moving oil rotate the spindle and the steel blades scrape the pipe. At the rear end of the "go-devil" a piston that approximately fits the pipe gives the instrument a forward motion, being impelled by the oil pumped through the line. Until within a few years it was customary for men to follow the scraper in its trip, knowing where it was by the whirring noise it made, any obstacle being located by the stopping of the "go-devil." This is no longer thought necessary. The lines are regularly patrolled to discover any leaks, although the system of checking from tank to tank makes it impossible for any serious break to occur without detection.

The export trade in petroleum is now carried on chiefly by means of tank steamships. Last year as many as fifty-nine steamers carried oil from the United States, and fully 76% of the total exports of crude and refined oil, other than those in cases, was made in bulk. These steamers are built entirely of iron, including the decks. When loaded, the whole body of the vessel is filled with oil, no unoccupied space being left between the tanks where gas might accumulate. The vessels are subdivided into eight tanks of moderate size by the introduction of nine thwartship bulkheads, which are very heavily stiffened and made extra thick to withstand the pressure due to any one tank being full while the others are empty. In addition to these there is a longitudinal bulkhead running the entire length of the oil compartments in the center of the ship, which further subdivides each tank into two. Wells, or water spaces, are formed at each end of the oil compartments, which are filled with water when the vessel is loaded with oil, and thereby isolate the oil from the rest of the ship and boiler room, to prevent risk of fire. Each tank is provided with a smaller tank above, running up through the 'tween-decks to the upper deck, which is fitted to allow for the expansion and contraction of the oil, due to difference in temperature, without permitting the oil ever to fall below the level of the top of the tank proper, which is essential to the vessel's stability at sea. It is usual to carry these expansion tanks about half full of oil.

The American Practice of Petroleum Refining.

In a few instances petroleum has been obtained from the earth of such quality that it could be burned for illuminating purposes in its natural state. Somewhat more frequently oils have been found heavy in gravity and so free from both light ingredients and paraffine that they are excellent lubricants in their natural condition, but these instances are rare.

It is no exaggeration to say that two hundred different products are now made from crude petroleum, which may be divided broadly into products that result from distillation and those that result from a reduction of the crude article. By distillation is meant the converting of the crude by heat into vapors, and the condensation of those vapors back to a liquid, from which the manufactured article is produced ; and by reduction, driving the lighter parts out of the crude by heat, leaving the remaining product behind still in liquid form. As petroleum in its crude state is composed of an almost indefinite number of differently compounded hydrocarbons, varying in volatility, and as the manufactured products are almost countless in number, it will be readily understood that the methods of manufacture must be many, complicated, and delicate. In the early days of the industry but one product was sought for, and to-day the staple article of manufacture is that same product—refined oil. But the possibility of making other valuable products was soon apparent, and each year experience and study in the art have developed almost unlimited extension of the uses of petroleum.

The main product of petroleum, refined oil for illuminating purposes, is always the result of distillation. At many large works to-day the crude oil, which is the base of all petroleum products, is received into storage tanks of 30,000 to 35,000 barrels' capacity direct from the main trunk pipe lines. Some of the less important refineries do not have this direct connection with the pipe lines, and crude is brought to them in tank cars. These have an outlet valve at the bottom to which hose is connected carrying the oil into a large pipe which conveys it to the tank from which the stills are filled. When the stills are ready to be charged, powerful pumps force the crude oil through large lines into them, as it is important that time should not be wasted in this preliminary work.

The production of refined oil is the result of four distinct steps. (1) Fractional distillation (that is, the vaporizing and condensing of the oil) in a still heated by fire. (2) Fractional distillation in a still heated by steam. (3) Treating the distillates with chemicals and washing them with water. (4) Settling to make the oil clear and bright for delivery.

Crude Oil Stills.—Many different sizes of stills have been tried, from the primitive cast-iron ones of a few barrels' capacity of the early days to the huge cheese-box vessels holding 3000 and 3500 barrels erected at several works. Many different varieties have been tested—upright cylinders, horizontal cylinders, cheese-boxes of various construction, not to mention the unsuccessful devices for effecting continuous distillation. Experience has narrowed the style of stills down to two, their competing merits being a subject of much controversy among practical men. These are known as the cylinder and the cheese-box still. The former is a simple horizontal steel or wrought-iron cylinder 12½ ft., or a little more, in diameter, and 30 ft., or a little more, in length. A cylinder of this size holds about 600 barrels of crude, and is the size generally found at the seaboard works. A circular dome about 5 ft. in diameter and 4 or 5 ft. high is set on the top of the still in the center, as an outlet for the rising vapors, a wrought-iron gooseneck 15 in. in diameter conducting them over to the condenser pipe, to be described later. The still rests on brickwork which surrounds the lower half, the upper half being left exposed. A double firebox is built under the front quarter of the still, but by having the flue for the exit of the gases of combustion in the rear, the heat is applied to the whole length of the bottom and well up on the sides of the cylinder. Some of these stills have flues running along their sides, with dampers to cut off the heat at certain stages of the run.

Cheese-box stills consist of a vertical cylinder 10 ft. in height and 30 ft. or a little more in diameter, of $\frac{5}{16}$-in. wrought iron, with a dome-shaped top of the same material, and a $\frac{5}{16}$-in. steel bottom made in a double curve to provide for expansion. The center is supported on a circular pier of brickwork, which serves also for an exit for the gases of combustion through an underground flue to the chimney. From the center pier a number of brick arches are sprung to the circumference, supplying the still and forming the sides for fire-boxes, of which there are varying numbers according to the design of the builder, which are placed at equal distances from one another on the circumference of the still. A still of the size mentioned holds about 1200 barrels of crude. The vapors from the distilled oil pass through three pipes into a vapor chest above the top of the still, from which they are conveyed through a large number of 3-in. pipes into the condenser. The advocates of this style of construction claim for it the production of a larger yield of refined oil distillate, of lighter gravity and superior color.

Condensers.—Originally these were copper coils, which were soon supplanted by coils of iron pipe in a tank of water. Coils of pipe are still sometimes used, but the general plan for condensers is to have straight pipe of convenient lengths laid one above another, and connected by return bends or manifolds in a rectangular box of iron or wood. Sometimes the distillate is carried through the condenser by a number of separate pipes, and in other cases the vapor passes through one continuous pipe. Any vapor reaching the end of the condenser pipe in the form of gas is taken away to be burned for fuel. The condensed vapor is received at what is known as the running room, where it is watched and tested by the refiner and turned into such one of the several tanks set apart for the different products as, from time to time during the progress of the run, seems best.

Distillation of Crude Oil.—As soon as the stills are filled, a gentle fire is started under them, and the more volatile constituents of the crude are driven off into the condensers, where they are cooled sufficiently to be liquefied, flowing as a liquid from the end of the worm. Some of the very lightest of the naphtha distillate can be condensed only at low temperatures, and then held in liquid form only under pressure. Usually this is not attempted, but the vapor is allowed to escape in gaseous form to be burned for fuel under either the stills or the boilers. As the fire under the still is increased in intensity the condensed vapors that appear at the mouth of the worm grow heavier, and separations or "cuts" are made by the refiner turning the stream into this or that receiving tank as his judgment directs. The points of demarcation between what is known as naphtha and as oil distillate or distillate and residuum are, as can be readily understood, purely arbitrary ones.

Generally the distillation is fractionated into four parts—a light and a heavy naphtha and two separations in the oil distillate, leaving a residuum or tar in the still. In the running of these products the gravity or density of the condensed distillates continues to grow heavier until a point is reached where, in the judgment of the refiner, the color has become so dark that the distillate cannot be treated up to a satisfactory shade in the finished oil. Then the fires are slackened in order to allow the "cracking," already described, to occur. By this the vapors are decomposed or split up into heavier and lighter ones, the former dropping back into the boiling oil, the latter passing over into the condenser pipe to be reduced to liquid form. During this process of "cracking" considerable quantities of uncondensable or permanent gas are produced and utilized for fuel.

From the different Pennsylvania crudes the range of products is somewhat as follows: Naphtha, from 8% to 20%; refined oils, from 70% to 78%; residuum, from 5% to 9%; loss, about 5%. The gravities of naphtha range from 90° to 62°, the gravities of refined oil distillate from 50° to 44°, the gravities of residuum from 25° to 16°. The yields and gravities vary according to the crude run and the products to be secured. There is left on the bottom and sides of the still, after drawing out the liquid residuum, from 1% to 1½% of the original charge, in the form of a coke or solid deposit. This is thrown out and used as fuel. The time required to run off a still of the size described is from three to four days.

Steam Stills.—The naphtha and oil distillates that have come from the crude stills are next put into a still worked entirely by steam. These stills are either horizontal cylinders or upright cheese-boxes, holding about 1000 barrels each. The distillation in them is effected by means of steam coils along their bottom and top. Distillates for illuminating oils are subjected to a reducing, not a distilling, process at this stage of manufacture. The aim is simply to drive off the inflammable gases carried over with the heavier product, in order that the distillate may be rendered safer for consumption in lamps. The heat of the steam vaporizes the more volatile gases and carries them into a condenser to be liquefied, the same as distillate from a crude still. This elimination of the lighter parts from the distillate is continued until the body of the distillate in the still will stand the fire test required.

Treatment with Chemicals and Washing.—The refined oil distillate as it comes from the crude stills is impregnated with tarry matter and inflammable gases, imparting a greenish color and an offensive odor. The gases are driven off in the steam still just described, and the color and odor are improved by the purifying action of chemicals and a thorough washing with water. For this treatment the distillate remains in a large vessel called an agitator—a vertical cylinder holding from 1000 to 2000 barrels, generally lined with lead. It is built with a conical bottom to facilitate the removal of the objectionable impurities and water, as the treatment progresses. The agitator having been filled with distillate, sulphuric acid is mixed with it, and the distillate and acid are thoroughly agitated by means of an air blast introduced at the base of the conical bottom. When the air blast is shut off, the acid, completely charged with the resinous matter which it has picked up in its contact with the distillate, gradually sinks by its gravity to the bottom, from which it is readily drawn off as sludge without disturbing the purified distillate above. The distillate is then treated in the same way with soda or some other alkali, to neutralize any trace of acid that may be left in it. The soda is drawn off like the acid. After these agitations the distillate is thoroughly washed with water sprayed on its top and allowed to percolate through to the bottom. The sludge is turned over to acid-restoring factories or to fertilizer works; the former producing fresh acid and the latter making ammoniated phosphates from it. The treated distillate is now allowed to run into broad shallow tanks called settling pans, where it stands so that water or other impurities will slowly settle. The oil is now bright, clear, and clean, and ready for delivery.

Naphtha and Naphtha Products.—Naphtha as it comes from the crude stills is charged in a still quite like the steam still just described. In this the naphtha is distilled by steam heat, the same as refined oil distillate, except that in the case of naphtha a much larger proportion of the contents of the still is driven out in the form of vapor. The most volatile portions are seldom condensed. These are rhigolene and chymogene, which are gases at ordinary temperatures, having a sp. gr. of 0.625 and boiling at 65° F. They have been used as anæsthetics for surgical operations, really freezing the parts to which they are applied. They also serve as substitutes for ammonia in artificial refrigeration, their evaporation being so rapid that a temperature of 19° below zero F. has been obtained.

The next heavier product is known as gasoline, used very generally in machines for carbureting air to make illuminating gas for dwellings and factories.

Then follows stove naphtha, and after it gas naphtha, which is delivered to gas works of cities, being now one of the staple articles from which illuminating gas is made.

These grades, and others especially made for the purpose, are used in paints and varnishes, because of the readiness with which they evaporate, and in the manufacture of floor cloths, patent leather, etc.

Many of the naphtha products have to be treated with chemicals to deodorize them. This is done in an agitator similar to that employed for treating refined oil distillate, but care has to be exercised to avoid large losses by evaporation. It was, therefore, for some time the practice to effect this agitation by some mechanical contrivance in the way of a vertical revolving shaft fitted with arms, but now an air blast is used as in the case of refined oil. Additional distillation and other manipulations are also needed to finish some of the products designed for particularly delicate uses.

Products from Residuum.—The residuum from the distillation of crude oil is put into stills much like those used for crude petroleum, except that they are smaller, and as the fire used is much hotter and the contained liquid heavier, they are built stronger. The charge is distilled to dryness, leaving a thick layer of coke or porous carbon in the bottom, of considerable value for the manufacture of carbon points for electric light lamps, for fuel, and for many other purposes.

The distillation of residuum for the manufacture of oils and waxes is an industry by itself, requiring perhaps more skill and the use of much more complicated apparatus than the production of refined oil from crude. Tar stills are often provided with a preliminary condenser in the form of cast or wrought iron 8 or 10 in. pipe suspended in the air above the still or condenser box, the temperature of the atmosphere being sufficient to liquefy a considerable portion of the vapors. These air condensers are provided with proper outlets to draw off the condensed oil, the rest of the vapor passing into a condenser, similar to a refined oil condenser, immersed in water. The first part of the distillate run from tar is generally found to be sufficiently light in gravity to be sold for gas-making purposes or to go back to the refinery to be re run for the production of refined oil the same as crude. After this is run off, paraffine oil distillate steadily pours forth from the end of the condenser worm, increasing in gravity and deepening in color until the still is empty. This distillate passes through a treating process much like that employed for refined oil and naphtha except that it is more severe, as the product is so much heavier, requiring longer time, more chemicals, and greater care. From this point the manipulation is in the hands of the producer of wax, as the production of the multiform paraffine lubricating oils is the result of methods used to secure the wax.

Paraffine Wax.—As made from petroleum, paraffine is translucent, of a light yellow to bluish white color, according to the grade of distillate from which it is made and the chemical treatment to which it has been subjected. Valuable paraffine products were not found as the result of a search for them, but in an effort to remove from lubricating oils an element that made them gum on machinery. Samuel Downer, in his experiments in this direction, chilled the oil until it solidified and then pressed it, the solid that was eliminated being wax.

The practice to-day is to slowly chill the heavy oil coming from the distillation of tar by means of a bath of a solution of sodic, or magnesic, chloride, brought to the required temperature by the use of an ammonia refrigerating apparatus. The semi-solid mass is then subjected to hydraulic pressure at a temperature of from 30° to 40°. The cakes remaining after pressing out the oil from the wax are melted and the wax allowed again to crystallize, to be subjected to a much greater pressure at a higher temperature, the aim being to expel as much of the oil as possible. The absence of the wax from the expressed oil gives it what is called a good "cold test," that is, the quality of withstanding a considerable degree of cold without developing paraffine crystals. The absence of the oil from the wax makes it dry instead of greasy when put to its various uses. The temperature to which the distillate is chilled before it is pressed determines what is known as the "melting point" of the wax—that is, the temperature at which it liquefies.

For many purposes, particularly for the manufacture of the finer grades of candles, wax that has undergone even the several purifying processes already described has to be still further freed from oil. This is done by washing it with naphtha or heating it almost to the point of melting, to drain the oil out of it, and then chilling it once more after a slight chemical treatment. In this way a most beautiful, hard, colorless article is secured, which is practically pure crystalline paraffine.

Reduced Lubricating Oils.—The paraffine oils just described are the result of the distillation of the residuum or reduced product left behind in the still when distilling crude petroleum. Other lubricating oils having different characteristics from those of paraffine oils, and therefore better adapted to certain uses, are made more directly from the crude by a reducing process. The lighter elements in the crude are driven off, generally with great rapidity, their quality being ignored in the effort to obtain a proper residue in the still. At some works vacuum stills are employed for this purpose. A refinery making these reduced products is generally known as a lubricating oil works.

MODES OF TESTING PETROLEUM PRODUCTS.

Refined Oils.—In addition to an inspection for color, which is a simple examination by the eye, refined oils are subjected to two tests—one to ascertain the specific gravity, and the other to determine the fire test. It has been pointed out that it is not practicable to make an oil absolutely free from the volatile elements of the crude, or the heavier elements that should be left in the still as residuum. The presence of too large a proportion of the former renders the oil unsafe for illuminating purposes, while too large a proportion of the heavier elements injures the illuminating properties of the oil by preventing it from burning freely. The specific gravity test aims to show the density of the oil, and so to indicate, in a general way, the quantity of the heavier hydrocarbons it contains.

Gravity.—To make a test for gravity, a tall glass jar is filled with the oil and a combined hydrometer and thermometer is immersed in it. The hydrometer, which is graded according to the Baumé scale, registers the gravity, and the thermometer indicates the temperature of the oil. Standards for gravity require the oil to be at 60° temperature when tested.

Flash and Fire Tests.—The test for gravity is of but little moment in comparison with that to ascertain the fire test of the oil. Upon it the public has to depend for a guarantee that the product can be used for illuminating purposes with safety. The apparatus adopted by the New York Produce Exchange for this purpose is that known as the Saybolt Electric Tester, which has been in use since 1879. It is much like the Tagliabue cup, but uses an electric spark instead of a burning splinter of wood to communicate the fire to the vapor. A copper water bath, heated by a spirit lamp or gas jet, has set in its top a glass petroleum holder. A thermometer is held in place in the water bath, and another in the oil, while a device throws an electric spark across the surface of the oil whenever desired. The water bath is filled and heated to 100° F., and the lamp removed. The oil cup is filled to within an eighth of an inch of its top and placed in the bath. When the temperature of the oil reaches 90° an electric spark is sent across it. The lamp is then replaced under the water bath and the spark applied when the temperature of the oil is 95°, and again when it is 100°, 104°, 108°, 110°, 112°, and 115°, or until the oil flashes. The cup prescribed by the Pennsylvania State law is the Tagliabue open cup, which is about the same as the Saybolt cup, except that a lighted taper, instead of an electric spark, is used, the objective point being that at which the oil itself ignites.

Undoubtedly the test most widely employed the world over is that of Sir Frederick Abel, adopted by the English Parliament Aug. 11, 1879. The specifications of the apparatus as described minutely in the law are briefly as follows :

A cylindrical oil cup of gun metal or brass, tinned inside, 2 in. in diameter and 2.2 in. high, provided with a close-fitting, overlapping brass cover which carries the thermometer and test lamp, is suspended in a bath or heating vessel consisting of two flat-bottom copper cylinders, the inner one 3 in. in diameter and 2½ in. high, the outer one 5½ in. in diameter and 5¾ in. high, the smaller set inside of the larger, and the space between them filled with water. A copper cylinder or jacket, 6½ in. in diameter, surrounds the water bath. A thermometer is provided for the water bath and another for the oil. The light for testing is furnished by a little lamp, supported on the cover of the oil cup in such a way that, as a slide is moved—uncovering a square hole in the cover of the cup—it is tilted so as to bring the flame just below the cover, returning to its original position as the slide is moved back. Near the lamp is a little bead, the dimensions of which represent the size of the test flame to be used. Where gas is to be obtained the oil lamp is to be replaced by a gas flame ; but the size of the flame is still to be regulated by the standard bead. The temperature of the water bath is brought to 130° and the lamp used for heating is withdrawn. The oil cup is then filled to within half an inch of the top with oil at 60° temperature and placed in position. When the oil reaches 66° the operation of testing is commenced, the test flame being applied once for every rise of one degree. This is done by slowly drawing open the slide, while a pendulum, 24 in. in length, performs three oscillations and closes during a fourth oscillation, the movement of the slide swinging the light of the testing lamp below the cover of the oil cup, as described above.

Lubricating Oils.—In addition to tests for gravity, flash and burning points, which are made in ways somewhat similar to the tests applied to the refined oil, lubricating oils are subjected to two other tests—to determine their "viscosity," and their "cold test." The test is made by noting the length of time occupied by a given quantity of the oil in flowing through a small orifice, of prescribed dimensions and form, at a given temperature; the longer the time required the greater the viscosity.

By cold test is meant the temperature at which the oil thickens or becomes cloudy, or ceases to flow because of the crystallization of the paraffine it contains. The test is usually made by slowly cooling the oil in a small tube or long bottle, about 5½ in. in length and 1½ in. in diameter, in which a thermometer is inserted to note the temperature at which the oil no longer flows when the bottle or tube is inclined, or the temperature at which deposition of paraffine commences.

Paraffine Wax.—This is subjected to two tests—one to ascertain the amount of oil left in it and the other to determine its melting point. The former test is applied by noting the loss in weight of a given quantity of wax when subjected to a specified pressure for a certain length of time. By melting point is meant the temperature at which the wax after being melted begins to solidify on cooling. A thermometer is inserted in the melted wax and used to gently agitate it until a film of the crystallizing product appears. The temperature as noted is the so-called melting point of the wax.

RUSSIAN PRACTICE OF PETROLEUM REFINING.

The Russian or Baku crude petroleum is a mixture of hydrocarbons, in which the unsaturated hydrocarbons of the olefine series $C_n H_{2n}$ predominate.

The Balakhana-Sabouncha crude (obtained near Baku) on being distilled without "cracking" gives: Light oil (benzine, gasoline), 5% to 7%; illuminating oil (petroleum), 27% to 30%; solar oil (heavy lighting oil), 13% to 15%; lubricating oils, spindle oil, 7%; lubricating oils, machine, 18% to 25%; lubricating oils, cylinder, 2% to 5%; vaseline (paraffine), 1%. The amount of ash in the crude does not exceed 0.09%.

Prof. D. T. Mendeléeff compares the Baku oil with that from Pennsylvania as follows:

1. At the same boiling point, the Baku naphtha (as the Russian crude is called) gives heavier products than the American, or products of equal specific gravity distill over at a lower temperature from the Baku naphtha than from the American.

2. The amount of carbon in the products of similar technical application, or like boiling points, is greater in the Baku naphtha than in the American, and therefore the lighting and lubricating capacity of the former is greater than that of the latter.

3. The amount of light volatile products of distillation, such as gasoline, benzine, etc., is far less in the Baku than in the American oil, and therefore the former can more easily give a safety lighting oil of the ordinary type than the American oil.

4. The ordinary Baku naphtha, of sp. gr. 0.87 to 0.88, gives 25% to 30%, by weight, of petroleum of sp. gr. 0.81 to 0.83, and has, owing to the removal of the more volatile components, a flash point of about 25 to 30° in Abel-Pensk's apparatus.

5. The Baku naphtha yields 40% to 50%, by weight, of heavy safety lighting oil, or Baku oil, having a sp. gr. of 0.82 to 0.84 and a flash point of 40° to 60°. This oil, however, requires lamps having a short distance between the wick and reservoir, and a regular current of air.

6. After separating from the Baku naphtha those lighter products which give the ordinary petroleum of American type, there remains from 10% to 30%, by weight, of an intermediate, so-called, solar or light house oil, of sp. gr. 0.84 to 0.88, which is an entirely safe illuminant, its flash point being very high, but which also requires lamps specially constructed to burn it.

7. After separating the benzine, petroleum, and intermediary oil from the Baku naphtha, and continuing the distillation with superheated steam, about 10% to 30%, by weight, of lubricating oils are obtained. These oils do not solidify in the cold nor oxidize in the air after prolonged purification with sulphuric acid and caustic soda, and have a sp. gr. from 0.87 to 0.91, and a flash point above 100° C.

8. After the distillation of these lubricating oils, the Baku naphtha gives a heavy refuse which, when distilled with the aid of highly superheated steam at 350° to 400° C., splits up into three parts, with the formation of gaseous and volatile hydrocarbons, viz.:

a. A product which solidifies in the cold, and is known as "naphtha tallow," or "sebonapht," containing solid paraffines, and, after the requisite purification, vaseline to the amount of 5% to 10% of the raw naphtha.

b. Liquid hydrocarbons, the amount increasing at the expense of the vaseline, as the pressure under which the distillation is carried on raises; suitable, after refining, for lighting in kerosene lamps.

c. Combustible gaseous hydrocarbons having a high illuminating power, and serviceable as a fuel for the distillation of the raw naphtha.

Thus the Baku naphtha is capable, as Mendeléeff proved by researches which he carried out on a large scale at the Constantinov Works, of being totally distilled—that is, without leaving any carboniferous residue. But in reality such a perfect distillation or utilization of the Baku naphtha is at present impossible, owing to the fact that by this means 100 parts, by weight, of Baku crude give, after deducting those portions which are wasted in the processes of distillation and purification, and which have to be consumed for conducting the actual process of distillation, not more than 80 parts of useful products. Hence the 280 poods of crude now produced should give about 225,000,000 poods of products. Out of this amount only 60,000,000, or at most 80,000,000 poods could be cheaply and profitably exported over the Trans-Caucasian Railway from Baku to Batoum, and 30,000,000, or at most 40,000,000 poods, can be transported via the Caspian Sea and along the Volga for home consumption in Russia. This forms a total of from 90,000,000 to 120,000,000 poods per annum—that is, about one-third of the annual production of crude, or less than half of the possible production of petroleum products. Moreover, the entire utilization of the Baku naphtha can only be realized when the construction of pipe lines from Baku to Batoum, a distance of 840 versts, or 577 miles, gives the possibility of cheap transportation from Baku of both the 50,000,000 to 70,000,000 poods of petroleum which the railway is capable of carrying, and the crude petroleum to be treated on the shores of the Black Sea. From there tank steamers could carry the oil to all parts of the world, and compete in the market with American oil. At present the treatment of the Baku petroleum tends toward the production of only 30% of distillation products, while the remainder forms the so-called refuse. A large part of this refuse is employed as fuel in the place of coal in the distilling plants, and a far smaller amount is sold and shipped, going principally to the Volga region, where the naphtha refuse forms an almost indispensable fuel.

PETROLEUM STATISTICS.

The production of petroleum in the United States since 1889, and the imports and exports, are given in the following table. The statistics for previous years may be found in THE MINERAL INDUSTRY, Vol. I. (1892), p. 361 *et seq.* The production of petroleum in Russia is given in the special tables for that country at the end of this volume.

Production.—The production of petroleum in the Pennsylvania fields last year was smaller than during 1892, but the situation was somewhat improved, and producers felt more encouraged by the reduction of surplus stocks and better prices. Only one new field of importance was developed, that at Primrose and

Midway, and it is in this extreme southwestern portion of the field that operations are at this time most active. The developments in Ohio Township are also promising. The old McDonald field and the newer one at Sistersville have been, however, almost sufficient to keep the pipe lines busy. As was the case last year, in prospecting for natural gas new pools were discovered in Washington and Allegheny counties.

PRODUCT OF CRUDE PETROLEUM IN THE UNITED STATES SINCE 1889.
(Barrels of 42 gallons.)

Year.	Penn. & N. Y.	West Virginia.	Ohio.	Indiana.	Colorado.	California.	Ky. and Tenn.	Other. (*a*)	Total, U. S.
1890............	28,458,208	492,578	16,124,656	63,496	368,842	307,360	6,000	1,532	45,822,672
1891............	33,009,236	2,406,218	17,740,301	136,634	665,482	323,600	9,000	1,504	54,291,9[illegible]0
1892	28,422,377	3,810,086	16,362,921	698,068	824,000	385,049	9,000	1,600	50,512,136
1893............	30,541,740*b*		16,134,485*c*	2,332,303	730,000	600,000	9,000	1,700	50,34[illegible],228

(*a*) Illinois, Kansas, Texas, and Missouri. (*b*) The crude from West Virginia and southwestern Pennsylvania being run into mutual pipe lines, its production cannot be given separately for each State.) Buckeye pipe line runs + Macksbury production.

EXPORTS OF MINERAL OILS FROM THE UNITED STATES SINCE 1889.
(1 = 1000 in quantities and values.)

Year.	Crude Petroleum.		Naphthas.		Illuminating.		Lubricating and Paraffine.		Residuum.		Total.	
	Gals.	Dollars.	Gals.	Dollars.	Gals.	Dollars.	Gals.	Dollars	Gals.	Dollars.	Gals.	Dollars.
1890 ..	96,573	6,535	12,462	1,051	550,873	39,826	39,461	7,687	1,831	92	601,200	55,099
1891 .	96,723	5,366	11,424	868	531,445	34,880	41,247	7,979	1,003	61	681,842	50,[illegible]93
1892 ..	104,013	4,660	16,351	1,033	586,406	31,488	33,805	5,071	329	31	740,905	42,283
1893 ..	114,609	3,926	16,249	933	705,675	31,283	34,763	4,888	461	28	871,757	41,118

MONTHLY AND YEARLY AVERAGE PRICE OF PIPE LINE CERTIFICATES PER BARREL OF CRUDE PETROLEUM AT THE WELLS SINCE 1889.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Av'ge.
1890	$1.05¾	1.05⅛	.90	.82⅝	.88⅞	.89¼	.89⅛	.89¼	.81⅞	.80⅛	.72⅜	.67¼	.86¾
1891.......	.74¼	.78⅜	.74¼	.71½	.69¾	.68⅛	.66½	.64	.58½	.60¼	.53¾	.59⅛	.67
1892	.62⅜	.60¼	.57⅛	.57⅛	.57⅜	54⅛	.52½	.55	.54⅜	.51⅜	.52	.53¼	.55⅝
1893.......	.53½	.57⅜	.65¼	.68¾	.58¾	.60¼	.57⅝	.58⅞	.64⅝	.70¾	.73⅞	.78¼	.64

According to the *Petroleum Review*, the domestic consumption of refined petroleum in 1893 reached 14,000,000 barrels, against 13,000,000 barrels in 1892, 12,000,000 in 1891, and 11,000,000 in 1890. The sale of Ohio and Indiana petroleum for fuel purposes is estimated at 9,000,000 barrels for 1893, against 11,000,000 for 1892, 10,000,000 for 1891, and 7,000,000 for 1890. The total home consumption, according to the foregoing figures, amounted to 23,000,000 barrels last year, against 23,500,000 barrels in 1892, 22,600,000 in 1891, and 18,000,000 in 1890.

The shipments of refined oils from New York were the largest ever known, and show an increase when compared with 1892 of 99,917,709 gallons, notwithstanding the active competition from Russian oil, the shipments of which from Batoum were 297,879,140 gallons, against 258,571,095 in 1892. Prices for American refined ruled lower, the average for the year being 5.23c. per gallon, against 6.07c. for 1892 and 6.85c. for 1891. Russia has not taken any American refined oil during the period under review. The export movement from Philadelphia and Baltimore was larger than usual during 1893. Crude oil for export ceased to be quoted in the New York market after March on account of the lack of demand. During the first three months of the year the average monthly prices were 5.35c., 5.41c., and 5.55c. respectively, against the average for the whole year of 1892 of 5.49c. and 6.32c. for 1891. The principal shipments of crude during 1893 were made from Baltimore, and it is reported that the great bulk of this went to a refinery in Cuba. The New York exports of crude last year were only 9,588,060 gallons, in comparison with 96,513,923 gallons for 1892. The total exports of crude and crude equivalent from New York in 1893 were 664,508,221 gallons, in comparison with 528,210,472 gallons in 1892, while the total shipments of refined, crude, and naphtha from the United States last year were 836,972,602 gallons, against 699,841,615 gallons for 1892. The exports of naphtha from New York were 4,896,626 gallons less last year than in 1892, and values ruled somewhat higher, the average price for 1893 being 5.55¼c., against 5.13c. in 1892.

The Petroleum Market in 1893.

The petroleum industry in the United States during 1893 showed a slight decline in production, an increased home consumption and export movement in refined oils, while lower values prevailed, except for crude certificates, which are now an obscure side issue at the Exchanges. The shipments from Russia to European countries continue to increase, and the progress made in this direction is at a larger ratio than during the preceding two years. Every legitimate effort is being made by American refiners to compete successfully with the Russian product in European markets by supplying a good article at low prices, and the downward course of values in the United States has doubtless enabled shippers to more than hold their own in foreign ports, while the profits of producers and manufacturers are curtailed thereby, and production restricted in consequence. There is no indication of an early change in the general characteristics of the home market; the industry is on a healthy basis; fluctuations are less violent on account of the absence of speculation; manufacturers are prosperous and enjoying an increased demand for the various products, except fuel oil, which shows a decreased movement during the year under review.

At present the Standard Oil Company practically controls prices in the United States, being the only buyer, and at the same time itself a large producer. The Indian and European market, where American petroleum formerly held full sway, is now being largely supplied by the Russian oils.

Mr. Worthington C. Ford, Chief of the Bureau of Statistics, in reviewing the present situation of our petroleum market abroad, makes the following remarks:

"American petroleum is meeting severe competition in foreign markets, and a competition, too, that has told adversely in many directions. The success of its only rival has been due to the natural protection of distance. While the exports of petroleum in the form of illuminating oil have shown a steady increase from year to year, with occasional fluctuations, yet the direction of the trade in this article has changed materially. Countries once good customers have diminished or ceased their demands. For example, Austria-Hungary, taking annually from 15,000,000 to 24,000,000 gallons, has almost ceased her imports since 1887.

France, never a large direct importer of the refined oil, took an unusual quantity in 1893 (8,161,023 gallons), more than her imports in any one year since 1871.

"By a treaty arrangement entered into by France and Russia, the concessions of which are temporarily granted to the American product, a differential tariff duty is fixed for crude and refined petroleum. The effect of this arrangement, unless it is made to apply permanently to the American product, will strongly favor the import of the Russian article, and so result in a diminution of the French market for American oil. Russia has practically ceased to be a customer in American oil, more intent upon fostering her own industry. So also the direct exports to Spain have come to an end, while Gibraltar has ceased to be the importer of the millions of gallons that she used to be. Turkey in Europe must obtain its supplies from the neighboring Russian oil field, as its imports of oil from the United States have practically ceased. The imports of Germany and the Netherlands are also much diminished in quantity, and only Italy, Norway, Sweden, and the United Kingdom give evidence of a steady increase in the demand for the American product. The position of American illuminating oil in Europe has materially changed since 1871, as well from the competition of the Russian oil fields as from a desire on the part of some nations to refine in their own establishments.

" In other parts of the world have occurred the same changes, but not due to a restriction of imports with the object of building up a local refining industry. It would be well to glance at the effect of Russian competition in British India. In 1887 and 1888 the imports of petroleum into British India were 31,412,000 gallons, and in 1892 they were 58,109,000 gallons, the general tendency being for the mineral oils to supersede the vegetable oils used by the peasantry. Within the five years Russian oil has been introduced into India and gained an important position ; and being of good quality and cheaper than the American oil, if for no other reason than the lower freight from Batoum, on the Black Sea, than from our Atlantic ports, it is not improbable that the American product may be driven out of the market. This would practically mean the nearly complete cessation of any direct trade of the United States with British India, for 92% of our exports to India consist of petroleum.

" As a matter of curiosity, the first import of Russian oil into India was noted in 1886–87, when about 1,500,000 gallons were imported. In that year 29,000,000 gallons of American oil were imported, and on this showing the imports of American oil have actually decreased, and the entire growth of the Indian demand has been absorbed by Russian oil interests. Price, Russian, 12.3c. per gallon ; American, 12.2c.

" Few countries of Europe admit petroleum free of duty. These few are Sweden, Norway, Belgium, and the United Kingdom. Germany admits mineral oil for industrial purposes or for refining, but not intended for manufacture of illuminating or lubricating oils. Under certain conditions and under official control it is free. A few countries have a uniform rate of duty for all grades of mineral oil, not discriminating between the crude, refined, heavy, or lubricating oils. Russia imposes a duty of 1 ruble the pood, a duty that is simply prohibitory, amounting to $2.45 per cwt. Turkey imposes a general duty of 80% ad valorem. Greece is peculiar in that it prohibits the importation of petroleum oil and levies a duty of $4 per cwt. on other mineral oils. The tariffs of France and Spain are designed to favor a domestic refining industry.

"Large as have been the increased exports of paraffine and paraffine wax, they have been monopolized to a great extent by the United Kingdom. Germany has proved the only competitor, gradually increasing its imports until in 1892 it took one-tenth, but in 1893 has declined to one-twentieth. In the English market there is no competition with the American product. Apart from a small quantity, 20,049 cwt. from Burmah, the only other item of importance is an import of 7050 cwt. from Germany. Of a total import of 552,572 cwt., the United States supplied 525,024."

Negotiations are progressing between the Russian petroleum exporters and the American Standard Oil Company about dividing the world's market between them in the following manner: The Standard Oil Company to supply 70% and Russia the remaining 30% of the requirements of the importing countries. While the Standard Oil Company and the Russian producers are thus endeavoring to compromise matters, the American concern is competing more keenly than ever against the new Crescent Pipe Line, which, especially in France, has proved a thorn in the flesh of the Standard. This latter company now intends to undersell the former in France, and has built a store at Rouen capable of handling 600,000 barrels per annum. Sites have also been bought for similar installations at Marseilles, Cette, Bordeaux, and Havre. A large depot has been erected in Paris, which is being supplied from Rouen. The Standard Oil Company is thus endeavoring to gain the same footing in France that it already holds in Germany through the German-American Petroleum Company; in England through the Anglo-American Oil Company; in Holland and Belgium through the American Petroleum Company; in the Scandinavian countries through the Danish Petroleum Company, and in Italy through the Italian-American Petroleum Company.

PHOSPHATE ROCK.

By C. Gustavus Memminger.

During the first half of 1893 the low prices of phosphate tended in a great measure to cause the mining companies to restrict their output, reduce all expenses, and in every way lower cost of production. The hurricane of the 27th and 28th of August practically destroyed the river-mining phosphate industry of South Carolina, and the subsequent conflict between the miners and the State, on the question of royalty from $1 to 50c., kept the river miners, with one exception, from taking steps toward resuming operation until the royalty question was settled by the legislature in December. This source of supply being cut off, a rise of prices ensued, and there was an increased demand for Florida phosphates to fill the place of the South Carolina river rock. The Florida miners met this increased demand, and, in spite of their restricted operations during the earlier part of the year, made an output of 70,130 tons more than in 1892.

The Hard-Rock Phosphate Region of Florida.—The hard-rock sections in 1893 showed marked improvement in mining and milling methods, the material being handled, where possible, by machinery, and every effort made to reduce cost of production. The output for the year was 245,851 tons, which was an increase of 43,832 tons over that of 1892.

In the earlier stages of hard-rock mining the boulder rock was the kind sought, all other material being carried to the waste dump. But as mining progressed, and the bowlders and larger pieces of rock became exhausted and more difficult and expensive to obtain, attention was directed to the smaller pieces of hard rock found with the bowlders. These were of the same grade as the bowlders, but could be made available only by a system of washing and screening to separate them from the clay and sand with which they were mixed. Various experiments were made in this direction, and now all well-equipped mines have washing plants.

The hard phosphate rock, which is mined by steam shovels or by hand, is dressed by crushing with rolls and treating the product in log-washers (like those commonly used for dressing iron ores), which discharge into revolving screens, where the phosphate is rinsed free from sand by clean water, and afterward dried in rotary cylinders or otherwise, and finally raised to the storage bins.

The recovery of the small pieces of high-grade phosphate (commonly called gravel) has thrown a new light on the industry. Formerly bowlder mining was a hazardous affair at best, the deposits being so extremely pockety that a regular output was absolutely uncertain, but since the gravel has been utilized operations have been systematized so that a regular and uniform output of high-grade phosphate can be counted upon. The thorough washing of the rock reduces the percentage of iron oxide and aluminum, and furthermore, by crushing the rock to a uniform size, it can be handled more economically by conveying machinery from storage bins to cars and from cars to vessels.

ANALYSES OF A NUMBER OF SAMPLES OF FLORIDA HARD-ROCK PHOSPHATE.*

Constituents.	Shepard's Lab'ratory, 1200 Samples.	English Analyses, 4 Cargoes.	O. Grothe, 8 Cargoes.	B. F. Gibbens' Lab'r't'ry, 1 Cargo.	Average.
Phosphoric acid	37.36%	....	....	....	....
Phosphate of lime	82.10	78.75%	79.80%	78.37%	80.02%
Carbonate of lime	4.27	....	....	....	....
Oxide of iron and alumina.	2.38	2.81	2.35	2.46	2.64
Carbonic acid	1.88	....	....	....	....
Moisture	1.70	....	.58	....	....
Undetermined	....	....	....	....	....

* Under head of "hard rock" is included plate rock and gravel.

An analysis of a sample from a cargo of hard-rock phosphate from Hernando County, by Augustus Voelcker & Sons, gave the following result: Organic matter and water in combination, 1.39%; phosphoric acid, 35.11%; lime, 47.07%; oxide of iron, 0.65%; alumina, 0.49%; magnesia, 0.26%; carbonic acid, etc., 0.54%; insoluble silicious matter, 8.49%—total, 100%. The equivalent to tribasic phosphate of lime was 76.5%; a rough sample contained 2.04% moisture.

An analysis of a sample from a cargo of hard-rock phosphate from the Dunellin district, also by Augustus Voelcker & Sons, gave phosphoric acid, 36.63%; lime, 49.08%; oxide of iron, 0.74%; alumina, 1.60%; insoluble matter, 3.39%; undetermined, 7.93%; organic matter and combined water, 0.63%—total, 100%; equivalent to tribasic phosphate of lime, 79.97%.

Florida Soft Phosphate.—Soft phosphate is being mined on a small scale, and used locally as a direct fertilizer without acidulation. The question of the availability of the phosphoric acid as a plant food in this form will require long and careful experimentation. The percentage of phosphate of lime in soft phosphate rock varies from 39% to 70%, averaging about 64%. The percentage of iron oxide and alumina ranges from 2% to 15%. The following analysis of a sample of soft phosphate from Hernando County, made at the Pratt Laboratory, gives the chemical composition of a selected sample: Moisture hydroscopic, 0.20%; water combined, 1.75%; silica, 26.90%; phosphoric acid, 29.49%;* iron and alumina, 2.75%.

Florida River Pebble Phosphate.—The output in 1893 was 99,325 tons. Peace River pebble phosphate was the first mined and shipped from the State. Up to January, 1894, 342,666 tons had been shipped. River pebble is very uniform in grade, ranging from 60% to 62% phosphate of lime, and from 2% to 3% iron oxide and alumina. On this account it is especially well adapted for the manufacture of superphosphate.

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* Equivalent to bone phosphate 64.38%.

Peace River, which has furnished the bulk of the river pebble, rises near Bartow, and flows in a southerly direction into Charlotte Harbor. Its total length is 200 miles. The Alafia River, a small stream flowing into Tampa Bay, has also produced a considerable quantity of river pebble. River pebble also occurs in the Caloosawhatchie, Miakka, Manatee, and Black rivers, but is of a low grade.

The method of raising the river pebble is simple. Dredge boats are used, furnished with 8-in. to 10-in. centrifugal pumps attached to which are suction pipes suspended from booms. The pebble in the river beds is loosely intermixed with sand and readily raised by the centrifugal pump. The pebble passes from the pump into a rotary screen, where a separation of the sand is effected; the pebble discharges from the screen into lighters alongside the dredge boat; these lighters are towed to the drying plant, where the pebble is raised into bins, whence it passes into rotary dryers and from the dryers to the storage bins. The storage bins are so arranged that the pebble can be loaded directly into cars by means of chutes.

River mining was very simple so long as the supply of pebble in the river beds lasted and the cost of mining was small, but it soon became apparent that their exhaustion was only a question of two or three years. The attention of the miners then became directed to the deposits lying under the swamps adjoining the present river course, which evidently were formed by the river at earlier periods. These swamp deposits lie under an over-burden of sand, varying in thickness from 5 to 15 ft., and usually covered with a heavy growth of timber. After clearing off the timber it was found practicable, by placing the pump suction under the banks, to cause them to cave in and then draw the over-burden off through the pump. After this was accomplished the underlying pebble deposits could be handled. Although at first sight this process may not appear practicable or economical, yet by actual demonstration it appears that the swamp deposits can be worked economically in the manner described; and although the cost of mining river pebble has increased, there is nothing to indicate the exhaustion of this class of pebble in the near future.

Florida Land Pebble Phosphate.—The output of land pebble phosphate in 1893 was 61,281 tons. The total production of land pebble since the commencement of mining operations in 1891 has been 82,001 tons. The output in 1891 was 2925 tons, and in 1892 it was 17,795 tons.

Land pebble occurs in a clay-like matrix carrying from 15% to 50% of the pebble, the average workable deposits containing about 25%, a cubic yard of matrix in an average deposit yielding from 700 to 1000 lbs. of clean dry pebble. The over-burden on a workable deposit varies from 3 to 10 ft., and the pebble beds range in thickness from 6 to 20 ft., 10 ft. being a good average deposit. An acre of such deposit will yield about 6000 tons of clean pebble. Land pebble ranges in composition from 65% to 70% bone phosphate, and from 2% to 4% iron oxide and alumina, careful washing and preparation being requisite to reduce the percentage of the latter to a minimum.

Two general methods of mining and preparing the pebble are in vogue: (1) Mining by means of a dredge, or steam shovel, and separating the pebble from the matrix by means of attrition in log washers, and (2) cutting down the banks of pebble by hydraulicking, the pressure being obtained by use of powerful steam pumps, giving from 150 to 300 lbs. pressure. The material thus cut down is passed by the stream of water to the suction of a centrifugal pump raised by this means and passed through screens and washers. Both methods have their advocates, and it will take time and further comparative tests to prove by which the pebble can be produced most economically.

The land pebble, after passing from the washers, is dried in rotary dryers and handled practically in the same manner as the river pebble.

The chemical composition of land pebble renders it especially suitable for making a high grade of superphosphate, and it is simply a question of a short time when it will be mined and prepared more economically than any other class of phosphate in Florida.

An analysis by Voelcker of a large average sample of land pebble phosphate sent to England gave the following result: Moisture, 0.45%; organic matter and water of combination, 1.55%; phosphoric acid, 33.07%; lime, 45.82%; oxide of iron, 1.19%, alumina, 1.63%; magnesia, etc., 5.37%; carbonic acid, 1.64%; insoluble silicious matter undetermined, 9.28%—total, 100.00%; equivalent to tribasic phosphate of lime, 72.19%.

The chief shipping points in Florida are Fernandina, Tampa Bay, and Punta Gorda. Fernandina has nineteen feet of water on the bar and a commodious harbor. The railroad has large well-arranged storage bins for phosphate, and elevators, conveyors, etc., for the expeditious handling of phosphate from the cars and loading into vessels. Tampa Bay has twenty-one feet of water on the bar; at Port Tampa extensive improvements are being made to furnish ample docking room, and every appliance for the economical and rapid transfer of phosphate from cars to vessel will be introduced. At Punta Gorda the phosphate is transferred from cars to lighters and taken to Boca Grande, at the mouth of Charlotte Harbor, where there is ample depth of water. Brunswick and Savannah, Ga., are also becoming shipping points.

The Commissioner of Labor, in a report on the phosphate industry published in 1893, reports the cost of production of phosphate rock at a land-pebble mine turning out from 40 to 50 tons in ten hours as $50 per day, of which $28 is for labor, $20 for wood (fuel), and $2 for oil, packing, waste, etc. The running expenses of a river-pebble mine, producing from 75 to 80 tons in ten hours, is put at $56 per day, of which $34 is for labor, $20 for wood, and $2 for oil, waste, packing, etc.; while the daily expenses of a clay-rock mine producing 30 tons in ten hours are given as $21 for labor, $12 for wood, $1 for oil, packing, waste, etc.—a total of $34. The conditions are so different at different mines, however, that these figures can by no means be taken as average results.

South Carolina Phosphates.—The Carolina phosphate-mining industry developed nothing worthy of note during the first six months of 1893. Owing to the low price of phosphates and the competition of Florida, several of the smaller miners were forced to shut down, but as an offset to this the Charleston Mining Company began erecting an extensive washing and drying plant, which, however, was not put in operation during the year.

On Aug. 27 the coast of South Carolina was swept by a cyclone that seriously injured the river mining industry, destroying the dredges and drying houses. After the storm the river miners called on the State for a reduction of the royalty from $1 to 50c. per ton, claiming that without this reduction they did not feel justified in going to the heavy outlay of refitting, especially in view of the active competition from Florida phosphates. The question of royalty was not settled until December, when a compromise was effected, fixing a royalty at 50c. per ton for a period of five years, provided the price of phosphate did not go above $4 per ton. All the companies, with one exception (the Farmers' Company), took no steps toward repairing damages while the royalty matter was being adjusted, consequently no river rock was raised after Aug. 27. The supply being cut off, the increased demand caused prices to advance somewhat, and induced the land-rock miners, who had shut down, to begin operations, and those companies mining to increase their output.

It is a question whether the world's consumption of phosphoric acid will increase with sufficient rapidity to absorb the Carolina output of phosphate with her rivers working to full capacity, in addition to the increasing output from Florida. An excess of production over consumption must tend to lower prices, and consequently should keep the supply within the demand.

The following list includes the names of all the river and land mining companies in South Carolina, showing the annual mining capacity of each in tons: Charleston Mining and Manufacturing Company, 100,000; William Gregg, 15,000; C. C Pinckney, Jr., 30,000; Charles H. Drayton, 15,000; Rose Mining Company, 15,000; William L. Bradley, 30,000; St. Andrew's mines, 20,000; Bolton mines, 20,000; Wando Phosphate Company, 15,000; C. O. Campbell, 15,000; E. B. Fishburne, 20,000; Horseshoe mines, 20,000; Meadville mines, 20,000; Mount Holly Mines and Mining Company, 15,000; Palmetto mines, 10,000; Beaufort Phosphate Company, 25,000; Coosaw Company, 150,000; Phosphate Mining Company, Limited, 50,000; Farmers' Company, 25,000; Bear Swamp Mining Company, 12,000; W. Y. Fripp's Company, 5000; Williman's Island Company, 15,000; E. C. Williams, 5000; Archdale Company, 15,000; Eureka mine, 15,000; Dotterer mine, 15,000; St. Helena Company, 10,000.

The shipments of South Carolina phosphate rock in 1893 (in tons of 2240 lbs.) were as follows:

	Charleston.	Beaufort.	Total.
Foreign	......	157,371	157,371
Domestic	159.000	75,512	234,512
Consumed	150.000	15,000	165,000
Total	309,000	247,883	556,883

Analyses of several hundred samples of South Carolina rock phosphate by Dr. C. W. Shepard, Charleston, S. C., have given the following average: Phosphoric acid, 25% to 28% (equivalent to bone phosphate of lime, 55% to 61%); carbonic acid, 2.5% to 5% (equivalent to carbonate of lime, 5% to 11%); sulphuric acid, 0.5% to 2%; lime, 35% to 42%; magnesia, trace to 2%; alumina, trace to 2%; sesquioxide of iron, 1% to 4%; fluorine, 1% to 2%; sand and silica, 4% to 12%; organic matter and combined water, 2% to 6%; moisture, 0.5% to 4%.

The total production of phosphate rock in the United States in 1893 was 983,340 long tons, of which 556,883 tons came from South Carolina, 424,457 tons from Florida, and 2000 tons from North Carolina. The production of South Carolina was about 8500 tons more than in the previous year, nothwithstanding the disaster to the river-mining industry, while the production of Florida was

70,130 tons larger. Complete statistics of the phosphate mining industry from the beginning will be found in The Mineral Industry, Vol. I. (1892), p. 366 *et seq.* The importation of fertilizing materials into the United States is given in a general table in another part of this volume.

ANALYSIS OF SEVERAL CARGOES OF RIVER PEBBLE PHOSPHATE.

Constituents.	Cargo of 2000 Tons.			Cargo of 1000 Tons.	
	Voelcker.	Dyer.	Shepard.	Dyer.	Teschemacher.
Phosphoric acid (dry basis)	28.03%	27.91%	28.00%	28.62%	28.75%
Equivalent to tribasic phosphate of lime	61.20	60.93	61.12	62.48	62.76
Lime	40.95	41.52	41.21	42.56	43.90
Oxide of iron	.84	1.01	.80	.81	2.25
Alumina	.93	1.56		1.59	

SHIPMENTS AND CONSUMPTION OF SOUTH CAROLINA PHOSPHATE FROM 1889 TO 1893.
(Tons of 2240 lbs.)

Year.	Shipped to Foreign Markets.	Shipped to Domestic Markets.	Manufactured at Home.	Total Domestic Consumption.	Total Production.
1889	143,002	308,643	90,000	398,643	511,645
1890	219,822	250,936	116,000	366,936	586,758
1891	126,798	295,151	151,000	446,151	572,949
1892	124.454	242,942	181,000	423,942	548,396
1893	157,371	234,512	165,000	399,512	556,883
Total	771,447	1,302,184	703,000	2,035,184	2,776,631
Total from 1867 to 1893	2,631,932	3,456,758	1,354,047	4,810,805	7,442,737

SHIPMENTS OF FLORIDA PHOSPHATES IN 1893.
(In long tons.)

	Hard Rock Phosphate.(*a*)			Pebble Phosphate.			Grand Total.
	Foreign.	Domestic.	Total.	Foreign.	Domestic.	Total.	
Fernandina	125,214	680	125,894				125,894
Tampa	48,900	1,026	49,926	27,412	35,594	63,006	112,932
Punta Gorda				66,629	21,810	88,439	88,439
Brunswick, Ga	34,386		34,386				34,386
Savannah, Ga	27 345		27,345				27,345
Railroads		8,300	8,300		14,500	14,500	22,800
Consumed in Florida							8,000
Unclassified							4,661
Total	235,845	10,006	245,851	94,041	71,904	165,945	424,457

(*a*) Under general head "hard rock" is included plate rock and gravel.

SHIPMENTS OF FLORIDA PHOSPHATES 1888-93.
(In long tons.)

Year.	Hard Rock.	Land Pebble.	River Pebble.	Soft Phosphate.	Total.
1888			813		813
1889	25		3,755		3,780
1890	17,345		33,336	1,700	52,381
1891	88,342	2,925	79,265	10,784	181,316
1892	202,019	17,795	126.172	8,341	354,327
1893	245,851	61,281	110,325	7,000	424,457
Total	553.582	82,001	353,666	27,825	1,017,074

TENNESSEE PHOSPHATES.

BY WM. B. PHILLIPS.

MUCH attention has been attracted by the reports of recent discoveries of phosphate in Lewis, Hickman, and Wayne Counties in the southern central region of Tennessee. So far as yet determined, these phosphate seams occur as regular veins underlying a black shale which is now known as the Chattanooga shale, and which is of Devonian age. They lie almost flat, running in under the shale like a coal seam, but of such color and texture as to forbid any one mistaking them for the latter. The maximum thickness of phosphate rock so far observed is 40 in., with black shale above and grayish blue limestone beneath. The rock is of at least three different colors, and of three different textures: 1. A blue-black, fine grained, dull-looking rock, filled with rounded nodules, some of them extremely small. 2. A yellowish brown, coarse or fine grained rock, inclosing a center of blue-black or grayish black rock. 3. A light gray rock, full of impressions of shells, and resembling a piece of air-dried coquina.

There is a persistent seam of grayish black, coarse or fine grained phosphate rock underlying the black shale in Hickman County. It is reported as being 24 in. thick in places. It will carry from 20% to 30% of phosphoric acid, with from 2% to 4% of alumina, but cannot be profitably mined at any locality yet discovered.

The black shale above the phosphate is very variable in thickness, being everywhere capped by what is known as the Harpeth shale, a knarled, bluish-gray rock, varying in thickness from 3 or 4 to 200 ft. Between this shale and the black shale there is a persistent stratum of phosphatic nodules, rounded and of the most diverse shapes, but rarely more than 6 in. thick. These nodules are imbedded in a bluish-green matrix and contain from 28% to 34% of phosphoric acid. They would make an excellent material for the manufacture of acidulated phosphate if it were possible to mine them, but it is not. Occasionally the nodules are distributed in the black shale itself. It is too early to speak of the workable area. Phosphate rock is known to occur over a territory 20 miles wide by 75 miles long, but in a great part of this the seams have received scant attention.

A typical vertical section of the rocks in Hickman County from the top of the Harpeth shale through the phosphate seam shows, in descending order: 1. Harpeth shale. 2. Phosphate nodules. 3. Black shale. 4. Phosphate rock. 5. Limestone bed-rock.

Analyses of phosphate rock from workable seams give these results: Oxide of iron, 2.32% to 6.92%; phosphoric acid, 26.74% to 31.94%; insoluble matter, 6.40% to 13.90%; alumina, 2.71% to 7.06%; lime, 29.60% to 41.30%; sulphur, 0% to 4%; carbonic acid, 0% to 1.50%; moisture, 0.20% to 0.60%. Sulphur occurred in two samples only.

It may be said that there is good phosphate rock in Hickman and Wayne Counties; some of this is so situated that it can be mined and treated properly, and some cannot. Explorations may reveal the existence of other deposits.

There are wide areas within which no careful prospecting has been done, although it is known that the phosphate rock is found in greater or less quantity. So far as the analyses show, the content of alumina is not such as to be a serious obstacle in the way of using the rock for the manufacture of acid phosphates. It is not likely that at any place large quantities of rock can be mined in any other way than as coal is mined, by drift or shaft.

Phosphate Mining in Canada.

By J. T. Donald.

The Canadian phosphate mines are opened in a series of rocks of Laurentian age, largely pyroxenine in character, which runs from about fifteen miles north of Kingston, on the St. Lawrence, in a northerly direction to the Ottawa River. Crossing this river, which is here the boundary between the provinces of Ontario and Quebec, it stretches far to the north. Owing to lack of means of communication, the limit and value of the northern portion are undetermined.

Mining was begun in Ontario as early as 1855 or 1856, and until about 1870 was entirely confined to that province.

During the first few years of the industry the output was insignificant, and it increased so slowly that the total production for the years 1865 to 1870 did not exceed 1000 tons per annum. About 1870 mining was begun on the deposits along the Lievre River in Quebec. The industry then grew rapidly, and from 1884 to 1889 was in an especially flourishing condition, but since 1889 it has steadily declined on account of the competition of other phosphate regions, which can produce more cheaply than the Canadian mines.

During 1893 only two phosphate companies were at work, and one of them for only a short time. In addition to their output a small amount of mineral has been obtained as a by-product in mica mining and by a few private owners.

One feature of the year was an attempt to improve the method of dressing the ore, by one of the companies which has been at work, resulting in shipments of mineral containing 87.83% tribasic phosphate of lime, which is believed to be the richest ever shipped from Canada. There was a demand for low-grade rock for the Chicago market, and to supply this, small lots of stuff that had been lying around various mines for years have been shipped.

The phosphate rock of Quebec is found in irregular pockets, and the mining of it is attended with much uncertainty. During the past year the British Phosphate Company, operating near Buckingham, had been using a diamond drill for exploration work, and the results already obtained show clearly that the use of this will be economical.

The shipments during the year were principally to London, Liverpool, and Chicago. A small amount is consumed by local factories in the production of fertilizers and as a source of acid phosphate of lime, which is used as a substitute for cream of tartar in self-raising flour and baking powder.

The exports of Canadian phosphate rock for the years 1878–91, as stated by the Geological Survey of Canada, are given in the following table. The writer is of the opinion that the amounts are approximately correct, but certainly the values for several years are largely exaggerated. The statistics for 1892 and 1893 are obtained from private sources.

Year.	Tons.	Value.	Year.	Tons.	Value.	Year.	Tons.	Value.	Year.	Tons.	Value.
1878	10,743	$208,109	1882	17,153	$338,357	1886	20,440	$343,007	1890	28,457	$499,309
1879	8,446	122,035	1883	19,716	427,668	1887	23,152	433,217	1891	17,271	384 661
1880	13,060	190,086	1884	21,709	424,240	1888	18,776	298,609	1892	8,530	76,770
1881	11,968	218,450	1885	28,969	496,293	1889	29,987	394,768	1893.	7,890	61,962

Of the shipments for 1893 Great Britain and the Continent took 5190 tons, 400 tons were required for local fertilizer manufacturers, and the remainder, 2300 tons, was exported to Chicago.

PHOSPHORUS.

Phosphorus (atomic weight, 30.96 ; vapor density, 61.92), when kept in perfect darkness under distilled water, from which the air has previously been expelled, is a colorless and transparent substance, but usually it has a yellowish-white color and waxy appearance. Its sp. gr. varies from 1.3 to 1.84. At the ordinary temperature of the air it is as soft as wax, but in cold weather it becomes brittle. It fuses at about 45° C., and remains fluid for a considerable time though cooled below its melting point, especially if kept in an alkaline solution. It distills at 269° C., but gives off fumes appreciably at the ordinary temperature of the air. The vapor of phosphorus is slightly soluble in water. The solid element is somewhat soluble in alcohol, ether, linseed oil, and oil of turpentine, but the best solvents are sulphide of carbon, chloride of sulphur, and chloride of phosphorus. Phosphorus ignites in the air at a temperature of 34° C.

Amorphous, or red, phosphorus is usually met as a powder of a red color, or in reddish-brown lumps, which break with a conchoidal fracture. Its sp. gr. is about 2%, being notably more than that of ordinary phosphorus. Amorphous phosphorus, moreover, is insoluble in bisulphide of carbon or the other solvents of white phosphorus, but, when ground, dissolves very easily in nitric acid. It is unaltered by exposure to air, and does not ignite until heated to 240° C. It is non-volatile and non-poisonous.

Phosphorus is widely distributed in nature as phosphate of lime, phosphate of alumina, etc., and it is a frequent constituent of iron ores, from which a large quantity of phosphoric acid is recovered by the basic process of steelmaking. It is an important ingredient of the soil, and is found invariably in the bones of animals.

Bone-ash was formerly the only material used for the production of phosphorus in the arts, the rock phosphates not having been found available until recently, notwithstanding the high percentage of phosphoric acid which they very frequently hold, while the bones used by phosphorus manufacturers contained before burning only from 11% to 12% phosphorus ; as bone-black they had from 16% to 18%, and as bone-ash from 20% to 25.5%. High-grade phosphate rock, containing over 70% of phosphate of lime, is now generally employed by phosphorus-makers instead of bone-ash, the process of manufacture otherwise remaining practically the same. This consists in decomposing the tricalcic phosphate ($Ca_3[PO_4]_2$) of the rock with sulphuric acid, which yields phosphoric acid and sulphate of calcium, according to the following reaction :

$$Ca_3(PO_4)_2 + 3H_2SO_4 = 3CaSO_4 + 2H_3PO_4.$$

The weak phosphoric acid solution is filtered and concentrated in lead-lined iron pans until it is entirely freed from gypsum. The sirupy fluid is then mixed with coarsely ground wood charcoal, and carefully dried over a fire in a cast-iron pot at a dull red heat. The ortho-phosphoric acid is thus resolved into meta-phosphoric acid (HPO_3), and the charred mass is then heated to a white heat in clay retorts in a galley furnace, when phosphorus distills over, according to the following reaction :

$$4HPO_3 + 12C = 2H_2 + 12CO + P_4.$$

The fire-clay retorts used in the process are generally shaped like those used for Nordhausen sulphuric acid, and are placed in a furnace holding twelve retorts or each side, so arranged that the flames draw around them in all directions. Each retort holds from 6 to 9 kilograms of the mixture to be reduced. The phosphorus is distilled over into receivers made of glazed clay, which are filled with water, and into which the necks of the retorts are tightly luted. The distillation of a charge requires about forty-eight hours' steady firing, a full white heat being reached at the end of the operation. The product obtained from the first distillation consists of crude phosphorus, amorphous phosphorus, and a mixture of phosphorous silicide, phosphorous carbide, etc. According to J. B. Readman, who is an excellent authority, the following figures may be taken to represent the yield from a known amount of phosphoric acid: 502 lbs. of phosphoric acid liquor containing 25.7% of free P_2O_5 were mixed with 137 lbs. of coarse wood charcoal and charred as described. The charred mass weighed 380 lbs., and on distillation it yielded 38 lbs. refined yellow phosphorus and 67 lbs. of retort residue. This represents 67.5% of the theoretical 56.2 lbs. of phosphorus contained in the free P_2O_5 of the original acid liquor.

The crude phosphorus is refined by various methods. One used in France consists in filtering molten phosphorus through a layer of coarsely powdered charcoal, covered with water at a temperature of 60° C. The filtered phosphorus is run off through a tap at the bottom of the apparatus. By another method molten phosphorus, previously mixed with charcoal powder, is forced by steam pressure through porous unglazed porcelain, or earthenware plates, fixed in an iron cylinder, the charcoal being used for the purpose of preventing the pores of the plates from becoming choked. In Germany crude phosphorus is refined by redistillation in iron retorts, while at a factory in Paris a chemical process is used, the crude phosphorus being treated with 3.5% sulphuric acid and the same proportion of potassium bichromate. This seems to be the most rational plan. It is claimed that very pure phosphorus is obtained by it. The yield of pure phosphorus by the various methods of refining is from 90% to 96% of the crude phosphorus.

An electrolytic process for the manufacture of phosphorus, known as the Readman-Parker & Robinson system, was tried experimentally at Wednesfield, England, early in 1892, and the results were claimed to be successful,* but the

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* *Journal of the Society of Chemical Industry,* Jan. 31, 1892 ; *Engineering and Mining Journal,* March 26, 1892, p. 351.

process has never been applied on an industrial scale. It is said that possession of it has been acquired by the firm of Albright & Wilson, who control the English market, and in fact the market of the world.

Phosphorus is found in the market in the form of round sticks, being molded in that shape through glass tubes. When large quantities—i. e., more than 100 lbs.—have to be shipped, it is usually packed in water in small casks, which are coated on the outside with molten pitch and finally covered with stout canvas. Another method of packing phosphorus is in sheet-iron or tin canisters, hermetically sealed. Phosphorus is stored at the factories, under water, in strong iron tanks or wooden tanks lined with tin.

Amorphous, or red, phosphorus is prepared by heating ordinary white phosphorus at a temperature of 250° C., with exclusion of air and water, in a closed vessel and under pressure. The time required for the operation is variable, and can be determined only by experience. On removing the red phosphorus from the vessel in which it has been produced it is placed under water, and crushed to a pulp in order to separate any unconverted white phosphorus. This operation is attended with much difficulty, it being impossible to use bisulphide of carbon to dissolve the white phosphorus on account of the danger of ignition. The plan usually followed consists in treating with a solution of caustic soda the mixture of the two varieties of phosphorus which are to be separated, whereby the white phosphorus is converted into phosphureted hydrogen gas and sodium hypophosphite, the red phosphorus which remains behind being subsequently purified by washing with water.

The manufacture of phosphorus is practically controlled by the firm of Albright & Wilson, with works at Oldbury, near Birmingham, England, which is said to produce about 500 long tons per annum. The next largest manufacturers are Coignet Frères of Lyons, France, who work in conjunction with the English concern. There is one phosphorus factory in Sweden, and a number of small works in Russia. During 1889 and in 1890 there were ten works in operation in Russia, nearly all of them being in the eastern and northern Governments, one only being situated at Tumen, in the western part of Siberia. The Government of Perm, where there are six works, is the chief center of the industry, the average yield being 10,450 poods (336,939 lbs.), or 91.8% of the whole product of the empire. The value of phosphorus in Russia varies from 28 to 41 rubles per pood for the white, and from 40 to 62 rubles per pood for the red. Russia exports phosphorus to other countries, and also imports a small amount, but the imports have been decreasing rapidly during recent years.

The only manufacturer of phosphorus in the United States is the firm of J. J. Allen's Sons of Philadelphia, which makes a small output. The American market is chiefly supplied by the English manufacturers, no other kind being imported into this country at the present time, although some years ago a small amount of Russian phosphorus was entered for consumption. The value of English phosphorus in New York at the present time is from 50c. to 55c. per lb. at wholesale.

The chief use for phosphorus is in the manufacture of lucifer matches, which were first made in Paris in 1816, though they do not seem to have become generally known until 1833. The industry, however, soon became one of vast importance. Besides the manufacture of matches the uses of phosphorus are insignificant, it being employed only in chemistry and for some minor purposes. Commercial phosphorus usually contains some impurities, such as sulphur, arsenic, and occasionally a trace of calcium, which is due probably to the lime of the phosphate rock used as raw material.

PRECIOUS STONES.

During the past year there have been no important developments in precious-stone mining in the United States. The exhibits which appeared at the World's Fair attracted a good deal of attention and were the means of selling several thousand dollars' worth of agatized woods and garnets from Arizona and New Mexico, though the latter find a ready sale at all times. During the past five years something over $250,000 worth of pearls has been secured in Wisconsin, and considerably over half as much from Texas, Tennessee, and Kentucky. A few diamonds have been found in California, North Carolina, Georgia, Wisconsin, Kentucky, and Montana, but not enough to be of any moment. Mr. George F. Kunz, the well-known gem expert, referring to the diamond industry, says that the subject of diamond cutting in the United States is well worthy of consideration when it is remembered that in the fiscal year ending June, 1893, there was paid a duty on $15,000,000 worth of cut diamonds imported into this country. The rough stones did not, in all probability, cost more than half of this amount, and allowing one-tenth for power and rental and an equal amount for profit, it would still leave $1000 a year for 4000 diamond cutters had the work been done in this country. This condition of the industry is said to be due to the difficulty which dealers have in obtaining "rough" at first hand.

The imports of precious stones into this country will be found in the tables in another part of this volume.

Kimberley Diamond Mines.—A description of the diamond fields of Brazil will be found in Vol. I. of The Mineral Industry. The following information concerning the Kimberley mines, Griqualand, South Africa, is from a valuable report by Mr. Gardner F. Williams:

At the Kimberley mines the diamond-bearing ground, or "blue," is of volcanic origin. It has been determined to be a picrite-porphyry, consisting of a much decomposed mass wherein numerous little olivine crystals, mica splints, and slate fragments are imbedded. The surface of the country is covered with red soil from 1 foot to 5 ft. in depth, underlying which is a much decomposed basalt from 20 to 90 ft. thick. Below the basalt is black slate or shale which contains considerable carbon and a large quantity of iron pyrites. This shale varies from 200 to 250 ft. in thickness and ignites spontaneously in the open mine and on the reef tops. Underlying the shales is a bed of conglomerate composed of small and large stones, well rounded and firmly cemented together. Below the conglomerate for about 400 ft. is a very hard amygdaloidal rock, called by M. Moulle "melaphyre," which has been determined by Stelzner as "olivine diabase," virtually composed of the same minerals,—plagioclase, augite, and olivine,—the one being granular, the other porphyritic. Underlying the amygdaloidal rock is quartzite 355 ft. thick, and beneath this there is a body of shale.

The mines were not filled with the same material at one and the same time. Each mine has its distinctive characteristics, and even in the same mine all the blue does not seem to have been deposited at once. In illustration of this is the striking fact that both in the De Beers and the Kimberley mines the west side blue ground is wholly unlike the other portions of the mines and carries very few diamonds, and even these are unlike the diamonds elsewhere in the mines.

All the rocks surrounding the pipes of blue ground lie nearly horizontal, but dip slightly to the north. In the De Beers mine there is a dike of igneous rock extending from the south part of the mine around the east and north sides, and lost in the unexplored poor blue of the west end. This rock, known as the "snake," owing to its serpentine course across the mine, is analogous to the main body of blue but not so much decomposed, and probably a younger eruptive formation coming from the same source. The "island," a gigantic horse of country rock imbedded in the blue ground of the De Beers mine, is an olivine diabase the same as the amygdaloidal rock except that it is filled with numerous veins of zeolite.

There are different opinions as to when the diamond itself was formed or crystallized. The proofs are most conclusive that the diamonds were not formed *in situ*, but have come up from below with the blue ground. The frequent occurrence of broken crystals imbedded in the blue is sufficient evidence that the diamonds are not in their original place of crystallization, for it is impossible for nature to produce a broken diamond.

In the vicinity of Kimberley there are four diamond-bearing mines—Kimberley, De Beers, Du Toit's Pan, and Bulfontein. There are numerous other pipes carrying blue ground, but these do not carry diamonds in payable quantities. The whole of the De Beers and Kimberley mines belong to the De Beers Consolidated Mines, Limited, and nearly the whole of Du Toit's Pan and Bulfontein mines is either perpetually leased or held under working agreements by this company. The four mines were discovered in 1867, and to-day produce over 90% of the world's diamond output. From the discovery until ten years ago all the mines were worked as open quarries, then underground working was commenced in the Kimberley mine. Two years later an inclined shaft was started at De Beers. The system adopted in the latter mine is as follows: Tunnels are driven across the mine from west to east, about 120 ft. apart, and are connected with each other by two tunnels running north and south, one near the west side of the mine and one midway between it and the east margin. From these short offsets 10 ft. long are driven every 36 ft. When near the rock they are widened out into galleries, and stoped on the sides until they meet, and upward until they break through the blue ground. The reef (rocks surrounding the pipes of blue ground) partly fills the open space. The workmen then stand on the fallen reef and drill the blue ground overhead. As the roof is blasted back the reef follows. When stoping between two tunnels, the blue is stoped up to the débris about midway between them. The upper levels are worked back in advance of the lower and the works assume the shape of irregular terraces. The main levels (or levels from which the blue ground is hoisted) are from 90 to 120 ft. apart, with intermediate levels every 30 ft.

No. 2 incline shaft at De Beers has four compartments—one for a ladder way, one for a man trolley, and two for the skips. The skip ways are each 5 ft. wide and 4½ ft. high, and provided with 46½ lb. steel rails upon which the skips run. The shaft is inclined 56° 20′ from the horizontal. The back wheels of the skips are about double the width of the front wheels. When the skips come into the pit-head frame, the back wheels take a broader gauge track made of angle iron to keep them in place, while the front wheels pass within the frame and downward and dump the ground automatically into the box. The gauge of the tracks in the incline is 3 ft. 11 in. These skips hold 64 cu. ft., or 4 loads, weighing 1600 lbs. each.

From the surface boxes, into which the blue ground is tipped at the shafts, it is filled into side-tipping trucks holding 20 cu. ft. and sent to the disintegrating floor by means of an endless wire rope haulage plant. The length of the main haulage is three miles, with two branches, one mile and three-quarters of a mile in length, respectively. The depositing floors commence about a mile from the mine and extend for three miles in an easterly and one mile in a westerly direction. The De Beers floors are laid off in rectangular sections 600 yds. long and 200 yds. wide, each section holding about 50,000 loads.*

For a time the blue ground remains on the floors without much manipulation. Moisture and the heat of the sun soon cause it to disintegrate, and large pieces, which when taken from the mine were as hard as ordinary sandstone, crumble to dust. At this stage of the work the winning of the diamonds assumes more the nature of farming than of mining, as the ground is continually harrowed to assist pulverization by exposing the largest pieces to the action of the sun. The length of time necessary for the ground to be exposed before it becomes sufficiently pulverized for washing depends on the season of the year, the amount of rain, and the mine from which it comes. The blue from Kimberley mine becomes quite well pulverized in three months during the summer, while that from De Beers requires double that time. The longer the ground remains exposed, the better it is for washing.

The washing machinery consists of pans, screens, and jigs, called "pulsators." The usual size of the pans is 14 ft. in diameter, with ten arms, each having six or seven teeth, set to form a perfect spiral, so that when the arms revolve the teeth carry the heavy deposit to the outer rim of the pan, while the lighter material passes toward the center and is discharged from the pan. The blue ground is hoisted to the top of the machine and tipped automatically into a long shoot which has perforated pipes laid across it, through which it passes into revolving screens. The ground which is too coarse to pass through the meshes or holes of the cylinder passes out of the lower end into trucks and is redeposited upon the floors, where it remains for about a year, when it is again washed.

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* A truck holding 16 cu. ft. is the unit of measurement throughout the fields. A load of blue ground weighs about 1600 lbs., and covers about 21 sq. ft. when deposited on the floors.

The fine ground which passes through the meshes of the cylinder flows into the pans at the outer rim and is discharged near the center. The heavy deposit which contains the diamonds remains on the bottom of the pan near the outer rim, and is scraped out through a slide opening every twelve hours. At De Beers every two pans are discharged into a third (safety pan) similar in construction to the others. From the safety pans the tailings pass into tanks and are hoisted in tubs by means of bucket elevators and deposited in heaps.

The average quantity of blue ground passed through a pan is from 400 to 450 loads in ten hours, which leaves a deposit in each pan of three to four loads. This is sent to the jigs, or "pulsators," for further concentration. Here it is first passed through screens and classified into four sizes ranging from one-eighth to three-eighths of an inch in diameter. The coarser material passes out at the end of the cylinder, where it is sorted. The meshes of the jig screens are a little coarser than those of the cylinder. Upon the screens a layer of leaden bullets is spread, which prevents the deposit from passing through the screen too rapidly. The heavy part with the diamonds passes through into pointed cones, whence it is drawn off through a pipe and taken to the sorting tables. The lighter material or refuse passes over a lip into a trough and from there is taken to the tailings heap.

The proportion of concentrates is as follows: One per cent. of the total number of tons of ground washed passes to the pulsator plant. Of this about one-third passes out of the sizing cylinder as too coarse, while two-thirds goes to the jigs. Of the jigged material one-eighth passes through the screen bed, and seven-eighths flows over away as waste. Out of every 240 loads of blue washed, one load, or 16 cu. ft., of gravel passes through the hands of the assorters. The assorting is done on tables, first while wet by white men, and then, when dry, by native convicts. The deposit is gone over as often as diamonds can be found in sufficient quantity to repay the cost of convict labor.

In a new plant erected at Kimberley for treating the harder and poorer rock directly—that is, without the usual long "weathering process"—rock breakers and other crushing machines are used.

PRODUCTION OF DIAMONDS AT THE DE BEERS CONSOLIDATED MINES, LIMITED, SINCE APRIL 1, 1888.

Year. (*a*)	Loads Hoisted.	Loads Washed	Carats Found.	Value.	Carats per Load.	Value per Carat.	Cost per Load.	Loads on Floors, Close of Year.	Dividends Paid.			Capital.
									Date.	Amount.	Equal to	
				£ s. d.		£ s. d.	s. d.			£ s. d.	%	£
1889..	944,706	712,263	914,121	901,118 0 5	1.283	19 8¾	9 10½	476,403	1888..	188,329 10 0	5	3,937,050
1890..	2,192,226	1,325,400	1,450,605	2,330,179 16 3	1.09	1 12 6¾	8 10½	1,576,821	1889..	394,786 10 0	10	3,948,955
										394,895 10 0	10	
1891..	1,978,153	2,105.182	2,020,515	2,974,670 9 0	0.96	1 9 6	8 8	1,449,792	1890..	394,895 10 0	10	3,948,955
										394,895 10 0	10	
1892..	3,338,553	3,239,134	3,035,481	3,931,542 11 1	0.92	1 5 6	7 4¾	1,624,803	1891..	394,895 10 0	10	3,948,955
										493,619 7 6	12½	
1893..	3,090,183	2,108,626	2,229,805	3,239,389 8 6	1.05	1 9 $\frac{6}{10}$	6 11$\frac{6}{10}$	2,606,362	1892..	493,619 7 6	12½	3,948,955
										493,619 7 6	12½	
									1893..	493,619 7 6	12½	3,948,955

(*a*) The years 1889, 1890, and 1891 end March 31; 1892 and 1893 end June 30.

PYRITES.

By W. H. Adams.

The year 1893 has been full of surprises to the trade, as pyrites has supplanted brimstone in a great number of instances where least expected a few years ago, all the commercial centers of the United States being now prepared to enter the lists with complete ore-burning plants, and thus in future to be entirely freed from the dictation of foreign sulphur producers.

My estimate of sulphur consumed in this country for the year 1893 is as follows, in tons of 2240 lbs.:

From 107,661 tons imported brimstone, 98% = 105,508 tons sulphur.
" 1,200 " domestic " 98% = 1,176 " "
" 221,000 " imported pyrites, 48% = 106,080 " "
" 95,000 " domestic " 45% = 42,750 " "

Total tons sulphur........................ 255,514

IMPORTS OF PYRITES INTO THE UNITED STATES SINCE 1881.

Year.	Quantity, Long Tons.	Average Sulphur Contents, Per Cent.	Year.	Quantity, Long Tons.	Average Sulphur Contents, Per Cent.
1881	11,927	35	1888	81,000	42
1882	29,818	35	1889	100,000	43
1883	35,811	36	1890	115,000	43
1884	44,250	36	1891	130,000	44
1885	50,000	38	1892	210,000	43
1886	60,000	38	1893	194,934	......
1887	60,000	38			

The growth of the trade in pyrites in America, by districts, is shown by this table:

CONSUMPTION OF PYRITES IN THE UNITED STATES.

	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.
New York and vicinity...	7,000	23,900	29,500	39,000	44 600	55,700	59,000	64,000	72,000	80,000	100,000	90,000
Boston and East'n States	.....	2,500	7,500	14,500	25,800	26,900	27,000	30,000	35,000	40,000	45,000	47,000
Philadelphia and vicinity	.....	2,500	5,000	5,500	11,500	23,600	25,000	25,000	28,000	32,000	50,000	55,000
Baltimore and vicinity. .	. ...	. ...	2,000	4,000	7,500	4,300	5,500	7,000	12,500	14,000	14,000	20,000
Southern States..........	1,000	2,000	3,000	3,000	3,000	3,000	3,500	4,500	7,000	16,000	26,000	30,000
Western States...........	.....	.....	1,000	2,000	4,000	5,000	5,000	10,500	30,000	40,000	55,000	75,000
Totals...	8,000	29,900	48,000	68,000	96,400	118,500	125,000	141,000	184,500	22,5000	290,000	317,000

The fluctuating and uncertain price of brimstone, heretofore the base of sulphuric acid in this country, has for years disorganized manufacturing in certain sections of the country, while at the same time it has been possible for the stronger works along the Atlantic coast to make and hold prices of all acids at rates based upon the cost of sulphur in pyrites.

This country now leads the world in the consumption of sulphur—a changed condition of things which has been hastened by several causes or events new to us as a nation. First in importance as an industry using sulphur is the refining of petroleum. The second has been the discovery and utilization of our enormous deposits of phosphatic materials, which have entered trade channels as a factor of the greatest value within the past fifteen years. We may also notice the benefit accruing to the country at large by placing sulphur and pyrites on the free list, the lessening of restrictions to the entrance of copper-bearing ores rich in sulphur, and a more liberal construction of customs laws relative to metallurgical treatment of ores and minerals from foreign countries. To these causes may be attributed the wonderful increase in the consumption of sulphur—shown by our table of imports to have been from 25,000 tons in 1867, 105,000 tons in 1881, to high-water mark, 135,000 tons, in 1889. The trade has, however, changed materially since that year by the gradual decline in importation of brimstone and the substitution therefor of pyrites, and we are now at the dawn of an era of prosperity in chemical industries which, from our already assured position of strength, promises soon to place us in the first position among the nations.

The belief has been general for many years that in the manufacture of sulphuric acid for chemical purposes brimstone alone was suitable as the source of sulphur, although a study of the abundant statistics in this work clearly shows that barely one-third of the world's production of sulphur comes from brimstone, and a large amount of the acid so produced is consumed in processes which do not require specially pure acids. Thus, if we place the annual consumption of sulphur in all countries at 1,000,000 tons, not over one-tenth that amount is actually used in the manufacture of products where absolute purity in the acid is essential. The large manufacture of sulphuric acid is from pyrites, and while this mineral, as well as some brimstone, contains deleterious substances, yet it is an interesting fact that this enormous tonnage of acid is taken into general consumption without protest. Few people appreciate the many improvements which have been going on in concentration and purification processes, not to speak of the practical methods instituted during the past ten years for the increased efficiency of chambers and other plants in acid-making. It is common at present to find chambers working steadily on pyrites with an output of 4.65 lbs. of 50° sulphuric acid for each 17 cu. ft. of chamber space, as compared with the former practice, where from 22 to 26 cu. ft. were required. Several examples of this excellent modern practice with pyrites, which equals the best averages of works formerly using brimstone, have been given me during the year, and in two cases it is shown that two tons of foreign ores purchased on a guarantee of 51% sulphur have equaled a ton of brimstone in acid-making properties.

This working example confirms the statements heretofore published as to the savings which come from the use of pyrites, and may be stated in this way: Calculating the cost on the basis of 100 units of sulphur in the works.

One ton brimstone "seconds" ex ship Atlantic ports	$20 00
Equivalent of these 100 units sulphur in two tons foreign pyrites, cost	13.00
Saving in using pyrites	$7.00

It is unnecessary to repeat the cost sheets of manufacture of sulphuric acid from brimstone and from pyrites given in THE MINERAL INDUSTRY, Vol. I. The growing popularity of pyrites shows that the advantage of its use is generally recognized.

The imports of pyrites and sulphur into the United States is given with the other imports and exports under appropriate heading at the end of this book.

In 1893 the consumption was as follows : 70,000 tons at New York and vicinity ; 36,000 at Boston and Eastern States ; 60,000 at Philadelphia and vicinity ; 35,000 at Baltimore and vicinity ; 50,000 at Southern States ; 65,000 at Western States—total, 316,000 long tons.

In a commercial sense there are but two States in this country which are regularly producing pyrites, viz.: Massachusetts and Virginia. The Davis mine, in Massachusetts, is credited with an output of 27,000 tons for the year. In Virginia, Louisa County has shipped about 65,000 tons during the year. At the sulphur mines operations were checked early in the season from several causes, and a disastrous fire occurred which entirely destroyed the expensive mill plant erected the year before, and communicated to the shafts and outbuildings at the north end of the mines. Since that time but a small force has been employed, the work being mainly directed to developments on the south end of the deposits. At the Arminius mines work has been prosecuted steadily during the entire year, with no change in the force. Farther depth has been gained, and the No. 3 shaft is now down 630 ft., with openings on the deposit in each direction. Very interesting prospect work, by means of the diamond drill, has disclosed new reserves on the lower levels.

The Virginia Pyrites Company continues, in a moderate way, exploratory work on its property, but without material gain in prospects for ore bodies, although a new shaft is being sunk on the north side of Contrary Creek, which promises better results.

A new development on property lying between Mineral City and the Arminius mines has been started with energetic courage, and a shaft to the depth of 150 ft. in dead ground has been sunk with the idea of drifting to explore the outlying territory. If ores are discovered, it is the intention to use the Arminius Railway to reach the railroad tracks.

In Prince William County the development of a small body of excellent pyrites still continues, and several shipments to Baltimore have been made during the year.

A very large production of acid from the sulphur of blende at the Matthiessen & Hageler Zinc Company of Lasalle, Ill., has been made during the year, and this business is growing rapidly.

The depression in general business throughout the Southern States has retarded explorations and workings which have been begun in many places along the mineral belt, and there are but two locations—at Blacksburg, S. C., and Tallapoosa, Ga.—where work is being prosecuted at present.

The Canadian mines at Capelton, opened in a large way in the year 1865, and regular producers of copper-bearing pyrites ever since, have continued to forward the usual supplies for seaboard chemical works, and have also shipped a large quantity into the interior of the country. The deposits are, however, gradually growing less in extent and the cost of production greater in the lower parts of the mines, and competition from Spanish ores is beginning to be felt in Eastern markets, so that a new era is soon to be met which the possible placing of acids on the free list will not overcome.

Newfoundland ores have also been shipped to us in quantities. There are many causes which preclude the shipment of over 50,000 tons annually from this island, and it is to be regretted that so excellent a class of ores should not be more plentiful, and thus enable the Eastern shore factories to make the favorable prices which alone can come from active competition.

Spanish pyrites has been imported to the same extent as last year, notwithstanding the depressed state of trade along the seaboard, and it is in this direction that our large manufacturers must look for their future supplies. It is only a question of a little time when local supplies of pyrites will be absorbed by owners of the mines, who will become manufacturers of all products which demand so excellent a base. Especially will this be true of the ore deposits which have for their residues favorable minerals for the manufacture of other and often more profitable products that can be gotten from sulphur. With an output of nearly or quite 700,000 tons of phosphate rock from our Southern States this year—which means the manufacture of at least 1,750,000 tons of commercial manures—and the steadily-growing trade in the Western States, as well as at home, in this essential of the soil, there will be manutactured of sulphuric acid alone at least 1,000,000 tons to meet the demand, and this tonnage is constantly increasing from year to year.

It is a source of great satisfaction to have followed this trade in acids from 1864 to the present year, and to have been an integral part of the increase in business from 25,000 tons sulphuric acid annually to the yearly output of 700,000. It will be a source of greater satisfaction to see within the year a combination works established on successful lines of several great works in Europe, wherein all products from ores, from sulphur to metals, will be utilized.

QUICKSILVER.

THERE were no new developments of importance in the quicksilver industry in 1893, but, contrary to all expectations, there was again an increase in production. This was due especially to the larger output of the New Almaden, Napa, Mirabel, and Ætna mines, which more than compensated for the falling off in the product of the Great Eastern and Great Western, and led to a net gain of a trifle more than 2000 flasks. This was the more surprising in view of the closing down of many of the silver-mills during the summer, and the consequent falling off in the demand from them for quicksilver, while the price for the metal declined from $43.50 per flask in July to $30 per flask in December, this great drop being due to the general business depression and fear of removal of the protective tariff.

No new mines were discovered in 1893, and all the old ones were worked to their fullest capacity. Most of them now are without any ore reserves worth mentioning. The profits derived from them were smaller than in previous years, owing to the low price for the metal and the increased cost of production, on account of the deeper workings. The margin of profit is now so small that, according to the assertions of the producers, a reduction of the present tariff on quicksilver (amounting to 10c. per lb., or $7.65 per flask) will be disastrous. The year closed with a dark outlook because of the great decline in the value of the metal, and the prospect is certainly not for a further increase in production in 1894.

HIGHEST AND LOWEST PRICES OF QUICKSILVER IN 1893 IN SAN FRANCISCO.

Month.	Highest	Lowest.	Month.	Highest.	Lowest.
January	$42.00	$39.00	July	$43.50	$40.50
February	42.00	39.00	August	41.00	39.00
March	42.00	39.00	September	41.50	39.50
April	43.00	40.50	October	41.50	40.00
May	43.00	40.00	November	41.00	39.50
June	43.50	40.50	December	39.50	30.00

Highest for year, $43.50 ; lowest, $30.

In London the market for quicksilver opened at £6 2s. 6d., advanced during the year to £6 17s. 6d., and finally closed at £6 5s. The following statistics of the London market for a period of years are taken from the Annual Metal Circular of W. P. Sargent & Sons, issued under date Jan. 11, 1894 :

Year.	Production.		Imports into London.		Total.	Exports from United Kingdom.	Price of Spanish.	
	Austrian.	Californian.	Italian.	Spanish.			Highest	Lowest.
	Flasks.	Flasks.	Flasks.	Flasks.	Flasks.	Flasks.	£ s. d.	£ s. d.
1884*.......	14,680	31,913	8 040	48 098	102,731	50,634	6 15 0	5 1 6
1885........	14,370	32,073	7,888	45,813	100,144	50,942	6 17 6	5 10 0
1886........	14,000	29,981	8,090	48,537	100,608	66,974	7 10 0	5 13 0
1887........	14,000	33,760	7,400	51,011	106,171	64,049	11 5 0	6 10 0
1888........	14,000	33 250	10,460	53.243	110,953	45.806	10 10 0	6 15 0
1889........	14,000	25,650	10,498	49,778	99,926	55,366	9 15 0	7 7 6
1890........	14,000	22,926	12,470	50,202	99,598	56,702	10 7 6	8 17 6
1891........	15,000	22,904	10,440	47,993	96,337	63,143	9 0 0	7 5 0
1892........	15,000	25,554	6,765	47,321	94.640	49,358	7 15 0	6 1 0
1893........	15,000	30,000	6,680	44,670	96,350	37,282	6 17 6	6 2 6

* Calculated from November to November.

In Mexico the Guadalcazar Quicksilver Mines, Limited, continued the development of its property, with promising results. At the annual meeting of the company, held in London in the early part of the year, it was reported that the production during the previous fiscal year had amounted to 3,383.5 tons (2000 Spanish lbs.) of ore, averaging 3.52% mercury. The company had then two furnaces in operation and was building a third, which it was expected would come into use before the end of December, and would give a productive capacity of 140 flasks per week. A rich body of ore was opened in the mines in December, 1892, and another rich find was made in March, 1893. A dividend of 10% on the preferred shares of the company, amounting to £3,000, was declared. There seems to be promise, therefore, that Mexico will soon become a noteworthy producer of quicksilver.

Mr. Edward Halse presented an interesting note on an occurrence of quicksilver in Colombia at a meeting of the North of England Institute of Mining Engineers. A vein of cinnabar was discovered in Colombia in 1786 near Quindiu. In 1886 special search was made for the old mines, and six levels, together with various furnaces, tools, etc., were discovered. The mine is nearly 10,000 ft. above the sea level. The formation in which the cinnabar occurs consists of chloritic, tal-cochloritic, arenaceous, and aluminous schists of Palæozoic age. At the foot of the mountain there is a mass of dioritic porphyry forming the bed of the river Bermillion, while near the summit of the mountain there is a large dioritic dike. The average percentage of cinnabar in the vein varies between ½% and 1½%. It is not improbable that more valuable deposits occur in the mountain and near the large dioritic dike, which is considered to traverse the hill. Mr. Halse considers that the Quindiu deposit may be regarded as impregnations, probably intimately connected with the intrusive dioritic dike. Heated waters bearing double sulphides of iron and mercury in solution may have made their way up and along this disturbance, and then passing between the bedding planes of the softer schists may have impregnated beds, occasionally filling joints and the fissures therein.

The following note concerning the quicksilver mining of Russia, where the production is also increasing, is taken from *Mining and Metallurgy in Russia*, by A. Keppen : "Deposits of mercury ores were first discovered in Russia in

1879 in the Government of Ekaterinoslav, near the station of Nikitovka, on the Kursk-Kharkov-Azov Railway. Mercury has also been recently discovered in the Caucasus at Daghestan, but these deposits have not yet been opened. The deposits near the station of Nikitovka lie in strata of the Carboniferous system, and consist of cinnabar which fills crevices in sandstone. Exploration has proved that they extend over an exceedingly large area. Traces of ancient workings have also been brought to light, and notwithstanding that they are found over an area of about two versts, there is no record of the epoch to which they belong. These deposits were first worked in 1885 by the present owners, A. A. Auerbach & Co., who in 1886 built small works capable of turning out about 4000 poods (65,440 kilograms) of mercury annually, which corresponded to the internal consumption of Russia at that time. But in 1887 these works were considerably enlarged, owing to the evident possibility of a market for their product being found abroad. The mines and works are models of their kind, and are said to be better organized and worked on a more economical and rational basis than those of Idria and Almaden. At the present time the locality of the works, which in 1885 was a bare steppe, is occupied by a population of over 1500 inhabitants."

The chief uses for quicksilver are in the reduction of gold and silver ores by amalgamation and the manufacture of vermilion, or artificial sulphide of mercury, which is a valuable pigment. Some interesting statistics concerning the consumption for the former purpose were given in THE MINERAL INDUSTRY, Vol. I. (1892), p. 409, where it was shown that the silver-amalgamation mills used from 0.5 to 2.5 lbs. of quicksilver per ton of ore treated, the consumption for the more part falling between 1 and 2 lbs. per ton of ore ; while the gold mills used from 0.01 lb. per ton (Alaska-Treadwell and Homestake) to 0.06 lb. in some of the Californian mills. The total make of vermilion in the United States amounts to about 240,000 lbs. per annum, valued at nearly $120,000. The mercurial contents of this output are 204,000 lbs., representing about one-tenth of the domestic production of mercury.

Vermilion is made by fusing a calculated mixture of mercury and sulphur at a moderate heat, the resulting product being of a cochineal-red color, which yields when pulverized a scarlet powder, the more beautiful the purer the materials used in its preparation and the greater the care taken to avoid an excess of sulphur. Vermilion may also be obtained by precipitating a solution of corrosive sublimate in ammonia with a solution of sulphur in ammonium sulphide. The manufacture of vermilion has fallen off within recent years on account of the competition of cheaper pigments which have taken its place. The most important of these is "orange mineral" (red lead), which is toned up to the proper color by means of eosine, one of the aniline dyes. These imitation vermilions are now used for almost all the commoner purposes, like wagon-painting, etc. They are inferior to the true quicksilver vermilion from the fact that they fade on exposure, but in wagon-painting and like purposes they do well enough, lasting so long as they are protected by a coating of varnish. True vermilion is sometimes adulterated with the imitation, but this can easily be detected by heating a sample, when the sulphide of mercury will be volatilized, while foreign substances remain behind. Quicksilver vermilion is now chiefly employed for red colors in printing, lithographing, etc.

We are indebted to Hon. James Butterworth Randol of San Francisco for the following statistics of the production of quicksilver in the United States. The statistics for previous years, beginning with 1850, will be found in The Mineral Industry, Vol. I. (1892), p. 408, together with much other valuable data concerning the industry.

PRODUCTION OF QUICKSILVER IN CALIFORNIA IN 1893. (IN FLASKS OF 76 5 LBS.)

Month.	New Almaden.	Napa Con'd.	Mirabel.	Ætna.	Great Western.	Great Eastern.	Sulphur Bank.	Redington.	New Idria.	Lake.	Abbott.	Total.
January.....	400	605	746	242	338	99	110	109	70	132	45	2,896
February....	390	450	640	285	400	86	110	138	60	211	18	2.788
March.......	375	300	485	328	201	96	100	156	55	....	70	2,166
April........	550	465	525	110	197	171	100	144	60	....	....	2,322
May.........	600	735	485	460	314	112	100	116	70	....	....	2,992
June.........	600	515	425	430	320	128	90	227	60	12	...	2,807
July.........	500	430	150	330	201	121	45	92	69	26	....	1,964
August.. .	500	340	255	300	145	117	123	....	70	55	....	1,905
September .	649	475	160	275	137	100	112	....	60	35	....	2,003
October.....	600	720	420	285	194	149	110	....	90	73	....	2.641
November..	650	370	400	245	340	112	100	30	95	34	....	2,376
December...	800	715	520	505	400	154	100	....	110	....	....	3,304
Total......	6,614	6,120	5,211	3,795	3,187	1,445	1,200	1,012	869	578	133	30,164
Total.. ...	5.563	5,680	......	1,592	5,867	1,630	1,393	728	848	..	....	27,993*

* In 1892 various mines were credited with an output of 4692 flasks.

QUICKSILVER PRODUCTION OF THE WORLD. (IN METRIC TONS.)

Year.	Austria.	Italy.	Russia.	Spain.	United States.	Total.	Year.	Austria.	Italy.	Russia.	Spain.	United States	Total.
1871.......	......	36	......	1,151	1,200	....	1883........	466	206	......	1,667	1,621	3.494
1872.	......	27	......	1,262	1,097	....	1884........	499	267	......	1,564	1,107	2,938
1873.......	......	31	......	929	960	....	1885......	487	237	......	1,694	1,113	3,044
1874.......	372	32	......	1,257	963	2,252	1886........	541	251	......	1,846	1,040	3,137
1875.......	370	82	......	1,426	1,744	3,252	1887........	532	244	64	1,949	1,180	3.437
1876..	375	99	......	1,334	2.605	4,028	1888........	541	339	165	1,865	1.154	3,523
1877.......	392	111	......	1,292	2.755	4,158	1889........	566	385	167	1,975	919	3,446
1878.......	370	124	.....	1,503	2,217	3,844	1890........	542	449	292	1,813	796	3,350
1879.......	429	132	......	1,611	2,557	4.300	1891........	570	330	324	1,665	794	3,113
1880.......	369	116	......	1,388	2,079	3,583	1892........	542	325	*a*324	1,682	971	3,302
1881.......	398	128	......	1,812	2,112	4,052	1893	......	......	......	1,672	1,047	......
1882.......	409	140	......	1,765	1,830	3,675							

(*a*) Estimated.

THE RARE ELEMENTS.

By Walter Renton Ingalls.

The solid crust of the earth is composed of certain elementary substances, usually in combination, which are independent forms of matter and are called elements. The spectroscope has shown that the sun and stars also contain many of these, and several of them have been found in meteorites. The number of elements is uncertain, the list of them constantly undergoing changes as new ones are discovered and some of those already enrolled prove to be compounds of still more subtle substances. The most recent list, therefore, is totally different from that of twenty, or even ten, years previous. There is no doubt that the present list is incomplete; for when the elements are arranged in a table in accordance with the periodic law of Newlands and Mendeléeff there are gaps which should be filled. The existence of the elements gallium, germanium, and scandium, and certain of their properties as well, was predicted in this manner before they were actually detected; an element with atomic weight approximately 100, and properties similar to those of manganese, is now required to fill another gap.

The generally accepted list of the elements at the present time includes 67 names. Not more than a dozen of these, however, enter largely into the composition of the earth, the solid crust of which, it has been calculated, is made up approximately as follows: Oxygen, 44% to 48.7%; silicon, 22.8% to 36.2%; aluminum, 9.9% to 6.1%; iron, 9.9% to 2.4%; calcium, 6.6% to 0.9%; magnesium, 2.7% to 0.1%; sodium, 2.4% to 2.5%; potassium, 1.7% to 3.1%.

Of the 67 elements there are 20 which are extremely rare, while fully one-half may be said to be uncommon. The list of elements found in nature, or in commerce, in their elementary forms is still smaller, numbering only about 28. Even the abundant elements, silicon and calcium, are rarely seen as such, occurring usually in combination with others, as in the minerals silica and calcite. Of the rare elements, some, like erbium and yttrium, have not yet been isolated; in the case of certain others it is doubtful if they have been obtained pure, and the discrepancy in the properties assigned to them by different investigators (see "Chromium") is to be explained thereby.

In this article the line classifying the "rare elements" has been drawn to include those which do not occur commonly in nature, and also those whose elementary forms are seldom seen outside of the laboratory, and are not ordinarily quoted in the market. Such of these as can be obtained at all are given, together with their values (as quoted by a prominent manufacturer of chemicals in Germany), in the following table :

Metal.	1890. Value.	1893. Value.
Barium, ex amalgam	$2.00	$2.12
per electrol	7.50	7.75
Boron, amorphous	1.50	1.12
crystalline	2.62	2.75
graphitoidal	2.12	2.25
Calcium, per electrol	5.00	5.25
Cerium, pulv	1.00	2.25
fusum in globulis	5.50	5.50
Chromium, fusum	.40	.40
crystal.	.75	.75
Cobalt, met. per kilo	8.75	10.00
purum per kilo	32.50	40.00
reductum pulv. per 100 grms.	4.00	....
Columbium, pulv	4.00	....
Didymium, pulv	5.00	5.50
Gallium	105.00	105.00
Germanium, met. fusum	37.50	37.50
met. pulv	35.00	35.00
Glucinum, met. pulv	6.75	7.00
met. crystal	10.50	10.75
Indium	5.00	5.50
Iridium, fusum	1.37	1.25
Lanthanum, met. pulv	5.75	6.00
per electrol in globulis	10.50	11.00
Lithium, met. in globulis	5.00	5.00
wire	6.25	6.25
Manganese, fusum puriss. per 10 grams	2.25	2.25
Molybdenum, metal. pulv. per 10 grams	$1.25	$1.25
Osmium	1.12	1.00
Palladium, sheet and wire	1.00	1.06
pulver	.87	1.00
Rhodium	1.00	1.62
Rubidium	6.25	6.25
Ruthenium	3.25	2.50
Selenium, pur. cryst	.50	.50
pur. in bacill. per kilo	43.75	47.50
pur. precipitated, per 10 grams	.62	.62
Silicon, cryst	1.00	1.12
amorphous	.52	.62
Strontium, per electrol	7.00	7.25
ex amalgam	3.00	3.25
Tantalum	4.50	4.75
Tellurium, fusum per 10 grams	2.00	2.12
precipitated	... .	2.00
Thallium, per 10 grams	.37	.37
Titanium	1.00	1.12
Uranium	.75	1.00
Vanadium	4.00	4.00
Wolfranium, per 100 grams	5.00	5.00
Zirconium, scales	2.37	2.12
pulv	2.00	1.62

Note.—The above prices are for Germany, and are per gram unless otherwise specified.

Barium (atomic weight, 137) does not occur native, but its sulphate ($BaSO_4$) barytes, is an abundant mineral, which is useful in the arts. The carbonate ($BaCO_3$), witherite, is less common. Barium, which resembles calcium and strontium, is a yellowish-white, malleable metal, of 4 sp. gr. Its salts color flames a pale green. It may be obtained by dissolving the carbonate in dilute hydrochloric acid and evaporating the solution. The chloride thus produced is fused at an intense white heat in a porcelain crucible and decomposed electrolytically, using a carbon rod as one electrode and an iron wire as the other. Barium amalgam is produced by using mercury as the negative electrode. It may also be made by shaking sodium amalgam with a strong solution of barium chloride, the sodium combining with the chlorine and setting free the barium, which is taken up by the mercury. The mercury is then distilled from the amalgam, but it is impossible to drive it off completely, and the barium, which is obtained as a yellowish-white metallic powder, is impure. The pure barium produced by electrolysis is more than three times as expensive as that obtained from amalgam.

Boron (atomic weight, 11) does not occur free in nature, but combined with oxygen as boric acid, and with bases as borates, it is somewhat abundantly distributed, the most common of the minerals containing it being borax ($Na_2B_4O_7+10\ H_2O$), biborate of sodium. Boric acid (H_3BO_3) is found native in many volcanic districts, especially in Tuscany, where it issues from the earth together with steam. Boron is an amorphous, dark brown powder, of 2.6 sp. gr., insoluble in water, but readily soluble in nitric acid. It is infusible at a white heat, and does not oxidize in the air at ordinary temperatures, but when strongly heated it burns with a dazzling bright flame, boric oxide being formed. Boron is prepared by reducing boric anhydride (B_2O_3) with sodium, potassium, or magnesium ($B_2O_3+3Mg=2B+3MgO$), or by reducing the chloride of boron, or the double fluoride of boron and potassium with sodium ($BCl_3+3Na=B+NaCl$, and $KF,BF_3+3Na=B+KF+3NaF$).

Hitherto there has been no use for boron in its elementary form, but recently it has been suggested that it may be employed in combination with iron.* A boron-iron was prepared by adding a solution of borax to one of ferrous chloride; the white precipitate of ferrous borate thus obtained, after drying thoroughly, was reduced by carbon in a plumbago crucible at a high temperature. In this way a compound with from four to five per cent. boron was obtained, which broke with the fracture of metallic manganese and was hard enough to readily scratch glass ; it was difficultly soluble in acid, and its melting point approached that of cast iron. Subsequently a more economical method of preparing the compound was found to be the reduction of ferric carbonate, or oxide, in admixture with boron oxide and charcoal. The effect of a small amount of this compound on a large amount of iron is striking, one ounce of it melted with about two pounds of iron causing the whole to break with a fracture analogous to that of the boron compound itself. The iron thus produced casts more soundly, expands slightly, and is free from blow-holes. An average of several analyses of the boron-iron compound was as follows : Iron, 94.08% ; boron, 4.02% ; combined carbon, 1.50% ; phosphorus, 0.09% ; sulphur, 0.31% ; silicon, trace; manganese, trace—total, 100.

Calcium (atomic weight, 40) occurs very widely distributed in nature, and in enormous quantities, principally as carbonate ($CaCO_3$) in the form of limestone, marble, and chalk ; as sulphate ($CaSO_4$) in the form of gypsum ; as phosphate ($Ca_3[PO_4]_2$) in apatite and phosphate rock ; and as fluoride (CaF_2) in fluorspar. Calcium is a yellowish-white, lustrous metal of 1.57 sp. gr., which in moist air becomes coated with a film of hydroxide. In hardness it is between lead and gold, and it is very ductile. It melts at a red heat, and at ordinary temperatures decomposes water, just as sodium and potassium do.

Calcium may be obtained by the following process : Eight parts of calcined gypsum and three parts of finely ground charcoal are thoroughly mixed and burned in a crucible at a white heat for one hour, calcium sulphide being the resulting product. This is then treated with water to which small quantities of iodine are gradually added, with frequent stirring, until the liquor gives off a great deal of heat and no longer changes color. A little slaked lime is then thrown in, and the mixture left standing for several hours in order that alumina, silica, and ferric or manganic oxides may be precipitated, these being subsequently removed by filtration. The clear liquor is then evaporated to dryness and heated until iodine vapor begins to come off, when the residue is put into a porcelain crucible, inclosed in an earthen pot (all spaces between the two vessels being filled with powdered charcoal), and heated again for half an hour. The contents of the crucible are then allowed to cool, and are transferred together with a certain amount of pure sodium to an iron crucible provided with a cover, which can be

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* H. N. Warren, *Chemical News*, Oct. 27, 1893.

tightly screwed on. The charge is then submitted to a great heat, fusion taking place, when the iodine combines with the sodium, leaving the calcium free. Calcium is also obtained by decomposing the chloride electrolytically in the same way that barium is made.

Cæsium (atomic weight, 133) is a soft, white metal of the sodium-potassium group, its properties being similar to those of the other metals of the series. It is heavier, however, its sp. gr. being 1.88. It melts at about 26° C. Its salts give a blue coloration to flames. Cæsium occurs in minute quantities in certain soils and spring waters (notably at Dürkheim, in the Bavarian Palatinate), and in lithia-mica. There are two rare minerals, castorite and pollucite, found in the island of Elba, which contain it. It has been prepared by the electrolytic decomposition of a mixture of the fused cyanide of cæsium with cyanide of barium, strips of aluminum being used as electrodes. Cæsium is one of the rarest of the metals.

Cerium (atomic weight, 141.5) is a member of a series of rare elements, which are usually referred to as the cerium group. They are, moreover, almost always associated with one another in the minerals, cerite, gadolinite, monazite, etc., in which they are usually found in nature. Metallic cerium may be obtained by the electrolysis of its chloride. It is a metal of 2.1 sp. gr., extremely ductile, and resembles iron in color and luster. It is unoxidized in dry air and retains its luster, but on being ignited burns with great brilliancy, like magnesium, but more readily. It melts at a lower temperature than silver, but at a higher temperature than antimony. It slowly decomposes cold water, and is readily soluble in hydrochloric acid.

The oxide of cerium, and also those of zirconium, thorium, yttrium, erbium, lanthanum, etc., find a use in the Welsbach system of incandescent gas-lighting, in which the property of these earths of glowing with great brilliancy when strongly heated is utilized. A hood, or "mantle," composed of one or more of the oxides, is prepared in the following manner: A cotton thread is knitted into a cylindrical shape in network form, washed first in dilute ammonia, then in water containing a little hydrochloric acid, and finally in distilled water. After drying, the knitting is cut into suitable lengths, saturated in a solution of the nitrates of cerium, lanthanum, etc., mixed in the desired proportion, and dried again. The hoods are then shaped properly, after which the cotton is burned out, leaving only a fine network of the oxides, which on being placed over the flame of a Bunsen burner at once become incandescent, emitting a bright, steady light.

The principal minerals employed for obtaining these oxides are monazite (which contains up to 70% of the oxides of cerium, thorium, lanthanum, and didymium, combined with phosphoric and silicic acids), orangite, cerite, allanite, gadolinite, samarskite, orthite, and zircon. The oxides of the rare elements are separated from these minerals and dissolved as nitrates by methods described in the *Journal of the Society of Chemical Industry*, March 31, 1891. It is most important that the salts employed be free from iron, as the presence of this metal materially impairs both the luminosity and durability of the mantles. As regards the intensity of the light emitted, McKean gives the following comparative values of the more important incandescent metallic oxides with a burner using 85 liters of gas per hour under a pressure of 25 m. (i. e., about 30 cu. ft. per hour, at a pressure of about one inch) :

Oxide of	Photometric Value.	Color of Light.
Thorium	31.56	Bluish-white.
Lanthanum	28.32	White.
Yttrium	22.96	Yellowish-white.
Zirconium	15.36	White.
Cerium	5.02	Reddish.

The best effect appears to be obtained by employing a mixture containing two-thirds thorium and one-third yttrium oxide. The life of the mantle also appears to depend upon the composition, and it would seem that after prolonged use some variation in the quantities of the constituents takes place ; but only a few experiments have been made in that direction. The oxides can be recovered from the old mantles and used over again.

Monazite, which has been found at numerous localities where the occurrence is of mineralogical interest only, is obtained in the form of sand in commercial quantities in North Carolina and Georgia, and in Brazil. In the gold gravels of Rutherford, Polk, Alexander, Burke, McDowell, and Mecklenburg counties, North Carolina, it is found in small brown, greenish, or yellowish-brown monoclinic crystals, associated with chromite, garnet, zircon, corundum, samarskite, and other minerals. The Brazilian monazite is found as a beach sand at Caravelhas, Bahia, where its existence was made known about thirteen years ago by Dr. Orville A. Derby.

The introduction of the Welsbach incandescent light created a new demand for the minerals containing zirconium, thorium, cerium, and lanthanum. The company interested in these lamps, however, quietly gathered a large stock before the new use for them was generally known. It was said in 1888 that the company had then accumulated 25 tons of zircon, 10 tons of monazite, 6 tons of cerite, and thousands of pounds of samarskite and other minerals containing elements of the cerium group. As a consequence zircon was then offered at less than 10c. per lb., monazite at 25c., and samarskite at 50c. It is said that the zirconia in one ton of zircon would make half a million Welsbach burners.*

Chromium (atomic weight, 52.4) does not occur free in nature, though its oxide combined with ferric oxide, forming the mineral chromite, is widely distributed, especially in regions of serpentine rock. The properties of chromium have been imperfectly described, variations being due probably to the different methods of preparing it. Its sp. gr. is stated variously between 6 and 7.3. Its melting point has not yet been determined definitely, but it is probably somewhat higher than that of pure iron.†

Wöhler prepared chromium by reducing its sesquioxide with zinc, obtaining it as a shining, green powder of 6.81 sp. gr., which became tarnished in the air, and was soluble in hydrochloric and warm, dilute sulphuric acid, but was not acted on by strong nitric acid. Deville ignited chromic oxide with sugar-charcoal in a lime crucible at an intense heat, and procured chromium of a bright steel-gray color, very hard, capable of a high polish, less fusible than platinum, and of

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* *Engineering and Mining Journal*, July 7, 1888, p. 2.

† R. A. Hadfield, *Journal of the Iron and Steel Institute*, 1892, No. 2, p. 53.

sp. gr. 6. Bunsen obtained the metal chemically pure by electrolysis of a concentrated solution of its chloride, in which form it resembled iron in appearance, but was less affected by damp air. It was acted upon by acids as described by Wöhler. Frèmy is said, however, to have obtained crystallized chromium, which was unattacked by the strongest acids.

Chromium may be obtained by the decomposition of a solution of its chloride by the electric current, by the reduction of its oxide at a high temperature, or by the reduction of potassium chromic chloride with magnesium. The first of these methods, which was employed by Bunsen, is described in Watt's *Electro-deposition.* The reduction of chromic oxide is described by James Park of the Millburn Chemical Works, Glasgow, in English Patent No. 377–88, issued in 1888. Chromic oxide is produced by heating a mixture of potassium bichromate and sugar. The oxide is then reduced by charcoal at a high temperature, the metal being obtained in a spongy mass. This is finely pulverized, and fused again at a very high heat. Mr. R. A. Hadfield states that a sample of metal made by this process and examined by him was found to contain only 78.93% chromium, the remainder being carbon (3.52%), iron, and silicon. The same author gives an analysis of an alloy furnished for metallic chromium by Johnson & Matthey, which contained only 86.6% chromium, while another sample supplied by Königswater & Ebell of Linden, Hanover, as metal 96% fine, was found to contain only 75.6%.

Metallic chromium is prepared by Dr. Emanuel Glatzel of Breslau, Prussia, in sufficient quantities for laboratory or industrial experiments, or in larger amounts, if necessary, by the reduction of potassium chromic chloride by magnesium in the presence of potassium chloride. A solution of 100 grams of potassium bichromate (the least possible water being used) is treated with 400 c.c. of hydrochloric acid, and then with 100 c.c. of 80% alcohol. Potassium chromic chloride is produced according to the following reaction: $K_2Cr_2O_7 + 8HCl + 3C_2H_5OH = 2KCl, Cr_2Cl_6 + 3CH_3COH + 7H_2O$. To the solution so obtained 160 grams of potassium chloride are added, and after filtration the whole is evaporated to dryness and again heated. Green particles are removed, and the mass is powdered and mixed with 50 grams of magnesium cuttings, this being about double the quantity theoretically necessary. The mixture is then heated to redness for half an hour in a covered Hessian crucible, whereby metallic chromium is produced: $2KCl, Cr_2Cl_6 + 3Mg = 2KCl + 3MgCl_2 + 2Cr$.

On cooling, the crucible is broken and the dark gray mass contained therein is leached with water, whereby the chlorides of potassium and magnesium are removed. The residue is freed from excess of magnesium and magnesia by treatment with dilute nitric acid, metallic chromium, which is dried on a water bath, remaining behind. It exists in so fine a state that filtration cannot be used in removing the solutions of potassium, magnesium chloride, etc., which are therefore separated by decantation. As thus obtained the chromium consists of microscopic crystals, almost white in color, which after being rubbed in an agate mortar show a metallic luster.*

According to E. Placet, chromium may be prepared electrolytically in the fol-

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* *Journal of the Society of Chemical Industry,* Feb. 28, 1891.

lowing manner : An aqueous solution of chrome alum is added to a solution of an alkaline sulphate and a small quantity of sulphuric acid ; on electrolyzing, pure chromium of a great brilliancy is deposited at the negative pole. The metal thus deposited is said to be of a beautiful bluish-white color and resists atmospheric oxidization and attack by concentrated sulphuric or nitric acids, or a concentrated solution of potash. Besides the production of pure chromium, this process has been applied to chromium plating of various metallic surfaces, where the metal deposits with a beautiful effect, resembling that produced by oxidized silver.*

Columbium, or niobium (atomic weight, 93.7), has been obtained as an iridescent, steel-gray powder of 7 sp. gr. It has a great affinity for nitrogen, and combines with chlorine, forming chlorides. It is prepared by reducing the chloride by means of hydrogen gas, in the same manner as vanadium. Columbium occurs in the minerals columbite (niobite) and tantalite. (See "Tantalum" and "Vanadium.")

Didymium is a yellowish-white metal of 6.5 sp. gr. It is usually associated with the cerium minerals, and is prepared in the same manner as cerium. Recently didymium has been separated into two elements, called neodymium (atomic weight, 140.8) and præsodymium (atomic weight, 143.6).

Erbium (atomic weight, 166) is a metal of the cerium group, which is extremely rare and has not yet been isolated. It forms one compound with oxygen, erbia (Er_2O_3), which has a pale rose color, and when strongly heated glows with an intense green light. Erbia is used in the Welsbach incandescent lamps. (See "Cerium.")

Gallium (atomic weight, 69.9) is a grayish-white metal, crystallizing in octahedrons, which is remarkably hard and resistant even at a temperature little below its melting point. It is only slightly malleable and flexible. It fuses at 30.15° C. (86.27° F.), and consequently melts when held in the fingers. The liquid metal is of a silver-white color and adheres to glass, forming a mirror like that of mercury. Its sp. gr. is about 6. Gallium was discovered in 1875 by M. Lecoq de Boisbaubran in the spectroscopic examination of a zincblende from Pierrefitte, in the valley of Argeles, Hautes-Pyrénées, which is said to contain about 0.002% of it. Subsequently it was found to exist in the blende of certain other localities. especially in that of Lüdrich and Apfel, at Bensberg on the Rhine. Gallium is the most costly of all the rare metals.

The existence of gallium was predicted by Mendeléeff, in accordance with the periodic law which bears his name, before the discovery was actually made. Its atomic weight, density, and other of its characters were also closely foretold. Gallium is obtained from zincblende containing it by decomposition with hydrochloric acid, the precipitation of various foreign metals in the solution by means of hydrogen sulphide, and the subsequent precipitation of the gallium from the filtrate as carbonate by means of carbonate of sodium, gallium being thrown down by that reagent before zinc. The precipitate of gallium carbonate is converted to oxide (Ga_2O_3), and a solution of the pure oxide in caustic potash is decomposed electrolytically, the metal gallium appearing on the negative platinum electrode.

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* *Comptes Rend.*, 1892, 115, 945.

Germanium (atomic weight, 72.3) is a white metal of 5.5 sp. gr., somewhat resembling antimony in appearance. It is very brittle and can be readily pulverized. It melts at about 900° C., and combines directly with oxygen, sulphur, and the halogen elements. It was first discovered in the mineral argyrodite,* found in the Himmelfahrt mine at Freiberg, which contained 6% or 7% of the sulphide of germanium.†

Germanium was first obtained by reduction of its oxide in a stream of hydrogen gas, but subsequently it became possible to deal with it on a larger scale. The finely divided oxide after undergoing an elaborate process of purification was mixed intimately with 15% to 20% of starch meal made into a paste with boiling water and rolled into balls, which were then placed in a crucible with powdered wood charcoal and heated to redness. On cooling, each ball was found to be converted into a regulus of metallic germanium. After removing the adhering charcoal the regulus was placed in another crucible covered with powdered borax glass, and melted in a gas furnace. On cooling, a brittle regulus was obtained, on the outer surface of which fine octahedral crystals formed.

Glucinum, or beryllium (atomic weight, 9), is a white malleable metal of 2.1 sp. gr. It is fusible at a lower temperature than silver. It does not burn in air or oxygen, but becomes coated with a layer of oxide, which seems to protect it from further change. The metal may be obtained by the action of sodium on its chloride (GCl_2). Glucinum occurs in nature as silicate in the mineral beryl, from which the chloride is obtained. Dr. John Gibson, in a paper before the Chemical Society (1893), states that of the many methods proposed for the preparation of glucina from beryl only a few give satisfactory results, and none of them can be applied easily on a larger scale. The percentage of glucinum in beryl is small, and it is therefore necessary to work up large quantities of it in order to obtain a stock of glucina sufficient for the purpose of investigation. Hitherto it has been found necessary to grind the mineral to a very fine powder as a preliminary to its complete decomposition by the usual agents employed in the case of refractory silicates. Dr. Gibson proposed a method based on the different behavior of the fluorides of aluminum, iron, and glucinum when heated together, it being found that if coarsely ground beryl be heated in an iron vessel with six parts of ammonium hydrogen fluoride, the mineral is completely decomposed at a temperature below red heat, the soluble aluminum fluoride at first formed being rendered insoluble in water if the heating be sufficiently prolonged, while the bulk of the fluorides of iron are decomposed and converted into ferric oxide, the glucinum fluoride remaining soluble in water.

Indium (atomic weight, 113.7) is an extremely rare metal, which occasionally occurs in association with zinc. It is white in color, soft and ductile, without crystalline structure, and much resembles lead in appearance. Its sp. gr. is 7.4 and its melting point 176° C. It is slowly dissolved by dilute nitric and sulphuric acids, and is easily soluble in concentrated hydrochloric acid. It may be melted

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* Winkler, *Berichte* 19, 210; *J. prakt. Chem.* (2), 34, 177.

† Germanium has since been found in canfieldite (Ag_8GeS_6), a new mineral from Bolivia, which has 6.5% Ge. Although 520 kilograms of germanium containing material were found in Freiberg, only 156 grams of germanium were obtained. The argyrodite was not found as clean ore, but as crusts and coating on pyrite and silver ore.

in the air without oxidizing, and is much less volatile than cadmium. At a bright red heat it burns with a violet flame, forming a yellow oxide, In_2O_3. Indium was first discovered by the spectroscope in Freiberg zincblende, which contains 0.05% to 0.1% of it, but it has since been found in blende from other localities, although always in minute quantities. Metallic indium is best prepared from the spelter made from indium-bearing blendes. The spelter is treated with an insufficient quantity of hydrochloric acid to dissolve it completely, a residue being thereby obtained which contains all the indium originally held. Indium is easily reduced from its oxide by hydrogen, and is precipitated from solutions by cadmium and zinc.

Lanthanum (atomic weight, 138.5) is a grayish-white metal of 6.1 sp. gr. It resembles cerium very closely in appearance, with the compounds of which it is usually associated. It is hard, malleable, and ductile, and melts at a lower temperature than silver. On exposure to the air it oxidizes superficially very quickly, and on being heated takes fire and burns with great brilliancy, but at a higher temperature than cerium. Lanthanum is obtained by the electrolysis of its fused chloride, in the same manner as cerium and lithium. Its oxide is used in the Welsbach incandescent lamps. (See "Cerium.")

Lithium (atomic weight, 7) is a silver-white metal of .59 sp. gr., being consequently the lightest of the metallic elements. It is softer than lead, but harder than sodium. It melts at 180° C., and at a somewhat higher temperature takes fire and burns to an oxide with a brilliant white flame. The salts of lithium, however, impart a characteristic red color to flame. In contact with water the metal gradually dissolves as hydrate ($LiOH$) with evolution of hydrogen, but without ignition. Lithium does not occur in nature, but its compounds are somewhat abundantly distributed, the carbonate being found in the waters of many mineral springs, which are very valuable for medicinal purposes. The most common and abundant of the lithium minerals, however, is lithium mica (lepidolite), which occurs in the granite and greisen of Zinnwald (Saxony and Bohemia) in large quantities.

Metallic lithium has been generally obtained by the decomposition of the pure fused chloride by electrolysis in porcelain crucibles, a rod of charcoal being used as the positive and a steel wire as the negative electrode. The metal separates out in small globules, which collect on the negative electrode, where they are protected from oxidization by the bath of molten chloride. The yield of lithium by this process is proportionately small, and recently it has been found that the loss is much diminished if a mixture of chloride of calcium and chloride of lithium is electrolyzed instead of pure chloride of lithium.* Chloride of lithium melts at about 600° C., and chloride of calcium at 750° C., while a mixture of equal parts of the two chlorides melts at 450° C. To prepare the metal, from 200 to 300 grams of the mixture of the chlorides are melted in a porcelain crucible. Carbon and iron electrodes are used, and a current of 20 volts and 20 ampères, when the decomposition takes place very quickly. The metal thus produced is free from iron and silicon, and contains only a small amount of potassium, which is of no consequence for most of the purposes for which lithium is used.

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* Guntz, *Compt. Rend.*, 1893, 117, 732.

Manganese (atomic weight, 55) is a soft, brittle, grayish-white metal, of 8 sp. gr., which oxidizes quickly on exposure to the air, dissolves easily in acids, and is feebly magnetic. A new process for the production of manganese on the commercial scale has recently been invented by Messrs. Greene and Wahl of Philadelphia. In this the dioxide of the metal is reduced to monoxide by heating in a stream of reducing gas. It is then mixed with granulated aluminum and with a flux of lime and fluorspar. The mixture is placed in a magnesite-lined black-lead crucible in a furnace commonly employed in melting brass. When the contents have reached a bright red, the aluminum begins its energetic reducing action upon the manganese monoxide, and in a few minutes the reaction is complete ($Al_2 + MnO = Al_2O_3 + 3\ Mn$). The inventors state that they have obtained a yield as high as 2.84 parts of manganese per unit of aluminum, equal to 94.5% of the theoretical yield. The metal obtained is dense and homogeneous, with a steel-gray color and a pinkish to reddish bronze tint. It is hard and brittle, having an irregular fracture. The sp. gr. varies between 7.26 and 7.38, or 7.32 on an average. Its average composition is Mn, 96.5%; Fe, 2%; Si, 1.5%. It retains only a slight trace of aluminum.

In operating a small plant capable of producing about 2 tons of manganese per week the inventors state that 1560 lbs. of aluminum and 5 tons of manganese ore will be required. Basing their calculations on the present market value of aluminum at 55c. per lb. and manganese ore at $40 per ton, they find that the manganese will cost about 34c. per lb., or 75c. per kilogram. It is proposed to use the manganese produced by this method in the manufacture of steel, for which purpose it has the advantage of containing no carbon.

Molybdenum (atomic weight, 95.9) is a white metal, of 8.6 sp. gr., which has a silvery luster and is exceedingly hard. It is obtained in a pure state by reducing its oxide (MoO_3) or its chloride ($MoCl_4$) in a stream of hydrogen gas. The oxide may also be reduced by carbon. Molybdenum occurs commonly as sulphide (MoS_2), molybdenite, which is by no means rare. This mineral, which resembles graphite in appearance, but is easily distinguished from it by giving off sulphurous fumes when heated, contains 59% molybdenum. It is found generally imbedded in or disseminated through granite, gneiss, or other crystalline rocks, but also occurs in veins in the same. Very pure molybdenite is found in Sweden, and has a ready market in Germany at about $4 per kilogram; but although the compounds of molybdenum have some important uses in the arts, the quantity of them required is small, and there is no general demand for the mineral. If there were, there is no doubt that it could be supplied in comparatively large quantities. Noteworthy deposits of molybdenite are said, for example, to exist among the mountains of Virginia and in the Adirondack region of New York.*

The mineral is also found in veins about four miles north of Pitkin, and near Rock Creek, Gunnison County, Colorado, in sufficient quantity to make the deposits valuable if there is ever a market for it.† Other localities in the United States where molybdenite is found are Blue Hill Bay, Maine, and Westmoreland, N. H.

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* Elwyn Waller, *Engineering and Mining Journal*, May 2, 1891, p.520.

† *Mineral Resources of the United States*, 1882, p. 446.

Molybdenum is used in the form of molybdic acid as a chemical reagent. Molybdate of sodium is employed in potteries to produce strong, solid, and brilliant blue colors; it is being used also for coloring woolens and silks. Recently it has been proposed to use molybdenum in an alloy with steel, the object being to obtain a product as hard as tungsten-steel and at the same time more malleable and less brittle. Attention was turned naturally to the employment of molybdenum for the purpose, this metal being nearly related to tungsten. Metallic molybdenum, as formerly prepared, however, being so expensive that even its use in experimental work was precluded, ferro-molybdenum was tried as a substitute. This was made by roasting molybdenite (sulphide of molybdenum) and smelting the oxide with iron, the resulting alloy containing 10% molybdenum. It was found impossible, however, to prepare it free from sulphur and phosphorus, and it was, therefore, unserviceable.

Recently a new process of molybdenum-winning was introduced by Sternberg & Deutsch at their chemical works at Grunau, near Berlin, whereby metal 96% to 98% pure has been brought into the market at 8 marks ($1.90) per kilo, or 86½c. per lb.[*] Their process consists in reducing molybdate of lime, which is easily obtained pure, with carbon. The lime is then separated from the metallic molybdenum by means of chlorhydric acid. The Grunau works are at present able to produce 200 kilograms of metal per day. The molybdenum obtained in this manner contains about 3% carbon, but no other impurities. Steel with 2% molybdenum is silver-white in color, has a velvety fracture, and is extraordinarily hard.[†]

Osmium (atomic weight, 191) is a metal of the platinum group.[‡] It is usually prepared by the method of Berzelius, which consists in calcining the sulphide in a carbon-crucible, when it takes the form of a powder or a spongy mass of a blue color. As thus obtained it is rapidly attacked by the oxygen of the air, with production of the volatile and dangerously poisonous tetroxide, OsO_4. Sainte-Claire Deville and Debray succeeded in obtaining metallic osmium in the form of grayish-blue crystals by passing the vapor of the tetroxide through a strongly heated carbon-tube. The density of these crystals, 22.48, was the highest which has been observed for the metal. Osmium melts at the temperature of a very powerful electric arc, in a manner analogous to ruthenium. After fusion it presents a brilliant metallic surface of a beautiful blue color slightly tinged with gray. It breaks with a crystalline fracture, and is distinguished by its remarkable hardness, being harder than ruthenium or iridium, readily cutting glass and scratching quartz. It resembles ruthenium very much in many of its properties, particularly as regards the ready formation of a volatile tetroxide. It differs entirely, however, from it in aspect, exhibiting, as above described, a remarkable blue metallic luster, while ruthenium is more white than platinum, resembling burnished silver.

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[*] *Stahl und Eisen*, August, 1893.

[†] Howe (*Metallurgy of Steel*, Vol. I., 1891, p. 86) states that according to Berthier molybdenum with iron produces alloys analogous to those of iron with tungsten, one with 2% molybdenum being fusible, extremely hard and brittle, but tenacious. Billings found, however (*Transactions American Institute of Mining Engineers*, Vol. V., 1877, p. 454), that 1% of molybdenum rendered good iron extremely red short, and utterly worthless. Some Mansfeld copper smelting salamanders consist chiefly of iron-molybdenum alloys, as much as 28.49% of molybdenum having been reported in them.

[‡] The occurrence of the platinum group of metals, their uses, etc., were fully described by Charles Bullman in THE MINERAL INDUSTRY, Vol. I.

Palladium (atomic weight, 106.2*) is a white metal of 11.4 sp. gr., resembling platinum in appearance. It is a member of the platinum group, and the most fusible of the series. It is soluble in hydrochloric acid. Palladium is usually found associated with platinum, but in Brazil it occurs both native and alloyed with gold. Palladium is obtained from platinum residues by neutralizing the solution with sodium carbonate and adding mercuric cyanide. The palladium is precipitated as palladium cyanide, which upon ignition yields spongy palladium. Palladium is employed to a small extent in the manufacture of watches, but the amount consumed in this way is insignificant.

Potassium (atomic weight, 39) is a bluish-white metal, which resembles sodium in many respects. Like sodium, it is never found in nature, although its salts are very abundant. It oxidizes immediately on exposure to ordinary air, and after a time deliquesces into a solution of potassium hydrate and carbonate. At ordinary temperatures it is so soft that it can be kneaded in the fingers, but below zero centigrade it is hard and brittle. Its sp. gr. is 0.865. It melts at 62.5° C., and volatilizes as a vapor of intense green color at about 720° C. When heated in the air it melts, and then takes fire burning to oxide, like magnesium. Like sodium it decomposes water, bursting into a violent flame immediately upon contact with it.

Potassium is prepared by the reduction of potassium carbonate by carbon in retorts, whence the metal is distilled and collected in condensers in about the same manner that sodium was formerly produced (Deville's method). It is necessary, however, to exclude oxygen from the apparatus with more care than in the preparation of sodium. During the distillation of potassium there is formed a black explosive compound of potassium, carbon, and oxygen ($K_6C_6O_6$), which diminishes the yield, and may cause serious mischief. On account of this and other difficulties the price of potassium is necessarily higher than that of sodium.

Rhodium (atomic weight, 104.1) is one of the rare metals of the platinum group, resembling the others of the series in its properties. Its sp. gr. is 12.1, or about the same as that of ruthenium, of which the atomic weight is also about the same. In point of fusibility it comes between iridium and ruthenium, being more infusible than the former. It is hardly attacked even by hot aqua regia, and does not oxidize at any temperature by itself, but when cupeled with lead remains as monoxide, RhO. Metallic rhodium is prepared from platinum residues by fusion with potassium bisulphate, and lixiviation of the rhodium sulphate thus formed with water.†

Rubidium (atomic weight, 85) is a white metal of the sodium-potassium group, much resembling the others of the series in its chemical and physical properties. It is, however, like cæsium, heavier than water, its sp. gr. being 1.52. It melts at 38.5° C., and at ordinary temperatures it is as soft as wax. Like potassium, it fuses when thrown on water and takes fire, burning with a violet-colored flame. The salts of rubidium, however, impart a red coloration to the flame, whence the

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* MM. A. Joly and E. Leidié report the mean result of their recent determinations of the atomic weight of palladium as 105.438.

† G. Matthey, *Journal of the Society of Chemical Industry*, 1879, p. 772.

name of the metal (from *rubidus*). Rubidium is far less widely distributed than lithium. It sometimes occurs in lepidolite, or lithia mica, and also in castorite and pollucite, two rare minerals found in the island of Elba. It is found in some mineral waters, particularly in those of a spring at Dürkheim, in the Bavarian Palatinate, from which it was first extracted. It also occurs in certain soils, and is absorbed by certain plants, in the ashes of which it is sometimes present. Rubidium is prepared by passing a current of electricity through its fused hydroxide, chloride, or cyanide. Setterberg in 1881 prepared a considerable quantity of it by electrolyzing a fused mixture of the cyanide with cyanide of barium, using strips of aluminum as electrodes.* Cæsium was prepared in the same manner. Rubidium may also be obtained by distilling its hydroxide with carbon in the same way that sodium and potassium are produced.†

Ruthenium (atomic weight, 103.5) is one of the rarest elements of the platinum group. Its specific gravity is about the same as that of rhodium, but it is more infusible than that metal. It becomes coated with a film of oxide even in cold air; at a red heat it is converted into Ru_2O_3. Besides forming a monoxide (RuO), a sesquioxide (Ru_2O_3), and a binoxide (RuO_2), there is a tetroxide (RuO_4), which resembles the corresponding salt of osmium in its properties, being easily fusible, very volatile (the vapor having a powerful smell), and dangerously poisonous. Ruthenium is prepared from platinum residues, being obtained after the extraction of the rhodium.

Professor Joly of the Paris École Normale, who has been investigating the compounds of ruthenium, recently submitted to the Académie des Sciences samples of a red coloring matter, resulting from an association not yet definitely determined (oxychloride of ammoniacal ruthenium), giving a tinctorial power equivalent to that of the richest dye materials obtained from coal-tar. A five-millionth part of the substance suffices to color water. It dyes silk directly, and the color thus procured is stable. Acids transform it into yellow, and alkalines bring it back to red.‡ (See also "Rhodium" and "Osmium.")

Scandium (atomic weight, 44) has not yet been obtained in the metallic form. This is one of the most recently discovered elements, and is especially interesting from the fact that its existence was predicted by the periodic law before it was actually detected, as was the case also with gallium and germanium.

Selenium (atomic weight, 79) is an elementary substance existing in a variety of forms. Amorphous selenium is a bright-red powder of 4.3 sp. gr., soluble in bisulphide of carbon, from which it may be obtained on evaporation in the form of dark-red monoclinic crystals. The sp. gr. of these crystals is 4.8. Both these kinds of selenium are converted by fusion and subsequent cooling into another crystalline variety, which is of 4.4 sp. gr., has a metallic luster, is somewhat malleable, breaks with a fracture similar to that of gray cast iron, and is insoluble in bisulphide of carbon, and furthermore at ordinary temperatures when exposed to the light is a conductor of electricity, which the non-metallic modification is not. It melts at 217° C. The most peculiar property possessed by selenium is the variation of its power of conducting electricity proportionally to the intensity of the light to which it is exposed. Attempts have been made to util-

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* *Annalen*, 211, 100. † Castner, *Chemical News*, 54, 218. ‡ *Journal des Mines*, Jan. 26, 1893.

ize this in the optical transmission of speech, and selenium came into active demand at one time when Alexander Graham Bell, the inventor of the telephone, was experimenting with it, but there was never any outcome of industrial importance to this work.

Selenium occurs in certain varieties of iron pyrites, and is concentrated in the chamber mud when the pyrites are used for sulphuric-acid manufacture. This mud constitutes the source whence selenium is obtained. The mud after washing and drying is fused with an alkaline nitrate or carbonate to form a selenate of potassium or sodium (K_2SeO_4), which is then leached with water. The solution is filtered and boiled with chlorhydric acid to convert the selenic into selenium acid ($SeO_3+2HCl=Cl_2+H_2O+SeO_2$), which is then reduced by sulphurous acid and heating ($SeO_2+2SO_2=2SO_3+Se$), the seleniumc oming down as a red precipitate. Selenium occurs in combination with certain of the metals forming selenides, which are analogous to the tellurides. Clausthalite ($PbSe$) contains 27.6% of selenium, while berzelianite (Cu_2Se) has 38.4%; both these minerals occur in the Harz. There is also a selenide of mercury, and a double selenide of lead and mercury.

Silicon (atomic weight, 28), occurring always in combination with oxygen as silica (SiO_2), or with oxygen and metals as silicates, is next to oxygen the most abundant of elements. Elementary silicon exists in two distinct modifications, the amorphous and the crystalline. Amorphous silicon, which may be obtained by heating the silico-fluoride of potassium (K_2SiF_6) with metallic potassium, or the corresponding sodium compound with metallic sodium, is a dull blackish-brown powder, which fuses at a temperature below the melting point of steel, and when heated in air or oxygen burns brilliantly with the formation of silica. Crystalline, or graphitoidal, silicon is obtained by heating a mixture of aluminum and silico-fluoride of potassium to the melting point of silver, whereby a metallic button is produced, which when treated successively with hydrochloric and hydrofluoric acids yields graphitoidal silicon in black lustrous tablets, or brilliant, hard iron-gray prisms. When the vapor of silicon tetrachloride ($SiCl_4$), a colorless liquid boiling at 50° C., which is prepared by heating silicon in an atmosphere of chlorine gas, is passed over fused molten aluminum, the chloride is reduced and the silicon dissolves in the aluminum, from which it separates after a time in large needles of a dark iron-gray color. Additional data concerning this element were recently reported by Mr. H. N. Warren, who states* that during the preparation of specimens of crystalline and other forms of silicon he obtained a most curious formation of that substance, which would appear, when treated analytically, to be composed of graphitoidal silicon, constituted so as to form most perfect and well-developed crystals consisting of oblique octahedrons. "This first made its appearance upon subjecting potassium silico-fluoride to a very intense heat in contact with impure aluminum. Upon separating the graphitoidal silicon thus formed by the aid of dilute acids, small quantities of the other substance were observed. Direct steps were at once taken to procure it, if possible, in larger quantities, after numerous experiments had failed to produce it. The following method was used with success, although still very uncertain:

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* *Chemical News*, 1893.

Graphitoidal silicon was first obtained by introducing pieces of metallic aluminum about the size of a walnut into a clay crucible of convenient dimensions, and subjected to a heat sufficient to maintain in a fused state a mixture of four parts of potassium silico-fluoride, one of potassium chloride, and two of potassium carbonate. After the violent reaction attending the introduction of the aluminum had subsided, the crucible was urged to whiteness for about five minutes; after cooling and breaking the same, a perfect round button consisting of about 80% silicon was obtained. This, after carefully detaching any adhering slag, was placed in a plumbago crucible in contact with about twelve times as much aluminum as the button originally obtained, together with an addition of two parts by weight of metallic tin, and covered with a layer of sodium silicate. The crucible with its contents was then subjected for about two hours to the most powerful heat that could be obtained. After cooling and breaking the piece of aluminum contained therein, the new modification was obtained in large perfect crystals possessing a full metallic luster, and true models of oblique octahedrons. After dissolving the small quantity of aluminum mechanically entangled, the analysis of the crystals denoted the existence of pure silicon only, being infusible and insoluble in all acids except hydrofluoric. In appearance the crystals resemble crystals of cast iron, which are sometimes met with upon breaking a pig of that substance, the largest assuming a size of over half an inch across the faces, and as perfect as a crystal of alum; in fact, it would be difficult to say as to what dimension these crystals could be obtained, as the author has on more than one occasion obtained perfect models over an inch and a half in length and thickness."

Strontium (atomic weight, 87.5) is a metal of the calcium group. Its sp. gr. is 2.5. It closely resembles calcium in appearance, but has a deeper color and is malleable. It is prepared in the same way as barium. Strontium is not abundant in nature, the carbonate (Sr_2CO_3), strontianite, and sulphate (Sr_2SO_4), celestine, being the only important minerals containing it, and these are by no means common. Strontianite, which is valuable in the arts, is a pale green, white, gray, or yellowish brown mineral of 3.6 to 3.7 sp. gr., and 3.5 to 4 in the scale of hardness. It is employed for the preparation of strontium nitrate, which is used in the red fire of the theaters, signal lights, and fireworks. Strontium compounds are also used in sugar refining, for which purpose they are said to be better than the corresponding ones of barium or calcium. Their use for this purpose, however, is limited by the small supply.

Tantalum (atomic weight, 182) is a rare element resembling columbium, with which it is often associated. It is said to be a black powder, but it is doubtful if it has been obtained pure. It occurs in the mineral tantalite, a tantalate of iron and manganese ($Fe(Mn)Ta_2O_6$). There is also a stanno-tantalate of the same bases, and some of the tantalic acid is often replaced by columbic acid. Tantalum also occurs together with columbium in the mineral columbite ($FeCb_2(Ta_2)O_6$), in which the percentage of tantalic acid may be as high as 29. Tantalite, which is confined mostly to albite or oligoclase granite, occurs at several places in Finland; at Vroddbo and Finbo, in Fahlun, Sweden; and near Limoges, France. Columbite occurs in about the same localities as tantalite. Specimens are found at Haddam and Middletown, Conn. An interesting new mineral containing columbium and tantalum was found recently in the alluvial tin field near Greenbush's, Western Australia. The mineral was as heavy as tin-stone, which in appearance it somewhat resembled, but chemical analyses proved it to be a columbo-tantalate of antimony, having the following composition: Tantalic acid (Ta_2O_5), 51.13%; columbic acid (Cb_2O_5), 7.56%; oxide of antimony (Sb_2O_3), 40.23%; oxide of bismuth (Bi_2O_3), 0.82%; oxide of nickel (NiO), 0.08%; ferric oxide, trace—total, 99.82.*

Tellurium (atomic weight, 125) is a silver-white metal of 6.2 sp. gr., which has a marked crystalline structure. It melts at about 500° C., and volatilizes at very high temperatures, its vapor being of a golden-yellow color. A bar of tellurium becomes feebly electrical when rubbed with a woolen cloth, and like selenium its electric conductivity is influenced by exposure to light, though not to the same extent. Tellurium is found native in Transylvania, and its occurrence has also been reported by Dana at the Red Cloud mine near Gold Hill, in Boulder County, Colorado. The element usually occurs, however, in combination with gold as telluride, and gold ores are the source whence it is derived. Since 1891 crude and pure tellurium have been produced by a wet process at the Royal Smelting Works, in Schemnitz, Hungary, from gold telluride ores from Nagyar (nagyargit, sylvanite). Up to the end of November, 1893, there had been produced 50 kilograms of metal containing 28.8% tellurium, 18 kilograms containing 43.2%, and 12 kilograms containing 59.5%, besides 2 kilograms of pure metal. At present there are 35 kilograms crude tellurium containing 43.2% and 2 kilograms containing 59.5% in stock at the works. The cost of producing the former was 40 marks ($10) per kilogram, while the latter cost 60 marks ($15) per kilogram at the works.† This metal is produced by a wet process invented by Prof. Alexander Mály, which is described in the "*Banya" Srati es Kohaszati lapor*, 1893, No. 22.

Thallium (atomic weight, 204) is a bluish-white metal of 11.86 sp. gr. It is extremely soft, and is almost devoid of tenacity and elasticity. It melts at 290° C., and boils at a white heat. When heated in air, however, it oxidizes quickly with the formation of a green vapor, it and its salts coloring flames green. It becomes coated with a film of oxide on exposure to the air, but the tarnished metal regains its metallic luster upon being plunged into water in which the oxide is soluble. When kept in contact with air and water, however, it is gradually converted into thallium hydrate, TlOH.

Thallium, which was first discovered in 1861 by means of the spectroscope, is a very rare element. It occurs in the mineral crookesite (selenide of copper, thallium, and silver, with 33.28% selenium and 17.25% thallium), which is found at the mine of Skrikerum, Småland, in Sweden, but this mineral is very scarce. Thallium is also found in certain pyrites, samples of which containing as much as 3.5% Tl have been analyzed, and the metal is prepared from the flue dust obtained in roasting these, and from the mud which accumulates in vitriol chambers. It is most easily obtained by heating its chloride ($TlCl_3$) at a red heat with cyanide of potassium, the metal being formed by the reaction: $2TlCl_3 + 6KCN = 2Tl + 6KCl + 3(CN)_2$.

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* *Iron*, May 26, 1893.

† The above data were kindly furnished by the director of the Royal Smelting Works at Schemnitz.

Thorium (atomic weight, 232) has been obtained as a dark-gray powder of 7.7 sp. gr., which is easily soluble in nitric acid, but difficultly soluble in hydrochloric acid. It occurs in the mineral monazite, which contains about 18% thoria (ThO_2), together with 26% cerium oxide and 23% lanthanum oxide, combined with phosphorus. Thorium usually occurs associated with cerium, lanthanum, and other elements of the same group. It has been prepared by heating potassium thorifluoride with sodium covered with a layer of common salt in an iron crucible. The oxide of thorium is used in the Welsbach incandescent lamps. (See "Cerium.")

Titanium (atomic weight, 48) is usually classed with the metals, although it approaches silicon more nearly in character. It is not a rare element, occurring very generally in iron ores, in which it is an undesirable constituent, and also in the mineral rutile, TiO_2. Metallic titanium is a dark-gray powder, like iron which has been reduced from its oxide by hydrogen. It is infusible, combines directly with nitrogen, and decomposes water at 100° C. When heated in the air it burns with a brilliant flame, forming titanic oxide. Titanium may be obtained by passing the vapor of its chloride over heated sodium, which combines with the chlorine, leaving the titanium. It may also be produced by the reaction of potassium on potassium titanifluoride ($2KF, TF_4 + 4K = Ti + 6KF$) in a red-hot porcelain crucible. Rutile, the oxide of titanium, is a brittle mineral of metallic-adamantine luster, 4.18 to 4.25 sp. gr., and 6 to 6.5 in the scale of hardness. In color it varies from reddish brown to black. It usually occurs in crystals in granite, gneiss, and similar rocks. It is used to give a peculiar ivory-like color to porcelain, and has also been extensively employed in the manufacture of artificial teeth, to give the enamel the requisite tint.

Uranium (atomic weight, 240) is a black powder of 18.7 sp. gr. which melts at a red heat, and fuses to a gray metallic button of great hardness ; it resembles iron in color, and tarnishes on exposure to the air. In the form of powder uranium takes fire at a comparatively low temperature, and burns with great brilliancy, forming a green oxide (U_3O_8). Uranium may be got from its chloride by heating it with metallic sodium in an iron crucible. The sodium unites with the chlorine while the metallic uranium sinks to the bottom of the crucible ($UCl_4 + 4Na = U + 4NaCl$). Recently an impure uranium has been obtained by Henri Moissan, the distinguished French chemist, in his electrical furnace, by which he claims to be able to obtain the extraordinarily high temperature of 3000° C. At ordinary temperatures the oxides of uranium are practically irreducible, but they have yielded to the heat of this furnace. To a mixture of uranic oxide (UO_3) and the green oxide of uranium (U_3O_8) a little powdered carbon is added, and the whole is strongly compressed. Upon exposing this in the furnace to a current of 450 ampères at 60 volts, a metallic ingot weighing 250 grams was obtained in about ten minutes.* The average composition of the ingots produced in this manner was 90% uranium and 10% carbon. Their melting point was much

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* Chromium and manganese have been prepared by M. Moissan in the same way, a mixture of protoxide of manganese and carbon having been reduced in the one case, and a mixture of calcined sesquioxide of chromium and carbon in the other. The manganese obtained, however, had only about 89% metal, and the chromium was of no higher grade, the remaining 11% being carbon, but it is claimed that pure chromium may be prepared by a further smelting.

higher than that of platinum (1780° C.). Incidentally may be mentioned a curious product, carbide of uranium, obtained by M. Moissan. This is a dull, blackish substance, which when shaken in a stoppered bottle sparks most energetically.

There is no use for metallic uranium, but its salts are valuable in the arts, being employed in the manufacture of uranium glass, which has the peculiar yellow color, with a greenish reflex, which is much admired. They are also used in coloring porcelain (black porcelain), and to some extent in photography. The amount of uranium consumed for these purposes, however, is very small. If uranium could be obtained in larger quantities there is no doubt it would find a more extensive use in the arts. Experiments made by certain steelmakers in England and Germany have shown that the addition of a small percentage of uranium to steel increases its elasticity, and at the same time its hardness to an extent which would make its use in the manufacture of guns, armor plates, etc., most desirable,* but the high cost of uranium at the present time precludes its employment for this purpose.

The most important minerals containing uranium are uranite, uraninite or pitchblende ($UO_2 + 2UO_3$), uranium ocher, uranium vitriol, chalcolite, and trögerite, the last two being of complex composition. They are mined at two places in the world, viz., at Grampound Road, in Cornwall, where 31 long tons of ore, valued at £620, were produced in 1891, and 37 tons, valued at £740, in 1892, by the Uranium Mines Company, Limited; and at Joachimsthal, in Bohemia. The production of uranium ore at Joachimsthal in 1891 was 22.52 metric tons, valued at 19,314 florins; in 1892 the output was 17.71, valued at 24,889 florins. At the fiscal works in Joachimsthal 6.18 tons of ore, valued at 20,783 florins, were treated in 1892, and 2.469 tons of uranium salts, valued at 28,398 florins, were produced. This was in part consumed in Austria and was in part exported. The salts of uranium produced at these works are the protoxide (U_3O_4), oxyhydrate ($U_2O_3 + 3H_2O$), potassium-uranium oxide (K_2O, U_2O_3), and oxide (U_2O_3). One kilogram of pure pitchblende costs about 9 florins ($3.60) in Joachimsthal, and one kilogram of uranium salts 18 to 20 florins ($7.20 to $8).†

I am indebted to Mr. Richard Pearce for the following memoranda of the occurrence of pitchblende in Cornwall: "Pitchblende almost invariably occurs associated with other rare Cornish minerals, and the laws which appear to regulate its deposit in various localities are strikingly analogous. At St. Austell Consols it was found with nickel and cobalt ores, and a quantity of this valuable mineral was sold as an ore of uranium. At Dolcoath, where I found it in 1859, it was associated with native bismuth and arsenical cobalt in a matrix of red compact quartz and purple fluorspar. At South Tresavean I discovered it in 1863 with kupfer-nickel, native silver, and rich argentiferous galena. I believe in all the localities I have named it was found in little veins crossing the lodes."

In the United States uranium has been found in the Archæan rocks of the Ball Mountain district in the Black Hills, South Dakota, in deposits which are

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* Herman Reinbold, *Engineering and Mining Journal*, July 18, 1891, p. 75.

† *Glückauf*, 1893, No. 64; *Oesterreichische Zeitschrift für Berg- Hütten- und Salinenwesen*, 1889, No. 30.

said to have promise of commercial value.* Mr. Pearce kindly furnishes the following interesting account of an occurrence of pitchblende in Colorado: "In 1871 I communicated to the Geological Society of Cornwall a short note regarding the occurrence of a deposit of pitchblende, discovered by me in the Wood Lode, in the Russell district, Gilpin County, Colorado. The deposit was lenticular in form and occurred in one of the ordinary gold-bearing lodes traversing the gneiss and mica schists of this district. The mine had been abandoned and was full of water, when my attention was drawn to the dump by the beautiful canary color of the uranvitriol (sulphate of uranium) which had resulted from the weathering of pitchblende when mixed with decomposing iron pyrites. When unwatered the shaft was found to be about 100 ft. deep, and I discovered that at 60 ft. from the surface a body of pitchblende had been passed through. On further development its dimensions were found to be 30 ft. long and 10 ft. deep. The vein of ore was about 10 in. thick. Nearly four tons of it, carrying 70% oxide of uranium, were obtained. The former owners had sent the best part of the deposit to the stamp mill with their ordinary gold quartz. Complaint was made of the hindrance which the heavy black mineral offered to amalgamation, but, being ignorant of its value, it was washed away with the water that flowed into the creek. Further search for another body of pitchblende proved unsuccessful. A small bunch of this mineral was, however, afterward found in the vicinity, at the Alps mine, on Quartz Hill."

Vanadium (atomic weight, 51.1) has been obtained as a whitish-gray powder, of 5.5 sp. gr., which has a brilliant metallic luster. It does not combine with oxygen at ordinary temperatures, but when heated over 100 C. it is rapidly oxidized and is finally converted into vanadic pentoxide, V_2O_5. Vanadium has been obtained by reducing its bichloride, V_2Cl_4, in hydrogen at a bright red heat, the utmost precautions being taken to exclude oxygen, as vanadium is at once oxidized at a red heat; moreover, since vanadium attacks porcelain, it is necessary to carry out the reduction in a platinum boat, which is placed in a porcelain tube.

There is no use for metallic vanadium, but its salts are employed to some extent in textile printing and dyeing. Vanadate of ammonium (which at present is worth about 90c. per oz.) and vanadic oxide are used for this purpose in conjunction with aniline, and serve to produce the most intense black known to the dyer and calico-printer. It may be observed, however, that just as the whitest white produced artificially has a bluish tinge, the vanadium black, which is the blackest black, has an olive-green cast. Vanadium salts are also used in the manufacture of ink. The amount of vanadium required, however, to make these colors is so minute (1.5 to 2.5 grains of acid sufficing for a gallon of dye) that the consumption of its minerals in the arts is very small. If there were a demand for them, they could doubtless be supplied in considerable quantities, being by no means rare.

The commonest of the vanadium minerals is vanadinite, which is a compound of the chloride and vanadate of lead, corresponding to the formula, $3Pb_3V_2O_8 + PbCl_2$, and containing 19.36% of vanadium pentoxide. Other vanadium minerals

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* Herman Reinbold, *loc. cit.*

are dechenite (PbV_2O_6), descloizite ($Pb_2V_2O_7$), pucherite ($BiVO_4$), and roscoelite ($2V_2O_3, V_2O_5$).* Vanadium frequently occurs in iron ores, and is often found in pig iron. Mr. J. T. Stead reports that British pig iron always contains it, and gives the following results: Clarence pig iron, 0.183%; Cleveland, 0.262%; Holwell, 0.186%; and Lincolnshire, 0.168%. No data as to the effect of vanadium on iron or steel have been recorded. Another interesting occurrence of vanadium is in the coal found at San Raphael, in the Province of Mendoza, Argentina. The coal seam at this place is 1 meter thick, and its ash contains as much as 38.22% of vanadium pentoxide.† Another vanadiferous coal from an unmentioned locality in Argentina is reported by A. Mourlot, who states that the ash contained 38.5% of vanadium, or 0.24% as calculated upon the entire coal, the ash forming 0.63% of the whole. The vanadium in the ash of this coal occurred in the form of alkaline and metallic vanadates.‡

The lead vanadates are frequently found in association with lead ores, as for instance in the deposits at Leadville, whence some very handsome specimens were formerly obtained. The most important occurrence of lead vanadates in the United States, however, is probably in Arizona, where it has been reported in the ores of several mines, among others those of the Castle Dome district, the Crowned King mine in the Bradshaw Mountains, and the Mammoth gold mines, at Mammoth, in Pinal County. The last-mentioned mines are probably the only ones in the United States from which vanadium minerals have been won on an industrial scale. I am indebted to Mr. T. A. Rickard for the following information concerning the occurrence and production of vanadium at Mammoth, contained in a private communication to him from Mr. G. W. Barnhart, who was on the staff of the mine at the time:

“The vanadium minerals, of which nearly all the known varieties occurred, the dechenite and descloizite predominating, were found in the upper levels of the mine, forming about 1% of the ore on the average, though within limited areas they formed from 3% to 4%. In the lower levels they occurred less abundantly, only an occasional pocket and a small quantity of disseminated crystals being found. The red crystals, according to an analysis by the late Dr. F. A. Genth, contained chlorine, 2.43%; lead, 7.08%; lead oxide, 69.98%; ferric oxide, 0.48%; vanadic acid, 17.15%; arsenic acid, 3.06%; and phosphoric acid, 0.29%. In milling the ore (gold) the vanadium minerals collected in riffles, placed about 18 in. apart in the sluices. The material thus obtained was worked over by hand in a sort of buddle, and the resulting concentrates were sold to the Kalion Chemical Company of Gray's Ferry Road, Philadelphia. The total quantity of concentrates obtained in this manner did not exceed six tons; an average sample of the lot, analyzed by Dr. Genth, gave the following results: Vanadic acid, 15.40%; molybdic acid, 3.35%; arsenic acid, 1.50%; carbonic acid, 0.90%; chlorine, 0.48%; oxide of lead, 56.80%; oxide of zinc, 10.70%; oxide of copper, 0.95%; oxide of iron, 0.35%; soluble silica, 0.60%; insoluble matter, 5.29%. The value of the gold and silver contents of the concentrates was about $140 per ton. The price

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* F. A. Genth, *Am. Jour. of Science*, July, 1876.

† J. J. Kyle, *Chemical News*, Oct. 28, 1892; H. D. Hoskold, *Iron*, 39, p. 340.

‡ *Comptes Rendus*, CXVII., No. 17, Oct. 23, 1893.

realized on this first lot was 12.5c. per lb., or $250 per ton on board the cars at Tucson.

"The vanadic salts manufactured from this lot of concentrates were said to have been the first produced on a commercial scale in the United States, and owing to the limited market for the same the price dropped over 50%.

"Frue vanners were then introduced into the mill, and the product obtained from them, amounting to about one ton per 100 tons of ore crushed, contained from 5% to 6% vanadic acid and $40 to $80 per ton in gold and silver. The Kalion Chemical Company offered to buy this product according to the following sliding scale: With the market price of ammonium vanadate $5 per lb., $100 per ton for the concentrates; vanadate of ammonium $4.50 per lb., concentrates $92; vanadate of ammonium $4 per lb., concentrates $82; vanadate of ammonium $3.50 per lb., concentrates $72; vanadate of ammonium $3 per lb., concentrates $64. Only a few tons of these concentrates were shipped to Philadelphia, the remainder being sold to the Denver smelters for their gold, silver, and lead value."

Vanadium minerals in minute quantities are found disseminated in many sedimentary formations, as for instance in the Mansfeld *kupferschiefer*. Very many iron ores also contain traces of vanadium. In the blast furnace the vanadic acid is reduced like phosphoric acid, and the vanadium thus isolated goes almost entirely into the pig iron. In converting the pig iron into steel, vanadium follows the phosphorus into the slag, from which it may be recovered. The slag is crushed and in small amounts is treated with a small amount of chlorhydric acid, which dissolves the vanadium as tetroxide. To obtain a more concentrated solution the first is neutralized and an alkaline acetate is added, whereby the phosphate of the tetroxide is precipitated.*

Vanadate of lead when used as a source of vanadium salts is first treated with nitric acid, after which the lead is precipitated with hydrogen sulphide. Ammonia and ammonium sulphide are added to the filtrate, whereby a dark brown sulphate of vanadium is precipitated from the red solution, which is then roasted and melted with saltpeter, the resulting product being vanadate of potassium.

Ytterbium (atomic weight, 173.2) has not yet been obtained in the metallic form.

Yttrium (atomic weight, 89) has not yet been obtained pure. A grayish-black lustrous powder, which is a mixture of yttrium and erbium, is prepared by the action of potassium on the impure chloride of the two metals.

Zirconium (atomic weight, 90) is an element closely related to silicon, occupying an intermediate position between it and the metals; zirconium, however, resembles silicon the more closely, especially in the properties of its oxide. It exists both in an amorphous and a crystalline state. It fuses at a very high temperature, and does not combine with oxygen at a red heat, but at a white heat it

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* *Berg- und Hüttenmännische Zeitung*, Vol. LII., No. 50, Dec. 15, 1893, p. 441.

Concerning the occurrence of vanadium in iron, Howe (*Metallurgy of Steel*, Vol. I., 1893, p. 86) says that Riley has found cast iron containing as much as 0.686%, while Sefström discovered it in the bar iron and the refinery slags from the Taberg (Swedish) ores, but there are no data concerning its influence. According to Witz and Osman (*Journal of the Iron and Steel Institute*, 1882, 2, p. 770, from *Comptes Rendus*, XCV., I., p. 42), it concentrates in certain slags, notably in those of the Bessemer process.

burns with great brilliancy, zirconia being formed. Crystalline zirconium (sp. gr., 4.1) is very hard and resembles antimony in color, luster, and brittleness. Zirconium occurs in the mineral zircon, which is not uncommon.

The oxide of zirconium when made into a paste with water and boracic acid, and baked in a very hot fire in iron molds, forms hard masses which burn in the flames of the oxyhydrogen blow-pipe with a luminosity and brilliancy far surpassing that of calcium. This is known as the zirconia light. It has never, however, come into extensive use. Zirconia is also used in the Welsbach incandescent lamps. (See "Cerium.")

Zircon is found on the Meridith-Freeman estate on Green River, Henderson County, North Carolina, where Gen. T. L. Clingman, who owned the property, mined 1000 lbs. of the mineral in 1869. At Anderson, in Anderson County, S. C., large quantities of the mineral are found loose in the soil under somewhat the same conditions as in North Carolina. The crystals are remarkable for their perfection and size, sometimes weighing several ounces. They come evidently from a decomposed felspathic rock. Crystals of zircon weighing as much as 15 lbs. have been found in Canada in Renfrew and adjoining counties, but they are so isolated that it would be impossible to obtain them in any quantity. Zircon occurs in beautiful but small crystals in alluvial gravel in California. According to the Sixth Annual Report of the State Mineralogist of California, it could be collected by the ton in cleaning up hydraulic mines if there were a market for it. The following localities are the most important: Arroyo Seco, and Irish Hill, in Amador County; Cherokee, Butte County; Picayune Flat, Fresno County; in the sands of the Novarro River, Anderson Valley, Mendocino County; and Eagle Gulch and Rock Island Hill, in Plumas County.

SALT.

Complete data concerning the geological occurrence of salt, its geographical distribution, and methods of preparation, will be found in The Mineral Industry, Vol. I. The following interesting information regarding the manufacture of salt is taken from an article on "Salt in Kansas," by Prof. E. H. Bailey.

The greater portion of the salt made in this State is by the evaporation of brine, which is usually secured by boring a well of about five inches diameter to the salt strata, lining with tubing, and placing within this a second tube of about three inches diameter. Water is forced down one tube and becomes saturated with salt to about 90° on the salometer, and then flows out of the other tube. This brine is stored in elevated wooden tanks until ready for evaporation. In central Kansas there are many "salt blocks" for the concentration of brine, all using artificial heat, except one at Solomon City, where solar heat only is utilized.

(*a*) *Evaporation by Direct Heat.*—The pan consists of a wrought-iron vessel about 125 by 25 ft. and 12 in. deep. Beneath one end of this is built a coal fire, the heat from which passes under its entire length. The first division of the pan over the fire, and in some cases several divisions, are so arranged that the brine can be retained in them till it has evaporated sufficiently to deposit some of its impurities, especially the calcium sulphate. When this has been accomplished, the solution, now saturated with salt, is allowed to flow into the last division, where the heat is not so intense. Here the salt crystallizes out and falls to the bottom, from which it is removed every two hours by workmen with long-handled rakes, and placed upon the platform at the side of the tank, where it can drain before being shoveled into carts for transfer to the storeroom. Each pan and furnace forms a complete "set" for making salt. In the larger "blocks" a number of these pans are usually placed side by side. When the brine contains a large quantity of magnesia salt, it is run off, since they are liable to contaminate the salt by adhering to the crystals as they dry.

(*b*) *Evaporation by Steam Heat; the "Grainer" Process.*—In this process the brine is first run from the storage reservoir into a large wooden tank heated by waste steam. This is a purifying tank where the calcium sulphate is allowed to deposit. It then passes into a long, rectangular wooden tank, having parallel rows of steam pipes across the bottom. Raking is performed only occasionally, as after a short time gypsum incrusts the pipes, and the brine must be drawn off, so that the incrustations may be removed. The salt, after being raked or "lifted" out of the pan, is drained, as in other processes.

(*c*) *Evaporation by Solar Heat.*—In the plant at Solomon City the brine is pumped from wells about 100 ft. deep into a series of wooden tanks or vats. In the first of the series concentration is allowed to proceed until calcium sulphate and other impurities deposit. After the salt begins to crystallize, the brine is transferred into other tanks, where the process is completed. As crystallization proceeds slowly, the crystals are large, often quite perfect, and of the characteristic hopper shape. Wooden covers are arranged to slide over the vats, to protect the salt from frequent showers and dust. If the covers are used at night much of the heat absorbed during the day is retained. This method is similar to that long used in the salt works at Onondaga, N. Y. The purity of the product depends upon the care used in allowing the brine to settle, and in carrying the first concentration far enough to precipitate a large portion of calcium sulphate. If the concentration is carried too far, some salt is lost. At the Solomon City works the brine is sometimes strengthened by the addition of crushed rock salt from the Kansas mines, but this mixture is said to yield a less desirable product.

With an abundant quantity and excellent quality of brine, the only obstacle to the economical production of salt is cheap fuel. By the use of "coal slack" the cost of fuel has been considerably decreased, but still the expense is large compared with that of some other salt regions. Improved furnaces will make a still further decrease in cost, as those now in use are very wasteful of fuel. Possibly some cheap system of compression may be found to utilize the vast quantities of straw and corn-stalks that are produced in the Western States, but at present nothing of the kind is done. In the matter of economy of production it is essential that only a saturated brine should be used, as every pound of unnecessary water evaporated adds to the expense. Many of the salometers in use are inaccurate, registering from 102° to 106° in saturated solutions of brine at the standard temperature. It has been found that, as a rule, the use of the ordinary specific gravity spindle is more satisfactory. When purity of the product is required, it is considered best to run the pans only a short time without running off the brine, as chloride of calcium, magnesium, and other soluble salts that drain from the crystals increase in quantity and tend to adhere to the product.

Mr. F. E. Engelhardt writes as follows regarding the salt industry during the past year: "No important improvements in the manufacture of salt were made during 1893, but new salt works were erected in New York State, at Pavilion, Gainsville, and on Seneca Lake near Watkins.

"The salt industry of the United States, like all other industries, has suffered from the business depression during the past year, without giving promise of improvement in the near future. The main causes, besides the general stagnation of business, to which the decrease in our salt production is due, are the slight demand for packing salt, owing to the scarcity of pork during 1893, the cessation of silver mining in the Western States and Territories, and the sending of fresh provisions directly to the seaports for home consumption or export. The Syracuse salt production was reduced from 881,135 barrels in 1892 to 613,181 barrels in 1893, a loss of 267,954 barrels, and the lowest production since 1842. The Michigan salt production decreased from 3,812,054 barrels in 1892 to 3,483,301 barrels in 1893, an actual loss of 328,753 barrels. Utah, which recorded in 1892 a production of 900,000 barrels, reached in 1893 hardly 196,000 barrels. That the place of the home product has not been taken by imported salt is evident from our salt importations from Great Britain, which amounted in 1892 to 88,695 tons and in 1893 to but 60,056 tons."

PRODUCTION OF SALT IN THE UNITED STATES BY STATES AND TERRITORIES.

(In barrels of 280 lbs.)

Year.	California.	Illinois.	Kansas.	Louisiana.	Michigan	Nevada.	New York.	Ohio and W. Va.	Utah.	Other States.	Total Barrels.	Total Short T'ns
1883	214,286	......	....	265,215	2,894,672	21,429	1,619,486	670,000	107,143	400,000	6,192,231	866,912
1884	178,571	......	....	223,964	3,161,806	17,857	1,788,454	630,000	114,285	400,000	6,514,937	912,091
1885	221,428	......	....	299,271	3,297,403	28,593	2,304,787	530,031	107,140	250,000	7,038,653	985,411
1886	214,285	......	....	299,691	3,677,257	30,000	2,431,563	650,000	164,285	240,000	7,707,081	1,078,991
1887	200,000	......	....	341,093	3,944,309	......	2,353,560	590,000	325,000	250,000	8,003,962	1,120,555
1888	220,000	......	155,000	394.385	3,866,228	......	2,318,483	600,000	151,785	250,000	8,055,881	1,127,823
1889	150,000	......	450,000	325,629	3,856,929	......	2,273,007	450,000	200,000	300,000	8,005,565	1,120,779
1890	62.363	......	882,666	273,553	3,837,632	......	2,532,036	461,241	427,500	300,000	8,776,991	1,228,779
1891	200,000	......	1,000,000	221,430	3,927,671	15,000	3,532,600	672,000	465,000	200,000	10,233,701	1,432,718
1892	235,000	60,000	1,232,850	192,850	3,812,054	20,000	4,400,000	738,000	900,000	*b*225,000	11,784,954	1,649,894
1893	312,850	70,000	1,607,000	172,500	*c*3,483,301	10,000	4,413,181	*a*925,320	196,900	*b*244,435	11,435,487	1,600,968

(*a*) Includes the production of Pennsylvania. (*b*) The production of Texas was 120,000 barrels in 1892, and 144,435 in 1893. (*c*) Amount inspected.

SALT PRODUCTION OF THE CHIEF COUNTRIES OF THE WORLD. (IN METRIC TONS.)

Year.	Algeria.	Austria	Canada.	France.	Germany.	Greece.	Hungary.	India.	Italy.	Russia.	Spain.	United Kingd'm	United States.
1872	......	293,155	......	....	514,549	....	162,105	....	22,340	....	54,397	1,320,964	....
1873	......	283,663	......	627,176	524,993	....	146,067	....	24,133	826,208	48,205	1,814,263	....
1874	......	278,628	......	656,169	568,477	....	121,121	....	24,858	769,631	34.127	2,344,390	....
1875	......	262,265	......	674,425	573,865	....	110,539	....	22,943	622,810	28,582	2,354,625	....
1876	......	249,465	......	585,380	577,884	....	120,116	....	23,316	717,046	144,715	2,310,522	....
1877	......	251,058	......	593,525	584,378	....	118,876	....	24,625	474,626	118,877	2.779,836	....
1878	......	241,294	......	571,255	607,318	....	145,796	....	25.447	781,615	90,679	2,726,912	....
1879	......	254,633	......	545,772	667,151	....	151,421	....	28,162	818,523	82,095	2,600,308	....
1880	......	255,936	......	699,876	722,457	....	157,879	....	....	779,867	105,921	2,688,361	....
1881	......	267,279	......	744,218	768,865	....	149,944	764,942	31,267	830,013	150,389	2,315,896	....
1882	......	....	......	706,626	781,941	....	163,929	1,194,260	29,025	1,664,950	112,582	2,170,472	....
1883	......	274,395	......	743,346	805,252	13,860	159,837	730.043	28,837	1,136,566	117,930	2,362,863	786,463
1884	......	264,771	......	739,823	809.678	....	159.547	1,206,360	27,227	1,022,521	112,317	2,370,945	827,449
1885	......	270,400	......	638,866	838,783	....	162,962	1,164,763	27,682	1,131,791	117,304	2,243,875	893,964
1886	......	282,702	56.587	663,443	923,882	....	152,222	....	29,275	1,194,359	124,851	2,177,338	978,861
1887	34,000	283,389	54.603	823,910	889,512	17,000	159,898	1,045,492	29,200	1,155,280	405,394	2,229,917	1,016,567
1888	26,000	280.062	53.602	631,540	910,945	17,500	163,750	....	29,749	1,111,679	413.886	2,343,305	1,023,161
1889	30,000	283,553	29,793	746,794	1,037,113	19,455	164,518	1,045.376	28,490	1,392,599	745,406	1,978,407	1,016,771
1890	23,974	304.084	39,704	842,529	1,049,644	18,000	159,912	1,052,849	26,978	1,388,365	615,727	2,182,045	1,113,148
1891	34,665	301,422	40,854	810,675	1,170,179	19,772	162,788	1,032,268	40,543	1,351,187	....	2,077,072	1,299,762
1892	......	288,424	......	....	1,167,264	21,660	163,514	....	23,721	....	....	1,988,024	1,496.771
1893	......	....	......	....	....	....	....	....	....	....	....	....	1,452,388

NOTE.—For Austria, Hungary, Russia, and Spain the production of all kinds of salt is given; Germany, rock salt and common salt; Greece, sea salt; France, rock and sea salt; Algeria, rock salt; Italy, rock and salt from brine; United Kingdom, rock and brine salt; India, salt which is liable to British salt tax only, and does not include salt made in certain native States.

SLATE.

Slate is an argillaceous shale, easily recognized by its cleavability, and varies in color from light sea-green and gray to red, purple, and black. It has been formed by sedimentary deposits, and now constitutes extensive beds in the Silurian formation.

Occurrence.—Slate occurs in many parts of the United States, some of the noted quarries being in Pennsylvania, Vermont, New York, Maine, Virginia, and Georgia. In the Fairhaven, Castleton, and Hydeville quarries of Vermont slates are found of purple, green, and variegated colors. The quarries at Poultney, Wells, and Pawlet, in the same State, produce large quantities of unfading sea-green slate and a limited amount of variegated and purple. Red slate is a product confined to Washington County, New York, and found in only six quarries, which are able, however, to supply the demand. At present there are 47 slate quarries in operation in Vermont and 11 in New York, the slate belt in these two States covering an area of 40 miles in length by from 1½ to 5 miles in width, forming a valley running east and west in the southern trend of the Adirondack mountains, a few miles south of the valley of Lake Champlain.

Historical Sketch.—Slate has been used since the remotest times of antiquity, and its value for preserving important records was recognized very early. Indeed, there is ground for the belief that the "tablets of stone" on which Moses recorded the Ten Commandments were made of slate. In the United States the primitive mode of covering a roof with slate, generally in vogue by the Welsh of North Wales and the Dutch settlers in New York some 200 years ago, was to fasten strips of wood to the rafters, and by means of wooden pegs fasten to them large slate slabs, an inch in thickness, having two holes bored through them. These were heavy and cumbersome, as large as six or eight slates of the present standard. During colonial times slate stones were commonly used, and set up to commemorate any unusual event or to mark a spot where some tragic event had taken place. In 1845 the first quarry was opened in the slate belt by Colonel Allen and Captain Ranney of Fairhaven, Vt., whose intention was simply to develop a quarry from whose product school slates could be manufactured. After perfecting a machine to manufacture the frames and another for smoothing the slate, they were able to produce about 600 slates a day, worth $30 or $40. After two years this business was abandoned for the manufacture of roofing slates. The manufacture of slate-pencils was carried on about the same time in the adjoining town of Castleton, and quite extensively, until they were forced from the market by the introduction of the German pencil, which is made at small cost from a plastic mass by being rolled and baked.

The two principal branches of the slate industry, roofing slate and manufactured or "milled" slate, were soon developed. Enameling or "marbleizing" slate, the invention of Magnus, was first introduced into this country by a Mr. Story of Boston. In 1853 a slate mill was erected at West Castleton, Vt., where sawing and planing slate for blackboards, billiard-beds, etc., were carried on. Two years later a shop was established for enameling, but was not financially successful. Previous to this time (in 1850) quite a large number of slate workers from North Wales arrived in Fairhaven, and the manufacturing of roofing slate became an important industry. Two hundred squares had been the output in 1847, but in 1855 this was increased to 45,000 squares. From 1860 to 1870 the slate business grew rapidly, and in 1875 the value of all the slate produced in Vermont was $375,000, chiefly from the quarries in the vicinity of Fairhaven. In Washington County, New York, a large number of quarries had been opened in 1853 and 1854, among others the so-called "Gould" quarry, started by Mr. Ben Williams. Jay Gould became Williams's partner a few years later, and quarrying what is now known as the sea-green slates begun. This deposit is the most extensive along the slate belt, and more slate is produced from the easy cleavable sea-green slate ledges than from any others in this section.

Prospecting is generally carried on by one or more quarry laborers anxious to better their condition, who search the country until they find slate outcroppings which will warrant the investment of time, labor, and the necessary capital. They then choose between two plans of working, according as they wish to make slabs or roofing slates. A quarry is opened, and the product sold in the form of slabs to the slate mills, the average price being 10c. per ft. The quarrymen realize returns every thirty days if they sell their stock for milling purposes. To open a quarry for roofing slate requires more time, labor, and capital, because of the stock which must be carried. There are some 40 or 50 different sizes of slate, the principal ones being from 12 in. by 6, 7, 8, and 10 in., to 24 in. by 12 and 18. In order to produce a car load of any one size, several car loads of other sizes will also be produced. A slate stone is raised from the pit by means of steam hoists, and taken by a workman who cuts or marks the stone crosswise by striking a few blows on each side with a chisel and hammer. Then, turning the stone on edge, a small slate chip is laid upon the place marked by the chisel, a heavy blow struck with a large wooden mallet, breaking the stone in two. It is then cleaved in sections perhaps one-quarter inch in thickness, and passed into the slate shanty, where it is made into "finished slate," the final operations being cleaving or splitting of slate into thin sheets about three-sixteenths inch thick, and cutting into different sizes with a slate trimmer. Slatemakers usually go in gangs of three, often with a boy to trim. A gang of men will make from 10 to 20 squares a day, the number depending entirely upon the cleavability of the slate. The number of pieces of slate to a square varies according to the surface required for a lap. A "square" of slates 12 by 6 in., with 4 in. lap, will contain 600 pieces while a size 24 by 18 in., with the same number of inches for lap, has but 80 pieces.

Slate intended for manufacturing purposes is in slabs, which will average, perhaps, 75 sq. ft., though rarely it may reach 100 sq. ft. An exceptionally large piece quarried last year was 4½ by 19 ft. and 5 in. thick, containing 475 sq. ft. The slab is taken into the mill, where it is sawed, planed, smoothed, and prepared for the cutters. It is then cut into the right form for mantels or other objects and given over to the "marbleizer." By the process of "enameling," either smooth or sculptured slate is transformed into imitation Mexican onyx, jasper, Lisbon, Sienna, sarrancolin, echaillon, or Bomgard. Besides the above uses, its application as an educational means is noteworthy and an important part of the industry.

The recently dissolved Vermont Slate Company consisted of twenty-two producers of sea-green slate, who united in order to maintain a standard price for this particular quality of slate. Last year it produced 200,000 squares, valued at $3 per square, or $600,000. This represents half the entire production of the slate section. The value of the red slate produced in 1893 was $70,000. On account of its scarcity, this product commands a high price, varying from $9.25 to $11.50 per square. The estimated value of the combined products of the unfading, variegated, and purple quarries for the past year is $180,000, and of slate manufactured for other purposes than roofing at $300,000, so that the value of the total output for the entire slate belt of Vermont and New York is not far from $1,100,000. The industry furnishes employment to nearly 3000 men and boys, and represents an investment of $80,000 in buildings, $800,000 in land, $230,000 in live stock and machinery, and $250,000 in cash. The slate belt of Vermont and New York is exceeded in the volume and value of its output only by that of Pennsylvania, but easily ranks first in the production of colored slates and in the quality and quantity of marbleized slate mantels and other manufactured products.

Acknowledgment is due Mr. George H. Harris for valuable information. The following table shows the number of quarries and the product and value of the slate industry in 1893, as compiled by the *American Slate Trade Journal:*

Regions.	Quarries.	Production of Roofing Slate in Squares.	Total Value of Roofing Slate.	Total Value of Other Manufactured Slate.	Total Value of Entire Product.
Bangor region, including the Pen Argyl and hard vein sections of Pennsylvania	61	330,000	$930,000	$200,000	$1,130,000
Lehigh region, including the Walnutport and Danielsville sections. Pennsylvania	49	143,000	533,000	225,000	758,000
Vermont and New York region, comprising Rutland County, Vermont, and Washington County, New York	73	305,000	876,000	300,000	1,176,000
Peach Bottom region, Pennsylvania	10	29,500	143,000	4,000	147,000
Maine	5	43,000	213,000	6 000	219,900
Virginia	4	21,000	85,600	2,400	88,000
Georgia	2	4,500	11,250	....	11,250
Total	202	871.500	$2,780,600	$737.400	$3,518,000

SODIUM.

SODIUM (atomic weight, 23.053) is a metal which does not occur in nature in an uncombined condition, though its salts are widely distributed. It is of high luster and silver-white color. Its sp. gr. at 15° C. is 0.985. It is soft at ordinary temperatures, melts at 97.6° C., and oxidizes in the air. It decomposes water with the formation of a solution of caustic soda, taking fire instantly in contact with hot water and burning with a bright yellow flame; with cold water, however, it seldom ignites.

Sodium unites with several other metals, forming an interesting series of alloys. M. Joannis describes* an alloy of sodium and lead, containing 18.38% sodium. On exposure to the air this compound heats strongly and in contact with water is decomposed, leaving soda and lead in the form of black flocks. The alloy of lead and potassium, Pb_2K, is obtained by the action of an excess of potassammonium upon lead. Bismuth-sodium, $BiNa_3$, and antimony-sodium, $SbNa_3$, are obtained in an analogous manner. Both these alloys ignite spontaneously in the air, throwing up a splendid sheaf of sparks, and are decomposed by water with an escape of pure hydrogen.

Until 1886 the only process employed for the production of sodium was that wherein a mixture of carbonate of soda, lime, and carbon was intensely heated in wrought-iron tubes of small diameter. The metallic sodium was thus reduced and distilled, small flat boxes being used as condensers. At that time the only manufacturers were the Magnesium Metal Company, at Patricroft, England, and M. Pechiney, at Salindres, France. Outside of the small quantities used for laboratory purposes, the only applications of the metal were for the production of aluminum and magnesium. The wholesale price was then $1.25 per lb., and in no one year did the combined production of these two works exceed 10 tons. In the early part of 1887 the Aluminum Company, Limited, of Oldbury, England, completed its works, and the production of sodium by the Castner process was commenced, caustic soda being the raw material from which the metal was reduced, according to the reaction $3NaHO+C=Na_2CO_3+3H+Na$. This reaction takes place at a comparatively low temperature, and as the charge or mixture fuses it is possible to employ large vessels, special means being adopted to insure contact between the liquid alkali and the reducing material while carrying on the operation.

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* *Comptes Rendus*, CXIV., No. 11.

This process entirely superseded the old one, and the price of sodium fell during 1887 to 75c. per lb., which caused the older manufacturers to cease production. The plant erected by the Aluminum Company, Limited, was capable of producing about one ton daily, and although it is quite probable that the works were never fully employed, practically the entire production was used for the manufacture of aluminum.

In 1889 Mr. Castner invented the present electrolytic process, which is now being used solely at the Oldbury works. This process consists practically in the electrolysis of caustic soda, maintained at a constant temperature of 313° C., in specially constructed cells, which are arranged in series, and carry a current of 1000 ampères, each cell requiring from 4 to 4½ volts. The electrical efficiency is about 80% of the theoretical electrical decomposition.

The present output of the Aluminum Company, Limited, which is now the sole manufacturer of sodium, is between five and six tons weekly, necessitating the use of about 1000 horse-power. In 1890 the manufacture of aluminum by means of sodium ceased, owing to the success of the electrical process, but since that time Mr. Castner has invented several chemical processes wherein sodium is now being used, the patents being owned by the Aluminum Company, Limited. Among them probably the most important is the manufacture of peroxide of sodium (Na_2O_2), which is quite a new commercial product and is rapidly taking the place of all other materials, especially peroxide of hydrogen, as an oxidizing agent in bleaching. Sodium peroxide is a stable compound when not exposed to the air and is easily kept in tin cans, in which it is put up. The oxygen of the compound is set free by the use of dilute acid, sulphuric acid being usually employed.

$$Na_2O_2+H_2SO_4=Na_2SO_4+H_2O+O.$$

Other uses for this substance, not having been patented, have never been made public, but its employment has been suggested in many commercial organic reactions, involving the production of artificial indigo, salicylic acid, pure alcohol, ethyl, phenacitin, etc. Meister, Lucius, and Brunning of Hoechst, near Frankfurt, Germany, have just erected a plant for the manufacture of sodium by the Castner process, the metal being required by them for the manufacture of antipyrine under Dr. Knorr's patent.

Sodium is usually preserved in naphtha or petroleum. According to Rosenfeld,* when sodium which has been kept under mineral oil and is covered with a crust is immersed in a mixture of three parts of petroleum and one part of amyl alcohol, or rubbed with a cloth soaked with this mixture, it acquires at once a silvery luster. If, then, it be put into petroleum containing five per cent. amyl alcohol, washed with pure petroleum, and kept in petroleum containing one-half to one per cent. of amyl alcohol, it preserves this luster for a long time; becoming covered very slowly, however, with a film of sodium-amyl oxide, which is easily removed with filter paper. Potassium and lithium can be cleansed in a similar manner. Sodium thus cleaned combines at once with mercury, evolving light. By pressing clean sodium and potassium together under a mixture of one part amyl alcohol and nine parts petroleum, the liquid alloy of these metals is easily obtained.

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* *Jour. Chem. Soc.*, LX., 982, September, 1891.

SULPHUR.

By J. F. Kemp.

Sulphur as such is almost invariably obtained from deposits of the native mineral. The only other source is in the accumulated alkali waste of the soda manufactories, which is treated by the Chance process in England and on the Continent. A brief outline of it is given under "England," p. 257. The process promises to be an increasingly strong competitor with Sicilian sulphur, although as yet, in the statistics that are available, it does not appear very prominently. The process reproduces in many respects the reactions that lead in nature to the formation of sulphur from gypsum.

Native sulphur resembles the artificial product in all respects. It is yellow, with an occasional brownish cast from contained bituminous matter. The presence of selenium also darkens the color. The hardness is 1.5 to 2.5; sp. gr. 2.07; the crystals are rather acute octahedra of the orthorhombic system, and are often extremely rich in faces. The common mineral is, however, massive, and the crystals only appear in cavities. The native mineral kindles readily in a flame, yielding the characteristic, suffocating odors.

The geology of sulphur may be summed up under two rather simple types.

I. *The Solfatara Type.*—This is deposited directly from sulphurous gases, especially sulphuretted hydrogen (H_2S) and sulphur dioxide (SO_2).* These two react on each other, most quickly in the presence of moisture, to produce water (H_2O) and sulphur (S). As is well known, H_2S is a powerful reducing agent. These gases emanate in regions of expiring or active volcanoes and form *solfataras.* The sulphur collects in cracks in the lava and in the tuffs, or in the kaolin and clay yielded by the corroding action of the acid fumes on the lavas. Gypsum, native alums, etc., are frequent associates. Some vents, as Vesuvius, yield in much the same way deposits of ferric chloride, whose yellow color at first suggests sulphur and deceives the hasty observer. Occasionally some arsenic is found with this volcanic sulphur, in the associated minerals orpiment (As_2S_3) and realgar (AsS).† Such was the case on the island of Vulcano, one of the

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* The chemistry of the process is best described by Ilosvay, in the *Foldtani Közlony* (Hungarian Geological Society), 1884, pp. 38, 147. An abstract appears in the *Zeitschrift f. Kryst.*, X., 91, in German. The natural process was successfully imitated artificially by Ilosvay.

† Specimens in the geological collection of Columbia College.

Lipari group, off the coast of Italy, where for a time these minerals were gathered. The same association also occurs in the Yellowstone Park. Small traces of selenium and tellurium have been detected in an orange-yellow Japanese variety.*

So far as can be learned, Japan and southern Utah are the only deposits of this character that are now of much actual importance.

II. *The Gypsum Type.*—The second type results from the alteration of gypsum through the reducing action of bituminous matter, and hence always occurs in a series of sedimentary rocks, with marls, shales, and limestones prominently developed. The general reactions involved are apparent from the following: Gypsum is $CaSO_4 + 2H_2O$. The reducing action of bituminous matter destroys the sulphate and yields calcium sulphide, carbonic acid, water, and the like. The further changes may take place elsewhere in case the calcium sulphide wanders away in solution. The oxygen of the air, carbonic acid, and water react on this (according to Bischoff, at as low a temperature as 35°C.) so as to produce calcium carbonate, sulphuretted hydrogen, and a polysulphide of calcium. The polysulphide in its turn yields carbonate of calcium, native sulphur, and sulphuretted hydrogen.† Fuchs and De Launay in their *Traité des Gîtes Minéraux*, etc., p. 274, remark that such a change would produce a mixture of calcium carbonate and sulphur, with about 24% sulphur as a maximum, and that this happens to be about the mean percentage of crude Sicilian sulphur rock. The original gypsum has, as a general thing, been deposited in the evaporation of isolated bodies of salt water, and it often has great beds of rock salt, as in Sicily, associated. It is a remarkable fact that such deposits of sulphur-bearing strata are very widespread in Europe and of uniform Tertiary (mostly Miocene) age. They are known in France, Spain, Sicily, northeastern Italy, Poland, and Greece. In the Caucasus they are Jurassic. The beds in southwestern Louisiana are in the Quaternary belt. The reports from western Texas are as yet too meager to warrant an inference as to geological age.

As of mineralogical interest it should be also noted that sulphur results from the alteration of pyrites, marcasite, and related sulphides, although it is doubtless true that here, as in the last case, the presence of bituminous or organic matter is necessary. Masses of pyrite in limestone, as in the calciferous strata on Lake Champlain, may yield crusts of sulphur an inch or so thick, and the decay of the same frequently affords, in coal seams, flaky coats. Gypsum is a common companion in both cases. In the oxidized zone or iron hat of veins of sulphurets, crystals of sulphur are found, often very prolific in faces. In this country such have been studied and measured from the Wheatley mine,‡ Phœnixville, Penn.; from the Bassick mine,§ Colorado; and from a small lead mine in Carroll County, Maryland.‖ Sulphur is thus one of the not unusual gossan minerals.

In the following descriptions the localities are alphabetically arranged by countries. Under each country, if there is more than one locality, these are further arranged alphabetically. Under the first type of deposit belong Celebes,

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* E. Divers, *Chem News*, XLIV., 217, 284, 1883. Te, 0.17%; Se, 0.06%; As, 0.01%, caused an orange tint.

† The chemistry of the change is well set forth in Roth's *Allgemeine und Chemische Geologie*, I., 88, and also in Fuchs and De Launay as stated.

‡ *K. Busz-Zeitschrift f. Kryst.*, XVII., 549; XX., 563. § *Ibid.*, XV., 620.

‖ G. H. Williams, *Johns Hopkins Univ. Circulars*, No. 87, April, 1891.

Iceland, Italy (near Rome, at Naples, and on the island of Vulcano), Japan, Mexico (Popocatepetl), the United States (Alaska, California, Nevada, and Utah), West Indies (Saba, Guadeloupe, etc.). Under the second, France, Greece, Italy (Sicily, Romagna), Russia (various widely separated districts), Spain, the United States (Louisiana, Texas). Sicily is much the most important producer. Spain, Japan, Greece, and one or two more follow in this order. The others are of greater scientific interest than of practical importance.

Alaska.—See under *United States.*

Austria.—For more than forty years sulphur has been known near Cracow, in Poland, at the town of Szwoszowice. The strata are of Tertiary age, and of the same horizon as those containing the rock salt at Wieliczka.

The principal associated rocks are gypsum, limestone, shales, marls, etc., practically the same section as in Sicily. Five upper beds at intervals of about 12 ft. were known in 1850, and three others lower, but only the upper one of 1 to 5 ft. was worked. The layers were not very regular or continuous, and were thought to have been deposited by ascending waters.

Literature.—VON ZEPHAROVICH: *Mineralogisches Lexikon,* II., 390. ZEUSCHNER: "Dépôt de Soufre à Szwoszowice, près Cracovie," *Bull. Soc. Geol. de France,* VII., 715, 1850.

California.—See under *United States.*

Celebes.—In the North Celebes, on Lake Lino, an old crater lake, large masses of sulphur occur in tufas along the shore, associated with solfataras and hot mud springs. They are not as yet exploited.

Literature.—A. FRENZEL: *Tschermak's Min. u. Petrog. Mitth.,* III., 289-300.

Egypt.—Some sulphur mines were discovered in 1850 on the shores of the Red Sea, at Bahar el Saphingue. The rock is said by Delaporte to yield 45% S. Further descriptions of these and neighboring occurrences will be found in the *Bolletino geologico d'Italia,* 1872, III., 367. The sulphur occurs along with petroleum in a middle-Tertiary limestone.

Literature.—DELAPORTE (consul of France at Cairo): "Sur les Mines de Soufre de la Haute Egypte," *Annales des Mines,* 5e., I., 599. 1852.

England.—The product of England, which is considerable, is obtained entirely from alkali waste. The same process is also employed by some Continental works. The problem of utilizing this waste from the Leblanc soda works has been long a matter of attention, and has been finally solved by Mr. A. M. Chance of Oldbury, England. The alkali waste, which forms many millions of tons around the works, contains calcium sulphide, about 25%; ferrous sulphide, 0.94%; calcium carbonate, about 25%; and moisture, 34%. We thus begin with much the same materials as were outlined under the second type of natural sulphur beds from gypsum. Carbonic acid gas in the presence of water breaks up the calcium sulphide into calcium carbonate and sulphuretted hydrogen. This was established as far back as 1861 by William Gossage. The problem was thus reduced to utilizing the H_2S. In the Chance process the alkali waste is sifted, and a thin cream or emulsion is made with the finer parts and water. These are confined in a series of suitable vessels, and the gases from lime-kilns (CO_2, 30%; N, 70%) are pumped through some or all. In the first vessel the CO_2 first combines with any free lime present, and next, together with the water present, acts on the CaS, so as to yield $CaCO_3$ and H_2S. The latter, passing into the next vessel, unites with the CaS, there to yield $Ca(HS)_2$.

Thus of the entering gases from the lime-kiln for a time only the nitrogen issues, but as a precaution it is run through a purifier containing oxide of iron or lime. As soon as H_2S appears in notable quantities, it is evident that the CO_2 is attacking the $Ca(HS)_2$ in the last vessel. As the object is to get as rich H_2S as possible, this last vessel is now closed, and the gases are tapped from an earlier one into a receiver. The sulphur is obtained from the H_2S by the so-called Claus kiln. This involves mixing the H_2S with a regulated amount of air, which will unite with the hydrogen and leave the sulphur. The mixture is forced through a layer of anhydrous oxide of iron, which undergoes no change itself, but is kept red hot by the reaction. Free sulphur and watery vapor pass off, and the former is condensed and caught in the depositing chambers. In 1887 it was estimated that 100,000 tons of sulphur per annum could be thus recovered, which would be sufficient to supply the home consumption (32,624 tons imported in 1887) and leave a very large quantity for export. These estimates have not been realized, for the *United States Consular Reports*, No. 141, June, 1892, p. 195, state that in 1890 England imported 25,385.7 long tons brimstone. In 1890 the United States, the great customer of the sulphur producers, imported from England but 4898 tons, and in 1891 only 5613. (See *Mineral Resources of the United States*, 1891, p. 567.)

A year or two ago the English concerns using the Chance process formed a combination, agreeing to sell their product through one office and at a uniform price.

Literature.—An account of the Chance process appears in the *Journal of the Society of Chemical Industry*, VII., 163.

France.—A small sulphur mine near the town of Apt, Departement Vaucluse, has been in operation for some years, with an output of from 3000 to 6000 tons annually. The sulphur is in a bed of dolomitic limestone and gypsum, 0.8 m. (2 ft. 8 in.) thick, which forms part of an old Miocene lake deposit. The sulphur runs fairly parallel with the natural surface, but is especially thick under the small swells or knolls, and is scarce or lacking under the depressions. It is supposed that it has been dissolved out under these natural waterways. It is also lacking in the outcrops of the bed. It occurs at about the same geological horizon as the Sicilian sulphur, and is of some scientific interest for that reason.

Literature.—Annales des Mines, 7 Série, XVII., 289. *Fuchs et De Launay*, I., 285, with statistics 1881-90.

Greece.—Deposits of both types are known in Greece. Those of the solfatara type are found on the volcanic islands and are reported from Milo or Melos, (where sulphur impregnates a porous trachyte over 30 ft. thick), Aegina and Methana, and several other islands. The one on Melos has been developed within the last year or two by a Greek company of Athens, known as the Hellenic Company of Public Works. The ore runs 20% to 30% and extends 200 meters. The company employs about 60 miners, 30 smelters, and 130 others. Wages vary from 40c. to 50c. per day for the miners and smelters, and 25c. to 36c. for common laborers. The furnaces are the Doppioni and Gill types. The present annual production is about 2000 tons, most of which is consumed in Greece, but some is exported to France, where it is considered superior to the Sicilian. The deposit of the second type is found about two and a half miles east of the Isthmus of Corinth, in connection with Miocene limestones, as in Sicily. Greece has been quite productive in past years (44,000 tons of rock in 1883, 14,000 in 1887).

Something has been written about a solfatara at Calamaki (or Kalamaki), on the Isthmus of Corinth, but the quantity of sulphur is not serious.

Literature.—Ansted: "On Calamaki," *Quart. Jour. Geol. Soc.*, XXIX., 340. 1873. The British Foreign Office Report, No. 303, Aug. 13, 1893, contains the most recent account of Melos. It is reprinted in the *Jour. Soc. Chem. Ind.*, Oct. 31, 1893, p. 879. A. K. Damburgis: "On Milo or Melos," *Oest. Zeitschr. f. Berg. u. Hütt.*, XXXVIII., 503. 1890. *Neues Jahrb.*, 1892, 84. Th. Fuchs: "On Kalamaki," *Verhand, d. k. k Geol. Reichsanstalt*, 1876, p. 54. *Neues Jahrb.*, 1879, 857. *Reiss u. Stübel. Ausflug nach den vulkanischen Gebirgen von Aegina u. Methana*, 1867, 53.

Guadeloupe.—See under *West Indies.*

Iceland.—Sulphur deposits have been long known in Iceland, and were noted by Bunsen during his famous visit. Those which have attracted commercial attention are in the southwestern portion of the island. There are two areas, of but slightly differing geology. One, near Krisnvik Namar, shows blue clay derived from decomposed lava. It is hot on top and scalding hot a few inches down. Many steam jets, or "soffioni," charged with boracic acid and sulphur, emerge and deposit a coat of the latter around the vents. More or less sulphur is also found in the clay. In the other district, at Bremmsteinsfjall (Sulphur Mountain), the lava is broken by little pits or craters, three to four feet deep, from which steam escapes. The sulphur has spread out from these as pure layers in the clayey residual product under the solid lava. Analyses of samples yielded Gascoyne the following:

	Samples at Mine.		At Warehouse, Havnefjord.		Hengill.		
Sulphur	72.73	64.41	91.80	92.17	76.96	79.50	83.26
Moisture	12 05	12.65	0.40	0.25	....	10.70	9.74
Insoluble	.....	.....	1-5	1-5	....	....	....

The sulphur was refined with carbon bisulphide. The deposits are continually reproduced. Some copper stains appear in the clays, and are of interest in their bearings on the origin of ores. Iceland does not figure in statistics as at present an important producer.

Literature.—W. J. Gascoyne: *Engineering and Mining Journal*, Aug. 9, 1879, p. 89. *Engineering*, XXVIII., 89, 1879.

Italy.—Small amounts of sulphur from deposits of the solfatara type have been mined in the past in the Phlegrean Fields, near Naples, and in the Province of Rome, at Latera, Scrofane, and Canale. The geology is not peculiar enough to warrant special description. From the Roman sources Fuchs and De Launay state that sulphur rock of 13% S. is obtained. Some years ago a Scotch chemical firm established a collecting depot on the island of Vulcano. The sulphur, arsenical minerals, etc., were gathered in a neighboring crater and utilized in chemical manufacture. A subsequent eruption somewhat interfered with the continuity of the work.

Romagna.—A region that has been productive in the past lies in the old Province of Romagna, in northeastern Italy. It is situated south of Ravenna and not far from the Adriatic. Tertiary marls, with much gypsum and limestone, are the associated rocks. They contain a principal sulphur-bearing bed from three to ten feet thick. The general geological relations are like those of Sicily, but the methods of mining were more modern, being largely managed by an English company. A method by pillar and chamber was employed, together with shafts and hoists. In 1889, however, the mines were reported as nearly exhausted, and the largest company, the Cesena, shut down entirely.

Literature.—On the geology, see Fuchs and De Launay, *Traité*, I., 282. 1893. Many other references are cited in this account. *Journal of the Society of Chem. Industry*, 1889, p. 142, for recent conditions.

Sicily.—Sicily is the greatest source of sulphur of all the productive regions, and is to this day the principal reliance of the United States for this commodity. The sulphur occurs in Miocene strata and in a geological section, involving from below up, sandy marls with beds of salt, limy marls, bituminous shales, diatomaceous earths with silicious marls and lignite, gypsum and limestone impregnated with sulphur, black shales called "tufi," and micaceous sands called "arenazzoli." Above all these comes the white, marly limestone called "trubi," which is Pliocene, while below the Miocene is the Eocene nummulitic limestone. The sulphur does not show in the outcrops, having been dissolved out by atmospheric waters, but the porous limestone left by it is called "briscale," and is esteemed a favorable surface indication.

The mining regions are in the southern central portion of the island. Girgenti and Lercara are the chief centers. Palermo, Licata, and Catania are shipping ports. The mines are distributed over an area 160 to 170 kilometers (about 100 miles) from east to west, and 85 to 90 kilometers (55 miles) from north to south. They occur in groups around centers, partly because the sulphur-bearing stratum is not continuous, and partly because the sulphur indications are concealed by later deposits. The region, moreover, is much faulted.

The sulphur is found in veinlets and sometimes in larger masses, which ramify through the cellular limestone. It occurs both over and under the gypsum. The beds containing it are not, as a general thing, so very thick, running from 1 to 3 meters (3 to 10 ft.), and being irregular and uncertain in their richness. The dip varies from 25° to 50°, reaching at times 65° to 70°. But, as in all mining districts, there are exceptionally thick and rich bonanzas that far exceed the average.

The yield in sulphur varies from 8% to 25%. Below 8% the rock cannot be worked. Vom Rath states that in 1873 12½% rock was necessary. Mottura gives the following: 8% to 16% low grade, 16% to 24% good, 24% to 40% rich to very rich. More or less petroleum and bitumen are found in the mines, and occasionally explosive gases are met. Barite and celestite sometimes accompany the sulphur. All mineral collections have the celestite crystals from the mines near Girgenti.

The common methods of mining are of the crudest description, and all who have written of the region, both native and foreign, refer in strong terms to the waste and dangers. In most cases the deposits are reached by steep slopes or circular stairways ("scala") with wide steps, up which boys laboriously bring the crude rock in baskets or sacks. No mine maps are made, and no precautions taken to work beds on a systematic scale. Timbering or any supports for the roof are not generally thought of. A feeling of distrust prevails between the owners of the land and the operators, and between the latter and the miners.

These objectionable features arise partly from the irregular nature and uncertainty of the deposits, partly from excessive subdivision of ownership and ill-adapted property laws, and partly from the local prejudices against innovations. Even in one case where an American and an Englishman in partnership secured the right to work a mine and set about installing suitable hoisting machinery, they were hampered by a lawsuit with the owner because of this innovation, and had a long legal contention to establish their undoubted rights. It is a striking fact that in the new development in Japan, on a remote island and against great natural difficulties, the most modern methods and management prevail, while in Sicily, in the center of the oldest civilization, these are to a great extent of the crudest. In 1889 the Sicilian industry experienced very hard times. Prices were low, and much hardship was caused. To some degree it led to improved methods, and in the larger mines pumps and hoisting engines are now installed. But of late years the depression has continued, and recently (*Iron,* April 28, 1893) three-fourths of the proprietors of the mines held a convention at Caltanisetta with the object of pooling their interests and controlling output and sale.

Literature.—The literature is large, and in almost all of the better known languages. The most important or most available papers alone are cited. British Foreign Office Reports, 1893, Miscellaneous Series, No. 297. G. Bruzzo: "Les Mines de Soufre de Lercara en Sicile." *Revue Universelle des Mines*, Liège, XXXVIII., 567. The United States Consular Reports contain frequent papers. See Philip Carrol, 1888, reprinted in the *Engineering and Mining Journal*, Sept. 1 and 8, 1888, p. 174; C. Heath: *Cons. Rep.*, 134, November, 1891, 363 (especially relates to smelting); H. C. Pugh: *Ibid.*, 141, June, 1892, 282. F. A. Flückiger. "Die Schwefelgewinnung bei Girgenti," *Archiv der Pharmacie*, CCXXVII., 1035. A. W. Hoffmann: *Entwickelung der Chemischen Industrie.* A. Von Lasaulx: "Schwefel Distrikte in Sicilien," *Neues Jahrb.*, 1879, 490. (Good paper.) C. Ledoux: "Mêmoire sur les Mines de Soufre de Sicile. *Ann. des Mines*, 1875, VII., 1. Mottura: "Formation Solfifere de la Sicile," *Bull. de la Société de l'Industrie Minérale de Ste. Etienne*, 2d Series, X., 147, 1881. Mottura has also written important papers in Italian, and has been the chief worker in establishing the geological relations. Perazzi: "Schwefelgewinnung in Italien," *Berg. u. Hütt. Zeit.*, 1866, p. 92; extracted from *Annales des Mines*, 1865, 303 Cites all the Italian sources of sulphur. Pirknez: "Procédés d'Extraction du Soufre en Italie," *Bull. de la Soc. de l'Ind. Min. de Ste. Etienne*, 1874, II., 609–825. G. Von Roth: *Neues Jahrb.*, 1873, 598.

Japan.—The Japanese mines are chiefly on the northerly island Hokkaido, and in the northeasterly part of it. They are distant forty to fifty miles from the coast. The largest is the Atosanobori. It belongs to the solfatara type, and is based on the sulphur which is found in an old volcanic crater of augite andesite, from which copious sulphur fumes still emanate. The sulphur impregnates the decomposed rock, etc., but a very rich material is afforded. The ore is sorted into four grades—special class, 90% S., 10% total product; first class, 75% S.. 35% total product; second class, 50% S., 40% total; third class, 35% S., 15% total.

To cheapen transportation a narrow-gauge railway was built in 1887 twenty-five miles to Hyocha, on the Kushiro River, where the refinery is situated. It has since been lengthened two or three miles. From Hyocha the sulphur is taken on junks down the Kushiro River thirty-one miles to the seaport Kushiro. From the mine to the cars the ore is drawn down hill in tubs, containing 25 to 30 cu. ft. One laborer can manage one tub. To solve the fuel problem the company leased a coal mine two miles from Kushiro, and in 1890 built a tramway 7000 ft. long to the docks. The refinery contains steam refiners and much labor-saving machinery. Another deposit of the same type is wrought in a small way in the province of Ibun, on the same island Hokkaido, but in its southwestern portion. It is called the Iwaonobori, and the operating company is the Mitsiu Production

Company. The same parties control the Ichibishinai and the Osorezan. They are all of the solfatara type.

Literature.—W. TSUNASHIRO: *The Mining Industry of Japan*, 1893.

Louisiana.—See under *United States.*

Mexico.—For many years (it is said even from the time of the invasion of Cortez) sulphur has been known to exist in the crater of Popocatepetl. This volcano, whose crater is still supplied with the sulphur-depositing solfataras, is one of the three or four highest peaks on the North American continent, reaching 17,780 ft. above tide, and 10,500 ft. above the City of Mexico. The sulphur is obtained on the floor of the crater, some hundreds of feet below the summit, and is there deposited as a fine powder by burning jets of H_2S. It is scraped up by the men of a tribe of Indians who, accustomed from childhood to climbing the mountain, are able to stand the fatigue. When placed in bags, the Indian packs it to the upper snow line, and then arranging himself and the bags on a mat, he slides swiftly to the lower edge of the snow, and thence carries it to the retorts, where it is purified and sent to the City of Mexico. Obviously this source is not likely to yield large amounts.

Literature.—M. RAHDEN: "Popocatepetl." New York *Evening Post*, Nov. 5, 1892.

Nevada.—See under *United States.*

New South Wales.—Some years ago (about 1887) a deposit of alunite was discovered in the county of Gloucester, and was developed for the local alum trade and for export to Liverpool. This development revealed sulphur in notable quantities, which it was expected would supply the colonial demand. Besides this Professor Liversidge, in his work on the minerals of New South Wales, gives the following localities for small quantities: Mount Wingen, in the Upper Hunter district; Tarcutta, near Wagga Wagga; and Louisa Creek, near Mudgee.

Literature.—McIVOR: *Chemical News*, LVII., 64, 1888.

New Zealand.—Sulphur is reported in large quantities in the volcanic regions of New Zealand, and it is expected that it will prove an article of commerce in the course of time. At White Island, off the coast off Auckland, it is deposited by hot springs, and has been exploited. It is known at several volcanic fumaroles and solfataras elsewhere.

Literature.—Trans. Federated Inst. of Min. Eng., IV., 75, Jan. 20, 1893.

Peru.—Mr. Hicks, the British Minister to Peru, reported in 1890 to the Home Government the existence of immense deposits of sulphur at Tumbez, in the north of Peru, and near Arequipa on the south.

Russia.—Sulphur has been recorded in a number of places in both European and Asiatic Russia, but in general their remoteness militates against them. In the Government of Kazan, at the village of Sukeevo, on the Volga, the sulphur forms druses and interlayers in limestone of the Permian, whose thickness varies from 2 to 7 ft. The percentage runs from 2.5 to 8, which is too low to be serious. In Poland is another deposit, in the Government of Kelets, at the village of Charkovo, near the junction of the rivers Nida and Vistula. The sulphur occurs in a Tertiary marl, in a related area to that which was described under Austria. The yield is variable, running 10% in the upper beds and 25% to 75% in the lower. Works were running in 1885 and yielded about 630 tons (35,000

Literature.—Journal of the Society of Chemical Industry. 1890, 666.

poods). There are other sulphur beds in the neighborhood. In Daghestan, about 100 miles west of the Caspian Sea, and on the nearly vertical slopes of a range of mountains 4500 ft. above the sea, there are beds of sulphur and clay of Jurassic age. As is usual in deposits of the gypsum type, gypsum is not lacking. The mines have been worked by a French firm, Perdoux, Fils et Cie., since 1883. In 1888 they yielded nearly 1600 tons (88,000 poods), but of late years less. It has been reported in Glückauf (1892, No. 8) that at Kchiut twenty calcarones were then running, and that 5000 tons of rock yielded 1500 tons of sulphur. Other furnaces were in operation near Abano and Katerfi. Very large deposits are reported from the desert of Karakum, 175 to 200 miles from Göktepe and Khiva. The sulphur occurs in a white sandstone, interstratified with Tertiary marls and limestone. The mines are as yet undeveloped, but large estimates have been made of their possibilities. Sulphur is also reported from the Fergan province, where there are works for treating the ore.

Literature.—"Mines of the Caucasus," *Engineering and Mining Journal*, June 16, 1888, p. 435. A. KEPPEN: "The Industries of Russia," *Mining and Metallurgy*, IV., 90, 91. A. M. KONSCHIN: "On the Trans-Caspian Deposits," *Verhandlungen, Russ. Mineralog. Gesellsch.*, 1888, XXIV., 23-35.

Saba.—See under *West Indies.*

Sicily.—See under *Italy.*

Spain.—The most important of the Spanish mines are in the Province of Murcia, in the southeastern part of the Spanish peninsula. They are similar to the Sicilian beds, and are found in upper Miocene marls. The ore runs 30% to 40%, but is pockety. Lorca is the principal town near the mines. The production has fallen off greatly of recent years, but it never was sufficient for export.

Literature.—FUCHS ET DE LAUNAY: *Traité*, etc., I., 283.

United States.—Although the United States forms the principal customer for the Sicilian product, its home sources are not as yet much developed. None the less the reports show that enormous bodies exist in Louisiana and in Texas, as yet undeveloped, and very rich deposits are opened in southern Utah, but too remote for the Eastern market.

Alaska.—For many years past it has been known that the volcanic islands off the coast of Alaska contained sulphur. Mr. Dall, in 1870, mentioned this mineral as being, next to coal and copper, the chief resource of the country. The largest deposit, so far as known, is on Kadiak Island, but others are recorded on Akutan, on an island southeast of Aklum, etc. They are all of the solfatara type, and are yet to be worked.

Literature.—W. H. DALL: *Alaska and Its Resources*, p. 478, Boston, 1870.

California.—Twenty years ago sulphur was obtained at Sulphur Bank, on Clear Lake, some forty miles north of San Francisco. It occurred in the white silicious residue of a basalt flow, that had been decomposed by the uprising solfatara, which deposited the sulphur. As development went deeper, however, the sulphur mine changed into a cinnabar mine, and as such had a brief career. Sulphur deposits were also for a time worked in Colusa County, and a small refinery was erected. Sulphur also occurs in the San Joaquin Valley, Kern County, cementing gravels, etc.

Literature.—W. A. GOODYEAR: *Rep. Cal. State Mineralogist*, 1890 (Lake County, 238; Colusa, 159). J. LECONTE: "On Sulphur Bank," *Amer. Jour. Sci.*, July, 1882, 23. J. A. PHILLIPS: "On Sulphur Bank," *Philosoph. Mag.*, 1871, 401.

Idaho.—Sulphur has been reported near Swan Lake, and also four miles from Soda Springs, Oneida County.

Louisiana.—Probably the richest and geographically the most accessible of the American localities is in southwestern Louisiana, 230 miles west of New Orleans and 12 miles from Lake Charles. The first hole which revealed this sulphur was sunk in search of petroleum, of which the presence of oil and tarry matter on the surface were regarded, quite justly, as an indication. While more or less of these bituminous substances were revealed by the drill, the great bed of sulphur is the main object of interest. A number of holes have since been put down with the results recorded below, and they leave no doubt that there is a very large body which awaits exploitation. The first explorations were made by the Louisiana Petroleum and Coal Oil Company. It was succeeded by the Calcasieu Sulphur and Mining Company. The Louisiana Sulphur Mining Company followed, and now the owners are the American Sulphur Company. The records of four holes are appended. Nos. 1 and 2 were the first sunk, and were about 150 ft. apart. Nos. 2, 3, and 4 were put down in 1886. No. 3 is northwest of No. 1.

RECORD OF SEVERAL OF THE BORE HOLES THAT HAVE PENETRATED THE SULPHUR BED.

	Original Well No. 1.	Granet's Well No. 2.	Granet's		Van Slooten's Well No. 5.	Amer. Sulphur Co.		
			Well No. 3.	Well No. 4		No. 6.	No. 7.	No. 8.
Clay, quicksand and gravel...	333	344	426	342	345	350	370	499
Soft rock.......	110	84	70	138	91	95	72	44
Sulphur bed 70% to 80%	108	112	119	45	110	125	126	52
Gypsum and sulphur	680	12	6	Stopped sulph.	57	32	30	Stopped in sulphur.
Depth of hole ..	1,231′	552′	621′	525′	603′	602′	598′	596′

Analyses from the large bed in Holes No. 2 and No. 3 gave the following :

Hole No. 2.

Depth,	428 ft.	Per cent. sulphur,	62
"	441 "	"	70
"	459 "	"	80
"	466 "	"	83
"	486 "	"	90
"	... "	"	80
"	... "	"	75
"	... "	"	80
"	540 "	"	68

Hole No. 3.

Depth,	503 ft.	Per cent. sulphur,	70
"	533 "	"	60
"	549 "	"	81
"	552 "	"	91
"	604 "	"	98

The difficulties in development lie in the quick sands and gravel, which are wet and soft, and in the soft rock (Hole 1), which yields sulphurous waters under a head at the surface of about 15 ft. The sulphur beds themselves are, however, tight. A shaft on the Kind-Chaudron system was proposed some years ago, but has not yet been sunk. Beyond all question this is an exceptionally rich deposit, and it ought to have a future. As the sections show, it belongs to the gypsum type, and has plainly been formed by the alteration of the gypsum under the influence of the neighboring bituminous matter. The geological horizon is the Quaternary.

Literature.—A. GRANET: *Engineer's Report to the Louisiana Sulphur Company.* PREUSSNER: *Zeitschrift der deutsch. Geol. Gesellsch.*, 1888, XL., 194.

Nevada.—Sulphur has been reported from Humboldt House, and is described by Russell as filling the craters of one or two extinct hot springs, along with gypsum, etc. Its quantity is small. The mineral is also mentioned from the Sweetwater Mountains, between Nevada and California, in latitude 38° 30′. The only important locality in Nevada is at the Rabbit Hole mines, on the eastern border of the Black Rock Desert. The sulphur charges a porous, rhyolitic tuff, and lines cavities in it to the depth at times of 5 or 6 ft. The impregnations lie along a great fault line, and are clearly of the solfatara type. The ore was treated with superheated steam and considerable quantities of sulphur were obtained in the past. Of late years the mines have not been worked. Very interesting sulphur crystals have been measured from them by E. S. Dana.

Literature.—E. S. DANA: "On the Crystals from the Rabbit Hole Mines," *Amer. Jour. Sci.*, (3). XXXIII., 386; *Zeit. f. Kryst.*, XII., 460. I. C. RUSSELL: "Sulphur Deposits of Utah and Nevada," *Trans. N. Y. Acad. Sci.*, 1882, I., 168; reprinted in the *Engineering and Mining Journal*, Jan. 20, 1883, p. 31, Mr. Russell's valuable monograph on Lake Lahoutan (*U. S. Geol. Surv.*, *Mono.* XI.) gives an excellent account of the general geology of the region.

Texas.—Mention of deposits of sulphur has been made by the Texas Geological Survey (Second Annual Report, lxxvi.) from Edwards County in the Llano Estacado, but as yet little of a definite character has been written. Northwestern Texas is known, however, to contain very extended deposits, although the definite description of the area has not yet been made public.

Literature.—The Reports of the Texas Survey make but passing mention of sulphur.

Utah.—The largest producer of any American locality is in Beaver County, southwestern Utah, near the Millard County line. The mines are 26 miles east of Black Rock, a station on the Utah Central Railroad, 204 miles south of Salt Lake City. From Black Rock to the mines a wagon road traverses desert and lava sheets. An old outpost of the Mormons called the Cove Creek Fort (also Ranch Fort) stands near the openings, and gives them their name—Cove Creek mines. The fort is on the eastern limit of a plain, which is bounded on the west by the Mineral Range, twelve miles away, and on the east by the Sulphur Range, a southern prolongation of the Tushar Mountains, which themselves belong to the larger Wasatch. The region is one of expiring volcanic activity, and the deposits, though presenting some variations, all belong to the solfatara type. The name "cove" originated in the crescentic depression of the Sulphur Range, with the convexity eastward, within which the mines are situated. Between the horns of the crescent, and several miles northwest of the fort, is an extinct basaltic volcano 1000 ft. high, with a cinder cone on its top. This is called the Cove Creek crater by Russell, but Mount Dickert by vom Rath. Subaërial gravels form the surface from the cone to the eastern hills, but at their base volcanic tuffs are developed.

Most of the mines are along the junction of the gravels and tufas. It is stated by Russell (from whom this description is chiefly taken) that there are three varieties. The first is the one now worked under the name of the Cove Creek mines. It is an extinct solfatara at least 1800 by 1000 ft., and with sulphur rock as much as 30 ft. thick. The sulphur richly impregnates sand, doubtless decomposed volcanic rock, lines cavities, and is associated with gypsum. After being mined out it is to some degree reproduced by the fumes which constantly rise. The workings are noticeably hot. The second variety of deposit is an impregnation of tuff and of the alluvial deltas resting on it. The third variety is in fissures in trachyte (andesite of vom Rath) and in dark, carboniferous limestone, along a line of faulting. Much gypsum has resulted from the action of the fumes on the limestone. Shales also appear in the section. Various claims are located on these last two forms of deposit, but the really productive one is the first named, in connection with which there is a refinery worked on the steam principle, with condensers, grinders, etc. Up to 2000 tons yearly are produced. Vom Rath estimates the ore at 75%, to extend over 300,000 sq. meters, up to 3 meters thick.

Prospecting was begun in this region in 1872 by Mr. C. A. Semler. The company operating in the eighties was the Dickert and Myers Sulphur Company. In 1891 eastern parties worked the mines under an option to purchase. The works were enlarged and improvements introduced. The present company is the Utah Sulphur Company. Mr. Burfeind, the manager of the works, informs us that a reservoir has been constructed in the neighboring heights, and that two miles of 6-in. steel pipe, with 1000 ft. of head, conduct the water to the mines. With this the surface gravels are sluiced off at less than one-tenth the cost of former methods. Further improvements in the way of removing the tailings by the same means were contemplated, when the recent financial depression checked them. At present the works have a capacity of 50 tons crude sulphur daily (99% pure). The mill can grind 30 tons to flour, and the condensing chambers can produce 1½ tons flowers of sulphur. Roll sulphur can be prepared in any quantity ordered. The necessary building materials for another subliming chamber of three tons daily capacity are on the ground. A railroad is now being constructed from Los Angeles, Cal., to Salt Lake City, that will touch at the works and ameliorate the present hard conditions of transportation.

Utah also contains another mine, the Barnes, near Frisco. Descriptions have not yet been published. It was productive in 1889, but in 1892 the entire Utah product came from the Cove Creek mines.

Literature.—A. F. Du Faur : "The Sulphur Deposits of Southern Utah," *Trans. Amer. Inst. Min. Eng.*, XVI., 33, 1887. H. C. Myers : "The Sulphur Industry of the West," *Amer. Jour. Pharmacy*, 1887, p. 16. G. vom Rath : *Neues Jahrb.*, 1884, I. I. C. Russell : "Sulphur Deposits of Utah and Nevada," *Trans. N. Y. Acad. Sci.*, 1882, I., 168. *The Mineral Resources of the United States*, published by the Geological Survey, contain frequent mention of the mines.

Wyoming.—Native sulphur has been reported from several places in this State, all quite remote. Thirty miles south of Evanston, on Salt Creek, is one, while another is in the western central part of Uinta County. The Wind River Mountains are likewise said to contain sulphur. Mr. W. H. Weed of the United States Geological Survey has reported sulphur from a number of the smaller vents and fumaroles of the Yellowstone Park. Some interesting crystals were yielded, but the deposits do not appear to be of practical importance. Orpiment and realgar were found in similar relations.

Literature.—W. C. Knight : "Resources of Wyoming," in Bulletin 14 of the State Experiment Station, 1893, p. 197. W. H Weed and L. V. Pirsson : "Occurrence of Sulphur, Orpiment and Realgar in the Yellowstone National Park," *Amer. Jour. Sci.*, November, 1891, p. 401.

West Indies.

Guadeloupe.—Sulphur deposits have been mentioned from this island, and one or two tons have been exported to the United States. The sulphur occurs in an old crater along a great fissure, from which emerge fumes and hot waters, that yield alum and gypsum as well. The crater is five or six miles from Basse Terre, and about 4500 ft. above tide. The amount does not appear to be either large or accessible.

Literature.—SAINTE CLAIRE-DEVILLE: "Sur le Gisement de Soufre, etc., de la Guadeloupe," *Bull. de la Soc. Geol. de France*, 1847 (2), IV., 428.

Saba.—This island, a Dutch possession northwest of St. Christopher, contains an extinct crater, with sulphur impregnations of the solfatara type. Attempts have been made to mine the sulphur, but the low grade of the gypsums in which it occurs has discouraged the investment of capital.

Literature.—N. S. HIGGINS: Extract from a report on the properties, *Amer. Jour. Sci.* (2), XLVIII., 278, 1868. MOLENGRAFF: *Geology and Crystallography, Zeitsch. f. Kryst.*, XIV., 46, 1887-88.

In general it may be said of sulphur deposits that they are apt to be irregular, and that, though very rich in places, quite extended test-pits or drill-holes are desirable before drawing too confident conclusions. In this country the principal employment of sulphur is in the sulphuric-acid industry, and especially in connection with the manufacture of fertilizers and in refining petroleum. We are also using for the manufacture of vitriol an increasing amount of pyrites, as elsewhere set forth in this volume. Sulphur is also used as an important ingredient of insecticides for vines and vegetables, as a medicinal agent, and for various other purposes. In the aggregate, as will be seen from the statistics, we use an enormous quantity, and the market is a tempting one for local producers.

TREATMENT OF THE ORE.

The treatment of alkali waste is discussed under "England."

As most of the sulphur deposits of the world are in dry and barren countries, remote from the great centers of industry, fuel and transportation are very expensive. The deposits, too, are irregular and of small local extent, and the permanency of a mine is very doubtful. Hence the methods used have been, for the most part, primitive and wasteful, and only within the last few years have economical processes come into any general use.

The treatment of native sulphur ores consists in either *melting*, *distilling*, or *dissolving* the sulphur out of the gangue. The first method is most generally in use. It is complicated by the fact that although sulphur melts to a thin liquid at 115° C., yet at higher temperatures (215° to 240°) it becomes very thick and viscid and will not liquate. Hence the operation must be so regulated as to keep the temperature a little above its melting point. There is also a constant loss of from 6% to 15%, which remains soaked up in the porous gangue. In the second method this loss is reduced to a minimum, but a much higher temperature is required, and there is danger at this temperature of loss by reaction of the sulphur on the lime carbonate in the gangue. The third method requires expensive chemicals and plant, but gives a high yield, of excellent quality.

I.—*Melting Processes.* These may be divided into:

a. Those using part of the sulphur as fuel to melt the remainder.

b. The sulphur is melted by hot air from the combustion of coal or wood.

c. The ore is treated with superheated steam.

d. The ore is treated with a concentrated solution of calcium chloride at a temperature above the melting point of sulphur.

The greater part of the Sicilian sulphur is extracted by methods of the first class. These are:

1. *Calcarelle, or Pile-smelting.*—This was the earliest and simplest. The pile is built up like the ordinary roasting pile, coarsest below, finer above, with a cover of spent ore. It is lighted with straw, and when well on fire the draft is choked and the fire allowed to smolder. Part of the sulphur runs down over the hard-beaten, sloping floor, at the lower edge of which is an aperture, where it is collected. The whole operation lasts about four days. It is exceedingly wasteful, only about 5% or 6% of sulphur being obtained even from rich ores. It is now abandoned in favor of the

2. *Calcarone.*—This is a circular stall, with floor of hard-beaten spent ore, sloping at an angle of 10° to 15° toward an opening or tap-hole at the side called the *morto.* The diameter is 20 to 30 ft., depth about 8 ft. at the lower side. The walls are of masonry, covered with plaster in the lower part. The ore is piled with the coarsest at bottom, and with a cover of spent ore or earth. The method of burning is like the calcarelle, but under better control. After from eight to fourteen days the sulphur begins to appear at the morto, and is tapped from time to time and cast in molds. It continues to run for two, three, or four weeks, or even more, according to the size of the calcarone, the character of the ore, etc. The whole operation must be conducted with great care, and is largely at the mercy of wind and weather. From 6% to 10% of sulphur, under favorable conditions, is lost in a 20% to 25% ore; most of this goes off as fumes of sulphurous acid, which do great damage to crops in the neighborhood, so that the burning is prohibited near houses or cultivated fields. For the six months in the year during which the crops are growing it is not allowed at all. About 65% of the Sicilian sulphur is extracted by this process. It has the advantage of requiring very little outlay for plant, and with poor ores it gives a comparatively large yield. The quality of the product, however, is poor, and the yield uncertain. Only a small proportion of the fine ore can be treated in the calcarone; most of it is usually thrown away, though sometimes treated by other processes. This causes an enormous waste, as the fines are the richest part of the ore.

Considerable sulphur remains to be burnt in the calcarone after the flow from the morto has ceased, and by an improvement devised by P. Le N. Foster the heat of combustion of this remainder is saved, the products of combustion from the spent ore being drawn through a flue over a fresh charge in another kiln.

b. Processes which melt the sulphur by heated air from the combustion of coal or wood. These consist in general of a number of cells in which the ore is placed, and around or through which pass the products of combustion from a grate. They give a large yield, but it is generally of poor quality from the irregularity of the heating. Various furnaces of this type are in use in Sicily, furnishing about 25% of the total product. They can be operated throughout the year, as little sulphurous acid is given off, but the plant is rather expensive and the cost of fuel considerable.

c. Melting by superheated steam. The ore is charged from above on a grate in a cylindrical iron furnace; below the grate is a conical kettle. Steam is admitted around the sides, the sulphur melts and flows down into the kettle, and thence to a settling tank, from which it is cast in large blocks. The yield of sulphur, as compared with the calcarone, is considerably larger with rich but smaller with poor ores. The quality is very much improved and the process is under complete control. The smelting can be carried on all the year, thus avoiding the expense of an idle plant and the necessity of storing up ore for six months. But the expensive plant, the high cost of fuel, and the skilled labor required to run the boiler, have prevented its general use, except in large and rich mines. Nor can it be used when the gangue is clayey, as a pasty mass is then formed, from which the sulphur cannot liquate. About 10% of the Sicilian sulphur is extracted by this process; it was also used in Nevada, and is now used in Japan.

d. Fusion of the sulphur in a calcic chloride solution.* This method has not been successful until recently, on account of the former high price of the chemicals required. It is now produced in great quantities as a by-product in the ammonia-soda industry. In 1868 Dépérais patented a process for extracting the sulphur in this way. The calcic chloride solution was contained in a spherical iron boiler of 2000 liters capacity, with a stopcock at the bottom and a vertical cylinder above, through which the ore was let down in a perforated iron basket. The solution was kept at a temperature of 130°; the sulphur collected at the bottom of the boiler and was drawn off through the stopcock. This process failed, chiefly on account of the expense of calcic chloride at that time.

Of late years this method has been successfully operated with the plant of MM. De la Tour and Dubreuil. This consists of two rectangular iron tanks each of about 2 cu. m. capacity, which are placed in a furnace and heated alternately to a temperature of 120°. The sulphur melts out and flows down to one end of the tank, the bottom being inclined $\frac{1}{10}$. After about two hours the flow of sulphur ceases, and the fire is transferred to the other tank. The calcic chloride solution is also transferred as far as possible and the lacking amount is pumped into it. Next the liquated gangue is washed to regain the lime salt which it has absorbed, and the dilute liquor is added to the original solution as may be necessary. Four or five per cent. of the sulphur remains in the ore. Some ores disintegrate in the solution, and for these a modified apparatus is used, which is also applicable to the rich fines which cannot be treated in the calcarone. The tank is divided through the center by a gutter in which the sulphur collects. The ore is kept from falling into this by iron gratings. The cost of extraction on a 33% ore is said to be $2.30 per ton; the product is very pure. The advantages claimed for this process are:

1. Extraction of nearly all the sulphur from the ore, and at a minimum cost.
2. The process is under perfect control.
3. The work is continuous throughout the year.

This method will probably come into common use, but it seems that there must always be considerable loss of sulphur, as its difference in specific gravity

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* See Vincent's paper in *Bull. de la Soc. Chim.*, 1883, p. 528; translation by W. S. Bayley, in *Amer. Chem. Jour.*, Vol. VI., p. 63.

from the concentrated solution used would not be enough to allow a very complete separation.

II.—*Distillation Processes.*

*a. Doppioni.**—This is conducted in iron retorts, each with a movable lid for introduction and withdrawal of the charge. A row of these, each of 30 to 40 gallons capacity, is placed in a furnace, and the sulphur distilling off passes through earthenware or iron pipes to iron condensing chambers, over the surface of which a stream of cold water flows. The product is mostly in the form of flowers of sulphur, which commands a higher price than the melted brimstone. This process is largely used for refining the crude product from the calcaroni, and is also well adapted to treat rich fines, and certain bituminous ores from which the sulphur cannot be obtained pure by melting or solution. The extraction is almost complete, except when the gangue contains considerable carbonate of lime; in this case the sulphur is apt to combine with the lime to form various sulpho-compounds. The amount of fuel consumed in this process is large and the production small, but it is obtained in a more valuable form than by melting or solution.

b. A process recently invented by Charles Dubois † consists in distilling the sulphur by steam, heated to 150° C., at which temperature a large amount of sulphur vapor is carried over with the steam. The apparatus consists of a revolving cylindrical iron chamber with hollow trunnions, through which the steam makes its entrance and exit. The sulphur condenses in a cooling chamber and is drained to separate it from the water which has condensed with it. The product is said to be of exceptionally fine quality, owing to the low temperature at which it is sublimed.

III. *Solution Process.*—There is only one solvent for sulphur to be obtained at any moderate price, namely, carbon bisulphide, CS_2. This has been used to some extent in the treatment of sulphur ores. The method is as follows: ‡ The ore is treated in four extracting pans, each of five tons capacity, made of wrought iron, and provided with a perforated false bottom. The CS_2 is passed by force-pumps from an iron store tank into the extracting pans. At the end of twelve hours, the sulphur being dissolved out of the ore, the liquid is drawn off into a solution tank and allowed to settle. Thence it is pumped into a steam-jacketed still, where the CS_2 is evaporated off, and passes into the store-tank again. The sulphur which remains behind is distilled, and condenses as flowers or brimstone according to the temperature of the cooling vessel. Considerable CS_2 remains soaked up in the gangue; it is driven out by passing in steam, condensed in a worm, and returned to the store-tank.

This method requires an expensive and complicated apparatus, and it is difficult to avoid serious loss of the reagent, which, moreover, is very explosive when its vapor is mixed with air. It is now in use in Iceland, on very rich ores; it was tried at Naples and failed, and was successfully operated for some time at Cracow. With careful management and well-arranged plant it promises to become more widely useful.

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* *Jour. Soc. Arts*, 1880, p. 508.

† S. B. Newberry, *United States Commissioner's Reports, Paris Exposition*, 1893, Vol. II., p. 538.

‡ *Jour. Soc. Arts*, 1880, p. 508.

PRODUCTION OF BRIMSTONE AND PYRITES IN THE UNITED STATES.

Year.	Brimstone.		Pyrites.		Total Value.
	Amount, Short Tons.	Value.	Amount, Short Tons.	Value.	
1882......	600	$21,000	13,440	$72,000	$93,000
1883.....	1,000	27,000	28,000	137,500	164,500
1884......	500	12,000	39,200	175,000	189,000
1885......	715	17,875	54,880	220,500	238,375
1886......	2,500	75,000	61,600	220,000	295,000
1887......	3,000	100,000	58,240	210,000	310,000
1888......	.....	....	60.850	167,658	167.658
1889......	450	7,850	104,950	202.119	209,969
1890......	.....	....	126,039	273,745	273,745
1891.....	1,200	39,600	122,438	317,280	353,280
1892......	1825	54,750	119,000	357,000	411,750
1893......	1.344	26,880	106,400	319,200	346.080

IMPORTS OF SULPHUR INTO THE UNITED STATES FROM 1867.

Years.*	Crude.		Flowers of Sulphur.		Refined.		Total Value.
	Quantity, Long Tons.	Value.	Quantity, Long Tons.	Value.	Quantity, Long Tons.	Value.	
1867........	24,544.10	$620,373	110.05	$5,509	250.55	$10,915	$636,797
1868........	18,150.55	446,547	16.48	9,948	64.75	12,721	450,216
1869........	23,589.69	678,642	96.59	4,576	645.04	27,149	710,367
1870........	27,379.60	829,677	76.34	3,927	157.24	6,528	831,132
1871........	36,131.46	1,213,202	65.54	3,514	92.26	4,328	1,221,044
1872.......	25,379.55	764,798	35.97	1,822	56.94	2,492	769,112
1873........	45,533.27	1,301,000	55.29	2,924	35.97	1,497	1,305,421
1874	40,989.55	1,260,491	51.08	2,694	56.68	2,403	1,265,588
1875........	39,683.10	1,259,472	17.83	891	......	......	1,260,363
1876	46,434.72	1,475,250	41.07	2,114	43.87	1,927	1,479,291
1877........	42,962.69	1,242,888	116.34	5,873	1,170.80	36,962	1,285,723
1878........	48,102.46	1,179,769	158.71	7,628	149.51	5,935	1,193,332
1879..	70,370.28	1,575,533	137.60	6,509	68.94	2,392	1,584,434
1880........	87,837.25	2,024,121	123.70	5,516	158.36	5,262	2,034,899
1881.	105,096.54	2,713,485	97.66	4,226	70.96	2,555	2,720,266
1882........	97,504.15	2,627,402	158.91	6,926	58.58	2,196	2,636.524
1883........	94,539.75	2,288,946	79.13	3,262	115.33	8,487	3,296,695
1884	105,112.19	2,242,697	178.00	7,869	126.00	4,765	2,255,331
1885...... ..	96,839.44	1,941,943	120.56	5,351	114.08	4,060	1,951,354
1886	117,538.35	2,237,989	212.61	8,739	116.05	3,877	2,250,605
1887........	96,881.55	1,688,360	278.56	9,980	83.55	2,383	1,700,723
1888.......	120,104.00	1,927,336	60.00	1,921	......	3	1,929,260
1889	135,935.00	2,068,208	282.00	8,184	10.00	299	2,076,691
1890........	131,096.00	2,147,481	†181.02	†5,139	†10.33	†299	2,152,919
1891........	116,971.00	2,675,192	206.00	6,782	10.00	1,997	‡2,817,221
1892........	100,938.00	2,189,481	158.00	5,439	26.00	4,106	‡2,787,007
1893........	107,601.00	1,903,191	240.962	5,746	42.73	1,017	1,909,954

* Fiscal years ending June 30 from 1867 to 1887, inclusive; subsequently, calendar years ending Dec. 21, unless otherwise specified. † Fiscal years. ‡ Includes value of ore.

The Market for Brimstone.

The chief feature of the brimstone market during 1893 has been the absence of violent fluctuations in prices or any speculative tendencies. Imports into this country in 1893, according to the United States Bureau of Statistics, were 107,601 tons, against 100,721 tons in 1892—an increase of 6880 tons in favor of last year. This is due to the fact that prices ruled lower than during 1892, and that foreign exchange rates favored importers of Sicilian brimstone. Owing to these facts the consumption in 1893 was greater than might have been expected, considering the general business depression. Some acid makers who used pyrites almost exclusively the year before, because of the high prices and the uncertainty of the brimstone market, returned to the use of the latter. The consumption by other industries was nearly normal—a fact which was really abnormal when the stagnation in most trade circles is taken into consideration.

The following table shows the highest and lowest prices at New York in 1893 per ton of brimstone (best unmixed seconds).

	January.		February.		March.		April.		May.		June.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
On the spot	$22.00	$21.50	$22.00	$20.25	$21.50	$20.25	$26.00	$19.50	$20.25	$19.00	$19.50	$18.75
Shipments.	20.75	19.50	20.00	18.50	20.25	19.50	20.00	18.75	19.00	18.25	19.50	18.50

	July.		August.		September.		October.		November.		December.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
On the spot	$19.25	$18.00	$18.25	$17.25	$18.00	$17.50	$18.75	$18.00	$19.00	$18.00	$21.00	$17.00
Shipments.	19.25	16.75	18.00	16.75	18.00	17.00	18.00	17.00	18.00	17.00	18.00	17.00

So-called "spot prices" are hardly a criterion of the true course of the market, as only small purchases are made from stocks in store here. The bulk of the trade is done on contracts calling for delivery two or three months after the date of the document. In this way the really speculative buying is eliminated. The broker here gets an order from a large consumer in January. He quotes "January-February" steamer and then cables to the exporter in Sicily, who fills the order, shipping when requested to do so, giving the prices ruling at that moment in Sicily.

TALC AND SOAPSTONE.

By C. A. Waldo.

In 1892 and 1893 men in the councils of the New York Central Railroad built a line from Gouverneur, St. Lawrence County, New York, to Edwards, a distance of eighteen miles, to furnish an outlet for the talc mines at Talcville and vicinity, in the township of Fowler, and for several mills scattered along the Oswegatchie River. After several failures, they succeeded in combining the principal companies engaged in the manufacture of fibrous talc into one large company, with a capital stock of $3,000,000.

The Natural Dam, Agalite, and St. Lawrence companies were thus united, and one or two mines purchased outright. This company will hereafter exercise a controlling interest over talc production in northern New York, and will stop most of the destructive rivalry and competition that threatened to strangle this industry.

During the seventies a mineralogist named Minthorne, prospecting in St. Lawrence County, was attracted by the fine deposits of soapstone in the vicinity of Gouverneur, and caused large quantities of a translucent variety to be sent away for manufacture into fountains and other ornamental devices, the rock being first turned into shape and afterward hardened by an oil process. Later, his attention was called to the rich deposits of foliated talc found on the Wight farm in the town of Fowler. He formed a company for milling this stone by a crude process and converting it into a fine, white, fluffy powder. The material, however, was refractory, the process slow, and the returns from its sale were unsatisfactory. The uses to which the product was put at the time were kept secret, though it was generally understood that it was mainly consumed as an adulterant. About this time, in improving the Freemansburg road, the workmen found a large vein of fibrous talc, which was the first of this variety discovered. Mr. Minthorne had some of it pulverized in his mill. His acquaintance with the processes of paper manufacture made him see in this curious product a material for weighting and finishing paper superior to any of the fillers then in use, some of them imported from Europe at large expense. Paper mills were induced to try the new material, and it gradually but surely worked its way into favor. Prospecting began; new mines were opened and new mills set in operation, until now nearly every available water privilege from Talcville down the Oswegatchie to Natural Dam, below Gouverneur, has been occupied by milling establishments wholly devoted to this one product, while two steam mills for the same purpose have been set in operation.

Up to the present time, with unimportant exceptions, all the mines that have been developed are found on a comparatively narrow ridge running northeast from near Sylvia Lake, seven miles to Talcville. The most valuable deposits are in the immediate vicinity of Talcville itself, where the Nelson Freeman mine and the Palmer have been the longest worked. In most of the mines to the south of Talcville the fibrous material is too largely mixed with the foliated talc, or rensselaerite, to be valuable. Rensselaerite, which is the most highly crystalline form of talc, has a pearly luster, a soapy feel, and is easily whittled with a knife, but because it cleaves into micaceous flakes it is almost impossible to pulverize it without leaving "shiners" which mar the surface of common papers and unfit it as a filler for writing paper. Passing north, the massive fibrous deposits increase in number and quantity until at Talcville beds of unknown depth and extent are composed of the fine fibrous material.

At the Freeman mine the shaft runs downward 50 or 60 ft. at an angle of 45°, then the slope suddenly changes to 60° from the horizontal to the point where active operations are being carried on, 300 or 400 ft. below the surface. The deposit is of vein form, 18 or 20 ft. thick, and has well-defined granitic walls. The material comes out in slabs like cord wood, easily split in the direction of the fiber, but quite refractory across the grain. The slabs have a pure, pale, sea-green tint, while the manufactured material is snowy white, entirely free from grit. When passed through the buhrstone, without going through the final cylinder process, the talc comes out in fine fibers which combine in flocculent masses and can be matted together like felt.

The various deposits of fibrous talc are penetrated at different points with crystalline rocks more or less hornblendic in nature. In the northern extremity of Gouverneur is a locality abounding in the brown tourmalines which have furnished the mineral collections of Europe and America with some of their most valuable specimens. The tourmaline is associated with tremolite, the veins of which remind one somewhat of the veins of fibrous talc in Fowler. Tourmalines are found abundantly all through Gouverneur, but in going east they disappear from the hornblendic deposits. The surroundings, the appearance of the veins, and the refuse common in the talc mines, leave a strong conviction that the whole deposit was originally tremolitic and anhydrous, but has been altered to a hydrous mineral with the essential crystalline characters of tremolite.

Numerous claims have been made, but thus far no other deposits of fine, white talc like those in Gouverneur have been pointed out. A knowledge of the conditions under which this valuable mineral exists in St. Lawrence County may lead to its discovery elsewhere. If fibrous talc is to be found elsewhere in quantities of economic importance, and the surroundings in St. Lawrence County are at all typical, we must look for it in an Archaic region where crystalline hornblendic rocks largely predominate. It is now pretty certain that whatever new deposits of it are discovered, its uses in the arts will make the demand greater than the supply for years to come.

The process of manufacture of the material was quite fully described in THE MINERAL INDUSTRY, Vol. I. It may be said, however, that the Cyclone pulverizer has been introduced quite recently, and its availability is still a matter of discussion. Several mills use a process differing in no important respect, except in the final stage, from a common flouring mill. Several more use the Griffin mill, instead of buhrstones, to prepare the talc for the final process in the Alsing cylinders. The two steam mills are trying the Cyclone pulverizers as an innovation. These two mills, worked by the American Company and the Gardner Pulp Company, together with the mills of the Asbestos Company and the United States Company, were not included in the combination formed last summer.

The principal use of fibrous talc is in filling and weighting paper. Its manufacture is purely mechanical, no trace of acid being found in the product. It gives strength, weight, durability, and finish to common papers of which it forms a part. There is probably a purpose to which foliated talc can be put that is apparently not yet appreciated. For certain common kinds of wall paper, pulverized mica is used to add a shimmer and gloss, but there is no doubt that pure rensselaerite could be prepared in such a way as to take the place of the mica fully and satisfactorily at a much smaller expense.

Pulverized talc is insoluble, and perfectly harmless, except in a mechanical way, when taken into the system; it will, therefore, continue to be largely used as an adulterant in certain drugs. Owing to its soapy feel it is largely mixed with cheaper kinds of soap. It forms the basis also of numerous fire and water proof paints and plasters that have been introduced during the last few years. To what extent fibrous talc enters into these substances it is difficult to ascertain, though it is certain that it is proportionately important. Taking all these uses together, it is likely that three times the amount produced in 1892—50,000 tons—will in the near future find a ready market at lucrative prices.

Pulverized fibrous talc has recently been furnished at Gouverneur, f. o. b., at from $9 to $12 per short ton (2000 lbs.). The entire cost of production has often reached the minimum figure. Improved appliances, railroads, and combinations may reduce this to some extent, but as long as the world's economic supply of the material is so narrowly limited it may be expected that the price will advance rather than recede from its present figure.

Production.—The production of fibrous talc in the United States since 1880 is given in the following table:

Year.	Short Tons.	Value.	Year.	Short Tons.	Value.	Year.	Short Tons.	Value.	Year.	Short Tons.	Value.
1880.....	4,210	$54,730	1884..	10,000	$110,000	1888..	20,000	$210,000	1892..	41,925	$472,485
1881.....	5,000	60,000	1885..	10,000	110,000	1889..	23,746	244,170	1893..	36,500	337,625
1882.....	6,000	75,000	1886..	12.000	125,000	1890..	41,354	389,196			
1883.....	6,000	75,000	1887..	15,000	160,000	1891..	53,054	493,068			

It is estimated that the producers carried over into 1894 about 2000 tons more of manufactured material than in 1893.

The financial disturbance, and the changes in the business caused by the consolidation of several of the companies, as mentioned previously, have combined to diminish the output for the past year. There has, however, been a steady increase in the capacity of the Gouverneur district. The consolidation of four of the largest companies into the International Pulp Company must tend to simplify, systematize, and stimulate the production of fibrous talc. Besides this there are four other strong companies. One has a capacity of 12,500 tons per year; another, with a present capacity of 4000 tons, is being reorganized and extended; a third, with a capacity of 12,000 tons, is just coming into the field; while a fourth, with a capacity of 28,000 tons, will start up about March 1, 1894. There will be, therefore, in the near future, five rival concerns in operation in the district, with an aggregate capacity of about 125,000 tons per annum. It is evident that the present demand must be largely increased before all the mills now established will be forced to their maximum. It may be added that while the old companies gradually expanded to their present dimensions, the new companies start in with a large cash capitalization.

SOAPSTONE.

The demand for this mineral is rapidly increasing. In the following table is shown the amount and value of that produced in the United States since 1880:

Year.	Short Tons.	Value.	Year.	Short Tons.	Value.	Year.	Short Tons.	Value.	Year.	Short Tons.	Value.
1880.....	8,441	$66,665	1884..	10,000	$200,000	1888..	15,000	$250,000	1892..	23,208	$423,449
1881.....	7,000	75,000	1885..	10,000	200,000	1889..	12,715	231,708	1893..	20,100	366,825
1882.. ..	6,000	90,000	1886..	12,000	225,000	1890..	13,670	252,309			
1883.....	8,000	150,000	1887..	12,000	225,000	1891..	16,514	243,981			

Soapstone is used chiefly for firebrick, laundry, bath, and chemical tubs, hearthstones, mantels, slate pencils, and griddles. Ground soapstone is used, among other things, in pigments, cosmetics, lubricants, skin and leather dressing, and as adulterant for soap. It may be ground into an exceedingly fine powder, and then it has the property of clinging to metal and stone with the tenacity of goldleaf. In this way it makes a finish for protecting stone and metal surfaces from weathering. For hundreds of years it has been thus employed in China with remarkable results. It is surprising, however, that we do not see it more generally used for heating-stoves. The typical German heater is made up of heavy pieces of porcelain which do not quickly become hot but have a great capacity for heat. Once brought to a moderately high temperature they cool slowly and give out a genial warmth for hours. Thus a room 16 ft. square and 8 to 10 ft. high is made in midwinter quite comfortable for a whole day by one or two small fires. Soapstone stoves might be made into ornamental shapes, and when sufficiently heavy would hold their heat like the Berlin stove, effecting a great saving of fuel and labor.

TIN.

In 1892 there were two tin mines in operation in the United States—the Temescal mines in California, and those of the Harney Peak Company in the Black Hills of South Dakota. The former produced 143,400 lbs. of metal during the first half of the year; but finally the directors, having arrived at the conclusion that they had embarked in a losing venture, closed down the mines in September, since which time they have not been worked. The Harney Peak Company erected large dressing works at Hill City, South Dakota, and put them in operation toward the end of the year; they were run during the month of January, 1893, and produced a small amount of concentrates, but on Feb. 2 the mines and works were both closed down, and were idle during the remainder of the year. Nothing worth mentioning was done at the Virginia mines, and for the present, at least, the tin industry in the United States is at an end.

The total production of tin in the world continues to increase, which is due entirely to the Straits Settlements, where the rich alluvial deposits, which are easily worked and have the further advantage of exceedingly cheap labor, are capable of making a still larger output. The production of tin in the Straits, moreover, has been much stimulated during the past two years by the low price of silver. The yield of tin in Cornwall was about the same in 1893 as in the previous year, but the shipments from Australia and the sale of Banca and Billiton tin in Holland fell off. The importation of Bolivian tin into England showed an insignificant increase, which was disappointing in view of the important stride from 1891 to 1892. No new tin supply has been reported in 1893.

The imports of tin and tin plate into the United States since 1885 are given in the following table; those for previous years may be found in THE MINERAL INDUSTRY, Vol. I. (1892), p. 457, to which the reader is referred.

IMPORTS OF TIN INTO THE UNITED STATES.

Year.	Block Tin.		Tin Plate.	
	Pounds.	Value.	Pounds.	Value.
1886..	29.531,355	$6.728,908	577,217,362	$17,495,564
1887..	29,344,553	6,921,948	635.729,760	18,699,145
1888..	34,294,135	8,802,854	667,231,988	19.752,180
1889..	35,177,648	7,044,939	724,135,688	21,726,707
1890..	33,821.319	$6,869,645	737,935.079	$23,670,158
1891..	41,146.123	8.091,363	734,425,267	25,900.305
1892..	46,821,958	9,415,889	601,378,109	17,102,487
1893..	40,184,556	8,007,292	567,806,461	15,559,423

The American Tin Market in 1893.

The year 1893 will long be remembered by importers, dealers, consumers, and all who have had to do with tin, and not with pleasant recollections, for almost everybody has been a loser by his dealings in connection with the article. The ill-advised section of the McKinley bill levying a duty of 4c. per lb. on tin on and after July 1, 1893, was a disturbing element in 1892, and even more so, of course, during the first six months of 1893, within which period prices fluctuated wildly. As the proposed duty was equal to about 20% of the value of the material taxed, it was only natural that as large supplies as could be obtained should be laid in prior to July 1, and in consequence the duty was but a nominal one so long as such stocks lasted. It was thought that what had been brought in duty free would not last longer than about the middle of November; but all calculations were upset by the financial panic through which the country passed, regarding which, Mr. Eckels, the Comptroller of the Currency, wrote as follows: "The financial situation of the past months was not the result of either a lack in the volume of currency, of which there is now a plethora, or a want of elasticity in the present system of issuing it, but arose from a loss of confidence on the part of the people in the solvency of the distinctively monetary institutions of the country."

The beginning of January found the market ruling at about 19¾c. for spot, and there was a gradual hardening until about 21¼c. was reached by the middle of March, the advance being accelerated by a growing scarcity of spot supplies. At that time the importers were buying, for shipment from the East as late as possible, quantities considerably in excess of the usual requirements, as they wanted to get in as much as possible prior to July 1 and the imposition of the duty. Of course, this free buying kept the foreign markets firm, and as the premiums commanded by future deliveries were very large, many consumers thought they would do well by buying to cover future wants prior to the levying of the duty. When the high prices which naturally resulted from all this were reached, London and the East sold freely, and as simultaneously there came a lull in trade here. The natural result was a sharp decline, with only occasional rallies to stay its progress, 20¼c. showing a decline of fully 1c. per lb. from the top, being reached by the middle of May, by which time stocks here were increasing rapidly, with further large supplies on the way. A great deal of this metal had gone and was going into the hands of weak speculators, and when the panic came, and it was impossible to borrow money to carry merchandise, they were forced to unload at the best prices to be had. The larger and stronger houses, having already taken in quantities that were excessive in comparison with what they usually carried, did not care to increase their holdings much, and this, of course, did not help matters. The market declined sharply because of the lack of support, and by the beginning of June the figures receded to 18⅞@19c., at which low level there was freer buying, the slight temporary easing in the money markets giving a little courage, resulting in a rapid advance to 20¼@20½c., shipments from abroad having by that time entirely ceased, because of the near approach of the day when the duty would go into effect.

This cessation of imports made the prospects fair for an advance here, regardless of the course of the London market, but the renewal of the financial troubles during the month of June interfered with everything, and by the middle of July prices were so low that actual sales were made at 18¼@18½c. At that time the consumption of all other metals had almost ceased, but with tin the case was different, as it entered into so many manufactures that there was always more or less of a demand for it, and at no time was the consumption less than 50% of the average of late years. When these very low prices were reached, it was decided by the principal holders of metal on this side the water that, as the foreign market was steady and could not, for some time to come, interfere with that here, it would be well to combine for the protection of mutual interests, by taking care of such distressed lots as appeared in the market from time to time, forcing prices down by the pressure exerted to sell them. As the operations of the associated interests were conducted with great skill and without any manifestation of greed by anybody concerned, the market was soon steadied and then slowly but surely advanced, 19c. being reached by the end of August, 20c. a fortnight later, and 21c. by the beginning of October. The last-named figure was then within ½c. per lb. of the price at which tin could be laid down here, duty paid, from abroad, where meanwhile there had been a serious decline, due to the temporary closing of the American markets and the consequent excessive supplies elsewhere. From early October on, prices were regulated strictly by the supply and demand, and, the demand growing lighter, prices declined during the month to about 20⅝c., afterward to be marked up again to 20⅞c.

During December the London market showed a decided tendency to sag off, and, of course, this affected prices here, the adverse influence being heightened by the very light consumption, causing prices to drop gradually until about 20½c. for spot delivery was reached at the end of the month.

From June 1 to the end of December the monthly consumption was never more than from 700 to 900 tons, or an average of 800 tons, and the supplies brought in before July 1 will prove sufficient for consumption during January, at the end of which month it is probable that all will be gone.

In anticipation of a better demand, several small lots, amounting in all to not more than 300 tons, have been brought in, most of them being put into bonded warehouses until wanted, only what was needed for the manufacture of articles to be exported being taken out of bond and the duty paid.

In the Wilson tariff bill, now up for consideration, it is provided that tin shall be restored to the free list; but as it does not seem probable that the bill as finally passed will become operative until some time after the duty-free stocks of metal at present on hand have been entirely exhausted, there is little doubt of our having again to enter the markets of the world, which will be thereby strengthened, and buy what we need and pay the duty of 4c. per lb., for there is no American tin to be had, both the California and Dakota mines having long since ceased to give hope of becoming a permanent source of supply.

Of course, the stocks of metal now in bonded stores will be drawn upon only to supply actual needs; but when the duty has been removed—by which time everybody here will be bare of stocks—consumption will undoubtedly be larger than now, due in part to more normal conditions and in part to the removal of uncertainty as to what the near future is to bring forth. Then those who have lost by their connection with the metal will probably have a chance partly to recover their losses.

THE LONDON TIN MARKET IN 1893.

The market opened in January very dull at £91 5s. per ton for spot Straits, and 5s. less on three months' tin. In the course of the month, however, three months' tin assumed its normal position relative to spot; *i. e.*, the former closed at about 10s. premium over the latter. As the month progressed, a moderate demand for home consumption developed itself. The chief buyer, however, then and for many months following, was America, which absorbed large quantities in view of the duty of 4c. per lb., or nearly £20 per ton, to go into force on July 1. The visible supply of foreign tin in and afloat to England on Jan. 1 was 7387 tons, but at the end of the month it had increased by about 800 tons, despite a depletion of the actual stocks in London, the difference consisting of heavy shipments afloat. American buying plus higher Eastern exchanges brought about an advance which culminated at £93 5s. for spot cash Straits toward the close of the month.

The range of prices during February was almost the same as for the preceding month, but in the opposite direction, with numerous fluctuations, caused in part by rumors of the probable repeal of the McKinley tariff. This chiefly affected distant dates, cash up to three months' closing firm on the last of the month at £93 and £93 5s. respectively. At the beginning of March cash tin fell rapidly to £91 7s. 6d. on rumors from America, but immediately recovered to the extent of a sovereign. During the next week £93 10s. was paid and then heavy purchases were made, resulting in a further advance to £95 spot cash, but three months' was again at a discount of about 10s. per ton, while prompts falling later than July 1 were fetching only about £5 per ton under spot value. The latter position, after reaching £95 10s., declined in sympathy with silver to £94 12s. 6d., and closed about 5s. better.

Early in April, after £95 had again been done, a fall of 30s. ensued upon the publication of the March statistics, revealing a considerable increase in the visible European supply. The next week brought a rally to £94 17s. 6d. spot cash, three months' being then at £90 10s., August-September at £88 2s. 6d, and all the year in seller's option at £87 17s. 6d. Spot subsequently ruled between £94 15s. and £93, futures continuing at a very heavy discount.

May was a month of rapid and extensive depreciation in values and deep depression in tone, the influential factors being the financial crises in Australia and the United States, and the consequent realizations of stock, held in anticipations of an active American demand which was not forthcoming. The total fall was from £93 10s. to £85 10s.

June was again a month of very wide variations in price. From £85 7s. 6d. spot the market gradually rose to £89 10s., owing to a scarcity of cash tin. Sellers coming out, there was a recoil to £88, and then, in the last week of the month, when silver fell from 36d. to 29¾d. per oz., there was a drop in tin from £87 to £83. The position at the end of June was that America had accumulated stocks sufficient to last for about six months at the usual rate of consumption, and abnormal purchases for that destination had ceased for some time past. On the other hand, the visible supply in and afloat to England had been reduced to about 4822 tons.

The month of July witnessed a further reduction of values. Under the influence of financial stress in America spot Straits fell in the first week from £84 to £83 10s., and in the second week to £82. The unlooked-for favorable result of the usual Banca sale toward the end of the month induced a reaction which sent spot up to £83 10s., three months' being at a discount of about 15s. This gain was, however, lost in the first days of August and a fresh retrograde movement set in, owing chiefly to the uncertainty respecting silver legislation in the United States. Spot Straits eventually touched £76 12s. 6d., but at this juncture a recovery of £2 per ton was brought about by the calling of the extra session of Congress and the prospect of a repeal of the silver laws, which led to speculative purchases of forward tin, so that it regained its normal status and closed at about 15s. contango.

Early in September active selling sent the cash price down from £79 15s. to £78 15s., when buyers came out and there was a rapid rise, which reached £81 2s. 6d. in the third week of the month. Before the month closed, however, £79 15s. and £79 5s. were recorded, and the final values were £80 spot cash and £80 7s. 6d. three months. An interesting feature of the month was the circumstance that, owing to the greatly reduced margin between Straits and English tin, it became possible to ship Straits to Cornwall, there to be turned into English ingots. Speculation was dull, the main operators holding aloof to a great extent, owing to the depressed state of trade, the weakness of American credit, and the deplorable condition of the tin-plate industry. The occasional upward jumps were caused partly by a report to the effect that tin smelters had combined for a speculation with the object of enhancing values.

October was characterized for the more part by steadiness of tone and values, £79 10s. to £78 constituting the actual range until the end of the month, when a sharp drop in silver led to a heavy fall in Straits, viz., to £76 15s., which was accepted for spot on the last day of the month. There was no salient feature this month. The demand for English was less active than it had been, and the margin over Straits continued to decline. No very considerable quantities were offered from the Straits, but the bulk of that available was readily absorbed here, America only taking small quantities.

In November values fluctuated over a considerable range, the extreme limits being £77 5s. and £74 17s. 6d. The opening price was £76 17s. 6d., and the closing price £75 10s., spot cash Straits. The premium for Australian had now declined to 10s. over Straits, as against 30s. or so some months back.

The continued efforts of some English smelters to help the article by buying Straits were not of much avail, being counteracted by sales on the part of leading operators in London. The most interesting features were, first, the stimulus supplied to production in the Straits by the more plentiful coolie labor now obtainable and by the high dollar price ruling, and secondly, the very large proportion of shipments made direct to the Continent. From £75 10s., the value of spot Straits at the end of November, there was subsequently a sharp advance to £77 2s. 6d. spot cash, but the year closed at £76 5s. spot cash, and £77 2s. 6d. three months' Straits. English was quoted at £80 10s. for common ingots, £81 10s. for bars, and £82 10s. for refined ingots.

PRICES OF STRAITS TIN IN NEW YORK.

(Cents per pound.)

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1885............	16⅝	17.45	17⅜	17.80	18⅝	20⅜	22⅜	21¼	20.95	20.95	20.65	21	19⅝
1886............	20⅝	20.70	20.80	20.85	21.30	22¾	22¼	21¾	22.20	22¼	22.40	22¼	21.65
1887............	20.30	22½	22.55	22½	22.95	23¼	23.35	23.30	23⅛	25⅛	31.05	36⅓	24.85
1888............	36.95	36.95	36.70	32.95	21.95	18.05	19¼	20¾	22.95	23.35	22.70	22.10	36.20
1889............	21⅞	21½	21.30	20⅞	20½	20.30	19⅞	20.20	21.30	20.80	21¾	21.30	21.80
1890............	20.95	20.87	20.39	20.13	21.52	21.53	21.17	21.62	24.00	22.60	21.07	21.21	21.42
1891............	20.20	19.99	19¾	19½	20.00	21.00	20.20	20.10	20¼	20.10	20.00	19.90	
1892............	20.50	20.00	20.25	20.50	20.80	22.00	21.00	20.50	20.35	20.50	20.80	20.00	
1893............	19.99	20.30	20.71	20.81	19.96	19.76	19.15	18.81	20.14	20.84	20.61	20.67	

MONTHLY AVERAGE PRICES OF STRAITS TIN IN LONDON.*

(Per ton of 2240 lbs.)

Year.	Jan. £ s. d.	Feb. £ s. d.	Mar. £ s. d.	April. £ s. d.	May. £ s. d.	June. £ s. d.	July. £ s. d.	Aug. £ s. d.	Sept. £ s. d.	Oct. £ s. d.	Nov. £ s. d.	Dec. £ s. d.	Year. £ s. d.
1872	142 15 0	137 18 9	147 10 0	156 5 0	153 16 0	149 10 0	154 12 6	148 2 0	149 12 6	142 17 6	138 10 0	136 7 6	146 9 9
1873	144 6 0	143 12 6	147 0 0	143 5 0	135 14 0	135 17 6	129 17 6	129 11 0	127 0 0	122 6 0	116 10 0	119 0 0	132 16 7
1874	117 2 0	105 15 0	92 0 0	91 3 9	98 14 0	100 8 9	97 6 0	93 0 0	92 13 9	91 15 0	93 17 6	93 7 6	97 5 3
1875	94 1 3	90 5 0	88 5 0	85 3 0	82 17 6	83 11 3	78 17 0	79 17 6	83 15 0	85 9 0	83 17 6	81 8 0	84 15 7
1876	**	....	....	....	....	....	....	....	....	....	....	....	74 10 2
1877	74 17 6	72 12 6	71 5 0	69 6 3	70 3 9	68 16 6	67 1 10	65 5 0	65 0 0	67 15 7	67 19 0	66 7 6	68 17 6
1878	64 8 9	63 8 1	64 0 0	62 10 7	61 7 0	61 18 1	61 8 9	60 1 0	57 6 3	54 19 4	62 18 6	61 9 4	61 6 4
1879	60 0 6	60 15 0	66 4 4	68 18 9	66 15 3	66 10 7	64 15 0	66 11 0	72 18 1	87 19 0	93 1 3	90 18 9	72 2 4
1880	95 13 0	94 5 10	88 8 1	83 2 6	75 0 0	76 0 7	88 3 6	89 3 9	82 4 4	87 0 0	91 5 7	91 4 4	86 16 0
1881	90 5 7	88 10 11	87 10 0	87 8 9	87 3 1	90 3 5	89 12 6	91 3 0	93 1 6	96 15 0	101 12 6	108 2 9	92 12 5
1882	111 13 9	111 13 0	110 1 0	98 16 3	96 5 0	96 14 6	103 13 0	101 18 0	106 0 6	104 9 4	98 16 10	94 6 6	102 15 6
1883	**	....	....	....	....	....	....	....	....	....	....	....	93 1 0
1884	83 0 6	82 5 9	83 2 0	84 2 3	85 0 0	82 15 3	82 16 0	82 10 9	81 18 0	75 4 9	75 0 8	74 2 3	80 19 10
1885	75 8 2	77 19 0	77 6 10	78 9 4	83 18 9	92 14 0	94 1 3	92 2 6	91 5 0	91 5 9	92 9 3	93 6 10	86 13 10
1886	92 7 9	92 14 6	93 4 0	93 9 3	95 16 0	101 5 0	99 6 6	98 0 0	99 19 3	101 4 0	100 12 9	100 11 6	97 7 6
1887	101 10 0	101 2 3	102 3 0	101 16 3	103 13 0	102 15 6	103 17 6	103 15 0	103 6 3	109 14 6	138 11 5	166 4 0	111 11 0
1888	167 7 6	166 18 6	166 1 6	166 1 0	83 7 3	79 19 6	83 9 1	92 5 0	100 8 3	101 17 6	101 9 1	98 13 9	117 6 6
1889	97 19 4	95 18 5	95 13 9	92 10 7	91 11 6	90 1 10	88 19 4	90 1 6	90 5 4	90 12 6	96 12 4	97 5 0	93 0 11
1890	95 1 0	90 17 10	90 7 6	90 10 7	93 11 0	95 0 7	94 3 9	95 8 3	100 14 4	99 14 6	93 3 2	91 15 7	94 4 0
1891	91 1 10	90 3 1	90 6 10	89 16 3	91 13 9	93 3 1	91 17 9	91 11 3	91 11 3	90 19 9	91 8 5	90 15 3	91 4 0
1892	89 19 4	89 3 1	89 8 1	91 17 6	95 19 4	100 13 5	97 2 6	94 5 0	92 10 9	94 7 6	94 1 3	92 6 3	93 9 6
1893	92 7 6	91 16 3	94 11 6	94 5 6	91 14 4	86 14 0	82 19 4	79 10 0	79 18 9	78 15 0	76 3 0	75 16 3	85 7 7

* From British blue books. ** The monthly prices were not given in the blue books for these years.

AVERAGE MONTHLY PRICE OF ENGLISH BLOCK TIN IN LONDON.*

(Per ton of 2240 lbs.)

Year.	Jan. £ s. d.	Feb. £ s. d.	Mar. £ s. d.	April. £ s. d.	May. £ s. d.	June. £ s. d.	July. £ s. d.	Aug. £ s. d.	Sept. £ s. d.	Oct. £ s. d.	Nov. £ s. d.	Dec. £ s. d.	Year. £ s. d.
1872	149 5 0	145 5 0	151 6 0	161 5 0	161 4 0	155 0 0	158 0 0	154 18 0	156 2 6	149 7 6	146 18 0	143 12 6	152 15 0
1873	146 14 0	146 10 0	149 0 0	147 17 6	139 16 0	136 5 0	131 2 6	129 16 0	127 10 0	125 8 0	121 7 6	120 12 6	133 7 0
1874	120 18 0	110 15 0	97 0 0	94 15 0	101 16 0	102 10 0	98 14 0	96 15 0	96 15 0	97 2 0	99 15 0	98 12 6	108 8 0
1875	100 10 0	95 0 0	93 12 6	92 0 0	90 2 6	90 0 0	85 16 0	85 5 0	89 2 6	89 8 0	87 13 9	84 19 0	90 2 0
1876	**	....	....	....	....	....	....	....	....	....	....	....	79 10 2
1877	78 0 0	75 12 6	74 13 0	73 15 0	74 5 0	72 18 0	71 15 0	69 4 0	69 7 6	72 17 6	74 11 0	71 11 3	73 3 6
1878	69 5 0	67 0 0	67 17 0	67 2 6	65 6 0	65 8 9	65 0 0	64 0 0	62 0 0	60 11 3	67 2 0	66 5 0	65 12 3
1879	63 18 0	63 7 6	68 7 6	69 11 3	66 16 0	65 2 6	64 0 0	67 4 0	74 7 6	89 8 9	96 10 0	95 0 0	72 6 6
1880	99 16 0	100 10 0	93 15 0	88 12 0	82 7 6	79 12 6	93 4 0	93 0 0	87 0 0	90 4 0	94 2 6	95 2 6	91 5 0
1881	94 12 6	92 7 6	90 10 0	90 17 0	91 0 0	94 15 0	95 8 0	96 10 0	98 15 0	101 13 9	107 12 6	113 12 0	97 9 3
1882	115 12 6	115 17 6	113 6 0	102 15 0	100 15 0	100 6 0	107 0 0	105 7 6	109 2 0	108 10 0	103 10 0	99 8 0	106 14 0
1883	**	....	....	....	....	....	....	....	....	....	....	....	97 1 6
1884	87 17 6	87 14 3	87 5 0	87 17 9	89 10 0	85 15 0	85 3 9	85 6 0	83 18 9	79 2 0	78 2 6	77 6 3	84 11 7
1885	78 9 0	81 0 0	80 17 6	82 0 0	87 2 0	95 0 0	95 10 9	94 0 0	93 0 0	93 0 0	95 7 6	97 0 0	89 7 2
1886	97 0 0	97 5 0	97 5 0	97 5 0	99 8 0	105 0 0	103 12 6	102 0 0	104 4 0	105 0 0	104 10 0	104 12 2	101 8 6
1887	105 6 0	104 18 9	105 14 3	105 13 9	107 2 0	106 6 0	107 4 3	107 12 9	106 10 0	114 11 8	135 12 6	149 0 0	112 9 6
1888	148 7 6	160 17 0	158 19 0	153 0 0	95 2 6	89 10 0	90 0 0	96 17 6	104 2 0	104 15 0	104 2 6	101 12 0	117 5 5
1889	100 17 6	98 12 6	97 4 0	95 15 0	93 18 0	93 15 0	93 3 9	93 17 0	94 7 6	94 6 10	100 12 1	102 0 0	96 10 9
1890	99 14 0	95 6 3	94 10 0	94 4 4	97 1 6	99 8 9	97 16 3	98 13 6	102 12 6	101 12 0	96 0 0	95 0 0	97 13 3
1891	94 1 6	93 5 0	93 5 0	93 0 7	94 10 0	95 13 5	94 17 0	94 6 10	94 2 10	94 5 7	94 15 8	94 6 1	94 4 1
1892	93 4 0	92 12 2	92 15 9	94 18 7	98 5 0	102 12 0	100 2 0	97 13 9	95 9 0	97 11 10	97 7 6	95 13 4	96 10 5
1893	95 11 3	95 15 0	98 7 0	97 2 6	93 17 6	90 7 0	87 7 6	85 2 0	85 12 6	83 11 3	81 3 0	80 3 9	89 10 0

* For the years 1872–92, inclusive, from British blue books. Those for 1893 are from current market reports, the prices being for English common blocks and ingots, f. o. b., 1¼% discount for cash.

** Monthly prices are not given in the blue books for these years.

AVERAGE YEARLY PRICE OF ENGLISH COMMON BLOCK TIN IN LONDON FROM 1800.*

(Per ton of 2200 lbs.)

Year.	£	Year.	£	Year.	£	Year.	£	Year.	£	s.	d.	Year.	£	s.	d.
1800....	92	1817....	92	1828....	72	1850....	81– 84	1858....	119	2	2	1866....	88	12	6
1806....	112	1818....	84	1830....	74	1851....	89	1859....	131	18	3	1867....	91	17	3
1810....	145	1819....	74	1836....	99–126	1852....	90–88	1860....	136	3	1	1868....	98	0	0
1811....	128	1820....	72	1837....	88– 95	1853....	223–127	1861....	122	5	0	1869....	123	2	0
1813....	130	1822....	90	1840....	81	1854....	117–130	1862....	116	0	0	1870....	127	8	6
1814....	150	1823....	116–184	1842....	67– 73	1856....	129–142	1863....	117	0	0	1871....	137	10	0
1815....	130	1826....	78	1843....	60– 64	1857....	108–146	1864....	107	1	0	1872....	152	15	0
1816....	110			1845....	78–106			1865....	96	5	0				

*From *Mineral Statistics of Great Britain and Ireland.*

PRICES OF BANCA AND BILLITON TIN IN HOLLAND. (*a*)

Month.	Banca.					Billiton.				Parity of Straits in London.				
	Florins.					*Florins.*				*Florins.*				
January......	55 to 56					54¼ to 55¾				54⅞	....	55⅞	....	55½
February......	56	....	....	55	55½	55¾	55	....	55¼	55½	....	55¼	....	55¾
March........	55½	57¾	56½	....	57	55¼	57	56	56½	55¾	....	57¼	....	56⅝
April..........	57	55½	....	....	56	56½	54¾	....	55	56½	....	57	....	55⅞
May..........	56	....	....	....	52	55	....	51¼	52	55⅞	54	54½	....	51½
June..........	52	56	....	....	54½	52	....	55¼	53¼	51½	51¼	53¼	50	51
July..........	54½	55½	....	52¼	53¾	53¼	....	....	51¼	51	49¼	49¾	....	49½
August.......	52¾	....	55	....	53¼	51¼	....	52¼	51¼	49½	....	46	....	47
September....	53¼	55¾	53	....	53½	51¼	....	52¼	49½	47	48½	47½	....	48
October......	53½	....	51½	....	52¾	49½	47½	48½	47¼	48	46¾	47	....	46¼
November....	52¾	....	47¼	....	48	47¼	....	45	45¾	46¼	....	45	....	45¼
December....	48	48¼	47¼	47½	46½	45¾	46½	45¼	45	45¼	....	46	....	44½

(*a*) Furnished by Messrs. De Monchy & Havelaar of Rotterdam.

AVERAGE PRICE OF TIN AT THE PRINCIPAL MARKETS IN GERMANY.*

(Price in marks per 100 kilos; 1 mark=23.8c.)

Year.	Frankfurt, Banca, from Dutch Storehouses.	Hamburg, Banca, in Slabs 2% Discount.	Year.	Frankfurt, Banca, from Dutch Storehouses.	Hamburg, Banca, in Slabs 2% Discount.
1879..............	153.25	157.04	1887..............	229.17	241.71
1880..............	181.02	188.94	1888..............	243.92	264.66
1881..............	193.87	201.04	1889..............	193.29	203.46
1882..............	214.71	226.97	1890..............	193.75	204.08
1883..............	195.08	208.81	1891..............	186.25	196.90
1884..............	174.25	184.88	1892..............	191.88	201.06
1885..............	179.13	193.28	1893..............	181.33	192.02
1886..............	199.92	219.02			

* From *Vierteljahrshefte zur Statistik des Deutschen Reichs*, 1893, Part I.

PRODUCTION OF TIN IN THE WORLD.†

(In tons of 2240 lbs.)

	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
English production.......	8,918	8,615	9,300	9,307	9,700	9,331	9,312	9,282	9,241	8,912	9,000	9,353	9,270	9,000
Straits' shipments to Europe and America......	11,735	11,400	11,705	16,958	17,548	17,320	19,674	23,977	23,855	28,295	27,470	31,457	34.648	39,670
Australian shipments to Europe and America...	9,177	10,100	10,067	11,121	9,337	9,088	8,064	7,750	7,975	6,800	6,415	5,991	5,972	5,579
Banca sales in Holland...	3.756	4,548	4,399	4,203	4,193	4,200	4,379	4,384	4,430	4,114	5,317	5,350	6,300	5,244
Billiton sales in Java and Holland................	4.735	4,740	4,200	4,157	3,600	3,760	4.128	4,978	5,220	4,857	5,232	5,753	5,560	5,462
Bolivian arrivals in England....................	......	......	......	......	......	224	354	982	1,363	1,389	1,664	1,559	2,819	2,909
Total................	38,321	39,403	39,671	45,746	44,378	43,923	45,911	51,353	52,054	55,367	55,098	59,463	64,569	67,864

† From the Annual Metal Circular of W. T. Sargent & Co.

CONSUMPTION OF TIN IN THE WORLD.*

(In tons of 2240 lbs.)

Year.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Deliveries from London after deducting all shipments to America	17,600	15,018	16,466	13,481	20,008	18,194	16,126	17,667	14,122	18,663
Deliveries from Holland after deducting exports to London and America	6,818	6,842	6,513	6,906	6,771	7,581	8,155	8,246	8,719	7,853
English consumed at home	4,200	4,350	4,330	4,088	3,286	3,830	3,872	3,834	3,158	2,260
Exports of English, minus quantity shipped to America	5,320	4,418	4,390	4.650	5,164	4,820	4,567	4,990	5,648	6,554
American consumption of all sorts	10,200	10,300	11,500	12,600	14,400	15,000	16,000	15,457	18,750	19,000
Billiton sent to other ports than Holland	1,000	1,500	1,406	1,900	2,420	1,287	1,617	1,972	2,605	1,919
Straits direct to Continent, less re-exports to America and England	597	611	1,915	1,785	1,340	3,680	3,700	3,579	5,500	8,900
Bolivian delivered from Liverpool	......	342	352	908	1.441	1,321	1,622	1,658	2,656	2,704
Total	45,735	43,381	46,872	46,318	54,830	55.713	55,659	57,403	61,158	67,853

* From the Annual Metal Circular of W. T. Sargent & Co.

STOCKS OF FOREIGN TIN AND QUANTITIES AFLOAT FOR ENGLAND AND HOLLAND.*

(In tons of 2240 lbs.)

	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Stock of foreign in London	4,885	6,561	3,110	7,128	4,231	2,290	2,524	2,155	2,776	4,392
Foreign landing in London	452	327	973	961	283	1,406	880	1,162	4,346	817
Straits afloat for London, including wire advices	1,870	1,160	1,020	3,398	2,718	2,225	1,205	2,225	2,170	3,470
Australian afloat for London, including wire advices	1,140	900	760	796	908	600	856	802	957	909
Banca on warrants in Holland	1,193	748	793	661	884	680	867	511	868	319
Billiton in Holland	1,155	594	730	497	671	984	277	357	326	640
Billiton afloat for Holland	1,154	990	1,093	1,345	1,062	1,335	1,396	1,912	1,240	1,600
Straits stock in Holland	......	......	......	......	......	......	......	160	190	670
	11,849	11,280	8,479	14,786	10,757	9,520	8,005	9,284	9,873	12,817
Estimated stock in America and quantity floating	1,480	2,150	3,200	1,251	3,000	2,670	2,925	3,228	5,492	2,730
	13,329	13,430	11,679	16,037	13,757	12,190	10,930	12,512	15,365	15,547
Trading Company's reserves of unsold Banca stock in Holland	2,898	2,400	1,678	2,301	4,447	4,813	2,787	3,140	3,480	4,200
Floating for Holland	702	111	345	400	180	60	303	......	139	......

* From the Annual Metal Circular of W. T. Sargent & Co.

EXPORTATIONS OF TIN PLATES FROM UNITED KINGDOM.*

(In tons of 2240 lbs.)

	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
To United States	211,860	223,869	263,585	268,364	292,623	336,692	318,108	325,145	278,479	255,583
To other places	76,848	73,859	71,190	86,409	98,668	93,931	100,617	123,587	117,101	123,650
Total tons	288,708	297,728	334,775	354,773	391,291	430,623	418,725	448,732	395,580	379,233

* From the Annual Metal Circular of W. T. Sargent & Co.

TUNGSTEN.

Tungsten in the metallic state is one of the rare elements, occurring neither in nature nor in the arts. It is prepared, however, as a curiosity by reducing the trioxide, WO_3, with hydrogen in a platinum tube at a high temperature. As thus obtained it forms resplendent tin-white or gray plates, or a dull black powder similar to hydrogen-reduced iron. Its sp. gr. is 19.129. It is unalterable in ordinary air; it is acted upon by oxygen and chlorine only at a high temperature, and it is not affected by hydrochloric or sulphuric acid. Nitric acid, however, attacks it slowly, and aqua regia readily with the formation of the trioxide, WO_3. Impure tungsten is prepared industrially for use in making tungsten steel.

The only important ores of tungsten are the minerals wolframite (FeMn), WO_3, and scheelite, $CaWO_4$, of which the former is the more abundant, occurring very frequently with tin ores. Wolframite is a black mineral of 7.1 to 7.55 sp. gr., and 5 to 5.5 in the scale of hardness. Sometimes it is weakly magnetic. Scheelite, on the other hand, is a light-colored mineral of vitreous luster and white streak. Its color may be white, yellowish-white, pale yellow, brownish, and sometimes orange-yellow. Its hardness is 4.5 to 5, and sp. gr. 5.9 to 6.076. It is a trifle richer than wolframite, containing 80.6% tungsten trioxide, against 76.47% in the other mineral.

Occurrence.

Australia.—Deposits of scheelite are known to exist in the Abercrombie ranges, New South Wales, and discoveries have been made in the neighborhood of Glen Innes and Inverell, in the New England district.

Bohemia.—Wolfram ore is produced by one mine in Bohemia, that of Prince Moritz von Lobkowitz, near Zinnwald, on the Saxon frontier. The Zinnwald mines, indeed, occur directly at the dividing line between the two kingdoms Saxony and Bohemia. The ore won in the Lobkowitz property is of the same character as that from the mine of the Vereinigte Zwitterfeld Fundgrube zu Zinnwald, in Saxony. The entire product is obtained from the old dumps of the mine, in sorting which forty men are employed. The output of mineral in 1892 was 71.9 tons, valued at 19,806 florins ($7,922), or 275.50 florins ($110) per ton, which was 101.6 florins ($40.50) less than the average price in 1891. All the wolfram ore produced in Bohemia is exported to Germany.

Cornwall.—The tin ore of Cornwall frequently carries wolframite. In two mines, the East Pool at Illogan and the South Wheal Crofty at Carn Brea, a considerable quantity of the mineral is saved annually, though the former was the only producer in 1892. The output of Cornwall amounts to 125 or 150 tons of ore per annum and exceeds that of any other country.

New Zealand.—Scheelite occurs in New Zealand, according to T. A. Rickard,* in workable quantities in Otago, the south island, but the want of a regular market has prevented the development of the industry. However, parcels of mineral have been sent occasionally to England from Waipori. At Glenarchy, at the head of Lake Wakatipu, there is a mine opened on a quartz lode three or four feet wide, traversing metamorphic slates, which contains large bodies of scheelite. It is interesting to note, by the way, that the quartz is slightly auriferous. Scheelite is also found at Nelson, on the north end of the same island.

Saxony.—The old tin mines at Zinnwald, on the Bohemian frontier, have been worked on a small scale for wolframite in recent years, the tin ore for which they were formerly exploited having been exhausted in 1870. Both wolframite and scheelite occur, but the former, which is by far the more abundant, is the mineral chiefly mined. The ore occurs in bed-veins from six inches to thirty inches thick in greisen, which passes into granite. The mine which is owned by the Vereinigte Zwitterfeld Fundgrube zu Zinnwald, employing about forty-five men, is worked in a very primitive manner. Its output is about forty tons of clean mineral per annum, the whole output credited to Saxony in the accompanying table being derived from this mine.

United States.—Wolfram minerals are found in the United States at numerous localities, the following being mentioned by Dana; Monroe and Trumbull, Conn.; on the Carndage farm, near Blue Hill Bay, Maine; at the Flowe mine, Mecklenburg County, N. C.; in Missouri near Mine la Motte and in St. François County; and in the Mammoth mining district of Nevada. They occur also in association with the tin ore at Irish Creek, Rockbridge County, Virginia, and at Grass Valley, California. Several of these occurrences are only of mineralogical interest, but attempts have been made to work the deposits at Monroe and Trumbull, Conn. (where one ton of mineral was mined in 1872), and that near Blue Hill Bay, Maine.

A full account of the occurrence of wolfram ore in Connecticut, which has some remarkable features, was read by Dr. Adolph Gurlt of Bonn, Germany, at the Chicago meeting of the American Institute of Mining Engineers, August, 1893. The wolfram ore, consisting of wolframite and scheelite, at this locality is found as a contact deposit, three to five feet thick, between crystalline limestone and gneiss. The ore-bed is traceable for a considerable distance, and probably averages, in Dr. Gurlt's opinion, from two to three per cent. wolfram. If this proves to be the case, it is without doubt one of the largest deposits of wolfram ore now known. Dr. Gurlt examined this property in 1887, since which time the only work done upon it has been a little exploration carried out under his direction. The result of this is reported to have been satisfactory.

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* *Engineering and Mining Journal*, April 23, 1892, p. 448.

Scheelite is said to occur in considerable quantity on the foot-wall of a gold mine on Howard Hill, Grass Valley, California.*

PRODUCTION.

The wolfram ores of commerce are obtained at the present time almost entirely from Cornwall, Saxony, Bohemia, Australia, and New Zealand, the annual production varying between 400 and 500 metric tons, according to information furnished by Messrs. G. G. Blackwell & Co. of Liverpool, England, who are the principal dealers in these ores. The production of wolfram ores in Europe is given in the following table :

PRODUCTION OF WOLFRAM ORE IN EUROPE.
(In metric tons.)

Year.	Cornwall.	Saxony.	Bohemia.	Total.	Year.	Cornwall.	Saxony.	Bohemia.	Total.
1875......	46.80	3.70	37.00	84.50	1884....	65.00	39.500	53.00	157.50
1876......	23.40	2.90	......	26.30	1885....	380.00	26.614	55.00	461.61
1877......	15.23	18.35	40.00	73.58	1886....	142.00	30.525	56.00	228.53
1878......	10.16	28.5	16.00	54.66	1887....	54.90	39.720	59.00	153.62
1879......	13.20	27.300	7.00	47.50	1888....	61.00	39.250	39.00	139.25
1880......	1.01	32 200	60.00	93.21	1889...	0.53	38.830	20.00	59.36
1881......	54.90	47.700	63.00	165.60	1890....	106.00	36.650	37.00	179.65
1882......	58.90	40.950	66.00	165.85	1891....	140.00	42.045	56.70	238.75
1883......	113.00	54.850	42.00	209.85	1892	127.00	37.000	71.90	235.90

These ores are almost wholly wolframite, very little scheelite being produced by the mines of Europe. On the other hand, scheelite forms the more part of the mineral which comes from Australia and New Zealand. An abundant supply of ore can be had from these colonies, but the shipments are irregular, depending upon the requirements of the market.

None but cleanly dressed mineral is bought. The value of such ore varies widely, ranging at present from £12 to £30 per long ton (2240 lbs.) in Liverpool, and depending upon its tenor in tungstic acid (WO_3). At present wolframite with 50% to 60% tungstic acid is worth about 7s. per unit, while scheelite with 70% WO_3 brings 8s. per unit.

USES OF TUNGSTEN.

The chief use of tungsten is in the preparation of ferro-tungsten for making tungsten steel, concerning which the reader is referred to the various treatises and technical publications on steel. Tungstate of soda has been employed as a mordant in dyeing cloth and for the impregnation of vegetable tissues, linen, and cotton, to render them non-inflammable, which is a remarkable property possessed by the substance. Its consumption for this purpose has never become large, however, as cheaper salts, like alum, can be used for the same purpose.

Ferro-tungsten, the alloy of tungsten and iron, is easily prepared from wolframite or scheelite. The mineral is pulverized and roasted to drive off any sulphur or arsenic with which it may be contaminated. It is then reduced, preferably with iron or ferric oxide, in brasqued crucibles, a long and strong heat being required. As obtained the alloy often appears as a dark, heavy, slightly sintered mass, containing varying amounts of tungsten, which unites with iron apparently in all proportions, at least up to 80%.† As tungsten raises the melt-

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* *Sixth Ann. Rep. Cal. State Mineralogist*, 1885-86, p. 134.

† Howe, *Metallurgy of Steel*, 1890, p. 81.

ing point of iron, however, alloys with more than 40% of it are seldom made. Ferro-tungsten may also be made by reduction in the blast furnace, but the demand for it at present is too small to make its production on so large a scale necessary.

In making tungsten-steel by the crucible process a calculated amount of ferro-tungsten of known composition is added to the ordinary charge, The product contains from 2% to 12% wolfram, from 6% ts 8% being the mean. Tungsten-steel with such a percentage of tungsten is exceedingly hard, readily scratching glass. A full discussion of its properties and uses is to be found in Howe's *Metallurgy of Steel.*

WHETSTONES AND SCYTHESTONES.

Several kinds of material are commonly used for oilstones, whetstones, and scythestones, but the most important are the novaculite of Arkansas, the Hindostan stone of Indiana, the mica-schist grits of New England, and sandstones of Cuyahoga County, Ohio, and Huron County, Michigan. The business of manufacturing these products is chiefly in the hands of the Pike Manufacturing Company of Pike Station, N. H., which has a world-wide reputation in this connection, while the Cleveland Stone Company, Grafton Stone Company, and Mussey Stone Company of Ohio, and the Huron Stone Company of Michigan, engaged principally in the manufacture of grindstones, also make a cheaper grade of scythestones.*

The best oilstones, which are so named because oil must be used to float off the particles of steel cut from the tools, and thus prevent them from filling up the minute pores of the stone, are made from novaculite composed of nearly pure silica, in small sharp-pointed grains or crystals, obtained in Garland County, Arkansas. The Arkansas novaculite, since it was first put on the market in 1840 to the present time, has steadily increased in demand, and is now recognized as the best sharpening material in the world for fine-edged tools. It is of two varieties—the Arkansas stone proper, which is of bluish-white color, semi-transparent and very fine grained, and the "Washita" stone, which is not so finely grained, more opaque, and of pure white color. The deposits of Washita stone in the mountains of Arkansas are very extensive; but most of the rock is vitreous or impure, and, not being sufficiently porous, is utterly unfit for good oilstones. The price for the different qualities varies from 10c. to 35c. per lb. At present the entire output is in the neighborhood of 18 car loads of rough rock per year, worth according to the quality, etc., from $300 to $400 per car of 25,000 to 30,000 lbs. The Arkansas rock has been so difficult and expensive to quarry and manufacture that its extremely high price has kept it from coming so generally into use as its superior qualities would warrant. The rough Arkansas rock is cut up into slabs by gang-saws at the slow rate of about three-quarters of an inch per day, which process is attended by a large amount of waste. The demand has largely increased, however, during the last few years, and about 20 tons of rough rock are shipped annually from the quarries at Hot Springs.

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* For information as to the history and development of this industry the reader is referred to The Mineral Industry, Vol. I (1892), p. 463.

The Indiana stone is known as Hindostan, and varies in color from white and gray to a buff or orange. It is a fine-grained, compact sandstone, and makes an excellent sharpening stone for ordinary tools. It is much lower in price than the Washita, as it is more cheaply quarried and finished. During the past few years the annual output of finished rock has averaged between 400,000 and 500,000 lbs., varying in price, according to quality, conditions of competition, etc., from 1½c. to 5c. per lb. There is also a coarse-grained stone quarried in Indiana known as "shoemakers' sandstone," or "kitchen rubstone," which is serviceable in setting a coarse edge, and can be quarried and finished very cheaply. Since the introduction of improved machinery for making shoes the demand for this stone has decreased largely, until now not more than 150,000 lbs., worth about 2¼c. per lb., are sold annually.

Scythestones are obtained chiefly from the quarries of Grafton County, New Hampshire, and Orleans County, Vermont, these two localities furnishing probably two-thirds of the entire production in the United States. The chief other scythestones of commercial importance are the Western grindstone grits, quarried and manufactured in connection with the grindstone business in Cuyahoga County, Ohio, and Huron County, Michigan. The Western grit is of a much coarser and more brittle texture than the New England product, and is therefore unsuitable for long transportation or for setting a fine edge. The New Hampshire scythestones are exported in large quantities to different European countries, and bring from $2 to $3.50 per gross. The Vermont scythestones are a little finer-grained and more compact than those of Indian Pond, N. H., and sell from $2 to $6 per gross.

PRODUCTION OF WHETSTONES AND SCYTHESTONES IN THE UNITED STATES.

Kind of Stone.	1892.		1893.	
	Amount.	Value.	Amount.	Value.
Oilstones, etc.				
Hindostan	400,000 lbs.	$12,000	300,000 lbs.	$9,750
Indiana sandstone	150,000 "	3,000	150,000 "	3,375
Arkansas stone	40,000 "	1,600	50,000 "	2,000
Washita stone	500,000 "	6.250	400,000 "	5,000
Scythestones.				
New Hampshire (Indian Pond, etc.)	8,000 gross.	22,000	10,000 gross.	27,500
Vermont	5,000 "	17,500	4,000 "	14,000
Ohio and Michigan grit	8,810 "	21,380	10,700 "	27,925

IMPORTS OF HONES AND WHETSTONES INTO THE UNITED STATES.

Years ended June 30.	Value.	Years ended June 30.	Value.	Years ended Dec. 31.	Value.	Years ended Dec. 31.	Value.
1880	$14,185	1884	$26.513	1887	$24,093	1891	$35,344
1881	16,631	1885	21,434	1888	30,676	1892	33,420
1882	27,882	1886	21,141	1889	27,400	1893	....
1883	30,178			1890	37,454		

The whetstone industry suffered in 1893 from the general business depression, like nearly every other branch, being directly affected by the decrease in building, which resulted in a falling off in the sales of carpenters' tools, etc. For this reason the production of the novaculite quarries in Arkansas was smaller than for two or three years previous, the output of manufactured Washita and Arkansas oilstones being about 25% less in 1893 than in 1892. The output of scythestones, on the other hand, was about 10% larger; the outlook for the latter during the current year, however, is by no means good, the hay crop having been a failure in many sections of the country during the past season. One or two new kinds of whetstones were brought forward in 1893, but so far they have not obtained much notice.

The average value of New Hampshire and Vermont whetstones in 1893 was about $2.75 and $3.50 per gross, respectively. The Hindostan stone sold for 3¼c. per lb., against 3c. in the previous year, while Indiana sandstone generally brought 2¼c. per lb., against 2c. The value of the rough Washita rock stands steadily at about 1¼c. per lb., and that of the Arkansas stone at 4c. per lb.

GRINDSTONES.

Most of the grindstones used in this country are obtained from the Subcarboniferous sandstones found in a bed which extends east and west from Cleveland, Ohio, along the shores of Lake Erie and inland as far as Marietta on the Ohio River. Another bed occurs on the shore of Lake Huron above Detroit, Mich.

The blocks of stone are removed from the quarry bed, roughly hewed to shape with a square hole in the center, and placed on a heavy square iron shaft furnished with a 9-in. collar, against which the stone is securely fastened by means of another collar strongly keyed in place. The shaft and stone are turned by steam-power, and two men standing at opposite sides dress it true by means of soft iron bars 6 ft. long, 2 in. wide, and ½ in. thick, which are drawn to a thin edge curved upward. This was formerly a very unhealthy operation owing to the dust produced, but this difficulty is now obviated by the use of blowers.

The production of grindstones is controlled by only a few companies. Imported stone comes mostly from Newcastle-on-Tyne, Nova Scotia, and New Brunswick. The imports and exports are shown in the general table in another part of this volume. The following table shows the value of grindstones produced in the United States since 1880. The output in 1893 amounted to 45,580 short tons.

Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.
1880..	$500,000	1882..	$700,000	1884..	$570,000	1886..	$250,000	1888..	$281,800	1890..	$450,000	1892..	$304,800
1881..	500,000	1883..	600,000	1885..	500,000	1887..	224,400	1889..	439,587	1891..	476,113	1893..	345,920

As may be seen by this table, the value of the grindstones produced has tended rather to decrease than increase. While this is due in part to the lower selling price, it shows also the effect that the increasing use of emery, corundum and similar other abrasives has had on the market for grindstones. Though the latter are almost universally used in agricultural districts as well as around manufactories, the smaller size, lighter weight and greater abrasive power of the emery is carrying it even into this market. For some specific purposes the grindstone is said to be superior to any other abrasive, but as manufacturers of the higher abrasives produce uniform wheels of varying grades of hardness, the field for the grindstone will be still further restricted. Experiments have been made looking toward the manufacture of a soft abrasive wheel from the powder and small chips resulting from dressing grindstones. This material was ground to a uniform size, mixed with some adhesive material, such as glue, and pressed into shape. These wheels worked very well for certain purposes, but glazed easily. Efforts have been made to overcome this latter difficulty, with more or less success.

ZINC.

The production of spelter in the United States in 1893 was 76,255 short tons (69,178 metric tons), against 84,082 short tons (76,279 metric tons) in the previous year. The figures for 1892 have been checked by each producer in furnishing his output for 1893. Some slight corrections were thus made in those published a year ago in Vol. I. of The Mineral Industry. This extreme care has been taken in collecting the production statistics of all the minerals and metals, and the very slight changes found necessary are evidence of the accuracy of the work brought out at so early a date. The falling off in the production of spelter was due to the general business depression prevailing in the United States during the latter half of 1893, wherefore the price fell to a lower point than had ever before been recorded. At the end of August spelter was quoted in the St. Louis market at 3.275@3.30c. per lb., this being equivalent to 3.525@3.55c. in New York, and lower than the price in London, where at the same time ordinary brands were selling at £17 2s. 6d. (3.71c. per lb.). Since it costs more to produce spelter in the United States than in Europe, this showed forcibly the weakness of the domestic market. The financial panic of the summer made business very bad among the brass-workers, while the galvanizers, from whom came the great increase in the demand for spelter in 1892, had a very serious set-back in their affairs.

The restriction in production began in June, when a strike among the coal miners of Kansas cut off the fuel supply of the Kansas-Missouri works. This strike had been threatened for a number of weeks previous and the market for spelter had undergone numerous fluctuations in anticipation of it. When it was finally declared, however, its effect on the industry was only temporary, being overshadowed before the end of the month by the serious financial distress which overtook the whole country. The price of spelter then fell below 4c. per lb. in New York, and kept below that mark during the remainder of the year, compelling many works to close down. The strike among the Missouri miners was declared off at a meeting of the United Mine Works Association on Aug. 20, and the men were ordered to go back to work on Aug. 23; but so far as the zinc industry was concerned their action was not of much consequence, though at an ordinary time it would have been of great importance, the producers of spelter being dependent for their supply of fuel upon the collieries affected.

An analysis of the statistics shows that the decrease in the production of spelter in 1893 occurred chiefly in the Eastern and Southern States, where the make fell off from 14,733 short tons in 1892 to 10,708 tons in 1893. The Eastern smelters (New Jersey and Pennsylvania) were more seriously affected than the Southern, who are, however, of less importance. The aggregate output of the Western works was 65,547 tons, against 69,349 tons in the previous year. The falling off in that section was due chiefly to the Missouri smelters, the make in Kansas and Illinois-Indiana having been only about 900 and 500 tons, respectively, less than in 1892. From this the inference might be drawn that the Eastern smelters are less well prepared to face a very low price for spelter than are the Western. In so far as certain works in the West are concerned this inference is undoubtedly correct, but the fact that there was no decrease of consequence in the production of Illinois and Indiana was due to the output of two new companies, which made up for the falling off on the part of certain others. In Kansas, also, there were several works which made much smaller outturns than in the previous year, but a few favorably situated ones increased their product, so that the net decrease for the State was insignificant.

There were no new producers of spelter in 1893, but two of the new plants of 1892 (the Wenona Zinc Company of Wenona, Ill., and the Columbia Zinc Company of Marion, Ind.) got to work at their full capacity and made increased outputs; the third new concern of 1892, the American Spelter Company of Galena, Kan., having remodeled its works, made a small amount of spelter, but then got into litigation, went into the hands of a receiver, and finally in November came to grief totally by a fire which destroyed its plant, and there is said to be little probability that it will be rebuilt. The Granby Mining and Smelting Company's works at Pittsburg, Kan., also were idle during the year. One new plant, that of the Kansas Zinc Mining and Smelting Company at Girard, Kan., having four blocks of furnaces, was erected in 1893, but it did not commence production until the current year.

There were two new zinc-white works in 1893, viz., those of the Lanyon Zinc Oxide and Paint Company at Waukegan, Ill., and the Florence Zinc Company of Florence, Penn., while the Empire Zinc Company of Joplin put in operation a small oxide department. The oxide furnaces of the Lehigh Zinc and Iron Company were put out of blast, however, in September for lack of orders, and those of the Washington Zinc Company of Lynchburg, Va., and the Mineral Point Zinc Company of Mineral Point, Wis., were idle for a number of months.

In zinc-ore mining there were no new developments of importance. The Indian Territory became a producer, mines in the extension of the Joplin district into the northeast corner being opened by the Peoria Mining and Land Company. A few car loads of ore were shipped from the Hanover district, New Mexico, but for most of the year the mines there were idle; they are too remote from market to be counted among the available zinc supplies of the United States at present.

In Missouri and Kansas the mining industry was seriously affected by the low prices for ore, which in October fell to $15 per ton for the ordinary grades and averaged only $19.25 for the year, against $22.50 in 1892. Many of the large producers suspended operations on this account during the autumn, and the total output for the year was therefore smaller than in 1892. New mines were opened at Spring City, eight miles from Joplin, in Newton County, which promise to be of importance. In Kansas, where the same conditions obtain as in Missouri, there was a slight increase, the output of this State in 1892 and 1893 having been 23,300 and 24,190 tons, respectively. The production of zinc ore in New Jersey fell off from 86,574 tons in 1892 to 66,416 tons in 1893. In Virginia and Tennessee, on the other hand, there was a small increase. In the former State the Pennsylvania Zinc and Iron Company was a new producer, its output being used, however, only for the manufacture of zinc-white at Lynchburg. The shipments of ore from Shullsburg, Wis., amounted to 1117 tons (about 500 tons calamine and 600 tons blende), and the total production of that State was probably about 3500 tons. The works of the Wisconsin Lead and Zinc Company were closed down in July and stood idle during the remainder of the year, but the tributers, to whom the company has leased much ground, continued operations.

PRODUCTION OF ZINC ORE IN THE UNITED STATES.

(In short tons, 2000 lbs.)

Year.	Kansas.	Missouri.	New Jersey.	Southern States.	Wisconsin.	Year.	Kansas.	Missouri.	New Jersey.	Southern States.	Wisconsin.
1870 ...	....	4,000	....	....	....	1882....	17,300	43,000	44,955	... .	....
1871....	....	5,000	24,640	....	.... .	1883....	18,200	45,500	62,814	....	....
1872....	....	6,000	....	....	....	1884 ...	20,300	54,000	44,905	... .	....
1873....	....	32,000	19,240	....	....	1885....	23,400	50,600	43,149	....	....
1874....	....		15,120	....	....	1886....	27,000	58,400	49.142	....	....
1875....	....	23,500	....	....	....	1887 ...	28,900	69,400	56,246	8,420	....
1876....	....	170,000	....	....	....	1888 ...	27,750	74,600	51,942	11,500	....
1877....	....		....	....	....	1889 ...	24,350	82,400	62,892	12,906	....
1878 ...	....		16,203	....	....	1890 ...	22,650	100,200	55,572	14,969	10,500
1879....	....		24,569	....	......	1891 ...	21,750	123,800	85,157	20,287	10,000
1880....	....		31,708	....	....	1892....	23,300	131,500	86,574	20,295	14,500
1881 ...	14,600	43,600	55,079	....	....	1893....	24,190	115,580	66,416	21,000	7,400

The figures for Kansas in the above table were compiled by Mr. J. R. Holibaugh of Joplin, Mo., from original sources, and though they differ from other published figures, the rigid verification which they have undergone makes them the most authoritative.

The Missouri figures for 1870-92, both inclusive, are from the pamphlet entitled *Geology and Mineral Products of Missouri*, by Arthur Winslow, State Geologist; those for 1893 were furnished by Mr. Holibaugh.

The figures for New Jersey, previous to 1893, are from the reports of the State Geologist; those for 1893 are due to Mr. J. A. Van Mater, who compiled them for this work.

The figures for the Southern States are compiled from returns made to THE MINERAL INDUSTRY by the producers, except for 1889, for which the census figures are used.

The statement of the production of zinc ore in Wisconsin in 1893 is due to Mr. W. P. Blake; the figures for 1891 and 1892 are from an article by Prof. W. H. Seamon in the *Seventh Annual Report of the State Mine Inspector of Missouri*, p. 160.

There are no official statistics of the production of zinc ore in Pennsylvania, and it has been impossible to get returns from the mining companies in that State.

Mr. J. R. Holibaugh furnishes the following report of the zinc market at Joplin, Mo., in 1893:

"The ore market opened at $22 per ton, but soon fell to $21. February opened at $21.50, and on Feb. 18 one sale of 400 tons of ore was made at $23 per ton, and some sales were made at $22. March opened at $22.50, April at $21, and May at $20. In June the strike of the coal miners in Kansas and Missouri forced the price of zinc ore down to $16.50@$17 per ton, and many of the large operators closed down, while others worked only a small force in prospecting and developing, so that zinc mining was almost at a standstill until the 1st of October, when there was some demand for ore at $15@$16.50 per ton. These prices were unsatisfactory to the large operators, however, and the production was confined entirely to the small concerns. November opened more favorably, and by the middle of the month prices had advanced to $17.50@$18 per ton; on the 16th $19 was paid, and on the 17th the Pittsburg and St. Louis Smelting Company took 1000 tons at $20 per ton; but the week following prices again declined to

$18.50@$19.50, and the month closed at $19.50@$20 per ton. The average for the year was $19.25. In 1889 the average price was $25 per ton, $23.90 in 1890, $25.90 in 1891, and $22.50 in 1892."

There was some talk among the mine owners in the Joplin district of insisting upon the adoption by the smelters of the system of purchase of ores by sample and assay, but nothing has yet come from this discussion. That the change must be made eventually, however, there can be no doubt, since the existing method, whereby ores are bought and sold on judgment alone, is unscientific and unfair (to the miners especially).

The Western methods of zinc mining and smelting at the present time are costly and wasteful in the extreme, which is due to the manner in which the industry has been developed. To whatever it may owe its beginning, the leasing system which obtains there has been a ruinous drag on the welfare and progress of the industry. By this system, as at present carried out, a tract of land is divided by its owner and leased in sections to smaller companies, which in turn subdivide it into small lots and sublease them to miners, who do the actual opening of the ground. The owner carries no risk except on the capital invested in the original purchase of the land and the taxes on it; the first lessees usually explore their territory with diamond drills or otherwise, and perhaps arrange for its drainage, but otherwise take no chances; the sub-lessees carry the burden of loss in exploration, but as each operates on a very small scale, no one suffers much from failure. The existence of the ore deposits near the surface and the ease of their exploitation, which often would be carried on by individual miners, together with the tardy attention of capital to these mines and the ignorance of approved methods of mining, contributed to the development of this uneconomical system.

The division of the mining land into a large number of small lots, each of which was opened independently, led to an unnecessary multiplication of shafts and hoisting plants. The shafts themselves were small and ill adapted for economical and systematic mining. In opening out from them the rule was to follow the ore, without regard to the proper development of the mine, and the ore bodies themselves were stoped in a wasteful, and to the mine ruinous, manner. In the case of an inflow of water, with which the feeble pumps were unable to cope, the mine was necessarily abandoned.

The methods of treating the ores on the surface were equally crude. Hoisting was done by windlass and horse-whims. The ore, mixed with its gangue, was picked over on uncovered platforms, and crushed and washed by hand-jigs at a loss which cannot now be told, but certainly was large, and in many cases may have been more than 50% of all the zinc in the ore. This work, being done without protection from the weather, was interrupted by storms, and at times there have been periods when for this reason the smelters have been unable to obtain their necessary supply of ore.

Within the past four years there have been some improvements in these methods. Attracted by the good profits to be realized in zinc mining in Joplin and vicinity, larger companies have engaged in the industry, opening their properties in a more systematic manner. Larger and better-located shafts, equipped with suitable hoisting machinery, have been sunk; the ground has been prospected from them in a more intelligent and far-seeing manner; the mines have not been gutted in the extraction of their ore bodies; and pumping plants capable of keeping the water out of them have been installed. On the surface proper shaft houses and ore-bins have been constructed, and at several mines more or less complete dressing works have been built. This progress is encouraging, but the methods of mining and ore dressing in the Joplin district, even at their best, are very far from what they should be, while the small shafts and hand-jigs of the minor leasers are still everywhere to be found. In 1893 there were six dressing works in the Joplin district, each of 50 to 75 tons per ten hours' capacity, but it was said that 75% of all the surface work in the district was still done in the open air.

The average grade of the blende concentrates produced in Joplin and vicinity is between 55% and 57%; first-class grades are made by some companies which assay 62% zinc, *i.e.*, not far from pure blende. The waste in bringing the mineral to that degree of purity would be large with the best designed dressing-works; with those used in the Kansas-Missouri district it is extravagant.

The necessity of making concentrates so rich is forced on the miners by the smelters, who will not buy material of a grade which in Europe would yet be considered very rich. The calcined calamine and roasted blende treated in Belgium do not average more than 45% zinc; in Missouri it would be difficult to sell a raw blende with 50% zinc, and clean blende concentrates containing 57% zinc and 5% iron are held to be of inferior grade because of their "high iron contents." The smelters are able to insist upon this unjust standard because the supply of ore is always a little in advance of the demand for it and pressing for sale, and because the sellers of ore are too many and too weak to stand out for a fair bargain.

It is desirable for the smelters to secure the richest ore possible, since their cost of production is thereby reduced correspondingly; because the same number of furnaces, and the same amount of coal, clay, and labor are required for the treatment of a ton of poor ore as for a ton of rich ore, while the yield of metal is so much the less. It is just this richness of the ores at their disposal that enables American zinc smelters, working with dear labor and high losses in distillation (except at one or two works), to produce spelter at a cost not very much above the European, so that recently it has even been possible to ship American spelter abroad—a consummation which is dreaded and anticipated by the producers there. This favorable condition for the American smelters, however, has been gained at the expense of the miners—who are obliged to throw away a large part of their mineral—and the consequent waste of the zinc resources of this country.

The conditions of the zinc industry in the Eastern and Southern districts are totally different. In these there are only a few companies, and they own the mines whence their works are supplied. Hence it is not policy for them to waste their own mineral by dressing to an unnecessary degree of purity.

PRODUCTION OF SPELTER IN THE UNITED STATES.*

	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.
Tons of 2000 lbs.	7,343	10,000	15.833	16,000	17,500	19,000	21,000	23,239	30.000
Tons of 2240 lbs.	6,556	8,928	13,690	14,286	15,625	16,964	18,750	20,740	26,786
Metric tons, 2204 lbs.	6,664	9,074	13,914	14,520	15,281	17,242	19,057	21,080	27,225

* The figures for the years 1873 and 1875 and for 1882 to 1888, inclusive, are from THE MINERAL INDUSTRY, Vol. I. The figures for 1880 are from the census report for the year 1880, ending May 31. Those for 1889 are from the census report for that year. The figures for 1874 and for 1876 to 1879, inclusive, and for 1881 are estimated. The figures for the years 1890, 1891, 1892, and 1893 are from returns to the *Engineering and Mining Journal* and THE MINERAL INDUSTRY by each of the producers.

PRODUCTION OF SPELTER IN THE UNITED STATES—*Continued.*

States.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Illinois.......	18,201	16.792	17,594	19,427	21,077	22,279	22,445	23,860	26,279	28,660	†30,227	†29,725
Kansas	7,366	9,010	7,859	8,502	8,932	11,955	10,432	13,658	16,380	21,460	22,953	22,085
Missouri	2,500	5,730	5,230	4.677	5.870	8,660	13,465	11,077	13,530	16,205	16,169	13,737
East & South.	5,698	5,340	7,861	8,082	6,762	7,446	9,561	10,265	11,153	13,938	14,733	10,708
Total tons, 2000 lbs..	33,765	36,872	38,544	40,688	42,641	50,340	55,903	58,860	67,342	80,263	84,082	76,255
Tons, 2240 lbs.......	30,138	32,837	35,317	36,328	38,072	44,946	49,913	52,553	60,126	71,662	75,073	68,525
Metric tons.	30,642	33,375	35,585	36,921	38,696	45,682	50,731	53,414	61,111	72,836	76,279	69,178

† Including the product of one works in Indiana.

IMPORTS OF ZINC INTO THE UNITED STATES SINCE 1867.*

Year.	Sheets, Blocks, Pigs, and Old.		Manufactures.	Total Value.
	Quantity.	Value.	Value.	
	lbs.	$	$	$
1867........	10,895,028	568,138	1,835	569,968
1868........	12,885,416	621,156	1,623	622,779
1869........	21,518,298	1,068,978	2,083	1,071,061
1870........	18,763,808	925,357	21,696	947,053
1871........	18,805,861	917,598	26,366	943,964
1872	22,507,191	1,116,409	58,668	1,175,077
1873........	17,962,040	1,047,105	58,813	1,103,918
1874.... ...	9,610,405	627,983	48,304	676.287
1875........	9,354,965	546,305	26,330	572,635
1876........	5,558,682	354,390	18,427	372,817
1877........	2,608,227	145,065	2,496	147,561
1878	2,526,804	127,134	4,892	132,026
1879...... .	2,531,016	106,344	3,374	109,718
1880†.......	10,448,681	515,678	*a*	575,678
1881........	8,187,993	328,212	*a*	328,212
1882........	30,320,128	1,240,117	*a*	1,240,117
1883........	8,695,898	319,890	7,5467	395,359
1884........	4,330,416	147,349	78,370	325,919
1885........	3,086,683	95,319	30,480	125,799
1886	4,791,521	150,101	48,278	198,379
1887........	9.525,070	309,744	44,703	354,447
1888........	3,520,194	137,714	18,270	155,984
1889........	1,928,480	81,078	66,312	147,390
1890........	2,112,626	107,017	53,469	160,486
1891.......	814,218	41,369	18,424	59,793
1892...... ..	410,896	23,307	22,709	46,016
1893	425,998	22,931	20,756	43,687

IMPORTS OF ZINC OXIDE INTO THE UNITED STATES.

Year.*	Dry.	In Oil.
	Lbs.	Lbs.
1886...	2,526,389	79,788
1887...	4,961,080	123,216
1888...	1,401,342	51,985
1889...	2,686,861	66,240
1890...	2,631,458	102,298
1891...	2,839,351	128,140
1892...	....	....
1893...	....	....

TOTAL EXPORTS OF ZINC AND ZINC ORE FROM THE UNITED STATES SINCE 1864.*

Year.	Ore and Oxide.		Plates, Sheets, Pigs, and Bars.		Manufactures.	Total Value.
	Quantity	Value.	Quantity	Value.	Value.	
	lbs.	$	lbs.	$	$	$
1864	1,658,720	116,431	95,738	12,269	. ...	128,700
1865	11,129,552	114,149	184,183	22,740	....	136,889
1866	502,320	25,091	140,798	13,290	....	38,381
1867	411,712	32,041	312,227	30,587	....	62,628
1868	934,528	74,706	1,022,699	68,214	....	142,920
1869	... .	65,411	....	....	....	65,411
1870	1,712,032	81,487	110,157	10,672	....	92,159
1871	1,077,552	48,292	76,380	7,823	....	56,115
1872	412,834	20,880	62,919	5,726	....	26,606
1873	26,208	2,304	73,953	4,656	....	6,960
1874	285,600	20,037	43,566	3,612	....	23,649
1875	345,296	20,659	38,090	4,245	1,000	25,904
1876	1,139,936	66.259	134,542	11,651	4,333	82,243
1877	719,936	34,468	1,419,922	115,122	1,118	150,708
1878	1,797,600	83,831	2,545,320	216,580	567	300,978
1879	1,195,920	40,399	2,132,949	170,654	....	211,053
1880 †	618,128	18,388	1,737,776	154,817	....	174,205
1881	2,130,240	16,437	1,382.853	116,941	....	133,378
1882	710,750	14,487	1,159.949	823.384	....	837.871
1883	235,200	9,292	125,594	8,616	....	17,908
1884	813,120	22.867	136,804	10,606	3,097	36,570
1885	697,080	20,297	171,577	11,638	9,704	41,639
1886	2,981,440	49,455	917,229	75,192	13,526	138.173
1887	526,400	17,286	136,690	9,017	16,789	43,092
1888	510,720	18,034	62,234	4,270	19,098	41,402
1889	2,997,120	73,802	879,785	44,049	35,732	153,543
1890	8,664,320	195,113	3,925,584	126,291	23,587	344,991
1891	13,071,840	149,435	4,294,656	278,182	38,921	466.538
1892	2,058,560	41,186	12,494,335	669,549	161.794	877,529
1893	109,760	1,271	7,278,874	403,590	248,382	653,243

(*a*) Not stated.

* Fiscal years ending June 30 until 1883 ; calendar years subsequently.

† From 1880 on the figures are taken from the summary statement of imports and exports published by the Bureau of Statistics, United States Treasury Department.

The European zinc industry also suffered from low prices in 1893, which reduced the profits of the producers, but did not restrict their output. On the contrary, there was an increase in production, due in part to the old works, of which nearly all exceeded their make of the previous year, but chiefly to the new concerns, of which there were six, viz.: (1) the Usine à Zinc de St. Amand at St.

Amand (Nord), France; (2) Beer, Sondheimer & Co., Neupelt; (3) Société de Zincs de la Campine, Budel, Holland; (4) Raôour & Co., Mæstricht, Holland; (5) the Dynevor Spelter Company, Dynevor, near Neath, England; and the (6) Erste Böhmische Bergbau- und Zinkhütten Gesellschaft, Merklin, near Pilsen, Bohemia. The estimated output of these works in 1894, with the exception of the last mentioned, is as follows: (1) 4500 metric tons, (2) 3000, (3) 3000, (4) 1500, (5) 3000. There are now rumors, moreover, of other new works to be erected during the current year, such a step having been for some time in contemplation by the Société des Mines de Malfidano, a powerful Franco-Sardinian zinc-mining company, which is said to have already acquired land for this purpose in the Pas-de-Calais, while other concerns have similar plans under consideration. With these prospects, and the over-abundance of the ore supply from the opening of new mines in Algeria, France, and elsewhere, which is becoming more and more marked, the situation of the zinc market in Europe is precarious indeed, and the opinion is expressed by well-informed persons that the convention between the producers to limit their output, which according to the agreement does not expire until Dec. 31, 1894, will not last through the year. The amount of spelter allowed to each group of producers by this convention, and the amount actually made, are shown in the following table:

	1889.		1890.		1891.		1892.		1893.	
	Licensed.	Made.	Licensed.	Made.	Licensed.	Made.	Licensed.	Made.	Licensed.	Made.
Franco-Belgium..	114,436	114,239	117,227	116,434	118,008	117,839	118.655	118,778	120,157	....
Silesia	88,152	86,784	90,262	89,307	90,864	88,186	91,361	88,944	92,518	....
Rheinland	38,607	38,301	39,548	39,545	39,811	39,772	40,029	39,980	40,536	....
England	25,839	23,859	26,469	22,011	26,644	22,766	26,791	24,154	27,130	....
Total..........	267,034	263,183	273,506	267,297	275,327	268,563	276,836	271,856	280.341	......

In the third quarter of 1892 the Silesian producers made an agreement among themselves to further restrict their output 1.25% in order to hold up the price of zinc; hence the difference in their make that year, and the amount for which they were licensed.

PRODUCTION OF ZINC IN THE WORLD. (IN METRIC TONS.)

Year.	Belgium.	England, native ores.	Germany.	Russia.	Spain.	United States.	Year.	Austria. (a)	Belgium.	England.		France.	Germany.	Russia.	Spain.	United States.	Total.
										Native Ores.	Foreign Ores.						
1858 .	34,191	3,522	... ..	.....	.....	......	1876..	3,979	47,981	6,750	......	......	83,227	4,626	4,349	14,520	....
1859..	28.631	3,757	......	....	.....	......	1877..	4,519	55.923	6,384	......	... ..	94,996	4,635	3,780	15,281	....
1860..	22,027	4,428	.....	1,838	.....	......	1878..	3,623	61,227	6,412	......	......	94,953	3,646	3.775	17,242	....
1861..	28,150	4,487	......	.....	.....	......	1879..	3,280	57,157	5,645	......	......	96,756	4,321	3.800	19,057	....
1862..	25,861	2,186	59,767	.....	.....	......	1880..	3,756	59,880	7,279	. ....	......	99.646	4,390	4,221	21,080	....
1863..	28,978	3,897	60,315	.....	.....	......	1881..	4,119	69,800	15,192	8,468	18,509	105.478	4,542	7,032	27,225	....
1864..	30,718	4,106	59,248	. . .	.....	......	1882..	4,791	72,947	16,344	10,157	18,525	113,418	4,462	7,310	30,642	......
1865	34,244	4.533	56,490	3,089	.....	......	1883..	4,539	75,366	13,826	15,804	15,915	116.854	3,809	6.843	33.375	284.331
1866..	34,659	3,244	60.221	.....	.....	......	1884..	4,536	77,487	10,081	20,157	16,884	125,276	4,313	4,295	35,585	298,614
1867..	38,684	3,811	63,874	.....	.....	......	1885..	3,948	80,298	9,938	14,752	15,108	129,096	4,579	4,247	36.921	298.889
1868 .	44,347	3,774	66,132	.....	.....	......	1886..	3,843	79,246	9,036	12,536	16,132	130,854	4,190	4,327	38,696	298,860
1869..	47,407	4,573	69,851	.. .	.....	......	1887..	3.609	80,468	9,920	10.238	16,712	130.444	3,621	5,349	45,682	306,093
1870..	45,754	4.000	63,980	3,780	....	......	1888..	4,001	80.675	10,166	17,048	16,960	133,224	3,869	5,117	50,731	321,791
1871	45,623	5,047	58,297	.....	3,166	......	1889.	4,840	82,526	9,546	21.756	17,982	135,974	3,681	5.640	53,414	335,359
1872..	41,838	5,276	58,386	....	2,940	......	1890..	5,449	82,701	8.692	20,922	19,372	139,266	3.768	5,919	61,111	347,200
1873..	42,314	4,544	62,755	3,378	2,993	6,664	1891..	5,006	85,999	9,037	20,846	20,596	139,353	3.675	5,656	72,836	363,004
1874..	46,088	4,543	70.426	4,128	3,295	9.074	1892..	5,237	91,546	9,496	21,302	20,680	139,938	3,600	5,925	76,279	374,003
1875..	49,960	6,823	74,337	3.988	3.831	13,914	1893..	. ..	......	,.	....	.. ..	....	......	......	69,178	.....

(*a*) The production of zinc in Austria in 1874 and 1875 was, respectively, 2818 and 2940 tons.

NOTE.—The above table is compiled from the official reports of the respective countries, with the exception of the column of zinc in England from foreign ores, which is arrived at by deducting the zinc. as reported in the official blue books. from the total output of the smelting works as stated in the reports of Messrs. Henry R. Merton & Co. The English blue books give only the zinc obtainable by smelting from ores produced in the United Kingdom. Messrs Henry R. Merton & Co. give 301,110 long tons as the European production for 1893, distributed as follows: Rhine district. Belgium, etc.. 149,750; Silesia, 90,310; Great Britain, 28,375; France and Spain, 20,585; Austria, 7560; Poland, 4530. Messrs. Vivian & Sons also furnished us with the zinc production of Great Britain in 1893, which corresponds with that given by Mr. Henry R. Morton.

The production of zinc ore in Europe by countries from 1880 to 1892, both years inclusive, is shown in the accompanying tables, which are compiled from the official publications of each country. The output of Spain in 1891 and the output of Algeria, France, Norway, Russia, and Spain in 1892 have not yet been reported. It should be noted with reference to this table that the very large production of Germany in point of tonnage is due in great measure to the low-grade ores of Upper Silesia, the statistics of which are given in a separate table. Practically all the zinc ore produced in Russia is derived from that part of the Silesian basin extending into Poland, and is also of low grade. The same is true of the Austrian ore mined in Galicia. The statistics of the production of zinc ore in each of these countries in years previous to 1880 will be found in the general statistics at the end of this volume. (See diagram production of zinc, page 675.)

PRODUCTION OF ZINC ORE IN EUROPE.
(In metric tons.)

Year.	Algeria.	Austria	Belgium.	Bosnia.	France.	Germany.	Great Britain	Greece.	Italy.	Norway.	Russia.	Spain.	Sweden
1880.	....	21,564	38,805	......	....	632,895	28,000	....	85,289	....	....	50,521	43,460
1881.	....	27,340	23,553	......	.. ..	659,530	36,109	....	72,176	... .	....	42,911	43,811
1882.	....	25,300	20,443	69	8,372	694,711	33,069	....	91,366	a300	97,000	57,353	46,255
1883.	....	28,749	20,738	697	7,156	677,794	30,215	43,731	100,574	a200	.. ....	54,193	45,347
1884	....	29,454	27,606	......	3,120	632,040	25,982	....	104,974	a571	....	49,838	44,893
1885.	....	23,598	18,185	......	5,078	680.654	25,072	....	107,887	a300	....	45,509	48,589
1886.	....	21,320	19,042	......	11,103	705,177	23,535	....	107,548	....	38,182	39,810	49,571
1887.	.... ..	21,099	20,879	......	13,321	900,712	25,862	42,258	93,143	... ...	....	69,012	46,241
1888.	8,521	26,312	24,537	......	20,702	677,761	26,841	43,405	87,310	a1,540	....	74,353	49,972
1889.	12,556	30,096	21,184	20	34,290	708,829	23,582	33,025	97,059	a3,278	....	71,774	59,381
1890.	13,091	32,632	15,410	61	47,540	759,437	22,402	33,054	110,926	a3,941	44,125	81,398	61,843
1891.	13,636	28,828	14,280	47	56,300	793,544	24,264	28,344	120,685	498	47,390	....	61,591
1892.	....	33,944	12,260	16	....	800,167	27,311	27,695	129,731	....	....	....	54,981
1893.	....	.. ....	....	......	.... ..	....	....	....	....	....	....	....	....

(a) Zinc-lead ore.

PRODUCTION OF ZINC AND LEAD ORE AND OF ZINC IN UPPER SILESIA.*
(In metric tons.)

Year.	Blende.	Calamine.	Total Zinc Ore.	Iron † Pyrites	Iron Ore.†	Lead Ore.	Zinc.	Zinc Sheets.	Zinc-White, etc.	Total.	Average Value per Ton of Zinc.
1861..	....	283,487	....	....	....	3,149	42,033	8,406	968	51,407	312
1862..	....	279,722	....	....	....	4,855	41,700	9,165	969	51,834	315
1863..	....	234,744	....	....	....	8,580	40,600	8,975	1,180	50,755	314
1864..	....	237,540	....	....	....	10,973	38,573	7,430	833	46,836	396
1865..	....	268,384	....	....	....	6,164	35,430	9,164	834	45,428	382
1866..	....	286,166	....	....	....	8,767	34,864	6,016	756	41,636	392
1867..	....	299,424	....	....	. ....	9,912	36,832	5,084	753	42,669	389
1868..	....	290,362	....	....	....	11,860	37,631	8,084	719	46,434	378
1869..	....	324,669	....	....	....	13,123	37,917	11,762	280	49,959	382
1870..	....	310,909	....	....	....	16,010	36,516	10,047	346	46,909	349
1871..	....	269,626	....	....	....	14,339	32,091	13,452	488	46,031	357
1872..	....	332,066	....	128	15,507	14,610	33,065	13,854	386	47,305	408
1873..	....	367,582	....	355	8,686	14,589	36,382	13,092	692	50,166	478
1874..	....	361,747	....	1,101	6,746	16,866	41,181	16,121	842	58,144	423
1875..	....	377,567	....	1,713	8,598	17,871	42,855	15,746	937	59,538	454
1876..	....	442,837	....	2,253	6,055	19,105	49,376	18,612	795	68,783	431
1877..	....	472,422	....	2,074	10,546	19,370	57,478	18,699	925	77,102	368
1878..	57,782	432,678	490,460	2,891	15,556	20,273	59.789	19,031	931	79,751	322
1879..	62,291	430,041	492,332	3,213	15,908	19,064	63,564	19,805	893	84,262	300
1880..	81,547	445,407	526,954	4,028	19.608	17,760	66,044	16,732	916	83,692	340
1881..	99,809	444,281	544,090	2,578	28,795	21,078	67,771	24,517	1,008	93,296	304
1882..	120,291	459.056	579,347	2,840	35,867	24,230	69,992	20,682	3,716	94,390	316
1883..	122,799	505,185	627,984	2,131	36,178	24,810	71,468	24.846	3,818	100,132	283
1884..	143,344	445.985	589,329	1.457	46,858	25.861	76,897	25,474	3,778	106,109	267
1885..	159,276	447,330	606,606	1,585	54,780	26,313	78,477	25,347	3,707	107,531	253
1886..	a172,780	371,935	544,715	2,083	53.112	29,286	82,712	25,066	3,746	111,524	256
1887..	a193,826	358,788	552,614	2,930	57,559	28,508	82,640	29,141	3,128	114,909	275
1888.	212.264	319,316	531,580	1,583	33,344	29,601	84.777	25,821	2,811	113,409	324
1889..	246,955	325,705	572,660	1,971	20,268	32,146	86,947	32,562	922	120,431	359
1890..	a261,921	343,495	605,416	1,949	11,287	32,498	88,699	32,547	896	122,142	441
1891..	a271,277	324,331	595,608	2,076	8,088	28,716	88,420	37,669	1,151	127,240	443
1892..	....	....	b659,847	2,520	9,371	29,049	88,175	33,266	895	122,336	388
1893..	290,087	c344,429	634,506	2,104	7,083	30,825	91,659	35,187	207	127,053	....

* For the years 1861–91, inclusive, from *Die Bergwerks- und Hüttenverwaltungen des Oberschlesischen Industriebezirks*, Kattowitz, 1892. For 1892 and 1893 from *Statistik des Oberschlesischen Berg- und Hüttenmännischen Vereins.*

† Products of the zinc-lead mines.

(a) Besides which there were recovered from the old dumps of the Scharley mines 26,555 tons in 1886, 252,747 tons in 1887, 25,000 tons in 1890, and 67,500 tons in 1891.

(c) Includes 31,362 tons from old dumps.

PRODUCTION OF ZINC ORE IN GERMANY.

(In metric tons. Values in thousands of dollars converted from marks. 4 marks = $1.)

Year.	Silesia.		Rhineland.		Westphalia.		All Germany.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1872......	337.601	$1,374	28,221	$322	31,124	$208	419,543	$2,154
1873......	366,426	2,231	27,952	355	32,827	252	444,950	3,116
1874......	367,476	1,869	30,699	391	27,303	197	451,222	2,777
1875......	377,939	2,157	37,615	486	29,013	218	467,953	3,171
1876......	449,374	2,244	36,395	476	25,123	218	533,559	3,252
1877......	477,919	1,775	43,868	480	29,798	233	577,312	2,785
1878.. ...	505,042	2,014	39,285	372	31,293	234	597,193	2,856
1879......	500,763	1,307	42,148	307	28,000	214	589,546	2,013
1880......	530,994	2,023	51,166	455	31,202	261	632,896	2,983
1881......	553,487	1,537	56,428	435	29,536	216	659,531	2,399
1882......	580,207	1,898	50,837	532	40,480	300	694,711	2,978
1883......	560,684	1,173	53,569	532	41,802	281	677,794	2,223
1884.....	515,317	963	57,604	526	39,161	258	632,040	1,955
1885......	554,297	968	63,735	463	41,781	271	680,654	1,912
1886......	578,856	887	67,260	571	39,133	259	705,177	1,931
1887......	768,429	1,386	68,601	582	40,969	277	900,712	2,506
1888......	540,384	2,173	64,857	614	38,192	315	667,761	3,437
1889......	582,149	3,077	64,549	610	38,315	297	708,829	4,423
1890......	635,538	4,318	59,743	620	38,849	342	759,437	5,854
1891......	666,615	4,589	61,707	700	38,507	336	793,544	6,239
1892......	661,369	3,633	69,260	777	42,575	380	800,237	5,305
1893......	....	....	....	....	....	....	....	....

GERMAN IMPORTS AND EXPORTS OF ZINC ORES.

(In metric tons. $1 = 4 marks.)

Year.	Imports.		Exports.	
	Quantity.	Value.	Quantity.	Value.
1880......	19,132	$215,000	12,798	$144,000
1881......	15,461	116,000	15,610	117,000
1882......	24,567	276,000	8,847	100.000
1883.. ..	19,651	209,000	11,923	127,000
1884	17,078	175,000	12,217	125,000
1885......	27,180	279,000	13,429	138,000
1886......	19,717	210,000	14,414	153,000
1887......	11,232	$169,000	20,971	$315,000
1888......	8,901	156,000	23,683	415,000
1889......	26,812	570,000	20,957	445,000
1890......	38,098	953,000	16,542	414,000
1891.	37,762	944,000	22,123	553,000
1892......	41,558	883,000	24,475	520,000
1893......	23,883	....	.. ..	....

The American Spelter Market in 1893.

During the first few months of the year the trade was in a very healthy condition, and for four months prices steadily ruled at about 4.15c. per lb. at East St. Louis, equal to 4.40c. at New York. In fact, for a while the consumption was in excess of the production, which during the first half of the year was practically the same as last year,—*i.e.*, about 45,500 tons (2000 lbs.),—and stocks became reduced to within very narrow limits. This pleasant state of affairs was, apparently, about to be made more secure and lasting, as a long-talked-of strike among the coal miners in Missouri and Kansas, whence the fuel supplies of the zinc smelters of those States come, finally broke out in June. All calculations were upset, however, as the demand, both from the galvanizing and the brass trade, became extremely small, and made impossible the marketing of even the small quantities of spelter that were on hand. Then came a stampede, with prices declining from week to week, notwithstanding that supplies were much lessened by the strike. The bottom was reached in August, when prices touched 3¼@3.30c. at East St. Louis, at which figure it became possible to export spelter to Europe. This, of course, relieved the market, which was further benefited by the reduction in output necessitated by the strike, which came to an end by the strikers giving in, although not until after riotous scenes, involving the shedding of blood, had been witnessed, and the places of the men filled with laborers brought from other States.

The sales for export, which were necessitated by the poor demand from home consumers and the lack of money, sorely felt by the zinc smelters, amounted in all to about 3000 tons, and, as already said, afforded needed relief to the market, which had been made worse because of the utter inability of the galvanizers to take the metal that they had long before contracted for. It was not until October that consumption at home began to improve, and although the increase was not great, it was sufficient, with the small current production, to cause prices to move up slowly until the end of November, when, consumption being actually somewhat in excess of the production, the top was reached. The increase in the demand led several of the smelters to start up idle furnaces, but by the time their product was ready for the market the most urgent needs of the galvanizers had been supplied, and the natural result of the increased quantities that were put on the market was a sharp decline in prices, which at the close of the year were 3.35c. at East St. Louis and 3⅝c. at New York, or about 1c. per lb. lower than the prices ruling at the same time a year ago. Ruling prices are still very close to the point at which exports are feasible.

The London Spelter Market in 1893.

The spelter market began the year with a dull and downward tendency, and from £18 7s. 6d. the price for ordinary brands declined to £17 17s. 6d. The delays in bringing forward Continental spelter, caused by the severe frost, created a certain amount of pressure for prompt delivery and produced a momentary rally in prices to the extent of about 5s. per ton, but the almost universal stagnation of trade quickly reasserted its influence, and January closed with a drop to £17 15s., while the first week in February saw the value touch £17 5s. The apathy of consumers everywhere became, if possible, still more pronounced, the galvanizing branch especially having to complain of unremunerative work. After £17 had been touched, a slight reaction set in and the value rose to £17 5s.

During March the demand was somewhat better, and a little Continental buying on the one hand and the raising of prices by the Continental producers on the other stiffened values in London, and ordinaries were dealt in at £17 15s. The improvement was, however, of brief duration, and moderate sales by dealers sufficed to send the price down to £17 6s. 3d.

Despite the low level to which this metal had fallen (so recently as 1890 it was worth £25 5s. per ton), new works in England and on the Continent were now in course of erection or actually producing—a circumstance which naturally did not tend to enhance values, although, with consumption more active, the proportionately small increase of output could, no doubt, be readily absorbed without detriment to the market.

The leading feature in April was a brisk Continental inquiry, resulting in an advance to £18, while May brought a reversal of these conditions, the fall amounting to 7s. 6d. per ton. The factor which mostly influenced the market at this period was the serious condition of Australian finance, the numerous bank failures there causing, among other things, the practical suspension, for a time, of exports of galvanized iron to that country. Late in May and early in June a little buying by dealers took place in anticipation of further Continental demand, but this seemed to form the only support of the market, and when withdrawn there came a decline of values, viz., from £17 17s. 6d. to £17 12s. 6d. Between these limits prices continued to range throughout July. Consumption remained poor, the galvanizers buying only sparingly.

The shipments of galvanized iron from the United Kingdom for the first six months of 1893 were 84,182 tons, against 76,561 tons for the same period of last year, but this increase was attributed to the endeavors to hurry forward shipments by way of forestalling the coal disputes, which proved to be bitter and protracted. The strikes had, of course, a great effect on spelter, the consumers of which article were compelled to defer purchases as long as they possibly could. Toward the close of August America came out as a seller, and though quantities were not large, the appearance of this formidable competitor in a market already depressed sent values down 12s. 6d. per ton, and £17 was accepted ex ship London.

September was a month of poor demand, the coal war continuing in full vigor, but America offering very little, there was an improvement in values to £17 7s. 6d. The month closed, however, at £17. The condition of the spelter-using industries throughout October gave rise to much dissatisfaction, values being unremunerative and the South American and other important markets for galvanized iron being practically closed. The yellow metal industry had also been very depressed. £16 16s. 3d. was the value of spelter at the close of October, but November brought an improvement of a few shillings, the American market being firmer and the coal strike in England settled. The market closed at £17 for ordinary and £17 2s. 6d.@£17 5s. for special brands.

AVERAGE MONTHLY PRICES OF SPELTER IN NEW YORK, IN CENTS PER POUND.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1875....	6 56	6 46	35	6 75	7 20	7 20	7 30	7 17.5	7 17.5	7 27.5	7 27.5	7 27.5	7 00
1876....	7 50	7 62.5	7 68.5	7 80	7 87.5	7 62.5	7 18.5	7 12.5	6 96	6 68.5	6 49.5	6 43.5	7 25
1877....	6 37.5	6 56	6 43.5	6 31	6 12.5	5 99.5	5 74.5	5 85	5 81	5 80	5 74.5	5 62.5	6 03
1878....	5 62.5	5 43.5	5 43.5	5 12.5	4 81	4 43.5	4 62.5	4 68.5	4 81	4 66	4 62.5	4 31	4 88
1879....	4 37.5	4 51	4 49.5	4 50	4 37.5	4 24.5	4 56	5 21	5 81	6 18.5	6 06	6 12.5	5 03.6
1880....	6 18.5	6 56	6 62.5	6 31	5 81	5 31	4 93.5	5 06	4 93.5	4 93.5	4 77.5	4 70	5 51
1881....	5 06	5 18.5	4 93.5	4 93.5	5 93.5	4 87.5	4 87.5	5 06	5 12.5	5 31	5 68.5	5 93.5	5 24.3
1882....	5 87.5	5 68.5	5 49.5	5 37.5	5 43.5	5 31	5 24.5	5 31	5 24.5	5 24.5	4 99.5	4 68.5	5 32.5
1883....	4 56	4 56	4 68.5	4 67.5	4 62.5	4 49.5	4 40	4 35	4 45	4 40	4 38.5	4 36	4 49.5
1884....	4 28.5	4 32 5	4 50	4 57.5	4 52.5	4 45.5	4 50	4 57	4 56	4 47.5	4 35	4 12.5	4 44.3
1885 ...	4 31	4 27.5	4 21	4 21	4 17.5	4 05	4 25	4 50	4 56	4 56	4 52.5	4 52.5	4 34.5
1886....	4 40	4 42.5	4 55	4 55	4 50	4 37.5	4 35	4 35	4 32.5	4 27.5	4 27.5	4 42.5	4 40
1887....	4 55	4 55	4 47.5	4 45	4 55	4 55	4 57.5	4 55	4 50	4 52.5	4 77.5	5 40	4 62.5
1888 ...	5 42.5	5 35	5 10	4 85	4 65	4 55	4 55	4 75	4 97.5	5 05	4 90	4 87.5	4 91
1889....	5 00	4 95	4 75	4 67.5	4 75	4 97.5	5 10	5 20	5 17.5	5 10	5 20	5 40	5 02.3
1890 ...	5 41	5 28	5 18.7	5 08.5	5 35	5 57.5	5 55	5 27.5	5 6	6 01.2	6 12.2	6 10.6	5 55
1891...	5 55	5 02.5	5 12.5	5 00	4 85	5 08.3	5 06.3	5 01	4 95.8	5 02	4 83	4 75	5 02
1892....	4 69	4 62	4 89	4 68	4 79	4 71	4 78	4 69	4 53	4 41	4 47	4 40	4 63
1893....	4 39	4 33	4 28	4 38	4 41	4 27	4 13	3 89	3 69	3 68	3 65	3 80	4 07.5

AVERAGE MONTHLY PRICE OF ENGLISH SPELTER IN LONDON.*

(Per ton of 2240 lbs.)

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1872	22 9 6	21 19 6	22 3 6	22 17 0	22 12 0	22 5 0	22 17 6	22 17 6	22 15 6	23 3 9	23 3 0	23 12 6	22 14 9
1873	24 6 0	25 12 6	27 13 0	27 15 0	27 11 0	27 8 9	25 17 6	25 15 0	27 10 6	27 8 0	27 15 0	27 6 3	26 16 6
1874	26 0 0	24 17 9	23 8 9	21 19 6	22 3 0	22 6 3	22 10 0	22 7 0	12 11 6	23 10 6	24 8 9	22 18 9	23 6 9
1875	23 18 9	23 11 3	23 7 6	23 3 9	24 2 6	24 11 3	24 0 6	23 17 6	24 15 0	24 18 0	25 3 9	25 10 0	24 5 0
1876	†	......	......	......	......	......	......	......	......	......	......	......	23 7 11
1877	22 10 0	22 10 0	22 10 0	22 10 0	22 10 0	22 10 0	21 0 0	21 0 0	21 0 0	21 0 0	21 0 0	21 0 0	21 15 0
1878	21 0 0	21 0 0	21 0 0	21 0 0	21 0 0	21 0 0	19 1 3	18 6 0	18 0 0	17 16 3	17 9 6	17 5 0	19 9 9
1879	16 19 0	16 3 9	16 0 0	16 0 0	16 0 0	16 0 0	16 2 6	17 16 0	19 0 0	19 0 0	19 0 0	19 0 0	17 5 0
1880	21 0 0	21 0 0	21 0 0	21 0 0	19 11 3	19 0 0	19 0 0	19 0 0	18 13 9	17 14 0	16 17 6	16 7 6	19 3 9
1881	16 15 0	17 10 0	16 15 0	16 7 0	16 0 0	16 0 0	16 10 0	16 10 0	16 12 9	16 17 6	17 17 6	18 18 0	16 17 8
1882	18 10 0	18 0 0	18 0 0	18 0 0	18 0 0	17 19 0	17 10 0	17 10 0	17 11 0	17 15 0	17 7 6	17 4 6	17 15 6
1883	†	......	......	......	......	......	......	......	......	......	......	......	16 1 0
1884	15 15 0	15 15 0	15 2 6	15 2 6	15 10 0	15 10 0	15 10 0	15 10 0	15 8 9	15 5 0	15 5 0	15 5 0	15 8 2
1885	15 5 0	15 5 0	15 1 3	15 0 0	15 0 0	14 2 6	14 3 3	14 10 6	14 19 9	15 2 6	15 3 9	15 13 0	14 18 10
1886	15 15 0	15 14 3	15 12 6	15 15 0	15 15 0	15 15 0	15 14 0	15 12 6	15 12 6	15 13 6	15 14 6	15 15 0	15 14 0
1887	15 15 0	15 15 0	15 15 0	15 15 0	15 15 0	15 15 0	15 0 0	15 0 0	15 16 0	16 2 0	16 12 6	19 16 8	16 1 5
1888	22 0 0	20 12 6	20 5 0	19 7 6	18 3 9	16 11 0	16 8 1	17 9 4	19 9 0	20 7 6	19 17 6	19 3 0	19 2 10
1889	19 7 6	18 15 0	18 4 6	17 8 9	18 0 6	18 11 3	20 0 0	21 8 9	22 16 3	22 13 5	23 11 9	24 12 10	20 9 2
1890	24 18 0	22 18 9	22 7 6	21 7 2	23 3 6	23 17 2	23 16 3	24 8 6	25 9 8	25 12 9	25 4 4	21 3 9	23 13 11
1891	23 9 3	24 6 10	23 18 1	23 10 0	23 9 9	24 3 1	24 7 3	24 3 9	24 8 9	24 5 3	23 11 3	23 2 9	23 18 5
1892	22 17 6	22 3 9	21 18 1	23 0 9	23 10 0	23 9 7	22 11 9	22 7 10	20 14 7	19 12 10	19 13 1	19 5 3	21 15 9
1893	18 0 6	17 7 3	17 9 3	17 16. 3	17 15 9	17 16 3	17 13 0	17 7 3	17 4 4	16 17 6	17 1 3	16 16 3	17 8 0

* From British blue books. † The monthly prices are not given for these years.

AVERAGE MONTHLY PRICE OF SILESIAN ZINC (ORDINARY BRANDS) IN LONDON.*

(Price per long ton, 2240 lbs.)

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1883	......	......	......	......	......	......	......	......	......	......	......	......	15 6 6
1884	15 0 4	14 12 6	14 10 0	14 10 0	14 10 0	14 10 0	14 8 9	14 2 0	14 6 6	14 10 0	14 5 8	14 2 6	14 9 0
1885	13 19 6	13 18 0	13 17 6	13 15 0	13 11 9	13 7 6	13 11 3	14 1 0	14 8 9	14 4 3	14 6 0	14 18 9	14 0 0
1886	14 19 9	15 10 0	14 14 0	14 7 3	14 0 3	13 17 9	14 1 0	13 17 3	13 12 0	13 19 9	14 7 0	14 7 3	14 0 0
1887	14 10 6	14 7 6	14 3 3	14 0 9	14 6 3	14 9 3	14 11 3	14 13 0	15 5 0	15 17 0	16 15 7	19 9 6	15 4 0
1888	20 4 4	19 4 0	19 4 0	18 0 4	16 17 6	15 11 9	15 15 11	16 18 1	18 8 11	18 18 9	18 11 6	18 6 3	18 0 1
1889	18 7 6	17 11 10	17 4 6	17 7 11	17 15 6	18 2 6	19 8 5	21 1 0	22 1 10	22 0 11	22 17 3	23 15 11	19 16 3
1890	24 3 0	22 2 6	21 13 9	20 17 2	22 6 9	23 2 2	23 0 7	23 13 3	24 15 3	24 17 9	24 10 4	23 9 4	23 4 4
1891	22 15 6	23 12 6	23 5 7	22 15 7	22 15 7	23 10 0	23 14 9	23 8 7	23 14 4	23 12 9	22 16 5	22 9 4	23 4 3
1892	22 3 9	21 7 4	21 2 6	22 3 7	22 10 7	22 2 3	21 12 9	21 5 7	19 4 5	18 17 6	18 19 4	18 10 8	20 16 8
1893	18 0 8	17 1 10	17 9 3	17 16 3	17 14 11	17 14 11	17 13 4	17 7 3	17 4 4	16 17 6	17 1 3	16 15 3	17 8 0

* For years 1883–92 inclusive, from British blue books. For the year 1893 compiled from Vivian, Younger & Bond's Metal Price Current. The prices are for Silesian, ex ship, net cash till July, and then for virgin ordinary, ex ship, net cash.

AVERAGE YEARLY PRICE OF ZINC AT THE PRINCIPAL MARKETS IN GERMANY.*

(Price in marks per 100 kilos. 1 mark = 23.8 cents.)

Year.	Breslau.		Cologne. Rhenish, crude. Marks WH & SS. 3 Months.	Frankfurt a/M. Refined Calamine and Blende. At Works.	Halberstadt. Rhein-Westph., Crude. 1 to 3 Mos., at Works.	Hamburg. Silesian in Plates.
	Good Silesian. At Works.	Upper Silesian. Mark CGH. At Works.				
1879	.....	31.89	34.27	36.38	32.44	35.14
1880	.....	.....	37.88	38.47	36.23	38.61
1881	.....	30.83	32.66	33.53	31.09	32.57
1882	.....	31.78	34.32	34.88	33.84	35.04
1883	28.60	28.86	30.58	31.35	30.19	31.68
1884	27.20	. . .	29.00	29.06	28.66	30.16
1885	26.08	26.37	28.14	27.91	27.68	28.60
1886	26.71	26.55	28.64	28.03	28.11	29.58
1887	28.38	28.93	30.47	29.96	29.88	31.23
1888	35.41	34.42	37.21	36.02	36.10	39.26
1889	38.25	39.34	40.56	39.68	39.48	41.55
1890	45.11	45.00	47.92	47.02	46.58	49.27
1891	44.98	.....	47.34	46.44	46.54	48.95
1892	40.54	. .	43.08	42.17	42.23	45.30
1893	33.60	33.27	35.78	35.13	34.42	38.07

* From *Vierteljahrshefte zur Statistik des Deutschen Reichs*, 1894, Part I.

THE PRESENT CONDITION OF THE ZINC INDUSTRY IN EUROPE.

BY WALTER RENTON INGALLS.

THE zinc industry is of more recent development than any other important branch of economic metallurgy. Iron, copper, lead, tin, and the precious metals were known and extracted from their ores in ancient times, but the first process of zinc-winning, industrially successful, was devised less than one hundred years ago, and it is scarcely seventy-five years that the industry has been of importance in Europe, while its growth in the United States is still more recent.

It is not known to whom the isolation of zinc is due, but it was mentioned by Paracelsus (1493–1541). In 1721 Henckel published his discovery of the fact that it could be obtained from calamine, and he is named by Beckman as the first who intentionally carried out this process.* The art of zinc smelting was practiced in England as early as 1740, the first works (according to Pryce) having been erected at Bristol by John Champion, to whom a patent for the process of distillation downward was granted in 1739; calamine brass had been made in Surrey a century earlier. In 1742 Van Swab produced the metal at Westerwick, in Dalecarlia, where it was proposed to erect large works.† None of these early experiments, however, seem to have been of much importance; certainly none of them led to the establishment of a permanent industry, which did not begin until more than eighty years after Henckel's discovery.

The principle upon which the modern process of zinc smelting is based, or rather the method of carrying out that principle in practice, was discovered in Silesia in 1798, or about that time. A similar discovery was made accidentally and independently in Belgium in 1805 by Abbé Dony, who does not appear to have been acquainted with the work of others in the same direction. The two processes of zinc smelting, the Silesian and Belgian, in use at the present time have been developed from these beginnings. Some features of the former have been introduced in the latter, and *vice versa,* but there have been no revolutionary improvements in either, as in the metallurgy of copper and lead, and each remains essentially unchanged. Numerous attempts have been made by zinc metallurgists, notably by Müller, Lencauchez, Clerc, Thum, and Köhler, to reduce the cost of producing zinc by distilling in shaft furnaces instead of in the small vessels used hitherto, but none of these experiments has led to the desired end, because it has been impossible to prevent oxidation of the zinc and the formation of zinc powder in comparatively large amounts, thereby giving products which must be reworked in small retorts and leading to higher metallurgical losses.‡

History of the Belgian and Silesian Zinc Industries.—Calamine, which occurs in certain Devonian and Carboniferous rocks of Belgium, was for a long time obtained from deposits at Vieille Montagne (Altenberg), in Moresnet, the neutral ter-

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* It is certain that zinc was made in the East at a much earlier date ; according to Raynal, the Dutch East India Company purchased annually 1,500,000 lbs. of zinc at Talenbang, and there can be no doubt that knowledge of the process was first brought to Europe from India.

† Phillips, *Elements of Metallurgy*, 1891, p. 551.

‡ For an account of some recent experiments in this direction the reader is referred to an article by Prof Walther Hempel in *Berg- und Hüttenmännische Zeitung*, Oct. 13 and 20, 1893.

ritory between France and Germany, which had been exploited at intervals since the beginning of the Middle Ages. In 1435 the concession of a mine of zinc by the Duke of Limbourg is mentioned, and in 1439 there is reference to the mountain of calamine "which those of Aix had the habit of working." This mine, which was then abandoned, had been worked previously; for how long it is not known, but on that account it received the name of Vieille Montagne (Altenberg), or the "Old Mountain."

In 1454 the mine was reopened, after the grant had been given by Philippe le Bon to Arnold van Zevel, and operations were resumed. The ore was calcined on the spot with charcoal from the Hertogenwald, and was then sent to the places where the manufacture of brass by cementation was carried on. It was first used at Aix-la-Chapelle, Stolberg, and Cornelius-Munster; afterward it was shipped to the brass manufacturers of Dinant, Bouvignes, and Oignies, in the neighborhood of Namur, and to Liège and elsewhere in Belgium, the rivers Meuse and Sambre being utilized for its transportation.

Under the Dukes of Limbourg and of Burgundy, as well as under the Spanish dominion, the mines were sometimes leased to private parties,—never for more than twelve years, however,—and sometimes were worked on Government account, the last system being used particularly under the Archduke Albert, and later in the time of Philippe IV., King of Spain. After the annexation of the Belgian provinces to France, in 1795, the Republican Government worked the Vieille Montagne for the good of the nation, but under this *régime* the success of the exploitation fell off, and the Imperial Government renounced it, conceding the mine, in 1806, to the Abbé Daniel Dony, a chemist of Liège, "with the obligation of making experiments, which could be recognized as useful, to demonstrate his ability to reduce, by the aid of proper furnaces, calamine to the metallic state."

The Société de la Vieille Montagne, in a pamphlet entitled *L'Industrie du Zinc*, presented at the Exposition Universelle de 1889, at Paris, from which the foregoing details concerning the history of the zinc deposits of Moresnet are taken, states that the Emperor thus ordered Dony, in a manner, to discover a method of winning zinc, and Dony obeyed and discovered it, although such discoveries are rarely made by decree. The probability is, however, that Dony, who had been experimenting on the subject since 1780, expressed to the Government his ability to produce zinc, and asked for the concession of the mines, which was granted on the condition that he should prove his statements.

Dony's success was finally achieved accidentally, after a long series of disappointing results. The story of the actual discovery is classical. When endeavoring to extract zinc from calamine by fusion in a reverberatory furnace it occurred to him that the heat applied was not sufficiently high, and he added coal dust to the mineral to attain a greater temperature. In order to observe what took place in the interior of his furnace, he built an ordinary flower-pot into one side to serve as a peep-hole through which he could look. The furnace having been charged and the firing begun, drops of zinc were observed to condense on the inside of the flower-pot, which was cooler than the furnace itself, and the method of extracting the metal by distillation was thus discovered.

Dony's experiments were carried out in a little workshop in the Faubourg St. Léonard at Liège, where he subsequently built furnaces and commenced the production of zinc on a commercial scale. There was no use then for the new metal, however, with which the public was unfamiliar, and it was necessary to raise it to the rank of the necessary commodities. This task was beyond the power of one man alone, and Dony, having ruined himself, died without having accomplished it.

Dominique Mosselman, a man of vast energy, took up Dony's work in 1818, devoting his life to perfecting the process for making zinc and to finding a market for it, but nevertheless at his death, in 1837, the industry could scarcely be said to exist in the west of Europe except in expectation.* In order to settle his estate, his children founded the Société de la Vieille Montagne, with a capital of 7,000,000f. divided into 7000 shares of 1000f. each, and since that time (1837) this company has been the leading zinc producer of Europe.

The property of the Vieille Montagne Company, at the time of its organization, consisted of the calamine mine in Moresnet, the St. Léonard zinc works at Liège, two small rolling mills at Hom and Houx, in France, and finally new smelting works at Angleur, on the river Ourthe, a branch of the Meuse, which were then in course of construction. A few months later the company bought the rolling mills at Bray, in France, and Tilff, in Belgium. For nearly ten years the company had a hard struggle, developing slowly, but after 1846, in which year the direction of its business was intrusted to M. St. Paul de Sincay, who continued to manage it until 1890, there was a rapid advance in its affairs. The Société Anonyme des Mines et Fonderies de Zinc et de Plomb de la Nouvelle-Montagne established works at Engis, in Belgium, in 1845, and other companies engaged in the industry soon afterward.

The history of the Silesian zinc industry is similar to that of the Belgian. It began a few years earlier, however, and once having been started grew more rapidly and more regularly, so that it seems strange that the Belgians did not borrow more from the experience of the Silesian metallurgists. The existence of the great deposits of calamine in the neighborhood of Beuthen, in Upper Silesia, was known in the sixteenth century, and even at that time the ore was used for the manufacture of brass by cementation. The zinc-mining industry began to assume important proportions in this province in the eighteenth century, when Georg von Giesche, a merchant of Breslau, received from the Emperor Leopold (Nov. 22, 1704) the privilege of exploiting the zinc deposits of the Beuthen domain and the right of selling the ore outside of Silesia, which grant was prolonged until 1802 by agreement with the Counts Henckel, the great landlords of the district. Toward the end of the century the industry increased largely in importance, the production averaging 500 tons of calcined calamine per year between 1780 and 1792 and rising to 900 tons in 1792. The cost of production was very small, and the selling price of the mineral was about 4 marks ($1) per centner, or $20 per ton. The calamine was at first calcined in open heaps, but subsequently calcining furnaces designed after the form of baking-ovens, and fired with stone-coal, were introduced.

The zinc industry of Upper Silesia was revolutionized at the beginning of the nineteenth century, when the fabrication of spelter was begun. This was due to

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* These facts are matters of record, but the situation seems strange in view of the development which the zinc industry in Silesia had attained at this time.

the Kammerassessor Ruhberg of Pless, who learned the art in England (where zinc smelting was then being carried on by the English process of distillation downward) and brought the secret to Upper Silesia. It is incomprehensible, indeed, that ten years later there should have been no knowledge in Belgium of what was being done in this branch of metallurgy in England, the two countries being separated by only a narrow strip of water, while the news had previously penetrated eastward to the Polish frontier. Ruhberg constructed the first zinc furnace in Upper Silesia, in the neighborhood of Wessola, utilizing for this purpose the pots in a wood-fired glass furnace, and it is noteworthy that the Silesian zinc process, in contradistinction to the Rhenish and Belgian, preserves to this day traces of the glass industry through which it originated.

After Ruhberg's first experiments others were taken up at the Königlichen Friedrichs-Bleihütte, and later at the Königs-Eisenhütte. In these experiments the round form of the Wessola glass furnace was still preserved, but more practical reduction retorts were adopted, long half-cylinders being used instead of the glass-pots. The experiments with these retorts gave such favorable results that the erection of larger zinc works at Königshütte was soon undertaken. These works, the Lydogniahütte, came into operation in 1809, and on Dec. 16 of the same year the Bergwerksgesellschaft "Georg von Giesche's Erben" put in operation a zinc furnace with four muffles at its calcining works at Scharley, the success of which led to the establishment of the Siegismundhütte, with ten furnaces, at the same place in the following year. In 1813 the Konkordiahütte, also situated at Scharley, were built by the same company. The production of the two works of Giesche's Erben from 1811 to 1814, in spite of the war which was then raging throughout Europe, amounted to 313,950 kilograms of spelter. Several other small zinc works had also been established in Upper Silesia in the meanwhile, and the increasing production caused a heavy fall in the price of the metal.

The consumption of coal in 1815 was from four to five tons per ton of calamine, and the success of the zinc works situated near the zinc mines and remote from the coal, or otherwise unfavorably located, was checked by the cost and difficulty of procuring fuel. This led to the establishment of the new zinc works near the collieries, the Giesche's Erben first building the Georgshütte, near the Fanny coal mine at Michalkowitz, in 1818. These works had 8 furnaces of 8 muffles each, and produced 131,900 kilos of zinc in 1818 at a cost of 90 marks ($22.50) per 1000 kilos for smelting. The two works at Scharley were then closed down. In 1822 the Georgshütte were increased by the erection of 8 new furnaces, each with 10 muffles, while 2 muffles per furnace were added to those previously in use. The production of these works then rose to 428,550 kilos, and the cost of production was reduced to 53⅓ marks ($12.80) per 1000 kilos.

The number of zinc works in Upper Silesia increased very rapidly after 1815; besides the Georgshütte, the Hugo and Liebehoffnung works were built at Neudorf in 1818 and 1820, respectively, while the Clarahütte were put in operation in 1822, and the construction of the Davidhütte at Chropaczow, with 5 double furnaces of 20 muffles each, was begun in 1825. The total production of spelter in Upper Silesia in 1825 amounted to more than 200,000 centners (10,000 metric tons) and largely exceeded the consumption at that time. Consequently the price of zinc fell to 9 marks per centner ($45 per ton) at Breslau, and many of the zinc works, whose supply of ore was not assured, were closed down.*

Of the great zinc producers of Silesia at the present time the Gieschen Erben engaged in the industry in 1809, as above described; the Counts Henckel von Donnersmarck in 1818, the Schlesische Actiengesellschaft für Bergbau und Zinkhüttenbetrieb in 1853, taking over works previously in operation, while the great works of the Herzog von Ujest, the Hohenlohehütte, were built in 1871.

Zinc was first made in the United States about 1838 at the United States Arsenal in Washington from the red zinc ore of New Jersey, for the brass designs for standard weights and measures ordered by Congress. The process proved so expensive, however, that for a long time there was no idea of treating this ore commercially. The regular manufacture of zinc was first undertaken in 1850 at the works of the New Jersey Zinc Company, Belgian furnaces being used, and the Silesian process was tried in 1856 by Matthiessen & Hegeler at the works of the Lehigh Zinc Company. Neither the Belgian nor the Silesian process was at first successful in the United States, owing apparently to the difficulty in making retorts and muffles of a composition adapted to the peculiar character of the ore, and their failure led to various experiments with different processes. Samuel Wetherill of Bethlehem, Penn., attempted to produce spelter by treating the ores in open furnaces, the oxidized fumes being drawn through incandescent anthracite to reduce the zinc oxide to metal. A few tons of zinc were made in this manner, but the process did not prove practicable. Mr. Wetherill subsequently designed a zinc furnace with upright retorts, for which he succeeded in devising a mixture sufficiently refractory to withstand the corrosion of the basic New Jersey ores. This obstacle having been overcome, the Belgian furnace was readopted, and in 1860 works were constructed at Bethlehem to carry out the process.

Price of Zinc.—The price of zinc, since the metal first became of industrial importance, has been subject to curious fluctuations. Unlike most of the other metals of which the value has gradually decreased with improved methods of winning, that of zinc is now little below the rate of previous years, and is actually higher than the general market price during the first two decades of the commercial history of the metal. This remarkable circumstance is due to the slight demand at first for the new and but little known metal, and the fact that the cost of production in Silesia eighty years ago was less than at present. The increase in the wages of labor and the cost of ore and coal since 1814 has more than kept pace with the saving effected by new and improved mining and metallurgical methods.

Previous to 1814 the price of zinc in Upper Silesia appears to have been over 30 marks per 50 kilos † ($150 per ton), but upon the rapid development of the industry in that year there was a falling off, so that in 1814 the price was 21 marks per centner ($105 per ton), in 1815 20 marks ($100), and in 1817 and 1818 only 16 marks ($80). In 1820 the price fell further to 10½ marks ($52.50), which was lower than the average cost of production at that time, wherefore arose the first

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* These data concerning the development of the zinc industry in Upper Silesia are drawn mostly from the excellent book by Dr. H. Voltz, *Die Bergwerks- und Hüttenverwaltungen des Oberschlesischen Industrie-Bezirks.*

† Zinc is quoted in Breslau customarily in German centners (50 kilos), and in recounting the course of Silesian zinc that form will be used, with the equivalent price in dollars per metric ton in parenthesis. With spelter at £17 15s. to £17 17s. 6d. per long ton in London the Breslau price is about 17.40 marks per 50 kilos.

crisis in the zinc industry, many of the newly established works being obliged to close.

Until 1820 the chief market for Silesian zinc was in Asia, whither it was shipped over Russia ; in 1821 exportations to British India were begun, and soon grew to such an extent that the Chinese zinc was driven out of that market. This circumstance, together with the restricted production and the erection of the first rolling mills at Malapane, Friedrichshütte, and Rybnik, thus affording a new home market for spelter, sent the price for the metal up to 32 marks ($160) at the beginning of 1823; but this led to such a great increase in the make that the demand was quickly outstripped, and a second crisis in the industry resulted, which lasted from 1826 to 1830. At times it was impossible to sell zinc at all, and only the most favorably situated works could keep in operation, the production of the province falling off more than one half its former maximum. The lowest point was reached in 1829, when spelter was quoted at 9 marks ($45) at Breslau.

In 1830 the zinc industry began to develop on a sounder basis. The price for the metal remained low during the next ten years, but sales became more regular, and gradually the demand began again to exceed the production, in consequence of which prices ruled high from 1840 to 1848, varying from 16 to 26 marks ($80 to $130). The political disturbances of 1848–50 then gave the industry a setback, which lasted until 1852, prices ranging from 11 to 13.50 marks ($54 to $67.50), but from that time until 1878 there was a steady period of prosperity, which was only interrupted by the financial crises of 1858 and 1873, and the wars of 1866 and 1870–71. The exhaustion of some of the important deposits of calamine (especially the Scharley and Marie mines) in 1870 led to a decrease in production, and an increase in prices owing to the higher cost of ore; but by the end of the decade all the works were equipped with roasting plants for the treatment of the blende, which had first begun to be exploited in 1870. The supply of this being large, the value of zinc in the five years following 1878 averaged 5 marks, or 25%, below that of the ten years preceding 1878, and in 1883 was lower than it had been for thirty years. The average price of Silesian zinc per centner and per ton at Breslau by decades since 1830 has been as follows: 1830–40, 13.04 marks ($65.20); 1840–50, 18.17 marks ($90.85); 1850–60, 18.42 marks ($92.10); 1860–70, 18.32 marks ($91.60); 1870–80, 20.15 marks ($100.75).* The history of spelter since 1880 is well known.

Ores of Zinc.—Zinc ores are widely distributed throughout the world, workable deposits occurring in nearly every country in Europe and in various parts of the United States, while there are others in Australia, Mexico, and less well explored regions, which are not yet available on account of their inaccessibility. The principal ores of zinc are the following:

Smithsonite ($ZnCO_3$)	52% zinc.	Zincite (ZnO)	80.2% zinc.
Hydrozincite ($Zn_3CO_5 + 2H_2O$)	57.1% "	Franklinite [$(FeZn)O + (FeMn)_2O_3$]	21% "
Willemite (Zn_2SiO_4)	58.1% "	Blende (ZnS)	66.9% "
Hydrosilicate ($Zn_2SiO_4 + H_2O$)	53.7% "		

The carbonate and silicates are commonly referred to by the general term "calamine," which was formerly the only class of zinc ore used for the produc-

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* These data concerning the fluctuations in the price of Silesian zinc are taken from a pamphlet by Herr Bergrath Bernhardi, general director of the Wilhelminehütte, on the fiftieth anniversary of those works.

tion of spelter, but the exhaustion of the easily worked surface deposits brought the undecomposed blende ore into the market, and during the past twenty years its importance has been steadily increasing. At the present time, however, the more part of the zinc produced in Europe is probably still derived from calamine,[*] though in the United States blende is, and has been for many years, by far the more important of the two ores. Red zinc ore and franklinite, which are used in New Jersey for the manufacture of zinc white, are ores peculiar to that State and comparatively unimportant as sources of spelter. Certain European zinc works, however, employ an artificial oxide of zinc, which is obtained from the upper parts of the blast furnaces smelting zinc-bearing iron ores.

The ores of other metals are usually associated with those of zinc, more or less affecting their value, which is also influenced by the character of the gangue. Most commonly lead and iron minerals are found with zinc ores; and as both these elements are hurtful in the process of zinc winning, their separation is an important preliminary step in the treatment of the ore. Besides the foreign minerals associated mechanically with zinc, however, there are impurities held chemically by the latter, like the monosulphide of iron (FeS), even to the extent of 30% iron, as in the case of the shining black blende of Freiberg (Saxony), and cadmium sulphide, of which reddish blendes may contain as much as 5%. The carbonates of iron and cadmium are also associated isomorphously with zinc carbonate, the Silesian ores containing from 0.5% to 2% Cd.[†]

The dressing of ordinary zinc-lead ores does not offer especial difficulties, owing to the great difference in the specific gravities of the two series of minerals.[‡] The separation of the zinc and iron minerals, however, is not easy, whether in the form of oxide, carbonate, or sulphide, the difference in their specific gravities being small. However, since iron is one of the most undesired elements in the zinc retorts, reducing the value of an ore rapidly when the percentage of it present exceeds a certain limit, it is important to eliminate it as completely as possible. Various modifications of the ordinary processes of wet-dressing have been tried for this purpose, with more or less success, and magnetic concentration has been introduced at several places, among others at Friedrichssegen on the Lahn; at the Ludwigseck mine in the Burbach Bergrevier (Germany); in Maiern (Tyrol); at Monteponi in Sardinia, and elsewhere.[§] In the United States magnetic concentration has been adopted at the mines of the Wythe Lead and Zinc Company, Austinville, Va., while the mechanical separation of blende and pyrite is effected successfully at Shullsburg, Wis.[‖]

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[*] This term is indefinite, owing to confusion as to its meaning, some mineralogists using it to designate zinc silicate and others zinc carbonate. In Europe it is used to describe the whole class of carbonate and silicate zinc ores generally, in which sense it is employed in this article.

[†] *Berg- und Hüttenmännische Zeitung*, 1888, 390, and 1890, 130.

[‡] This does not refer to the class of complex silver-bearing zinc-lead sulphide ores with little or no gangue, like those of the Rammelsberg in the Lower Harz; Leadville, Colo.; Broken Hill, New South Wales; and elsewhere, the economical treatment of which is still an unsolved metallurgical problem.

[§] W. B. Kunhardt, *Ore Dressing in Europe*, p. 106 *et seq.*; M. Bellom, "Préparation Mécanique dans la Saxe, la Hartz, et la Prusse Rhénane," *Annales des Mines*, 1891, pp. 5–186 (Friedrichssegen); W. R. Ingalls, *Scientific American Supplement*, Oct. 7, 1893; *Journal Iron and Steel Institute*, 1893, p. 205; *Oesterreichische Zeitschrift für Berg-Hütten- und Salinenwesen*, 1892, No. 20 (Monteponi); *Le Génie Civil*, 1890, Vol. XVII., pp. 337–340; *Transactions Federated Institute of Mining Engineers*, 1893, Vol. III., p. 1091; *Oesterreichische Zeitschrift für Berg-Hütten-und Salinenwesen*, 1893, 4 and 5 (Maiern); *Transactions American Institute of Mining Engineers*, IX., 420; Werner Siemens, *Gesammelte Abhandlungen*, 1881, p. 537 *et seq.*

[‖] W. P. Blake, *Transactions American Institute of Mining Engineers*, Vols. XXI., XXII.

The zinc smelters of Europe draw their supply of ore from nearly every country on the Continent, Germany and Italy being the largest producers in point of tonnage.* It should be borne in mind, however, that the Silesian ore, which forms the most part of the total credited to Germany, is of very low grade, while the Russian (Polish) and Galician (Austrian) ores are also poor, consisting chiefly of calamine with less than 25% zinc. The smelters of Upper Silesia, Poland, and Galicia, which are situated in the immediate neighborhood of the mines, depend almost entirely upon this ore for their supply, only a very little imported ore reaching them. The ore produced in the other provinces of Germany is reduced by the Rhenish and Westphalian smelters, with the exception of the few thousands of tons exported annually to Belgium. The English ore, which comes chiefly from Wales, is all smelted at home, and the same is true of the product of the Belgian mines, which is rapidly diminishing. France and Spain treat a part of their output in domestic works and export the remainder. Italy, Sweden, and Greece make no spelter, sending all their ore to other countries, chiefly to Belgium.

The principal markets for zinc ores in Europe are Swansea (Wales) and Antwerp (Belgium), of which Antwerp, where nearly all the ore for the Belgian and Rhenish works is entered, is by far the more important.†

Value of Ore.—The value of a zinc ore at Antwerp or Swansea depends in general upon its grade and character and the price of spelter in London. There are various formulæ based on the cost of treatment, loss in treatment, London quotation for spelter, and other component elements, whereby the value of an ore, aside from the needs or requirements of an individual smelter at a particular time, may be determined. One of these used by Antwerp buyers is the following :

$$V = \left(\frac{T - \frac{T}{S}}{10} \right) (P - 2.50) - D.$$

V = Value of ore in francs per ton ;
T = Per cent. zinc in ore ;
S = Loss in treatment expressed fractionally, commonly calculated $\frac{1}{5}$;
P = Price of spelter in francs per 100 kilos;
D = Cost of treatment, commonly calculated 60f.

Different values may be substituted for S and D to suit different conditions, and that for P varies naturally with the fluctuations of exchange and the London metal market. According to this formula the value of an ore containing 50% zinc, ex ship at Antwerp, with spelter quoted at 44.68f. per 100 kilos (£18 in London, exchange being taken at 25.20), would be 108.72f. per ton.

The principal ore buyers in Swansea employ the following rule in estimating the value per ton of ore : From 100 deduct the calcination loss and divide the percentage of zinc in the ore, less one, by the result. From the quotient deduct one-fifth plus one, and multiply the remainder by the London quotation for spelter per ton less £1 and divide by 100; deduct £2 10s. for smelting charge, and then subtract the calcination loss from the remainder, finally subtracting 5s.

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* See the tables in the zinc statistics preceding this article.

† Some trial lots of zinc ore have been shipped from Missouri to Antwerp, and in 1891 the Southwest Missouri and Southeast Kansas Lead and Zinc Mining Association sent an agent to Europe to call the attention of the spelter producers there to the resources of the Kansas-Missouri zinc region, and to induce them to enter that market for ores. He reported that it was impossible to accomplish this (see THE MINERAL INDUSTRY, Vol. I., 1892, p. 466), the supply of ore in Europe being abundant, and the Missouri miners being unable to offer any advantages in the way of price.

per ton for cost of calcination. With a calamine ore assaying 40% zinc and a calcination loss of 30%, spelter being quoted in London at £17, the value of the ore ex ship at Swansea would be calculated as follows: $100 - 30 = 70$; and $40 - 1 = 39$; $\frac{39}{70} = 0.557$; $0.557 - \frac{1}{5} = 0.446 - 1 = 0.436$; $\frac{0.436 \times £16}{100} =$ £6 19s. 6d.; £6 19s. 6d. — £2 10s. = £4 9s. 6d.; £4 9s. 6d. — 30% for loss in calcination or £1 6s. 10d. = £3 2s. 8d.; £3 2s. 8d. — 5s. for calcination = £2 17s. 8d., which is the net value of the ore.*

The zinc ore is often contracted for on a fixed basis, with a sliding scale according to the percentage of metal contents and the London price for spelter, the terms being governed by the demand for the ore and the needs of the smelters. The latter aim usually to buy ores of the same kind, so as to give their furnace men familiar material and keep a uniformity in their metallurgical process. There is a great surplus of ore in Europe, and it is often impossible to sell promptly occasional cargoes of ore of indifferent character, though contracts for a steady output can usually be made without difficulty. The Vieille Montagne Company, which owns mines in many parts of Europe, imports, of course, its own ore, although it buys also from other producers. Such concerns as the Société des Mines de Malfidano, which owns large mines in Sicily and produces a very much desired class of ore, usually make long contracts for their output. The impurities which detract most from the value of a zinc ore are manganese and iron, and if the percentage of these elements exceeds 10 the ore will not find a ready market.

Most of the zinc ore arriving at Swansea or Antwerp comes in a calcined or desulphurized condition, having been subjected to this preliminary treatment at the mines in order to save freight, especially in the case of calamines, of which the calcination is easy and the saving in weight is large, perhaps 30%. The Vieille Montagne Company, however, has a large installation of roasting furnaces at Campine, near Antwerp, where raw ores are treated before shipment to its spelter works, which are not equipped with roasting furnaces. The zinc ore brought into Antwerp probably averages in grade between 45% and 50% zinc. This is the standard required by the Belgian and Rhenish zinc works, and the miners generally in Europe dress their ore accordingly.

Zinc ore from Sardinia, Spain, and elsewhere is brought to Antwerp chiefly in steamers of 2500 to 3000 tons, unloaded into railway wagons on the wharf, and thence dispatched to Liège, Stolberg, etc. The method of discharging cargoes is crude. The ore is raised from the vessel's hold in bags or baskets, which are weighed separately by beam-scales. The railway wagons carry about 10,000 kilos each, and a basket of ore weighs about 50 kilos. Eight baskets per wagon, or one in twenty-five, are reserved as a sample, the sample basket being chosen at random. The sample is then removed to a shed, where it is quartered down and divided into three parts for analysis in the usual manner. Settlements are made in Antwerp on this basis.

With spelter at £17@£18 in London, a calcined calamine containing 50% zinc is worth from 120 to 125f. per ton in Antwerp. The price is usually based

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* H. D. Hoskold, *Trans. Fed. Inst. Min. Eng.*, Vol. V., Parts I. and II., 1893, p. 93.

on a zinc tenor of 50%; for each unit in excess 3.5 to 4f. is added, and for each unit below 50% the same amount is deducted from the basis price. A 50% zinc ore to bring 125f., however, must be of good quality, and must not contain more than 10% iron. A typical ore is that shipped to Antwerp from Sardinia by the Société des Mines de Malfidano, of which 25,000 tons had the following average composition: Zinc, 54.40%; lead, 6.00%; oxygen, 13.75%; oxide of iron and aluminum, 6.80%; lime and magnesia, 6.60%; silica, 9.40%; water, carbonic acid, etc., 2.80%. This ore was contracted on a 50% basis at 120f. per ton with spelter in London at £15, and 7.75f. for each pound sterling over £15. It is considered to be of better grade than the average, and is eagerly sought by the smelters.

The works which make a specialty of buying lead-bearing zinc ores pay for the lead contents in excess of 6% to 8% at the rate of 1.5 to 2f. (30 to 40 cents) per unit. None of the zinc smelters are inclined to pay for silver in zinc ores, and practically no silver-bearing ore comes to the market. When payment is made for this, only that in excess of 125 grams per ton is allowed for, and then only at the rate of 0.06f. per gram. On distilling a silver-bearing zinc ore the silver remains in the residue, but for obvious reasons its recovery is not easy, and unless in considerable amount is quite out of the question.

The freight on zinc ore from Antwerp to Liège is 5f. ($1) per ton; to Stolberg in Rheinland it is 6f. ($1.20). Liège is distant about three hours by express train from Antwerp, and Stolberg is about one and a half hours farther.

The value of zinc ores in Antwerp does not differ much from that in Kansas and Missouri. For instance, when spelter was quoted in London at £17 10s. ($84) per long ton, or 3.75c. per lb., the New York price was 4.30c. per lb. Zincblende ore of average grade (56% zinc) sold in Joplin then for $21.50 per ton of 2000 lbs., which was equivalent to $23.70 per metric ton; allowing $3 per ton as the difference between the value of a sulphide and a calcined carbonate ore of this grade,* the value of a 56% ore in Joplin and a 50% ore in Antwerp at the same time was $26.70 and $24 per ton, respectively, or 47.7c. and 48c. per unit of zinc contained. This comparison is only indicative of the relative values of ore in the two markets, and is not exact, because in Missouri the price of ore does not fluctuate so closely in accordance with the price of spelter as in Belgium, and at the time selected it may have been abnormally affected by local causes To make an exact comparison it would be necessary to take the quotations for a long period; the preceding will show, however, that the difference in values is not large. This is the reason why the attempt to sell American ores in Europe, which was made two or three years ago, failed. The European smelters could not buy them as cheaply as other ores of which there was an abundant supply, and the American miners after paying the freight could not get so good prices as they realized at home.

European Zinc Smelters.—The metallurgy of zinc is comparatively simple in theory, depending upon the reduction of the oxide at a high temperature by carbon in a closed vessel or retort. In practice, however, there are complications

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* In general a carbonate ore is worth more than a sulphide ore of equal tenor in zinc and purity only by the difference between the cost of calcination and roasting and the value of the zinc lost by volatilization in roasting and in distillation through incomplete preliminary desulphurization.

which make the process one of the most delicate in the whole field of the metallurgy of the common metals. This arises from several causes, the more important being the completeness of the desulphurization required, the necessity for carrying out the reduction of the oxide of zinc at a high temperature in small and comparatively fragile vessels from which air must be excluded, and the fact that the reduced metal has to be dealt with in vapor form instead of liquid. These conditions lead to a high loss of the metallic contents of ores treated and a high cost of production for the metal won.

There are two general processes of zinc smelting, the Belgian and the Silesian, which are based on the same principle, but differ in the type of furnaces employed, the grade of the ore treated, and the manner of manipulation. A combination of the two, known as the Belgian-Silesian, is used in some places, chiefly in Rheinland and Westphalia, but it is more Belgian than Silesian, and hardly merits designation as a distinct process.* There were other methods formerly in use, the most important among them being the English, in which the zinc was reduced in pots and distilled downward through pipes in the bottom, and the Carinthian, in which a series of short vertical pipes formed the retorts, but these were abandoned long ago.†

The Belgian and Silesian zinc processes were begun differently, as previously described, and in their development to their present stage have followed different lines, thus preserving the distinctive features originally introduced, though now they are beginning to lose them to some extent, and are tending toward a common type. The Silesian process is used exclusively in Silesia, Poland, and Galicia; the Belgian and Rhenish works use the Belgian process or the Belgian-Silesian; while the English zinc smelters employ either the Belgian or the Silesian process, and sometimes a combination of both is found in the same works, but the latter is used much less now than formerly.

The chief seat of the English zinc-smelting industry is Swansea, in Wales. The ore supply is drawn from Wales and from foreign countries, chiefly from Italy and Greece.

The Belgian-Rhenish zinc industry is centered in the vicinity of Liège, Belgium, and in Rheinland, near the Belgian frontier. There are also works at Boom, near Antwerp; at Budel and Maestricht, in Holland; at Auby, Viviez, and St. Amand, in France; at Oberhausen (Hamborn-Neumühl), Letmathe, Berge-Borbeck, Eschweiler, Gladbach, Dortmund, and Neupelt, in Rhenish Prussia and Westphalia, which are of the same type as the Liège and Stolberg works, and are governed by the same conditions. These works, especially the Rhenish, draw their ore in part from domestic sources, but the Belgian import the most of their supply, chiefly from Grece, Italy, Sardinia, Algeria, Spain, and Norway.

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* There is some confusion as to the classification of the processes of zinc smelting. The old Silesian process, which is now everywhere abandoned, was modified by the introduction of certain features of the Belgian process, and the combination is called by some writers the "Belgian-Silesian process" (see Kerl, *Grundriss der Metallhüttenkunde*). The Belgian process, on the other hand, has been in some places modified by the adoption of some of the Silesian methods, especially in Rhenish Prussia, and this combination is also referred to as the "Belgian-Silesian" process, though it is quite different from the other. In this article the process now commonly used in Upper Silesia is designated the "Silesian process," and its predecessor is referred to as "old Silesian," while the term "Belgian-Silesian" is reserved for the Rhenish modification.

† Pictures of the English furnaces are commonly reproduced in the text-books, but they have been of only historical interest for more than thirty years. Dr. Percy saw one of these furnaces in operation in 1859, and even then they were considered rare.

The center of the Silesian zinc-producing district is Beuthen, a small city in the corner of the province, only a few kilometers from the Russian and Austrian frontiers. The deposits of zinc ore and coal upon which the industry in this region is based extend into Poland in one direction, and into the Austrian province of Galicia in another. The few small zinc works in Poland and Austria, therefore, are grouped naturally with those of Silesia, working on the same grade of ores and operating under the same conditions. The Silesian zinc smelters obtain nearly their whole supply of ore from mines within a few kilometers of the works, which themselves are built near the collieries. A small amount of ore is imported from Sweden and from other provinces in Austria, notably Carinthia, but the quantity is not large.

There are only seven producers of zinc in Europe outside of the groups above mentioned. There is one works in Spain, two in England, one each in Carinthia, Krain, and Bohemia, and a small works which forms a part of the Muldnerhütte at Freiberg, in Saxony.

The process of zinc-winning, both in Belgium and in Silesia, consists of the following steps: (1) Calcination of the ore to drive off the carbonic acid if it be a calamine, or roasting to drive off the sulphur if it be blende, the object in each case being to convert the zinc into oxide; (2) crushing the calcined, or roasted, ore to about one or two millimeters in size and mixing with half its weight, or the proper proportion, of non-caking coal or coke, which is to serve as the reducing agent; (3) charging the mixture into cylindrical or muffle-shaped retorts, about 25 kilos of ore per retort in Belgium, 35 kilos in Rhenish Prussia, and 90 to 105 kilos in Silesia; (4) heating the charged retort to a white heat, or to the temperature at which zinc oxide is reduced by the carbon or carbonic oxide of the coal mixed with it, and volatilization of the reduced metal, which passes from the retort over into a condenser, where it collects as liquid metal, and whence it is drained and cast into molds at suitable intervals; (5) withdrawal of the residue in the retorts from which the zinc has been driven, replacing broken retorts and recharging as before. In the case of ores containing much lead which may contaminate the spelter, the latter is refined, in Silesia, by a further process, consisting in remelting and separating the excess of lead (not alloyed with the zinc) by virtue of the difference in the specific gravity of the two metals.

Blende Roasting.—In Europe zincblende ores are roasted in reverberatory furnaces, Gerstenhöfer kilns, Hasenclever furnaces, and muffle furnaces of the type of the Grillo, Eichhorn-Liebig, and the new Hasenclever. Mechanical furnaces are seldom employed, the opinion of zinc metallurgists being that it is impossible to attain with them the degree of desulphurization that is required in roasting blende;* and the old reverberatory furnaces (Fortschaufelungsöfen and the double-hearth Freibergeröfen), which allowed the sulphurous gases to escape into the air, are now going rapidly out of use, having been replaced in the great metallurgical centers by furnaces of which the fumes may be utilized for sulphurous or sulphuric acid fabrication. The best practice in blende-roasting is probably that of the Rhenania works at Stolberg, in Rheinland, which have always been the leaders in this branch of metallurgy. The first Hasenclever-Helbig

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* The experience at the Matthiessen & Hegeler works at Lasalle, Ill., where a modification of the Spence furnace is used, does not bear out this view.

furnace was introduced at these works as early as 1870.* They were subsequently installed at other works in Germany, but have now been entirely abandoned, the last of them, at a works in Upper Silesia, having been dismantled recently. The Hasenclever-Helbig furnace was followed (in 1880) at the Rhenania works by the Eichhorn-Liebig;† this was in turn succeeded by an improved furnace designed by Hasenclever, which under the name of the "New Hasenclever," or "Rhenania," furnace is the most popular in Germany at the present time.

The new Hasenclever furnaces were built originally with three hearths, each with twelve working doors, and an ordinary fire-box at one end. The flames drew first through flues under the third (lowest) hearth, then between the third and second, second and first, and finally over the first to the stack, whereby a complete circuit was made around each muffle; in furnaces subsequently built the flues between the first and second muffles were omitted, so the flames drew first under the third muffle, then under the second, and finally over the first (uppermost). In the latest furnaces there is only one circuit of flues, which pass under the lowest muffle and back over the uppermost. These modifications were made after calorimetric determinations and practical observation had given the uniform result that the oxidation heat of zincblende is higher than the combustion temperature of coal, wherefore the firing could not further the chemical reaction after the blende was ignited, and an important saving was of course made in thus simplifying the construction of the furnace. A further improvement consisted in building a vertical partition wall through all the three muffles, dividing the furnace transversely into two parts, whereby its capacity was increased 30% and from 25% to 30% labor was saved.‡ The flues pass around both sections in one circuit.

The new Hasenclever furnace as at present constructed has hearths 12.4 m. long and 1.5 m. wide, divided into two sections each 6.25 m. long. The arch over each hearth is very flat, being only 0.23 m. high at the center and 0.12½ m. at the sides. The outer walls of the furnace are built of firebrick and common red brick, 0.125 m. of the former and 0.375 m. of red brick. The inside partition wall is built of firebrick, and is 0.25 m. thick. The arches and soles of the muffles and the flues around them are constructed of firebrick tiles of special shapes, which are carefully fitted together. Each hearth has ten doors (five in each section), which are made of iron and slide in grooves, so as to admit of a careful regulation of the air supply. The furnace is run with a vacuum of about one atmosphere pressure in the muffles, and is sometimes fitted with a manometer for adjustment of this. The air supply is preheated before entering the muffles by passing through conduits immediately under the lower flame-flues. Two furnaces are usually built side by side, with a common parting wall between them, and independent fire-boxes at one end. The ore to be roasted is dried on the top of the furnace, and is pushed along the uppermost hearth by men working through the side doors; at the end of the first hearth it drops through a hole to the next, and so on.

At the Münsterbusch and Rhenania works at Stolberg blende containing 27% to

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* *Berg- und Hüttenmännische Zeitung*, 1873, 16; 1879, 176; 1886, 80 and 180.

† *Ibid.*, 1883, 260, 273, 413, 479, 505; 1884, 5; 1886, 201. *Wagner's Chemical Technology* (American edition, 1892), p. 256 *et seq.*

‡ *Berg- und Hüttenmännische Zeitung*, Sept. 29, 1893.

28% sulphur is roasted down to 0.5% or 1.0%; with blende free from lime the latter figure is not to be exceeded, but with calcareous or magnesian mineral the roasted charge may still show 2% or 3% sulphur, owing to the formation of calcium or magnesium sulphate. The ore is crushed to about 2 mm. size before roasting.

Each block of two furnaces roasts about 8000 kilos of ore in twenty-four hours and requires the labor of 8 men—*i.e.*, 2 each side per shift.* The consumption of coal is about 20% of the weight of the ore roasted. The cost of roasting is approximately as follows: Labor, 8 men at \$1 (4 marks), \$8; coal, 20% of 8 tons = 1.6 ton, at \$2.50 per ton, \$4; repairs, 5% of cost of furnace (26,000 marks), \$1; interest (5%), superintendence, general expense, etc., \$2—total, \$15, or \$1.87½ per ton of crude ore.

Wherever the Hasenclever and similar muffle furnaces are employed the roast gases, which should contain 6% or 7% by volume of sulphurous anhydride, are utilized for the manufacture of sulphurous or sulphuric acid. Liquid sulphurous acid is made at the works of W. Grillo at Hamborn-Neumühl (Westphalia), and at those of Graf Guido Henckel von Donnersmarck at Chropaczow, and the Schlesische Actiengesellschaft für Bergbau und Zinkhüttenbetrieb at Lipine, in Upper Silesia.† In some works the sulphur fumes are conducted to towers and neutralized with lime, whereby calcium sulphite is formed (Upper Silesia), or otherwise rendered harmless, this being required by law.

The Belgian zinc smelters are not so well equipped with roasting furnaces as the Rhenish and Westphalian, their supply of ore coming more largely in desulphurized condition. In Silesia the same kinds of furnaces as in Rhenish Prussia are used, but the old double-hearth Freiberg furnaces (hearths 7 m. long) are more generally found.

The progression in the desulphurization of a zincblende ore in three types of furnaces is shown in the following table: ‡

I. Corphalie.				II. Flône.				III. Stolberg.			
Sample.	Zinc Sulphide.	Zinc Sulphate.	Zinc Oxide.	Sample.	Zinc Sulphide.	Zinc Sulphate.	Zinc Oxide.	Sample.	Zinc Sulphide.	Zinc Sulphate.	Zinc Oxide.
%	%	%	%	%	%	%	%	%	%	%	%
C	64.5	0	0	C	83.0	0	0	C	57.2	0	0
2	58.0	3.4	4.6	2	70.5	3.7	15.2	2	53.5	3.5	0.8
3	38.0	7.9	19.0	3	52.2	3.9	34.6	3	53.0	3.8	3.4
4	17.5	8.4	39.0	4	51.5	4.2	38.0	4	48.4	4.2	4.6
5	10.0	2.6	50.5	5	43.0	11.0	41.5	5	39.9	4.3	12.3
D	1.2	2.2	59.7	6	23.2	12.3	57.8	6	35.2	5.0	16.5
				7	17.7	7.8	65.0	7	34.8	6.9	17.0
				8	8.6	6.2	75.5	8	25.2	6.3	27.1
				L	1.9	5.9	81.0	9	24.2	5.2	30.0
								10	19.2	5.8	32.6
								11	10.0	7.8	40.0
								12	7.9	6.2	44.9
								13	1.5	4.7	52.5
								14	1.6	2.6	53.0
								D	1.2	0	55.0

C: Charged. D: Drawn.

The first set of figures in the above table shows the result of a simple reverberatory furnace at the Austro-Belge works at Corphalie, Belgium; the second is

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[*] About the same results are obtained with these furnaces at the Silesiahütte, at Lipine, in Silesia.

[†] Concerning the fabrication of liquid sulphuric acid see *Revue Universelle des Mines*, Jan. 18, 1890; *Berg- und Hüttenmännische Zeitung*, 1886, 428; 1887, 358; 1888, 48; Eilers, *Transactions American Institute Mining Engineers*, XX., 336; Kosmann, *Oberschlesien, Sein Land und Seine Industrie*, p. 202.

[‡] Letrange, *Réduction de Minerais de Zinc par Électricité*, p. 10.

from a furnace with two hearths at the Vieille Montagne works at Flône (Belgium); and the third a new Hasenclever furnace at the Rhenania works at Stolberg.

The following results, also from the new Hasenclever furnaces at the Rhenania works, are interesting as showing the comparative rate of desulphurization with ores of different tenor in sulphur:

Sample.	I. Sulphur.	II. Sulphur.	III. Sulphur.
	%	%	%
Crude ore	19.2	26.8	26.5
After 1st muffle	17.6	19.1	15.4
" 2d "	12.0	11.2	9.9
" 3d "	3.4	1.02	0.75
Roasted ore	0.6	0.35	0.75

The temperature varies according to the percentage of sulphur in the ore; in the first muffle it is from 580° to 690° C.; in the second and third 750° to 900° C. With rich sulphur ores the middle muffle is the hottest, but with poor ores the highest temperature is registered in the lowermost.*

Calamine ores are usually calcined in kilns or ordinary reverberatory furnaces, the former for lump ore with a consumption of 7% or 8% fuel, and the latter, using 10% fuel, for the fines. The waste heat from the distillation furnaces was formerly used for the calcination of calamine, but this practice has been generally abandoned as interfering with the operation of the more delicate process. At the Silesiahütte (Lipine) it is still carried out, however, a calcining kiln being built between the abutting ends of every pair of double furnaces.

Retort and Muffle Fabrication.—Before taking up the further treatment of the roasted ore it is proper to consider another preliminary step, retort and muffle fabrication, which is of prime importance in the subsequent process. Upon this as much as anything else, indeed, does the success of zinc distillation depend, since large losses may occur through bad retorts and muffles; † and it is in this direction, moreover, that there has been the greatest economical improvement in zinc-winning in Europe during the past ten years.

The retorts and muffles commonly used are of three sizes. At most of the works in Belgium the retorts are of elliptical cross-section—at Angleur 0.20 by 0.16 m. inside and 1.4 m. long, and at the Laminne works (Ampsin) 0.18 by 0.22 m. and 1.45 m. long, the sides being 0.03 m. thick in each case. At the Austro-Belge works at Corphalie they use cylindrical retorts 0.25 m. in diameter inside and 1.3 m. long. The works in Rhenish-Prussia, employing the Belgian-Silesian system, have larger retorts. At the Münsterbusch works (Stolberg) they are muffle-shaped, 0.15 m. wide at the bottom, 0.34 m. high, and 1.45 m. long inside, the sides being 0.03 m. thick. The retorts used at the Rhein-Nassau works, also at Stolberg, are of about the same size, but are somewhat longer. The Silesian muffles are of a type totally different from the preceding. A common size is 0.14 m. wide and 0.60 m. high at the front end, and 1.7 m. long (Wil-

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* Wagner's *Chemical Technology, loc. cit.*

† The distilling vessels in the Belgian furnaces are usually called "retorts" (Ger., *Röhren*; French, *creusets*); in Wales they are called "pots." In the Silesian furnace they are known as "muffles" (*Muffeln*), on account of their shape.

helminehütte at Schoppinitz). The sides of the Silesian muffle are made somewhat thicker at the back than at the front, and the muffle itself is a trifle wider there, tapering slightly toward the front.

The length of the retorts is restricted by their own weakness, and by the ability of the workmen to charge them. With respect to the latter limitation it is impossible to charge even a large Silesian muffle properly in the necessary manner—*i.e.*, with a long narrow shovel working through a comparatively small hole—if it is over 2 m. long. The length of the Belgian muffles, which are supported in the furnace at the two ends only, is further limited by their lack of transverse strength. The lengths adopted—viz., about 1.45 m. for Belgian and 1.7 m. for Silesian—are about the maximum possible with their respective types of furnaces.

There are many requisites in retorts for zinc distillation. They must be made of refractory material, which will resist intense heat and will not be corroded by the slag-forming impurities of the ore. They must be so compact that the zinc vapor will not penetrate them; and they must be strong enough to preserve their shape when loaded with say 40 kilos of ore and coal, and heated to a temperature of 1600° C. (white heat), supported only at the two ends. At the same time they must be so thin that the heat of the furnace may act upon their contents as strongly as possible. It is the fact that zinc oxide must be reduced in such small vessels, and the limitation of the conditions with respect to them, that make the process of zinc distillation wasteful and costly.

The suitability of various kinds of fire clay for retort fabrication can be determined only by actual trial in the furnace of a specimen set of retorts. A chemical analysis of the material alone is a very unsatisfactory guide. In order to show the kinds of clay used in Europe, however, the following analyses are given, together with two of American clays used for zinc retorts for the sake of comparison:

	I.	II.	III.	IV.	V.	VI.
SiO_2	54.00	63.00	44.87	45.11	*a*50.80	*c*46.90
Al_2O_3	26.00	24.00	39.76	39.68	31.53	35.90
Fe_2O_3	2.00	1.00	1.14	1.25	1.92	1.10
CaO	....	1.00	0.76	0.07	....	....
MgO	....	....	tr.	tr.	....	....
K_2O	....	....	0.67	0.66	0.40	0.28
Na_2O	...	....	...	....	....	0.16
TiO_2	....	....	....	...	1.50	1.30
H_2O	20.00	11.00	12.95	13.24	*b*13.80	*d*14.30
Total	102.00	100.00	100.15	100.01	99.95	99.94

(*a*) Free silica (quartz), 12.70%. (*b*) Combined water, 11.30%. (*c*) Free silica (quartz), 6.40%. (*d*) Combined water, 12.80%.

I. Clay from Andenne, Belgium. Kerl, *Grundriss der Metallhüttenkunde*, p. 451.
II. Clay from Namur, Belgium. Kerl, *idem.*
III. Clay from Briesen, near Lettowitz, Moravia; analysis of Hecht; Kosmann, *Oberschlesien*, etc., p. 206.
IV. Clay from Lettowitz, Moravia; analysis of Hecht; Kosmann, *op. cit.*
V. Clay from St. Louis, Mo.; Moxham, *Engineering and Mining Journal*, Nov. 25, 1893, p. 544.
VI. Clay from Perth Amboy, N. J., *idem.*

In general clay for zinc retorts should be low in ferric oxide, lime, and alkalies, which would increase its fusibility, and should not have much free silica if to be used for an ore with a basic gangue; for a silicious ore a more quartzose clay may be employed. It is impossible, however, to foretell the chemical action of an ore on the clay of a zinc retort so certainly as in the case of crucibles in other kinds of furnaces for reasons which will be explained subsequently. Physically the clay should be of such character that it can be made into a plastic, tough, tenacious paste. The strength of the retort and its impermeability will then depend chiefly upon the manner of fabrication.

New clay alone is never used in making zinc retorts, a mixture of raw or burned clay with chamotte, or the crushed material obtained from old retorts and condensers, and various other constituents, being generally employed. The composition of this mixture varies within wide limits at different works; this is doubtless because each has found by experience that a certain formula gives the best results with the kinds of ore usually treated.

In Silesia the muffles are commonly made of a mixture of about 60% chamotte and 40% raw clay, the latter consisting in part of Moravian (from Briesen or Lettowitz), in part of Silesian, and in part of burned shale (*thonschiefer*) from the collieries at Neurode. The Silesian clay is cheaper than the Moravian, but it contains as much as 4% iron, and on that account cannot be used alone. Clay from Szczakowa, in Galicia, is also employed, but the Polish clay from Mirow is no longer used. The Moravian clay is very plastic and at the same time refractory. Muffles are made from this and Neuroder shale, which have 53% silica and 45% alumina, and which can stand a temperature of at least 1800° C.* The Silesian ores being basic in character,—containing much ferric oxide and a lime gangue,—the muffles are not made so silicious as those used in Belgium and Rhenish Prussia. They rest on a solid base in the furnace, and it is not necessary, therefore, to make them so strong proportionately as the Belgian and Belgian-Silesian retorts, which are supported only at the ends.

In Belgium retorts are commonly made of clay from Andenne, which is also used to some extent in Rheinland. This is mixed with varying proportions of chamotte and quartz sand ; at many of the works also 6% or 7%, or more, of coke dust is added to the dough, which makes the finished retort smooth, compact, and impermeable, and gives it a graphitic appearance. It also diminishes the corrosion and the absorption of zinc. A mixture formerly used for retorts at Engis consisted of 30% raw clay, 27% chamotte, 18% coke, 15% old retorts, and 10% sand.

In making the mixture for retorts the clay and chamotte are ground usually in Chilean mills, and kneaded subsequently with the proper proportion of water (which may be about 8% or 10%) in pans or other suitable mechanical arrangements. The clay is ground to a meal, but the chamotte and old material are not made so fine, being crushed only to pass a 5 mm. hole, or about that size. If all the material were fine the retort would be weak, and would bend easily in the furnace. On the other hand, if the grains of sand, chamotte, etc., in the mixture are too large, the muffle is porous. Too much chamotte also makes the muffle porous, and, moreover, fragile and hard to form.

The mechanical methods of muffle fabrication in Belgium and Silesia are as widely different as the material used. It may be said, indeed, that the Belgian and Silesian processes of zinc-winning begin to diverge with the manufacture of the muffles. In Belgium they are always made by machine; in Silesia they are invariably made by hand.

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* Kosmann, *op. cit.* p. 207.

There are two methods employed in Belgium for this purpose. In one the thoroughly kneaded clay is hammered solidly into a canvas sack in cylindrical or elliptical molds of the shape and size of the desired retort, which is subsequently reamed out by a vertical boring machine. The molds, which are made of wood, open longitudinally to discharge the finished retort, the two halves, when in use, being clamped together by screws. The clay is packed solidly into these by means of a hammer working up and down by a simple mechanical contrivance. The mold with its compact clay contents is transferred on a truck to the boring-machine, which cuts out an elliptical or circular hole as required. The retort is then removed from the mold and sent to the drying-house, where the canvas sack inclosing it is stripped off and the inside is made smooth by hand, after which it is set aside to dry at normal temperature, and finally is placed in the hot room. This method of retort fabrication superseded the old slow and expensive manufacture by hand, and it is still employed at the great works of the Vieille Montagne Company at Angleur (Chenée).

These machines were introduced more than thirty years ago. Percy describes them in his *Metallurgy*, 1861, p. 583, and states that retorts made with them at Angleur cost 1.6f. (32 cents); at Moresnet, in 1857, one man made 18 to 20 retorts by hand in twelve hours, and they cost, finished and burned, 2f. to 2.1f. (40 to 42 cents) apiece. The great saving effected by the machine-made retorts, however, was in their durability. In 1840 the consumption of retorts was 11.9 to 25 per 1000 kilos of zinc (average 17), and in 1888 it was only one-twentieth as much.*

Most of the Belgian and Rhenish works have now adopted hydraulic presses for retort-making. The clay is prepared for the hydraulic machines, after a thorough kneading, by compression into cylinders (ballots) about 0.5 m. in diameter and 0.6 m. long. These are made by hammering lumps of the soft, homogeneous clay into a mold, of which the bottom is an hydraulic piston. When thoroughly solidified the cylinder is lifted out of the mold by the piston, so that it can be pushed on the table at one side. It is then ready for the hydraulic press.

The hydraulic machines, which were first introduced by M. Dor, are of two kinds.† In one a prepared block (ballot) of clay is forced by an hydraulic piston into a vertical-standing steel cylinder, the inside of which is of the same shape and size as the outside of the retort to be made. Within the cylinder there is a steel core of the same size and shape as the inside of the retort. The clay having been forced from below into this mold, around the core, under a pressure of 150 or 200 atmospheres, the top of the cylinder is removed, and the formed retort is pushed upward and out by raising the hydraulic piston. The retort is then cut by a wire at the proper length, received on a carriage, and sent to the drying-house. A chunk of clay is thrown from above into the cylinder to make the bottom of the next retort, the end-block of the cylinder is replaced and locked on securely, and pressure is exerted as before. The core inside of the cylinder is hollow, and is provided with ports, which admit air to the interior of the finished retort when being forced out of the mold, and thereby prevents its crushing.

The other style of hydraulic retort-press consists of a similar cast-steel cylinder, fixed vertically, the interior of which has the shape of the exterior of the pot to

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* *Bulletin de la Société de l'Industrie Mineral*, 2me Livraison de 1888, p. 505.

† These machines were used at the Asturienne works at Auby, France, as early as 1877.

be made. Inside of the cylinder there is an annular ram, exactly fitting the interior surface, while within this is a cylindrical (or elliptical) ram or piston, which is of the same form as the inside of the retort to be made. Both of these rams work from the bottom upward. The top of the cylinder is closed by a heavy block of cast-steel, which is secured and locked as in the machines previously described. In making a retort a cylindrical block of clay of the proper size is put into the cylinder from the top. The top block is then closed and locked, and both rams together are moved upward, pressing the clay solidly into the cylinder. The inner ram is then forced into the clay, while the annular ram, still under pressure, retreats as the clay is crowded downward around the inner piston. When the retort has been thus formed, the top block is pushed aside, and the retort is thrust up and out by raising the annular ram. Of the two styles of machines the latter seems to be the preferable, requiring fewer men for its manipulation, and being on the whole simpler than the other.

The retorts are formed under a pressure of 150 or 200 atmospheres, usually the latter, exerted for about two minutes. At the works of M. de Laminne (Ampsin) a machine of the first type is used. For its operation two men are required on the upper floor and two on the lower; one man prepares the cylinders of clay, and another wheels the finished retorts to the drying-house; two men attend to the mixing of the clay and the kneading of the dough, which is done in iron pans in which a series of steel knives revolve slowly; a total force of eight men is therefore required. The output is easily 145 retorts in ten hours.

At Münsterbusch (Stolberg), where a press of the second type is employed, there are two men mixing clay and delivering to hammer; three men operate the machine and prepare the clay for it; and one man removes the finished retorts, making a total of six. The output is about the same as at Ampsin, viz., 140 to 150 per ten hours.

At Angleur (Chenée) a set of the machines previously described requires three men and two boys, while one man is needed to remove the retorts to the drying-house and another to finish them; their output is about 140 per ten hours, so that there is not much difference in favor of the hydraulic presses in point of cost of fabrication. The retorts made by the latter are very strong and dense, however, and are undoubtedly better and more economical than those made in any other manner; else the machines, which are very expensive, would not have been introduced so generally.

In Upper Silesia the muffles are always made by hand, the method employed being the same as commonly described in the text-books. The workman begins by plastering clay on the bottom and sides of a wooden form, which is one-third of the length of the muffle, and is made in two sections, so as to open longitudinally, the two halves being held together by clamps. The first section having been finished, another similar form is set on top of it, and after that a third. When the muffle is completed the sections are removed by unscrewing the clamps which hold them. Muffle fabrication in this manner is slow, laborious, and costly, but they answer their purpose well, and there is no tendency to adopt the expensive machines which are now used in Rhenish Prussia and Belgium. The Silesian metallurgist is not inclined to abandon the tapering sides of his muffles, which it would probably be difficult to make with a press, and there is not the same requirement of strength in them as in the Belgian and Belgian-Silesian retorts; hence there has not been the same necessity for improvement in that direction.

The finished retorts are moved to the drying-house, where they remain for a period varying from six weeks to three months—the longer the better. The retorts are first placed in rooms at normal temperature until stiff enough to be handled safely, when they are carried to another room, where the temperature is maintained at about 30° C. From this the retorts are drawn for the furnaces as required. The extensive drying-rooms necessary and the large number of retorts that must be carried in stock are by no means an unimportant item in the cost of zinc-winning.

The condensers (allonges) are invariably made by hand, both in Belgium and in Silesia, but their preparation is unimportant in comparison with the retorts. They are not called upon to withstand a high temperature, nor corrosive slags, nor the penetration of gases; nor have they to be especially strong. They therefore can be made of cheaper clay than the retorts, and a higher percentage of old material can be used in their composition.

The Belgian condenser is made in a long, tapering mold, into which a ball of clay is wrought into shape by a few deft movements of the workman with a conical wooden core. The tube is then removed from the mold and allowed to dry a little. When still soft, however, a V-shape piece is cut out of the larger end, and the two sides of the gash are drawn together, thereby producing a belly in the condenser, which when in position in the furnace forms a basin where the liquid zinc collects. The inside having been made smooth, the condenser is put away to dry for about a month, a much shorter time sufficing for this than in the case of the retorts. The Belgian condensers vary in length from 0.6 m. (Angleur) to 1.1 m. (Stolberg). One man can easily make 100 or 110 of these in ten hours. In Silesia the Kleeman, Dagner, and other patented condensers are generally used, and these will be described subsequently.

Before leaving the subject of retorts and condensers mention should be made of the Welsh-Belgian type, which is used at Swansea. These are made of oval cross-section, with the small end downward, and a thick clay base, which is penetrated by a D-shape hole parallel to the length of the retort, through which a current of air passes, keeping the bottom of the retort cool and supplying heated air to the fire. There does not seem to be much in this arrangement, however, to recommend itself.

The Distillation Furnaces.—The zinc distillation furnace in its elemental form is merely a large rectangular combustion chamber built of firebrick in which the clay retorts or muffles, set in series, are heated at a high temperature. The firing is done from an ordinary grate, or by burning gas from a generator. In either case the flames draw around the distilling vessels, and thence pass to the stack. In so far the Belgian and Silesian furnace are the same; in their details and manner of construction, however, they are widely different.

The Belgian furnace consists of a long rectangular chamber, about 1.3 m. wide and of variable height and length. Four of these are usually built together, forming a "block," or "massive," the back wall being common to two sections. The top of the furnace, which is arched, is supported in front on columns, the façade being open save for a stout, deep frame of iron, divided into rectangles about 0.4

m. high and 0.6 m. wide, which look like a series of big pigeonholes. The ends of the furnace and the top are built solidly of brick, and the whole block is substantially bound together by stout stay-braces. The back wall, which is made very thick, has as many horizontal ledges as there are rows of retorts, on which the inner, or closed, ends of the retorts are placed, the outer, or open, ends resting on tiles on the deep iron checker-work which constitutes the front of the furnace. The retorts are inclined toward the front, where the ends are about .01 m. lower than at the back. Two retorts are placed in each rectangle, or pigeonhole, and the spaces around them are closed with moist clay, which is packed as solidly as possible. The front wall of the combustion chamber of the furnace is thus completed. Once placed in position a retort is not moved until broken, when another is substituted for it. The condensers, which are necessarily taken out every day in order to recharge the retorts, are inserted into the ends of the latter, themselves resting on the broad shelf of the iron checker-work. The joint with the retort is tightly luted with clay. At a certain period in the distillation a long tin cone, or can, is placed on the ends of the condensers. These are called "prolongs," or "oxide pipes"* (French, *ballons;* German, *vorstecktuten, blechkegeln*). They project from the furnace and are supported on a horizontal rod carried by iron brackets.

The number and arrangement of the retorts in the Belgian furnace varies. The double furnaces at Angleur have 100 retorts per side in five rows of 20 each, the total number of retorts in the works being 5600 (28 double furnaces). At the Laminne works (Ampsin) there are furnaces with 50 per side in five rows of 10 each, and 40 per side in five rows of 8 each (total 1620). The Austro-Belge works at Corphalie have furnaces with 70 per side in seven rows of 10 each, 84 per side in seven rows of 12 each, and 60 per side in six rows of 10 each. At Bleiberg furnaces with 70 and 84 retorts per side are also used.

In the ordinary Silesian furnace the combustion chamber is lower than in the Belgian, there being only one row of muffles, which set directly on the sloping base of the chamber, and there is no dividing wall in the middle. The top is arched flatly, and supported on pillars. The façade of the furnace consists of a series of niches (capelle) through which the muffles are put into the combustion chamber. Each niche contains two muffles, the space between their front ends being closed with clay. The condensers are contained entirely within the niches, and do not project from the furnace at all. The escaping zinc fume from them passes through an opening in the top of the niche to a common collecting pipe extending longitudinally above the furnace; in the base of each niche there is a hole through which the waste cinder raked out of the muffles drops into the receiving cars under the furnace. The front of the niche is closed by a sheet-iron plate balanced by a weight and sliding up and down in grooves, whereby the temperature of the condensers is regulated. The furnace is substantially bound and braced with iron.

As in the case of the Belgian furnaces, the Silesian are usually built in pairs. Each furnace has from 32 to 40 muffles; *i.e.*, 64 to 80 in a block. At two of the works in Upper Silesia (Hohenlohehütte and Chropaczow) experiments have been made with furnaces containing two rows of muffles, each niche having four muf-

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* South Wales.

fles, or 64 per furnace. They are the same length and width as the ordinary type, but are only 0.36 m. high, and take only half the charge. The muffles of the upper row are supported so that the flames draw around them. The new Guidottohütte at Chropaczow, which were built in 1887, were equipped with furnaces of this type, but they did not prove successful and have since been rebuilt. The experiments at the Hohenlohehütte have had a similar outcome. These results indicate that there will not be much approachment between the Belgian and Silesian processes in this direction. The large muffle seems to be best adapted for the low-grade ores of Upper Silesia.

In the Belgian-Silesian furnaces, which are used generally in Rhenish Prussia, the retorts are supported at the ends as in the Belgian furnaces, and are usually arranged in three rows. At the Münsterbusch works (Stolberg) each double furnace has 120 retorts, or muffles, per side (240 in a block); while at the Rhein-Nassau works (Stolberg) and at Bergisch-Gladbach (Actiengesellschaft Berzelius) there are 216 retorts in a massive. The retorts in the Belgian-Silesian furnace are larger than in the Belgian, and there are some minor differences in their arrangement, but otherwise the furnace now commonly used in Western Germany is essentially the same as the Belgian. Furnaces more distinctively of the Silesian type were formerly employed, but these have been for the more part displaced by those previously described.

The Belgian, Belgian-Silesian, and Silesian furnaces may be heated in one of three ways, viz.: firing with forced draught (*unterwindöfen*) or without it, by simple gas-firing, and by regenerative gas-firing—which do not need detailed explanation, as their application will be readily understood. In direct-fired furnaces the grates are built at one end below the lowest tier of retorts, so that the flames draw around the retorts on all sides toward the stack. In gas-firing the producers are charged with coal through openings in the floor at the ends of the furnace-blocks, and the gas is burned around the retorts in the combustion chamber. Air is admitted for the complete burning of the gas through empty retorts in the bottom tier. The producers are, of course, below the level of the charging floor, and there is a sub-gallery around the base of the furnace for removing the ashes, etc. The waste cinders from the retorts are dropped through holes in the floor into this, whence they are removed in cars. The Siemens system of regenerative gas-firing is used at many zinc-works in Silesia and elsewhere, but it is gradually being abandoned in favor of plain gas-firing, as in the Boetius furnaces. This is because of the irregularities in the working of the Siemens furnace,—like those occasioned by the accumulation of coal tar and of zinc oxide (from breaking retorts, etc.) in the regenerative checker-work under the furnace, which interferes seriously with its operation,—and the more attention which it requires. Direct-fired furnaces are still used at some works (those working with forced draught being especially common in Upper Silesia), but the tendency at the present time seems to be for simple gas-firing, which gives a more uniform temperature in the furnace than direct-firing, and thereby a better yield of zinc and longer life for the retorts. On the other hand, there are none of the disadvantages of regenerative gas-firing.

The great improvement in furnace construction in recent years has been in building them more substantially than formerly, whereby their campaigns have been much increased. Nowadays a Belgian furnace may be expected to last for two or three years, and even more, whereas formerly but little more than half that time could be hoped for. In the early days (1844) of the zinc industry in Belgium only two months' regular operation of a furnace was possible.[*] The Silesian furnaces last longer than the Belgian, their average life being from three to four years. At the Hohenlohehütte it is claimed that the average is longer; and at the Wilhelminehütte in May, 1893, there was one furnace in course of reconstruction which had been in operation for six years.

The height and length of a zinc furnace are limited by the ability to heat the retorts or muffles to the proper temperature and evenly. Thus there are always some which are a trifle cooler than others, owing to their position, and which consequently make a trifle smaller output, though this is by no means so important in the gas-fired furnaces as in the direct-fired. The limit in furnace size according to European practice seems to have been reached already, as there has been no especially noteworthy increase recently, or indeed since the general introduction of the Siemens system. The retort furnaces of Belgium and Rhenish Prussia, however, have been far surpassed in dimensions by those at the Matthiessen & Hegeler Works at Lasalle, Ill.[†]

Distillation.—Oxide of zinc (ZnO) is reduced at a temperature of about 1300° C.; while metallic zinc melts at 400° C. and volatilizes at between 1000° and 1050° C. The metal is reduced, therefore, in the form of vapor, which is subsequently liquefied by cooling; in practice, by cooling to a point between 400° and 550° C.

It is uncertain whether the reduction of zinc oxide is effected by carbon or by carbon monoxide. The preponderance of evidence, however, seems to be in favor of the former. It has been shown that nearly pure carbon monoxide escapes from the condensers, which can be explained if the carbon forms only carbon monoxide ($ZnO + C = Zn + CO$), or if it forms carbon dioxide ($2ZnO + C = 2Zn + CO_2$) which is subsequently reduced again ($CO_2 + C = 2CO$). The latter process requires 73,000 heat units, while the former takes only 56,000, and is therefore more probable.[‡] A series of experiments to determine this point was made at

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[*] *Bulletin de la Société de l'Industrie Minérale*, 2me Livraison de 1888, p. 505.

[†] The Matthiessen & Hegeler Zinc Company kindly furnishes the following note concerning its works: "The ore treated consists of zincblende from Missouri, Kansas, and Wisconsin. The calcining furnaces are built in pairs with a common middle wall running lengthways. They have seven hearths of considerable length and moderate width, one above the other; they are heated with producer gases which are burned in flues alternating with the ore hearths in the lower part of the furnace, so that the fire gases do not come in contact with the ore. The calcination is aided by heating the air of oxidation by the waste heat of the fire gases. The ore is charged at one end of the topmost hearth, and carried by mechanical rakes successively over the full length of each hearth to the discharge end of the lowest, from which it falls into a bin. The gases from the roasting are delivered to a sulphuric-acid plant. The zinc furnaces, with cylindrical retorts four or six rows high, 56 to 72 retorts long, are arranged in pairs with a common middle wall. In the largest furnace massives there are 876 retorts. The furnaces are fired from gas generators with a light fan blast, the gases entering at the small end of the double furnace and passing through it lengthwise. The air of combustion, furnished by the same fans, is admitted at intervals along the furnace front, so that the combustion of the fire gases is a gradually progressive one, and the heat is practically uniform throughout the length of the furnace. There are tramway tracks along the front of each furnace to facilitate the work of charging and discharging. The fuel supply consists of the run of mine bituminous coal from a shaft in the same yard with the zinc works. The configuration of the surface allows of a very convenient arrangement in regard to transportation of coal, residue, ashes, etc. All the appointments of these works are locally developed, and quite different from those of other zinc works. By far the largest part of the zinc produced is rolled in the mill of the company and sold as sheet zinc."

[‡] Wagner's *Chemical Technology*, New York, 1892, p. 214.

the Wilhelminehütte (Upper Silesia), with very instructive results. In these the ore to be reduced and the reducing agent were charged into a muffle in different layers, separated by pieces of lime. The zinc oxide and carbon were not, therefore, in contact. The yield of zinc obtained from these muffles was so small that all could be attributed to the reducing action of carbureted hydrogen in the carbonaceous material.

Concerning these experiments Herr Bergrath Bernhardi, director of the Wilhelminehütte, wrote as follows :

"On the other hand, the remaining possibility that it is chiefly the solid carbon which reduces the zinc oxide is itself a great riddle. Solid bodies can act chemically on one another only by direct contact, and it is inconceivable that the zinc reduction process can be carried out in the muffle in this manner so completely as it is really done. We cannot imagine how every atom of zinc oxide in a piece of zinc ore can come in contact with an atom of solid carbon. Whether the active molecular movement of the glowing fragments of ore and carbon play a part in this, or whether at the temperature prevailing in the muffle there is formed a lower oxide of carbon (a compound of carbon and carbon monoxide), must remain undetermined. It has been proved, however, by many experiments and the results of actual practice that as intimate a mixture of ore and carbon as possible is desirable ; if the ore is too coarse or the charge is not well mixed, the yield of zinc falls off. The ore and reducing material must not be too fine, however, else the charge in the muffle will be too dense, and the gases developed will not have the necessary freedom of escape." *

The zinc vapor in the retort or muffle is forced by its own pressure into the condenser, where it cools and collects in liquid form. This part of the process is by no means perfect, and important losses of metal arise through failure of a part of the zinc to condense, which may happen especially if the receiver is too hot. If the hot zinc vapor is cooled too suddenly, however, it does not condense wholly in liquid form, but a part of it comes down in very fine solid particles, which are immediately enveloped with a film of oxide, wherefore it is impossible to collect the zinc in this form by remelting, and it is consequently necessary to re-treat it in the retorts or by a special process. In ordinary practice the amount of zinc powder formed varies from 5% to 10% of the weight of the metal produced, and it assays from 70% to 90% zinc. Ordinarily this is recharged into the coolest retorts of the furnace, being easily reducible ; sometimes, however, it is sold as zinc gray, which is valuable as a reducing agent in certain chemical work. One zinc works in Upper Silesia makes a specialty of this, but in most works the formation of this objectionable between-product is kept at the minimum to avoid the loss in its re-treatment.

The composition of the zinc gray found in the market is shown by the following analyses :

	I.	II.	III.
Zinc	29.59%	97.82%	40%
Zinc oxide	57.74	....	49.80
Iron	2.05	0.16	....
Lead	trace	0.23	2.50

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* *Denkschrift zur Feier des fünfzigjährigen Bestehens der Bergwerksgesellschaft Georg von Giesche's Erben gehörenden Wilhelmine-Zinkhütte zu Schoppinitz*, p. 25.

Cadmium	....	0.08	4.00
Arsenic	0.32	....	....
Antimony	0.37	....	...
Sulphur	0.03	....	....
Carbon	1.22	....	....
Zinc carbonate	....	....	3.30
Insoluble	9.61	....	0.40

The zinc dust is formed mostly at the beginning of the distillation, when the condensers are coolest. According to Thum, the formation is greater the higher the temperature of the retort and the smaller the cooling surface of the condenser in proportion to the velocity of the metal vapor entering it. If the condenser is run too cold, moreover, there is not only an increased formation of dust, but there is the danger of the solidification of the molten metal in the receivers—which is more dreaded than are hot condensers—and consequent loss of metal through incomplete condensation. It is always more likely, therefore, that the condensers will be too hot than too cold.

The retorts and condensers must be full of reducing gas in order to prevent reoxidation of the zinc vapor, and it is for this reason that a much larger proportion of carbon is used in the retort charge than is necessary for the reduction of the zinc. Theoretically one kilogram of zinc oxide should be reduced by 0.148 kilogram of carbon. In practice about five times that amount of coal is used.

In putting a zinc furnace in operation it is fired strongly for two or three days with empty retorts until white heat is attained. Charging is then begun, and the campaign continued without interruption until necessary to stop for repairs. The furnace does not begin to make its maximum output until several days after receiving the first charge, on account of absorption of zinc by the new retorts and loss of vapor through them.

The ore, ground to about 1 mm. or 2 mm. size (rather finer in Belgium than in Silesia), is mixed intimately with the reduction material, which is usually noncaking coal, alone or mixed with cinder from the gas-producers, or with finely crushed coke. It must be free from water, which oxidizes zinc vapor rapidly, and increases the formation of zinc powder. The ore is generally a mixture of several kinds, part being calcined calamine and part roasted blende, made up according to the ideas of the metallurgist in charge. Zinc metallurgists have not yet arrived at the point of calculating definitely the composition of a charge to give the best results, as in the treatment of lead and copper ores, and the mixtures are still based chiefly on the results of experience. However, this is a question to which much attention is now being given, and there is progress toward a more scientific system.

The charge for the retorts should be intimately mixed, for the reason previously explained. Sometimes this is done before crushing the ore to the desired degree of fineness, as at Angleur, where the ore and coal are passed together through a Vapart mill, which gives a product ground to 1.5 m. size and mixed thoroughly, but usually the ore and coal are dumped in piles in front of the furnaces and mixed by hand immediately before charging. In Belgium and Rhenish Prussia, where the ores treated average 40% to 50% zinc, the proportion of reduction coke in the charge is about one-half of the weight of the ore; the ores distilled in Upper Silesia are of lower grade, averaging only about 25% zinc, but nearly the same percentage of reduction coke is used as in Belgium.

At the works in Upper Silesia and in Rhenish Prussia the muffles are charged once in twenty-four hours; the same practice is now followed also at many works in Belgium, where the retorts are made somewhat larger than formerly. The charging is usually done in the morning. The liquid zinc having been drained from the condensers and cast into slabs, the necessary repairs are made to the furnaces with pieces of brick and clay, after which the leaky retorts are patched and the broken ones removed and new ones substituted. The latter have previously been "tempered" by heating strongly for twenty-four hours, which is usually done in kilns at the sides of the zinc furnace sheds, heated by the waste heat from the zinc furnaces. The hot retort carried on an iron bar is inserted into the furnace, which work requires two men, and the space in the inclosing niche around its front end is filled compactly with clay. The new retorts having been placed in position, the charge is introduced into each by means of long, narrow, scoop-shaped shovels. The condensers are then inserted and the joint sealed with clay. It may be said in passing that nowhere in Europe are there such excellent mechanical facilities for tapping and recharging the furnaces as at the best American zinc works, as, for instance, at Lasalle, Ill.; nor is there anywhere so large a furnace as at the Lasalle works.

The tapping and recharging is usually begun at about 5 or 6 A.M.; it will probably be 10 or 11 A.M. before it is completed. The furnace crew then go away except the stoker and one man per side to watch the furnace during the distillation.

The retorts in the same distilling furnace are charged differently, according to their position and consequently their temperature, the hottest receiving the heaviest charge. Easily reduced oxides—zinc powder and other between products—that are to be reworked are placed in the cooler retorts, while incompletely distilled ashes from a previous charge are mixed with fresh ore and re-treated in the hottest retorts. The variation of the retort-charges depends largely upon the judgment of the brigadier in charge of each furnace, and his skill—or the lack of it—has for this reason especially an important bearing upon the yield of the furnace. With the gas-fired furnaces now generally in use, however, the difference in the temperature of muffles in different parts of the furnace is not so great as with the old direct-fired furnaces.

As soon as the charge in the retort is heated sufficiently to develop carbonic oxide gas a bright flame appears at the end of the condenser, where the gas takes fire and burns. After about two hours there will be a greenish-white flame at the condenser end (brown at first if the ore is cadmium-bearing*), which is a sign that zinc is beginning to distill. The "ballons" are then placed on the condensers to collect the zinc oxide and powder, which would otherwise be lost. These are sheet-iron cans, with a small hole at the end for the escape of gas, and are merely a prolongation of the condensers, saving part of the zinc fume which is not liquefied in the condenser. After the zinc has begun to collect in the bellies of the condensers it is from time to time (two or three times during the distillation of a charge) withdrawn by means of a semicircular rake into a ladle, powdered charcoal being strewn on the liquid metal to prevent oxidation. The dross,

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* See article on "Cadmium" in this book.

which goes back into the retorts with the next charge, is then skimmed off, and the metal cast into slabs of the regulation size.

Condensers of the same kind as those now employed in Belgium and Rhenish Prussia were formerly used in Upper Silesia, where they replaced the old downward-turned pipes from which the condensed zinc dripped into receivers, which were originally adopted there. Nowadays, however, the Kleeman and Dagner condensers, or some modification of them, are used nearly everywhere in Upper Silesia.

The Kleeman condenser consists of a rectangular clay pipe bent at right angles so as to form an elbow. One arm, which is about one meter long, is placed horizontally and connected with the retort in the ordinary manner. The other arm, which is only about 0.1 m. long, sets vertically. Its upper end is covered by a grate on which a bed of coal, perhaps 0.1 meter thick, is burned. The outer end of the horizontal arm is made open, and is closed by a rectangular iron plate, the joint being tightly luted with clay. In the center of the plate there is a small round hole, which may be closed if necessary with a plug of clay. The whole arrangement is contained within the niche (capelle) of the furnace, no part projecting beyond the front wall. The zinc vapor condenses to liquid and collects in the horizontal arm of the pipe, whence it is tapped into ladles at proper intervals by removing the tile, which closes the outer end of the pipe. This opening also gives access to the muffle. The uncondensed zinc vapor passes up through the short vertical arm of the condenser and through the thick bed of coal burning above it. The object of this is to keep free oxygen from entering the condenser. It was also thought originally that the zinc fumes rising through the fire would be reduced and would run back into the condenser, but, on the contrary, it was found that they burned to oxide. The fumes and products of combustion escaping from the grates are conducted through a flue in the top of each niche to a common pipe above the furnace, whence they are led to condensing chambers.

The Kleeman condenser was first introduced in 1879, and was for a time generally used, but was subsequently replaced in most of the works by the Dagner type. The Kleeman is still used, however, at some works, particularly at those of the Schlesische Gesellschaft für Bergbau- und Zinkhüttenbetrieb at Lipine.

The Dagner condenser consists of a rectangular tube about one meter long on which rests another about 0.6 m. long, and on that a third, also 0.6 m. long. The outer ends of these pipes are closed by means of iron plates or tiles, which are luted tightly with clay, each plate having a small round hole in the center, sealed with clay. The three are connected by corresponding holes at alternate ends. The zinc vapor from the retort passes into the lowermost tube (connected with the retort in the usual manner), where it is for the most part liquefied; the uncondensed vapor passes into the middle tube, and then into the uppermost, following a labyrinthine course through the openings as described. It finally escapes through the outlet hole near the end of the uppermost tube, where it is ignited, burning to oxide with the characteristic green zinc flame. The condenser is entirely contained within the deep niche, which is distinctive of the Silesian furnace. In the top of the niche there is an opening through which the fumes of zinc oxide are drawn into a large pipe running longitudinally over the whole series of furnaces, whereby they are conducted to a condensing and collecting chamber outside the furnace house. An analysis of the zinc oxide deposited in the condensing chamber at Wilhelminehütte showed the following composition: ZnO, 88.20% (70.82% Zn); CdO, 1.46% (1.27% Cd); PbO, 4.44% (4.12% Pb); SO_3, 4.12%; Mn_3O_4, 0.05%; residue and Fe_2O_3, 1.50%—total, 99.77%.* This product is mixed with fresh ore and recharged into the muffles.

The zinc is tapped from the lowermost section of the condenser by removing the tile, which closes the end, and the zinc dust and oxide which collect in the two upper sections are removed in a similar manner. In case the zinc vapor has not a free passage through the channel of the condenser on account of an accumulation of zinc oxide, the way is cleared by a rod inserted through the small holes in the tiles which close the end of each section. Each niche contains two of these condensers corresponding to the two muffles. The space between the ends of the condensers is sometimes plastered up with clay in order to make a small combustion chamber within the niche itself, in which the burning of the zinc may be better regulated. The front of each niche is closed by a sheet-iron covering-plate, whereby the temperature of the condensers is governed and the escape of zinc fume is prevented.

The Kleeman and Dagner condensers have reduced the loss in zinc vapor by increasing the length of the cooling surface and making possible the recovery of part of the vapor which finally escapes. They have also done away with the formation of zinc dust. At the Antonienhütte, where zinc gray is prepared as a marketable product, the old-fashioned style of condensers with sheet-iron ballons is used in order to make it. The new condensers have also improved the sanitary condition of the zinc works, the escape of zinc vapor into the furnace house having been prevented by them.

The distillation process is disturbed by impurities contained in the ore, chiefly by those which at a high temperature have a corrosive action upon the muffles. The material of which the muffles are made being more or less silicious, it is usually the basic impurities of the ore that are the most destructive, especially the oxides of iron and manganese, which combine with the silica forming easily fusible silicates, whereby the walls of the retort or muffle are rapidly corroded. On account of this the value of a zinc ore is affected to an important extent by its tenor in iron and manganese. European smelters do not consider ore with more than 10% iron to be a desirable product to buy.†

Lead was formerly thought to be a very objectionable element in the retort, the opinion being that the oxide of lead would combine with the silica to form silicate of lead. One metallurgist wrote in 1880: "The influence of lead in any state is bad, the silicate formed thereby being very corrosive, while a large proportion of the metal passes into the spelter, of which the quality is injured. More than 2% lead should not be tolerated in a calamine, and a penalty of $1 per unit per ton of ore should be inflicted for any excess over that limit." Investigation has proved, however, that there is not much danger from lead silicate, and ores assaying high in lead are distilled with reasonable success. Some works, indeed, make a specialty of buying lead-zinc ores, and even pay a small price for the former

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* Kosmann, *op. cit.*, p. 210.

† The American smelting works of the Mississippi Valley draw the line much lower, making important reductions in the price of ores when the iron contents exceed three or four per cent.

metal when it exceeds a certain percentage, say 7 or 8. In distilling such ores a part of the lead is reduced and volatilized, going over into the condensers with the spelter, which is contaminated by it. The more part, however, remains behind in the zinc ashes, from which it is subsequently recovered by jigging. Ores with 52% zinc and from 6% to 7% lead are distilled at the Laminne works (Ampsin); the retort ashes and old retorts are screened and crushed finely in a Chilean mill; they are then jigged, whereby concentrates assaying 34% to 39% lead are produced. The same system is followed at the Austro-Belge works, where similar ores are treated. At Bleiberg zinc-lead ores with from 5% to 8% lead are distilled. The residues contain about 9% lead in the form of metallic globules, and some undecomposed galena, which is then concentrated to about 22% by jigging. At the Wilhelminehütte (Schoppinitz) one side of a furnace was charged regularly with calcined calamine, which averaged 10% lead (originally in the form of cerussite), but occasionally contained as much as 25%, while the other side of the furnace was run on ordinary ore. The result did not show any increase in the breakage of the muffles working on the lead-bearing ore, and afterward ore of this kind was regularly treated at the Paulshütte, the lead-holding ashes being subsequently smelted in shaft furnaces at the Walther-Croneckhütte at Rosdzin.*

The Silesian zinc ores generally contain some lead, and the spelter produced from them is always lead-bearing in consequence thereof. The reason that the oxide of lead in the retorts does not combine more readily with the silica, and indeed the reason that the presence of iron and manganese and other basic impurities is not more harmful than is actually the case, is due to the fact that the atmosphere within the retort or muffle is composed of carbonic oxide, and is, therefore, reducing in its action. The lead oxide in the calcined or roasted ore is reduced in the retorts and is found in metallic globules mixed with the unburned coke and ashes. There is danger of oxidation of the lead and formation of lead silicate corroding the retorts, however, when the air strikes in at the opening of the latter. The Belgian metallurgist would be slow, therefore, to undertake the distillation of charges containing more than 8% lead.

Loss in Distillation.—The loss of metal in distilling zinc is large compared with the loss in lead or copper smelting. It is seldom less than 10%, and often is more than 25%.† The loss in zinc distillation is incurred in so many ways that, unlike lead or copper smelting, it may be very different in two smelteries in both of which good work is being done.

The loss in distilling zinc may be attributed to the following causes, each of which is important to a greater or less extent: (1) Absorption of zinc by muffles, and filtration of zinc vapor through them into the combustion chamber of the furnace. (2) Breakage of muffles. (3) Escape of uncondensed zinc from condensers. (4) Undistilled zinc retained by ashes in the retorts.

A new muffle inserted in a Silesian zinc furnace does not begin to make its maximum output of zinc until several days after it has been placed in position.

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* Bernhardi, *op. cit.*, p. 28.

† Loss in distillation is sometimes referred to in terms of the ore; thus an ore assaying 50% zinc is said to yield 45%, 5% being lost, which is a loss of 10% of the metal contents of the ore. In this article losses are referred to the percentage of metal.

This is due in part to absorption of metal by the clay with which it combines as aluminate of zinc, forming an artificial zinc spinel. It is this compound that gives the deep blue coloration to old zinc retorts, which upon analysis may be found to contain 6% zinc or more. F. C. Degenhardt found that old retorts of the Bethlehem Zinc Works (Pennsylvania) sometimes had as much as 21.47% of zinc oxide, a series of analyses giving the following results: 21.47%; 18.09%; 15.72%; 10.72% ; 6.10% ; the first was dark blue and the last was nearly white.* The amount of zinc that may be lost in this manner may be calculated easily. The retorts 0.15 × 0.34 × 1.45 m. inside measurement used at a certain works in Rhenish Prussia weigh 70 kilograms. If an old retort should assay 6% zinc, therefore, it would hold about 4.2 kilos of metal. These works use 12,000 retorts per annum, which would mean a loss of about 50.4 tons of zinc in old retorts, or 0.63% on the output of 8000 tons of spelter. The ordinary Silesian muffle weighs about 250 kilos. The absorption of zinc by the retorts has been very much reduced, however, by the use of coke in their composition, and blue, old material is rarely seen lying around a Belgian or Rhenish works. At the small zinc works connected with the Muldnerhütte at Freiberg, Saxony, coke is used in making the muffles for the Silesian furnaces employed there, but in Upper Silesia it is never added to the clay.

A more important source of loss is the filtration of zinc vapor through the retorts, which are more or less porous until the inside surface has become fritted or slagged, and consequently more impervious to gas. The loss of zinc in this manner is increased by an excess of pressure inside of the retort, or a low pressure in the combustion chamber of the furnace, which there is likely to be with a strong draught. The reverse of these conditions, however, means the penetration of air from the furnace into the retorts, and the oxidation of zinc thereby. The retorts are frequently glazed inside with a wash of clay, soda, etc., to make them impervious, but the fabrication of them at great pressure, making them exceedingly dense, has been the most important improvement toward reducing loss in this manner.

Breaking retorts mean, of course, a large loss of zinc, since their contents at the time are volatilized and escape into the combustion chamber of the furnace. With regenerative furnaces this fume partly collects in the flues of the checkerwork, which thereby interferes with their operation.

The breakage of retorts at Angleur is about 2% of the whole number daily ; at Ampsin, where more corrosive ore is distilled, it is about 3% ; at Münsterbusch (Stolberg), about 2% ; at Hohenlohehütte, 2.5% ; at the Silesiahütte II. and III. (Lipine), 2.6%. Probably 2.5% is about the average in both Belgium and Upper Silesia. This is equivalent to an average life per muffle of 40 days. The reason that the machine-made retorts used in the West do not last longer than the hand-made muffles of the East is to be looked for in the more intense heat and the peculiar conditions to which they are subjected in the Belgian process. The increased life of the Belgian retorts through the improvements in their fabrication, however, has been very noteworthy.

The escape of zinc vapor from the condensers is an important source of loss.

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* *American Chemist*, 1875, No. 58, p. 355.

The metallurgist is confronted by the two alternatives of running with condensers too cold and producing a high percentage of zinc powder, which is a troublesome product, or running with condensers too hot, when a part of the vapor will fail to be liquefied and will burn at the end of the condenser with the brilliant greenish-white flame characteristic of zinc. The loss of zinc fume in this manner is reduced by the prolongs, or "ballons," of which there are many modifications based on the simple Belgian canister, and also by the use of the Kleeman and Dagner condenser, as in Upper Silesia. Notwithstanding these improvements, however, there is always an important percentage of zinc lost through imperfect condensation. At the time of opening the retorts or muffles, moreover, to withdraw the waste ashes, any zinc vapor which is still contained in the vessel is oxidized and lost. The total loss by the preceding causes (all due to volatilization) usually amounts to more than half the whole loss, from 10% to 15% of the metal contents of the ore being wasted in this manner in Upper Silesia.

The last important loss in distillation occurs in the waste ashes or residues in the retorts, from which the metal is never completely expelled, their tenor of zinc ranging from 2% to 8%. In Upper Silesia, where the ores distilled average about 20% zinc, the waste ashes should not assay much over 3% with good work, though they often go higher; but in Belgium, where the ore treated averages about 45% zinc, the ashes may contain 4% or 5%, the total loss in distillation, however, being much less in Belgium than in Silesia.

The degree of loss which shall be suffered in this manner is determined largely by economical considerations. In Upper Silesia it has been found impossible to obtain residues with as low as three per cent. zinc in less than twenty-four hours' distillation. In order to drive an additional percentage of zinc out of them would require a disproportionate expenditure of coal and an increase in the time. Some ores can be distilled more quickly and more completely than others, owing to their peculiar chemical composition or physical condition, but the extent to which it is profitable to carry the distillation is always governed by the cost. Rich residues are sometimes mixed with fresh ores and recharged in the hottest retorts of the furnace, whereby a part of their metal contents is recovered. The zinc held by undecomposed blende in the charge is irrevocably lost, however, and hence the necessity for a careful preliminary roasting and the attention devoted to that branch of the metallurgy of zinc. Each unit of sulphur combined with zinc in the roasted ore holds back two units of zinc in the retort.

The total loss in distillation varies usually between 10% and 25%. In Belgium and Rhenish Prussia, especially, the losses incurred have been much reduced in recent years. At the Vieille Montagne works, at Angleur, the average yearly loss in distillation is about 10%. At Münsterbusch (Stolberg) a loss of 10% is the standard, but ordinarily better work is done, each furnace crew being paid a premium on the yield of zinc in excess of the amount determined on the metallurgist's basis. The superintendents of some works in Belgium often claim to be effecting distillation with a loss as low as 7%, but these are probably exceptional results, and do not represent the outcome of a regular campaign. It may be confidently asserted that a loss of only 10% zinc represents the best average work that is being done in Belgium or Rhenish Prussia at the present time, and there are many works where it is higher. At Bleiberg it amounts to 13% or 14%; at Letmathe it is said to be from 10% to 18%; and at Bergisch-Gladbach, 10% to 13%.

In Upper Silesia the average loss in distillation in good practice may be set down as 25%, and this figure is frequently exceeded. At the Wilhelminehütte (Schoppinitz) the ore treated averages 20% zinc, and the loss in distillation is 21%; and at Hohenlohehütte the loss is 25%, with the same grade of ore. The small Silesian furnaces at Freiberg, in Saxony, are run on roasted blende containing 31% to 32% zinc, with a loss of about 18%.

It is interesting to compare present losses in distillation with those of previous years. The following are taken from Kerl's *Grundriss der Metallhüttenkunde*, 1881, and represent the practice of 1870–80: At Birkengang (near Stolberg), 15% to 18%; at Dortmund, 18% to 20%; at Stolberg, 18%; at Letmathe, 20%; at Engis, 22.5%; other Belgian works, 18%. These were works in Belgium and Rhenish Prussia distilling ores with 40% to 50% zinc, the three first mentioned using the Belgian-Silesian process, and the others the Belgian. Although comparisons are unfair without explanation of conditions, some idea of the progress in the metallurgy of zinc in the past twenty years may be derived from these figures. Where formerly losses of 18% to 22% were common in good practice, the average nowadays is probably only between 10% and 13%.

Cost of Production.—The cost of producing zinc depends upon three general conditions: (1) the cost of the ore, (2) the cost of treatment, and (3) the loss in treatment. The cost of production varies at different places, therefore, as widely as these elements vary, and general statements are of slight value. Nevertheless the data given under this caption will probably be of interest for comparison even in the absence of actual figures from the books of producers.

The cost of treating zinc ores for the recovery of their metal depends chiefly upon the cost of coal, wages of labor, and cost of refractory material, these being the principal items which enter into the total. The location of the works is indeed generally determined by these, and not by proximity to the supply of ore. In treating by the Belgian process 1000 kilograms of ore containing 50% zinc about 2000 kilograms of coal and 100 kilograms of fire clay are consumed. It is therefore cheaper to carry the ore to the coal than the coal to the ore. Hence the English zinc industry has become centered at Swansea, where the excellent Welsh coal is easily obtained; the Belgian works are nearly all in the Province of Liège, over the great coal basin; and the Rhenish are situated near the Westphalian coal beds. Ore goes to each of these places from countries so distant as Sardinia and Greece. Through fortuitous circumstances the ore and coal of Upper Silesia occur in close juxtaposition, but the works are built by the latter. The same is true in the Kansas-Missouri district of the United States (with one or two exceptions), but from there also the ore is carried at a high cost for freight to the great works in Illinois, which are built near coal mines.

The cost of Liège coal delivered at the works is 10@11f. ($2@$2.20) per ton; fire clay costs 12@13f. ($2.40@$2.60) per ton, also delivered. The cost for average labor is about 3.5f. (70 cents) per day, the maximum, paid to foremen, etc., being only 6f. ($1.20) per day.*

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* The average wages at Angleur in 1887 were 3.15f. (63 cents); in 1837 they were only 1.35f. (27 cents).

In Rheinland coal for combustion (Westphalian) costs 10@11 marks ($2.50@ $2.75) per ton, while reduction coal (anthracite fines from the washers) is obtained for 5 marks ($1.25); fire clay (imported from Belgium) costs 12 marks ($3). Wages range from 2 marks (50 cents) to 4 marks ($1) per day, the former being for trammers, etc., and the latter for the best class (furnace men). The furnace men are often paid on the premium plan, both in Rheinland and in Belgium, the premium being awarded according to the excess of output of a furnace over a certain calculated amount and for economy in the use of coal.

In Upper Silesia the best run of mine coal costs 8 marks ($2) per ton, from which figure the price ranges downward for inferior grades. The best fire clay is imported from Briesen, in Moravia (Austria), and costs 30 marks ($7.50) per ton at the works; other Moravian clay is obtained for 22 marks ($5.50); while the ordinary Silesian clay is bought for 15 marks ($3.75). The best class of labor is paid from 3 to 4 marks (75 cents to $1) per day, but women, who are paid considerably less, are used for much of the common work.*

A comparison of these conditions with those of the western districts of the United States shows that the American works have cheaper coal than in Liège, but it is inferior in quality; while fire clay is somewhat cheaper in Belgium than in the United States, and labor costs less than half as much.

The consumption of coal in Belgium averages from three to four tons per ton of metal produced; formerly it amounted to six or seven tons, which shows the great saving effected by modern furnaces and methods. In Upper Silesia the consumption of coal for fuel and in the muffles averages at present about 10 tons per ton of metal produced. About 40% of the weight of the ore is used as reducing agent in the muffles. Since it takes about seven tons of ore to make one ton of metal, the coal for reduction would amount therefore to about 2.8 tons per ton of metal, but part of this is cinder, or coke, from the generators. The total consumption of coal in Upper Silesia in 1870 was 19.16 tons per ton of metal, and in 1880 it was 12.41 tons.

The total consumption of fire clay in good practice in Belgium and Rheinland at works where the loss in retorts is about the average (*i.e.*, 2.5% daily) amounts to about 200 kilos per ton of metal produced, which includes all used for retorts, condensers, brick, and repairs to furnaces. The consumption of refractory material in Upper Silesia is somewhat less.

With respect to labor there is more variation. The present practice in Belgium, Rheinland, and Upper Silesia may be compared from the results of three works, where the practice is equally good, according to their different conditions. The first employing the Belgian system, with retorts charged with 28.5 kilos of ore, has one man at the distilling furnaces for every 14 retorts, 5.8 men producing 1000 kilos of metal. At the second (in Rhenish Prussia) the Belgian-Silesian system is used, retorts taking 34 kilos per charge, and there are 13.3 retorts per man, 4.8 men producing 1000 kilos of spelter. At the third works (in Upper Silesia) there is one man to 13.6 muffles, which take 103 kilos of ore, and 4.5 men per ton of spelter produced.

The men in charge of the distilling furnaces work a shift of twenty-four hours;

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* The women employed at the ore-dressing works in Upper Silesia receive 0.90 to 1.20 mark (22@30 cents) per day, working a 12-hour shift.

i.e., they are continuously in charge of the furnace through day and night. In Belgium and Rheinland at works where the retorts are charged once in twenty-four hours, a block of furnaces will be in the hands of, say, four crews, each of which attends to one-fourth of the retorts. Each crew consists of one brigadier or foreman, two smelters, and one trammer, who brings ore and coal from the storage bins and wheels away ashes, spelter, etc. There will also be two stokers for the four sections. The men report for work at about 5 A.M., and begin discharging and recharging retorts, which work is finished probably by 11 A.M., and certainly by noon. The smelters then go off, leaving one man per side, perhaps, to attend to the distillation. The two stokers work twelve-hour shifts, each firing for a block of furnaces, *i.e.*, from 200 to 240 retorts. The trammers work day shifts, and will be engaged in other parts of the works besides the furnace house. A similar system is followed in Upper Silesia, where five or six men run a double furnace of 64 or 72 muffles.

Zinc Refining.—The crude Silesian spelter always contains lead, the amount being generally from 1.75% to 2.25%. The crude spelter of the Wilhelminehütte carries about 3% lead, and that of the Hohenlohehütte the same amount. The Guidottohütte at Chropaczow, on the other hand, produce a comparatively pure metal, which contains only 1.3% lead.

Since more than 1.5% lead in spelter affects the malleability of the latter, it is necessary to separate the excess of the former metal. This is accomplished easily by virtue of the fact that zinc will not alloy with more than 1.3% to 1.5% lead, and any additional amount of the latter exists merely as a mechanical mixture, from which it will separate by gravity upon fusion, the sp. gr. of lead being 11.4 and that of zinc 6.8 to 7.3. This operation is effected in a reverberatory furnace 15½ ft. (4.7 m.) long and 6½ ft. (2 m.) wide, sloping about three degrees toward the flue, at which end there is a sump, about 2 ft. (0.567 m.) deep, in the hearth. The crude spelter is charged on the hearth near the fire-bridge, and melting runs down to the sump at the other end, where the lead settles to the bottom, whence it is drawn off through a pipe. The oxide scum is skimmed off the surface of the molten zinc, and is sent back to the muffles for redistillation. The clean zinc is then ladled into molds, the percentage of lead having been reduced from 3 to 1.5 or 1. The arch of the furnace is very low, and an excess of coal is used on the grates so as to keep a smoky reducing flame over the molten zinc, and thereby prevent oxidation. Such a furnace is capable of refining 9 tons of spelter per day with a consumption of about 900 kilos of coal.

The spelter ladled from the sump of the refining furnace nearest the underlying lead is richer in the latter metal than that near the top. This is usually cast into slabs separately, and sold as second-class metal. At the Silesiahütte (Lipine), however, experiments have been made recently on a somewhat large scale for the electrolytic refining of this product by the Nahnsen process. This process consists of the electrolysis of a mixture of sulphate of zinc and sulphate of potassium, or some other alkaline sulphate, maintained at a temperature of 122° to 140° F., with anodes made of the crude spelter, and the precipitation of impurities taken into the electrolyte from the anodes by means of zinc powder.* The electrolyte

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* English Patents 2225 (1892) and 2913 (1892).

contains 1.375 to 2.75 oz. (39 grams to 78 grams) of zinc sulphate and 10.75 to 5.375 oz. (304 to 152 grams) of the alkaline sulphate per liter. The amount of zinc powder necessary is calculated from the composition of the crude spelter; thus if the latter were contaminated with 1% copper the consumption of zinc powder for an output of 1000 kilos of pure zinc would be 11 kilos. A current of 0.5 to 1 volt and 120 ampères per square meter of anode is used.

The experimental plant at Lipine has been producing from 500 to 600 kilos of fine zinc per day, which assays 99.93% zinc, 0.06% lead, and 0.01% iron. The zinc-silver alloy obtained in the Roessler-Edelmann process of lead desilverization is also refined by electrolysis at Frankfurt-am-Main, and at Hoboken, near Antwerp. This alloy containing from 20% to 40% silver, 3% to 4% lead, 1.5% to 2% copper, and 76.5% to 54% zinc, together with small quantities of aluminum, iron, arsenic, and antimony, is freed from the surplus lead by liquation and is then electrolyzed, yielding a spelter containing 99.9446% zinc, 0.0099% iron, 0.0114% copper, and 0.0341% lead, with only traces of silver, arsenic, and antimony. It is noteworthy, however, that this electrolytic zinc is not so pure as the famous Bertha spelter, made at Pulaski, Va., by direct distillation from ore, of which a recent analysis showed 99.981% zinc, 0.019% iron, and only traces of lead and sulphur.* This spelter is made from ore assaying 47.61% oxide of zinc (36.08% zinc), 29.37% silica, 9.23% oxides of iron and aluminum, 4.54% carbonate of lime, 2.07% carbonate of magnesium, and 8.23% water.

The impurities most commonly found in commercial spelter are lead and iron, of which the former may exist up to 1.5% without much affecting the quality of the metal for ordinary purposes. Only 0.25% of iron, however, makes the zinc hard, and necessitates great care in rolling. Cadmium, of which there is sometimes as much as 0.3% in Silesian spelter, has no important effect on the metal when in small amount. The less common impurities, arsenic, antimony, tin, sulphur, and copper, have generally a bad effect on zinc, making it hard and brittle.

The following analyses show the average composition of Silesian zinc: †

	I.	II.	III.	IV.	V.
Lead	1.4483%	1.7772%	1.1921%	0.633%	0.541%
Iron	0.0280	0.0280	0.0238	0.032	0.010
Cadmium	0.0245	......	......	0.054	......
Copper	0.0002	......	0.0002	trace	......
Silver	0.0017	trace	0.0007	trace	......
Arsenic	trace	......	......	......	......
Antimony	......	trace	trace	......	trace
Bismuth	......	......	trace	......	......
Sulphur	trace	0.0020	trace	trace	......

I. From Georgshütte. II. From Georgshütte, marked CH. III. From Bergwerksgesellschaft G. von Giesche, etc. IV. From Sagorhütte (Austria). V. From Sagorhütte (Austria).

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* Moxham, *Engineering and Mining Journal*, Nov. 25, 1893.

† Analyses I.-IV. by Schneider and Peterson, Wagner's *Chemical Technology;* V., Prcivoznik, *Mittheilungen aus dem K. K. General Probiramt in Wien*, 1890-91.

ZINC MINING IN MISSOURI AND KANSAS.

By J. R. Holibaugh.

The discovery of the zinc-ore deposits of southwestern Missouri was brought about by the development of the lead mines of that district in 1870 and 1871. In the summer of 1872 W. S. Mesplay visited the mines which were being opened along Joplin and Turkey creeks and what is now the north part of the city of Joplin, and noticing the piles of black-jack that the miners had thrown aside as waste from their lead ore recognized it as zinc ore, and wrote an article on the subject, which attracted some attention. Peter Blow, superintendent of the Granby Mining and Smelting Company, then commenced to make investigations, and had samples of the ore analyzed in St. Louis. He informed Lee Taylor of the value of the hitherto considered worthless black-jack, and the latter purchased some of it from the miners at $3@$4 per ton. The first shipment of ore from the district was made by Patrick Murphy and E. D. Porter in the autumn of 1872, who sent a lot of about 20 tons to Lasalle, Ill.

The lead and zinc district of southwestern Missouri includes not only the southwestern corner of that State, but also the southeastern corner of Kansas, and extends into the northwestern corner of Arkansas and the northeastern corner of the Indian Territory. The largest area of the mineral district, however, is in Missouri.

As this district was opened and developed without much assistance from capital, the methods adopted for mining and treating the ore were of necessity primitive, and even up to the present time have been carried on chiefly under the lease and royalty system. An owner of a tract of mineral-bearing land divides it into lots or claims 200 ft. square and throws them open to lease under certain rules and regulations, which he prescribes in accordance with a State law, approved March 26, 1877. Sometimes a company will lease a tract of land for a long term of years, divide it into lots, and let them out to individual miners, or smaller companies, at an advanced royalty. The shafts sunk to open the ore bodies are usually small, seldom being more than 3½ by 4 ft. or 4 by 5 ft. in size.

The zinc ore first produced in the district came entirely from bowlders associated with the lead ore, which required but little dressing; as the demand for zinc ore increased, however, the miners turned their attention to that, taking out the ore mixed with chert, which had to be concentrated. The latter was done at first by dumping over a coarse screen and washing the fines in sluices. This slow and wasteful method was superseded by hand-jigging, which system is still in use. The hand-jigs employed in Joplin consist of a tank 5 by 6 by 3 ft., with a jig-box 2 by 5 ft. and 8 in. deep working inside of it. The jig-pole is 16 to 18 ft. long. There are some small and rude plants equipped with Blake crushers, Cornish rolls, and mechanically-driven jigs, and within the past few years the mine owners have commenced to erect better designed dressing works, of capacity varying from 30 to 200 tons of crude ore per day.

The Joplin ore varies much in grade; some ore bodies yield as much as 75% to 80% of mineral, while in others the average is not over 10%. It is difficult, therefore, to arrive at the average cost of production in the district, but this is probably not less than $14 per ton of dressed mineral.

The ore of the Joplin district is for the most part blende, but considerable calamine and smithsonite are produced by the mines at and near Carthage, in Jasper County, Missouri, while those of Aurora, in Lawrence County, Missouri, are large producers of willemite.

ZINC MINING IN NEW JERSEY.

BY J. A. VAN MATER.

MAJOR A. C. FARRINGTON, after industrious historical research, reported to the president of the New Jersey Zinc Company, under date of Nov. 1, 1852, that "it is a fact, pretty well established by history, that about 1640, while New York was held by the Dutch, a colony of miners from the Duchy of Nassau settled on the Minisink flats, upon each side of the Delaware River, and worked the copper mines at Paquarrhy, sending their mineral to the Hudson River at Esopus, now Kingston. The zinc mines are situated in almost a direct line between Kingston and Paquarrhy, and from their prominent position would have attracted the attention of persons acquainted with mining: but if the large amount of labor that was performed here was by these old German miners, it would be interesting to know for what object they mined, as the remains of their works show it was not zinc they sought, for their excavations were not on the zinc vein.

"Lord Sterling (who at one time owned the mines at Sterling Hill) caused a large quantity of the franklinite ore to be mined and taken to the Charlottenburg furnace, of which he was a proprietor; but the attempt to smelt it as an ore of iron proved unsuccessful, and most of the ore, removed at a great expense over mountain roads, ninety-five years ago, may now be seen at Charlottenburg.

"The red zinc ore of Sterling does not appear to have been understood, or known as an ore of zinc by the local miners. We have current traditionary accounts of its being called an ore of copper. About eighty years since, a number of tons were shipped to England through the agency of a mercantile house in New York, of which Peter Van Brugh Livingston was a prominent member. But we can find no record of returns, or results that attended this commercial venture. It is fair to presume, however, that cabinet specimens of red zinc ore, now found in several English collections, the history of which has been lost, and have been attributed to certain localities in England, where nothing of the kind can now be found, was once a part of this shipment.

"The late Dr. Bruce of New York was the first who called public attention to these mines, by publishing a scientific account of them, embracing an analysis, and also furnishing a list of associated minerals. He was followed in 1819 by Professors Keating and Vanuxem, who furnished the Philosophical Society of Philadelphia with an interesting paper describing the jeffersonite associated with the zinc and franklinite."

Character.—The zinc ores of New Jersey differ from those found in any other part of the world, and have made the places where they exist famous among geologists and mineralogists; they are complex, consisting of a mechanical combination of the minerals zincite, willemite, and franklinite. The zincite, red oxide of zinc, is of a deep red color, varying in some specimens to orange yellow. Its streak is orange yellow, luster non-metallic, hardness about that of limestone, and sp. gr. 5.4 to 5.7. It contains from 72% to 80% of zinc, and in all cases carries manganese, which gives the red color. Willemite, silicate of zinc, varies in color from apple-green to yellow, red, and brown, in all their various shades. Its sp. gr. is 3.9 to 4.2, streak colorless, and hardness nearly that of feldspar. It contains from 60% to 72% oxide of zinc and 22% to 27% silicic acid, together with oxide of iron and manganese. Upon exposure to the weather this ore becomes brown from the contained manganese. The franklinite is an iron-black mineral, of a metallic luster, about as hard as feldspar, and slightly magnetic; its sp. gr. is 5.05 to 5.16. It is composed of about 66% oxide of iron, 18% oxide of zinc, and 16% oxide of manganese; but it is a variable mineral, and no two specimens show the same analysis.

Formerly only the red oxide of zinc was mined, as that was the only ore from which the zinc could be profitably extracted. The franklinite and willemite were at that time collectively called "franklinite ore," and, in spite of many experiments, were not successfully smelted until the discovery of the lime process.

These ores were first supposed to be more valuable for iron than for zinc, but since the invention of improved methods of treatment they have become most valuable for zinc, though their iron and manganese contents are both recovered as by-products.

Occurrence.—The New Jersey zinc ores occur in beds in the white limestone which extends across the State from Pennsylvania to New York. They have been found in workable quantities only at Sterling Hill, Ogdensburg, Sparta Township, and at Mine Hill and Franklin Furnace, Hardyston Township. At Sterling Hill the bed has dips about 45° southeast, and pitches about 60° northeast.

The southern part is owned and worked by the Passaic Zinc Company through two incline-shafts upon the dip of the bed. The northern portion is owned and worked by the New Jersey Zinc and Iron Company through an incline-shaft which is also upon the dip. This mine has been idle during the past year, there having been a large surplus upon the bank, which is now being shipped to the works. The mine is over 500 ft. deep along the dip. At Sterling Hill the red oxide of zinc is the predominant constituent of the ore, and as it was the only kind that could be treated formerly, this bed was the first opened.

At Mine Hill, where the ore is chiefly franklinite and willemite, the bed dips southeast 60° with a pitch of about 27° to the northeast. This bed has been proved 3000 ft. in length, and 700 ft. in width in its widest portion. These are surface measurements, but if calculated along the dip and pitch the figures would be materially increased. The thickness varies from a few feet to 60 ft.

The south end of this deposit is owned and worked by the New Jersey Zinc and Iron Company through an incline-shaft on the dip and a slope on the pitch. The shaft is down about 350 ft., but most of the mining is being carried on at about the 250-ft. level. Here the bed is folded upon itself, and the space between the walls (55 ft. to 85 ft.) is filled almost entirely with rich ore, the waste being insignificant. The middle portion of the bed is owned and worked by the Lehigh

Zinc and Iron Company through two incline-shafts upon the dip. This mine is about 500 ft. deep on the dip. The north end of the bed is being developed by the Sterling Iron and Zinc Company through a vertical shaft which is now being sunk. It is already 775 ft. deep, and will be continued to a depth of 1100 ft.

This ore deposit at Mine Hill is undoubtedly the most valuable in the State, and its magnitude and value are just beginning to be fully appreciated. Underhand stoping is the universal practice in this section.

Value.—As both of the producing properties are owned by companies which have their own smelting works, no ore finds its way into the general market, and hence there are no quoted market prices.

Uses.—Until recently the ore was used entirely for the production of zinc-white (white oxide of zinc) by the direct process, whereby the zinc oxide is driven off and collected in bag-rooms after being cooled, and then spiegeleisen (ferro-manganese) is recovered from the residue in the bottom of the furnaces, but recently Mr. G. G. Converse, superintendent of works for the Lehigh Zinc and Iron Company, patented a process by which a high-grade spelter is made direct from these ores, which is almost chemically pure, and which finds a ready sale in the market.

Production.—The production of zinc ore in New Jersey has been greatly restricted during the past year (1893) by the general business depression. The total shipments from these two localities, which are the only mines of the kind in the State, amounted to 59,300 long tons. By private arrangement a portion of the ore extracted at Mine Hill is shipped to the Passaic Zinc Company to mix with its Sterling Hill ore.

TREATMENT OF FRANKLINITE.

BY TITUS ULKE.*

THE franklinite ore of New Jersey is a complex ore, composed of franklinite, willemite, and calcite in varying proportions, together with occasional and smaller quantities of zincite, tephroite, garnet, fowlerite, and a few other minerals. As it comes from the mines the ore varies widely in composition, but the following will serve as an example: Iron sesquioxide, 32.06%; manganese protoxide, 11.06%; zinc oxide, 29.35%; carbonate of lime, 12.67%; silica and insoluble matter, 14.57% —total, 99.71%. The mineralogical composition of this ore may be calculated as follows: Franklinite, 51.92%; willemite, 31.58%; calcite, 12.67%; zincite, 0.52%; tephroite and other silicates, 3.31%—total, 100%. The sp. gr. of these minerals is as follows: Zincite, 5.43 to 5.70; franklinite, 5 to 5.09; tephroite, 4 to 4.12; willemite, 3.89 to 4.18; calcite, 2.50 to 2.77.

Before shipment from the mines this ore is crushed so as to pass an 8-mesh sieve (2 mm.) and concentrated on Harz jigs and round tables. The concentrates, which consist of the zinc minerals, are shipped to the zinc works at Bethlehem, Penn., where they are separated into two classes, one of which goes to the spelter furnaces and the other to the oxide of zinc department. This separation is

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* Acknowledgment is due Mr. S P. Wetherill, Manager Lehigh Zinc and Iron Company, for kindly furnishing valuable information.

effected by the Converse process, which is as follows: The ore is mixed with 20% of its weight of anthracite coal, and charged into a brick-lined revolving furnace, heated by gas from a Taylor producer. The furnace is run at such speed and heat that the ore becomes bright red. The hot ore is discharged into a revolving cooler, on the outside surface of which water is sprayed. The cool ore is raised to storage hoppers, whence it is drawn as needed and passed over a series of magnetic separators. The non-magnetic mineral is used for the manufacture of spelter, while the magnetic goes to the oxide furnaces. The former contains 46.38% zinc, 3.76% iron, and 6.68% manganese. The latter contains 29.66% oxide of zinc, 37.20% iron, and 9.34% manganese. The high-grade "Sterling" brand of spelter is made from the former class of ore.

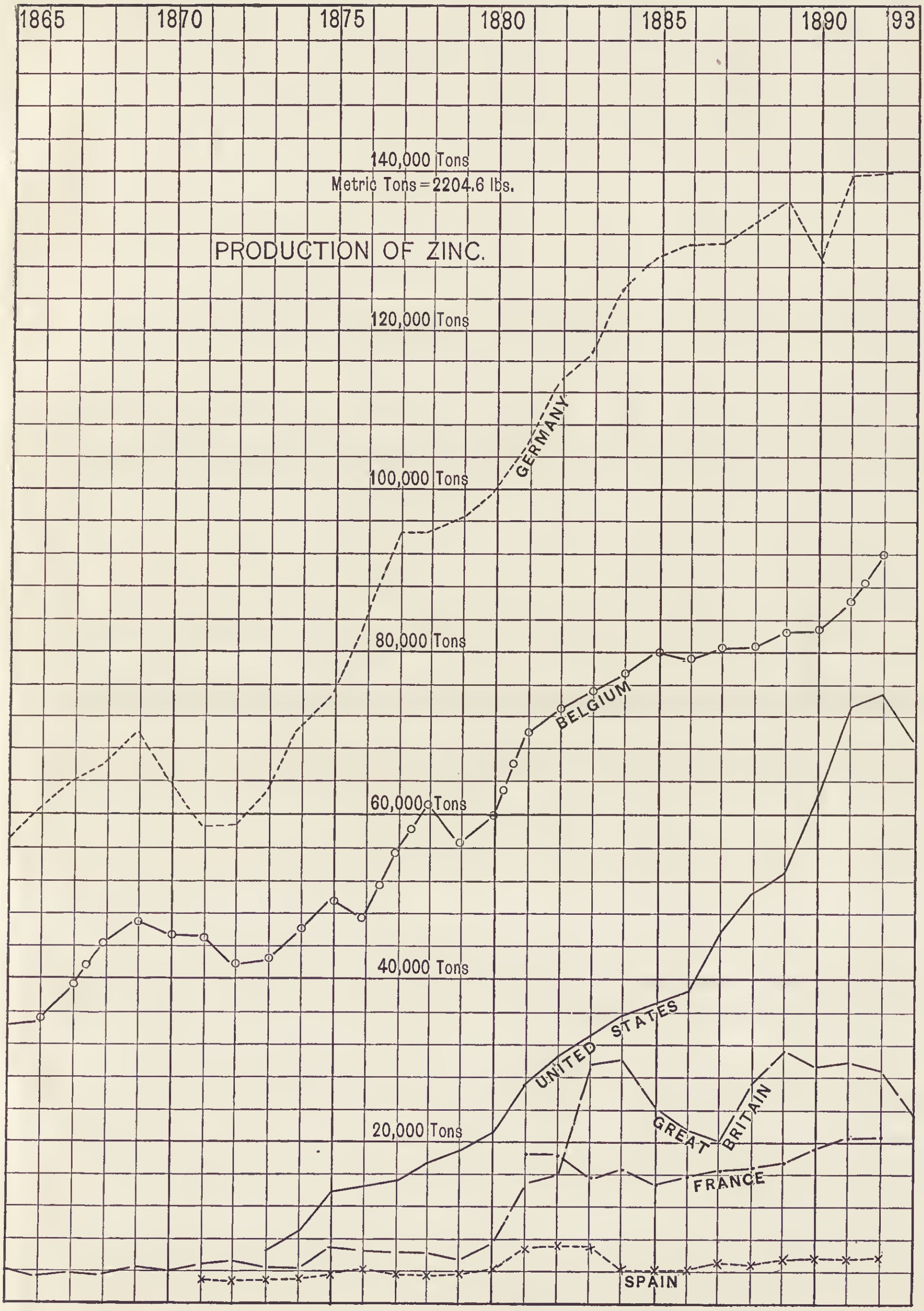
The oxide furnaces have a cast-iron grate 4 ft. wide and 10 ft. long, above an ash-pit into which cold air is blown at a pressure of from 2 to 4 in. water-gauge. The grate is covered lengthwise by a firebrick arch, and each end is closed, except openings for charging. The products of combustion escape through holes in the arch.

In operation a thin layer of anthracite coal is placed on the grate, and allowed to burn until well ignited. The ore mixed with an anthracite coal is then spread in a layer 5 to 7 in. thick over the ignited fuel and the doors at each end of the furnace are closed, when the blast is slowly admitted under the grate and increased to the maximum as required. At the end of six hours the operation is completed, 83% of the zinc having been volatilized and driven off as oxide, the remaining 17%, together with all the iron and manganese, being in the residue on the grate.

A series of these furnaces are built in a row. Two sheet-iron pipes from each convey the zinc oxide fume to a common pipe, through which it passes to a brick tower, where the heavy particles of ash carried over by the blast settle. The fume is then passed to another tower, where more ash settles. The purified fume is forced by a fan into a cooling room, on the floor of which the first marketable oxide is collected, and then goes to the bag-rooms, where there are four rows of distributing pipes in each room, with nineteen muslin bags descending from each pipe. The products of the combustion of the fuel contained in the fume strain out through the bags, while the condensed oxide of zinc collects inside, whence it is shaken to the bottom night and morning. The oxide is bolted in order to make a uniform product, and is finally packed in barrels holding 200 lbs., in which it is sold.

The residue remaining on the grate bars is smelted in a blast furnace 35 ft. high, with a 9-ft. bosh, from which the iron and manganese are obtained as spiegeleisen. The zinc in the material is reduced in the lower part of the furnace, and is volatilized and oxidized in the upper part, where it collects in scaffolds on the sides. So far as present practice has gone, 40 ft. furnace height is the limit to which the gases retain sufficient heat to carry enough zinc out of the furnace to permit continuous working.

The escaping gases, which are heavily charged with zinc fumes, are passed through condenser pipes, where they settle against the cold sides and are removed three times a week. The furnace connects with two separate sets of condensers, so that while one is in use the other can be emptied. This oxide is yellowish-brown in color, and can only be used for the manufacture of metallic zinc.


1865
1870
1875
1880
1885
1890
'93
140,000 Tons
Metric Tons = 2204.6 lbs.
PRODUCTION OF ZINC.
120,000 Tons
100,000 Tons
80,000 Tons
60,000 Tons
40,000 Tons
20,000 Tons
GERMANY
BELGIUM
UNITED STATES
GREAT BRITAIN
FRANCE
SPAIN

THE MINERAL STATISTICS BY COUNTRIES.

In the following tables are collected the statistics of production, imports and exports of minerals, metals, and other mineral products of nearly all the countries of which the statistics were not given in the first volume of The Mineral Industry. Under the title of each substance will be found in this or in the first volume of The Mineral Industry the full statistics of that substance and information concerning its production in each country. Though it is sought in this work to avoid repetition of tables as far as possible, yet since it is desirable to have in collected form the statistics of the mineral industry of each country by itself as well as of each substance for all countries, the following tables summarize these national statistics conveniently for reference. The reader should in all cases refer to the subject article in each volume of this work to get the detailed information concerning the world's production, etc., of the particular substance.

While the following tables, and those in the first volume of The Mineral Industry, are extremely condensed in form, they yet contain, in nearly every case, the full statistics of the industry in each country from the earliest period at which such statistics were compiled. The utmost care has been taken to use only the most authoritative figures. As later statistics are obtainable the blanks in the tables will be filled in future editions of this work, and tables of errata will be published for the use of those who have this first edition. Future volumes will supply any omissions yet existing, carry forward the statistics already given, and will take up the industrial statistics of costs, and study the conditions which affect the development of the industry in the various countries.

Thus each succeeding volume will not only be complete in itself and contain records of the utmost value to all interested in the industry, but it will also render more and more valuable the information given in those volumes which preceded it. The series will form a comprehensive history of the industry and give the conclusions arrived at from a serious study of the economic results.

Since the information given in this volume supplements, and does not repeat, that given in the first volume of this work, the reader should in all cases refer also to Vol. I., the table of contents of which is reproduced in the fore part of this book. It is greatly to be desired that some uniform system of recording mineral statistics and valuing mineral products be adopted in all countries, and we trust this work will lead to earnest effort in this direction.

AUSTRALASIA.

THE mineral industry of Australasia has shown a remarkable increase, both in the quantity and variety of its products, within the past ten years, the value of the total output having increased over 100%. New South Wales is the most important of the colonies. Its mineral output in 1892 was valued at over $26,000,000. The principal product of New South Wales is coal, of which 3,841,842 tons, valued at $7,311,942, were produced, and 2,560,767 tons exported. This represents the entire coal production of Australasia, with the exception of 343,107 tons, of which 269,354 tons were produced in Queensland. The most important single product of the colonies is gold, the production in 1892 being almost $35,000,000. Of this, $13,089,120 came from Victoria. This is $1,561,140 more than in the preceding year, but $2,483,240 less than the production of 1884, which has not since been equaled. Queensland is the second in order of gold production. In 1892 it yielded $12,311,160, an increase of $782,380 over 1891, and a gain of 173% over the production in 1882. The maximum was reached in 1889, when the output was $14,782,060. New Zealand is the third greatest producer, the output in 1892 being $4,773,720. While this is but little less than the product of the preceding year, and about the average of the period from 1882 to 1892, it is less than in 1866, which was $14,222,585.

The only two of the Australasian colonies in which the production of silver and silver-lead has attained any importance are New South Wales and Tasmania. In New South Wales the output increased in value from $917,150 in 1881 to $12,389,180 in 1892, through the output of the Broken Hill mines. The production of copper and copper ore has been declining for some years past. The output in 1891 of South Australia and New South Wales, which are the important producers, amounted to 7531 metric tons of ingots, valued at $1,870,100, and 13,921 metric tons copper ore, valued at $331,950. Tasmania has large deposits of copper ore at Mount Lyell, which seem likely to bring that colony forward as a source of supply of copper. There has been a notable decrease in the production of tin and tin ore in New South Wales and Queensland, though the output of Tasmania has remained up to the average of the past ten years.

Among the new industries in the colonies are the production of cobalt, lead, manganese, and zinc in New South Wales, gems and opals in Queensland, and tin ore in Western Australia. None of these has yet attained importance. Australasia has a magnificent future in the mineral industry.

MINERAL PRODUCTION OF NEW SOUTH WALES. (*a*) (IN METRIC TONS.) (£1 = $5.)

Year	Alunite.		Antimony Ore.		Bismuth		Coal.		Coke.		Cobalt.		Copper, Ingots.		Copper Ore and Regulus.	
1858.	...	...	...	...	...	...	219,881	$810,810	...	...	...	...	...	...	59	$7,000
1859.	...	...	...	...	...	...	313,175	1,021,855	...	...	...	...	30	$2,890	...	...
1860.	...	...	...	...	...	...	374.806	1.132,465	...	...	...	...	...	...	44	7,675
1861.	...	...	...	...	...	...	337.574	1,094,100	...	...	...	...	...	...	146	16,950
1862	...	...	...	...	...	...	481.194	1,526,170	...	...	...	...	...	...	216	28,710
1863.	...	...	...	...	...	...	440,875	1.181,150	...	...	...	...	23	8,400	116	2,100
1864.	...	...	...	...	...	...	557,851	1,350,855	...	...	...	...	55	26.150	...	...
1865.	...	...	...	...	...	...	594,952	1,371,515	...	...	...	...	251	79,100	22	2,725
1866.	...	...	...	...	...	...	786,703	1,620'245	...	...	...	...	259	94,525	23	9,425
1867.	...	...	...	...	...	...	782,409	1,713,275	...	...	...	...	399	150,945	0.1	25
1868.	...	...	...	...	...	...	969,594	2,089,045	...	...	...	...	654	116,485	175	20,000
1869.	...	...	...	...	...	...	934,582	1,730,730	...	...	...	...	2,012	373,025	106	10,350
1870.	...	...	...	...	...	...	882,548	1,584,180	...	...	...	...	1,010	328,355	6	300
1871.	...	...	...	...	...	...	913,254	1,581,700	...	...	...	...	1,372	437,895	96	6,485
1872.	...	...	...	...	...	...	1,028,726	1,980,990	...	...	...	...	1,052	463,680	424	65.760
1873.	...	...	...	...	...	...	1,212,067	3,328,735	...	...	...	...	2,840	1,187,060	52	8,450
1874.	...	...	...	...	...	...	1,325,616	3,951.120	...	...	...	...	3,693	1,557.595	530	68.105
1875.	...	...	...	...	...	...	1.351,138	4.097,145	...	...	...	...	3.577	1,486,670	160	21,780
1876.	...	...	...	...	...	...	1.341.169	4,016.501	...	...	...	...	3,156	1,215,710	172	34,180
1877.	...	...	...	...	...	...	1,467,524	4,294,992	...	...	...	...	4,220	1.535,905	366	85.225
1878.	...	...	...	...	...	...	1.600 862	4.604.682	...	...	...	...	5,063	1,687,045	240	38,745
1879.	...	...	...	...	...	...	1,608,873	4,754.395	...	...	...	...	4,172	1,282,185	37	4,575
1880.	...	...	...	...	...	...	1,189,785	3,076.683	...	...	...	...	5,347	1,796,300	134	23,995
1881.	...	...	...	...	...	...	1,798,088	3.016.241	...	...	...	...	5,447	1.750,435	135	24,875
1882.	...	...	...	...	...	...	2,143,241	4,744.825	...	...	...	...	4.943	1,609,435	94	14.200
1883.	...	...	382	$27,775	4	$3,250	2.562,052	6,209,708	...	...	...	...	9.016	2,872,485	86	13.520
1884.	...	...	441	32,290	15	13.850	2,793,370	6.515 385	...	...	...	...	7,404	2,078.005	19	2,890
1885.	...	...	298	21 480	14	18.500	2,925.213	6.701,063	...	...	...	...	5,838	1.324,525	0.75	75
1886.	...	...	277	16,905	21	19,350	2 875,741	6.515,821	...	...	...	...	4.033	832,145	59	6.180
1887	...	...	171	8,205	37	33,475	2,969 549	6,732.200	...	...	...	...	4.536	978,760	304	16,750
1888.	...	...	193	14,590	18	19,555	3,255 019	7,275,991	...	...	...		3.847	1,360,550	115	14.620
1889.	224	$15,000	225	16,720	43	56,745	3,714,488	8,164 244	...	...	...	...	4,048	1,016,595	201	16.610
1890.	715	9,440	1,043	101,200	2	1,530	3,110,156	6,395.445	31.598	$205,735	...	.	3.216	817,685	590	48,870
1891.	834	16,420	930	110,285	40	500	4,162,940	8.713.978	30.798	172,365	1.2	$2.350	3.922	959,390	676	66,075
1892.	..	...	740	73,400	14	5,400	3,841,842	7,311.942	8,026	44,260	77	5,550	3,592	802,365	1,320	136,165
1893.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Year.	Gold. (*c*)		Iron. (*b*)		Iron Oxide.		Lead.		Limestone Flux.		Manganese.		Shale.	
1858	8.920.56	$5,520,870	...	...	...	...	...	...	...	...	...	...	...	...
1859	10,244.51	6,295,637	...	...	...	...	...	...	...	...	...	...	...	...
1860	11.945.58	7,326,865	...	...	...	...	...	...	...	...	...	...	...	...
1861	14,484.67	9,030 858	...	...	...	...	...	...	...	...	...	...	...	...
1862	19,925.91	12,338,899	...	...	...	...	...	...	...	...	...	...	...	...
1863	14.497.92	8,980.851	...	...	...	...	...	...	...	...	...	...	...	...
1864	10,533.66	6,524.632	...	...	...	...	...	...	...	...	...	...	...	...
1865	9,963.11	6.156,214	...	...	...	...	...	...	...	...	...	...	579	$12,750
1866	9,020.60	5,582,018	...	...	...	...	...	...	...	...	...	...	2,814	40,750
1867	8.456.72	5,267,891	...	...	...	...	...	...	...	...	...	...	4,145	76,245
1868	7,952.11	4.973,325	...	...	...	...	...	...	...	...	...	...	17,225	244,080
1869	7,822.38	4,870,743	...	...	...	...	...	...	...	...	...	...	7,621	93,750
1870	7,491 65	4,655,082	...	...	...	...	...	...	...	...	...	...	8,718	137,850
1871	10.065.53	6.252,424	...	...	...	...	...	...	...	...	...	...	14,937	170,250
1872	13,223.21	8,217,909	...	...	...	...	...	...	...	...	...	...	11.218	143,500
1873	11,254.93	6,975,877	...	...	...	...	...	...	...	...	...	...	18,137	252,375
1874	8,423.68	5,201 643	...	...	...	...	...	...	...	...	...	...	12,295	136.500
1875	7,181.35	4,388,470	...	...	...	...	...	...	...	...	...	...	6,266	77,500
1876	5,207.15	3,065,952	...	...	...	...	...	...	...	...	...	...	16,246	239.970
1877	3,860.32	2,357,091	...	...	...	...	...	...	...	...	...	...	19,268	232.620
1878	3,722.06	2,150,165	...	...	...	...	...	...	...	...	...	...	24,763	286,055
1879	3,410.52	2,036,093	...	...	...	...	...	...	...	...	...	...	33.043	334.653
1880	3,688.93	2,207.717	...	...	...	...	...	...	...	...	...	...	19.510	223.624
1881	4.653 99	2,832,565		...	...	...	...	...	...	...	...	...	28 343	203,740
1882	4,369 15	2,632,608	...	...	...	...	...	...	...	...	...	...	48,839	420,570
1883	3,850.83	2,292,514	3,489	$134.540	...	...	...	...	...	...	...	...	50,043	454,307
1884	3,334.29	1,976,458	3 820	122,860	...	...	...	...	...	...	...	...	32,127	360.880
1885	3,226.60	1,893,325	4,243	128,965	...	...	...	...	...	...	...	...	27.904	336,195
1886	3,154 44	1,831,472	3,745	95 340	...	...	...	...	...	...	...	...	44,264	499.880
1887	3,430.40	1,972,894	2,751	72,715	...	...	...	...	...	...	...	...	40,654	438.805
1888	2.721.69	1,585.498	3,807	118.605	...			...	...	...	...	...	35,430	368 060
1889	3,724.98	2.170.352	2,171	91.650	497	$6,645	531	$33.555	...	...	...	...	41.214	388,334
1890	3 973.85	2,301,424	3,468	199,740	457	4,420	128	7,935	42,104	$209,945	102	$1,625	56,912	520,517
1891	4.769.36	2,791,528	4,192	180.505	233	2.170	194	10,125	75,249	326,785	140	1,700	40,998	390.800
1892	4,879.13	2,845,889	2,827	113,025	460	4,345	72	3,630	105,032	465,155	16	235	75,392	680,395
1893	...	...	...	...	...	...	...	...	...	...	...	...	...	...

(*a*) From *Annual Reports of Department of Mines and Agriculture*, Sydney. (*b*) Not manufactured from the ore, but old iron. (*c*) For the production prior to 1858, see table on p.

MINERAL PRODUCTION OF NEW SOUTH WALES.—*Continued.*

Year.	Silver.(*d*)	Silver Lead. (*d*)			Sundry Minerals.	Tin, Ingots.		Tin, Ore.		Zinc.	
		Ore.	Metal.	Value.							
1872	....	....	....	....	....	48	$32,410	863	$206,685	....	....
1873	....	....	....	....	....	926	538,975	3.719	1,133,205	....	....
1874	....	....	....	....	....	4,167	1,830,945	2,152	590,665	....	....
1875	....	....	....	....	....	6,156	2,375,840	2,055	430,715	....	....
1876	....	....	....	....	....	5,537	1,896,590	1,533	301,600	....	....
1877	....	....	....	....	....	7,346	2,389,760	837	152.940	....	....
1878	....	....	....	....	....	6,183	1,810.360	1,143	168,750	....	....
1879	....	....	....	....	....	5,189	1,715,375	827	146,370	....	....
1880	....	....	....	....	....	5,564	2,403,075	693	153,610	....	....
1881	$892.025	195	....	$25,125	....	7,713	3,432,555	619	187,460	....	....
1882	45,120	12	....	1,800	....	8,189	4,002,855	621	164,450	....	....
1883	82,440	138	....	10,375	$800	8,820	4 014,335	452	108,425	....	....
1884	98,900	9,316	....	1,209,700	....	6,417	2,533,630	355	74,305	....	....
1885	795.935	2,130	193	538,130	39,550	4,733	1,952,290	544	125,840	....	....
1886	987,720	4.879	....	1.472,425	26,635	4,716	2,246,515	332	91,750	....	....
1887	162,290	12,731	....	2,709,760	78 120	4,745	2,545,045	296	82,055	....	....
1888	333,340	11,928	18,393	5,378,685	17,190	4,636	2,845,910	251	66,570	..	....
1889	360,005	47,725	35,136	9,495,985	3,595	4,480	2,015,555	246	60.300	98	$4.940
1890	477,050	91,164	41,985	13,335,720	114,260	3,464	1,585,585	263	63,620	214	11,890
1891	674,250	93,871	56,288	17,423,695	66,935	2,989	1,308,845	207	48,215	222	13,110
1892	284,420	88,914	46,588	12,104,760	35,870	3,305	1,507,705	243	62,865	452	25,275
1893	....	....	....	....	....	....	....	....	....	....	....

MINERAL IMPORTS OF NEW SOUTH WALES. (*e*) (IN METRIC TONS.)

Year.	Copper.		Copper Ore.		Hardware.	Iron and Steel.	Machinery.	Railway Rails.	Tin Ingots and Ore.
1876	1,700	$649,860	26,608	$1,194,600	$1,676,195	$1,996,220	$693,440	....	$855,505
1877	1,736	581,030	27,106	1,107,525	1,653,460	4,488,820	1,330.485	....	1,447,210
1878	432	121,065	25,283	933,225	2,310,990	3,517,050	956,760	$439,595	1.089,800
1879	469	169,065	17,930	672,190	2,376,995	2,664,895	1,144,300	342,810	740,365
1880	294	104,720	17,715	710,415	1,863,805	3,090,800	821,115	598,070	1,747,940
1881	31	7,700	21,524	888,315	2,714,845	4,415,700	1,397,360	1,000,800	2,060,725
1882	1	360	27,043	974,645	3,689,200	5,735,580	1,943,805	1,085.155	2,770,235
1883	3	675	18,486	870,450	3,968,110	4,887,745	2,548,800	331,695	3,166,655
1884	....	....	23,576	1.196,225	3,584,460	5,186,100	2,887,185	954.225	2,411,050
1885	....	....	19,973	994,940	3,245,660	6,092,380	2,426.355	756,290	2,067,190
1886	....	85	15,832	762,355	3,086,245	3,112,575	1,633,255	479,680	2,212,570
1887	....	4,135	15,396	754,295	1,823,430	3,310.980	1,738,230	....	2,561,080
1888	....	94,495	13,947	708.405	2,140,195	5,312,435	1,844,125	....	2,490,890
1889	....	13,225	18,745	926,915	2,382,205	4,261,570	2,313,835	....	1,198,630
1890	21	7,525	14 557	730,225	3,106,750	4,879,135	2,553,655	....	1,288 355
1891	3	960	14,837	669,780	3,326,465	7,207,940	2,721,640	....	1,054,125
1892	....	....	..	....	....	....	....	....	....
1893	....	....	....	....	....	....	....	....	....

MINERAL EXPORTS OF NEW SOUTH WALES. (*e*) (IN METRIC TONS.)

Year.	Coal and Coke.		Copper, Refined.		Hardware	Tin, Ingots.		Tin, Ore.	
1876	884.926	$3 145,190	4,982	$1,923,660	$378,255	5.994	$2,051,300	9	$1,600
1877	932,105	3,255,920	6.348	2 325,535	390,810	7,828	2,538,950	838	152,790
1878	1,023,682	3,548.595	6,077	2,025 420	328,510	6,765	1,987,305	1,145	168,885
1879	1,015,336	3,482,215	6,041	1,867,050	332,525	5,617	1,894,905	828	146,370
1880	767,061	2,138,060	6.316	2,134,530	437,955	8,532	3,363,730	701	154,945
1881	1,050,218	2,118,025	6,877	2,210,560	495,610	10,668	4,716,800	622	187,900
1882	1,285,886	3,262,620	5,762	1.873,170	632,500	10,873	5.306.700	643	170,600
1883	1,542.243	4,186,720	10,112	3,222,515	712,500	11,655	5,302,590	453	108,500
1884	1,722,946	4,687,610	10,620	2,999.620	680,510	9.492	3,742,675	356	74,305
1885	1,786,777	4,846,205	8,226	1,848,000	601,690	8,389	3,485,070	544	125,920
1886	1,767,302	4.769,530	6 579	1,361,380	421,415	7,343	3,492,825	412	107,470
1887	1,823.518	4,837,450	6,162	1,314,765	487,840	7.447	4,027,720	334	92,805
1888	1,970,910	5,447,015	5;742	2,021,125	503,490	6,419	3.966,320	270	72,120
1889	2,436,560	6,670,770	6,150	1,506,330	377,295	4,831	2.177,335	243	59.645
1890	1,863,065	5,028,295	4,313	1,099,015	309,050	4,628	2,119,845	265	63.795
1891	2,560,767	6,569,305	4,868	1,198,140	261,825	3,948	1,724,450	211	49,490
1892	....	....	....	....	....	....	....	....	....
1893	....	....	....	....	....	....	....	....	....

(*d*) The figures given under 1881 are the totals of production prior to 1882. The total value of the mineral products of this colony to the end of 1892 was £98,842,779, the details of which are: Coal, £27,271,429; gold, £39,202,656; silver, silver-lead, and ore, £13,779,931; copper, exported, £6,211,137; tin, exported, £9,840,910; shale, £1,552,796; coke. £84,473; iron, £406,171; antimony, exported, £130,478; pig lead, exported, £11,049; bismuth, exported, £37,722; zinc spelter, exported, £11,043; limestone flux, £200,378; opals, £17.600; alunite, exported, £8172; building, exported. £8043; oxide of iron and pig iron. exported. £3516; marble, exported, £2577; lime, exported, £1780; cobalt, exported, £1580; ballast stone, exported, £989; manganese ore, exported. £712; slates, exported, £351; grindstones, exported. £311; fire-clay, exported, £135; sundry minerals exported, £56,841. (*e*) From British Statistical Abstracts.

MINERAL EXPORTS OF NEW ZEALAND. (*a*) (IN METRIC TONS.)

Year.	Antimony Ore.		Coal. (*a*)		Coke.		Chrome Ore.		Copper Ore.		Gold, Kilos.		Hematite Ore.		Kauri-Gum.	
1853	....	....	....	....	....	....	....	....	....	....	....	....	....	....	843	$79,860
1854	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1,688	144,320
1855	....	....	....	....	....	....	....	....	....	....	....	....	....	....	361	22,570
1856	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1,463	92,955
1857	....	....	....	....	....	....	....	....	....	....	325	$202,110	....	....	2,563	176,255
1858	....	....	2	$20	....	....	3	$125	357	$25,000	421	262,320	....	....	1,840	100,185
1859	....	....	....	....	....	....	8	600	249	13,025	228	142,135	....	....	2,042	103,880
1860	....	....	1	10	....	....	118	7,200	139	7,950	141	87,925	....	....	1,063	49.255
1861	....	....	....	....	....	....	53	2,600	112	6,500	6,035	3,759,365	....	....	870	49.440
1862	....	....	....	....	....	....	3,905	123,595	52	5,120	12,779	7.956.945	....	....	1,121	55,535
1863	....	....	....	....	....	....	605	21 590	....	....	19,547	12,158,615	....	....	1,423	135,130
1864	....	....	....	....	....	....	780	24,550	....	....	14,935	9,284,185	....	....	2,264	302,950
1865	....	....	....	....	....	....	....	....	....	....	17,872	11,132,370	....	....	1,897	230.300
1866	....	....	265	2,000	....	....	286	6,575	....	....	22,873	14,222.585	....	....	2,576	352,860
1867	....	....	989	6,140	....	....	....	....	250	13,500	21,365	13,494,310	....	....	2,728	387,455
1868	....	.	1,044	6,050	....	....	....	....	85	4,885	19,828	12,521,630	....	....	2,733	362,465
1869	....	....	762	4,000	.	....	....	....	....	....	19,107	11,814,975	....	..	3,912	556,535
1870	..	....	1,690	7,540	....	.	....	....	7	600	16,948	10,787,925	....	....	4,462	875,370
1871	.	....	1,723	8,060	....	....	....	....	....	....	22,707	13,937,600	....	....	5,135	839,790
1872	..	....	1,006	4,275	21	$250	....	....	....	....	13,853	8,656,305	....	....	4,888	770,835
1873	....	....	736	3,275	....	..	....	....	....	....	15,718	9,937,125	....	....	2,880	429,080
1874	....	....	1,487	6,815	88	1,140	....	....	....	....	11,707	7,526,655	....	....	2,610	399.930
1875	.	....	3.439	15,645	15	255	....	....	....	....	11,052	7,038,850	....	....	2 267	692,615
1876	....	....	1,884	9,770	54	945	....	....	....	....	10,016	6 421,640	....	....	2,934	546,170
1877	.	....	2,701	10,355	26	360	....	....	....	....	11 561	7,480,400	....	....	3 691	591,740
1878	4	$510	6.566	25,695	86	885	....	....	6	575	9,657	6.200,395	....	....	3,500	664,875
1879	.	....	7,259	30,935	156	1,620	....	....	55	5,525	8,941	5,740,540	....	....	3,281	737.675
1880	61	3,060	7,133	29,885	88	675	....	....	....	....	9,494	6,136,260	....	....	4.801	1,214,085
1881	2	120	6,728	28,050	227	1,765	....	....	5	180	8,416	5,403,950	....	....	5,549	1.268,940
1882	30	4.500	3,259	11,900	279	2,400	....	....	9	205	7,813	5,013.600	....	..	5,622	1,301,845
1883	31	4,020	6.627	24 395	1,453	10,285	....	....	46	3,390	7,725	4,966 760	½	$60	6,623	1 683,030
1884	....	....	6,202	22,305	240	1 860	....	....	20	530	7,152	4.608,985	....	....	6.496	1,710,755
1885	677	26,445	44,600	256,285	271	1,925	....	....	....	....	7,383	4.743,075	51	1,040	5 970	1,048,810
1886	63	8,920	46.879	260.665	505	3,575	....	....	20	1,950	7,063	4,517,845	....	....	5,000	1,288,265
1887	136	19,945	44.839	223.250	186	1 330	....	....	....	....	6.341	4,055,500	....	....	6,900	1 812,245
1888	382	31,230	69,183	324,855	968	8.230	....	....	2	375	6,259	4,005.330	....	....	8,619	1,904.665
1889	501	26,595	87,796	421.735	2.166	17.035	....	....	....	....	6,321	4,042,745	....	....	7,640	1.647,950
1890	523	55,605	70,735	335,015	2 254	16.670	....	....	....	....	6 009	3.867.190	1½	25	7.558	1.892.815
1891	420	24,750	93,140	455,865	2,585	18,290	....	....	¼	20	7,838	5,037,440	....	5	8,523	2.185,280
1892	370	24 500	80,181	401,125	4,375	28,455	....	....	....	....	7,405	4,773,720	....	....	8,845	2,588,390
1893																

Mineral Exports.—*Continued.*

Year.	Manganese Ore.		Mixed Ores.	Silver, Kilos.	
1869	....	....	....	344	$14,965
1870	....	....	....	1,155	56,900
1871	....	....	....	2,497	115,725
1872	....	....	....	1,153	49,550
1873	....	....	....	1,126	49.250
1874	....	....	....	1,262	51,900
1875	....	....	....	905	37,845
1876	....	....	$74,120	394	15,855
1877	....	....	48,320	1,154	37,780
1878	2.557	$52,080	40	654	28.775
1879	2,174	41.690	....	642	22.560
1880	2,653	52,115	56,675	622	22,500
1881	1,291	16,415	21,515	587	21,180
1882	2,216	34,815	42,985	177	6.430
1883	390	5 775	550	523	18 925
1884	323	4,045	....	775	25.625
1885	112	8,580	4,965	517	15,845
1886	334	6,580	9.230	377	14,730
1887	310	4,475	20,710	647	17,265
1888	1,102	12.020	14,775	13	355
1889	1,097	12.345	49,925	750	20,215
1890	490	5,020	1,365	1,015	30,810
1891	1,172	13,170	30	872	25.755
1892	529	6,195	3,155	686	19,980
1893	....	....	....	....	....

Mineral Imports of New Zealand. (*b*) (In Metric Tons.)

Year.	Coal.		Iron.	Machinery.	Railway Materials.	Tools and Implements.
1869	....	....	....	....	....	....
1870	....	....	....	....	....	....
1871	....	....	....	....	....	....
1872	....	....	....	....	....	....
1873	....	....	....	....	....	....
1874	....	....	....	....	....	....
1875	....	....	....	....	....	....
1876	160,121	$1,205.840	$2,811,235	$870,945	$1,555.610	$141,910
1877	158,553	1,203,190	2,482,875	712,455	767,020	115.660
1878	177,003	1,342,180	3,662,000	1,332,780	984,055	339,470
1879	160,667	1,107,285	2,968,805	1,225,505	2,026,310	457,450
1880	125,319	847,750	2,138,340	830,940	708,815	171,965
1881	132,093	789,125	2,978.485	964,205	450,735	251.165
1882	131,706	820.885	4.092.990	1,249,540	257,000	412,685
1883	131,879	778,340	3,293.235	1,557,210	1,175,870	500,825
1884	160,370	959.970	3,113,980	1,308,580	1,688,525	302,045
1885	133,515	735,415	3 213,185	877,885	868,240	249 820
1886	121,838	616,725	2,912,025	839.140	392,745	242,425
1887	108.988	541,440	2,746,945	1,078,350	378,485	226,375
1888	103.002	492,155	2,262,315	873,715	242,950	198,400
1889	130,162	570,265	3,028,450	1,078,285	242,640	233,560
1890	112,758	510,830	2,955,340	1,094,990	264.155	262,660
1891	127,325	602,110	2,829,635	1,019,620	142,905	245,870
1892	127,473	....	....	....	....	....
1893	....	....	....	....	....	....

(*a*) From *Mines Statement*, 1893, by the Hon. R. J. Sheddon, Minister of Mines, Wellington. There is no statement of the production of minerals in New Zealand save that of coal (for the statistics of which see article on coal); but the exports practically represent the whole production. The total value of the mineral products of this colony to the end of 1892 was £59,219,736, some of the details of which are: Gold, £18,387,861; silver, £144,144; kauri-gum, £6.349.421; coal, £3,531,202; manganese ore, £55,164; antimony ore, £46.040. (*b*) From British Statistical Abstracts.

MINERAL PRODUCTION OF QUEENSLAND. (*a*) (IN METRIC TONS.) (£1 = $5.)

Year	Antimony Ore.		Coal.		Copper Ore.		Gems. (*e*)	Gold. (*b*)		Opal.	Silver Ore.		Tin Ore.	
.	Tons	Value	Tons.	Value.	Tons.	Value	Value	Kilos.	Value.	Value	Tons.	Value.	Tons	Value.
1860	.....	.....	12,525	$46 220	1	$250	.....	.....	.....	.....	.....	.....	.....	.....
1861..	.....	.....	14,440	49,610	50	7,250	.....	.....	.....	.....	.....	.....	.....	.....
1862..	.....	.....	24,454	96,265	272	51,660	.....	.....	.....	.....	.....	.....	.....	.....
1863..	.....	.....	24,386	75,000	1,118	150,000	.....	.....	.....	.....	.....	.....	.....	.....
1864 .	.....	.....	25,402	77,500	2,032	300,000	.....	.....	.....	.....	.....	.....	.....	.....
1865..	.....	.....	33,531	97,125	722	292,200	.....	.....	.....	.....	.....	.....	.....	.....
1866	.....	.....	39,949	106,245	3,176	459,360	.....	.....	.....	.....	.....	.....	.....	.....
1867..	.....	.....	18.278	47,830	6,239	421,000	.....	.....	.....	.....	.....	.....	.....	.....
1868	.....	.....	19,927	57.595	9.047	365,100	.....	.....	.....	.....	.....	.....	.....	.....
1869..	.....	.....	11,299	29,535	6,411	381,150	.....	.....	.....	.....	.....	.....	.....	.....
1870	.....	.....	23,003	61,555	1,356	403,973	.....	.....	.....	.....	.....	.....	.....	.....
1871..	.....	.....	17.273	47,035	2,530	871,500	.....	.....	.....	.....	.....	.....	.....	.....
1872	.....	.....	28,173	80,600	2,487	980,000	.....	.....	.....	.....	.....	.....	1,430	$549,080
1873..	15	$785	34,154	110,260	2,480	929,040	.....	.....	.....	.....	.....	.....	9,081	3,030,920
1874..	210	10,705	44,142	98,500	2,264	820,200	.....	.....	.....	.....	1	$300	5,793	1.792,750
1875..	61	1,800	32,624	74,175	1,701	609.900	.....	.....	.....	.....	.....	.....	4,547	1,189,395
1876..	18	1 080	51,442	132,350	2,139	735.000	.....	.....	.....	.....	.....	.....	4,384	936,005
1877..	103	3.030	61,898	128.295	1,990	836,685	.....	*c*82,330	$52,938,320	.....	.....	.....	3,388	667,160
1878	27	2,025	53,427	106,360	583	175,630	.....	9,630	6,192,240	.....	.....	.....	2,895	441.830
1879..	4	200	55.999	113,795	576	173,955	.	8,975	5.771,120	.	12	1,425	2 923	601,955
1880..	....	.	58,987	122,865	331	100,685	.....	7,308	5,342,720	.....	114	12,295	2.893	714,885
1881 .	361	18.325	66,668	145,165	336	98,185	.....	8,427	5.419,100	.....	595	67,470	3,511	968,495
1882	255	22,235	75,634	167,960	1,752	74,910	.....	6,995	4,497,860	.....	2	700	4.329	1,349.520
1883 .	535	32,750	106.436	264,470	1,829	105,400	.....	6,618	4.255,740	.....	5,347	330,960	3,400	936,460
1884	760	32,345	122,671	300,125	1,679	154,360	.....	9,574	6,156,080	.....	4,456	176,635	3,437	652.300
1885..	71	1,500	213,348	436,140	1,361	94,600	.....	9,673	6,218.820	.....	3,848	318,555	3,305	759,355
1886 .	112	2,000	232,337	476,215	914	35.000	.....	10,606	6,819,960	.....	1.657	263,985	3,204	810,620
1887..	....	.....	242,658	487,300	1,026	38,000	.....	13,248	8,518,460	.....	2.218	400,460	3,332	1,086,945
1888..	....	.....	316,426	639,735	1,144	46 240	.....	14.981	9.632.860	.....	1,209	220,075	3,644	1,000,095
1889..	59	1,075	269,782	605,590	1,096	60,000	.....	22,989	14.782.060	.....	1,122	307,500	3.083	782,030
1890..	175	24,080	343 791	785,355	188	15,000	.....	18,992	12,211,740	$15.000	1,944	283,195	3.018	774,815
1891..	220	18.125	275,949	640,990	100	4,325	.....	17.920	11.528,780	50,000	889	109.395	2,272	581,935
1892	26	1,390	269,354	616,540	82	12,305	$22,185	19.146	12,311,160	50,000	*d*6,992	182,180	2,427	615,490
1893..	....	.....	.....	.....	.....	.....	.....	19,189	.....	.....	.....	.....	....	.....

MINERAL IMPORTS AND EXPORTS OF QUEENSLAND. (*b*) (IN METRIC TONS.)

Years.	Imports. (*f*)			Exports. (*f*)							
	Hardware and Ironmongery	Iron and Steel.	Machinery.	Copper Ore.		Copper Smelted.		Tin Ore.		Tin Smelted.	
	Value.	Value.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1876..	$475,370	$538,940	$334,365	48	$7,505	2,091	$854,405	4,158	$831,185	300	$104,820
1877	480,745	843,270	445,230	39	8,680	1,953	828.005	3,222	613.510	171	53,650
1878..	447,635	705.525	354.940	84	11,505	498	164,125	2,385	376,005	213	62,550
1879..	388,165	499.795	214,505	27	4,500	507	183,205	2,556	482,240	333	119,340
1880..	478.610	717.610	272.090	15	4,290	318	96,395	2.457	535.200	438	179,685
1881..	701,010	954.235	633.200	.....	.....	336	98,185	2,463	599,005	486	230,470
1882..	1,175,325	1,536,795	1.864.580	....	.....	9	3,250	3,735	1,045,455	600	304,065
1883..	1,381.090	1,688,840	1,878,765	195	12,100	18	6,375	4,326	1,191,775	693	302,450
1884..	1,300,420	1,657,095	1 574,800	45	4,570	30	10,500	3,930	1,020,815	318	121,470
1885..	1.206,870	1,877,600	1,294.165	57	6,430	.....	.....	2,628	697,205	261	86,680
1886..	1,234,375	2,253,900	831,745	93	22,685	165	78,305	2,052	424 635	1,488	538,185
1887 .	1,087,380	2,136,260	998,250	6	640	180	35,400	3,087	934.520	357	181,850
1888..	1,288,805	1.827,575	1,163.395	18	2,075	72	20,735	3,120	967,865	345	183,935
1889..	954,220	1,359.290	830.260	39	2,735	270	67,895	2,565	789 335	408	201,325
1890..	580,305	1,402,030	667,100	87	12,025	18	5,090	2,844	731,350	537	263,250
1891 .	524,010	2,032,240	659,830	36	2,550	87	17,770	1,800	506,525	193	97,000
1892..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1893..	.....	.....	.....	....	.....	.....	.....	....	.....	.....	.....

(*a*) From *Annual Report of the Under Secretary for Mines* for 1892. (*b*) Value estimated at $20 per oz The gold returns for 1893 show a total output of 600.327 oz., being a decrease of 15.231 oz. on the previous year. The output for the latter half of the year, however, shows an increase of 881 oz. over the first half of the year, the totals being 299,723 oz. and 300.604 oz. The principal yields for the year were: Charters Towers, 256,352 oz.; Rockhampton, 114,039 oz.; Gympie, 78.966 oz.; Croydon, 71,120 oz.; Etheridge, 29.236 oz.; Ravenswood, 9286 oz.; Gladstone fields, 7666 oz.; Eidsvold, 7328 oz.; Palmer, 7175 oz.; Clermont, 4963 oz.; Herbonton fields, 4159 oz.; Paradise, 2491 oz. (*c*) Total yield to end of 1877. (*d*) Kilos. (*e*) Gem-mining in the Withersfield district is expanding, and may assume considerable proportions ere long if the several claims and prospecting areas should fully realize the expectations of their owners. The drift that carries the precious stones is fairly rich in zircons, spinnels, and the several varieties of the corundum class, such as sapphires, oriental emeralds, and topazes. (*f*) From British Statistical Abstracts.

MINERAL EXPORTS OF SOUTH AUSTRALIA. (*a*) (IN METRIC TONS.) (£1 = $5.)

Year.	Copper.		Copper Ore.		Gold, Kilos.		Lead.		Lead Ore.		Manganese Ore.		Regulus.		Total. (*f*)
1844	.....	.....	281	$20,045	.....	.....	.....	.....	206	$12,135	....	.....	.....	.....	$32,180
1845	.....	.....	673	54,370	.....	.....	.....	.....	87	4,355	....	.....	192	$8,695	67,420
1846	.....	.....	6 566	703.970	.....	.....	1	$100	149	7,185	....	.....	.....	.....	711,255
1847	.....	.....	9,299	859,415	.....	.....	11	1,015	147	10.520	....	.....		.....	870,950
1848	4	$1,075	16,586	1,550,860	.....	.....	7	520	693	52,260	...	.....	...	.....	1,609,715
1849	441	169,060	10.160	914,035	.....	.....	2	145	263	14.385	....	.....	1	110	1,097.735
1850	2,266	872.870	8,925	896,580	.....	.....	31	1,965	340	14,705	....	.....	211	41.200	1,827,320
1851	2,579	977,725	5,028	511,545	.....	.....	.....	....	133	7,960	...	.....	236	55,350	1,554,580
1852	1.991	809.235	11,493	1,001,505	.....	.....	.....	.....	.....	.....	....	.....	409	63,150	1,873,890
1853	1,235	566,165	3,828	315,560	.....	.....	1	180	23	1,805	....	....	.....	.	883,720
1854	412	176,560	3,299	283.920	.....	.....	.....	.....	22	2,125	....	.....	32	11,550	474,155
1855	623	336,915	4,104	403.620	.....	.....	1	400	146	18,250	...	.....	64	18,600	777,785
1856	2,285	1,242,300	9,620	781,755	.....	.....	.....	.....	35	1,885	....	.....	72	14,270	2,040,210
1857	2.890	1,453,695	8,165	706.425	.....	.....	.....	.....	1,445	119,275		.....	80	14,800	2,294,195
1858	2 428	1,250,210	6.805	523.900	.....	.....	.....	.....	867	71,000	....	.....	156	21,300	1,866.410
1859	2,883	1,449.205	7.424	508,725	.....	.....	64	28,550	266	40,340	....	.....	143	28,270	2,055,090
1860	3.324	1,658,875	7,211	445,650	.....	.....	93	41,375	69	12,400		.	343	74,385	*b*2.232,685
1861	3,102	1,472,860	7,942	668 745	.....	.....	64	22,130	15	1,500	...	.....	396	95,625	2,260,860
1862	4.363	2,002,955	6,316	621.315	.....	.....	22	4,905	98	11,330	...	.....	425	97,590	2,738,095
1863	4.879	2,239.720	5,429	416 310	.....	.....	14	2,625	458	45,035	....	.....	40	8,275	2,711,965
1864	6.811	3,188,955	4,618	190,625	.....	.....	3	605	576	65,535	....	.....	53	12,400	3,458,120
1865	5,091	2,168,975	16,436	923,385	.....	.....	4	665	87	7,535	....	..		.....	3,100,560
1866	6.568	2,922,545	17,095	1,128,415	.....	.....	69	14,955	658	56,590	....	.....	.....	.....	4,122,505
1867	7,969	3.136,920	11,614	567,045	.....	.....	172	27,320	215	16,765	....	.....	25	2,800	3,767.065
1868	5.290	2,003,455	21,059	1,037.595	.....	.....	155	28,350	77	6,225	....	.	10	1,065	3,120,110
1869	4,714	1.857,830	27,267	1,251,295	.....	.....	149	22,355	24	1,480	....	.....	.....	.....	3,135,760
1870	5,559	1.974,595	21,222	869,305	.....	.....	130	20,445	3	105	....	.....	.....	.....	2,870,450
1871	6,499	2,590,400	20,451	599,515	.....	.....	172	27,485	.....		....	.....	.....	.....	3,242.845
1872	7,573	3 403,570	27,398	610,100	.....	.....	.....	.....	62	11,620	....	.....	.....	.....	4,031,820
1873	7,201	3,175.655	27,823	666,855	2·38	$1,465	1	100	.....	.....	....	.....	.....	.....	3,852,950
1874	6,736	2.786,530	23,222	682 650	34·56	20,875	.....	.....	24	1,660	....	....	.....	.....	*c*3,501,615
1875	6.952	2,890,325	26,862	875,505	56·06	35,170	.....	.....	134	330	...	.	.....	.....	3.811,930
1876	5,551	2,137,015	23.047	822.985	77·79	49,440	1	70	17	1,075	....	.....	.....	.....	3.013,860
1877	5,226	1,988,010	18.830	827,040	.....	.....	19	1,475	6	600	....	.....	....	.....	2,825,495
1878	3,651	1,261,030	17.281	776,905	10·08	6,125	.....	.....	.....	.....	....	.....	40	4,685	2,048,745
1879	3,423	1,085,930	13,936	671,010	0·62	450	3	450	.....	.....	....	.....	44	7,005	*d*1.768.905
1880	3,308	1,166,870	14,857	563,865	.....	.....	.....	.....	.....	.....	....	....	35	5,455	*e*1,736,230
1881	3,886	1.316.850	21,986	774,630	6·84	4,400	.....	.....	91	5,910	....	....	10	1,000	2,102.790
1882	3.707	1,299,420	26,314	978,430	23·76	15,400	.....	.....	83	10,555	138	$3,320	.....	.....	2,311,350
1883	3,454	1,173,900	18,988	702,725	83·08	52,670	.....	.....	921	68,785	338	10,395	.....	.....	2,012.250
1884	4,646	1,438,765	24,354	907,385	123·48	77,345	.....	....	392	29,490	60	1,180	.....	.....	2.459,750
1885	3.574	970.450	18.939	644.465	145·94	91.475	8	685	37	7,480	132	4,465	.....	.....	1,722,255
1886	3,694	816,650	15,020	292,690	274·49	162,675	1	....	34	3,010	1,575	54,925	.....	.....	1,375,040
1887	3 936	933.120	12,899	268,545	586·186	343.870	*g*300	68,375	.....	.....	...	..	.....	.....	1,620,520
1888	3,216	1.263,135	13 080	363,000	271·476	161,025	*h*141	9,865	174	12,750	52	17,535	... ..	.....	....
1889	4,074	1,064,665	18,015	411,775	314·897	186,525	*h*261	14,710	*g*333	11,660	1,622	25,535	.....	.....	....
1890	3,009	777.085	15,628	357,875	161·243	104,040	.....	.....	1.062	84,520	2,808	35,115	*a*1,176	104.935	....
1891	3,609	910,710	13,245	265,875	214·742	136,900	.....	.....	130	8,935	*a*861	8,625	*a*41	2,500	....
1892	.....	.....	.....	.....	.....	.....	.	.....	.....	.....	.....	.....	.....	.....	....
1893	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....

Year.	Salt.		Slates, Roofing		Spelter.		Tin Ore.		Various.		Total.
1888	2,734	$16,470	286,580	$12.985	12	$900	....	....	....	$6,235	$1.880.760
1889	3,339	18,345	418,!56	20,055	63	4,125	71	$1,700	239	9,505	1,785,550
1890	5,689	34,015	339.084	19,540	17	1,305	....	....	45	1,850	1.520,280
1891	7,628	49,695	170,000	7,100	16	1,135	10	340	....	*i*11,495	1,403,310
1892	....	....	......	....	....	......	....	....	....	......	....
1893	....	....	....	....	....	....	....	....	....	....	.....

MINERAL IMPORTS OF SOUTH AUSTRALIA. (*k*)

Years.	Coal, Coke, and Other Fuel.		Hardware.	Iron; Bar, Sheet, etc.		Iron, Galvanized, Plain, and Corrugated.		Implm'ts Not Agr.	Machinery.
1876	97.713	$473,955	$311,105	4,944	$257,670	4,216	$515,050	$273,590	$133,240
1877	83,157	420,825	327,140	4,780	239,285	5,755	626,930	212,300	191,050
1878	102,436	529,120	447,105	7,878	366,815	6.610	678.770	267,415	179,870
1879	105,036	525,555	380,880	4,968	206,410	5.486	511,630	202,180	236,475
1880	98,993	472,935	415,310	6,670	288.625	6,487	681,995	204.815	207,960
1881	117,963	492,630	397,710	5,144	203,120	4,936	440,170	183,090	238,125
1882	140.600	542,415	567,095	8,353	338,875	7,336	658.215	310,095	359,220
1883	138,728	455,080	509,505	8.383	300,725	6,871	586,065	260,015	377,510
1884	121,791	897,380	451,965	6,188	244,785	6,164	505,550	....	278,170
1885	153.135	498,660	411,325	7,257	261,905	6,647	511,710	198,270	326,055
1886	139,722	497,820	222,355	5.504	187,340	2,888	207,055	160,615	314.860
1887	156.596	485,580	187,200	4,846	160,575	3,326	225.055	142,720	494,555
1888	173,459	722,145	160,505	7,484	239,990	7,049	548,440	138,120	551,030
1889	235.650	845,380	244,795	6,559	231,625	2,348	185,160	135,170	322,715
1890	232,686	1,253,645	321,255	10,270	426,445	4,634	422.530	171,925	446,110
1891	402,552	2,008,190	539,375	6,739	250,955	13,752	893,830	206,510	382,990
1892	....	....	....	....	....	....	....	....	....
1893	....	....	... ...	...	.. ..	.....	....	....	....

(*a*) From *Mining Records of South Australia,* Adelaide, 1887, and British blue books. These ex-

MINERAL PRODUCTION OF TASMANIA (*o*).—(IN METRIC TONS.) (£1 = $5.)

Year.	Coal.		Gold.		Limestone.		Silver.		Stones, Building.		Tin Ore.		Tin.	
	Tons	Value	Kilos	Value	Tons	Value	Kilos	Value	Tons	Value	Tons	Value.	Tons	Value.
1866	......	......	*p*26	$13,540	....	......	......	......	....	......	.....	....	.....	....
1867	......	......	42	21.910		......	......	......	....	......	.....	....	.....	.....
1868	......	......	22	12,680	....	......	......	......	....	......	.....	....	.....	....
1869	......	......	4	2.570	....	......	......	......	....	......	....	....	..	....
1870	......	......	30	18.330	....	......	......	......	....	......	.....	....	.....	....
1871	......	......	187	117,335	....	......	......	......	....	......	.....	....	.....	....
1872	......	......	217	136,570	....	......	......	......	....	......	.....	....	.....	....
1873	......	......	145	91,950	....	......	......	......	....	......	...	....	3	$1,100
1874	......	......	145	92,455	....	......	......	......	....	......	.....	....	102	36.590
1875	7,843	......	94	59 910	....	......	......	......	....	......	.....	....	372	156,625
1876	6,198	......	345	224,615	....	......	......	......	....	......	.....	....	1,476	498,025
1877	9,622	......	180	116,445	....	......	......	......	....	......	.....	....	4,837	1,484,705
1878	12,509	......	785	500,000	....	......	......	......	....	......	.....	....	5,449	1,581,555
1879	9,667	.....	1,871	1,154,475	....	......	......	......	....	......	....	....	4.440	1,516,015
1880	12.416	$54,990	1.636	1,006,485	....	......	......	......	....	......	.....	....	4,017	1,708,680
1881	11,343	50,235	1,763	1,084,505	....	......	......	......	....	......	.....	.....	4,189	1,878,875
1882	8,944	39,615	1,529	936,685	....	......	......	......	....	......	5,685	$1,783,565	3 706	1.805.230
1883	9.015	39,925	1,449	882,210	....	......	......	......	....	......	.....	....	4,166	1.882,230
1884	7,310	32,375	1,317	802,020	...	......	......	......	....	......	5,617	1,270.995	3,757	1 507.115
1885	6,761	29,945	1,283	776.545	1,351	$2,660	......	......	232,036	$47,185	5,549	1,975,490	4 310	1,787,935
1886	10.558	46.760	965	586.250	3,763	22,965	......	......	409,354	41.275	5,820	2.047,435	3,837	1,816,820
1887	28,078	124,350	1,325	792,665	2,482	11,815	6	$575	*q*248.617	*r*42.970	5,794	2,929,040	3.664	2,039.285
1888	42,246	187.100	1.232	735,770	1,837	10,750	424	29,190	*q*230.442	*r*29.980	5.329	1,707,365	3,836	2,131.630
1889	37.291	165,150	1,006	598,515	2,061	12,245	422	35.220	*q*126 883	*r*28,590	5,639	1,609,505	3,847	1,727,035
1890	51.332	227,335	638	379.440	3,259	14,050	2,086	132.435	*q*115,873	*r*31,120	4,790	1,099,340	3,265	1,483.805
1891	43,952	194.650	1,207	727,295	5,132	9,245	4.887	261,420	*q*93 838	*r*44,740	4.392	1,309,575	3,074	1,309,575
1892	36.243	90.110	1,403	870,350	....	......	9,476	227,510	....	....	.....	....	3,317	1,280,415
1893*s*	43,398	161,995	1,089	653,975	....	......	15.571	919,440	....	....	.....	....	3,374	1,186,000

Year.	Mineral Imports of Tasmania. (*t*)				Mineral Exports of Tasmania. (*t*)	
	Coal.		Ironmongery and H'dware	Railway Material.	Tin, Ore and Smelted.	
	Tons.	Value.	Value.	Value.	Tons.	Value.
1876	21,583	$138,080	$405,575	$129,245	1,642	$498,025
1877	22,562	145,590	406,610	32,540	5,841	1,484.705
1878	25,322	135,035	451,800	115,510	6,044	1,581,555
1879	12,858	74,905	464,080	124,045	4,638	1,516.015
1880	21,044	101,910	536,790	48,100	4,019	1,708,680
1881	20,633	104,230	647,400	56,230	4,192	1,878,875
1882	33,065	141,985	684,830	103,145	3,730	1,805,230
1883	34,544	176,920	922,205	308,045	4,190	1.882,230
1884	39,702	202,785	655,415	271,445	3.768	1,507,115
1885	42,990	214,330	680,785	16,935	4,312	1.787.935
1886	36 690	186,705	605,510	401,105	3,839	1,816,820
1887	31,633	159,185	584.165	140.575	3,666	2.039,285
1888	32,872	166,185	663,985	125.710	3,839	2,131,630
1889	38,499	191,255	536,765	110.255	3,857	1,727,035
1890	32,462	163,615	672,745	295,190	3,267	1,483,805
1891	40,468	200,710	809,110	177,685	3,346	1,965,850
1892	....	....	....	....	......	....
1893	....	....	....	....	......	....

port returns practically represent the total production. The "total" column is officially designated, "Total declared value of all mineral exports." The total mineral exports in 1841 amounted in value to $1950, and in 1843 to $635, copper ore being exported to the extent of a little more than 1 ton and lead ore to 19 tons. Of bismuth were exported, in tons, from 1867 to 1876 inclusive, respectively, 19.5, $10.305; 25.4, $5225, 2.1, $2800; 3.7, $5650; 11.3, $23,600; 1.1, $5840; 4 6, $8875; 1.5, $9800; 5.0, $10,600; 1.0, $1000. (*b*), (*c*), (*d*) (*e*) include unenumerated, valued, respectively. at $2055, $100, $4060, and $40. (*f*) The totals for 1876–77 and 1883–85 include tin to the value of $5280, for 1848–49 include emery to the value of $5110, for 1868–69 include copper precipitate to the value of $44,105, for 1870 include silver to the value of $350, for 1887 include 28 tons of tin ore, $6610, and for 1860–80, inclusive, include iron and iron ore to the value of $6255. (*g*) There were also 21 tons of silver-lead, valued at $5000 and 60 kilos silver, valued at $1860, produced. (*h*) There were also 80 tons of silver-lead, valued at $14,500, and 84 kilos silver, valued at $2450, exported. (*i*) This includes mica to the value of $6045, and precious stones to the value of $1490. (*k*) From British Statistical Abstracts.

(*o*) The figures for the tin production as well as all figures prior to 1880, and for 1892 and 1893, are furnished by Mr. A. Montgomery, Inspector of Mines and Geological Surveyor, Tasmania. The gold and coal production for the other years from *Report of the Secretary for Mines*, 1891-92, and the rest of the figures from British blue books In 1888, 1889, and 1890 there were produced of copper ore, respectively, 102 tons, $1500; 51 tons, $1500; 5 tons, $85. In 1887 and 1888 there were also produced 2 and 6 tons, respectively, of zinc ore. In 1887 1 ton of manganese ore, and in 1889, 2600 cu. ft. of bluestone, valued at $65. In 1885, 1886, and 1887 there were produced 538,000, 1,117,177 and 1,165,000 roofing slates, respectively, valued at $26.900, $39,100, and $40,775. (*p*) Total of production prior to 1867. (*q*) Cubic feet. (*r*) Includes the value of road metal, which amounted to $11,400, $10,825, $12.645, $12,150, and $22,145, respectively, in 1887, 1888, 1889, 1890, and 1891. (*s*) Last quarter estimated. (*t*) From British Statistical Abstracts.

MINERAL PRODUCTION OF VICTORIA. (*a*) (IN METRIC TONS.) (£1 = $5.)

Year.	Antimony Ore.		Calcite and Silicate of Aluminum		Coal.		Lignite.		Copper Ore.		Gold.		Lead Ore.	
	Tons.	Val.	Tons.	Val.	Tons.	Value	Tons.	Val.	Tons.	Val.	Kilos.	Value.	Tons.	Val.
1883 *b*..	11,183 *d*	......	......	......	9,945	....	6,811	......	103	......	1,625,013	$1,044,907,340	68	.....
1884 *c*...	192 *d*	......	......	......	3,333	....	587	......	......	......	24,217	15,572,360	.....	......
1885....	....	......	......	......	813	....	125		......	...	22,868	14,704,360	51	$2,020
1886 ..	....	......	......	.. ..	87	....	1,235	......	3,906	$9,610	20,690	13.303,920	......	......
1887....	....	......	......	......	3,410	....	.....	......	......	......	19,215	12,355.020	......	.....
1888....	....	......	......	......	8,711	$35,145	156	......	8 *e*	50	19,441	12,500,520	14	70
1889 *h*..	5	$785	......	......	14,831	54,955	563	$700	178	875	19,124	12,296,760	20	100
1890....	132	15,600	610	$1,500	14,836	69,495	10,016	12,500	254	500	18,307	11,771,200	51	250
1891...	67	5,940	102	25	23.202	98,655	6,424	8,365	61	1,080	17,928	11,527,980	9	45
1892....	299	11,390	......	......	23,739	100,220	6,706	18,625	......	......	20,356	13,089,120	......	......
1893 ...	....	......	......	......	....	....	.....		.. ..	......	20.874	....	......	.. ...

MINERAL PRODUCTION OF VICTORIA—*Con'd.*

Year.	Silver. (*b*)		Slate and Flagging.		Tin Ore.	
	Kilos	Value	Tons.	Value	Tons.	Val.
1876....	......	....	......	....	....	......
1877....	......	....	. ....	....	....	......
1878....	......	....	......	....	....	.. ..
1879....	......	....	......	....	....	......
1880....	......	....	......	....	....	......
1881 ...	......	....	......	..... .	....	......
1882....	......	....	..	....	....	. .
1883 ...	7,401	....	249	. . . .	4,481 *d*	......
1884 ...	842	......	244	.	42 *d*	......
1885 ...	1,569	$50.440	2,476	$16,998	....	.. ..
1886...	2,747	86,685	1.371	17,096	2	$450
1887....	772	25,500	2,793	32.662	7	2.100
1888 *f*.	62	1,835	4,240	10,430	55 *g*	16,805
1889....	877	27.500	4,681	5,030	111	5,560
1890....	1,309	46,290	3,568	6,060	924	19,180
1891....	*i*	.	2,311	2,675	1,807	25.460
1892....	16	400	626	900	414	5,195
1893....	......	....	......	.	....	......

MINERAL IMPORTS OF VICTORIA. (*j*) (IN METRIC TONS.)

Year.	Coal.		Iron and Steel.		Iron-mongery.	Rails.	M'chinery.
	Tons.	Value.	Tons	Value.	Value.	Value.	Value.
1876	229,940	$1,387,655	51,302	$3.267,065	$431,285	$700,310	$466,170
1877	256,316	1,626,835	58,062	3,542,300	578,175	866,615	502,335
1878	274,004	1,784,970	51,755	2,962,400	786,790	600,075	552.730
1879	275,961	1,774,620	33,087	1,788,645	490.710	90.635	431,320
1880	268,290	1,534.830	37,753	2,329,130	383,400	242,935	302,440
1881	307,215	1,567,905	46.036	2.399,435	581,865	677,220	516,685
1882	331,366	1,708.330	88,744	3,805,420	843,180	827,065	757,005
1883	392,176	1,879,735	68,726	3,456.835	889,400	3,232,325	1,166,780
1884	417,816	2,063,485	67,477	3,324,725	955 510	648,585	1,249 625
1885	468,235	2,254,870	82,825	3,784,005	1,012.835	697,405	897,965
1886	534.700	2.553,840	82,666	3,743,010	1,131.020	804,855	927.990
1887	563.387	2,667,885	89,111	3,633,180	962,765	1,612.880	1,211,715
1888	633,817	3,086,625	115.786	4,889,640	1,190 305	1,186,670	1,544,030
1889	770,746	3,765.240	121.798	5,014,200	1,335,265	2,180.920	2,218.945
1890	708,122	3,727 945	100.050	4,932,570	742,530	812,740	1,749.635
1891	861,826	4,189,050	88,106	5,233,515	785,250	52,945	1,283,970
1892	....	....	....	....	. .. .	... .	....
1893	....	....	....	....	....	....	....

MINERAL EXPORTS OF WESTERN AUSTRALIA. (*k*) (METRIC TONS.) (£1 = $5.)

Year.	Copper Ore.		Gold.		Lead.		Lead Ore.		Pearls.	Tin Ore.	
	Tons.	Value.	Kilos.	Value.	Tons.	Value.	Tons.	Value.	Value.	Tons.	Value.
1881........	3	$150	....	....	......	....	1,662	$65,460	....	....	....
1882........	.. .	....	... .	....	......	....	....	....	....	....	....
1883........	5	375	....	....	......	....	1,055	36,330	$87,500	....	....
1884	120	8,850	....	....	......	....	707	24,360	50,000	....	....
1885	122	8,960	....	....	......	....	472	16,275	75,000	....	......
1886........	36	2,625	....	$6,035	......	....	691	23.800	75,000	....	....
1887........	23	1,725	151.57	97,460	10	$600	479	23,550	75,000	....	....
1888	88	7,435	108.65	65,495	..	200	541	26,600	125.000	.. ....	....
1889........	114	9,520	481.88	294,355	......	....	254	12,500	150,000	5	$1.500
1890........	8 *l*	680	709.36	433,320	......	....	217 *l*	10,675	200,000	68	27,025
1891........	266 *l*	22,310	942.79	575,910	......	....	25 *l*	1,250	200,000	207	51,000
1892........	2.5 *m*	43,480	1,852.18 *n*	1,131,420	......	....	12 *m*	750	200,000	270 *m*	69,215
1893.......	.....	....	....	....	...	....	....	....	....	....	....

(*a*) From the blue books of the Mines Departments of the colony. Besides the minerals reported in this table there were also exported prior to 1884 973 tons of copper, 980 tons of copper regulus, 1734 tons of iron, 938 tons of antimony, 3828 tons of antimony regulus, 309 tons of tin, 97 tons of lead, and 3891 tons of iron ore. (*b*) Including the total production of the colony previous to 1884. (*c*) In 1884 there were also exported 70 tons of crude antimony and 11 tons of tin, while 1626 tons of iron ore and 813 tons of iron were produced. (*d*) Exports. (*e*) Five tons of copper ore were also shipped to Great Britain for treatment, its value at the pit's mouth being $5 per ton. (*f*) During 1888 68.08 tons of silver amalgam, valued at $31,550, were exported. (*g*) Including 40.64 tons of tin sand, valued at $300 per ton. (*h*) There were also exported 5.58 tons of iron ore, valued at $25. (*i*) There were exported from Melbourne 10.16 tons of silver-lead, valued at $400, and 13.21 tons of ore, valued at $650. (*j*) From British Statistical Abstracts. (*k*) From British blue books and Western Australian Year Book for 1892–93. The exports represent the production, as practically all ores are exported. (*l*) Estimated. (*m*) Production of mineral leases under clause 82 of the Land Regulation of 1887. (*n*) Production of auriferous leases under the Gold Fields act, 1886.

AUSTRIA AND HUNGARY.

By Carl von Ernst.

The year 1893 was, on the whole, not propitious for the mining industry of Austria-Hungary, as the value of mining products decreased, like business generally. Nevertheless, the profit of the mines and smelting works could be deemed sufficient, but this is due partly to efforts to reduce the minimum cost of production, and partly to the effect of the Austro-Hungarian duty on some unrefined, and all refined, metals and metal manufactures. This duty is not to be considered as unjustly imposed on the importation of foreign products; the provisions of the tariff rather balance the difference in price between the products of Austria-Hungary and those of foreign countries.

The greater expense of production in Austria-Hungary is due to several causes. In the first place, the location of the smelters, dependent on the situation of the mines and the supply of ore, is unfavorable. A second reason lies in the high wages of the workingmen and the many contributions which the mining and smelting companies are legally required to pay regularly to the Bruderladen (miners' relief fund) and the sick and accident funds. Furthermore, all industries, including mining and smelting, are taxed more heavily in Austria than in any other country. The freight rates also are very high, which largely increase the cost of transporting raw products to the refineries and the delivery of articles of manufacture to the market. All these reasons have led to a stoppage of internal competition and resulted in the formation of a mutual protective association (*Cartelle*), which aims at securing a higher selling price, and regulating sales, so that every plant is guaranteed the sale of its products. Although this arrangement favors better prices, there is a maximum limit of price fixed by foreign competition, which cannot be exceeded without resulting immediately in the importation of cheaper goods. Such agreements exist between the various lead manufacturers with reference to lead pipe, sheet lead, oxides, etc.; between zinc rolling mill people as to zinc plate; between the iron founders, screw and bolt makers, wire drawers, and especially between the bar-iron workers of Austria-Hungary. The last-mentioned agreement was renewed in January, 1894, to continue in force for the next three years. The most important provision of the agreement is that which divides the bar iron consumed by Austria-Hungary among the various iron works according to their respective capacities. No plant is allowed to exceed the production thus stipulated. A special committee receives monthly statements of the production and sale from the various works and enforces the provisions of the agreement. If, notwithstanding this, any plant is forced by large orders to exceed the stipulated production, all the other works participate in its net profits. Works that do not act up to the agreement are subjected to a fine, which goes to the other works. The above "cartelle," now in force over a year, has resulted in great good to the iron industry in Austria-Hungary and kept the market steady and firm. Yet prices have not ruled abnormally high, because German competition does not allow a certain limit to be exceeded.

A peculiar feature of mining in Austria-Hungary is that a number of properties are owned by the Government, and might therefore easily force competition with private mines and works. This, however, is not the case, because the Government mines and smelters are managed like those privately owned, are taxed the same, and run on principles of economy and production, in accordance with the mining-law statutes.

Formerly the mines of Austria-Hungary were owned by private individuals or mining companies (*gewerkshaften*). Frequently these "gewerkschaften" needed money and applied to the Government for assistance, which, for political reasons, was readily granted. The Government also undertook to manage the mines, and as a result it secured a larger or smaller interest in the properties, often through money advanced, until they ceased to be profitable to the owners, when the remaining interests were bought with the avowed intention of making the properties pay by investing larger capital and engaging technical experience. This genesis of the properties now in Government possession can be proved by documents preserved to this day, especially concerning the highly developed properties such as the lead-silver mines and smelters at Przibram, in Bohemia; the quicksilver works at Idria; the mines near Schemnitz and Nagybanya, in Hungary; several gold mines in Siebenbürgen; and in recent times (1874) the lignite mines of Brüx, in Bohemia, etc.

That it was not the Government's object to secure the largest possible number of mines from private owners is shown by the appointment of a *Schürfungs-Commission* (prospecting committee) in 1842 and 1843, which examined the land and made public the locations of good prospects. At that time the principal object was to secure fuel for the railroads and factories then building. As a result, and based upon conclusions reached in the publications of the "Schürfungs-Commission," mining began in the coal districts of Ostrau, Moravia, and Silesia, which were first opened and operated by the Government, but afterward given over to private ownership. Likewise the Austrian Government in 1867–72 (on account of its financial difficulties) gave up all its iron works, which are to-day in the hands of large companies and pay handsome profits. In the Government's possession now are only the silver and lead mines of Przibram and the silver and uranium mines of Joachimsthal, Bohemia; the quicksilver works of Idria, in "Krain"; the copper works at Brixlegg; the zinc mines on the Schneeberg; the copper mines "am 6 funderer Berge" and near Kitzbiehl; the lignite or brown coal works at Kirchbiehl, in the Tyrol; the lead and zinc mines of Raibl, in Carinthia; the zinc smelter at Cilli, in Steiermark; and the brown coal works in northern Bohemia, near Brüx.

In Hungary other conditions prevailed. The division of the empire took place at a time when Austria was forced to sell its mining interests to private parties, partly to secure money needed after the wars with Prussia and Italy, and partly because it was claimed that under private ownership and management the mining properties could be made to pay better than when governed by the State. In Hungary, on the contrary, since it secured its own Constitution in 1867, the Government has kept all of its State mining and smelting works, and has tried to keep them in a prosperous condition. It still owns all the properties it possessed in olden times, and has equipped its iron works, silver and gold mines, as well as copper, brown coal, and salt works, with modern machinery, and placed them in the hands of progressive managers. The Austro-Hungarian Government has not in view the operation of its properties merely as a source of revenue and wealth, but considers the general welfare of the country, and for such reasons has endeavored to bring them to their highest development. The last object is clearly seen in the close attention paid by the Department of Mines and Metallurgy to every practical advance in mining and metallurgical practice, examining and testing new methods and apparatus elsewhere introduced or recommended by experts, although often at great expense and without reaching favorable results. As an example, in 1835 Herr von Gersdorff agitated the question of the making of bar iron directly from the ore. For ten years Mr. Gersdorff personally conducted the experiments in works specially built for this purpose, and finally attained his chief aim. The operation proved too expensive, however, and was not adopted. In 1850 experiments were made at the Staatswerken in Tajora, in Hungary, and at Joachimsthal, in Bohemia, for the wet extraction of silver, which were successful, and resulted in building finely equipped extraction works, recognized as model plants of their class. One of the first Bessemer converters was erected in the steel works at Neuberg, in Steiermark, immediately after the publication of Sir Henry Bessemer's invention. Such work resulted in stimulating the private establishments, and in many further improvements and cheaper processes. To-day, as most of the mining and smelting properties are in the hands of private owners who compete with foreign trade on their own account, the above outlined aim is not the chief object with the Government. Nevertheless it is still kept in view, as is shown by the fine iron works of Diosgyör, Vajda Hunyad, Brizora, etc., in Hungary, and the modern ore-dressing and concentration works in Przibram and Raibl; the magnetic concentration of zincblende at Maiern, in the Tyrol; the introduction of electrolytic copper extraction at Brixlegg, and the new shaft and roasting furnaces in Idria (also introduced by Mr. Randall into New Almaden), and other examples. It would, however, be unjust to say that the mining and smelting properties not in Government hands are operated by unprogressive managers, or by owners not ready to introduce improvements. The contrary may be easily shown. The Prague Iron Company was the first on the Continent to secure the rights of the Thomas-Gilchrist patent and introduce it in the iron works at Chladno; electric lighting was first introduced to the mining world in the salt mines of Maros-Ujvár, in Hungary; and a private gold mine in Siebenbürgen was the first in possession of the Munktel process of gold extraction.

The Thomas-Gilchrist process, which was early employed in Rothschild's works at Witkowitz and in the steel works of Teplitz in Bohemia, has given the Austrian iron industry a new development. Formerly the steel works of Steiermark had the advantage in securing pig iron free of phosphorus obtained from the pure carbonate ores of the Erzberg bei Eisenerz. All other steel mills in the monarchy were likewise compelled to use Styrian pig for special purposes in manufacturing steel. This condition of affairs was altered by the Thomas-Gilchrist process, which made it possible to use local ores, rich in phosphorus, occurring near the Bohemian, Moravian, and Hungarian steel works. The trade in Styrian pig iron suffered, but the steel products of the Bohemian and Moravian works are in increasing demand.

The purpose has been to hurriedly sketch the status of the mining and smelting industry of Austria-Hungary. But one metal should not be passed without mention—a metal of high importance to Austria, because it can be mined in sufficient quantity to supply the home demand, but is now quoted so low that the mines producing it are seriously threatened with idleness. The product referred to is silver, of which Austria produces yearly 36,000 kilos and Hungary 18,000 kilos. Until now this has been chiefly used for coinage purposes, and paid for at the rate of 90 florins ($36, equivalent to $1.12 per oz.) per kilogram. In 1892 a gold standard was adopted by Austria-Hungary, and silver was therefore soon put on the market. In 1893 it was quoted at 33d. per standard ounce in London, or a kilogram of fine silver at 58 florins ($23.20, or 74c. per oz.). For example, if the imperial smelter at Przibram, with a production of 35,000 kilos silver, formerly made a profit of 80,000 florins, to-day, at the difference in value (90—58), 32 florins of silver, these same works lose a yearly income of $35,000 \times 32 = 1,120,000$ florins. During the current year (1893) the Minister of the Treasury has permitted the mints to buy *bergsilber* (silver bullion) for as much as 80 florins ($32). Next year, however, it is probable that a much lower rate will rule, and finally silver will not be purchased at all. Then the Staatswerke Przibram, which now employ over 500 workmen, may be closed down permanently, and the same thing might be predicted for all the public and private mines and works in Hungary, which formerly received a good income from the sale of silver ore or bullion. As to the mineral statistics of Austria and Hungary in 1893, no official documents have as yet been made public. It is therefore impossible to make anything like accurate estimates. In general the figures of production will be about the same as in the previous year. The table furnishes a good idea of the development of the Austro-Hungarian mineral industry, especially as regards iron and steel.

BOSNIA.

BY CARL VON ERNST.

SILVER mining was carried on in Bosnia in the Middle Ages, mostly by the Ragusians. Almost immediately after its occupation of Bosnia and Herzegovina in 1878 the Austrian Government turned its attention to the mineral resources, and in 1879 sent experts to examine the country. Not only were the old workings discovered, but also some very good prospects. The first company to commence operations was the Kohlen-Industrie Verein, which possessed collieries in Hungary and Bohemia, and commenced on the lignite deposits of Zenica, the mines being near the new railroad from the Brod to Serajevo, realizing good profits. In 1880 the Gewerkschaft Bosnia was incorporated in Vienna with 100 shares of 3000 florins each, the Government taking 20 shares. Besides this company private capitalists from Vienna and Trieste acquired rights to prospect, and later on to conduct mining operations in Bosnia. The Austrian mining laws of 1854 being very unsatisfactory in many respects, and particularly in those relating to prospecting, they were not enforced in these countries, but on May 14, 1881, the Government published a special code of mining laws for Bosnia and Herzegovina better adapted to the existing conditions. A mining bureau (Bergmannschaft) was established at Serajevo to superintend and settle all matters pertaining to mining, and the Government sent several engineers out to begin prospecting and operating.

The Bosnia commenced mining for silver at Srebrenitza, but it was discovered that the Ragusians, who had worked the mines centuries before, had taken out the ore to a considerable depth. New manganese mines were opened up near Cevljanovic and chrome mines in Dubostica, but the discovery of manganese deposits in the Caucasus and chrome ore in Greece stocked the market so that the Bosnia was on the point of being dissolved five years after its incorporation. In order to foster the mining industry the Government took over the management of the properties and also the settlement of the debts, and has since then carried on extensive developments. Silver mining at Srebrenitza has been suspended on account of the high price of extraction, owing to the great depth of the mines, but near the copper mines of Sinjako smelting works with steam hammer and rolling mills have been erected. At the iron mines of Vares a blast furnace has been built, and refining works at the antimony mines at Cemernica. At Simin Han and Dolnja Tuzla salt works have been constructed. The expectation that capitalists would interest themselves in mining has not been realized. They seem afraid to invest large sums of money in the Bosnian mines, though the good example of the Government in continuing its development of the mineral resources with such noteworthy skill and perseverance will ultimately induce others to invest in the unquestionably rich mineral resources of Bosnia. At present there are only a few private individuals engaged in mining, the major part of the industry being in the hands of the Government. In 1893 there were 23 mines operating for lead, iron, antimony, copper, mercury, manganese, chrome, lignite and salt, and 6 smelting works and 2 salt works, which together employed 1500 men. Ninety per cent. of these men are natives, and the rest engineers and miners from the old Austrian mining provinces. The best workingmen are the Mohammedans. The pig-iron industry, formerly carried on by the natives with small "Majdans" furnaces (Wolfsöfen, bloomery), has entirely ceased since the construction of the blast furnaces at Vares. The small iron works which obtain the pig iron from Vares continue in operation.

The development of the mining industry of Bosnia is shown by the accompanying table, which has been carefully compiled. The figures for some years have been obtained by adding the output of the different companies as given in their reports, Government reports not being published. The high value of the salt production is due to the fact that this is a Government monopoly in Bosnia as well as in Austria-Hungary, and is sold by the Government at high rates through special officials.

MINERAL PRODUCTION OF AUSTRIA. (*a*) (IN METRIC TONS AND FLORINS.)

Year.	Alum & Alum Slate.		Antimony Ore.		Arsenic Ore. (*b*)		Asphalt.		Bismuth Ore.		Coal. (*c*)		Lignite. (*c*)	
1856..	37,643	11,203	10	499	..	......	143	1,276	.....	......	1,287,424	4,354,574	1,050,575	2,866,171
1857..	26,669	7,937	5	52	0.2	52	216	1,927	0.3	1,114	1,397,296	4,550,436	1,015,690	2,707,018
1858..	26,252	7,814	....	......	....	......	1,088	3,186	.....	......	1,610,151	5,120,447	1,300,492	3,306,555
1859 .	......	......	....	......	....	......	.....	......	.....	......	1,804,548	......	1,327,356	......
1860..	......	......	....	......	....	......	.....	......	.....	......	1,948,189	......	1,555,706	......
1861..	......	......	....	......	....	......	.....	......	.....	......	......	......	......	......
1862..	......	......	....	......	....	......	.....	......	.....	......	......	......	......	......
1863..	......	......	....	......	....	......	.....	......	.....	......	3,969,772	......	......	......
1864..	......	......	....	......	....	......	.....	......	.....	......	4,068,613	......	......	......
1865..	......	......	....	......	....	......	.....	......	.....	......	1,308,824	......	......	......
1866..	......	......	....	......	....	......	.....	......	.....	......	4,193,683	......	......	......
1867..	......	......	....	......	....	......	.....	......	.....	......	5,361,663	......	......	......
1868 .	......	......	....	......	....	......	.....	......	.....	......	6,091,710	......	......	......
1869..	76,829	34,298	34	3,823	626	5,047	97	206	383	289,786	3,475,594	11,931.606	3,132,584	6,397,177
1870..	72,209	30,758	62	6,308	479	4,301	92	254	394	61,777	3,758,623	14,774,876	3,458,187	7,788,085
1871	......	......	....	......	....	......	.....	......	.....	......	4,352,692	......	4,222,357	......
1872..	......	......	....	......	....	......	.....	......	.....	......	4,146,721	21,104,299	5,503,231	......
1873..	61,647	59,787	86	19,350	293	2,665	307	3,957	7	8,735	4,486,914	23,014,428	5,782,906	15,203,893
1874..	114.035	93.244	516	80,102	85	730	294	4,120	22	......	4,471,234	20,882.968	6,409,659	16,180,417
1875..	124.242	81,846	422	49.941	11	112	155	1,742	5	......	4,549.624	18,588,216	6.851,266	15,424,495
1876..	113,463	78,047	46	6,373	281	4,063	127	1,574	3.5	510	4,934.335	18,448,675	6,933,382	14,726.600
1877..	147,661	91,953	173	29,039	135	1,352	79	946	0.1	458	4,885,863	17,530,272	7,126,019	14,500.903
1878	109,480	78,180	139	15,052	68	680	40	733	.....	......	5.078,219	17,682,166	7,241.103	13.829.175
1879..	117,125	73,511	173	20,940	....	......	186	255	5	......	5,378,605	18,245,803	7,905,935	14.297,871
1880..	100,293	73,344	202	40,373	....	......	201	2,826	200	......	5,889,631	19,336,728	8.420,647	15.375,757
1881..	81,152	63,065	187	20,435	...	......	49	86	14	......	6.343,316	20,736,431	8,961,498	16.019,507
1882 .	57,248	44,070	509	22,232	....	......	109	146	21	......	6,559,002	21,440,815	8,996,290	16.936.886
1883..	51.721	36,273	495	27,801	...	......	39	775	64	29,020	7,194.096	22,875,877	9,853,865	18,286.790
1884..	51,535	38,684	306	37,421	...	......	89	1,490	77	11,994	7,190,866	22.777,568	10,008,653	18,081,618
1885..	58.609	40,866	780	37,524	....	......	100	1,638	78	26,558	7,378,665	22,669,018	10,514,153	18,258,134
1886..	65,461	48,256	393	34,980	0.6	20	291	5,460	1,206	35,952	7,421,278	22,307,434	10,931,352	18,674.730
1887..	62,961	54,192	391	47,536	.	......	330	6,804	1,186	44,872	7,796,151	22.967,454	11,573,172	18.982,566
1888..	63,039	51,194	353	42,042	...	......	316	6,068	917	24,728	8,274.461	23,970,312	12,860,255	20.741,078
1889..	65,204	42,322	343	39,312	....	......	369	6,374	773	21,374	8,592,876	26,647,936	13,845,863	22,861,112
1890..	58,838	35,998	770	51,880	....	......	181	2,960	792	19,032	8,931,064	30,401,070	15,329,056	27,639,114
1891..	34,394	20.750	333	42.574	4	390	180	2,808	1,083	25.476	9,192,885	32,684,692	16,183,076	30,769.056
1892..	20,480	12,863	97	11,765	...	......	78	1,407	856	22,308	9,241,126	31,680,036	16,190,273	30,096,891
1893..	......	......	....	......	...	......	.....	......	.....	......	......	......	......	......

Year.	Copper Ore.		Gold Ore.		Graphite.		Iron Ore.		Iron Pyrites.		Lead Ore.		Mangan. Ore.	
1856..	13	8	......	......	3,566	53,306	1,674	5,125	5,960	33,197	21	4,759	56	961
1857..	3,493	82,838	......	......	4,097	67,035	6,732	44.951	4,404	26,197	297	123	50	768
1858..	4,003	79,436	......	......	4,399	62,794	8,255	43,146	3,675	20,943	3	1,347	67	860
1859..	......	......	......	......	......	......	......	......	......	......	1,913	......	......	......
1860..	......	......	......	......	......	......	......	......	......	......	1,624	......	......	......
1861..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1862..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1863..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1864..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1865..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1866..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1867..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1868..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1869..	24,145	378,999	2,921	34,362	20,275	368,797	688,053	2,218,882	12,706	66,780	8,870	1,015,764	161	2.839
1870..	25,977	358,238	2,142	29,401	24,945	413,149	835,151	2,724,017	13,188	108,160	8,765	955,127	101	1,393
1871..	......	......	......	......	......	......	853,965	3,368,119	......	......	......	......	......	......
1872..	......	......	......	......	......	......	925,529	3,825,192	..	......	......	......	......	......
1873..	7,507	319.540	89	9,535	30.500	542,244	1,040.460	4,492.024	15,582	163,984	5,773	862.823	3,162	20,633
1874..	6,761	283,386	153	20,879	27,692	592,756	906,485	3.701,414	......	......	6,566	903.849	4.424	51,795
1875..	5,551	284,805	110	11,591	20,317	450,581	704,984	2.733.690	......	......	6.888	1,012.894	10,690	131,253
1876..	4,561	252,220	175	12,282	12.717	513,350	554,966	2.023,855	......	......	7,662	1,099,372	6.782	74,229
1877..	4,845	263.584	105	12,780	11,858	533,382	538,701	1,864,576	5.895	147,120	9,400	1,385.683	7.900	69,854
1878..	3,348	172,266	173	20,495	12,147	546,325	666.159	2,004,280	5,902	117.908	10.345	1,187.455	4,184	36.647
1879..	4,270	228,645	237	20,621	11,491	501,444	628.246	1,817,363	6,017	129.661	10.960	1,176,895	3,434	37,389
1880..	4,927	205,475	128	15,300	13,718	564,862	696,832	1,982.246	6,666	151,556	10.842	1,144.012	8,874	77,837
1881..	4,445	247,118	784	12,810	13,379	536,693	618,964	1,788,202	6,331	144,984	13.542	1,030.056	9.110	95,219
1882..	4,154	229,036	355	16,839	15.577	563,932	902.510	2,397.464	5,294	115.365	14,765	1,172.847	8.418	74.124
1883 .	4,533	245,389	173	16.832	17,566	609,180	882,313	2,376.396	3.656	78,355	15,612	1,153,216	9,382	84,309
1884..	6.728	280,238	202	17,677	17,249	622,397	973,829	2,617.558	4.349	92,919	15.931	1,071,266	7.942	80,030
1885.	6,244	254,080	101	14,072	16,051	579.286	931,471	2,260.300	3,225	90.442	13,481	946,344	6.158	81,756
1886..	6.141	255,138	111	12.620	17,267	526,794	796,116	1,924,736	3,195	90,698	13,821	1,057,604	9,246	130,526
1887..	6,355	330,122	163	16,64[illegible]	19,796	628,250	846.566	1,977,272	4,702	95,746	15,195	1,179,906	9,311	123,442
1888..	6.618	361,174	367	11,100	19,646	634,746	1,009,320	2,279,270	3.850	81,521	12,531	1,137,450	6,554	97,194
1889.	7,142	313,698	331	10,376	22.336	702,122	1,115,153	2,487,872	3,539	68,798	12,836	1,137,546	3,926	68,318
1890..	7,503	343,422	1,547	18,168	23,728	726,036	1,361,548	3,105,764	3,717	66,596	11,237	969,622	8,007	102.624
1891..	9.318	354,574	440	14,440	21,346	693,326	1,231,244	2.854,888	2.831	48,522	13.361	1,068.512	5,279	70,742
1892.	8,636	329,824	164	14,886	20,978	637,012	993,290	2,325,088	1,210	25,292	13,265	922,270	4,558	54,830
1893..	......	......	......	......	......	......	......	......	......	......	......	......	......	......

(*a*) From *Oesterreichische Zeitschrift für Berg- und Hüttenwesen.* Before 1874 the returns are very incomplete, and are given in "wiener centners" (1 w. c. = 56 kilos). The figures on production of petroleum and salt were furnished by Dr. C. von Ernst of Vienna. Of chrome ore were produced, in 1873, 123 tons, 7260 florins; in 1874, 47 tons. 2788 florins; and in 1876-81. inclusive. respectively, 30 tons, 2196 florins; 95 tons, 5892 florins; 31 tons, 1922 florins; 305 tons, 19,053 florins; 277 tons, 16.602 florins; and 295 tons, 15,498 florins. Of arsenic were produced. in 1873-80, inclusive, respectively. 74 tons. 6895 florins; 18 tons. 3360 florins; 13 tons, 1070 florins; 27 tons. 6715 florins; 24 tons. 6065 florins; 170 tons. 1377 florins; 7 tons. 1540 florins; and 0.7 tons, no value given (see Dr. C. von Ernst). The average annual value of the florin in exchange on London is given in the *Transactions of the Royal Statistical Society*, Vol. LVI., Part III., pp. 500-504, as in the table on the opposite page.

MINERAL PRODUCTION OF AUSTRIA—*Continued.*

Year.	Nickel and Cobalt Ore.		Petroleum.		Quicksilver Ore.		Salt.		Silver Ore.		Sulphur Ore.		Tin Ore.	
1856..	0.136	47,016	......	......	......	......	402,847	33,803,548	......	......	......	......	......	......
1857..	387	137,720	......	......	......	......	403,270	33.347,408	......	......	......	......	......	......
1858..	342	152,595	......	......	......	......	392,693	31,852,992	......	......	......	......	......	......
1859..	371	......	......	......	......	......	......	......	......	......	......	......	......	......
1860..	281	......	......	......	......	......	......	......	......	......	......	......	......	......
1861..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1862..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1863..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1864..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1865.	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1866..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1867..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1868..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1869..	166	1,656	......	......	24,746	141,205	266,403	19,926,929	5,139	1,764,905	......	......	2,746	......
1870..	50	270	......	......	24,101	182,680	274,345	20,400,468	5,182	1,902,668	......	......	2,208	44,103
1871..	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1872..	......	......	......	......	......	......	293,155	22,994,916	......	......	......	......	......	......
1873..	452	30,610	12,000	56,000	24,534	544,834	283,663	22,235,692	6,422	1,955,840	15,592	163,982	841	16,050
1874..	156	31,368	14,778	73,640	32,942	816,135	278,628	22,687,667	6,633	2,094,645	11,783	96,146	1,637	......
1875..	112	24,662	15,555	77,777	32,797	1,013,559	262,265	20,602,390	8,069	2,404.801	12,544	112,779	2,021	......
1876..	97	20,854	17,450	87,250	31,945	1,098.585	249,465	21,518,077	8,468	2,479,963	9,842	106,949	1,172	......
1877..	105	11,978	18,433	92,165	32,112	773,958	251,058	22,328,815	9,562	3,107,246	6,365	76,084	786	......
1878..	76	5,606	22,066	110,330	30,767	696.266	241.294	21,531,820	9,848	2,924,463	8.455	87,477	1,390	......
1879..	27	1,797	28,433	142,165	39,170	602,913	254,633	21,638,632	10,773	2,880,014	8,680	87,623	598	......
1880..	16	1,103	32,000	1,440,000	45.364	483,972	255,936	22,013,727	12,573	3,133,559	10,466	112,212	624	......
1881..	40	500	39,844	1,713,292	48,204	491,174	267,279	23,200,497	12,384	3,030,297	8,918	96,922	1,051	......
1882..	15	528	46,100	1,644,000	46,968	543,005	......	......	11,841	3,043,935	9,005	101,012	2,602	20,063
1883..	4	395	70,766	2,830,640	48,462	593,176	274,395	22,674,122	12,733	3,231,013	9,282	108,073	2,731	20,230
1884..	5	851	35,000	255,000	57,069	606,226	264,771	22,196,240	12,952	3,020,365	9,460	107,660	951	4,000
1885..	137	3,868	50,000	350,000	62,283	605,900	270,400	21,628,277	13,883	3,194,626	9,929	118,636	1,099	11,050
1886..	37	386	65,000	455,000	67,354	739,402	282,702	22,163,952	13,693	3,174,682	8,095	94.080	389	9,322
1887..	......	......	80,000	560,000	70,520	660,266	283,389	22,277,657	13,341	3,332,428	7,519	79,638	75	7,006
1888..	......	......	100,000	400,000	73,155	803,190	280,062	21,703,090	13,922	3,229,952	11,545	119,108	991	11,140
1889..	......	......	112,000	468,000	73,395	850,052	283,553	21,576,780	13,957	3,130,016	9,785	120,444	549	7,274
1890..	0.4	318	122,500	490,000	70,730	891,616	304,084	23,044,927	14,494	3,167,178	5,422	64,624	569	5,168
1891..	......	......	123,006	492,150	70,633	1,035,560	301,422	22,639,125	14,538	3,180,882	3,088	37,204	720	3,600
1892..	0.3	0	120,000	482,000	79,447	1,007,829	288,424	20,796,030	14,171	2,672,606	1,804	20,987	33	2,900
1893..	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Year.	Uranium Ore.		Wolfram Ore.		Zinc Ore.		Alum.		Antimony.		Bismuth.		Copper.		Copperas.	
1856..	0.56	2,049	0.1	13	5,465	46,496	1,489	143,406	219	79,052	......	......	2,351	2,560,376	2,405	67,221
1857..	5	12,400	......	......	5,236	40,370	1,367	143,204	532	120,980	0.336	1,114	1,892	2,139,765	2,593	118,360
1858..	0.66	3,547	16	1,400	5,916	53,856	1,560	153,063	238	78,944	......	......	2,309	2,296,590	3,198	116,504
1859..	......	......	......	......	5,304	......	1,367	......	......	......	......	......	2,546	......	3,173	......
1860..	......	......	......	......	5,382	......	1,826	......	......	......	......	......	2,632	......	3,736	......
1861..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1862..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1863..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1864.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1865..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1866..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1867..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1868..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1869 .	9	59.417	21	1,411	16,564	167,024	1,851	173,742	163	33,839	1	13,238	529	510,602	7,093	164.500
1870..	9	62,222	33	2,209	13,694	148,290	1,591	157,609	159	54,601	0.9	10,542	566	532,024	6,873	156,882
1871..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1872.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1873 .	0.2	5,205	87	587	14,642	240,618	836	88.555	83	41,715	1	8,270	410	412,869	2,282	97.200
1874..	5	33,159	38	2,638	21,147	358,637	1,773	151,663	163	59,880	1.4	3,491	365	348,357	1,923	75,608
1875..	6	47,076	37	2,196	25,728	401,513	1,718	139,007	74	29,076	......	......	394	378,086	1,212	37,817
1876..	7	44.719	......	......	26,458	447,912	1,930	164,302	145	52,130	0.08	612	442	427,522	1,465	44,894
1877..	7	49,892	40	3,352	24,002	342,447	2,052	160,462	42	14,723	......	......	469	434,651	1,519	57,062
1878..	7	53,512	16	1,051	33,387	317,721	1,817	148,648	74	23,690	14.3	......	303	244.896	1,656	61,022
1879..	7	39,387	7	539	19,389	220,545	1,973	160,264	85	25.115	0.4	1,605	258	187,009	1,374	50.078
1880..	5	33,638	60	5,136	21,564	286,537	2,104	166,936	125	41,687	0.5	2,248	500	382,157	1,202	44,529
1881..	6	45,975	63	6,924	27,340	361,003	2,040	145,847	84	26,106	0.6	......	482	355,082	1,195	42,180
1882..	6	39,144	66	8,936	25,300	374.093	1,966	132,604	161	58,357	0.4	3,047	483	375,829	1,728	63.606
1883..	7	39.871	42	11,790	28.749	361,040	1,732	125,829	131	44.140	0.8	3,265	581	463,997	1,800	65,718
1884..	9	46,960	53	19,430	29,454	314,596	1,917	136,135	169	64,699	1	7,604	681	473,237	2,111	76,475
1885..	11	103,072	55	24,480	23,598	208,994	1,949	131,392	191	64,300	2	18,450	592	358,514	2,049	61.536
1886..	43	228,052	56	20,200	21,320	206,064	1,808	127,860	203	61,416	0.28	2,486	744	426.168	1,398	42.006
1887..	26	98,380	59	16,400	20.099	220,170	2.129	156,776	258	76,476	0.16	1,528	896	537,822	958	27.030
1888..	32	80,360	39	10,750	26,312	352.556	1,683	125,174	213	65,558	......	......	889	720,730	1,019	29.900
1889..	16	53,178	20	7,662	30,096	432,910	1,547	112,606	221	75.792	0.1	1,048	863	583,638	1,082	34,040
1890..	25	41,674	37	12.336	32,642	558,812	1,464	101,632	200	83,584	0.1	1,914	992	602,162	1,296	38,982
1891..	22	19,314	57	21,380	28,878	575,557	1,127	74,340	115	45,118	0.68	5,606	1,033	584.720	1,184	30,158
1892..	18	24,889	72	19,806	33,944	580,365	1,096	69,902	114	44,489	0.55	4,765	837	502,593	1,085	31,698
1893..	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Years.	Pence.	Years.	Pence.	Years.	Pence.	Years.	Pence.	Years.	Pence.	Years.	Pence.	Years.	Pence.	Years.	Pence.
1863...	......	1867...	19.05	1871..	......	1875..	21.47	1879..	20.46	1883..	20.00	1887..	18.96	1891..	20.55
1864...	......	1868..	......	1872..	21.71	1876..	19.78	1880..	20.37	1884..	19.69	1888..	19.32	1892..	20.12
1865...	21.10	1869...	......	1873..	21.64	1877..	19.64	1881..	20.37	1885..	19 21	1889..	20.08	1893..	......
1866...	......	1870...	......	1874...	21.64	1878..	20.17	1882..	20.07	1886..	19.05	1890..	20.68	1894..	......

MINERAL PRODUCTION OF AUSTRIA—*Continued.*

Year.	Copper Sulphate.		Gold, Kilos. (*d*).		Iron, Pig.		Lead.		Litharge.		Nickel and Cobalt Products.		Mineral Paint.	
1856	...	...	2,913	2,137,424	287,521	19,369,598	5,331	1,393,270	1,391	369,874	...	...	...	...
1857	...	...	2,723	1,997,638	317,802	21,760,216	5,992	1,601,949	1,569	418,657	...	...	5	282
1858	...	...	2,470	1,817,599	333,475	22,577,861	5,808	1,351,471	1,501	302,434	...	...	1	74
1859	...	...	1,647	...	317,342	...	6,163	...	1,280	...	11	...	...	...
1860	...	...	1,596	...	312,634	...	7,000	...	1,267	...	5	...	...	...
1861	...	...	...	...	...	...	6,839	1,904,782	1,936	490,994	...	...	...	...
1862	...	...	...	...	...	...	5,691	1,585,683	1,675	401,002	...	...	...	...
1863	...	...	1,513	...	...	...	5,355	1,265,495	2,260	460,167	...	...	...	...
1864	...	...	1,799	2,428,665	...	...	...	...	...	...	...	...	...	...
1865	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1866	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1867	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1868	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1869	136	19,208	31.96	21,574	278,070	18,503,859	4,073	1,012,880	1,634	340,135	...	...	...	...
1870	82	11,850	32.18	21,699	278,570	19,382,809	4,522	1,139,343	822	177,439	...	...	28	1,000
1871	...	...	...	...	291,705	20,277,956	...	...	...	...	...	...	...	...
1872	...	...	...	...	312,542	25,473,843	...	...	...	...	...	...	...	...
1873	...	...	5.3	7,480	*e* 371,039	31,568,485	3,990	1,083,161	1,904	429,584	23	50,375	25	1,557
1874	...	...	14.6	16,377	332,159	18,950,285	4,394	1,193,192	2,337	536,442	37	56,153	10	346
1875	...	...	14.5	15,345	303,459	17,928,835	4,133	1,055,042	2,977	681,697	22	47,230	8	240
1876	...	...	13.6	17,388	273,046	15,159,611	4,291	1,115,033	3,238	747,827	22	34,346	1,367	43,325
1877	...	...	9	10,304	259,036	13,737,003	5,314	1,313,278	3,502	786,257	14	19,740	1,494	16,240
1878	...	...	17	19,875	293,197	14,488,345	5,611	1,237,853	3,542	785,460	6	8,758	1.511	32,350
1879	...	...	17	20,689	285,840	13,627,841	5,980	1,131,086	3,201	543,207	5	3,200	1,344	27,446
1880	...	...	41	58,300	320,302	15,253,096	5,644	1,086,868	3,590	652,001	4	2,856	1,384	29,866
1881	...	...	19	26,046	379,640	17,571,449	6.386	1,159,840	2.996	514.813	...	...	1,467	33,290
1882	...	...	16	21,642	435,478	21,062,759	8,013	1,347,814	3,876	666,608	19	3,342	1,182	25,144
1883	...	...	18	23,675	522,400	24,261,288	7,922	1,245,552	4,015	573,958	...	...	874	19,148
1884	2.5	825	27	38,115	539,621	23,723,730	8,511	1,266,045	3,600	469.001	...	...	1,026	22,820
1885	28	9,262	25	34.970	499,097	20,624,272	8,525	1,254,562	3,306	430,948	...	...	1,099	25,018
1886	161	42,514	16	23,164	485,313	18,986,122	8,048	1,240,458	3,084	418 980	...	...	255	9,108
1887	95	20,431	16	22,882	511,777	18,792,430	7,826	1,227,880	2,836	422,932	...	...	554	20,978
1888	69	14.452	9	13,920	586,121	21,841,028	7,993	1,340,466	2,697	449,224	...	...	646	19,066
1889	158	42,620	13	17,772	617,012	23,587,454	8,218	1,402,764	2,302	367,238	...	...	773	22,004
1890	438	108,804	21	29,092	666,273	27,300,616	8,297	1,399,494	1,913	296,554	...	...	778	22,136
1891	198	42,286	14	19,272	617,145	24,881,094	7,583	1,206,104	2,267	353,058	1.5	450	838	25,350
1892	133	24,587	13	17,580	630,790	24,417,266	7,252	1,125,493	2,520	393,356	...	...	2,022	57,429
1893	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Year.	Quick-silver.		Silver, Kilos. (*d*)		Sulphur.		S'lph'ret of Carb.		Sulphuric Acid.		Uranium Salt.		Tin.		Zinc.	
1856	256	479,670	59,615	2,857.885	1,402	141,865	...	...	...	...	...	...	36	42,258	866	172,707
1857	402	702,706	53,499	2,551,893	1,366	119,028	...	...	...	...	...	...	43	64,481	1,055	229,371
1858	243	445,881	51,859	2,481,632	1,448	147,465	...	...	...	...	0.1	651	61	69,771	1,580	315,910
1859	356	...	34,527	...	1,516	...	...	...	...	...	...	...	51	...	1,246	...
1860	235	...	34,094	...	1,784	...	...	...	...	...	...	...	63	...	1,301	...
1861	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1862	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1863	...	...	35,318	...	...	...	...	...	...	...	...	...	...	...	...	...
1864	...	...	40,963	3,689,744	...	...	...	...	...	...	...	...	...	...	...	...
1865	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1866	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1867	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1868	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1869	317	654,632	15.233	1,370,962	1,293	118,250	...	...	...	...	3.8	74.503	31	48,065	1,866	380,570
1870	370	908,622	15,535	1,397,192	1,297	135,558	...	...	...	...	3.6	70,374	37	55,121	1,908	374,930
1871	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1872	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1873	377	1,677,844	19.064	1,834,960	1,194	115,513	...	...	...	...	5	88,877	24	36.590	2,285	567,022
1874	372	2,191,875	21,085	1,965.394	902	87,644	...	...	...	...	3.9	76,709	62	64,688	2,818	616,340
1875	370	1,548,462	24,848	2,282,262	947	82,268	...	...	...	...	4.6	98,636	160	156,625	2,940	684.721
1876	375	1,092,029	25,166	2,355,276	*f* 347	34,329	...	...	...	...	4.6	95,738	207	196,975	3.979	949,101
1877	392	938,255	27,169	2,420,928	*f* 305	35,238	...	...	9,739	1,294,808	4.5	96,000	101	101.738	4,519	966,162
1878	370	803,017	29,091	2,654,354	588	61,925	...	...	9,361	969,972	4	84.500	26	25,362	3,623	663,503
1879	429	823,073	29,535	2,631,539	210	14.877	60	16,688	12,003	1,009,791	3	72,300	33	32,734	3,280	547,848
1880	369	775,679	30,257	2,696.108	402	30,069	90	23,348	12,235	1,171,780	3	58,097	29	34,383	3.756	712,712
1881	398	771,908	31,360	2,794,111	436	30,282	178	46,254	14,268	1,211,329	3	63,327	39	43,852	4.119	708,555
1882	409	770,254	31,095	2,770,509	394	26,645	216	54.663	12,282	681,133	3	61,069	34	41,252	4,791	787,662
1883	466	796,236	32,626	2,906,967	270	23,206	72	19,374	11,338	649,468	2	39,778	36	44,209	4,539	734,457
1884	499	851,009	34.857	3,105,740	257	21,586	19	3,900	11,242	661,230	3	65,291	40	45,293	4,536	704,348
1885	487	940,044	36,076	3,214,198	88	7,842	...	...	11,559	599,358	9	193,890	35	41,144	3.948	651,890
1886	541	1,177,670	35,696	3,180,528	101	10,184	...	...	12,025	785,588	12	363.194	42	47,838	3,843	632.612
1887	532	1,291,024	35,181	3,136,874	105	10,724	...	...	12,792	659,704	6	88,704	31	45,820	3,609	639,494
1888	541	1,405,290	35,325	3,154.428	109	12,902	...	...	10,788	412.582	0.7	15,552	38	55,468	4,001	869,114
1889	566	1,537,014	35.435	3,157,152	40	2,854	...	...	9,732	522,356	3.8	79.604	56	70,298	4,840	1,101.028
1890	542	1,596,562	35.862	3,197,584	37	2,642	.	... ..	11,334	441,946	4	64,212	50	59,438	5,449	1,467,840
1891	570	1,383,682	36,037	3,219,048	45	3.416	...	...	12,268	374,576	4	45,244	56	63,718	5,006	1,375,076
1892	542	1,148,320	36,658	3,293,746	53	4,338	...	...	11,038	315,433	2	28,398	72	85,184	5,237	1,264,587
1893	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

(*b*) In 1874, 1877, 1878, and 1880, respectively, there were produced 18, 24, 170, and 0.7 tons of arsenic. (*c*) The figures under "Coal" for 1863-68, inclusive, are for both coal and lignite. (*d*) Before 1869 the output of gold and silver in Hungary is included in "Gold" and "Silver," respectively. (*e*) Includes probably the amount of pig iron in stock. (*f*) Includes sulphuret of carbon.

THE MINERAL PRODUCTION OF HUNGARY. (*p*) (IN METRIC TONS AND FLORINS.)

Year.	Antimony Ore. (*q*)		Asphaltum and Asphalt Oil.		Chrome Ore.		Coal.		Lignite.		Briquettes.		Coke.	
	Tons.	Value.	T'ns	Value.	T'ns	Value	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1863	......	....	.....	....	899	11,479	340,407	1,238,643	265,011	787,312	......	....	......	....
1864	......	....	.....	....	842	3,360	349,495	1,196,412	244,330	673,324	......	....	......	....
1865	......	....	.....	....	825	8,843	461,523	1,238.348	257.742	743,346	......	....	......	....
1866	......	....	.....	....	73	780	413,174	1,405,087	287,074	724,107	......	....	......	....
1867	......	....	.....	....	145	1,632	402,739	1,431,558	334,402	839,525	......	....	......	....
1868	......	....	.....	....	140	1.625	486,806	1,970,675	443,240	1,544,373	......	59,430	......	....
1869	......	....	.....	....	419	3,894	493,532	1.778,872	562.338	1,822,697	......	97,604	......	....
1870	......	....	.....	....	593	5,716	537,153	2,223,974	601,982	2,463,962	......	115.726	......	....
1871	......	....	.....	....	591	5,700	517,120	2,763,895	855,701	3,218,935	......	174,313	......	....
1872	......	....	.....	....	2,794	27,443	641,301	3,111,358	944,710	3,767,249	......	364,303	......	....
1873	......	....	.....	....	1,189	11,674	684,275	3,576,279	949,979	3,639.940	......	210,531	......	....
1874	87	12,024	.....	....	590	5,793	625,425	3,100,378	773,739	2,781.773	18.982	155,821	......	....
1875	82	11,178	.....	....	576	5,140	635,611	2,928,114	815,547	2,598,653	18.040	159,171	......	....
1876	239	25,893	.....	....	20	176	666,991	3,240,402	884,139	2,572,735	17,471	128.254	......	....
1877	142	19.873	.....	....	.....	....	682,449	3,769,339	907,126	2,821,195	19,976	141,819	......	....
1878	216	27,448	.....	....	.....	....	686,985	3,738,199	908,702	2,416,054	29,307	216,850	......	....
1879	2,131	22,967	.....	....	.....	....	674,087	3,707,234	932,475	3,030,420	35,047	259,167	......	....
1880	583	65,756	.....	....	.....	....	805,047	4,167,936	1,013.392	2,783.811	30,704	227,008	......	....
1881	768	84,729	.....	....	.....	....	848,516	4,093,982	1,112,633	2,826,155	32,137	176,524	......	....
1882	734	73,324	.....	....	.....	....	799,319	3,718,548	1,259,896	4,378,694	35,369	202,846	......	....
1883	613	44,934	.....	....	.....	....	892,501	4,190,175	1,473,779	4,173,071	31,385	174,785	......	....
1884	490	38,474	.....	....	.....	....	940,434	4,381,502	1,584,623	4,749,278	30,610	200.994	......	....
1885	687	40,444	.....	....	.....	....	955,878	4,539,635	1,586,766	4,546,587	15,729	124,434	......	....
1886	191	21,396	.....	....	.....	....	859,197	4,345,475	1,567,614	4,657,145	18,075	137,945	......	....
1887	238	28,844	.....	....	.....	....	786,408	3,788,041	1,723,440	4,998,149	17,461	134,245	......	....
1888	198	28,930	.....	....	.....	....	850,691	4,051,010	1,874,201	5,156,588	23,390	179,124	......	....
1889	174	42,565	.....	....	.....	....	937,452	4,467,453	1,952,226	5,814,056	22,797	179,855	......	....
1890	224	40,590	.....	....	.....	....	994,812	4,831,308	2,249,098	6,835,016	25,184	198,877	......	....
1891	......	....	7,649	$9.518	.....	....	1,019,352	4,990,356	2,427,126	7,713,443	35,446	275,086	17,124	167,298
1892	853	72,788	.....	200,000	.....	....	1,052,214	5.174,772	2,741,391	8,085,417	34,882	232,663	2,129	18,951
1893	......	....	.....	....	.....	....	....	....	....	....	......	....	......	....

Year.	Galena. (*q*)		Iron Pyrites.		Manganese Ore.		Mineral Wax.		Nickel and Cobalt Ore. (*r*)		Petroleum.		Realgar.		Salt.	
	T'ns	Value	Tons.	Value.	T'ns	Value	T'ns	Value	T'ns	Value.	T'ns	Value.	Tons.	Value	Tons.	Value.
1863	.....	......	......	....	.....	......	.....	......	397	224,223	.....	....	......	......	....	....
1864	.....	......	......	....	297	8,587	.....	......	620	394,643	.....	....	......	......	....	....
1865	.....	......	......	....	305	6,762	.....	......	569	335,043	.....	....	......	......	....	....
1866	.....	......	......	....	128	3,082	.....	......	434	259,372	.....	....	......	......	....	....
1867	.....	......	1,512	7,727	198	7,238	.....	......	464	281,878	.....	....	......	......	145.684	12,519,673
1868	.....	......	2,112	13,340	124	4,623	.....	......	517	216,942	.....	....	......	......	136,724	13,207,250
1869	.....	......	4,135	14,755	151	4,794	.....	......	572	259,399	.....	....	......	......	148.050	12,353,585
1870	.....	......	1,911	9,770	77	2,391	.....	......	424	291,947	.....	....	......	......	155,447	13,379.956
1871	.....	......	5,985	30,982	122	5,402	.....	......	442	294,374	.....	....	......	......	169,278	13,062,928
1872	.....	......	3,809	137,390	221	8,141	.....	......	373	342,237	.....	....	......	......	162,105	14,043,050
1873	.....	......	6,102	34,220	209	7,032	.....	......	389	661.866	.....	....	......	......	146,067	12,955,560
1874	.....	......	11,777	61,994	593	12,092	24	197	250	333,412	1,781	143,075	......	......	121.121	10,323.887
1875	.....	......	22,183	119,027	1,044	20,555	146	637	234	351,337	1,693	112,989	......	......	110,539	10,197,671
1876	.....	......	32,422	210,302	692	14,951	221	747	39	38,715	1,967	147,608	......	......	120,116	10,989,473
1877	.....	......	49,920	335,830	527	9,203	158	1,011	2.332	168,207	1,966	157,280	......	......	118,876	12,369,599
1878	.....	......	47,673	320,083	823	14,012	887	3,519	163	97.668	1,793	143,440	......	......	145,796	11,858,399
1879	.....	......	56,283	355.651	994	10,431	180	1,348	349	84,890	1,640	131,200	......	......	151,421	12.026,553
1880	.....	......	53,782	257.595	2,408	16,788	179	2,273	158	90,742	1,646	131,648	......	......	157,879	12,371,331
1881	5	147	47,129	206,890	2,832	20,308	48	316	137	79,214	1,875	149,800	......	......	149.944	11,752,323
1882	327	45,903	57,488	267,560	4,360	25,085	255	2,669	180	82,960	743	63,898	......	......	163,923	12,599,118
1883	542	55,575	56,128	261,066	2.846	19,548	426	11,033	151	78,491	.....	....	......	......	159,837	12,249,309
1884	441	48,126	38,029	173,662	2,829	18,447	205	5,489	174	89,148	21	1,388	......	......	159,547	12,484,675
1885	.....	......	39,257	218,517	2,757	18,965	181	3,332	428	105,147	14	1,000	......	......	162,962	12,608,300
1886	255	31,265	45,324	258,870	2,192	19,977	967	2,863	409	78,781	6	840	......	......	152,222	13,299,421
1887	22	3,330	50,262	275,633	963	10,664	733	8,017	176	68,046	29	1,816	......	......	159,898	14,033,588
1888	4	555	45,959	254,194	622	8,912	1,112	8,920	336	61,561	35	1,957	6	33	163,750	14,336,307
1889	155	26,418	52,416	280,563	98	1,339	570	7,982	366	53,127	68	3,065	169	1,261	164,518	14,432,718
1890	207	35,266	56,746	294,446	1,445	6.955	1,200	48.000	57	23,270	990	26,407	......	......	159,912	13,943,165
1891	.....	......	57,715	250,349	128	2,357	1,656	94,767	.....	....	.....	....	0.2	......	162,788	13,862,083
1892	.....	......	56,050	236,097	1,304	8,340	.....	......	340	29,240	20	690	1	......	163,514	14,119,613
1893	.....	......	......	....	.....	......	.....	......	.....	....	.....	....	......	......	....	....

(*p*) For 1863-90, inclusive, from *Magyar Statistikai Evkonyv;* for 1891-92, from *Ungarische Montan Industrie Zeitung.* In 1885, 1886, 1887, and 1890 there were also produced 130, 50, 25, and 4 tons of arsenic products (*mireny kovand*), valued at 562, 150, 50, and 46 florins. (*q*) This does not include the ore produced in Hungary from which the metallurgical products given in the table were derived. It gives only the amount of ore which was sold, and presumably was not smelted in the country. (*r*) Till 1873, inclusive, includes speiss; no separate data given. (*s*) In 1881, 1883, 1884, 1887, and 1888 there were also produced 26, 17, 13, 14, and 15 tons of antimony amalgam, valued, respectively, at 7770, 5312, 2990, 2380, and 3390 florins. (*t*) Gold glätte.

THE MINERAL PRODUCTION OF HUNGARY—*Continued.*

Year.	Zinc (q) Blende.		Acid.				Alum.		Antimony. (s)		Copper.		Copper Sulphate.		Gold.	
			Nitric.		Sulphuric.				Crude	Regulus.						
	Ts.	Val.	Ts	Value	Tns.	Value.	Ts.	Value.	Tons.	Value.	Tns.	Value.	Ts.	Value.	Kilos.	Value.
1863	....	....	....	....	....	....	301	44,640	242	59,840	2,032	2,030,124	83	36,740	1,498.0353	2,022.353
1864	....	....	....	....	....	....	280	37,500	262	75,507	2,230	2,182,559	103	35,791	1,773.3986	2,394,088
1865	....	....	....	....	....	....	291	32,000	317	56,791	2,244	2,011,909	159	56,247	1,797.2942	2,426,074
1866	....	....	....	....	....	....	303	33,925	534	92,231	2,172	1,875,663	213	74,985	1,614.5206	2,179,549
1867	....	....	....	....	....	....	616	63,900	487	75,204	2,382	2,079,432	257	91,659	1,827.3186	2,467,879
1868	....	....	....	....	....	....	579	62,550	306	54,604	2,065	1,824,406	190	54,400	1,660.7101	2,241,958
1869	....	....	....	....	....	....	652	78,279	291	56,040	1,749	1,488,795	128	35,927	1,557.3704	2,102,450
1870	....	....	....	....	....	....	494	62,279	330	70,589	1,189	1,027,644	94	26,466	1,482.3398	2,001,158
1871	....	....	....	....	....	....	468	59,097	142	41,894	1,275	1,070,776	31	9,239	1,392.1528	1,879,406
1872	....	....	....	....	....	....	353	50,942	95	29,820	1,187	1,119,832	106	30,484	1,434.1795	1,936,142
1873	....	....	....	....	....	....	319	45,616	74	18,918	1,056	911,993	....	....	1,233.4226	1,720,625
1874	....	....	....	....	....	....	130	17,445	94	20,634	953	824,972	20	6,145	1,291.1602	1,801,169
1875	....	....	....	....	....	....	218	29,141	62	16,538	1,047	948,980	202	48,008	1,576.9760	2,199,881
1876	....	....	....	....	....	....	140	12,600	37	10,597	1,025	902,856	197	47,172	1,890.0275	2,637,293
1877	....	....	4	1,305	113	1,290	105	8,921	15	4,446	986	840,138	227	54,112	1,704.7061	2,378,065
1878	....	....	12	3,579	1,365	28,475	179	17.880	10	2,871	1,019	809,156	222	48,955	1,807.1997	2,521,044
1879	....	....	17	4,930	1,803	32,908	112	11,245	63	19,925	1,036	737,725	182	33,484	1,593.6513	2,223,144
1880	....	....	16	3,752	3,037	69,161	120	12,015	174	51,675	830	602,333	465	79,851	1,604.0683	2,237,675
1881	....	....	12	2,817	1,830	36,866	160	16,000	265	79,035	828	580.934	482	91,434	1,578.6045	2,195,700
1882	....	....	18	4,515	1,817	34,926	161	16,070	231	63,932	672	506,570	222	39,428	1,724.2977	2,398,373
1883	....	....	20	5,231	2,033	38,487	....	....	206	49,198	803	604,700	153	26,412	1,628.8380	2,266,038
1884	....	....	....	....	855	10,775	....	....	136	27,839	614	428,109	225	34,930	1,684.5770	2,349,984
1885	....	....	....	....	2,642	37,799	141	12,713	268	76,353	504	303,916	202	29,557	1,719.2958	2.384,349
1886	....	....	....	....	560	5.694	....	....	254	68,656	371	213,779	355	50,553	1,788.7442	2,483,423
1887	....	....	....	....	767	6,978	....	....	236	74,653	339	184,371	232	32,982	1,861.9188	2,597,377
1888	....	....	....	....	864	5,286	....	....	304	111,429	383	239,020	132	19,312	1,806.4258	2,575,167
1889	....	....	....	....	2,059	23,213	....	....	333	131,126	305	181,586	205	37,813	2.215.2153	2,977,253
1890	77	2,378	....	....	1,559	21,956	....	....	352	137,184	275	156,836	197	36,864	2,131.3557	2,973,041
1891	127	2,650	....	....	2,230	60,387	....	....	1,370	268,745	247	156,552	....	....	2,183.9253	3,046,440
1892	116	2,825	....	....	3,340	54,983	....	....	343	138,003	317	165,215	5	1,871	2,246.7720	3,134,437
1893	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Year.	Iron, Pig.		Iron Sulphate.		Lead.		Litharge.		Litharge, Gold. (t)		Nickel and Cobalt Products.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1863	108,202	4,812,414	2	283	1,645	332,032	577	125,383	....	....	....	....
1864	116,661	5,361,412	0.4	59	1,558	290,652	588	125,768	....	....	....	....
1865	101,403	4,310,094	....	....	1,259	195,379	726	137,107	0.5	160	....	....
1866	106,720	4.259,863	30	1,784	1,242	229,989	685	150,662	0.6	150	....	....
1867	104,048	4,188,390	40	2,191	1,584	330,414	524	116.654	0.7	144	....	....
1868	112,575	5,424,732	1	85	1,141	232,216	597	144,238	0.6	150	....	....
1869	127,012	6,564,900	1	65	1,537	307,209	667	168,268	0.6	120	....	....
1870	124,383	6,557,524	....	....	1,057	208,538	547	138,120	0.2	63	....	....
1871	132,901	7,464,551	....	....	1,617	360,731	433	111,454	0.5	180	....	....
1872	146,857	8,868,724	111	5,324	1,662	349,910	360	89,750	....	152	....	....
1873	163,469	10,148,614	163	10,378	1,471	290,653	148	34,603	....	160	....	....
1874	161,898	8,230,893	....	....	1,469	327,385	209	52,809	....	....	82	129,308
1875	159,604	7,521,622	89	5,007	1,733	355,251	202	48,008	....	....	120	208,751
1876	127,379	5,915.421	37	2,127	2,223	446,203	197	47,172	....	....	78	151,027
1877	128,594	5,678,977	30	1,693	2,120	447,167	227	54,112	....	....	10	4,986
1878	141.053	5,965.019	23	1,135	1,896	384,862	222	48,955	....	....	120	89,660
1879	118,322	4,777,206	438	8,974	1,967	321,051	182	33,484	....	....	64	38,220
1880	143,932	5,729,609	398	8,795	1,699	251,369	465	79,851	....	....	64	45,227
1881	164,001	6,500,685	240	4,416	1,785	245,566	482	91,434	....	....	60	40,292
1882	176,261	7,110,661	330	5,882	1,665	193,130	222	39,428	12	941	61	47,333
1883	176,457	7,556.574	274	5,309	2,105	261,705	153	26,412	77	5,852	54	40,311
1884	194,725	8.270.765	352	8,231	1,765	254,701	225	34,930	87	2,237	53	35,868
1885	215,687	8,206,293	364	7,460	3,968	458,799	202	29,557	37	1,149	62	32,268
1886	234,667	8.055,656	235	3,525	2,141	263,572	355	50,553	13	297	77	34,650
1887	192,753	6,563.599	240	5,328	1,779	220,383	232	32,982	9	212	65	29,304
1888	204,106	7,129,049	251	5,572	1,995	278,626	132	19,312	32	344	38	15,662
1889	238,801	8,763,758	244	5,416	2,385	376,190	205	37,814	141	1,515	47	20,984
1890	299,109	11,338,308	87	1,931	1,266	181,945	197	36,864	....	....	59	23,449
1891	304,701	11,525,357	540	10,212	2.173	350,230	351	60,988	....	....	58	29.240
1892	309,494	11,690,952	595	10,233	2,335	412,558	507	93,884	....	....	58	20,272
1893	....	....	....	....	....	....	....	....	....	....	....	....

(*a*) From *Statistische Ubersichten betreffend den auswärtigen Handel des oesterreichisch-ungarischen Zollgebiets. Wein.* (*b*) Part of these figures since Feb. 1, 1892. (*c*) Net weight. (*d*) Partly net weight. (*e*) In the crude state were imported and exported, respectively. in 1891, 1892 and 1893, 101, 16, 98. 15, 9 and 47 tons. (*f*) Of crysolite in the crude state were imported and exported, respectively, in 1891, 1892 and 1893, 79, 128, 131, 10, 14 and 2 tons. (*g*) Of fluorspar in the crude state were imported and exported, respectively, in 1891, 1892 and 1893, THE MINERAL PRODUCTION OF HUNGARY—*Continued.*

Year.	Mineral Paints.		Quicksilver.		Silver.		Sulphur.		Sulphuret of Carbon.		Zinc.	
	Tons.	Value.	Kilos.	Value.	Kilos.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1863..	1	69	28,112	53,488	20,001.6	1,800,043	103	16,991	......	....	......	....
1864..	22	200	32,424	69,832	26,122.8	2,351,049	94	15,181	......	....	116	28,080
1865..	56	400	42,728	91,705	26,127.3	2,352,806	7	933	......	....	204	41,796
1866..	11	80	55,776	119,615	26,827.9	2,414,065	47	6,386	......	....	375	83,762
1867..	280	7,000	60,984	131,483	27,113.1	2,440,186	52	5,794	......	....	348	83,187
1868..	246	4,480	42,784	92,363	27,010.1	2,430,913	26	3,291	......	....	323	67,274
1869..	185	5.610	33,712	75,370	26,007.2	2,340,648	46	5,455	......	....	458	94,493
1870..	146	4,110	25,648	75,530	20,455.8	1,841,021	33	3,786	......	....	415	81,565
1871..	157	6,170	18,088	48,677	20,127.5	1,811,469	21	2,140	......	....	463	85,927
1872..	138	4,980	15,319	51,980	17,136.3	1,542,270	10	1,320	......	....	557	120,270
1873..	164	5,690	14,056	80,250	18,576.6	1,671,893	17	1,892	......	....	616	166,065
1874..	105	3,700	13,269	71,082	17,421.3	1,567,938	20	1,991	......	....	622	151,149
1875..	116	3,726	18,006	48,900	21,235.7	1.911,209	18	1,550	......	....	513	126,411
1876..	127	3,838	23,078	58,700	22,784.4	2,051,320	15	1,366	......	....	567	130,387
1877..	133	4,176	27,909	62,643	20,506.4	1,845,575	9	1,325	......	....	66	13,312
1878..	128	4,083	24,386	47,821	19,571.1	1,761,403	24	1,920	......	....	418	72,720
1879..	127	4,067	22,859	45,518	18,660.9	1,679,488	12	960	......	....	13	1,978
1880..	119	5,521	18,071	36,142	17,443.8	1,569,942	7	408	......	....	554	99,835
1881..	260	8,320	17,737	33,680	17,583.1	1,579,420	13	1,455	......	....	612	99,617
1882..	180	7,200	13,515	25,573	16,568.2	1,490,754	26	2,424	......	....	605	104,375
1883..	210	8,400	12,587	22,027	16,708.3	1,503,550	60	3,617	......	....	205	31,522
1884..	210	8,400	8,308	14,123	15,049.9	1,353,989	35	1,681	......	....	......	....
1885..	215	7,525	5,673	9,643	16,671.7	1,499,855	47	2,227	......	....	......	....
1886..	300	9,000	7,105	15,425	16,042.9	1,443,822	24	1,645	8	1,551	......	....
1887..	250	8,750	9,619	21,199	17,664.9	1,588,184	30	2,100	48	9,025	......	....
1888..	190	7.400	10,353	25,523	16,692.9	1,497,712	41	2,870	103	19,532	......	....
1889..	172	6,694	10,545	25,206	17,229.5	1,532,595	42	2,905	194	30,318	......	....
1890..	237	6,487	8,102	20,253	17,049.8	1,597,907	63	887	266	30,561	......	....
1891..	221	8,820	8,631	19,385	16,736.6	1,506,294	40	3,392	174	31,329	......	....
1892..	263	10,508	7,853	15,641	18,423.8	1,658,143	42	3,773	116	20,208	......	....
1893..	......	....	....	....	....	....	......	....	......	....	......	....

MINERAL IMPORTS AND EXPORTS OF AUSTRIA-HUNGARY. (*a*) (IN GROSS METRIC TONS.)

IMPORTS.

Year.	Alumin. Alloys, & Manuf'e.	Antim'ny Regulus.	Asb'st. (*e*)	Asphalt.		Ba-rytes.	Bo-rax.	Brass, Manf'e.	Coal.	Coke.	Char-coal.	Lig-nite.	Chrome Ore.	Clays.	
				Raw.	Ref.									Cr'de.	M'f'd.
1891	42.8	0.4	137	1,082	2,022	3,585	1,535	2,269	3,670,196	248,193	1,150	15,174	10	24,115	*d* 97,539
1892	*bd*49.3	2.1	112	1,822	1,442	4,584	852	*bd*1,731	3,352.129	254,000	1,023	18,338	10	27,776	*bd*121,632
1893	41.2	......	99	2,144	1,012	4,413	1,451	....	3,840,874	309,861	853	20,111	570	25,149	....
EXPORTS.															
1891	6.3	276.4	42	51	35	192	27	1,138	713,069	73,453	20.238	900,255	157	28,447	47,974
1892	22.9	305.9	78	287	......	33	30	1,234	653,667	87,745	16,181	6,748,844	293	30,882	39,448
1893	28.1	......	187	223	22	35	68	....	642,424	108,576	14,838	6,763,186	327	31,307	....

IMPORTS.

Year.	Cobalt & Nick.Ore.	Copper.		Packfong & M'f'es.	Tomback & M'f'es.	Cryol'e(*f*)	Fluor-spar. (*g*)	Glass and Glass-ware.	Gold.			Graphite.		Gypsum, Crude.	Hydro-chlor. Acid.	Iron M'f'res.
		M'f'e.	Ore.						Coin.	Met'l.	Ore.	Crude.	Ref.			
1891	249	9,951	909	349	1	132	4,344	*d* 4,147	23.6	20.7	0.5	691	181	1,657	499	*d*47,623
1892	459	8,337	909	*bd*321	*bd*5	201	3.112	*bd* 3,652	29.2	30.8	......	638	93	1,441	460	*d*49,237
1893	971	11,822	638	292	41	100	228	*d*3,599	46.9	62.1	......	782	......	862	438	....
EXPORTS.																
1891	233	590	10	488	24	12	35,539	42,788	5.3	65.5	0.3	6,490	4,887	855	1,540	36,502
1892	194	619	19	435	26	14	35,210	44,093	8.5	41.1	66.4	7,074	4,911	970	1,876	31,782
1893	305	683	14	448	4	2	......	45,087	9.4	45.5	73.2	7,253	4,284	838	1,841	....

3,900, 2,837, 18,813, 35,524, 35,187, and 159 tons. (*h*) Of kaolin in the crude state were imported and exported in 1891, 1892, and 1893, respectively, 2827, 2154, 2273, 5811, 16,982. and 23,624 tons.

MINERAL IMPORTS AND EXPORTS OF AUSTRIA-HUNGARY—*Continued.*

IMPORTS.

Year.	Iron. Ore.	Iron. Pig.	Iron. Rails.	Iron. Spiegel.	Iron Pyrites.	Iron Sulp.	Kaolin.(*h*)	Lead. Lead, Alloys, M'f'e.	Lead. Litharge.	Lead. Ore.	Lime. Crude.	Lime. Hydraulic.	Chlor Lime.	Manganese Ore.	Marble.
1891	68,121	40,743	705	104	30,770	745	4,049	*d*4,561	250	283	7,536	16,744	867	425	1,494
1892	71,679	*b*45,843	*b*333	*b*920	33,261	1,424	3,777	*d*7,348	316	355	8,558	18,931	1,016	519	1,939
1893	73,248	*b*57,733	927	697	45,530	800	1,874	6,286	316	299	9,115	17,098	1,559	354	1,816

EXPORTS.

Year.	Iron. Ore.	Iron. Pig.	Iron. Rails.	Iron. Spiegel.	Iron Pyrites.	Iron Sulp.	Kaolin.(*h*)	Lead. Lead, Alloys, M'f'e.	Lead. Litharge.	Lead. Ore.	Lime. Crude.	Lime. Hydraulic.	Chlor Lime.	Manganese Ore.	Marble.
1891	88,059	8,394	253	294	8,539	747	40,691	255	1,007	3,658	19,924	58,750	311	8,364	3,041
1892	108,120	7,932	161	1,153	6,833	417	47,167	202	1,334	3,784	14,432	59,784	38	3,768	2,389
1893	106,259	9,274	20	371	3,042	476	26,192	270	1,311	1,608	28,019	66,543	216	3,697	2,638

IMPORTS.

Year.	Oil, Mineral. Crude.	Oil, Mineral. Ref. or Partly Refin'd.	Paint, Min'l. Crud.	Paint, Min'l. Ref.	Nickel and Manufacture.	Peat.	Phosp. & Phos. Ac.	Platin. & Oth. Prec. Metals.	Potassium.	Chlor of Potassium.	Nitrate of Potassium.	Quicksilver.	Salt.	Silver. Coin.	Silver. Metal	Silver. Ore	Slag.
1891	*c*122,790	*c*16,735	1,718	2,409	52	2,485	217	0.05	767	1,917	27,199	17	*d*26,801	49	79	22	426
1892	*c*135,823	*c*14,479	1,295	*b*2,165	*bd*46	2,935	200	2.1	*b*164	1,945	28,071	2	*d*27,836	60	88	0.5	3,621
1893	*c*139,168	*c*16,764	1,680	3,147	*d*51	2,228	238	......	......	1,869	37,626	3	26,609	59	58	1.0	1,659

EXPORTS.

Year.	Oil, Mineral. Crude.	Oil, Mineral. Ref. or Partly Refin'd.	Paint, Min'l. Crud.	Paint, Min'l. Ref.	Nickel and Manufacture.	Peat.	Phosp. & Phos. Ac.	Platin. & Oth. Prec. Metals.	Potassium.	Chlor of Potassium.	Nitrate of Potassium.	Quicksilver.	Salt.	Silver. Coin.	Silver. Metal	Silver. Ore	Slag.
1891	443	2,188	1,138	1,605	83	2,712	1	0.7	5,157	315	44	488	4,861	31	120	10	84,484
1892	576	1,873	1,169	1,232	237	5,101	1	3.3	6,001	925	11	465	10,088	79	127	23	49,647
1893	613	3,767	922	1,409	79	5,441	6	1.2	......	1,118	15	414	7,678	87	131	14	45,478

IMPORTS.

Year.	Soda. Calcin.	Soda. Caustic.	Soda. Crude & Crys.	Glauber Salt.	Stone Quartz, Etc.	Stoneware.	Stucco.	Sulphur.	Sulphuric Acid.	Tin and Manufacture.	Vari. Min's. Cr'de	Vari. Min's. Gr'd or Tre'd	Various non-Prec. Metal and Manuf'e.	Various Ores.	Zinc. Ore.	Zinc. Spelt. M'f'e.
1891	1,391	*d*690	911	5,484	115.893	*d* 42,711	7,544	14.939	2,689	2.378	49.704	33,840	1,484	327	104	11,715
1892	807	*bd*1,316	197	5,389	117,773	*bd*55,477	7,925	13,900	*b*1,909	*d*2,406	46.506	40,266	*bd*1,417	432	3,481	*b*14,724
1893	953	....	....	6,688	155,571	*d*70,394	.....	13,090	2.090	2,921	50,722	455,478	....	401	3,739	*b*15,529

EXPORTS.

Year.	Soda. Calcin.	Soda. Caustic.	Soda. Crude & Crys.	Glauber Salt.	Stone Quartz, Etc.	Stoneware.	Stucco.	Sulphur.	Sulphuric Acid.	Tin and Manufacture.	Vari. Min's. Cr'de	Vari. Min's. Gr'd or Tre'd	Various non-Prec. Metal and Manuf'e.	Various Ores.	Zinc. Ore.	Zinc. Spelt. M'f'e.
1891	1,063	626	806	78	315,857	37.731	1,814	352	3,953	125	25,773	34.085	3,380	1.283	7,766	1,184
1892	1.048	202	271	77	260,946	36.943	1,766	474	2,855	144	21,598	35.405	3,400	905	12,578	1.442
1893	608	....	323	570	272,239	36,743	.....	1,508	3,906	150	118,665	33,642	....	619	7,578	1,939

MINERAL PRODUCTION OF BOSNIA, SINCE ITS ANNEXATION TO AUSTRIA-HUNGARY. (*a*)
(IN METRIC TONS.)

Year.	Chrome Ore.		Lead-Silver Ore.		Lignite. (*b*)		Manganese Ore.		Salt.		Zinc Ore.		Antimony, Crude.		Copper.		Pig Iron.		Quicksilver.	
1882	1,346	$9,840	102	$1.096	12,027	$30,800	2,283	$22.000	.....	.....	69	$498	..	......	...	......	.....	......	...	.....
1883	2,663	8,814	53	488	13,361	22.044	4.003	19.202	....	....	697	. ...	..	......	...	......	.....	......	...	....
1884	470	4,800	...	......	17,787	33,428	4,210	12,223	....	....	...	.....	14	$2,412	...	......	.....	......	...	....
1885	722	7,310	...	......	12.952	23,876	4.406	13,796	1,850	$51.800	...	.....	32	5,360	...	......	.. ..	......	...	.....
1886	1,411	12.160	...	......	22,250	28,012	5,308	32,800	2,400	67,200	...	.....			...	......	.....	......	0 6	$480
1887	2.450	20,401	...	......	33,150	35 802	5,202	28,410	3,170	100,760	...	.....	..	......	...	......	240	$6.721	2	1,666
1888	1,350	12,002	...	......	44,209	43,480	100	561	4,930	142,040	...	.....	..	......	50	$2,560	386	6.160	...	... .
1889	1,460	15.080	96	1,440	46.650	43,560	1,000	5,200	5,350	149,800	20	299	..	.. ...	71	6,808	404	6,400	...	.....
1890	1.000	10,800	92	800	59,906	49,080	5,500	36,801	5,000	140,000	61	248	36	5,480	134	28,400	230	3,640	5.3	6.360
1891	918	10,030	109	2,280	77,266	66,160	8,847	58,000	5,970	167,660	47	188	27	2,720	160	32,000	987	11,200	5.2	5,560
1892	1.296	14,411	41	1,680	85,449	76,049	7,944	51,203	8.006	224,000	16	64	91	6,240	140	26,602	3.173	41,360	0.3	281
1893	965	10,996	...	.. ...	118,263	113,434	7,403	44,265	8,517	238,476	...	.....	3	198	101	19,796	2,816	36,613	0.2	600

(*a*) These figures were kindly furnished by C. von Ernst of Vienna. There has also been produced · Antimony ore, in 1882, 201 tons; 1891. 108 tons; 1892, 276 tons. Quicksilver ore: 1891, 88 tons; 1892, 3.5 tons. (*b*) The output in 1881 was 5034 tons, $14,060.

BELGIUM.

The production of minerals in Belgium has apparently passed its zenith and is steadily declining, while the production of metals from imported ores is increasing. In zinc ores, it is seen that the more easily treated calamine reached its maximum output in 1855, and as it declined the production of blende increased, reaching its highest point in 1878. Since 1856, when the total amount of zinc ores produced was 83,274 tons, this has steadily decreased, amounting in 1892 to but 12,260 tons. The output of metallic zinc, however, has as steadily increased during the same period, amounting to 22,900 tons in 1856, and in 1892 to 91,546 tons, produced almost entirely from imported ores. Under the subject head "Zinc," pages 623 to 675, will be found a very comprehensive description of this industry in Belgium.

The production of iron ore has declined from its maximum of 1,018,231 tons in 1865 to 209,943 tons in 1892. Pig iron has increased in the same period from 470,767 tons to 753,268 tons in 1892, reaching its maximum of 832,226 tons in 1889. The production of wrought iron reached its height in 1889, when 577,204 tons were produced, but since then there has been a decline to 479,008 tons in 1892. Cast and rolled steel, on the contrary, have steadily increased and while the maximum output of both was, in 1889, 261,397 tons cast and 214,561 tons rolled, the production of 1892 was but little less. The growth of the steel industry is reflected in the production of various kinds of pig iron. Since 1881 forge iron has barely held its own; foundry pig has increased about 50%; Bessemer pig has increased 118%, and Thomas pig 231%. The production of metallic silver has increased from 8835 kilos in 1881 to 30,267 kilos in 1892, this being, of course, entirely from imported ores.

In its quarry production Belgium shows little advance since 1881 excepting in chalk-marl, of which 7500 tons were produced in that year, 114,400 tons in 1890 and 32,610 tons in 1892; phosphate of lime, which reached 30,000 tons in 1881, 301,210 tons in 1890 and 268,210 tons in 1892; plastic clay, which has increased from 171,779 tons in 1881 to 276,855 tons in 1892, and silica for pottery, the production of which has varied widely. Under the subject head of "Coal" will be found an interesting review of this industry in Belgium, by Mr. Emile Harze, director of mines, and also diagrams showing the production and consumption of coal compared with those of other countries.

MINERAL PRODUCTION OF BELGIUM.* (IN METRIC TONS.)

Year.	Blende.		Calamine.		Total Zinc Ore.		Iron Ore.		Iron Pyrites		Lead Ore.		Totals.
	Tons	Value	Tons	Valuc	Tons	Value.	Tons.	Value.	Tons	Value	Tons	Value	Value.
1840.......	......	....	20,482	$161,000	20.482	$161,000	191,812	$294.200	500	$2,000	66	$2,400	$459.600
1841.......	......	....	18,380	148,400	18,380	148,400	179,073	257,200	1,200	4,800	34	1,600	412,000
1842.......	......	....	18,466	142,200	18.466	143,200	200 709	291,800	1,700	6.800	1,042	22,400	464,200
1843.......	......	. ...	25,668	198 400	25,668	198 400	164.374	243.800	1,700	6,800	749	14,400	463,400
1844.......	......	....	22,689	283 200	22.689	283,200	214,377	274,600	1,530	6,200	651	18,400	582,400
1845.......	264	$1,600	29,763	366,000	30.027	367,600	394.544	730,000	2,256	7,600	1,892	70,600	1,175,800
1846.......	2,461	20.600	39,904	278,400	42.365	299,000	745,086	1,519,000	7,432	9,400	3,195	79,000	1,906,400
1847.......	1,786	15.000	45,877	545,800	47,663	560.800	703,658	1,414.400	6,643	11,200	5,936	207,600	2,194,000
1848.......	4,378	30,600	33,204	572.800	48.582	603,400	265,548	453,800	3 059	4,200	2,604	62,200	1,123,600
1849.......	7,442	41.800	42.270	400 800	49.712	442,600	271,299	437.000	1,504	5.000	3,077	105.600	990,200
1850.......	7,308	41,600	62,193	599.200	69.501	640,800	299 272	482.600	4,084	7,400	3.854	95,600	1,226,400
1851.......	14,183	87,400	66,083	371,400	80,266	458.800	364,284	480.600	6,442	14,600	3,598	108,000	1062,000
1852.......	10,442	72,600	67 903	515,400	78.345	588,000	432,314	691,000	3 346	11.800	2,593	102,000	1,392,800
1853.......	13,640	162,000	66 452	633,400	80,092	795.400	669.277	1,259.200	7.643	24,000	4,583	208 600	2,287,200
1854.......	11,333	138,600	68.139	591,400	79.472	730.000	798,873	1,561.800	25,321	37 800	7,795	195 600	2,525,200
1855.......	10,905	112.400	70,368	628,400	81.273	740,800	852,134	1,846,000	21.607	35.800	5.590	181.000	2,803,600
1856.......	11,418	138,200	71.856	806,800	83.274	945,000	778,412	1,624,000	19,150	28 000	6,909	113,200	2,710,200
1857.......	10,487	144 600	65 749	964,800	76.236	1,109.400	651,903	1,350,000	14,620	32,600	10.776	188,800	2,680,800
1858.......	19,467	179 800	55.931	660.600	75.398	840,400	879,465	1,771,600	24,466	86.000	14,000	269,600	2,967,600
1859.......	13,751	164.200	56,639	560,800	70.390	725,000	883,031	1,643,200	34.982	176.200	6 993	288,800	2,812,400
1860.......	17,284	166.800	48.857	424,800	66,141	591,600	809.176	1.549.800	42,513	250,600	9,980	321,200	2,713,200
1861.......	17,267	138.800	55,888	359,800	73,155	498,600	859.115	1,895,200	53,116	285,000	10,800	417,400	3,096,200
1862.......	18,884	162,800	55,124	393,800	74,008	556,600	859,926	1,629.000	46,430	190,400	17,431	411.600	2,787,600
1863.......	14,899	137.600	46,868	390.400	61,767	528,000	856,190	1,658.600	36,244	141.000	12.228	357,800	2685.400
1864.......	16,309	197,600	41,757	466.000	58 066	663,600	968,108	1,914,400	28.956	96,200	16,779	502,200	3176 400
1865.......	14 657	170,200	41.528	453.600	56,185	623,800	1,018,231	1,966,000	31,818	128.000	14,658	462 800	3,180,600
1866.......	15,734	205 200	38,782	462 200	54.516	667,400	886,641	1,676,600	55,004	256,200	12,453	415.800	3016.000
1867.......	16,594	209,400	41.452	413.200	58.046	622,600	602,829	1,139,200	41,298	189,200	12,541	480.400	2,431,400
1868.......	16,485	181,800	52 214	542,000	68,699	723.800	519,740	950.200	37,933	166,800	15,390	564.800	2405.600
1869.......	17,334	187,800	49,584	527.800	66.918	715,600	628,046	1,141 800	31,670	132.600	15,304	588.200	2,578,200
1870.......	15.783	161,400	41,316	323,800	57,099	485,200	654.332	1.161,000	28,665	124,200	13,380	494.600	2,265,000
1871.......	19,970	228,600	41,159	357.000	61.129	585,600	696,636	1,264.800	42,272	180,200	11,549	394,000	2424.600
1872.......	20,623	332.000	34,914	421,200	55,537	753,200	749,781	1,478.000	40.932	197.000	11,887	387,200	2,815,400
1873.......	13,952	272,000	28,630	330.800	42 582	602,800	777,469	1,566,800	36,651	212 000	11.280	436,600	2,818,200
1874.......	17,087	247,000	26,212	293,800	43,299	540,800	527.300	1,035,600	28.872	155,600	10.894	438 800	2171,400
1875.......	18,750	284,600	23,754	291,000	42,504	575,600	365,044	684,600	30.747	161,400	10,567	401.000	1822,600
1876.......	21,739	322,200	15.974	188.800	37,713	511,000	269.206	491,600	23,588	113,200	12.422	340.400	1456,200
1877.......	26,310	310,400	18.677	190.600	44,987	501,000	234,227	431,600	26,207	127,800	11,542	383,800	1444,200
1878.......	27,134	296,800	18,159	191,000	45,293	487,800	207.157	351,600	21,721	104,600	13.477	309,600	1261,600
1879.......	23.229	275,200	19,460	153,800	42,689	429,000	191.512	311,600	15,577	64.800	9,384	217.400	1022.800
1880.......	23,080	309,200	15,735	139 200	38,815	448,400	253.499	375,000	7.913	32,800	5,434	178,400	1034,600
1881.......	8,169	107,800	15,384	131,200	23.553	239,000	224.882	363,400	2 965	9.800	3,741	131.400	743.600
1882.......	2,171	21.200	18,272	120,200	20,443	141,400	209 212	318.600	2,555	4,200	2,918	97,200	561,400
1883.......	3,814	24,125	16.924	125,806	20,738	150,000	216 490	299.400	1.623	3,600	1,749	62,200	515,200
1884.......	12,057	92,247	15,549	110 475	27,606	202,800	176.755	256,000	2,243	7,000	1,796	51,400	517,200
1885.......	11,597	94,058	6.588	41.900	18,185	136,000	187.118	262,200	4,533	13,000	1,299	37,400	448 600
1886.......	12,718	106.094	6,324	46 230	19,042	152,400	153 378	191,000	3.209	6,200	1,292	38,800	388,400
1887.......	12 405	110.392	8.474	69.065	20,879	179.400	185.186	236,600	3,490	6.400	548	18,400	440,800
1888.......	12,370	144.600	12.167	87,600	24,537	232,200	213.327	280,400	3.916	8.200	414	8,800	529,600
1889.......	10.248	146.400	10,936	112,800	21,184	259,200	202 431	272 600	5 051	8,600	194	4,000	544.400
1890.......	10,370	174 400	5.040	65,600	15 410	240,000	186,546	251,800	2.980	5,600	150	3,200	500,600
1891.......	10,200	163,280	4,080	47.410	14.280	210.690	*a*202.204	234,540	1,990	3,820	70	1,620	501,540
1892.......	8,250	126,880	4,010	49,440	12,260	176,320	*a*209,943	218,620	2,570	5,480	60	1,640	463,720
1893.......	.....	. .....	.....	....	.. ...	......	....	....	.....	....	.. .	....	....

METALLURGICAL PRODUCTION OF BELGIUM.

Year.	Pig Iron.	Wro'g't Iron.	Lead.	Zinc.	Year.	Pig Iron.	Wro'g't Iron.	Cast Steel.	Rolled Steel.	Lead.	Zinc.
1845........	134,563	62.299	226	7,221	1863........	392,078	279,745	......	......	8,112	28,978
1846........	189,318	67,124	397	8,963	1864........	449,875	343,921	460	350	9,639	30.718
1847........	248,387	80,855	290	10,241	1865........	470.767	349.691	650	545	9,849	34,244
1848........	161,581	57,808	1,768	10,850	1866........	482,304	388,227	1,050	930	9,154	34,659
1849........	148,537	67,024	1,213	13,579	1867........	423,069	362.109	1,575	1,420	10,518	38,684
1850........	144,452	72,708	1,309	14,808	1868........	435,754	350,142	1,928	1,857	11,729	44,347
1851........	167,709	74,598	1,691	15,250	1869........	534,319	494,020	2.940	2,826	10.799	47,407
1852........	178,796	76,671	1,768	16,672	1870........	565,234	522,515	4,321	4,062	10,034	45,754
1853........	230,124	110,883	2.346	18,817	1871........	609,230	500.361	7,453	6,622	9,287	45,623
1854........	284,853	114,210	2,316	19,553	1872........	655,565	531.070	15.079	12,389	6,535	41,838
1855........	294,270	144.551	2,753	20,633	1873........	607,373	503,432	21,657	18,533	6,387	42,314
1856........	321,934	179,925	3,545	22,900	1874........	532,790	518,818	37,683	30,932	8,020	46,088
1857........	302,211	176.189	3,182	24,526	1875........	541,805	456,880	54,420	45,536	7,459	49,960
1858........	324,204	161,324	4,173	34,191	1876........	490.508	356,214	76,524	64,543	7,225	47,981
1859........	318,799	174,774	4,736	28,631	1877........	470,488	497,858	104,182	90,646	7,733	55,923
1860........	319,943	218,318	4,153	22,027	1878........	518,646	417,908	124,195	102,259	8,141	61,227
1861........	311,838	236,919	5,336	28,150	1879........	453,371	431,618	111 275	88.952	7,961	57,157
1862........	356,550	260,453	7,891	25,861	1880........	608,084	493,326	132,052	102,772	8,204	59,880

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* From *Statistique des Mines, Minières, Carrières, et Usines Métallurgiques.* (5 fr. = $1.)

(*a*) Does not include ferro-manganese ore, which amounted to 18,498 tons and 16,775 tons $50,092 and $41,660), respectively, in 1891 and 1892.

METALLURGICAL PRODUCTION OF BELGIUM.* (IN METRIC TONS)

Year.	Forge Pig.		Foundry Pig		Manganiferous Pig.		Bessemer Pig.		Thomas Pig.		Castings.		Total Pig.	
1881	472,433	$10.42	43,968	$13.67	4,438	$17.81	87,396	$17.40	16,501	$10.73	....	....	624,736	$11.71
1882	539,287	10.85	58.474	14.00	5,957	17.96	118,297	16.25	4,631	12.86	300	$16.00	726,946	12.05
1883	564,417	10.46	68.921	13.13	9.572	16.63	127.313	14.08	12,690	11.11	540	15.93	783,433	11.12
1884	547,328	9.15	50,620	13.14	5,388	14.85	130,900	12.27	16.576	10.62	....	....	750,812	10.06
1885	509,137	8.51	75,417	10.18	5,041	13.29	119,115	11.24	4.166	10.99	....	....	712,876	9.19
1886	495,186	8.00	64,254	9.45	....	....	134,290	11.39	7,547	9.88	400	20.50	701,677	8.80
1887	516,518	8.33	67,311	9.89	1,705	13.96	166,428	10.67	2,619	10.00	1,200	18 17	755,781	9.02
1888	607,193	9.19	58.814	10.59	....	....	157,129	11.77	2,614	9.26	1 100	19 45	826,850	9.79
1889	586,776	9 74	59.676	12 36	4,065	19.53	165,493	13.12	15,116	11.54	1,100	20.69	832,226	10.69
1890	526,644	11 64	60,183	13.51	1,786	17.03	164,943	15.60	24.210	13.18	1,070	25.42	787,836	12.71
1891	445,436	10.18	56,241	11.78	....	....	147,913	14.01	34,536	11.40	....	....	684,126	11.20
1892	442,009	9.15	67,236	9 62	....	....	190,599	13.09	53,424	10.39	....	....	753,268	10.28
1893	....	....	....		....	....	....	....	....	....	....	....	....	....

Year.	Wrought Iron.		Cast Steel.		Rolled Steel.		Lead.		Silver.†		Zinc.	
1881	479,807	$32.31	141,640	$23.21	119,237	$32.61	7,651	$69.41	8,835	$37.81	69,800	$76.55
1882	503,113	33.36	182,627	22 41	151,291	32.09	8,805	68.14	10,154	37.21	72,947	77.43
1883	487,226	31.92	179,489	19.54	56,301	30.26	8,391	60.37	10,847	35.73	75,366	72.62
1884	471,040	28.85	187,066	18.77	153,999	26.78	7,751	53.21	9,956	36.84	77,487	68.74
1885	469,249	25.69	155,012	14.63	125,461	24.83	8,656	52.84	13,056	35.54	80,298	66.87
1886	470.255	23.83	164,045	14.22	137,771	23.24	8,665	62.00	14,757	33.27	79,246	67.90
1887	534,056	23.81	229.321	15.70	191,445	22.73	10,044	63.64	22,568	32.02	80,468	72.17
1888	547,818	25.58	243,647	16.63	185,417	24.38	10,921	65.95	29,329	31.35	80,675	85.87
1889	577,204	28.00	261.397	19 66	214,561	27.20	9,412	62.11	24,622	31.22	82,526	93.06
1890	514,311	32 27	245,566	22.97	201,817	30.99	9.617	65.28	33.083	35.10	82,701	111.76
1891	497,380	29.20	243,913	19.63	206,305	28.22	12,698	61.35	33,950	32 76	85,999	112.26
1892	479,008	27.09	260,037	17 90	208,281	26.50	10,146	53.03	30.267	28.94	91,546	101.74
1893	....	....	....	....	....	....	....	....	....	....	....	....

QUARRY PRODUCTION IN BELGIUM.

Year.	Building Stones.		Chalk Marl.		Dolomite.		Flagstones.		Limestone for Flux.		Marble.	
	Cubic Meters.	Value.	Cubic Met'r.	Val.	Tons.	Val.	Sq. Met'rs.	Value.	Cubic Meters.	Value.	Cub. Met.	Value.
1881	1,892,764	$4.543,180	7,500	$5,860	....	....	136,118	$102,920	106.000	$42.340	8,422	$279,340
1882	2,031,736	4,914,000	8,900	7.600	....	....	154,923	116,000	123.500	45,200	9,603	317.200
1883	2,034,527	4,857,000	19,050	10.200	....	....	123.121	86,200	115,300	40,400	11,179	381.600
1884	2,412,751	4,441,000	2,930	7.600	....	....	101,073	69,000	109,300	33,400	12.321	433,400
1885	1.696,044	3,231.800	3.460	3.800	500	$200	111,988	71.600	90,290	30,200	10,850	338,400
1886	1,685,407	3,350,800	27,320	27,000	2.200	1,000	152,832	113 000	136,900	39,800	11,290	398,000
1887	1,834,162	3,430,000	27,235	24,800	3,200	1,200	116,670	77.400	133,430	41.000	11,124	361,800
1888	1,841,626	3,520.200	25,650	24,400	1,750	800	125,522	72,200	182,865	64,400	11.277	390,400
1889	1.886,212	3,730,800	13,980	19,000	2,150	1,000	138,180	86.400	122,925	44,200	11,605	351,600
1890	1,874.340	3,798,200	114,400	48,800	2.650	1,200	129,848	82,600	140,720	48.600	12,122	427,400
1891	1,737,951	3,502 800	38,075	28,600	1.500	600	123,875	76,200	197,365	61,600	11,350	441,800
1892	2,502,692	3,980,800	32,610	26,600	3,100	1,800	105,793	67,400	140,800	55,800	11,750	455.400
1893	....	....	....	....	....	....	....	....	....	....	....	....

Year.	Paving Stones.		Phosphate of Lime.(*a*)		Plastic Clay.		Pudding Stones.		Quartz Gravel.	
	Pieces.	Value.	Tons.	Value.	Tons.	Value.	Cu. Met.	Value.	Cu. Met.	Value.
1881	98.612,000	$1,734.600	30,000	$226,000	171,779	$283,880	550	$22,400	227,600	$145,640
1882	108,674,000	1,856,400	41,050	247,800	195,448	341,600	550	22,400	275,900	196.200
1883	87,900,000	1,663,200	59,800	456,800	178,650	309,600	550	22,600	435,740	338,200
1884	90,161,700	1,457,200	69.720	358,400	153,095	250,200	....	....	17,420	10,000
1885	89,290.545	1,372,000	162,250	636,400	171.661	302,200	....	....	512,200	246,000
1886	87,186.200	1,211,000	145.520	509 000	159,248	261,800	95	2.800	556.760	267,400
1887	79,760,500	1,362,000	166,900	520.800	171,186	312,400	....	....	457,310	237,600
1888	82.054,500	1,212,000	190,000	532,000	183,605	311,800	....	....	591,080	243.200
1889	80,247,400	1,352,000	218.980	838.000	191,650	316,600	....	....	567,950	250,600
1890	72,913.700	1,421,800	301,210	1.093,800	215 592	343,600	....	....	632,430	259,600
1891	86,158,700	1,517,200	291.080	1,006.000	222,760	279,200	....	....	465.380	228,000
1892	88,048,700	1,497,800	268,210	756,000	276,855	341,800	....	....	18,100	10,400
1893	....	....	....	....	....	....	....	....	....	....

* From *Statistique des Mines, Minières, Carrières, et Usines Métallurgiques.* (5 fr. = $1.) † Kilos.

(*a*) The production of phosphate of lime in 1877 amounted to 3910 tons, valued at $27,120; in 1878, 5720 tons, $41.780; in 1879, 7700 tons, $45,860; in 1880, 15,745 tons, $113,400.

QUARRY PRODUCTION OF BELGIUM—*Continued.*

Year.	Sand.		Silica for Pottery.		Slate.			Sulphate of Baryta.		Whetstones.	
	Cubic Meters	Value.	Cubic Meters.	Value.	Pieces.	Cubic Meter.	Value.	Tons.	Value.	Pieces.	Value.
1881	369,665	$155,440	15,250	$21,480	31,505,000	*b*1,690	$185,960	12,400	$7,440	120,000	$7,000
1882	330,698	142.800	38.767	27,600	35 545.000	*b*6,127	194,800	12,000	7,200	258,000	22.600
1883	318,480	177,000	36,860	59,600	34.065,000	*b*455	189.800	12,000	7,200	260,000	18,400
1884	280,840	120,800	12,000	19,800	31,728,500	515	177,400	12,000	7,200	62,000	400
1885	236,892	102,200	*c*20,730	37,400	30,090,000	775	170,800	7.000	4,200	49,000	400
1886	212,990	90,600	20,380	33.200	28,505,000	....	150 200	9,600	5,400	52.000	400
1887	218,799	89,600	25.720	40,800	26.882,000	....	130,400	9,800	10,800	*d*50,000	400
1888	306,867	125.200	17,800	33,6 0	26,808.000	210	134.800	9.800	10,800	....	....
1889	294,068	127.200	22,400	43,600	27,115,000	640	135 600	9,800	10,800	....	....
1890	316,419	107.600	25.900	45,800	30.951,500	140	166,200	9,800	10,800	....	....
1891	328,731	126,000	34,300	65,400	31.569.000	220	189,400	20,000	16,000	*d*130.000	24,400
1892	383,545	163,600	*c*38,370	48,800	33,903,000	415	224,400	42,000	16,800	*d*153,000	38,000
1893	....	....	....	....	....	....	....	....	....	....	....

COAL PRODUCTION OF BELGIUM.*

Year.	Metric Tons.	Dollars.	Per Ton.	Pr'fit per Ton.	No. Work-men.	Ann. W'ge	Year.	Metric Tons.	Dollars.	Per Ton.	Pr'fit per Ton.	No. Work-men.	Ann. W'ge
1861	10,057,163	22,003,000	$2.19	$.19	81,675	$145	1878	14.899,175	29,564.200	$1.98	- $.02	99.032	$168
1862	9,935,645	20,897,000	2.10	.16	80,302	138	1879	15,447.292	28,999,000	1.88	—.002	97,711	162
1863	10,345,350	20,957,400	2.03	.14	79.187	140	1880	16,886,698	33,936,000	2.01	.05	102,930	184
1864	11,158,336	22.110,800	1.98	.18	79,779	143	1881	16.873.951	32,740,800	1.94	— .02	101,351	186
1865	11,840.703	24,779,200	2.09	.23	82,368	157	1882	17,590.989	35,179,200	2.00	.05	103,701	185
1866	12,774,662	30,206,400	2.36	.36	86,721	173	1883	18,157,754	36,955,400	2.03	.05	106,252	201
1867	12,755,822	31,650,600	2.48	.32	93,339	178	1884	18. 51,499	34 406,400	1.91	07	105 582	183
1868	12.298,589	26.774.200	2.18	.16	89.382	161	1885	17,437,603	30.923,600	1.77	.08	103,095	162
1869	12,942.894	27.223,200	2.10	.12	89,928	166	1886	17,285,543	28.508,400	1.65	.06	100,282	157
1870	13,697.118	29,727,000	2.17	.18	91.993	176	1887	18,378,624	29,534.800	1.61	.10	100,739	163
1871	13,733,176	30,760,600	2.24	.21	94,286	173	1888	19,218,481	32,403,600	1.69	.13	103,477	174
1872	15.658 948	41,711,800	2.66	.45	98,863	209	1889	19.869,480	37,543,600	1.89	.22	108,382	186
1873	15,778,401	67,527,400	4.28	1.19	107.902	271	1890	20.365,960	53,700,600	2.64	.58	116,779	223
1874	14.669 029	48.182,000	3.28	.31	109,631	237	1891	19,675,664	49,490,800	2.52	.36	118,983	217
1875	15,011,331	45 968,000	3.06	.17	110,720	233	1892	19 583,173	40,257,600	2.06	.12	118,578	191
1876	14,329.578	38.823,800	2.71	.05	108,543	206	1893	19,407,254	....	....	....	...	....
1877	13,938.523	30,591,400	2.19	—.02	101,343	167							

— Loss.

MINERAL IMPORTS OF BELGIUM. (*a*)

Year.	Coal.	Coke.	Coal.	Coke.	Mineral Raw Material.						
	Tons		Value		Lime.		Iron Ores, Iron & Steel Filings.[2]		Sulphur.		Various.
1835	8,967		$26.800		62	$200	....	....	800	$55,000	....
1840	21,148		63,400		53	2,200	....	$4,600	732	47,000	....
1850	9,397		28,200		987	2.400	....	5.400	1,536	57,600	....
1860	97,009		310.400		9.659	38,600	1,486	8,000	2,900	156,600	....
1870	220,656	8.108	$662,000	$35.600	15,610	50.000	568.571	3,070,200	5.226	281,000	....
1880	917,033	19,217	2,641,000	76,800	39,055	125,000	921,612	2.211 800	6,647	265,800	....
1881	1,039,454		2,976,000		[12]	....	1,169,502	2.806,800	[12]	....	$10,441,400
1882	1,059.076		3,089,200		[12]	....	1,198.037	2,875.400	[12]	....	12,973,100
1883	1,302,232		3,827.000		[12]	....	1.612,470	3.870,0 0	[12]	....	7.952,200
1884	1,256.504		3,361,000		[12]	....	1,488.140	3.571,600	[12]	....	7,097,400
1885	1,238,116	22,094	3,107,600	77,400	36,787	81,000	1,393.601	3,344.600	35,810	1,432,400	6,279,600
1886	1,002,671	21.867	2,566,800	74,400	34.092	75,000	1,367,978	3.284,800	22,576	913.000	6,029,200
1887	1,016.678	18,788	2,501,000	60,200	36.587	80,400	1,451,822	3,484,400	38,497	1 339,800	7,295,000
1888	1,034,748	27,461	2,721,600	98,800	30.780	67,800	1.746,997	4.192,800	35,030	1,501,500	7,674,200
1889	1,005,969	18,545	2,897,500	75.000	35,313	77,600	1.805,250	4,332.800	51.771	2,070,800	7,649,200
1890	1.721.238	65,339	6,025 400	34,800	36,311	79,800	1,164.548	3,947,600	42,309	1,692,400	9,563,200
1891	1,624,751	140,576	5,624,000	598,800	25,378	55,800	1,534,609	3,071,400	33,020	1,320,800	10,282,400
1892	....	....	....	....	....	....	....	....	....	....	....
1893	....	....	....	....	....	....	....	....	....	....	....

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* From *Statistique des Mines, Minières, Carrières, et Usines Métallurgiques.*

(*a*) From *Annuaire Statistique de la Belgique.*

(*b*) Tombstones, 1881, value $21,560; 1882, $15,400: 1883, $12,000.

(*c*) Excluding kaolin produced in 1885, 750 cubic meters, value, $1600; and in 1892, 750 cubic meters, $1600.

(*d*) Excluding grindstones produced in 1887, 55 cubic meters, value $1600; in 1891, 90 cubic meters, $400; in 1892, 17,100 cubic meters, $3400.

MINERAL IMPORTS OF BELGIUM. (*a*) —*Continued.*

Year.	Steel.		Copper and Nickel.		Iron, Pig and Scrap. (*b*)		Iron, Wrought.		Gold, Silver and Platinum Jewelry.	Lead.		Zinc.	
1835	......	$212,200	493	$253,400	....	$107,600	......	$62,200	$58,400	2,215	$146,800	2	$200
1840..	......	240,200	740	367.600	....	29,800	......	123,600	80,000	2,684	182,600	13	2,400
1850	......	241,200	1,121	562,600	....	42,600	. ..	75,000	72,600	870	78,200	8	1,000
1860..	......	532,000	1,665	882,400	725	12,400	1,874	124,000	82,000	3,225	354,800	2.493	249,400
1870..	5,437	1,451,600	5,154	2,142,000	82.330	1,317,200	9,014	542,800	218,000	2,632	263 200	1,940	174,600
1880..	9,557	1,061,800	4,881	2,227,000	222 292	2,889,800	28,339	1,308,600	320,600	7,046	775,200	754	251.400
1881..	......	1,618,800	5,973	2,709,400	201,507	2,619,600	27,404	1,438.600	*l*	*l*	....	*l*	....
1882..	......	1,074,200	6,704	3,030,000	194,146	2,523.800	22,412	1,230.000	*l*	*l*	....	*l*	....
1883..	7,467	825.400	6,827	3 050,000	187,859	2,442,000	20,268	1,017,200	*l*	*l*	....	*l*	....
1884	5,208	341,800	7.612	3,392,400	139,488	1,562,000	16,178	601.000	*l*	*l*	....	*l*	.
1885..	3,824	239,400	8,125	3,613,800	117,615	1,211,800	12,902	483.800	532,600	4,900	343,000	1,975	158,000
1886..	2,672	146,600	6,105	2,718,000	99,542	1,010,200	13,584	495.000	594,600	3,524	260,800	2.005	160 400
1887..	3,318	168,000	6,255	2.792,400	159,293	1,770,000	15,275	608,800	604,000	10.820	800,800	1,525	122.000
1888..	4,922	310,600	4,661	2.087.800	236,322	2,075,500	18,243	713,800	689,200	15,640	1,155,400	4,209	336,800
1889	12,376	738.800	7,550	2,635,600	263,357	3,027,000	24,070	967,200	662,800	30,312	2,425,000	5,113	429,400
1890	13,517	665.600	7,386	2,580,800	264,275	3,435,600	23,136	985.200	755,200	35,985	2,878,800	5,242	440,400
1891	13,174	599.000	8,269	2,199.800	205,482	2,401,000	25,286	987,200	678,200	34,093	2,044,600	6,972	794,800
1892..	......	....	.. ..	... .	....	....	.....	....	....	31,054	.. ..	5,936	.....
1893..	.....	....	......	......		....	......	...	....	..	....	..	. .

Year.	Various Other Metals. (*c*)	Stone.		Chemical Products.	Glass and Glassware. (*j*)	Salt, Coarse.		Salt, Refined.	
1835	$216,200	.... .	$54,400	$161,600	$76,400	22.391	$1,119,600	1	$200
1840	236,800	. ..	80,200	143.400	97,800	26,097	1,304,800	2	200
1850	116,000	......	81,400	356,600	73,400	32,143	1,607,200	....	....
1860	253.600	44,469	177,800	1 174,400	103.200	40,513	324,200	1	....
1870	1,150 800	52,256	261,200	2,297,800	93,600	46 240	370,000	2,916	58,400
1880	809,600	57,781	809,000	4,018,200	286,800	54,517	545.400	35,899	502,600
1881	*l*	......	......	4,834,200	....	65,159	521.200	....	....
1882	*l*	.. ..	....	5,366,000	....	57,992	464,000	....	....
1883	*l*	......	....	6,894,600	....	67,466	404,800	....	....
1884	*l*	... ..	....	7,615.200	....	75,197	451,200	.....	..
1885	607,000	49,158	688,200	6,656,800	320,000	54.121	324,800	34,308	303,000
1886	589,400	47,216	661.000	10,533,800	288,200	73,500	441,000	34,616	346,200
1887	1,477.000	37,697	527,800	11,056,800	300,800	74,516	447.400	39,941	399,400
1888	1,590,400	46,553	651,800	13,715,800	328,000	72,547	435,200	51,414	514,200
1889	1,800,400	......	.... .	15,093,200	332,600	78,117	468,400	32,320	323,200
1890	1.498 000	54,433	762,000	11,928.200	409,800	64,031	384.200	39,100	391,000
1891	2,159,800	59,042	826,600	13,780,400	409,800	79,422	476,600	39,586	395,800
1892	....	......	....	....	....	....	....	....	....
1893	....	.. ..	....	....	....	... .	....	....	....

(*a*) From *Annuaire Statistique de la Belgique.*

(*b*) The imports of iron ores and pig iron amounted to 438,830 tons ($2,820,800) in 1868; 623,500 ($3,965,800) in 1869; 678,704 ($4,558,600) in 1871; 927,601 ($7.146,400) in 1872; 884,752 ($7,769,200) in 1873; 897,126 ($6,437.800) in 1874; 951,257 ($6,449,000) in 1875; 878,398 ($7,244,400) in 1876; 967,534 ($7,185,800) in 1877; 1,040,838 ($7,893,600) in 1878; and 806,288 ($6,679,400) in 1879.

(*c*) Of metals and minerals (except iron, copper, tin, and coal) were imported 220,582 tons ($6 176,400) in 1868; 221,978 ($6,215,400) in 1869; 219,328 ($6,141.200) in 1871; 337,494 ($9,449.800) in 1872; 327,917 ($9.181.600) in 1873; 270,507 ($7,574,200) in 1874; 242,679 ($6,795,000) in 1875; 298,977 ($8,371,400) in 1876; 324,631 ($9,089,600) in 1877; 402,341 ($11,265,600) in 1878; and 336,666 ($9,427,000) in 1879.

(*j*) The quantities of crushed glass imported were 153,700 liters in 1835; 700 in 1850; 1,505,300 in 1860; 381 tons in 1870; 445 in 1880; 820 in 1890; and 841 in 1891.

MINERAL EXPORTS OF BELGIUM. (*a*) (IN METRIC TONS).—*Continued on next page.*

Year.	Coal. (*d*)	Coke (*e*)	Value. Coal.	Value. Coke.	Lime.		Iron Ores, Iron and Steel Filings.		Sulphur.		Various Other Minerals.
1835	696,000		$2.086,800		21,833	$87 600	....	....	.....	....	....
1840	779,000		2.338.400		44,627	179.400	....	......	.....	....	....
1850	1,987,000		5,961,600		52,164	125,200	......	.	561	$19,200	....
1860	3,450,000		11 041.000		100,800	242,000	152,114	$658,200	1,300	70,200	$522 200
1870	3,176.000	577,000	$9,527,400	$2,536,600	161,045	418,800	179,867	539,600	3.246	129 800	779,000
1880	4,525,000	850,000	13,032,200	3.401,400	288,734	750,800	310,582	497,000	6.647	265,800	1,495 800
1881	4,477,000	915.000	12.714.000	3,531,400	*l*	....	367,163	587,400	*l*	....	2 239.200
1882	4,292,000	1,095,000	12,446 800	4,466,000	*l*	....	334,901	535.800	*l*	....	1,885,600
1883	4,441,000	997,000	12,879,800	4,186 000	*l*	....	367.104	587,400	*l*	....	2.963.200
1884	4,619,000	854,000	12,240,800	3,075,400	*l*	....	190,988	305.600	*l*	.. ..	3,232,800
1885	4,338,000	849,000	10,889,200	2,970,600	*l*	.. ..	157,590	252.200	*l*	....	3,358,000
1886	4,273,000	908,000	10,938,400	3.087,000	285,488	628,000	107,532	182 600	5,[illegible]69	202.800	2,777,600
1887	4,591,000	927,000	11.294,200	2,965,000	296,148	651 600	180,097	311,000	3,528	141,200	3,280,400
1888	4,467,000	1,061,000	11,777,000	3,818,800	314,697	692,400	150 705	256.400	4,275	171,000	2,930.400
1889	4.597,000	1,220,000	13.270.800	4,928.600	328,024	721,600	157,908	270.600	4,528	181.200	3.563,200
1890	4,534,000	1,065.000	15.868.200	5,570,800	357,474	786,400	174.231	295,200	4,232	169,200	5,288,800
1891	4,750.000	934,000	16,435,800	3,977,400	373,671	822,000	194.933	370,200	4,071	164,800	5,958,600
1892	4,539,000	991,000	....	....	....	....	....	....	.....	....	. ...
1893	... .	....	... .	....	....	...	......	....	....	....	....

(*a*) From *Annuaire Statistique de la Belgique.*

(*d*) Of coal were exported 3,755,000 tons ($11,264,000) in 1868; 3,581,000 ($10,743,800) in 1869; 3,678,000 ($11,034,-

MINERAL EXPORTS OF BELGIUM (IN METRIC TONS).—*Continued.*

Year.	Steel.		Copper and Nickel.		Iron, Pig and Scrap.		Iron, Wrought.(*g*)		Gold, Silver, and Platinum Jewelry.	Zinc.(*i*)	
1835	....	$16,400	42	$20,400	5,336	$154,800	4,584	$517,600	$10.600	1,637	$356,400
1840	....	38	81	32,800	10,438	302,800	6,200	649,000	22,400	3,126	616,400
1850	....	16,600	416	221.400	92,345	2,678,000	16,773	279,000	14.000	11,946	2,446,000
1860	....	72,200	694	372,600	22,086	375,400	81,957	3,924.400	18,000	25,803	2,851,000
1870	854	382,800	2,205	902,400	10,176	162,800	240,490	9.092,800	60.400	33,576	3,357,600
1880	49,309	4,566,400	2,705	1,220.000	41.904	544,600	272,597	10,706.400	11,800	45,317	5,891,200
1881	....	....	2,580	1,185,200	51,980	675,600	291,411	11,561,400	....	53,650	6,974.400
1882	....	....	2,873	1,325,600	49.290	640,800	330,311	13,179,000	....	49,138	6,387,800
1883	....	....	3,167	1,485,000	20,799	270,400	324.984	12,787,600	....	55,255	7,183,200
1884	....	....	4 464	2,070,800	21,783	262,000	323,872	10,010,000	....	63,110	8,204,400
1885	....	......	4,485	2,042,000	10.718	201,400	322,292	9,476.400	....	61,536	5,538,200
1886	63,521	2,354,000	3,753	1,737,200	51,101	542.400	353,182	10.281,200	29,600	62,156	5,972,600
1887	86,669	2.772,800	4,298	1,981.800	22,748	261.400	393,929	11,229,800	30,800	68,227	6,140,400
1888	97,345	3,290,600	2,939	1,371,000	13.332	157,600	368,342	11,460,400	27,400	62,264	5,603,800
1889	118.217	6,288,400	3,751	1,390,800	22.573	288,800	412,453	14,707,400	30,200	67,489	6,344,000
1890	109,604	5.811,200	4,671	1,692,800	23,165	301,200	356,109	13,585.000	21,600	67.026	6,300,400
1891	87,431	4,524,800	4.674	1,318,200	23,963	317,600	359,740	12,182,200	17,000	68,026	7,755,000
1892	....	....	....	....	......	....	....	....	....	76,823	....
1893	....	....	.....	.....	......	....	......	....	....	....	....

Year.	Lead.		Various Metals.	Stone.(*h*)		Chemical Products.	Glass and Glass-ware.(*f*)	Salt, Coarse.		Salt, Refined.	
1835	2	$200	$14,200	....	$95,800	$4,200	$241,800	......	....	663	$79,600
1840	12	800	30,000	....	133,200	25,200	880,400	......	....	2.503	35,000
1850	102	7,000	32,200	....	162,400	58,000	1,014,600	......	....	162	2,200
1860	4,596	505.600	43,800	252.581	555,600	68,000	2,683,400	......	....	2,225	44,400
1870	6.539	653,800	499,600	524,095	2,620,400	747,600	3,155.400	5	....	520	7,200
1880	13.476	1,482,400	342,600	830,919	11,632,800	2,079,800	9.939,200	1,521	$15,200	......	....
1881	12,081	1,328.800	....	866,141	12,126,000	1,339,000	10,888,800	......	....	......	....
1882	7,707	847,800	1,885,600	887,026	12,418,400	1,820,200	10,583,000	......	....	......	....
1883	7,817	859,800	2,963,200	1,069,566	14.974,000	1,999,200	11.320,400	......	....	......	....
1884	7,064	777,000	....	1,411,985	19,767.800	2,031.800	9,681,200	......	....	......	....
1885	6,918	484,200	....	870,500	12,187,000	2,993,600	9,778,400	......	....	......	.....
1886	6,362	470,800	272,600	824,200	11,538,800	3,710,200	5,854,600	580	3,400	70	800
1887	10,401	769,600	436,000	900,228	12,603.200	4,560,000	10,947,800	600	3,600	2,081	20.800
1888	13,835	1,023,800	613,400	845,919	11,842.800	5,782,400	9,127,600	1,243	7,400	3,365	33,600
1889	20,070	1,605,600	584,200	829,615	11,614.600	7,039,600	9,268,000	248	5,400	216	2,200
1890	27,370	2,189,600	493,200	911,258	4.556,200	7,035,800	9,026,800	341	2,000	106	1,000
1891	24,073	1,414,400	521,800	872,937	4,364,600	7,011,200	9,054.800	1,216	7,200	152	1,600
1892	24,709	....	....	....	....	....	....	......	....	.....	....
1893	....	....	....	....	....	....	....	......	....	.....	....

CONSUMPTION OF CERTAIN METALS. (*m*)

Year.	Lead Unwrought.	Iron.		Steel.		Zinc Unwrought.
		Pig.	Finished Products.	Ingot.	Finished Products.	
1890	18.232	1,022,329	251.260	253.147	98,150	20,917
1891	22,718	814,666	226,737	249,529	126,432	24,945
1892	16,501	815,436	207,858	267,939	130,061	20,659

000) in 1871; 4,608,000 ($17,049,600) in 1872; 4,158,000 ($22,036.800) in 1873; 3,902.000 ($16,390.000) in 1874; 4.064,000 ($16,255,800) in 1875; 3,828.000 ($13,782,600) in 1876; 3,515,000 ($10,545,000) in 1877; 3,889,000 ($11,279,200) in 1878; and 4,236,000 ($11,860,200) in 1879.

(*e*) Of coke were exported 540.000 tons ($2,375,800) in 1868: 688,000 ($3,025,400) in 1869; 508,180 ($2,439.200) in 1871; 749,072 ($4,194,800) in 1872; 801.820 ($7,056.000) in 1873; 599,020 ($3,474,400) in 1874; 645,787 ($3,616 400) in 1875; 571,123 ($2,969.800) in 1876; 575,632 ($2,417,600) in 1877; 576,607 ($2.248,800) in 1878; and 596,064 ($1,907,400) in 1879.

(*f*) Of glass and glassware were exported $2,890,200 in 1868; $3.357,200 in 1869; $2,525.000 in 1871; $3.405,600 in 1872; $6,297,200 in 1873; $7,835,600 in 1874; $8.209,800 in 1875; $7,702,600 in 1876; $7,556,400 in 1877; $7,912,600 in 1878; and $8,645,200 in 1879. The quantities of crushed glass exported were 544,300 liters in 1860; 640 tons in 1870; 1539 in 1880; 3217 in 1890; and 3411 in 1891.

(*g*) Of iron wrought, wire, rails. etc., were exported 156,307 tons ($5,210,000) in 1868; 240 386 ($7,908,400) in 1869; 186,922 ($7,063,000) in 1871; 210,043 ($10.435,200) in 1872; 181,661 ($11,331,400) in 1873; 227,450 ($12.070,600) in 1874; 182.668 ($9,874.800) in 1875; 166,161 ($9,057,800) in 1876; 174,409 ($9,517,400) in 1877; 193,138 ($10,722,200) in 1878; and 211,079 ($11.778,000) in 1879.

(*h*) Of stone, rough and hewn, were exported $1,926 400 in 1868: $1,825.000 in 1869; $2,155.400 in 1871; $3.239,200 in 1872; $8,301 600 in 1873; $7,829,200 in 1874; $8,045,400 in 1875; $10,128,200 in 1876; $10,793,000 in 1877; $9,721.400 in 1878; and $10,843,600 in 1879.

(*i*) Of zinc unwrought, were exported 33,840 tons ($4,060.800) in 1868; 34,624 ($4,154,800) in 1869; 37.073 ($3.707,400) in 1871; 35,266 ($4.232,000) in 1872; 35,192 ($4,978.800) in 1873: 31,239 ($4.061,000) in 1874; 35.934 ($4,671,400) in 1875; 35,919 ($4,669,400) in 1876; 42,335 ($5,503,600) in 1877; 38,853 ($5,050,800) in 1878; and 44,326 ($5,762,400- in 1879.

(*l*) Included under "Various Mineral Raw Materials."

(*m*) From *Statistiques des Mines, Minières, Carrières et Usines Mètallurgiques.*

CANADA.

The mineral production of Canada, while embracing a wide variety of materials, does not show any considerable increase since 1886 except in a few articles. Antimony and arsenic, which were produced in small quantities up to 1891, do not any longer appear on the list, though there is an abundance of arsenic ores in the province. Asbestos reached its maximum in 1890 during the "boom," when 8947 tons, valued at $1,260,240, were produced, but in the following year it commenced to decline both in quantity and value and in 1892 amounted to but 5518 tons, valued at $390,462, all of which was exported to the United States. In bricks and building material there was in 1892 a notable increase in production.

In the production of coal the output in 1891 was greater than that of any preceding year, amounting to 3,085,734 metric tons, valued at $8,144,247, or an average of $2.64 per metric ton, as compared with about $1.20 per ton average value at the mines of the United States. The manufacture of coke increased steadily, though as it is dependent upon the iron industry, which is in its infancy in the province, the amount required is small. Under the head of "Coal" are given diagrams showing the growth of this industry in Canada and a comparison with that of other countries. The manufacture of pig iron has not shown any material change from 1886 to 1892, but in this latter year the output of the New Glasgow furnace in Nova Scotia increased the total production from 21,697 tons, valued at $379,000, in 1891, to 38,514 tons, valued at $637,421, in 1892.

The output of nickel was 2,103,012 kilos in 1891; 1,094,837 kilos in 1892, and in 1893 it was 1,811,202 kilos. Canada consumed in 1892 $5,640,346 worth of anthracite coal and imported 1,769,347 tons of bituminous coal and coke and exported 960,619 tons. The heaviest item of imports is in iron and steel, the products of which amounted to $12,625,422, with but $243,857 of exports to offset it. The imports of coin and bullion, mineral oils, and tin are also quite heavy. Among the exports those of most importance other than coal are fine copper, gypsum, mica, nickel, and phosphates.

The gold output in 1893 was valued at $927,244; copper, $875,864; silver, $321,423 at coining values; coal, 3,000,700 tons, valued at $8,422,259; iron ore, 124,702 tons, valued at $298,018.

In 1893 the total value of the mineral production of Canada is given officially at $19,250,000, or $250,000 less than in 1892.

MINERAL PRODUCTION OF THE DOMINION OF CANADA. (*a*) (IN METRIC TONS.)

Year.	Antimony Ore.		Arsenic.		Asbestos.		Baryta.		Bricks, Thousands. (*b*)		Building Material.				
											Stone, Cu. Yd (*b*)		Flagstones, Sq. Ft.		
1886....	603	$31,490	109	$5,460	3,138	$206,251	3,506	$19,270	139,345	$873,600	165,777	$642,509	......	*b*70,000	*b*$7,875
1887....	530	10,860	27	1,200	4,191	226,976	363	2,400	181,581	986,689	262,592	552,267	......	*b*116,000	*b*11,600
1888....	313	3,696	27	1,200	3,996	255,007	1,000	3,850	165,818	1,036,746	411,570	641,712	......	*b*64,800	*b*6,580
1889....	50	1,100	...	......	5,547	426,554	.....	*f*	200,561	1,273,884	341,337	913,691	......	14,000	1,400
1890....	23	625	23	1,500	8,947	1,260,240	1,672	7,543	211,727	1,266,982	382,563	964,783	......	17,865	1,643
1891....	9	60	18	1,000	8,167	999,878	.....	......	176,533	1,061,536	187,685	708,736	24,773	*h*27,300	2,721
1892....	...	....	...	......	5,518	390,462	286	1,260	202,147	1,251,934	219,747	609,827	......	13,700	1,869
1893....	....	....	...	......	6,577	313,806	.....	....	205,000	1.275,000	220,000	610,000	......	40,800	3,487

Yr.	Building Material.				Cement, Barrels.		Clay, Fire.		Pottery.	Tiles and Sewer Pipes. (*b*)	Miscell. Clay Prod. (*b*)	Coal.		Coke.	
	Granite.		Marble & Serpentine.												
1886	5.501	$63,309	*b*455	*b*$9,900	......	......	...	......	....	$142,617	$112,910	1,898,345	$4,017,225	32,120	$101,940
1887	19.253	142,506	*b*220	*b*6,224	69.843	$81,909	...	......	....	230,068	182,150	2,149,629	4,758,590	36,686	135,951
1888	19,376	147,305	173	3,100	50,668	35,593	...	......	*b*$27,750	380,377	....	2,412,100	5,259,832	41,173	134,181
1889	9.253	79,624	*c*73	*g*980	90,474	69,790	363	$4,800	....	134,265	239,385	2,467,766	5,584,182	49,491	155,043
1890	12.075	65,985	708	*g*10,776	102,216	92.405	...	.....	195,242	488,877	....	2,829,093	6,496,110	51,225	166,298
1891	9.977	70,056	217	1,752	93,473	108,561	227	750	258,844	368,699	....	3,085,734	8,144,247	51,800	175,592
1892	22.047	89,326	308	3,600	117,408	147,663	...	9,567	265,811	558,517	....	2.986,999	7,184,510	*n*50,926	160.249
1893	22,884	94,398	599	5,100	134,645	201,583	549	700	180,467	*385,462	....	3,779,049	8,422,259	164,395	61,078

Yr.	Charcoal, Bushels.		Copper, Fine.		Feldspar and Quartz.		Glass and Glass-ware.	Gold, Kilos.		Graphite		Grind-stones.		Gypsum (Exports).	
1886..	901,500	$54,000	1,590	$354,000	...	......	....	1,797	$1,330,442	454	$4,000	3,648	$46,545	147,005	$178,742
1887..	1,610,900	88,823	1,479	342,345	...	......	....	1,549	1,178,637	272	2,400	4.802	64,008	139,753	157.277
1888..	1,500,000	87,000	2,524	667,543	...	......	*b*$375,000	1,433	1,098,610	136	1,200	5,230	51,129	159,607	179,393
1889..	1,593,300	93,463	3,090	885,424	...	.....	150,000	1,691	1,295,159	218	3,160	3,089	30,863	193,533	205,108
1890..	*e*	*e*	2,729	902,050	817	$3,500	537,130	1,497	1,149,776	159	5,200	4,432	42,340	205,544	194,033
1891..	....	....	4,324	1,160,760	622	3,425	....	1,595	930,614	236	1,560	4.064	42,587	184,705	206,251
1892 .	....	....	*i*3,215	826,849	159	525	....	*j*1,566	907,601	151	3,763	4,793	51,187	218,679	241,127
1893..	....	....	*i*3,679	875,864	584	4,525	....	1,605	927,244	...	......	4,674	38,379	195,668	196,150

Year.	Iron Ore.		Chromic Iron Ore.		Pyrites.		Iron, Pig.		Iron Manufactures.		Steel Manufactures.		Lead (in Ore).	
1886....	63,256	$126,982	54	$945	38,935	$193,077	*b*20,138	*b*$237,768	.....	....	....	....	.....	......
1887....	69,265	146,197	34	570	34,522	171,194	22.529	366,192	28,609	$1,087,728	6,648	$331,199	93	$9,216
1888....	71,313	152,068	.....	....	57,603	285,656	19,781	313,235	40,789	1,592,931	8,669	472.611	306	27,472
1889....	76,389	151,640	.....	....	65.540	307,292	23,522	499,872	66,453	2,763,062	*b*25,293	973,282	75	6,604
1890....	69,429	155,380	.....	....	44,671	123,068	......	*e*	.....	*e*	....	....	51	5,085
1891....	62,594	142,005	.....	....	59,312	203,193	21,697	379,000	21,680	....	....	....	267	25,607
1892....	93,667	263,866	.....	....	54,223	179,310	38,514	637,421	......	....	....	....	*k*802	72,505
1893....	126,710	298,018	.....	......	59,485	175,626	....	....	......	....	....	....	968	80,996

Yr.	Lime, Bushels. (*b*)		Limestone for Flux.		Manganese Ore.		Mica, Kilos.		Water, Mineral, Gallons.		Nickel, Kilos.		Mineral Paint.	
1886..	1,535,950	$283,755	.....	......	1,623	$41,499	9,255	$29,008	....	....	....	....	....	....
1887..	2,269,087	394,859	15,582	$17,500	1,130	43.658	10,038	29,816	....	....	....	....	*b*91	*b*$1,500
1888..	2,216,754	339,951	15.297	16,533	1,634	47,944	13,193	30.207	*b*124,850	*b*$11,456	....	....	360	7,900
1889..	2.948,249	362,848	20,074	21,909	1,320	32,737	16,604	*d*28,718	424.600	37,360	....	....	721	15,280
1890..	2,501,079	412,308	16,768	18,361	1,205	32,550	350,436	68,074	561,165	66,031	652.610	$933,232	...	......
1891..	1,829,894	251,215	10,323	11,547	213	6,694	....	71,510	427,485	54.268	2,103,012	2,775,976	818	17,750
1892..	2,260.640	411.270	20,836	21.492	104	10,250	....	*o*104,745	640,380	75,348	*l*1,094,837	1,399.956	354	5,800
1893..	2,400,000	440,000	28,139	27,519	232	14,458	......	69,622	725,096	108,347	1,811,205	2,076,351	1087	17,710

Year.	Petroleum, Barrels.		Phosphate.		Fertilizers.		Platinum, Kilos.		Precious Stones.	Roofing Cement.		Sand and Gravel (Exports).		Molding Sand.	
1886....	486,441	$437,797	18,598	$304.338	.....	....	....	......	....	.....	......	586,708	$143,641	.....	......
1887....	763,933	595,868	21,497	319,815	*b*452	*b*$25,943	33	$5,600	....	...	.....	....	....	*b*145	*b*$800
1888....	733,564	755,571	20,404	242,285	497	21,600	35	6,000	....	.....	......	236,778	38,398	*b*153	*b*845
1889....	639,991	612,101	28,120	316,662	703	26,606	23	3,500	....	....	.....	256,846	52,647	154	850
1890....	765,029	902,734	28,814	361,045	1,092	31,889	....	4,500	$700	1,063	$6,502	310,488	65,518	290	1,410
1891....	755,298	1,004,546	21,405	241,603	....	....	....	10,000	1,000	817	4,810	221,165	59.501	209	1,000
1892....	779,753	*p*982,489	11,932	*q*157,424	....	....	....	3,500	1,000	726	12,000	270,235	85,329	313	1.380
1893....	798.406	834,334	8,330	70,942	....	....	....	1,800	1,500	966	5.441	33.441	121,795	.....	*1,000

(*a*) For 1886 to 1891 compiled from *Reports on the Mining and Mineral Statistics of Canada*; for 1892, from copy of revised table kindly furnished by Mr. Elfric Drew Ingall of the Geological Survey of Canada. Of ocher were produced, in 1886 and 1887, respectively, 318 and 349 tons, valued at $2350 and $2233; the production in 1888 and 1892 is included under "Mineral Paint." (*b*) Incomplete. (*c*) Report gives 980. (*d*) Exports. (*e*) Statistics for iron, steel, and charcoal not collected in 1890. The pig iron produced was all included under "Iron Ore." (*f*) Included under "Mineral Paint." (*g*) Marble only. (*h*) Short tons. (*i*) Copper contents of ore, matte, etc., at $12\frac{2}{3}$c. per lb. (*j*) Nova Scotia and British Columbia gold are computed at $19.50 and $17 per oz., respectively. (*k*) Lead contents of ores at $4\frac{1}{10}$c. per lb. (*l*) Exports of fine nickel in matte ore, etc., at 58c. per lb. Computed thus to conform to the system adopted. In the condition of matte as it

MINERAL PRODUCTION OF THE DOMINION OF CANADA—*Continued.* (IN METRIC TONS.)

Year	Salt.		Silver, Kilos.		Slate.		Soapstone.		Sulphuric Acid.		Terra Alba.		Terra Cotta.	Various Products.	Whiting.	
1886.	56.587	$227.195	....	b$209,090	4,850	$64,675	45	$400	....	....	3,630	$24,000	....	$156	68	600
1887.	54.603	166,394	....	349,330	6,676	89.000	91	800	2,485	$70,609	... .	......	.. ..	1,610.499	68	600
1888.	53,602	185,460	......	395.377	4,822	90,689	127	280	3,959	121,515	.. .	......	b$49,800	397,172	27	240
1889.	29,793	129,547	8,961	343,848	6,293	119,160	177	1,170	.....	....	4,990	152,592	... .	992.838	...	..
1890.	39,704	198,897	9,367	420,662	5,779	100,250	832	1,239	.....	700	5,044	145,235	90,000	995,667	454	500
1891.	40,854	161,179	9,713	406,233	....	....	522	863	.....	... ...	... .	....	113,103	694,441	...	...
1892.	41,267	162,041	m9,661	269,489	4,699	69,070	...	.....	.....	....	.....	....	c97,239	(s) 752,610	...	...
1893.	63,327	195,926	12,907	321,423	7,227	90.825	729	1.920	.....	....	.....	....	....	†366,703	...	...

* Estimated. † Zinc, $470; natural gas, $366,233.

MINERAL IMPORTS OF THE DOMINION OF CANADA. (*t*) (IN METRIC TONS.)

Year.	Brass. (*u*)	Cement	Clays.	Bricks and Tiles.	Earthenware and China.	Coal, Anthracite.		Coal and Coke.		Copper (*u*)	Glass.	Gold and Silver. (*u*)
1888	$540,010	$190,504	$53,269	$143,775	$697,082	2,172.341	$5.290.412	1,306,603	$3,588,725	$410,858	$1,203,537	$220,355
1889	536,650	197,580	53.170	131,475	697,949	1,307,189	5.193,025	1,339,685	3,377,212	405,504	1,205,090	231,285
1890	563,245	328,110	61,848	105,818	695,206	1,221,029	4.595,727	1,523,523	3,692,121	484,189	1,230,585	256,164
1891	603,043	313,767	56,766	120,667	634,907	1,421,969	5,224,452	1,725.312	4,274,631	563,522	1,247,692	244,042
1892	537,105	287,729	82,619	81,495	748,810	1,503,353	5,640,346	1,769,347	4,333,490	431,427	1,257,858	261,471
1893	....	.... ..	.. ...	... ...	....	....	....	... .	... .	....	....	... ..

Year.	Coin and Bullion.	Gun-powder	Iron and Steel. (*u*)	Lead. (*u*)	Metal Manufactures.	Mineral Oils, Gallons.		Precious Stones and Jewelry.	Salt.		Stone and Marble. (*u*)	Tin. (*u*)
1888	$2,175.472	$100,158	$10,482,208	$272,435	$375,500	4,895,066	$449,446	$709,863	88,329	$253,111	$267,881	$1,164,273
1889..	575.251	104.722	12,225,962	285.571	365.407	4.925,680	518,664	684,322	86,144	284,817	321,091	1,243,794
1890.	1,083,011	127,578	13.524.899	380,242	352.859	5,244,108	546.051	560,961	......	309.840	385,468	1,289,756
1891..	1,811.170	110,515	13.826,492	325,455	351,809	5,321,524	550.925	425,012	......	380,550	392,941	1,206,918
1892..	1,818,530	136,171	12,625,422	317,142	373.819	5,793,636	494,004	344,827	......	380,958	276,005	1,594,205
1893	.. ..	....	. ...	....	....	. . ..	....	....	.. ...	....	.... ..	....

Year.	Whiting.	Zinc.	Various Metals.	Various Minerals.
1888	$20,508	$65,827	$5,175	$102,757
1889	22,735	83,935	142,408	114,270
1890	27,471	92 530	197,355	103,118
1891	27,504	105,023	191.730	88,962
1892	26,867	127,302	199,777	107,103
1893	... ...	......	......	......

MINERAL EXPORTS FROM THE DOMINION OF CANADA. (*t*) (IN METRIC TONS.)

Year.	Asbestos.		Agric. Impl.	Barytes.		Brick.		Cement.	Cinders.	Clay, M'f'es of.	Coal.	
1888	3.484	$228,335	$155,219	.	.....	...	... ..	*w*	.....	... ..	572,576	$1,730,466
1889	4,724	323.886	321,341	.	.....	...	.....	*w*	.....	......	656,097	2,232,154
1890	6,670	444,159	367,198	9	$850	...	$5,168	$322	$6,902	.....	727,091	2,447,936
1891	7,035	513,909	252,620	9	1,190	128	858	1,746	5,884	$50	847,351	2,916,465
1892	7,435	514,412	402,778	.	.....	504	2,750	1,495	5,451	120	960,619	3,195,467
1893	. ..	... .	....	.	.....	...	... .	....	.. ..	......	....	... .

Year.	Coke.		Charcoal.	Coin and Bullion.	Copper Ore.		Copper Matte, Regulus, etc.		Copper, Fine.		Explosives.		Glass and Glassware.	Grindstones	Gypsum, Crude.		Iron and Steel, M'f's of
																$	$
1888	...	......	......	....	1,533	$95,585	...	... ...	462	$50,900	..	....	$1,352	$31.974	126,556	133,238	423.488
1889	...	......	... .	....	1,287	195,182	.. .	......	69	7.602		......	8,396	23,544	179,766	189.491	296,719
1890	356	$1,050	$31,634	..	1,429	111,086	217	$23.924	816	109,327	9	$19,219	9,668	21,673	177,981	193,899	294.928
1891	7	21	61,323	$129,324	3,129	269,169	780	64,719	1,414	171,308	61	66.153	5,521	24,568	175.323	184,977	257,461
1892	...	. ....	46,817	306,447	345	30,755	...	....	1,723	185,848	75	61,763	1,964	23,465	181,444	194,304	243.857
1893	...	......	....	....	... .	..... .	...	....	....	....	..	... ...		... ...	....	....	...

Year.	Lime.	Metals other than Iron and Steel, M'f'res of.	Mica, Crude and Cut.		Mica, Ground.		Mineral Oils, Gallons.		Nickel, in Ore.		Antimony.		Ores. Gold, Quartz, etc.	Ores. Iron.		Ores. Lead.	
1888	v$100,547	....	3	$6,884	127	$1.883	455,501	$66,834	... .	....	417	$10,777	$810,352	13,766	$39,945	10	$724
1889	v131,066	$40,215	17	32,505	214	3,128	110,470	18.601	.. .	....	59	1,942	623,479	25,157	60,289	.	18
1890	175,184	36,639	16	34,865	...	2,453	358,804	15,812	.....	... ...	63	1,520	657,022	14.037	31,366	4	2,000
1891	153.265	42,633	74	19.666	.	2,646	436.516	18,726	2.428	$240,499	..	..... .	554,126	14,888	32.582	..	.....
1892	124,152	17,495	618	63,708	...	4,758	440,906	18,217	6,911	617,639	4	60	316,177	7,833	36,935	30	5,200
1893	.. ..	....	...	....	...	....	....	....	.....	......	. .	....	....	......	..... .	..	....

Year.	Ores. Manganese.		Ores. Silver.		Phosphates.		Fertilizers.	Plumbago.		Salt.		Sand and Gravel.		Slate.		Stone.	Tin.
1888.	1.433	$24,760	559	$299,420	22,207	$397.493	......	117	$1.025	4,874	$10,044	221,170	$33,236	31	$525	$83,872	.....
1889.	1,578	29,027	219	168,265	23,537	364,583	......	101	802	500	3,750	254.431	42,067	27	398	67,783	..
1890.	1,817	37,697	242	201,615	30.202	401,827	$4,291	53	1,905	225	1,522	335,052	60,359	24	3,268	91,998	$6,410
1891.	894	16,218	314	238,367	24,653	422,200	5,128	...	163	228	1,429	329,433	63,326	..	.....	63,308	12,615
1892.	168	6,106	330	193,441	17,526	380,462	8,763	67	438	130	763	233,537	60,285	64	1,507	60,209	5,115
1893.	.. .	... .	...	....	.....		. ..	...	..	....	.. ...	....	. .....	..	.....	......	.. .

leaves Sudbury the values of the metals would be nearer 6c. for copper and 18⅔c. for the nickel. Total spot value of the matte shipped from Sudbury during 1892 = $450,560. (*m*) Production of Quebec and British

MINERAL PRODUCTION OF NOVA SCOTIA. (*x*)

	1892.		1893.			1892.		1893.	
	Quan.	Value.	Quan.	Value.		Quan.	Value.	Quan.	Value.
Brick............	....	....	....	$85.000	Gypsum. ...met. tons	147,225	$156,108	160,000	$155,000
Coal....met. tons	1,762,490	....	2,258,468	2,556,085	Iron ore..... " "	68,040	....	89,000	178,000
Coke... "	49,836	....	79,878	....	Iron, pig.... " "	....	....	37,128	....
Copper ore "	23	....	1,134	18,000	Limestone. . " "	4,012	2,211	....	80,000
Gold.. .....kilos.	727	....	619	....	" .. ....bbls.	7,319	5,173	....	....
Grindstones.	....	$11,792	....	12,000	Manganese..met. tons	101	8,691	104	8,625

MINERAL PRODUCTION OF ONTARIO IN 1893. (*y*)

	Quantity.	Value.		Quantity.	Value.
Apatite................metric tons	18	$200	Mica......................metric tons	18	$1,600
Brick (common)...... ....No.	162.350,000	932,000	Natural gas...........M cubic feet	1,962,000	190.705
Brick (pressed) .... "	20,208,000	192,672	Natural rock cement... .... bbls.	74,353	63.567
Brick (fancy pressed).......... "	1,373,700	20,911	Nickel... ....metric tons	1,490	454.702
Building stone.....	....	721,000	Petroleum.....................bbls.	1,045,000	1,100,000
Cobalt. ....metric tons	17	9,400	Portland cement............. "	31,924	63,848
Copper.................. " "	1,298	115,200	Pottery	....	115.000
Draining tile ....No.	17,286,000	190,450	Roofing, tile and terra cotta.......	....	5.790
Gold........... ....kilos.	53	30,120	Salt....................metric tons	43,546	150,000
Gypsum and products..metric tons	2,683	22,163	Silver ore.............. " "	454	....
Lime................... ....bushels	2,700,000	364,000	Sewer pipe........	....	200,000

MINERAL PRODUCTION OF QUEBEC IN 1893. (*z*) (In metric tons.)

Asbestos..	6,576	Iron, Magnetic ore	1,575
Copper, low grade ore	58,935	Lead	91
Copper, high grade ore	45	Mica. rough and dressed.....................	1,056
Feldspath	907	Ocher	862
Gold, kilos......................................	11.056	Phosphates......................................	10,342
Granite, cu. ft..................................	100,000	Serpentine......................................	272
Graphite	296	Slate...	4,341
Iron, Bog ore...................................	26,967		

Columbia and exports from Ontario at 86⅔c. per oz. (*n*) Oven coke, all the production of Nova Scotia. (*o*) Exports, plus quantity sold to Canadian electrical works and stove founders. (*p*) Calculated from the inspection returns at 100 gallons crude to 38 gallons refined oil, and computed at $1.26 per barrel of 35 imperial gallons. The barrel of refined oil is assumed to be 42 imperial gallons. (*q*) Exports, plus quantity used in Canada. (*r*) Includes fireproof porous terra cotta, etc., and a certain quantity of high-priced ornamental pressed brick. (*s*) Does not include natural gas, $150.000. (*t*) From *Tables of the Trade and Navigation of the Dominion of Canada.* (*u*) And manufactures thereof. (*v*) Includes cement. (*w*) Included with "Lime." (*x*) For 1892, from *Report of the Department of Mines*, Nova Scotia; for 1893, kindly furnished by Mr. E. C. Gilpin, Jr., of the Department of Mines.—The official figures for 1893 are for nine months only, according to the provisions of the Acts of 1893, which require that all reports of the several departments of the government shall in 1893 be made up for a period of nine months ending Sept. 30. From and after the first day of October, 1893, the fiscal year of the Province shall begin on the first day of October and end on the 30th of September, and all reports must be made up for the year so beginning and ending. (*y*) Kindly furnished by Mr. Archibald Blue, Director Bureau of Mines, Toronto. (*z*) From *Report of the Mining Inspector for* 1892–3. Year ends June 30.

OTHER BRITISH COLONIES.

THE mineral productions of the various British colonies, as shown in the following tables, add over $50,000,000 annually to the wealth of that nation.

In Ceylon the most important product mined is plumbago, of which 20,000 tons, valued at $1,502,025, were produced in 1891. The output in 1882 was 13,217 tons, valued at $1,084,025; so, while the quantity mined has increased 53%, the value per ton has decreased from $82 to $73, or about 10%. The two items of importance in the imports of Ceylon are coal and hardware, both of which have almost doubled in the past ten years.

Cyprus does not yield any important mineral products other than gypsum and umber, and these only in small quantity. In the Channel Islands, Guernsey and Jersey, the only product is stone, and in British Guiana, gold. The rapid growth of the gold-mining industry in this colony is well shown by the fact that in five years the output has increased from $568,210 to $2,542,996, or 347%, and it is destined to grow rapidly and to a very important amount in the near future.

The mineral production of India is particularly interesting, as it indicates the future possibilities of this country. The coal output has doubled in ten years, amounting in 1891 to 2,366,067 tons, valued at $2,638,050, though the value per ton has steadily decreased during the same period from $2.46 in 1881 to $1.11 in 1891. In gold there has been a still greater increase from 2533 kilos in 1889 to 6442 kilos in 1893, and several of the Indian gold mines are paying large dividends. The output of precious stones, for which India was famous, amounted to but $101,245 in 1891, and has not exceeded this figure since the ruby mines of Burmah proved so great a disappointment. In petroleum, however, there is a marked increase, and Burmah may yet become a strong competitor of the United States and Russia in the Pacific markets. The largest item of imports, in values, is iron, amounting to $11,605,220; the next is copper and brass, $10,767,225, and machinery, $10,557,985. The imports of railroad material have declined since 1888, during which year they reached the maximum value of almost $13,000,000.

Among the British colonies in Africa, the Cape of Good Hope stands foremost in mineral output, producing in 1891 3,255,545 carats of diamonds, valued at $20,871,040, and 24,585 kilos of gold, valued at $13,907,880, besides $1,270,920 of copper ore, a total in these three products of $36,049,840.

MINERAL PRODUCTION OF CEYLON. (*a*) (IN METRIC TONS;) (£1=$5.)

Year.	Lime Cement. (*b*)	Plumbago. (*b*)		Precious Stones (*b*)	Salt. (*a*)		Building Stone. (*b*)	Granite. (*b*)
1882..	...	13,217	$1,084,025	...	*a*3,494	$49,605	...	...
1883..	...	13,350	1,094,890	...	*a*3,056	20,300	...	...
1884..	...	9,268	760,105	...	*a*8,660	27,700	...	...
1885..	...	9,978	818.335	...	*a*1,802	5,545	...	...
1886..	...	12,283	906,600	$5,340	1,656	4,590	...	...
1887..	$95	12,122	857,465	10.310	4,212	11,180	$1,200	...
1888..	200	11,343	767,515	3,220	1,389	4,700	2,600	...
1889..	220	28,988	1,961,370	16,050	1,468	3,775	...	$20,510
1890..	45	32,225	626,275	21,045	7,741	21,425	28,740	14,180
1891..	180	20,349	1,502,025	18,445	2,031	5,625	49,395	15,675
1892..	...	...	...	...	...	...	...	...
1893..	...	...	...	...	...	...	...	...

IMPORTS OF CEYLON. (*c*)
(IN METRIC TONS.)

Year.	Coal and Coke.		Hardware.
1882..	170.982	$1,458,125	$92,380
1883..	199,093	1,647,860	92,135
1884..	195,695	1,645,595	95,450
1885..	204,404	1,609,770	87,170
1886..	188,552	1,471,735	94.685
1887..	184,506	1,406,585	99,860
1888..	289,127	2,343,220	121,130
1889..	326,278	2,742,285	99,505
1890..	308,877	2,494,050	146,505
1891..	338,106	2,486,875	164,115
1892..	...	...	...
1893..	...	...	...

(*a*) From British blue books. (*b*) Export returns (*c*) From British Statistical Abstracts. The earlier imports were, respectively, for coal and coke and cutlery and hardware, as follows: In 1876, 65,050 tons, $616,475, and $181,175; in 1877, 88,434 tons, $844,950, and $280,130; in 1878, 87,572 tons, $846,835, and $163,575; in 1879, 72,107 tons, $674,465, and $144,815; in 1880, 82,418 tons, $918,910, and $130,900; in 1881, 106,073 tons, $911,805, and $99,235.

MINERAL PRODUCTION OF CYPRUS. (*d*) (IN METRIC TONS.) (£1=$5.)

Y'r.	Flagstones, Number.		Gypsum. (*e*)		Umber. (*e*)		Total Value.
1885	...	...	1,415	$4,440	923	$2.785	$7,225
1886	10,250	$315	*f*2,018	6,215	2,184	5,845	12,375
1887	13,075	380	2,145	5,490	2,613	7,730	13,600
1888	9,815	255	1,809	5,330	1,687	3,640	9,230
1889	*e*12,491	310	1,119	3,775	1,197	3,115	7,215
1890	...	...	...	...	...	...	...
1891	*e*7,506	195	2,948	7,595	2,351	6,210	14,005
1892	...	...	...	...	...	...	...
1893	...	...	...	...	...	...	...

GUERNSEY & JERSEY. (*d*)

Y'r.	Stone. (*e*)	
1885	...	...
1886	...	...
1887	...	...
1888	238,317	$687,545
1889	247,577	708,890
1890	251.546	697,340
1891	232,163	655,440
1892	...	...
1893	...	...

GUIANA, BRITISH. (*d*) (IN METRIC TONS.)

Y'r.	Gold, Kilos.		Granite.		Prec. Stones (*e*)
1885	...	...	...	...	...
1886	...	...	...	...	...
1887	...	...	...	...	...
1888	...	...	...	...	...
1889	912·249	$568,210	5,604	$4,595	...
1890	*e*1,947.577	1,171,620	5,508	4,500	$1,000
1891	*e*3.150.773	1,876,450	5,917	5,770	...
1892	4,031.	2,303,163	...	...	...
1893	4,441.	2,542,996	...	...	...

(*d*) Production in metric tons, from British blue books. (*e*) Exported. (*f*) Return incomplete.

MINERAL PRODUCTION OF BRITISH INDIA. (*g*) (IN METRIC TONS.)

Y'r.	Coal.		Copper Ore.		Gold, Kilos.		Iron Ore.		Mica.		Miscellaneous.		Prec. Stones.
1881	1,013,703	$2,493,855	...	...	...	...	...	...	...	...	...	...	...
1882	1,148,439	2,825,605	...	...	12	$7,670	...	...	...	...	...	...	...
1883	1,337,163	3,289,940	...	...	...	...	...	...	...	...	...	...	...
1884	1,420,323	3,145,090	...	...	...	...	...	...	...	...	...	...	...
1885	1,315,058	3,235,550	...	...	...	...	...	...	...	...	...	...	...
1886	...	...	...	...	...	...	...	...	...	...	...	...	...
1887	1,585,515	1,692,135	...	...	...	...	...	...	...	...	...	...	...
1888	...	...	...	...	...	...	...	...	...	...	...	...	...
1889	1,468,629	2,299,475	4,332	$77,705	2,533	1,476,865	40,129	$38,820	89	$21,635	7,249	$71,975	$95,340
1890	2,203,434	2,459,205	4,486	78,010	3,400	1,967,800	28,751	65,065	314	49,065	12,793	168,890	101.245
1891	2,366,067	2,638,050	...	...	...	...	33,872	64,325	...	...	...	...	...
1892	...	...	...	...	5,074	...	...	...	...	...	...	...	...
1893	...	...	...	...	6,442	...	...	...	...	...	...	...	...

MINERAL PRODUCTION OF INDIA—*Continued.*

Y'r.	Petroleum.		Salt. (*h*)		Soapstone.		Stone.
1876	...	...	...	...	...	...	...
1877	...	...	...	...	...	...	...
1878	...	...	...	...	...	...	...
1879	...	...	...	...	...	...	...
1880	...	...	...	...	...	...	...
1881	...	...	764,942	$1,882,055	...	...	...
1882	...	...	1,194.260	2,003,465	...	...	...
1883	...	...	930,043	1,610,535	...	...	...
1884	...	...	1,206,360	1,964,505	...	...	...
1885	...	...	1,164,763	1,886,630	...	...	...
1886	...	...	...	...	...	...	...
1887	...	...	1,045,492	3,025,130	...	...	...
1888	...	...	...	...	...	...	...
1889	3,343,237	$83,705	1,045,376	2,135,225	340	$13,720	$1,828,215
1890	1,962,184	130,420	1,052,840	1,858,355	513	10,980	2,005,400
1891	6,235,293	158,970	1,032,268	1.730,630	...	...	...
1892	...	...	...	...	...	...	...
1893	...	...	...	...	...	...	...

MINERAL IMPORTS OF INDIA.
(IN METRIC TONS.)

Y'r.	Coal and Coke.		Copper and Brass.		Glass and Manuf'es.
1876	385,359	$3,327,675	12,380	$6,280,120	$1,749,665
1877	528,097	4,658,550	14,217	7,217,745	1,401,950
1878	611,114	5,040,775	16.803	7,759,095	1,456,880
1879	483,763	4,447,385	15,096	6,613,810	1,593,520
1880	597,566	5,691,040	20,160	8.370,015	1,646,605
1881	694,977	6,199,275	19,995	8,404,420	1.901,205
1882	647,569	5,100,220	17,676	7,607,185	2,274,010
1883	639.133	5,099,415	23,496	10,015,320	2,418,715
1884	719,970	5,818,950	27,867	11,472,005	2,800,310
1885	753,279	6,336,065	28,791	10,690,280	2,498,505
1886	803,896	6,542,075	33,699	10,700,350	2,526,520
1887	778,220	6,583,075	31,833	10,216,290	2,504,250
1888	862,794	8,319,555	27,555	10,242,680	2,894,795
1889	847,142	9,536,065	5,523	3,092,840	3,290,270
1890	611,533	6,542,950	29,541	11,470,095	3,235,635
1891	797,527	7,719,970	23.352	9,462,635	3,251,185
1892	748,672	6,752,650	26,528	10,767.225	3,636,015
1893	...	...	...	...	...

(*g*) From British blue books. Ocher was produced in 1889 and 1890 to the amount of 582 and 577 tons. valued at $745 and $1095, respectively. (*h*) These figures for 1881–84, inclusive, relate only to salt, which is liable to British salt tax, and do not include a quantity of salt made in certain native States. The values for the same years are estimated cost of production.

MINERAL IMPORTS OF BRITISH INDIA—*Continued.*

														Mineral Exports of India. (*i*)	
Year.	Iron.		Steel.		Lead.		Machi'ry and Mill Work.	R'y Materials.	Spelter.		Tin.			Saltpeter.	
1876	102,851	$7,122,990	4,175	$444,980	1,842	$315,495	$6,958,335	$2,998,850	3,006	$413,255	1,839	$846,180		21,105	$1,744,780
1877	114,404	7,642,030	5,521	561,225	2,058	362,880	4,411,865	3,459,540	4,911	718,600	1,896	903,970		23,706	1,908,530
1878	123,884	7,177,805	4,445	405,315	2,682	485,550	4,254,985	4,535,010	6,624	897,265	2,475	1,110,785		19,779	1,895,010
1879	120,191	7,230,075	3,633	328,355	3,378	557,965	4,317,275	5,234,160	6,594	782,735	1,779	758,700		19,443	1,808,830
1880	107,288	6,146,925	4,877	422,735	3,738	531,480	3,084,165	5,165,245	6,465	721,800	1,059	494,230		25,899	2,348,985
1881	135,465	7,737,705	4,220	372,045	2,886	465,525	3,849,220	5,588,825	7,572	833,505	1,575	886,915		17,949	1,758,640
1882	124,636	7,071,920	8,883	660,485	3,426	482,485	6,105,225	5,397,545	6,909	676,175	1,371	848,575		18,045	1,797,185
1883	160,181	9,352,470	10,820	817,075	3,741	505,520	6,711,990	5,582,170	6,477	628,345	2,172	1,386,530		20,316	1,943,830
1884	182,120	10,702,455	12,879	906,895	4,197	527,980	8,945,330	8,166,415	6,744	640,330	1,983	1,177,085		24,999	2,322,050
1885	183,067	10,074,545	14,734	927,775	5,304	585,815	7,420,620	7,963,100	5,757	505,075	2,094	1,112,270		22,980	2,125,000
1886	177,523	9,674,440	14,168	872,860	3,894	427,065	4,957,765	10,090,325	7,584	682,295	1,872	1,109,065		20,451	1,851,000
1887	166,708	8,914,950	17,752	1,049,310	4,845	598,865	6,857,295	7,175,620	9,162	920,040	1,950	1,339,390		20,217	1,880,455
1888	219,621	12,236,975	21,391	1,294,055	5,694	752,045	9,001,090	12,888,015	6,831	740,975	1,065	846,390		19,647	1,820,080
1889	203,421	12,575,895	27,564	1,722,945	5,751	794,315	11,584,355	12,466,195	3,291	422,570	1,713	1,277,725		21,381	2,009,005
1890	183,378	12,071,585	23,804	1,642,200	5,361	767,450	12,176,925	9,106,685	4,266	567,385	2,025	1,422,765		21,471	2,056,380
1891	197,006	12,811,535	35,851	2,360,940	5,238	739,530	10,319,315	10,009,265	5,691	887,175	2,136	1,391,510		20,322	1,900,295
1892	186,978	11,605,220	39,274	2,297,675	6,221	854,540	10,557,985	7,420,865	6,039	963,070	1,972	1,321,655		19,772	1,828,090
1893	....	....	......	....	.....	....	....	....	.....	....	.....	....		....	....

(*i*) From British Statistical Abstracts. Fiscal years ending March 31. The rupee has been taken at 2s.

MINERAL IMPORTS OF MAURITIUS. (*a*) (IN METRIC TONS.)

Years.	Coal.		Hardware.	Guano.		Years.	Coal.		Hardware.	Guano.	
1876........	37,817	$275,475	$198,070	14,919	$491,930	1885........	38,541	$604,530	$228,270	4,124	$242,025
1877........	22,106	131,805	378,130	35,977	1,149,405	1886........	55,993	621,260	430,135	12,897	456,060
1878........	13,816	118,135	262,900	25,427	686,605	1887........	43,866	561,780	283,825	12,702	801,200
1879........	31,047	256,030	348,795	27,998	652,740	1888........	44,399	472,320	389,855	5,086	389,360
1880........	34,199	170,020	372,550	30,521	555,500	1889........	55,291	1,137,225	493,360	10,030	1,014,110
1881........	34,296	251,765	283,275	10,647	315,885	1890........	41,766	704,075	862,345	1,481	62,945
1882........	45,599	559,960	476,180	9,487	337,275	1891........	35,266	810,065	344,030	3,590	92,375
1883........	33,063	339,015	649,850	12,478	839,460	1892........	....	....	....	....	....
1884........	51,454	893,510	430,585	29,162	1,439,755	1893........	....	....	....	....	....

(*a*) From British Statistical Abstracts.

MINERAL PRODUCTION OF NEWFOUNDLAND. (*b*) (IN METRIC TONS.)

Year.	Copper Ingots.		Copper Ore and Regulus.		Iron Pyrites.		Year.	Copper Ingots.		Copper Ore and Regulus.		Iron Pyrites.	
1882....	......	....	19,574	$468,575	......	....	1888....	1,224	$491,945	4,684	$324,440	*c*1,880	$37,000
1883....	......	....	12,551	256,795	......	....	1889....	1,365	241,740	3,116	114,610	*c*7,651	64,000
1884....	......	....	4,527	99,125	965	$7,200	1890....	619	182,700	1,662	53,540	1,697	75,325
1885....	......	....	4,777	102,420	......	....	1891....	488	296,615	10,858	292,810	19,458	863,755
1886....	*c*24.38	$2,910	*c*7,024	243,240	......	....	1892....	......	....	....	....	....	....
1887....	122	51,040	7,612	124,860	*c*417	8,540	1893....	......	....	....	....	....	....

(*b*) From British blue books. There were also produced of antimony ore in 1889–91, respectively, 30.48 tons, $5250; 10.16 tons, $1250, and 81.28 tons, $5000; of selenite in 1891 254 tons, $1300, and of mica in 1887 12 barrels, $250. (*c*) Export returns.

BRITISH COLONIES IN AFRICA.

MINERAL PRODUCTION OF THE CAPE OF GOOD HOPE. (*d*) (IN METRIC TONS.)

Year.	Asbestos. (*e*)		Coal.		Copper Ore.		Crocidolite. (*e*)		Diamonds, Carats.		Gold, Kilos. (*e*)		Salt. (*e*)	
1882	..	......	20,083	$323,825	19,986	$1,970,160	....	......	....	$19,962,510	......	....	......	......
1883	..	......	20,277	279,780	23,071	2,270,565	....	......	1,830,935	13,712,350	......	....	......	......
1884	..	......	9,145	36,250	20,676	2,027,075	....	......	*e*2,263,734	14,036,645	......	....	......	......
1885	..	......	16,745	75,250	20,538	1,978,375	....	......	2,440,788	12,448,295	......	....	365	$2,530
1886	..	......	21,336	293,980	20,995	802,265	....	......	*e*3,135,061	17,523,775	......	....	......	......
1887	..	......	20,336	280,235	31,397	1,432,225	21	$5,085	*e*3,692,265	20,631,440	799	$464,680	276	3,655
1888	..	......	33,348	123,075	*e*40,667	4,284,015	25	10,175	*e*3,841,937½	20,111,895	4,721	2,589,105	1,018	8,410
1889	..	......	26,677	101,735	*e*32,859	3,484,598	17	7,605	*e*2,961,978	21,625,685	7,971	4,302,475	593	5,520
1890	1	$155	33,553	165,105	*e*33,210	3,471,780	26	10,310	*e*2,504,730	20,810,365	13,109	7,225,195	395	3,440
1891	38	4,500	28,123	172,980	*e*24,072	1,270,920	7	4,900	*e*3,255,545	20,871,040	24,585	13,907,880	807	9,410
1892	..	......	....	....	....	....	....	......	....	....	......	....	......	......
1893	..	......	....	....	....	....	....	......	....	....	......	....	......	......

(*d*) From British blue books. (*e*) Export returns.

MINERAL PRODUCTION OF NATAL. (*a*) (IN METRIC TONS.)

Year.	Asbestos.		Coal.		Copper Ore. (*b*)		Gold, Kilos. (*b*)		Gold Quartz. (*b*)		Iron. (*b*)		Lead Ore. (*b*)		Silver-Lead Ore. (*b*)		Stone.	
1886	..	.....	*c*69	$590	36	$4,550	......	....	......	$695	*d*11	$1,275	....	......	....	....	....	....
1887	..	.....	*c*5,690	17,325	7	190	......	....	......	700	....	......	....	......	....	....	....	$29,400
1888	..	.....	10,929	24,380	..	4,300	......	....	......	585	....	......	....	......	....	....	....	29,000
1889	..	.....	55,359	197,060	..	5,650	......	....	......	1,025	....	......	....	......	....	....	....	....
1890	..	.....	66,238	210,635	..	9,505	7	$4,455	......	7,870	....	......	....	$8,135	....	$37,705	....	....
1891	3	$100	128,480	360,365	..	......	......	....	263	26,080	88	6,525	418	41,125	169	15,495	78,392	20,175
1892	..	.....	....	....	..	......	......	....	......	......	....	......	....	......	....	....	....	....
1893	..	.....	....	....	..	......	......	....	......	......	....	......	....	......	....	....	....	....

(*a*) From *Mineral Statistics of the United Kingdom*. There were also produced and exported of plumbago in 1886, 5 tons, $135; in 1889, 2 tons, $10; and in 1890, $25. Of the coal produced in 1882, 5080 tons, $5000, were exported. (*b*) Exported. (*c*) Exported; does not represent the whole production. (*d*) Cobalt ore.

MINERAL IMPORTS AND EXPORTS OF THE STRAITS SETTLEMENTS.(*g*)

Year.	Imports.					Exports.				
	Coal.	Gold, Bullion.	Petroleum.	Silver, Specie.	Tin.	Coal.	Gold.	Petroleum.	Silver.	Tin.
1889	$3,839,101	$796,126	$1,875,134	$12,570,061	$19,522,147	$29,091	$145,889	$874,065	$13,950,266	$23,180,747
1890	2,993,761	1,154,885	1,680,182	15,873,944	17,799,818	39,039	136,342	949,333	20,880,946	22,019,860
1891	3,195,076	1,445,253	1,319,936	14,295,151	14,382,086	45,930	199,516	866,622	19,970,022	22,275,232
1892	....	....	....	....	....	......	....	....	....	....
1893	....	....	....	....	....	......	....	....	....	....

(*g*) From the *Imperial Institute Year Book*, 1893. The Straits Settlements comprise Singapore, Penang, Province Wellesley, and Malacca. The principal wealth of the protected native States (Perak, Selangor, Sungei Ujong, Jelebu, Negri Sembilan, Pahang) lies in the deposits of tin, whose exports pass through the Straits Settlements, and are shown in the above table. There is a large tin-smelting establishment in Singapore which turns out about 100 tons of smelted tin a month.

MINERAL PRODUCTION OF BRITISH WEST INDIES. (*h*) (IN METRIC TONS.) (£1=$5.)

Year.	Redonda and Sombrero.		Trinidad.			
	Phosphates of Alumina and Zinc. (*k*)		Asphalt, Refined.		Asphalt, Raw.	
1885	*l*4,710	$81,110	6,839	$67,280	28,964	$142.525
1886	8,586	147,875	5,503	54,165	30,742	151,275
1887	8,190	128,625	8,156	80,270	35,637	175,360
1888	7,555	111,470	11,416	123,505	41,448	209,370
1889	5,532	94.220	11,745	115,590	67,637	334,425
1890	*i*4,034	84,130	10,811	106.400	69,299	341,005
1891	*i*1,992	19,725	10,192	100,015	87,342	429,790
1892	....	....	....	....	....	....
1893	....	....	....	....	....	....

(*h*) From British blue books. (*i*) Export returns. (*k*) Mainly phosphate of lime, which is produced in Sombrero. (*l*) This is for Sombrero, in return for Redonda.

SILVER PRODUCTION OF BOLIVIA* IN 1890 AND 1891. (*a*) (In marcos.)

Name of Mines and Districts.	Situation.	Production.	
		1890.	1891.
Huanchaca	Province of Porco	656,192.50	792,279.527
Colquechaca	" " Chuquisaca	37,378.12	51,111.380
Aullagas	" " "	151,309.12	157,234.225
Real Socavon de Potosi	" " "	24,894.78	37,840.456
Compañia Minera de Oruro	" " Oruro	75,316.92	125,226.513
Compañia Minera de Itos	" " "	54,535.42	6,342.848
Guadalupe	" " Chuquisaca	32,235.88	69,709.980
Consuelo	" " "	....	4,858.250
Andacaba	" " Linares	14,635.94	....
San Miguel	" " Chuquisaca	250.56	....
Flamenca	" " "	10,908.98	3,095.420
Districts:			
Machacamarca	Department of Oruro	6,900.00	8,775.000
Potosi	" " Potosi	26,550.00	35,000.000
Nor y Sur Chichas	" " "	2,550.00	4,250.000
Chayanta	" " Chuquisaca	43,875.00	(*b*)62,625.750
Norte	" " La Paz	52,625.00	45,000.000
Total Marcos		1,190,158.22	1,403,345.349
Kilos		273,783.0	322,771.3

* For full particulars of Bolivia, see THE MINERAL INDUSTRY, Vol. I.

(*a*) For 1890, from *Bulletin No.* 55 *of the Bureau of American Republics;* 1891 kindly furnished by the Bolivian consul-general, at New York. The marco contains 8 Spanish ozs., and 4.3478 marcos — 1 kilo.

(*b*) Estimated.

THE MINERAL STATISTICS OF CHILE.

MINERAL EXPORTS OF CHILE SINCE 1844. (*a*)

Year.	Coal.		Cobalt Ores.		Copper Bars.		Copper Matte. (*b*)		Copper Matte, Argentiferous. (*c*)	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1844..	5,156	$39,327	2.3	$87	4,026.1	$1,236,747	5,085.3	$437,352	....	....
1845..	1,369	10,312	....	....	4,382.7	1,313,687	4,268.1	330,531	....	....
1846..	230	2,401	....	....	6,006.5	1,778,525	4,743.3	345,504	....	....
1847..	4	84	4.8	416	6,481.1	1,899,253	3,965.3	298,667	....	....
1848..	1	10	68.4	4,654	6,920.4	2,081,347	3,908.9	275,804	....	....
1849..	632	4,523	352.4	23,058	8,220.9	2,445,768	2,730.9	204,160	....	....
1850..	431	7,490	266.8	10,709	9,116.1	2,653,979	5,024.5	333,534	....	....
1851..	229	2,540	8.4	360	6,022.2	1,749,780	3,031.7	216,539	....	....
1852..	6,623	74,437	....	....	9,729.7	2,736,951	6,675.1	473,490	....	....
1853..	5,788	43,188	....	....	5,823.1	1,854,659	5,400.7	465,677	....	....
1854 .	24,341	163,623	....	....	7,911.5	2,772,364	6,633.9	662,269	....	....
1855..	17,079	91,982	200.0	8,219	8,177.2	2,929,066	11,860.3	1,729,793	....	....
1856..	30,986	195,670	....	....	6,418.9	3,000,173	16,839.5	3,314,579	....	....
1857..	36,212	213,910	67.8	2,059	6,281.5	3,008,610	23,135 9	4,672,514	....	....
1858..	34,200	185,944	233.5	19,155	8,724.8	3,922,003	15,579.2	2,759,785	....	....
1859..	68,839	408,856	130.3	9,885	9,345.7	4,063,340	14,963.5	2,927,646	299.8	$195,510
1860..	47,192	274,041	332.1	14,453	13,456.7	5,821,362	18,487.4	3,966,207	814.0	530,850
1861..	53,342	336,099	227.8	7,427	14,499.8	5,594,610	22,740.9	3,584,168	581.3	214,846
1862..	47,597	263,830	46.0	370	12,704.2	4,918,100	33,442.9	5,307,254	868.2	184,875
1863..	44,948	283,124	245.5	19,643	14,969.5	5,545,046	20,250.8	2,960,563	903.2	528,943
1864..	44,960	287,725	143.9	3,599	23,805.0	9,506,957	29,468.2	4,714,912	846.8	496,687
1865..	48,442	251,442	37.1	5,097	16,801.7	6,208,652	39,360.8	6,266,170	1,163.9	404,462
1866..	31,856	170,374	26.5	398	19,005.2	6,351,842	20,078.6	4,820,769	762.1	383,327
1867..	40,766	223,602	51.6	2,581	25,475.0	8,916,251	28,550.5	4,216,972	1,443.1	981,735
1868..	43,445	188,305	....	....	27,385.9	8,211,729	25,919.6	2,905,350	1,302.1	781,340
1869..	37,742	215,155	....	....	28,108.1	5,662,346	41,829.6	5,299,443	1,445.9	925,412

(*a*) For 1844 to 1890, from a compilation made by the *Sociedad National de Mineria*, from the custom-house records; for 1889, from *Memoria de Hacienda*, 1890; for 1890, *Commercio Esterior de Chile*, by Alberto Herrmann, in the *Bolletin de la Sociedad National de Mineria*, No. 46, 1892; for 1891, various sources.

MINERAL EXPORTS OF CHILE SINCE 1844.

Year.	Silver Bars.		Silver, Old Plate.		Silver, Lead.		Silver Lead Ores.		Silver Ores.		Silver Sulphide Ores.	
	Kilos.	Value.	Kilos.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1844	27,595.49	$1,230,458	81.17	$2,875	......	......	......	......	35.9	$4,056	......	......
1845	35,949.15	1,655,698	106.07	4,610	......	......	......	......	130.3	12,824	......	......
1846	40,522.78	1,773,949	12.42	540	......	......	......	......	51.0	2,803	......	......
1847	40,562.58	1,798,083	305.80	13,240	......	......	......	......	54.6	9,628	......	......
1848	49,469.17	2,239,644	96.64	3,780	......	......	......	......	150.9	22,838	......	......
1849	71,185.69	3,215,572	102.85	4,023	......	......	......	......	46.3	4,418	......	......
1850	92,381.50	3,914,148	109.75	3,816	......	......	......	......	332.5	41,385	......	......
1851	80,160.00	3,277,319	23.01	800	......	......	......	......	1,908.4	270,018	......	......
1852	85,665.44	3,511,553	36.12	1,206	......	......	......	......	4,807.7	487,843	......	......
1853	56,850.67	1,738,054	......	......	......	......	......	......	5,048.7	1,454,555	......	......
1854	69,391.85	2,714,193	9.02	640	......	......	......	......	7,250.4	1,428,462	......	......
1855	62,352.51	2,648,746	5.06	154	......	......	......	......	11,766.7	1,603,889	......	......
1856	56,746.43	2,589,563	......	......	......	......	......	......	6,460.3	1,076,730	......	......
1857	34,730.32	1,584,254	5.75	250	......	......	......	......	4,521.7	1,279,151	......	......
1858	27,383.80	1,248,666	4.14	180	......	......	......	......	3,895.4	784,397	......	......
1859	15,954.00	718,829	277.27	6,025	......	......	......	......	4,343.4	379,267	......	......
1860	33,624.02	1,534,066	156.00	4,746	......	......	......	......	5,347.4	906,210	......	......
1861	28,354.35	1,308,680	362.17	11,018	......	......	......	......	4,735.7	830,188	......	......
1862	47,791.30	2,180,861	210.31	6,312	......	......	......	......	5,553.4	1,026,228	......	......
1863	49,357.00	2,241,476	294.00	10,958	......	......	......	......	4,365.9	1,021,318	......	......
1864	35,539.00	1,638,272	504.00	16,632	......	......	12.3	$368	3,786.5	810,243	......	......
1865	22,009.00	1,001,666	240.00	8,880	......	......	......	......	2,621.6	626,629	......	......
1866	37,916.00	1,694,350	152.00	5,030	177.2	$35,224	......	......	1,864.2	143,985	......	......
1867	64,592.00	2,906,640	283.00	9,905	310.1	40,500	210.5	14,737	2,314.9	130,686	......	......
1868	69,545.55	3,129,551	51.31	1,694	575.4	87,973	340.3	31,532	1,050.1	68.751	......	......
1869	82,523.80	3,300,943	50.00	1,500	816.8	163.236	238.3	23,830	872.5	82,051	......	......
1870	45,600.51	1,828,409	48.90	1,604	615.6	123,113	228.8	21,481	1,889.6	293,571	......	......
1871	53,534.09	2,409,033	27.00	945	440.4	88,091	506.2	61,887	1,578.5	376,492	......	......
1872	36,995.53	1,664,599	15.50	543	197.8	39,435	182.7	38,017	823.0	167,132	......	......
1873	64,827.23	2,917,225	......	......	......	......	760.4	58,524	769.9	127,693	......	......
1874	74,819.85	2,992,818	......	......	......	......	......	......	1,001.9	163,957	......	......
1875	73,463.14	2,938,510	......	......	57.3	31,907	277.7	27,774	159.8	43,918	......	......
1876	34,799.74	1,394,565	60.65	2,053	117.1	77,090	159.5	12,939	66.2	22,076	......	......
1877	43,101.16	1,724,046	26.00	910	282.7	128,291	1,241.9	86,973	326.1	58,999	......	......
1878	41,148.40	1,645.935	7.09	142	362.8	53,776	582.0	35,220	111.2	21,930	......	......
1879	60,213.14	2,408,526	34.50	872	1,061.8	160,983	......	......	40.8	9,094	......	......
1880	84,284.11	3,372,740	70.18	2,445	585.0	75,884	114.2	3,455	78.3	14,640	6.6	$30.305
1881	37,560.13	1,593,395	18.12	362	250.2	69,724	275.4	19,100	5.7	3,299	14.1	129,173
1882	96,631.70	3,909,852	35.42	1,399	127.8	20,613	21.7	2,740	4.5	13,533	5.4	45,303
1883	76,681.42	3,074,842	2,636.24	94,903	91.5	43,919	32.8	6,500	363.8	307,466	.5	5,433
1884	66,465.60	2,989,355	94.34	3,000	80.8	6,609	58.1	16,654	5.2	1,980	......	......
1885	155,616,59	6,768,902	297.80	9,248	81.3	5,687	......	......	229.2	27,158	.7	6,780
1886	154,545.56	6,566,715	129.00	3,870	39.6	2,773	5.4	651	76.6	9,189	......	......
1887	193,736.96	8,291,920	55.90	1,677	19.0	1,766	......	......	215.4	22,955	96.6	120,721
1888	182,672.85	7.723.957	330.23	9,907	18.8	1,316	......	......	248.2	62,039	140.1	175,186
1889	123,695.60	4,906,791	......	......	296.7	61,564	782.0	117,300	669.6	179,924	39.0	48,778
1890	101,925.20	4,335,219	......	382,109					1,676.3	926,374		
1891	115,630.38	4,506,771	......	250,512	......	......	126.0	74,238	618.0	174,289	132.0	166,023
1892	138,845.38	5,017,390	1,147.88	311,535	......	......	......	......	920.1	......	......	......
1893	......	......	......	......	......	......	......	......	......	......	......	......

MINERAL EXPORTS OF CHILE SINCE 1874.

Year.	Borax.		Calcium Borate.		Iodine.		Manganese Ores.		Nitrate.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1874	180.0	$27,010	273.4	$29,529	......	......	......	......	......	......
1875	248.1	54,375	11.9	719	......	......	......	......	......	......
1876	......	......	46.8	3,347	......	......	......	......	......	......
1877	......	......	......	......	......	......	......	......	......	......
1878	......	......	0.6	120	......	......	......	......	741.5	$40,262
1879	......	......	679.9	135,984	77.35	$1,160,205	......	......	59,344.1	4,747,529
1880	......	......	644.9	128,982	83.86	1,236,981	......	......	226,090.3	15,425,558
1881	......	......	3,140.5	628,097	200.06	2,953,628	......	......	358,105.9	22,891,786
1882	......	......	4,311.9	862,379	263.98	3,963,240	......	......	489,346.5	28,698,364
1883	1,497.6	299,527	1,559.7	124,780	220.92	2,987,491	......	......	584,798.4	32,043,572
1884	842.4	168,480	1,367.7	70,386	218.19	2,181,947	4,324.0	$21,620	559,646.3	25,163,038
1885	94.5	14,174	1,868.6	93,431	256.80	2,567,960	8,160.2	57,247	429,662.5	20,654,122
1886	1,519.7	227,960	200.4	10,020	175.68	1,756,860	24,375.7	243,757	452,788.3	19,230,047
1887	3,053.3	457,980	1,453.2	72,680	77.20	771,960	47,504.4	475,044	712,767.8	28,690,970
1888	538.3	80,742	1,131.6	56,578	91.37	913,750	17,947.1	179,471	784.249.8	33,866,196
1889	......	......	3,670.2	183,509	201.39	2,013,950	26,452.9	264,529	921.388.0	36,387,210
1890	37.0	5.161	3,536.1	176,809	419.74	4,197,420	50.997.5	509,975	1,025,617.1	36,925,414
1891	815.0	106,969	6,463.0	318,080	424.02	4,240,190	36,183.0	356,106	891,727.1	32,418,491
1892	......	......	......	......	......	......	......	......	804,213	......
1893	......	......	......	......	......	......	......	......	943,570	......

MINERAL EXPORTS OF CHILE SINCE 1844.—*Continued.*

Year.	Coal.		Cobalt Ores.		Copper Bars.		Copper Matte. (*b*)		Copper Matte, Argentiferous. (*c*)	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1870..	40,538	228,318	15.3	1,909	24,261.3	8,067,178	36,138.8	4,250,898	2,305.2	346,185
1871..	66,267	350,653	85.7	21,431	19,824.3	5,947,283	33,634.6	4,612,900	4,807.5	1,640,068
1872..	63,565	527,623	83.3	9,452	27,097.8	8,129,325	27,071.4	2,362,297	6,466.7	3,060,803
1873..	27,695	276,441	250.4	23,116	27,456.7	8,310,377	22,110.9	3,316,811	3,145.4	831,181
1874..	42,468	411,209	685.4	56,290	33,372.5	8,143,661	23,205.9	3,543,761	4,061.8	860,473
1875..	37,831	244,713	183.0	9,243	35,594.3	10,950,504	17,396.9	3,018,149	3,127.9	702,331
1876 .	46,280	326,526	92.5	15,322	41,766.2	16,079,969	14,632.6	2,519,741	4,862.5	1,130,790
1877..	102,250	487,709	171.2	20,930	35,128.2	11,767,955	10,763.4	1,270,788	3,517.4	747,645
1878..	104,478	649,183	167.9	16,366	40,894.6	13,026,285	11,750.8	1,435,267	2,888.0	478,756
1879..	72,308	578,464	92.3	7,649	39,176.6	14,456,061	10,296.6	1,369,759	4,145.7	749,797
1880..	59,273	404,872	76.8	11,517	32,542.2	13,912,631	9,382.6	1,431,314	3,062.4	747,519
1881..	92,746	631,121	105.7	21,148	32,837.3	13,606,798	10,208.1	1,808,526	2,609.1	720,899
1882..	111,232	741,027	75.4	13,538	36,726.1	14,778,333	12,263.8	2,066,649	3,209.8	688,638
1883..	148,632	975,000	111.7	6,704	34,822.6	13,682,290	5,755.5	807,392	4,197.3	780,338
1884..	140,426	1,151,916	67.7	5,419	35,890.0	11,231,006	9,946.9	1,223,033	4,973.0	990,805
1885..	111,922	736,066	216.8	13,185	36,071.4	9,424,174	3,476.6	382,424	3,174.5	634,891
1886..	129,855	779,130	122.2	7,332	34,915.0	8,186,426	2,527.5	278,033	2,423.3	561,059
1887..	153,255	919,530	215.5	12,928	26,733.1	6,993,137	3,988.5	478,615	1,999.4	499,851
1888..	128,236	1,314,259	25.0	3,745	31,336.0	13,878,439	2,283.3	456,668	1,905.6	762,251
1889..	146,208	1,315,872	....	....	20,145.7	5,689,329	4,566.9	456,695	2,727.6	818,277
1890..	194,676	1,674,394	....	....	24,287.8	8,543,469	1,420.0	220,619	2,499.1	879,977
1891..	....	2,053,988	....	....	17,464.0	4,872,964	2,838.0	338,558	1,666.0	681,776
1892..	....	....	....	....	....	....	....	....	*f*1,531·3	301,239
1893..	....	....	....	....	....	....	....	....	....	....

Year.	Copper Ores. (*d*)		Copper, Silver Ores. (*e*)		Gold.		Gold Ores.		Gold and Silver Ores.		Guano.	
	Tons.	Value.	Tons.	Value.	Kilos.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1844 .	9,459.1	$376,420	......	....	217.22	$116,367	......	....	......	....	937.7	$12,536
1845..	6,752.4	269,665	......	....	376.72	218,875	......	....	......	....	4,708.7	93,663
1846..	9,865.8	381,260	......	....	371.40	217,944	......	....	......	....	2,202.7	24,534
1847..	4,350.5	166,485	......	....	258.18	301,415	......	....	......	....	216.7	2,356
1848..	4,104.6	173,290	......	....	545.45	296,440	......	....	......	....	880.8	10,379
1849..	3,536.6	118,492	......	....	484.05	263,070	......	....	......	....	1,255.4	13,645
1850..	2,382.9	90,211	9.2	$351	64.34	35,343	......	....	......	....	3,479.2	37,708
1851..	2,775.6	106,195	......	....	551.54	299,753	......	....	......	....	3,744.6	55,392
1852..	10,429.8	366,322	1,399.4	49,107	......	....	......	....	......	....	5,066.7	82,609
1853..	20,912.2	685,507	1,480.6	63,743	10.81	6,006	......	....	......	....	1,792.4	24,174
1854..	20,471.9	881,983	88.9	5,963	4.74	2,640	......	....	......	....	1,625.4	26,502
1855..	25,765.5	1,355,489	465.0	97,156	1.44	781	......	....	......	....	722.8	15,714
1856..	28,978.7	1,841,936	490.9	313,470	9.20	5,072	......	....	......	....	1,118.5	18,237
1857..	30,417.3	1,953,600	90.1	63,915	2.87	1,600	......	....	......	....	432.1	9,394
1858..	40,912.2	2,718,931	474.9	115,420	58.91	35,229	......	....	......	....	1,253.4	27,248
1859.	31,963.5	3,413,268	124.3	81,075	......	....	......	....	......	....	366.3	7,964
1860..	55,032.7	4,387,781	58.7	42,430	19.97	12,256	......	....	......	....	....	....
1861..	37,247.7	1,923,600	41.9	6,377	7.96	4,490	......	....	......	....	....	....
1862..	36,359.2	2,196,369	178.2	27,118	53.19	29,600	......	....	......	....	75.8	1,237
1863..	30,783.5	1,853,723	73.3	10,842	73.78	40,565	......	....	......	....	2,967.0	59,333
1864..	18,468.6	1,268,588	159.9	22,037	35.75	18,802	......	....	......	....	....	....
1865..	20,637.3	1,268,276	131.4	19,717	33.39	18,029	......	....	......	....	....	....
1866..	18,265.6	963,648	102.4	6,292	4.30	2,325	......	....	......	....	....	....
1867..	13,476.5	739,186	......	....	7.17	3,858	......	....	......	....	....	....
1868..	5,588.4	286,660	51.6	3,375	......	....	......	....	......	....	217.9	4,359
1869..	10,282.9	596,122	......	....	......	....	......	....	......	....	....	....
1870..	3,462.1	208,064	177.8	17,087	0.30	445	......	....	17.48	$3,097	....	....
1871..	1,950.5	115,083	226.9	50,446	......	....	......	....	......	....	....	....
1872..	24,461.8	1,698,727	128.2	8,689	146.11	81,823	45.2	$1,358	9.77	880	....	....
1873 .	9,484.6	431,221	1,194.9	51,789	......	....	2.9	89	.52	46	....	....
1874..	5,865.5	315,603	201.6	17,059	......	....	......	....	134.12	12,034	....	....
1875..	8,696.3	410,552	488.8	46,544	8.89	4,436	......	....	13.01	566	....	....
1876..	3,931.0	284,609	54.6	6,687	52.17	46,211	......	....	9.86	1,973	....	....
1877..	6,813.3	346,589	56.1	8,740	20.13	20,131	......	....	9.08	7,111	....	....
1878..	1,411.1	64,588	268.9	23,265	21.00	21,000	......	....	......	....	....	....
1879..	81.1	7,573	53.1	8,560	22.86	22,856	......	....	......	....	9,254.0	416,431
1880..	3,933.0	137,215	184.7	28,386	21.39	21,393	......	....	......	....	23,555.2	824,225
1881..	3,517.8	223,586	30.8	2,210	35.42	35,416	......	....	4.45	834	51,563.2	1,792,411
1882..	3,031.1	190,922	161.4	18,067	25.93	22,796	......	....	......	....	33,814.5	1,014,437
1883..	1,222.6	77,335	92.2	8,860	69.83	52,220	......	....	.05	100	175,430.3	5,262,910
1884..	5,576.5	203,500	387.2	25,640	117.59	96,655	......	....	......	....	37,762.5	1,132,874
1885..	1,577.1	80,930	551.4	63,352	100.97	100,970	......	....	177.05	31,748	11,651.5	349,545
1886..	267.9	13,398	132.9	13,289	241.87	193,498	90.3	17,707	177.60	26,641	70,988.0	2,129,642
1887..	621.6	34,079	261.5	26,148	463.08	370,463	3,436.6	1,148,899	9.35	1,869	1,282.0	38,462
1888..	1,647.3	131,782	116.5	16,473	935.75	748,596	3,795.5	1,213,834	1.68	385	51,167.9	1,535,035
1889..	4,463.0	178,522	} 462.7	42,768	{ 415.38	332,301	1,465.5	515,820	2,365.90	591,483	83,009.7	2,429,991
1890..	1,175.9	68,794			665.17	531,945	1,818.2	418,200	1,230.90	275,555	41,323.4	1,237,003
1891..	5,860.0	203,403	47.0	4,694	599.00	479.789	288.0	69,142	87. 0	65.343	....	....
1892..	....	....	92.5	11,197	954.55	783,638	97.0	19,010	*f*2.73	961	....	....
1893..	....	....	....	....	....	....	......	....	....	....	....	....

(*b*) 50% copper. (*c*) 50% copper; 0.53% silver. (*d*) 20% copper. (*e*) 15% copper; 0.63% silver. (*f*) Copper, silver, and gold matte, 188,1 tons, $40,037, and copper, silver, and gold ore, 219.1 tons, $26,356, were also exported during 1892.

Mr. Courtenay de Kalb furnishes the following information concerning the nitrate deposits of Chile. The output of nitrate of soda in Chile, which is almost exclusively controlled by the nitrate combination, amounted in 1893 to 20,506,639 Spanish quintals (1 Sp. qu. = 101.44 lbs. avoirdupois). There has been a very general complaint in Chile against the methods of the nitrate combination, and it is pointed out that the production per laborer employed has never been so small before, averaging 1293 quintals per workman, as against a maximum of 2162 quintals per workman in 1886. This is due in part to the fact that the grade of the deposits is becoming poorer, but it is charged that no improvements in the methods of mining and treatment have been introduced in ten or twelve years. The present cost of production of nitrate is thus analyzed by Alejandro Bertrand, Chilean Minister of Hacienda.

Cost of 1 quintal, in place	2.4c.@17.2c.
" " extraction and treatment	32.0c.@44.6c.
Shipment to the coast	13.6c.@19.5c.
Loading on shipboard and brokerage	0.4c.@ 3.1c.
Export duty	55.94c.@55.94c.
Total	104.34c.@140.34c.

The distribution of the total shipments of nitrate in 1892 was as follows: Germany, 38.5% ; France, 21.2% ; England, 13.2% ; Belgium, 11.6% ; United States, 9.1% ; Holland, 5.4% ; Italy, 1.0%.

The total exports of nitrates since 1830 are shown in the following table :

EXPORTS OF NITRATES FROM PERU AND CHILE.

Year.	Metric Tons.	Year.	Metric Tons.	No. of Workmen.	London Price per Ton.	
					Lowest.	Highest.
1830–34	16,735	1877	231,665			
1835–39	35,247	1878	325,139	...	...	...
1840–44	74,180	1879	146 342	...	...	...
1845–49	95,397	1880	225,417	2,848	$65.36	$74.40
1850–54	150,948	1881	358,287	4,906	57.60	69.20
1855–59	261.049	1882	495,416	7,124	49 20	60.00
1860 64	323,111	1883	593,518	7,077	43.80	49.68
1865–69	490,464	1884	562,592	6,505	44.20	55.40
1869	116,065	1885	438,796	4,571	42.84	55.40
1870	182,546	1886	453,932	4,534	42 40	56.60
1871	166.944	1887	722,787	7,201	44.00	55.28
1872	204 676	1888	784,249	9,180	40.20	44.40
1873	290.000	1889	921,388	11,422	...	...
1874	258,472	1890	1,025,617	...	47.40	47.30
1875	332,917	1891	891,727	13,060	...	...
1876	338,750	1892	804,213	11,657	...	...
		1893	943,570	13,511	...	...

It is interesting to compare with these figures the production of sulphate of ammonia in England, the only dangerous competitor of nitrate of soda.

	Tons.	Price.		Tons.	Price.
1887	113,700	£11 3s. 7d.	1890	134,000	£11 9s. 0d
1888	122,800	11 17 8	1891	143,000	10 15 5
1889	132,000	11 18 0			

Formerly large quantities were shipped to Germany, but the sulphate is now being largely manufactured in that country. It is estimated that the United States, England, and Europe possess at present a productive capacity of 600,000 tons; that is to say, a quantity almost equal in its nitrogen content to the total production of Chilean nitrate of soda. The total production of ammonium sulphate, however, is only about 300,000 tons per annum at the present time.

FRANCE.

The mineral industry of France is but inadequately represented in this volume. We have found here, as elsewhere, the utmost courtesy on the part of officials in their desire to furnish the necessary information, but nevertheless we have been disappointed in securing the full returns of imports, exports, etc., in time for this volume.

The statistics of coal and iron production in France have been kept from the earliest times, and are given here from 1819, but those of other substances are available only from 1873. Unfortunately, the tables here given show many blanks, which, however, will be filled in subsequent editions of this book.

The coal production of France has increased quite steadily though not rapidly during the last twenty years. It has never sufficed for the consumption of the country, an important part of which is supplied from England, Belgium, and Germany. Doubtless the reasons the coal production has not increased more rapidly are that for some years past the wages of workmen have been higher than in Belgium or Germany, and the extras allowed the workmen through benefit funds, house rent, fuel, doctors' fees, and other allowances which custom and the miners' unions have imposed on the French mine owners, and which are equivalent to from 12% to 15% of the wages paid, have been too heavy a charge on the industry. The frequent strikes of the workmen, who, notwithstanding these comparatively large wages, still complain that the increasing cost of living absorbs them all, have rendered the present of the French iron and coal industries far from satisfactory financially, and have thrown a deep shadow over their future.

The iron ore production has remained almost stationary, though quite important during the past score of years. The exports of ore from Algeria to the United States have ceased, never to recommence, owing to the diminishing cost of ore in the United States and to the opening of mines in Cuba to supply the market here, which formerly took some of the French ore. The output of iron pyrites has increased to about 250,000 tons a year, owing to the vast chemical industry which consumes so large an amount of sulphuric acid. The increase in salt production is also due to the growing alkali industry.

The French mineral industry as a whole is only moderately successful, and its increase is chiefly in those branches dependent on domestic consumption, especially in the steel trade, which has found a large market in the heavy purchases on Government account.

MINERAL PRODUCTION OF FRANCE. (*a*) (IN METRIC TONS; 5 francs = $1.)

Year.	Alunite.		Antimony Ore.		Bauxite.		Bituminous Substances. (*b*)		Coal.		Copper Ore.	
1873....	......	......	79	$4,596	650	$1,950	156,107	$196,990	16,974,236	$56.897,728	2,432	$36,426
1874....	1,219	$8,777	177	8.273	1,366	3,278	137,702	198,667	16,428,626	54,708,610	6,008	55,166
1875....	1,219	8,777	223	11,296	1,450	3,480	140,696	188,963	16,504,635	52,980,109	8,698	94,589
1876....	......	......	......	......	......	......	......	......	......	......	......	......
1877....	......	......	......	......	......	......	......	......	......	......	......	......
1878....	......	......	......	......	......	......	......	......	......	......	......	......
1879....	......	......	......	......	......	......	138,431	180,476	16,576,901	43,191,081	......	......
1880....	......	......	......	......	......	......	144,622	204,549	18,804,767	48,255,039	......	......
1881....	......	......	......	......	......	......	179,257	240,175	19,211,963	48,033,393	......	......
1882....	709	5,248	1,073	38,690	......	......	188,064	237,609	20,046,796	49,842,166	7,136	41,727
1883....	285	2,280	1,059	36,152	......	......	147,337	227,522	20,759,429	52,209,150	16,475	138,121
1884....	......	......	......	......	......	......	202,307	280,819	19,527,120	48,296,857	......	......
1885....	......	......	......	......	......	......	198,385	258,312	19.068,548	44,870,809	......	......
1886....	......	......	247	8,892	24,772	45,365	189,742	253,496	19,454,127	43,663,329	167	4,067
1887....	......	......	341	8,745	20,515	32,984	179,207	227,274	20,809,982	44,395,908	11	732
1888....	......	......	789	21,953	19,160	37,746	191,718	263,865	22,172,029	45,825,779	6	288
1889....	......	......	......	......	......	......	......	......	......	......	......	......
1890....	......	......	4,962	161,259	......	......	233,344	311,847	25,591,545	61,365,211	15	541
1891....	......	......	5,316	133,518	......	......	260,626	338,889	......	......	16	1,625
1892....	......	......	......	......	......	......	......	......	......	......	......	......
1893....	......	......	......	......	......	......	......	......	25,249,731	......	......	......

Year.	Iron Ore.		Iron Pyrites.		Lead-Silver Ore.		Lignite.		Manganese Ore.		Peat.		Plumbago.	
1873..	3,051,124	$3,575,735	161,659	$616,299	9,865	$619,919	505,105	$1,175,831	12,378	$160,781	324,092	$742,292	2	$16
1874..	2,516,548	2,974,558	148,768	535,990	10,445	670,055	479,287	1,174,868	11,392	110,675	323,198	733,095	..	....
1875..	2.505,870	2,760.353	131,154	462,300	8,728	644,224	452,205	1,060,128	9,016	93,237	317,748	731,530	..	....
1876..	2,393,340	2,674,505	139,269	456,013	9,330	602,931	......	......	......	......	333,110	874,603	..	....
1877..	2,426,279	2,693,921	149,969	466,782	10,962	650,147	......	......	......	......	310,821	807,580	..	....
1878..	2,469,953	2,542,996	131,046	403,183	10,070	513,264	......	......	......	......	296,241	730,136	..	....
1879..	2,271,173	2,278,628	119,558	366,039	11,517	565,925	534,078	1,074,052	......	......	234,369	544,942	..	....
1880..	2,874,263	2,981,711	132,288	419,059	13,990	645,876	556,797	1,082,989	9,652	......	248,122	550,967	..	....
1881..	3,032,070	3,034,347	160,030	499,312	12,316	585,520	554,020	1,124,922	13,708	......	233,521	513,892	..	....
1882..	3,467,251	3,368,389	180,339	548,140	13,462	656,704	556,908	1,082,334	7,538	48,028	216.633	501,282	..	....
1883..	3,297,853	3,085,258	172.462	562,128	14,568	731,709	574,455	1,140,899	6,573	39,557	201,371	449,990	..	....
1884..	2,976,948	2,565,609	165.583	541,624	11,657	552,119	496,394	1,066,251	4.535	......	196,691	420,378	..	....
1885..	2,318,104	1,789,615	167,984	546,538	11,044	515,944	441,982	908,303	3.424	......	190,196	392,512	..	....
1886..	2,285,648	1,643,806	184,884	539,140	14,672	611,697	455,767	886,511	7,676	53,099	175.311	378,164	..	....
1887..	2,579,465	1,730,862	209.253	653,785	17,436	717,980	477,607	878,497	12,124	50,501	204,798	498,815	..	....
1888..	2,841,757	1,894,216	203,814	614,381	19,419	842,796	430,865	773,299	11,048	60,757	159,658	351,227	15	228
1889..	3,070,389	2,084,198	201,490	585,882	21,306	886,248	......	......	......	......	147,826	314,015	..	....
1890..	3,471,718	2,477,079	229,661	655,922	25,787	1,057,679	491,573	917,290	15,984	89,517	157,701	342,317	32	115
1891..	3,579,286	2,557,084	246,827	682,412	25,897	946,324	......	......	15,343	90,316	168,365	387,454	18	47
1892..	......	......	......	......	......	......	......	......	......	......	......	......	..	....
1893..	......	......	......	......	......	......	488,342	......	......	......	......	......	..	....

Year.	Salt, Rock.		Salt, Sea.		Sulphur Ore. (*c*)		Tin Ore.		Zinc Ore.		Aluminum.		Antimony.	
1873..	206,460	$1,219,476	420,716	$1,058,005	5,007	$13,651	901	$20,040	1,279	$19,649	1.068	$21.360	....	......
1874..	228,721	1,355,677	427,428	1,269,831	4,318	11,614	1,200	26,280	3,848	57,446	1.430	28,600	....	......
1875..	231,642	962,571	442,783	977,046	4,900	14,122	1,000	21,600	4,088	59,507	0.920	18,400	....	......
1876..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1877..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1878..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1879..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1880..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1881..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1882..	298,465	2,039,763	468,161	1,489,404	649	2,597	....	......	8,372	59,535	......	......	....	......
1883..	32,423	2,016,043	41,912	1,632,999	1,469	5,012	....	......	*d*7,156	53,832	......	......	....	......
1884..	......	......	......	......	......	......	....	......	3,120	17,936	......	......	....	......
1885..	......	......	......	......	......	......	....	......	5,078	65,432	......	......	....	......
1886..	311,677	1,103,033	351,766	1,260,425	4,776	19,102	....	......	11,103	136,079	......	......	....	......
1887..	519,060	1,476,809	304,850	924,309	4,274	14,105	....	......	13,321	139,059	......	......	....	......
1888..	464,205	1,680,124	167,343	717,475	3,065	10,114	....	......	20,702	296,554	......	......	....	......
1889..	......	......	......	......	......	......	....	......	34,290	719,979	......	......	....	......
1890..	490,819	1,783,366	351,710	1,699,898	4,285	13,535	....	......	47,540	950,619	37	136,000	843	$212,880
1891..	502,110	1,542,418	308,565	1,285,359	6,749	20,072	....	......	56,338	1,285,504	36	85,520	880	177,153
1892..	......	......	......	......	......	......	....	......	......	......	......	......	....	......
1893..	......	......	......	......	......	......	....	......	......	......	......	......	....	......

(*a*) From *Statistique de l'Industrie Minérale*, *Annuaire Statistique de la France*, and British Statistical Abstracts. (*b*) Under this head are included pure bitumen, bituminous schist, bituminous sand, asphaltic limestone, and boghead. (*c*) Native sulphur or limestone impregnated with sulphur. (*d*) Includes tin ore. (*e*) There were also produced in 1873, copper and brass, 5846 tons, $2,926,300; brass, 6070 tons, $2,599,502; in 1874, copper and brass, 5705 tons, $2,782,621; brass, 5928 tons, $2,510,026; copper and silver matte, 188 tons, $35,798; in 1875, copper and brass, 5886 tons, $2,801,663; brass, 6500 tons, $2,766,102; argentiferous copper matte, 222 tons, $43,063; in 1890, silicium, 124 kilos, $446. (*f*) Does not include 27,372 tons imported to be desilverized, the silver of which is included in the silver production.

THE MINERAL PRODUCTION OF FRANCE—*Continued.*

Year.	Bitumen and Mineral Oil.		Copper. (*e*)		Gold, Kilos.		Iron, Pig.		Iron, Wrought.		Steel.	
1873..	15,353	$304,104	9,721	$5,010,349	875	$600,115	1,381,626	$38,057,734	760,930	$48,137,646	150,529	$12,700,765
1874..	14,747	313,439	11,264	5,691,769	850	582,680	1,415,807	33,744,556	742,131	40,325,331	208,787	14,878,092
1875..	17,509	307,274	11,478	5,547,628	959	657,520	1,448,272	31,278,305	745,753	37,408,770	256,393	16,244,588
1876..	....	....	......	....	....	....	1,435,212	28,311,061	837,112	....	241,844	....
1877..	....	....	......	....	....	....	1,506,827	28,575,917	884,493	....	269,181	....
1878..	....	....	......	....	....	....	1,521,274	26,690,287	843,112	....	312,921	....
1879..	....	....	......	....	....	....	1,400,286	23,943,227	857,071	37,536,176	333,265	19,681,236
1880..	....	....	......	....	....	....	1,725,293	32,093,812	965,761	44,512,880	388,894	22,381,017
1881..	....	....	......	....	....	....	1,886,350	34,493,852	1,026,290	46,731,662	422,416	23,701,602
1882..	....	....	......	....	....	....	2,039,067	37,127,253	1,073,021	49,518,911	458,238	25,719,512
1883..	....	....	......	....	....	....	2,069,430	33,676,849	978,917	42,988,394	521,820	27,134,513
1884..	.......,	....	......	....	....	....	1,871,537	27,965,179	876,751	34,539,942	502,908	24,482,387
1885..	....	....	......	....	....	....	1,630,648	20,136,733	782,431	26,537,408	553,839	24,460,663
1886..	....	....	......	....	....	....	1,516,574	16,743,200	766,556	23,622,904	427,589	20,530,341
1887..	....	....	......	....	....	....	1,567,622	17,932,589	771,610	23,561,637	493,294	23,573,131
1888..	....	....	......	....	....	....	1,683,349	19,137,161	816,973	24,646,282	517,294	23,422,385
1889..	....	....	......	....	....	....	1,734,000	21,301,600	....	....	....	....
1890..	20,632	316,966	2,306	721,280	200	128,000	1,962,196	27,523,973	825,369	29,593,160	581,998	30,152,391
1891..	26,790	417,233	2,125	635,471	220	140,800	1,897,387	24.827,169	833,409	29,546,616	638.530	33,497,528
1892..	....	....	......	....	....	....	2,057,258	....	828,519	....	825,486	....
1893..	....	....	......	....	....	....	2,032,567	....	829,951	....	803,063	....

Year.	Lead.		Litharge.		Nickel.		Silver, Kilos.		Zinc.	
1873......	20,607	$2,216,913	180	$17,480	26	$76,650	32,591	$1,418,992	12,627	$1,749,118
1874......	26,982	2,839,982	181	15,566	37	59,200	48,914	2,030,967	12,783	1,320,417
1875......	28,271	2,920,479	192	16,512	4.6	7,339	49,735	1,957,382	13,739	1,908,303
1876......	....	....	......	....	....	....	....	....	....	....
1877......	....	....	......	....	....	....	....	....	....	....
1878......	....	....	......	....	....	....	....	....	....	....
1879......	....	....	......	....	....	....	....	....	....	....
1880......	....	....	......	....	....	....	40,370	....	....	....
1881......	....	....	......	....	....	....	54,710	....	....	....
1882......	....	....	......	....	....	....	66.940	....	....	....
1883......	....	....	......	....	....	....	48,490	....	....	....
1884......	....	....	......	....	....	....	52,680	....	....	....
1885......	....	....	......	....	....	....	50,820	....	....	....
1886......	....	....	......	....	....	....	46,780	....	....	....
1887......	....	....	......	....	....	....	....	....	....	....
1888......	....	....	......	....	....	....	....	....	....	....
1889......	....	....	......	....	....	....	....	....	....	....
1890......	*f*4,544	307,731	43	2,838	330	333,000	71,117	2,275,744	19,372	1,977,211
1891......	6,680	417,116	63	3,906	330	336,000	71,303	2,281,696	20,596	2,070,333
1892......	....	....	......	....	....	....	....	....	....	....
1893......	....	....	......	....	....	....	....	....	....	....

IRON AND STEEL PRODUCTION OF FRANCE FROM 1819 TO 1872. (IN METRIC TONS.)

Y'r.	Pig.	Wr'ght	Steel.	Y'r.	Pig.	Wr'ght	Steel.	Y'r.	Pig.	Wr'ght	Steel.	Y'r.	Pig.	Wr'ght	Steel.
1819	112,500	74,200	......	1833	236,099	152,265	6,544	1847	591,590	376,687	12,670	1861	966,894	631,177	37,776
1820	....	....	......	1834	269,063	177,163	6,648	1848	472,442	276,253	7,130	1862	1,090,837	734,257	47,095
1821	....	....	......	1835	294,799	209,538	6,579	1849	414,195	243,453	9,293	1863	1,156,875	770,244	37,483
1822	110,781	86,154	......	1836	308,363	210,580	5,319	1850	405,653	246,196	10,981	1864	1,212,750	792,058	41,559
1823	....	....	......	1837	331,678	224,613	6,523	1851	445,808	254,167	14,040	1865	1,203,710	769,240	40,574
1824	197.599	141,690	......	1838	347,776	234,195	7,148	1852	522,643	301,758	18,097	1866	1,260,348	819,383	37,764
1825	198,566	143,548	......	1839	350,171	231,760	7,215	1853	660,933	450,989	22,552	1867	1,229,044	776.278	46.467
1826	205,843	145,519	4,914	1840	347,773	237,378	8,262	1854	771,069	511,135	23,959	1868	1,235,307	813,728	80,564
1827	216,421	148,853	......	1841	377,141	263,747	7,848	1855	849,296	557,217	21,974	1869	1,380,965	903,719	110,227
1828	220,917	151,387	......	1842	399,455	284,823	8,133	1856	923,147	568,669	19,019	1870	1,178,113	830,785	94,386
1829	217,124	153,623	......	1843	422,621	308,445	9,961	1857	992,332	559,959	25.625	1871	859,641	677,410	86.125
1830	266,360	148,468	......	1844	427,175	315,012	15,994	1858	871.556	530,101	23,279	1872	1,217,838	883,348	141,704
1831	224,805	141,057	5,537	1845	438,969	342,261	12,373	1859	864,399	533,381	23,123				
1832	225,035	143,488	5,229	1846	522,385	360,190	12,954	1860	893,353	532,211	29,848				

GERMANY.

THE mineral and metallurgical production of Germany has been remarkably free from any violent fluctuations in either output or prices; but it has shown a steady growth which, as in the case of Prussia, reflects fairly the solid and conservative business methods of the German people. In the majority of cases the production during 1893 fell below that of 1892, the total valuation in the latter year being $314,602,698, as against $297,165,732 in 1893, a decline of $17,436,966, or about 5%. The mineral production alone during 1892 was valued at $168,324,104, as against $167,581,676 in 1893, showing a decline in values during the latter year of less than half of one per cent. During the same period the tonnage produced increased from 107,884,365 metric tons in 1892 to 110,932,873 metric tons in 1893, a gain of over 2%.

The greatest increase in output was in kainit and other potash salts, of which the output in 1893 reached 1,526,148 tons, valued at $6,159,834. This magnificent industry may be said to have commenced only in 1877. In coal there was an increase in output from 71,372,193 tons in 1892 to 73,908,990 tons in 1893, but the value of the product declined from $131,744,794 in the former year to $124,616,605 in the latter. The production of iron ore decreased slightly during 1893, as also did imports of this material, but the exports increased a little. In pig iron the latest figures show a very small increase in both production and imports, and a decrease in exports, indicating a larger consumption. The production of copper ore increased 17,137 tons during 1893, but the value of the product declined from $5,128,386 to $4,530,683. In 1862 the production of lignite amounted to 5,084,399 tons, valued at $3,527,522. In 1893 this had increased to 21,567,218 tons, valued at $13,750,754, which is nearly $1,000,000 less than the value of the preceding year's output, which was slightly less in tons.

In Germany a greater advance has been made than in any other country in utilizing the by-products from various industrial operations. One of the most important of these has been the utilization of the waste gases from coke ovens. There are now about 3000 of the improved ovens in operation, each taking 6½ tons of coal every forty-eight hours, and producing about 76% of coke. In addition there is yielded 1.15% to 1.25% sulphate of ammonia, and from 2.5% to 4% tar. In the Ruhr district 51,300 tons of coke are produced in these ovens, the coal yielding on an average, per ton, 1672 lbs. of coke, 60.5 lbs. tar, and 25.3 lbs. sulphate of ammonia. In Silesia 48,000 tons are produced annually, the coal yielding 1496 lbs. coke, 93.5 lbs. tar, and 26.4 lbs. sulphate of ammonia per ton. The district of Saar produces 40,500 tons of this coke, the coal yielding per ton 1540 lbs. coke, 91.3 lbs. tar, and 18.7 lbs. sulphate of ammonia per ton. In Silesia the approximate gross value of these products is: For the tar, $30,000, and for the sulphate of ammonia $46,200, a total of $76,000 in addition to the value of the coke. To this may be added the fuel saved over and above the amount required for the actual coking process, amounting to 16,000 cubic feet of gas per oven. This, if estimated at its full value, is equivalent to nearly 9000 tons of coal per day. The average first cost of the ovens and plant is, of course, considerably greater than the ordinary bee-hive oven, varying from $1200 to $1800 each, but the cost in the United States for ovens having these advantages is estimated at less than half these figures.

It is largely because of the economies observed in such processes that the mineral industry in Germany has enjoyed so steady a progress, and they are unquestionably the reason why, in spite of the steady decline in selling price, the German exporters have been able to increase their trade, forcing their goods into markets hitherto controlled by Great Britain.

MINERAL PRODUCTION OF GERMANY AND LUXEMBURG *(IN METRIC TONS.) (4 marks=$1.)

Year.	Antimony Ore.		Arsenic Ore.		Asphaltum.		Boracite.		Coal.		Cobalt, Nickel & Bismuth Ore.		Copper Ore.	
	T.	Value.	T.	Value.	Tons.	Value.	T.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1862	188	$8.565	1,681	$16,430	520	$4,725	....	....	15,576,278	$20,774,474	1,453	$99,758	123,847	$728,903
1863	262	7,717	1,964	17,543	515	4,721	....	....	17,906,708	21,367,168	1,788	123,274	140,579	827,254
1864	181	5,712	2,216	16,725	595	5,993	....	....	19,408,982	25,139,310	1,629	111,088	156,139	902,389
1865	146	4,005	1,925	14,731	803	7,591	....	....	21,794,706	30,132,273	1,220	80,267	151,636	917,098
1866	80	2,012	2,090	12,986	675	5,595	....	....	21,629,746	31,807,528	394	73,690	162,791	1,004,029
1867	44	1,105	1,845	10,574	....	....	....	....	23,808,072	34,353,550	655	80,276	178,850	988,908
1868	55	1,412	1,639	11,286	....	....	....	....	25,704,758	36,447,772	308	56,553	201,691	1,262,385
1869	23	583	1,312	12,152	....	....	....	....	26,774,368	38,946,302	267	55,650	217,416	1,281,584
1870	15	344	1,126	15,499	....	....	....	....	26,397,769	40,884,270	260	60,279	207,381	1,214,953
1871	11	249	484	3,670	....	....	....	....	29,373,272	54,587,824	272	180,676	217,160	1,373,947
1872	18	541	744	1,579	6,017	17,401	....	....	33,306,418	74,167,125	452	165,099	282,192	1,766,657
1873	22	1,080	3,520	9,144	22,678	58,175	....	....	36,392,280	100,911,324	526	164,612	292,138	1,853,375
1874	13	596	2,419	6,504	31,147	105,557	....	....	35,918,614	96,795,723	1,068	179,048	262,498	1,621,233
1875	33	2,356	2,568	23,030	30,586	78,927	....	....	37,436,368	74,371,159	1,715	136,164	279,122	1,708,682
1876	43	2,895	1,670	12,569	35,988	76,546	....	....	38,454,428	65,919,569	1,563	147,086	304,502	1,781,235
1877	162	12,139	1,134	7,916	39,735	173,110	38	4,556	37,529,549	54,243,101	498	120,478	343,541	1,933,610
1878	189	10,414	2,031	12,507	47,329	179,806	52	4,105	39,589,778	51,978,922	264	125,529	373,539	2,141,392
1879	72	4,655	640	15,682	45,430	98,654	104	9,012	42,025,687	51,425,687	406	130,444	398,828	2,518,456
1880	96	5,173	727	10,784	50,072	112,415	99	12,081	46,973,566	61,416,229	424	117,822	480,853	2,998,892
1881	77	4,175	867	11,357	42,330	89,184	124	21,412	48,688,161	63,062,962	266	126,938	523,697	3,582,474
1882	75	1,998	480	7,171	37,120	63,107	118	22,627	52,118,595	66,964,844	323	137,646	566,509	3,680,150
1883	37	1,129	275	3,966	42,930	65,185	199	26,987	55,943,004	73,407,112	399	138,464	613,211	4,017,330
1884	25	1,136	1,240	20,431	41,139	57,913	166	27,781	57,233,875	74,695,048	476	132,897	593,330	4,536,724
1885	5	393	1,824	28,996	45,412	64,037	140	16,782	58,320,398	75,735,539	617	134,092	621,381	4,813,628
1886	2	176	1,140	16,513	42,894	54,018	144	13,043	58,056,598	75,181,924	344	121,385	495,756	3,603,835
1887	2	170	323	4,972	34,483	46,531	153	15,267	60,333,984	77,769,327	319	135,868	507,587	3,637,928
1888	2	110	1,521	20,484	41,534	63,812	180	14,367	65,386,120	85,265,832	339	145,269	530,956	4,379,758
1889	1	62	2,668	30,855	43,496	87,311	121	9,059	67,342,171	96,269,970	793	125,059	573,290	4,549,752
1890	1	75	2,655	32,058	51,144	94,497	182	13,710	70,237,808	134,511,033	976	159,338	596,100	5,041,683
1891	1	41	3,124	32,563	49,150	93,928	177	12,660	73,715,653	147,379,551	1,074	159,328	587,626	5,216,192
1892	...	....	2,146	19,491	53,279	104,713	179	13,614	71,372,193	131,744,794	3,185	198,208	567,738	5,128,386
1893	16	100	2,756	25,363	47,238	89,245	184	11,289	73,908,990	124,616,605	4,370	189,410	584,875	4,530,683

Year.	Epsomite.		Graphite.		Iron Ore.		Iron Pyrites. (*a*)		Other Vitriol & Alum Ores. (*a*)		Kainit. (*a*)	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1862..	....	....	1,009	$18,267	2,216,057	$2,702,406	....	....	43,915	$73,789	....	....
1863..	....	....	804	17,501	2,374,745	2,937,147	....	....	56,613	96,435	....	....
1864..	....	....	1,141	17,143	2,620,020	3,240,899	....	....	53,355	94,834	....	....
1865..	....	....	815	10,863	3,013,313	4,336,825	....	....	55,298	96,348	....	....
1866..	....	....	368	5,250	2,995,971	4,286,078	....	....	74,593	252,230	....	....
1867..	....	....	564	7,944	3,264,463	4,593,383	....	....	96,772	352,309	....	....
1868..	....	....	831	14,116	3,634,368	4,847,070	....	....	116,449	436,462	....	....
1869..	....	....	931	17,040	4,083,707	5,817,368	....	....	95,696	278,322	....	....
1870..	....	....	680	7,040	3,839,223	6,028,349	....	....	120,298	313,883	....	....
1871..	16	$4,410	953	17,010	4,368,075	7,699,701	140,310	$369,439	140,310	369,439	....	....
1872..	25	7,500	894	10,966	5,895,673	10,592,950	152,916	470,679	39,241	46,123	....	....
1873..	17	7,282	995	13,869	6,177,576	10,837,915	131,712	708,930	38,355	61,944	....	....
1874..	18	6,954	753	18,874	5,137,468	7,148,638	131,619	620,733	43,645	64,410	....	....
1875..	31	8,559	1,622	29,506	4,730,353	6,688,366	126,443	653,108	42,219	25,248	....	....
1876..	35	4,990	1,005	25,445	4,711,982	5,905,900	113,703	536,458	35,319	22,026	....	....
1877..	152	359	975	24,378	4,980,048	5,912,029	107,664	402,703	43,149	25,302	31,741	$112,710
1878..	520	1,299	1,255	28,910	5,462,059	6,579,154	101,089	327,414	34,803	25,809	32,742	147,359
1879..	765	1,907	992	28,035	5,869,439	6,673,104	100,537	274,026	20,652	13,794	49,891	173,772
1880..	2,144	4,391	1,450	38,338	7,238,639	8,613,373	112,287	291,038	21,768	11,065	137,425	441,394
1881..	4,625	9,545	1,510	32,921	7,600,800	9,090,154	125,057	319,841	21,018	12,358	160,538	542,184
1882..	8,130	18,078	2,161	52,774	8,263,254	9,795,415	158,419	451,405	23,742	10,953	141,272	508,009
1883..	4,850	10,890	2,945	49,192	8,756,617	9,829,677	149,521	340,071	13,198	10,283	230,071	777,422
1884..	4,917	10,894	1,925	22,925	9,005,796	9,385,779	150,130	325,310	13,813	8,132	203,120	722,401
1885..	4,207	9,409	3,359	40,128	9,157,869	8,478,355	116,212	239,660	7,207	4,889	242,281	929,641
1886..	13,850	28,301	2,906	30,425	8,485,758	7,410,853	113,656	224,795	2,523	1,876	240,421	880,753
1887..	23,235	44,565	2,960	46,585	9,351,106	8,501,318	101,136	192,824	550	1,156	239,412	852,254
1888..	13,269	26,198	3,353	46,925	10,664,308	9,940,280	109,516	212,129	515	1,181	318,576	1,166,666
1889..	10,951	21,237	3,327	43,122	11,002,188	11,617,129	117,366	222,653	696	1,496	324,477	1,181,655
1890..	8,030	17,449	4,355	73,921	11,406,132	11,957,255	122,372	251,939	1,379	1,921	361,827	1,299,939
1891..	7,454	16,314	3,824	73,540	10,657,521	9,852,076	128,288	239,468	2,406	1,517	472,256	1,701,640
1892..	10,207	22,331	4,036	63,240	11,539,033	10,319,938	115,243	215,887	2,973	2,016	548,445	1,955,717
1893..	8,818	17,057	3,140	52,010	11,457,491	9,950,140	121,334	219,427	791	1,199	664,986	2,397,774

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*From *Vierteljahrs und Monatshefte zur Statistik des Deutschen Reichs.* The first official statistics were published in 1874, and embraced all years back to 1862. The production prior to 1872 is that of the States which now form the empire, namely: Preussen (Prussia), Baden, Bayern (Bavaria), Sachsen (Saxony), Würtemberg, Hessen, Mecklenburg-Schwerin, Oldenburg, Braunschweig (Brunswick), Hanover, Waldeck, Schaumburg-Lippe, Anhalt, Thuringen (Sachsen-Weimar, Sachsen-Meinengen, Sachsen-Altenburg, Sachsen-Coburg-Gotha, Schwarzburg-Rudolstadt, Schwarzburg-Sonderhausen, Reuss alt Linie, Reuss jung Linie), Hamburg, Elsass-Lothringen (Alsace-Lorraine). Prior to 1868 Schleswig-Holstein, and to 1869 Mecklenburg, is omitted, Hamburg and Luebeck prior to 1871, and Bremen and Alsace-Lorraine prior to 1872. When any changes have been made in later books we have always taken the corrected figures. The great increase of the sulphur, sulphuric acid, and

MINERAL PRODUCTION OF GERMANY—*Continued.*

Year.	Other Potash Salts. (*b*)		Lead Ore.		Lignite.		Manganese Ore.		Petroleum.		Rock Salt.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1862	18,824	$85,081	150,238	$2,820,397	5,084,399	$3,527,522	18,294	$173,639	....	....	80,253	$297,823
1863	58,743	272,549	161,713	3,274,138	5,459,950	3,795,931	18,242	165,054	....	....	83,078	213,416
1864	116,840	501,796	170,572	3,542,832	6,203,918	4,388,382	20,883	167,216	....	....	81,005	188,244
1865	92,872	232,545	171,627	3,368,965	6,758,057	4,945,928	25,973	238,257	....	....	84,338	181,846
1866	145,024	329,526	168,299	3,600,161	6,533,059	4,712,023	42,162	381,091	....	....	102,619	223,382
1867	153,429	367,171	96,360	3,916,726	6,994,816	5,012,761	60,342	498,914	....	....	117,900	255,236
1868	181,423	448,250	95,286	3,922,517	7,174,365	5,001,630	35,406	375,558	....	....	144,853	271,629
1869	231,615	556,339	101,024	4,173,178	7,569,545	5,262,920	24,845	245,754	....	....	132,921	253,026
1870	291,892	657,041	106,378	4,168,855	7,605,234	5,513,279	14,706	141,194	....	....	112,929	240,436
1871	375,288	839,453	96,866	3,706,502	8,482,838	6,553,161	17,703	179,039	....	....	139,571	279,832
1872	489,491	1,411,226	94,037	3,758,094	9,018,048	7,373,905	24,384	280,187	4,094	$33,349	145,328	303,917
1873	450,954	1,130,489	101,270	4,434,833	9,752,914	8,656,640	22,161	311,477	1,700	38,537	151,953	360,945
1874	429,542	879,887	104,088	4,568,806	10,739,532	9,807,970	16,242	228,079	892	22,099	161,870	345,673
1875	529,539	1,105,044	113,808	5,260,522	10,367,686	9,221,045	16,523	204,479	781	21,878	170,417	328,489
1876	580,897	1,167,436	120,603	5,096,665	11,096,034	9,610,646	11,658	141,183	593	22,869	170,124	303,516
1877	779,975	1,500,375	147,012	5,680,687	10,700,334	8,980,297	7,743	92,888	865	21,049	170,786	286,250
1878	737,470	1,464,681	152,843	5,265,788	10,930,120	8,614,782	6,000	67,506	845	18,166	202,939	340,672
1879	611,781	1,354,619	149,055	4,460,674	11,445,029	8,806,726	6,748	67,866	1,895	38,285	238,160	397,695
1880	528,424	1,254,397	159,725	4,780,454	12,144,469	9,177,503	11,889	119,895	1,309	39,858	272,270	451,284
1881	745,353	1,801,001	164,771	4,810,084	12,852,324	9,530,548	13,642	117,672	4,108	131,446	311,907	490,254
1882	1,060,120	2,410,216	177,655	5,155,235	13,259,616	9,038,892	6,735	66,523	8,158	187,669	322,442	526,974
1883	959,292	2,135,490	169,754	4,522,714	14,499,644	9,751,747	6,488	53,679	3,755	87,895	336,400	522,474
1884	766,076	1,888,805	162,772	3,934,914	14,879,945	9,894,586	9,672	66,996	6,490	137,789	344,797	484,984
1885	678,662	1,852,766	157,869	3,773,304	15,355,117	10,094,458	16,628	104,757	5,815	117,654	377,491	488,806
1886	704,849	1,938,058	158,505	3,979,656	15,625,986	10,055,566	27,050	203,837	10,385	240,386	444,397	537,664
1887	840,691	2,359,260	157,570	3,980,810	15,898,634	10,050,345	38,385	255,731	10,444	233,280	405,520	465,516
1888	916,759	2,561,931	161,777	4,170,963	16,573,963	10,224,096	28,710	167,037	11,920	256,973	414,557	453,937
1889	861 273	2,601,592	169,569	4,432,581	17,631,059	11,087,328	45,167	236,793	9,591	220,290	544,591	563,704
1890	913,030	2,826,199	168,234	4,524,580	19,055,026	12,442,209	41,841	196,379	15,226	310,508	557,060	618,301
1891	898,993	2,771,494	159,215	4,163,988	20,536,625	13,541,457	40,335	202,445	15,315	298,659	666,793	744,754
1892	802,630	2,532,169	163,372	3,671,881	21,171,857	14,626,475	32,861	126,924	14,527	219,941	662,577	708,046
1893	861,162	2,762,060	168,414	3,536,042	21,567,218	13,750,754	40,788	122,987	13,974	195,733	669,042	736,029

MINERAL PRODUCTION OF GERMANY—*Continued.*

Year.	Silver and Gold Ore.		Tin Ore.		Uranium and Wolfram Ore.		Zinc Ore.	
	Tons.	Value.	T.	Value.	T.	Value.	Tons.	Value.
1862	31,504	$828,902	216	$58,193	...	....	333,598	$1,350,811
1863	33,849	876,377	214	58,139	...	....	291,693	1,298,980
1864	34,558	925,977	215	58,807	...	....	313,299	1,763,136
1865	31,072	855,441	156	42,027	...	....	335,348	1,772,073
1866	31,574	976,073	202	39,644	...	....	353,149	1,818,797
1867	31,186	1,099,027	261	54,068	...	....	368,929	2,010,677
1868	27,679	1,178,428	271	60,536	...	....	369,874	1,903,520
1869	25,958	996,281	227	65,514	...	....	405,025	2,144,921
1870	24,818	992,458	243	78,523	...	....	366,780	1,736,572
1871	27,434	1,323,787	242	77,287	6	$185	335,173	1,342,553
1872	24,755	1,280,854	222	74,527	5	128	419,543	2,154,167
1873	22,408	1,179,834	237	78,244	22	615	444,950	3,116,329
1874	24,112	1,187,432	181	28,091	10	1,580	451,222	2,777,196
1875	21,101	1,145,316	186	34,445	4	388	467,953	3,171,245
1876	23,117	1,095,714	185	31,893	12	11,142	533,559	3,251,705
1877	18,796	997,291	196	31,271	24	16,846	577,312	2,785,112
1878	15,446	847,390	137	26,871	30	2,245	597,193	2,855,779
1879	22,314	977,088	147	32,432	29	2,079	589,546	2,012,441
1880	20,578	952,916	200	43,428	38	2,614	632,895	2,982,584
1881	26,787	1,068,859	164	57,573	48	5,809	659,530	2,398,603
1882	22.977	1,082,811	158	54,868	63	9,307	694,711	2.978,018
1883	25,302	1,100,116	139	38,108	57	9,223	677,794	2,222,606
1884	25,186	1,204,740	185	42,825	43	10,084	632,040	1,954,843
1885	24,561	1,070,469	196	47,419	31	9,877	680,654	1,911,852
1886	21,230	1,119,605	131	41,662	48	22,002	705,177	1,930,502
1887	25,726	1,044,430	126	41,250	33	16,549	900,712	2,505,524
1888	20,390	1,017,150	152	45,700	42	9,345	667,761	3,436,753
1889	22,264	1,010,433	120	32,817	45	13,618	708,829	4.422,495
1890	21,360	1,146,000	102	29,267	42	9,274	759,437	5,853,998
1891	22,569	1,151,723	75	22,839	47	10,564	793,544	6,238,384
1892	17,536	910,501	63	23,001	48	11,507	800,237	5,305,324
1893	18,778	773,931	69	18,888	44	10,778	788,394	3,574,162

METALLURGICAL PRODUCTION OF GERMANY.

Year.	Antimony and Alloys. (*c*)		Arsenical Products.		Bismuth. (*d*)		Cadmium.	
	T.	Value.	Tns.	Value.	T	Value.	Kil.	Value.
1862	81	$23,060	338	$17,678	18	$87,863	.....	....
1863	79	16,418	590	34,200	16	77,520	.....	....
1864	77	22,122	588	29,496	13	63,347	113	$312
1865	64	12,450	729	36,806	30	127,500	88	242
1866	60	11,700	748	43,164	26	139,282	500	140
1867	60	11,700	1,001	55,822	25	128,625	500	68
1868	60	11,700	881	60,602	17	131,291	100	12
1869	60	11,700	922	62,534	18	101,033	.....	....
1870	....	....	906	45,311	37	212,760	.....	....
1871	5	1,226	1,318	....	29	164,864	710	5,250
1872	9	2,257	862	59,245	14	67,545	1,480	15,000
1873	4	998	809	59,582	14	62,976	1,070	5,700
1874	....	....	891	72,245	30	76,348	1,260	4,948
1875	....	....	967	86,139	26	67,890	1,920	8,006
1876	....	....	858	82,701	22	62,980	1,780	6,144
1877	93	12,267	843	74,609	32	100,977	2.020	6,049
1878	125	14,353	1,230	84,973	32	116,592	2,490	7,010
1879	150	17,343	1,307	85,275	42	152,228	3,115	7,191
1880	265	44,668	1,131	87,481	47	163,465	3,327	7,564
1881	258	35,079	1,237	96,074	56	199,963	3,367	6,807
1882	181	29,463	1,486	106,207	..	....	3,671	8,634
1883	140	26,469	1,290	101,857	..	....	2,419	5,380
1884	154	28,288	1,601	117,388	..	....	2,768	5,768
1885	156	26,383	1,824	116,527	..	....	3,267	6,394
1886	126	20,226	1,571	106,806	..	....	4,964	9,234
1887	57	14,831	1,755	104,251	..	....	7,310	12,124
1888	83	18,408	1,930	116,508	..	....	4,794	5.714
1889	177	29,445	1,929	126,580	..	....	5,067	4,436
1890	139	31,732	2,167	147,241	..	....	4,157	3,788
1891	198	43,175	1,988	138,626	..	....	2,797	2,468
1892	249	44,931	1,667	109,127	..	....	3,000	2,850
1893	....	....	.....	....	..	....	.....	....

sulphate production in 1881 is only apparent, and is due to the fact that before 1881 in some districts the production of chemical works was not included. Of quicksilver ore were produced from 1862–90, after which no production is reported, 684 tons, $16,178. The output of quicksilver aggregated 6457 kilos, $65,553. Of uranium salts were produced from 1870–81, 81.535 tons, $58,528. The returns for the respective years are 13.5 tons, $169; 437 tons, $3496; 504 tons, $3896; 632 tons, $4665; 713 tons, $5194; 614 tons, $4420; 546 tons, $4129; 594 tons, $4512; 783 tons, $5310; 807 tons, $5982; 1096 tons, $7425; 1414 tons, $9330.

METALLURGICAL PRODUCTION OF GERMANY—*Continued.*

Year.	Cobalt Products. (*d*)		Copper, (*e*) Matte & Black.		Copper, Pig. (*e*)		Gold.		Iron.		Lead, Pig. (*f*)	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Kilos.	Value.	Tons.	Value.	Tons.	Value.
1862	825	$235,810	......	....	2,933	$1,350,938	10	$6,644	696,350	$15,626,251	34,868	$3,123,086
1863	941	281,039	......	....	3,131	1,461,947	46	31,561	812,555	17,867,288	36,764	3,419,402
1864	525	216,707	......	....	3,338	1,578,074	42	28,877	904,658	19,128,725	39,365	3,602,876
1865	366	266,329	......	....	3,414	1,553,566	35.5	24,451	988,191	21,028,137	42,517	3,726,457
1866	472	207,139	......	....	3,690	1,588,303	155	106,343	1,046,954	21,543,690	42,967	3,855,774
1867	447	211,577	......	....	3,672	1,563,728	85	58.769	1,113,606	21,158,466	49,346	4,440,716
1868	473	219,266	......	....	4,303	1,701,662	115	79,507	1,264,347	23,226,533	53,818	4,822,724
1869	511	225,605	......	....	4,552	1,740,293	79	54,611	1,413,029	26,184,781	69,851	5,287,020
1870	455	231,051	......	....	4,797	1,749,695	68	46,695	1,391,123	26,591,183	63,980	5,132,914
1871	497	254,576	581	....	4,626	2,522,360	82	55,883	1,563,682	31,764,272	53,618	5,292,163
1872	624	319,081	1,245	....	6,356	3,142,582	328	223,478	1,988,395	55,585,552	53,549	5,644,485
1873	320	305,061	1,475	....	6,322	2,910,467	315	213,833	2,240,574	62,153,690	60,427	7,098,041
1874	383	316,797	439	....	5,855	2,720,366	365	249,729	1,906,263	40,280,456	65,056	7,239,753
1875	456	348,599	594	....	6,760	3,244,845	332	230,728	2,029,309	36,543,743	65,465	7,574,268
1876	358	290,982	504	....	7,918	3,208,784	281	196,165	1,846,345	28,707,687	71,477	7,826,441
1877	360	393,395	522	$116,053	8,362	3,179,383	308	214,461	1,932,726	27,913,345	76,656	7,456,665
1878	339	364,011	268	36,934	9,323	3,219,048	378	264,084	2,147,641	28,645,564	79,482	6,410,750
1879	363	406,679	560	53,229	10,051	3,053,581	467	325,599	2,226,587	28,088,021	82,362	5,719,216
1880	357	418,992	989	73,363	14,252	4,766,756	463	322,938	2,729,038	40,847,595	85,928	6,353,854
1881	348	419,598	1,079	104,286	15,273	5,046,557	381	265,641	2,913.009	44,993,670	86,729	6,006,923
1882	......	....	886	78,884	16,290	5,656,813	376	262,789	3,380,806	48,977,102	92,591	6,297.897
1883	......	....	545	46,996	17,485	5,945,185	457	319,578	3,469,718	46,245,998	90,732	5,481,875
1884	......	....	300	25,981	18,113	5,470,195	556	387,714	3,600,618	43,159,979	94,809	5,054,490
1885	......	....	343	22,339	19,928	5,043,388	1,378	963,728	3,687,434	40,236,629	93,134	4,853,097
1886	......	....	423	27,005	19,314	4,173,597	1,065	743,584	3,528,658	35,566,527	92,520	5,525,189
1887	......	....	416	43,228	20,192	4,398,798	2,251	1,570,370	4,023,953	41,610,652	94,921	5,623,797
1888	......	....	1,010	88,550	21,017	7,678,588	1,793	1,250,953	4,337,121	47,830,067	96,995	6,211,947
1889	......	....	263	25,267	24,160	6,888,559	1,958	1,366,377	4,524,558	54,342,633	100,601	6,372,531
1890	......	....	793	66,026	24,427	7,220,606	1,855	1,290,417	4,658,451	66,894,961	101,781	6,407,359
1891	......	....	596	46,139	24,092	6,952,884	3,077	2,141,998	4,631,218	58,107,003	95,615	5,816,587
1892	......	....	625	24,630	24,781	6,189,532	3,859	5,683,944	4,937,461	57,324,072	97,742	5,136,861
1893	......	....	......	....	......	....	....	....	....	....	......	....

Year.	Litharge. (*f*)		Manganese and Alloys. (*c*)		Mineral Paints		Nickel Products (*d*)		Selenium.		Silver.		Sulphur.	
	Tons.	Value.	Tons.	Value	Tons.	Value.	Tons.	Value.	Kilos.	Value	Kilos.	Value.	Tons.	Value.
1862	......	....	......	......	......	....	182	$152,434	......	......	63.986	$2,846,079	39	$1,878
1863	......	....	......	......	......	....	280	197,906	......	......	68,256	3,033,921	43	1,788
1864	......	....	......	......	......	....	183	171,559	......	......	74,340	3,317,845	29	1,316
1865	......	....	......	......	......	....	141	183,426	......	......	73,346	3,280,658	19	532
1866	......	....	......	......	......	....	256	163,173	......	......	78,543	3.521,152	25	952
1867	......	....	......	......	......	....	119	141,516	......	......	78,326	3,956,878	19	729
1868	......	....	......	......	......	....	99	136,469	......	......	93,559	4,189,612	....	....
1869	......	....	......	......	......	....	115	168,179	......	......	92,168	4,111,819	19	693
1870	.....	....	......	......	......	....	119	158,732	......	......	92,923	4,162,457	10	422
1871	4,343	....	......	......	......	....	143	245,668	5.500	$405	98,100	4,540,276	8	300
1872	5,492	....	......	......	......	....	226	397,697	......	......	127,007	5,643,559	20	1,025
1873	4,334	....	......	......	......	....	342	585,346	......	......	177,211	7,697,973	2	119
1874	5,019	....	......	......	......	....	243	600,258	......	......	155,852	6,693,337	188	9,105
1875	4,715	....	......	......	... ..	....	326	713,836	......	......	157,218	6,586,421	198	9,787
1876	4,118	....	......	......	......	....	371	683,822	1.200	60	139,779	5,492,354	338	16,523
1877	3,795	$353,266	......	......	344	$15,987	139	271,283	0.350	18	147,612	5,953,014	1,198	47,715
1878	5,046	388,577	600	$615	239	8,543	115	191,946	0.140	7	167,660	6,347,583	734	27,676
1879	4,605	288,338	2,900	3,085	225	8,955	162	202,866	0.250	13	177,507	6,629,531	1,244	46,614
1880	3,923	274,517	1,740	2,035	394	14,437	148	201,727	......	......	186.010	7,151,890	1,541	44,184
1881	4,514	302,686	4,419	4,209	430	16,685	135	218,390	......	......	186,990	7,128,520	2,775	91,802
1882	4,432	293,869	......	......	521	18,447	585	878,109	......	......	214,982	8,190,764	3,624	119,496
1883	5,291	311,834	......	......	564	21,571	533	843,038	......	......	235,063	8,771,974	3,999	130,519
1884	4,919	256,956	......	......	492	19,045	530	766,385	......	......	248,116	9,263,965	4,068	131,532
1885	4,186	214,775	......	......	518	20,368	567	803,035	......	......	309,418	11,034,448	3,484	103,012
1886	3,876	223,954	......	.. ...	660	24,235	600	872,851	......	......	319,598	10,676,887	3,768	104,442
1887	4,446	260,897	......	......	880	28,641	711	974,049	......	......	367,633	12,039,502	2,286	60,525
1888	4,571	290,721	......	......	1,144	38,576	703	928,876	......	......	406,603	12.869,059	2,537	64,051
1889	3,924	255,367	......	......	1.621	52,360	781	1,176,630	......	......	403,037	12,703,182	2,394	63,346
1890	3,972	264,071	......	......	2,112	56,653	934	1,372,069	......	... ..	402,945	14.037,716	1,915	44,810
1891	3,124	197,317	......	......	2,332	61,820	1,062	1,606,200	......	......	444,852	14,749,420	495	9,421
1892	3,468	201,765	......	......	2,629	68,313	1,238	1,713,556	......	......	489,350	14,307,172	668	13,814
1893	......	....	......	......	......	....	......	... .	......	......	....	. . ..	....	....

(*a*) From 1861 to 1870, inclusive, iron pyrites is included with other vitriol ores. (*b*) From 1861 to 1870 kainit is included with other potash salts. (*c*) From 1882 to 1892 manganese is included with antimony. (*d*) From 1882 to 1892 nickel products include bismuth, cobalt, and uranium salts. (*e*) From 1862 to 1870 the production and value of matte and black copper is included with that of copper. From 1871 to 1877 the values only are included. (*f*) From 1862 to 1870 the production and value of litharge is included in that of lead. From 1871 to 1877 the value only is included. (*g*) From 1862 to 1870 the production and value of iron, zinc, nickel, and mixed sulphates is included with that of copper sulphate. From 1871 to 1877 the value only is included.

METALLURGICAL PRODUCTION OF GERMANY—*Continued.*

Year.	Sulphuric Acid.		Sulphate. (g)								Tin.		Zinc.	
			Copper.		Iron.		Zinc & Nickel		Mixed.					
1862	......	....	3,956	$206,750	......	....	......	....	......	....	135	$88,926	59,767	$4,765,649
1863	......	....	4,600	246,095	......	....	......	....	......	....	110	65,868	60,315	4,750,438
1864	......	....	4,758	265,508	......	....	......	....	......	....	119	62,734	59,248	5,419,208
1865	......	....	4,938	291,109	......	....	......	....	......	....	91	43,738	56,490	5,194,743
1866	......	....	5,374	286,552	......	....	......	....	......	....	105	44,367	60,221	5,705,527
1867	......	....	7,139	363,161	......	....	......	....	......	....	136	60,161	63,874	5,995,570
1868	......	....	6,432	347,473	......	....	......	....	......	....	141	66,889	66,132	6,052,898
1869	......	....	6,688	353,366	......	....	......	....	......	....	112	70,574	69,851	6,355,475
1870	......	....	6,572	343,169	......	....	......	....	......	....	135	84,583	63,980	5,354,957
1871	52.136	$1,135,036	2,413	339,093	1,856	....	746	....	113	....	123	82,829	58,297	5,282,696
1872	57,354	1,231,364	2,849	437,392	1,328	....	733	....	348	....	104	79,141	58,386	5,854,157
1873	54,953	1,081,968	3,462	599,339	2,237	....	707	....	554	....	128	84,013	62,755	7,072,365
1874	67.086	1,186,153	4,553	602,561	1,528	....	418	....	876	....	58	30,686	70,426	7,161,880
1875	103,547	1,906,435	4,578	615,727	1,692	....	550	....	1,032	....	85	38,274	74,337	7,721,229
1876	102,625	1,675,011	4,024	519,829	2,361	....	685	....	375	....	184	47,698	83,227	8,703,055
1877	104,797	1,229,077	3,435	345,916	2,556	$36,837	443	$13,709	35	$1,723	88	33,057	94,996	8,453,212
1878	110,753	1,680,092	4,388	388,568	2,709	38,508	327	9,948	21	971	83	26,871	94,953	7,951,628
1879	135,106	1.944,970	4,801	403.768	3,816	50,564	511	15,052	83	3,193	93	34,324	96,756	7,456,223
1880	156,052	2,121,795	4,728	471,684	4,965	64,395	812	21,842	103	4,473	104	44,965	99,646	8,467,684
1881	258,626	3,335,984	4,804	444,284	7,413	.68,949	617	14,211	547	18,523	106	60,795	105,478	7,913,484
1882	286,953	3,576,686	4,663	430,806	6,597	73,437	788	26,047	490	19,268	102	54,365	113,418	8,987,492
1883	297,437	3,594,929	5,132	525,139	6,315	70,026	992	22,182	644	22,527	99	46,837	116,854	8,432,436
1884	345,139	3,696,801	6,040	623,859	6,684	68,727	1,155	23,332	441	17,639	96	40,038	125,276	8,525,624
1885	343,295	3,367,051	5,410	471,566	6,436	65,201	1,130	19,292	359	12,906	107	48,681	129,098	8,465,042
1886	352,723	3,166,579	4,712	337,189	6,531	61,086	1,147	18,001	369	11,955	79	42,877	130,854	8,630,291
1887	382,894	3,181,430	4,797	318,716	8,771	72,337	1,268	20,933	330	10,957	66	36,905	130,494	9,149,352
1888	398,797	3,368,392	4,416	357,604	10,620	82,180	1,494	23,438	258	8,988	84	46,680	133,224	10,905,920
1889	429,739	3,531,244	4,818	504,698	9,176	68,429	2,685	42,055	293	9,365	63	30,096	135,974	12,333,655
1890	464,044	3,820,918	5,854	624,757	8,351	57,401	3,769	60,683	344	11,023	64	30,887	139,266	15,598,177
1891	467,633	4,018,746	3,502	288,938	9,089	68,150	4,117	103,453	298	10,038	287	131,131	139.353	15,639,337
1892	488,047	3,716,014	4,024	281,234	8,670	53,179	4,479	92,372	217	7,684	684	309,973	139,938	13,765,510
1893	......	....	......	....	......	....	......	....	......	....	......	....	......	....

FINISHED PRODUCTS OF GERMAN SALT WORKS.*

Year.	Alum.		Alumin. Sulph. (*a*)		Common Salt.		Glauber Salt. (*a*)		Magnesium Chlor.	
1872......	26	$1,219	....	....	369,221	$2,608,510	922	$12,932	22	....
1873......	2,446	112,575	1,084	$127,500	373,040	2,572,170	10,388	115,061	25	$45
1874......	2,494	114,106	500	21,875	406,607	2,778,168	21,200	351,532	365	3,150
1875......	3,886	177,838	400	18,000	403,448	2,633,644	13,342	217,033	467	4,813
1876......	3,660	154,118	400	18,000	407.760	2,763,621	7,276	101,994	2,366	22,915
1877......	3,952	160.385	443	15,488	413,592	2,778,182	13,403	162,538	7,795	73,476
1878......	3,731	148,376	....	....	404,379	2,724,503	10,481	161,230	8,543	59,625
1879......	3,771	139,857	2,342	80,091	429,051	2,832,050	22,694	342,045	8,949	51,139
1880......	4,708	176,784	12,819	400,528	450,187	2,966,848	46,579	657,156	11,210	57,700
1881......	5.068	185,207	12,837	357,102	456,958	3,075,853	49,062	612,135	11,070	45,880
1882......	3,855	138,543	14,519	381,877	459,499	3,105,677	48,064	666,115	12,446	53,677
1883......	3,620	126,642	18,273	414,254	468,851	3,154,266	47,883	617,168	19,259	73,043
1884......	4,164	141,445	16,679	399,787	464,881	3,078,031	57,243	683.014	12,458	36,098
1885......	3,880	131,241	20,313	470,901	461,292	2,937,836	60,459	670,803	11,994	34,448
1886......	3,223	104,364	19,463	440,771	479,485	2,946,994	63,667	520,261	13,062	42,112
1887......	3,777	120,217	21,930	487,299	484,092	2,848,401	53,997	384,029	12,667	37,833
1888......	3,999	130,276	24,641	535,159	496,388	2,665,620	52,213	333,016	16,643	45,904
1889......	4,215	135,502	24,929	499,789	492,522	2,994,166	69,101	415,017	16,728	44,163
1890......	4,460	136,611	31,010	554,160	492,584	3,321,576	68,716	434,831	14,958	37,453
1891......	5,619	137,590	28,710	541,805	503,386	3,355,586	79,983	514,301	15,619	39,528
1892......	4,270	117,465	29,588	570,735	504,687	3,460,869	74,184	504,252	14,386	50,828
1893......	....	....	....	....	....	....	....	....	....	....

Year.	Magnesium Sulphate.		Potassium Chloride.		Potassium Sulphate.		Double Sulph. of Potas. Magnes.	
1872	1,569	$8,225	18,551	$805,495	... .	....	3.568	$28,219
1873	6,206	4,427	32,720	1,121,324	721	$22,486	11,777	70,264
1874	5,393	12,737	37,870	1,156,806	1,043	55,790	14,691	107.639
1875	8,038	20,123	40,360	1,177,559	500	3,750	7,335	105,580
1876	15,023	28,985	42,326	1,230,570	216	1,202	7,008	52,280
1877	18,220	23,169	93 371	2,708,616	6,219	102,277	8,372	112,235
1878	11,451	79,832	105,837	2,811,902	11,028	170,985	6,966	33,228
1879	23,347	51,295	90,078	2,343.805	15,749	249,485	598	2,056
1880	20,493	45,789	83.628	2,371,416	10.602	430,951	3,942	36,089
1881	25,908	56,830	113,168	3,522,396	13,280	476,657	5,620	59,766
1882	27,052	48,637	148,403	4,994,495	18,810	893,898	5,869	90,819
1883	19,591	31,905	147,496	4,916,425	16.201	699,817	13,037	174,160
1884	21,009	46.537	116,371	3,902,528	12,495	522,446	25,765	324,437
1885	24,601	63,238	107,253	3,618,943	18,149	739,499	27,207	354,703
1886	22.994	46,341	114,136	3,816.730	17,246	670,159	29,045	389,145
1887	28,974	72,982	128,230	4,292,549	25,365	1,006,087	24,082	308,844
1888	25,110	71,204	142,765	4,590,096	33,412	1,243,271	11.478	228,145
1889	26,978	87,589	133,957	4,197,639	29,709	1,231,468	16,325	322,712
1890	26,376	79,778	137,005	4,433,685	31,126	1,233,036	11,094	214,629
1891	23,126	71,126	129,512	4.282,290	37,674	1,514,382	10,508	199,155
1892	23,879	84,008	123,962	4,106,579	26,267	1,072,097	11,593	228,172
1893	......	......	......	....	......	....	....	....

* From *Vierteljahrs und Monatshefte zur Statistik des Deutschen Reichs.* The production of the works at Stassfurt, which produce potassium and magnesium chloride and magnesium and aluminum sulphate, is included only from 1877.

(*a*) The production of glauber salt and sulphate of alumina in Saxony before 1880 is not known. Also one works in Hanover gave no returns for aluminum sulphate and alum for 1878 and 1879. The apparent increase of glauber salt, alum, and aluminum sulphate in 1880 is due to the fact that a great many chemical works did not report their production before that year.

MINERAL IMPORTS OF GERMANY.* (IN METRIC TONS.) (Unit of value, $1000.)

Year.	Alabaster and Marble.		Alum.		Ammonia, Sulphate of.		Brass, Copper, Aluminum, and Nickel Ware		Coal.		Coke.		Lignite.		Cobalt and Nickel Metal, Crude. (*d*)	
1880	......	.....	739	$32	33,783	$3,378	1,015	$750	2,058,768	$6,434	228.207	$685	3,081,269	$2,542	....	......
1881	......	.....	560	23	34,652	3,552	1,119	817	1,953,132	6,104	170.308	596	3,064,080	3,064	....	......
1882	......	.....	441	14	34,147	3,586	1,211	879	2,090,622	6,011	201,323	805	3,020,984	3,021	....	......
1883	......	.....	326	11	27,904	2,442	1,239	898	2,181,182	5,726	166,309	561	3,319,944	3,320	123	$184
1884	......	.....	330	11	35,967	2,698	1,307	909	2,296,777	6,029	123,190	339	3,466,322	3,466	122	182
1885	10,224	$511	462	15	35,070	1,973	1,339	1,055	2,375,905	6,771	151,124	442	3,647.777	3,374	32	44
1886	13,365	668	456	15	36,558	2,102	1,286	987	2,560,291	7,041	250,307	751	4,084,930	3,779	41	54
1887	14,007	700	434	14	33,926	2,036	1,360	1,025	2,674,739	7,356	236,729	739	4,424,327	4,093	47	53
1888	15,953	798	451	15	35,835	2,239	1,350	1,147	3,252,409	9,269	268,635	1,108	5,211,668	6,515	325	487
1889	17,325	866	352	12	33,646	2,103	1,648	1,287	4,556,559	15,919	385,703	1,851	5,650,300	4,944	600	899
1890	20,213	1,011	272	9	33,873	2,033	3,273	2,150	4,164,538	15,883	351,258	1,967	6,506,404	6,507	646	888
1891	19,003	950	157	5	31,110	1,867	2,126	1,498	5,032,826	19,219	318.798	1,731	6,805,586	6,806	784	1,078
1892	21,298	959	....	....	34,207	1,881	......	......	4,436,983	14,870	465,726	2,147	6,701,309	6,366	1,356	1,611
1893	......	....	....	....	......	......	......	......	4,664,648	......	439,182	......	6,705,672	......	1,006	......

Year.	Copper Bars, Sheets, and Wire.		Copper, Pig.		Gold and Silver, Articles of		Gold, Coined.		Gold, Crude and Bars.		Gold and Silver, Platinum Ores. (*d*)		Iodine.		Iron Ore. (*a*)	
1880	770	$381	12,301	$4,152	....	......	....	......	....	....	....	......	....	......	607,007	$3,035
1881	437	201	11,020	3,719	....	......	....	......	....	....	....	......	....	......	626.175	3,131
1882	475	218	10,579	3,597	....	......	....	......	....	....	....	......	....	......	785,360	2,945
1883	544	229	11,665	3,791	27	$1,329	7	$4,257	1	$957	....	......	....	......	800,373	3,002
1884	560	230	13,819	3,973	29	1,440	4	2,761	3	1,845	....	......	....	......	980,442	2,696
1885	406	127	13,168	3,128	30	1,494	14	8,650	3	1,988	8,704	$3,917	74	$479	852,316	2,621
1886	393	109	11,913	2,532	26	1,317	6	3,446	12	8,269	11,236	5,056	88	459	812,676	2,174
1887	556	165	12.427	2,734	29	1,425	14	8,815	7	5,043	15.859	5,551	136	884	1,036.217	2,772
1888	780	350	8,082	2,929	30	1,507	20	12,799	30	20,756	14,197	3,549	135	891	1,163,373	3.665
1889	778	255	29,643	7,263	30	1,479	24	14,925	2	1,616	10,853	2,713	157	866	1,234,789	4,411
1890	906	339	31,432	9,272	27	1,330	33	20.369	7	5,093	13,756	3,783	138	916	1,522,501	5,297
1891	1,104	369	34,182	9,400	28	2,378	58	36,350	27	18,893	18,962	5,215	156	1,035	1,408,025	4,862
1892	....	......	32,498	7,962	30	1,242	45	28,045	24	16,572	19,308	5,551	169	1,119	1,655,843	5,589
1893	....	......	38,455	......	....	......	26	......	31	....	20,516	......	....	......	1,573,202	......

Year.	Iron, Pig.		Iron Wire.		Iron, Wrought.		Iron, Various Manufactures of.		Kaolin, Feldspar, Fire Clay.		Lead, Pig.		Lead and Copper Ores.		Lead, Tin and Zinc—Fine Manufac's of.	
1880	232,195	$3,599	3.038	$228	12,504	$750	18,906	$3,888	....	......	......	......	26,578	$4,651	148	$93
1881	244,601	3,669	3,277	246	14,198	817	17,563	3,801	....	......	......	......	22,316	3,905	151	93
1882	283,009	4,245	3,439	258	15,785	908	15,985	3,783	....	......	......	......	26,472	4,633	136	83
1883	274,821	3,710	3,783	255	16,128	847	17,347	3,648	69,214	$692	3,165	$198	31,269	5,081	139	111
1884	264,501	3,174	3,630	232	16,505	784	19,285	3,574	67,342	674	1,482	79	32,136	4,821	170	121
1885	215,974	2,295	2,840	284	16,153	757	18,237	3,165	95,933	959	1,489	80	32,207	4,831	174	127
1886	164,865	1,649	2,847	285	16,211	739	17,075	2,849	96,216	962	2,037	131	27,744	4,162	206	138
1887	157,102	1,649	3,234	324	17,596	792	27,585	3,168	100,700	1,007	7,619	476	38,611	6,274	177	124
1888	216,958	2,224	4,322	418	17,850	803	20.016	3,397	115,270	1,153	7,358	506	47,444	9,489	215	168
1889	337,731	4,771	4,978	518	22,237	1,112	32,880	4,635	145,951	1,459	9,499	623	52,884	7,272	233	185
1890	385,328	5,591	5,732	526	28,942	1,339	40,674	9,224	157,311	1,573	12,766	862	54,572	7,504	223	183
1891	244,852	3,264	5,692	478	22,364	929	45,653	5,936	153,750	1,538	17,625	1,091	49,040	6,130	189	144
1892	209,306	2,519	......	......	21,085	831	......	......	151,398	1,514	17,501	941	43,893	3,292	....	....
1893	218,998	......	......	......	17,054	......	......	......	....	......	23,857	......	43,490	......	....	....

Year.	Lime, Chloride of.		Limestone and Mortar.		Lubricating Oil, Mineral.		Machinery. (*e*)		Petroleum.		Phosphate of Lime.		Superphosphate.	
1880	7,221	$226	....	......	......	......	24.287	$4,119	266,587	$12,163	....	......	15,600	$585
1881	7,145	179	....	......	......	......	26,117	4,531	364,879	14,595	....	......	20,404	714
1882	5,817	146	....	......	......	......	31,853	5,544	342,510	12,416	....	......	24,879	933
1883	5,127	192	134,212	$839	......	......	34,502	5.669	370,305	13,887	....	......	31,564	1,026
1884	6,339	269	172,240	990	......	......	39,399	6,129	462,545	17,346	....	......	30,273	908
1885	6,178	216	161,710	929	30,717	$1,459	37,147	5,777	482,189	17.479	54,084	$1,217	23,336	525
1886	5,630	190	184,583	1,061	22,635	990	30.935	4,711	438,395	14,248	50.525	1,011	33,337	709
1887	3,450	147	213,642	1,229	33,012	1,444	35,045	5,458	509,399	15.282	94,335	1,769	40,540	811
1888	5,257	210	192,833	1,109	36,932	1,708	42,697	6,622	564,172	21,157	62,691	1,176	81,582	1,836
1889	4,716	189	190,204	1,094	44.565	1,894	45,799	8,013	625,668	20,334	86,268	1,618	124,962	3,062
1890	6,647	216	173.612	998	52,311	2,289	56,942	10,485	646,804	18,272	115,524	2,166	148,440	4,056
1891	3,431	120	164,029	820	60,666	2,578	42,713	7,776	675,528	16.348	92,411	1,733	114,011	3,135
1892	......	......	174,483	873	63,150	2,684	.....	......	743,433	15,185	169,798	2,972	86,851	1,954
1893	......	......	....	......	......	......	......	......	....	....	....	......	....	....

MINERAL IMPORTS OF GERMANY—*Continued.*

Year.	Precious Stones. (*b*)		Pyrites. (*c*)		Salt.		Silver.				Silver and Gold, Refuse.		Slags.		Slate.		Soda, Crude and Crystals.	
							Coined.		Crude and Bars.									
1880	....	....	....	......	31,641	$204	....	.....	....	......	...	......	....	......	38,496	$722	13,261	$257
1881	....	....	....	......	29,492	189	....	.....	....	......	...	......	....	......	52,146	978	14,569	273
1882	....	....	....	......	30,451	187	....	.....	....	......	...	......	....	......	59,992	1,125	10,448	183
1883	12	$1,375	103,611	$596	29,879	157	9	$288	35	$1,291	...	......	....	......	43,631	927	9,330	163
1884	13	1,508	123,447	709	25,969	134	6	189	33	1,237	...	......	....	......	51,885	1,103	6,677	117
1885	103	2,366	130,502	751	24,148	123	6	199	16	571	13	$1,647	119,571	$188	66,800	1,421	6,103	92
1886	121	3,669	141,864	709	21,967	112	50	1,634	24	794	21	2,668	101,166	185	36,800	843	1,216	17
1887	101	2,837	166,424	832	21,713	109	34	1,083	33	1,082	26	3,216	167,176	334	50,537	1,192	530	7
1888	161	2,966	179.197	896	22,289	124	8	229	79	2,506	32	3,837	314,108	942	52,516	1,212	233	3
1889	140	3,176	216,164	1,081	20,731	122	13	376	34	1,081	49	5,965	413,880	2,225	63,620	1,543	72	1
1890	136	2,797	210,725	1.054	20,961	105	23	741	43	1,494	28	3,405	423,532	1,112	68,695	1,183	82	1
1891	139	2,730	238,644	1,193	20,751	311	28	845	69	2,297	34	4,162	361,457	949	66,587	1,147	90	1
1892	95	1,762	218,272	982	....	.....	30	783	64	1,871	35	4,230	410,631	1,283	62,566	1,095	......	.....
1893	....	....	274,766	......	....	.....	24	.....	78	......	...	......	....	......	......	.....	......	.....

Year.	Soda and Bicarbonate of Soda, Calcined.		Soda, Caustic.		Soda, Nitrate of.		Stone, (*f*) Rough or Hewn.		Tin.				Zinc.			
									Pig.		Plate.		Ore.		Pig.	
1880	8,744	$334	8,004	$560	55,078	$4,264	274,489	$2,573	5,167	$2,390	2,764	$304	......	.....	......	.....
1881	9,527	340	5,548	388	89,950	6,746	325,053	3,047	5,981	2,841	2,709	271	......	.....	......	.....
1882	9,203	305	6,577	444	126,949	8,252	263.135	2,467	5,636	2,888	2,749	275	......	.....	......	.....
1883	5,893	196	5,231	353	166,185	9,140	245,510	2,302	6,124	2,909	2,426	237	19,651	$209	4,474	$302
1884	4,222	136	3,615	235	200,647	10,032	280,273	2,628	6,511	2,767	5,417	494	17,078	175	4,519	283
1885	2,494	79	3,262	179	156,738	7,837	273,984	2,293	6,108	2,749	5,989	509	27,180	279	4,000	245
1886	1,795	53	2,031	107	181,115	8,150	277,134	2,452	6,868	3,391	3,510	289	19,717	209	4,584	281
1887	1,945	56	1,821	91	199,276	9,217	377,895	3,309	7,176	4,081	3,194	268	11,232	169	4,585	287
1888	1,786	43	1,389	66	271,208	13,561	552,949	4,457	8,163	4,592	3,641	296	8,901	156	6,063	485
1889	1,128	29	1,165	58	332,797	15,808	570,107	5,245	9,191	4,412	2,924	241	26,813	569	7,821	724
1890	847	24	710	39	344,209	13,768	696,638	6,252	9,013	4,281	4,296	376	38,099	953	8,625	895
1891	569	17	350	21	395,653	17,309	691,720	6,179	9,081	4,200	1,199	102	37,762	944	7,969	847
1892	....	....	....	.....	379,899	16,146	....	....	8,765	4,163	......	.....	41,558	883	13,021	1,399
1893	....	....	....	.....	....	....	....	....	10,538	......	......	.....	23,883	.....	12,211	.....

MINERAL EXPORTS OF GERMANY.* (METRIC TONS.) (Unit of value $1000.)

Year.	Aluminum and Nickel Wares.		Cement.		Coal.		Coke.		Copper, Bars and Sheet.		Copper, Manufactured.		Copper, Pig.	
1880	1,130	$1,696	211,464	$2,643	7,236,466	$11,759	348,804	$1,395	....	....	......	....	....	....
1881	1,530	2;295	235,032	2,497	7,458,248	13,052	430,272	1,829	....	....	......	....	....	....
1882	1,809	2,714	250,175	2,658	7,631,617	14,309	478,351	2,033	....	....	......	....	....	....
1883	2,276	3,414	309,817	3,098	8,705,000	19,586	602,138	2,333	1,380	$524	4,229	$2,824	5,751	$1,941
1884	2,429	3,643	337,632	3,208	8,816,935	19,838	670,606	2,179	1,283	449	4,516	2,870	6,906	2,072
1885	2,231	3,347	345,633	3,024	8,955,629	20,150	633,897	1,981	3,178	866	6,186	4,037	5,706	1,391
1886	2,868	4,303	365,915	3,202	8,655,240	19,907	640,280	1,950	3,080	755	6,181	3,885	6,510	1,416
1887	3,169	4,753	398,983	3,741	8,781,377	19,978	724,763	2,351	3,354	872	6,581	4,284	5,154	1,185
1888	2,341	3,804	360,517	3,621	9,460,258	23,414	917,904	3,603	2,720	1,190	6,527	4,791	4,530	1,699
1889	1,590	2,584	326,507	3,543	8,847,202	23,857	812,570	3,746	2,636	889	7,341	4 789	7,146	1,840
1890	1,379	2,241	396,046	4,320	9,145,187	28,896	1,074,755	6,227	2,906	1,054	8,417	5,451	8,429	2,571
1891	1,417	2,125	388,457	3,816	9,536,374	29,961	1,354,298	7,138	4,145	1,430	9,675	5,992	6,244	1,779
1892	1,317	1,647	432,153	2,776	8,971,055	24,974	1,717,893	7,295	4,507	1,352	10,076	5,832	6,598	1;666
1893	....	....	....	....	9,677,305	....	1,902,424	......	4,390	....	......	....	7,517	....

Year.	Gold, Bars and Crude.		Gold, Coined.		Iron Ore. (*a*)		Iron, Pig.		Iron, Wrought.		Iron, Various Kinds of.		Iron and Steel Rails.	
1880	....	....	....	....	1,263,036	$1,895	207,776	$4,036	145,129	$5,261	117,779	$2,915	230,204	$7,482
1881	....	....	....	....	1,443,278	2,165	245,496	4,603	152,805	5,157	112,305	2,401	250,709	7,521
1882	....	....	....	....	1,621,182	2,432	186,338	3,505	144,407	5,054	96,202	2,037	186,054	6,047
1883	3	$1,884	11	$6,631	1,886,650	2,830	258,461	4.329	146,989	4,777	99,973	1,972	176,178	4,845
1884	3	2,392	8	5,239	1,898,491	2.136	230,008	3,048	153,964	4,427	73,011	1,385	144,464	4,244
1885	3	2,422	6	3,710	1,771,158	2,214	213,534	2,349	144,466	3,792	81,103	1,597	164,799	4,532
1886	3	2,038	5	3,097	1,831,649	1,832	250,681	2,695	177,303	4,433	125,609	2,350	163,222	3,795
1887	3	2,014	3	1,637	1,744,551	1,483	212,293	2,548	184,135	5,064	152,943	3,223	174,226	4,007
1888	9	6,044	30	18,732	2,211,820	1,825	144,251	1,659	170,197	4,893	106,371	2,639	114,946	2,730
1889	3	1,812	18	11,292	2,179,836	1,798	156,435	2,347	165,882	6,221	105,039	3,195	110,949	3,051
1890	3	1,890	14	8,518	2,208,480	1,800	116,922	1,917	142,811	4,999	116,848	3.281	130,837	3,762
1891	7	4,781	41	25,608	1,984,428	1,501	111,154	1,808	193,253	5,725	176,185	4,230	142,846	3,571
1892	10.6	7,421	48	30.036	2,276,155	1,711	113,391	1,568	199,064	5,340	185,616	4,046	113,712	2,559
1893	5.3	....	35	....	2,353,232	....	108,675	. ....	231,297	......	225,902	....	87,300	....

MINERAL EXPORTS OF GERMANY—*Continued.*

Year.	Wire Nails.		Iron, Various Manuf's of.		Kaolin, Feldspar, Fire Clay. (*i*)		Lead.		Leads, Crayons, & Pastels.		Lead, White; Zinc, White; Zinc, Gray.		Lead, Tin, and Zinc, Man'f'es of.		Machinery. (*j*)	
1880	16,450	$823	276,892	$38,967	....	....	45,419	$3,634	669	$502	10,822	$1,245	3,466	$1,041	63,091	$10,779
1881	21,710	1,248	353,638	46,149	....	....	46,799	3,393	668	501	12,308	1,231	3,548	1,247	66,601	11,413
1882	23,877	1,433	430,199	51,036	....	....	41,916	2,829	642	481	13,277	1,261	4,046	1,403	84,808	15,603
1883	28,206	1,551	434,604	50,244	7,933	$79	49,574	3,098	705	529	15,876	1,469	4,022	1,656	92,405	16,402
1884	38,619	1,931	422,396	48,366	7,637	76	49,313	2,651	683	513	17,153	1,544	4,407	1,692	84,307	14,142
1885	38,762	1,648	409.618	35,749	26,854	269	41,123	2,210	655	573	16,333	1,470	4,412	1,836	72,872	12,469
1886	39,673	1,612	455,991	34,562	30,425	304	38,771	2,423	672	588	15,064	1,394	5,079	2,126	72,332	12,037
1887	41,303	1,729	497,596	39.649	30,981	310	39,108	2,395	825	722	17,599	1,496	5,904	2,335	79,864	13,193
1888	48,740	2,133	474,417	44,681	40,762	408	34,890	2,355	863	755	19,252	1,642	5,773	2,086	84,602	14,188
1889	46,410	2,263	416,040	46,224	55,956	559	32,780	2,110	948	829	21,422	1,939	5,452	2,194	82,373	15,457
1890	41,040	1,898	408,588	46,564	59,785	598	32,124	2,128	978	807	21,212	2,090	5,357	2,261	88,112	16,551
1891	49,709	2,051	492,303	49,074	75,396	754	24,971	1,514	943	743	22,128	2,066	5,738	2,261	91,110	17,139
1892	50,323	1,887	(*l*)	....	82,983	829	25,647	1,363	.....	......	(*k*)	....	......	....	......	....
1893	54,849	......	....	....	....	....	23,945	....	.....	......	....	....	......	....	......	....

Year.	Phosphate, Super.		Potash.		Potassium Salts. (*g*)		Precious Metal Wares.		Salt.		Saltpeter.		Silver, Bars and Crude.	
1880..	....	......	7,771	$787	56,690	$2,126	78	$9,797	147,663	$1,108	....	......	....	....
1881..	....	......	7,408	815	75,089	3,098	85	10,579	185,408	1,391	....	......	....	....
1882..	....	......	7,534	848	96,205	3,608	82	10,198	148,853	893	....	......	....	....
1883..	7,452	$261	8,901	957	101,678	3,686	97	12,113	146,219	896	6,575	$756	....	....
1884..	11,435	372	8,449	887	77,330	3,577	90	11,218	125,404	768	6,840	718	....	....
1885..	19,161	527	9,203	805	85,085	2,817	88	10,972	118.340	725	4,175	428	....	....
1886..	26,484	662	9,703	825	80,532	2,424	103	12,829	154,188	945	4,448	445	....	....
1887..	44,087	1,047	11,373	995	98,023	3,174	109	9,552	133,872	820	3,124	297	....	....
1888..	60,507	1,513	11,406	998	121,516	3,805	116	10,114	125,657	833	4,341	456	....	....
1889..	75,555	2,040	11,576	1,071	97,307	3,105	123	9,556	189,707	1,257	8,102	810	....	....
1890..	56,253	1,677	10,628	1,011	86,971	2,779	95	9,040	199,467	889	10,135	1,014	....	....
1891..	43,318	1,299	11,094	1,137	107,176	3,336	98	7,837	254,370	985	9,663	1,015	....	....
1892..	56,075	1,402	12,233	1,254	....	....	......	(*m*)	197,371	765	8,874	932	352.756	$10,345
1893..	....	......	......	....	....	....	......	....	....	....	....	......	450.596	....

Year.	Silver, Coined.		Stone, Rough and Hewn. (*h*)		Ultramarine.		Zinc. Sheets.		Zinc. Spelter.	
1880	....	....	506,753	$5,701	5,692	$1,779	12,525	$1,189	40,022	$3,351
1881	....	....	502,194	5,649	5,420	1,694	18,276	1,713	59,963	4,872
1882	....	....	534,679	6,015	5,429	1,493	14,270	1,356	56,478	4,801
1883	....	....	568,889	2,845	5,414	1,354	16,505	1,465	54,939	4,327
1884	....	....	588,379	2,942	5,450	1,363	16,273	1,363	56,995	4,132
1885	....	....	452,966	2,426	5,421	881	16,632	1,352	68,432	4,876
1886	....	....	451,213	2,376	5,242	813	16,858	1,349	65,372	4,658
1887	....	....	526,156	2,695	5,173	737	18,153	1,588	65,258	4,731
1888	....	....	526,005	2,726	5,327	746	14,926	1,493	59,114	5,320
1889	....	....	430,549	2,298	5,283	739	14,084	1,497	59,981	5,998
1890	....	....	540,908	2,951	5,258	763	16,178	1,982	57,427	6,389
1891	....	....	505,574	2,748	4,404	639	15,370	1,979	57,852	6,581
1892	37.613	$992	....	....	......	......	16,304	1,875	53,287	5,529
1893	....	....	....	....	......	......	17,459	......	62,592	......

* From *Statistisches Jahrbuch für das Deutsche Reich*, 1892 and 1893, and for the year 1893 from advance sheets kindly furnished by Herrn von Scheel, *Kaiserliches Statistisches Amt*, Berlin. The classification in the issues of 1892 and 1893 differ. As the statistics for 1892 as well as those given only from 1883 are from the Annual of 1893, the lack of some figures for 1892, as well as considerable fluctuations in the figures, may be a matter of different book-keeping rather than of industrial changes. For the same reason the columns beginning with 1883 are likely to be in part duplicate of some of the full columns. (4 marks = $1.)

(*a*) Includes slag before 1885. (*b*) Includes imitation gems before 1885. (*c*) After 1885 *Alaunerz* (a mixture of lignite, clay, and finely divided pyrites) is included. (*d*) To June 30, 1888, only nickel. (*e*) "Machinery, chiefly of cast iron," (a new class) was imported in 1891 and 1892, respectively, to the extent of 28,148 tons, $4433, and 23,500 tons, $3408. (*f*) These statistics from 1885–92, respectively, are in the Annual of 1893 as follows: 253,379 tons, $1584; 253,996 tons, $1588; 343,269 tons, $2146; 518,337 tons, $3239; 537,254 tons, $4029; 665,221 tons, 4989; 660,459 tons, $4954; 685,592 tons, $5142. (*g*) From the Annual of 1892, under the caption "Kali, schwefelsaures und salzsaures (Chlorkalium)"; the Annual of 1893 gives under "Chlorkalium" the following figures, respectively, for 1885–92: 68,982 tons, $2415; 57,998 tons, $2030; 77,456 tons, $2711; 88,958 tons, $3114; 75,459 tons, $2641; 67,658 tons, $2368; 76,987 tons, $2695; 63,242 tons, $2253. (*h*) The Annual of 1893 gives the following figures for 1885–92, respectively: 450,175 tons, $2251; 449,873 tons, $2249; 525,122 tons, $2626; 525,114 tons, $2626; 429,009 tons, $2145; 537,229 tons, $2686; 501,473 tons, $2507; 537,220 tons, $2686. (*i*) Before 1885 only kaolin; fire clay only since July 1, 1888. (*j*) The categories adopted in the Annual of 1893 are:

	1891			1892		
Machinery of cast iron	63,987	tons	$10,558	63.341	tons	$9,501
" " wrought iron	10,994	"	2,144	11,165	"	2,009
Sewing machines, chiefly of cast iron	7,846	"	1,595	7,898	"	1,599

(*k*) In 1891, and 1892, and 1893, were exported respectively of white lead 11,730 tons, $1027; 13.712 tons, $1063 and 13,412 tons. The other articles in the class amounted to 10.398 tons, $1039; 10,595 tons, $951; and 12,343 tons. (*l*) The exports for 1892 as given in the Annnal of 1893 include different groups of goods from those of the preceding years, and are therefore unfit for comparisons. "Various other manufactures of iron" for 1891, 1892, and 1893, according to the new classification are, respectively, 472,502 tons, $45,010; 449,806 tons, $36,705; and 486,085 tons. (*m*) The value of the exports of manufactures of gold and silver only were for 1891 $7,835 and for 1892 $6,373.

SOME GERMAN STATES.

The mineral production of Baden is unimportant, being valued at only $1,676,003, of which iron castings were $1,160,640. Bavaria is a more important producer, its output of minerals being valued at over $11,000,000 annually. The largest single item in value is iron castings, and the next bar iron, both amounting to over $2,000,000. The value of the steel produced in 1892 was $1,887,673, showing a very rapid growth in this industry. It is noticeable that the output of building stones, flagstone, and sandstone has been steadily increasing, the value in 1892 being $1,282,554. The Bavarian lithographic stone is considered the best in the market, but its production does not exceed 9000 tons a year.

The mineral statistics of Prussia are of record since 1852. Coal and lignite form the principal products; the former in 1892 was 67,528,558 tons, valued at $117,677,458, and the latter 17,219,033 tons, valued at $11,913,033. The increase in fuel production has not been very rapid of late years. Pig iron is next to coal in importance, the value of the output in 1892 being $42,515,551. Zinc comes next with a product valued at $13,743,287, the increase in ten years being only 23%. The silver output was valued at $8,786,415. The output of copper in 1892, amounting to 21,559 tons, valued at $5,383,722, has increased but 3% in the past ten years, as against an increase of 260% in the production of the same metal in the United States. The great Stassfurt deposits of potash salts have added a very important item to the Prussian mineral output since 1877 and now yield about 1,000,000 tons a year, valued at $3,000,000. Taken altogether, the figures of Prussian mineral production show a healthy condition of the industry with few serious fluctuations, and while there are no phenomenal increases in production, there is a steady growth which speaks of permanency.

In Saxony the mineral output for 1892 was lower than since 1889, amounting to $11,888,706. The most important product was coal, of which 4,212,876 tons, valued at $9,939,670, were produced. Lignite produced during 1892 was valued at $674,682. Saxony is no longer a very important mineral producer; its mines are worked mostly by the Government to give employment to the workman, and Government control never stimulates industry.

MINERAL PRODUCTION OF BADEN. (*a*) (IN METRIC TONS; 4 marks=$1.)

Year.	Coal.		Clay, Fire.		Gypsum.		Iron, Cast, 2d Fusion.		Iron Ing's (Steel).		Iron, Wrought.		Lead Ore.		Limestone, etc.	
	Tons.	Value.	Tons.	Val.	Tons.	Value.	Tons.	Value.	T.	Value.	Tons.	Value.	T'ns	Val.	Tons.	Val.
1887	6,006	$14,490	2,339	$3,392	13,561	$21,075	19,242	$830,308	..	....	846	$41,168	18	$620	6,178	$2,711
1888	5,374	15,853	2,131	3,698	16,217	25,543	20,569	922,459	..	....	1,028	52,072	1	53	6,895	2,726
1889	5,159	15,476	3,158	4,808	21,170	23,826	23,528	1,063,214	61	$5,000	2,567	122,698	3	229	6,690	1,536
1890	5,167	17,693	2,491	3,155	24,835	19,993	24,965	1,174,722	53	4,100	3,117	168,974	1	105	5,480	1,470
1891	5,616	16,744	2,485	3,140	22,086	15,326	25,215	1,160,640	58	4,063	2,833	126,093	13	1,507	5,700	1,290
1892	....	....	......	......	......	....	....	....	..	....	....	....	.....	.....	......	......
1893	....	....	......	......	......	....	....	....	..	....	....	....	.....	.....	......	......

Year.	Mangan. Ore.		Quartz-sand.		Salt.		Sandst.		Sulphate of Alumina.		Sulph. Acid.		Tripoli.		[Zinc Ore.		Total.
	T.	Val.	Tons.	Value	Tons.	Value.	Ts.	Value	T'ns	Value.	Tons.	Value.	Ts.	Value	Tons	Value.	Tot. Val.
1887	1	$11	2,071	$2,105	31,830	$172,972	...	......	2,300	$47,150	8,000	$80,000	12	$908	1,033	$4,650	$1,222,660
1888	½	9	1,324	1,380	30,854	145,495	...	......	2,437	51,750	8,200	92,250	14	1,130	912	4,341	1,318,759
1889	10	174	2,081	2,104	28,814	168,551	10	$200	2,150	40,313	10,030	125,375	15	1,461	1,215	7,899	1,582,864
1890	...	....	2,036	1,647	27,819	202,454	10	45	2,000	33,750	9,872	86,380	12	1,447	1,282	7,692	1,723,627
1891	30	232	1,714	1,612	29,493	196,663	87	415	1,768	39,776	10,633	106,327	12	1,447	97	728	1,676,003
1892	...	....	......	......	......	....	...	......	.....	....	......	....	....	......	.....	......	....
1893	...	....	......	......	......	....	...	......	.....	....	......	....	....	......	.....	......	....

(*a*) From official statistics compiled for THE MINERAL INDUSTRY by *Domaenendirection*, Carlsruhe.

MINERAL PRODUCTION OF BAVARIA. (*b*) (IN METRIC TONS; 4 marks=$1).

Year.	Antimony Ore.		Barytes.		Building Stones.		Cement.		Coal.		Lignite.		Cobalt Ore.	
	Tons.	Val.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	T's.	Val.
1881	11.72	$925	1,470	$2,958	282,991	$545,801	66,523	$48,392	494,287	$1,076,090	16,642	$15,625	....	......
1882	33.20	830	1,107	2,005	293,997	422,383	54,953	47,534	492,179	1,056,591	16,938	15,295	....	......
1883	3.42	415	2,687	4,967	385,176	480,840	59,237	51,820	488,875	1,070,818	16,977	17,345	....	......
1884	2.73	251	3,356	9,056	402,093	445,198	47,252	41,103	507,843	1,104,250	15,205	15,451	160	$600
1885	1.72	153	2,070	4,795	406,313	508,657	44,775	40,590	561,186	1,226,597	8,966	9,359	349	1,050
1886	1.91	176	2,230	3,670	416,061	556,345	43,764	36,690	571,972	1,283,901	7,590	7,895	....	......
1887	2.06	170	3,832	5,065	412,059	639,838	64,664	54,386	654,974	1,459,281	6,025	7,728	....	......
1888	1.75	109	4,375	6,668	434,740	682,407	74,292	62,744	696,594	1,573,734	5,309	5,161	....	......
1889	0.92	61	4,640	8,375	496,865	851,638	81,053	77,751	771,776	1,861,863	5,616	6,320	....	......
1890	1.00	75	5,114	13,023	575,016	891,265	76,135	73,839	740,753	1,992,507	8,117	10,187	....	......
1891	0.59	40	5,124	9,962	612,657	998,182	71,648	68,104	756,148	2,012,768	10,044	11,762	....	......
1892	......	......	4,765	9,543	582,784	883,062	87,571	78,798	713,052	1,815,415	13,367	15,662	....	......
1893	......	......	......	....	....	....	....	....	....	....	....	....	....	......

Year.	Copper Ore.		Emery.		Feldspar.		Fire Clay.		Flagstones.		Fluorspar.		Gold.		Graphite.	
	Tons.	Value	Ts.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value	Tons.	Val.	Tons.	Value.
1881	3	$338	71	$696	426	$1,065	59,416	$132,440	32,881	$132,139	1,166	$3,060	0.124	$81	1,551	$33,943
1882	......	......	86	723	80	200	66,923	160,899	17,464	78,838	2,377	6,239	0.201	131	2,123	52,570
1883	......	......	56	515	175	337	70,576	156,004	24,633	94,686	2,570	4,443	0.158	103	2,945	49,192
1884	474	2,325	81	719	110	211	60,144	124,816	17,883	80,069	3.650	4,776	0.114	75	1,925	22,925
1885	13	2,125	131	1,130	250	437	65,505	125,446	7,221	24,685	2,510	2,613	0.057	37	3,359	40,128
1886	7	1,161	194	1.847	110	192	68,544	130,572	12,387	34,633	2,920	2,135	0.008	5	2,906	30,425
1887	6	1,500	102	1,163	781	1,368	69,015	146,642	19,743	45,888	3,480	2,200	0.023	15	2,960	46,585
1888	90	2,175	344	3,023	1,107	2,892	75,993	132,584	18,571	44,116	4,055	3,654	0.006	4	3,352	46,925
1889	50	350	356	3,371	1,296	3,290	91,465	172,737	13,708	34,270	4,750	3,655	....	.....	3,327	43,122
1890	50	125	275	2,484	999	3,596	91,009	182,452	19.597	49,392	4.223	4,076	....	.....	4,355	73,921
1891	......	......	184	1,511	1,445	2,890	103,287	206,674	20,772	69,005	7,847	8,420	....	.....	3,824	73,540
1892	1,831	7,706	170	1,710	1,200	2,400	108,312	237,056	19,538	79,930	4,594	5,907	....	.....	4,036	63,240
1893	......	......	...	....	......	....	....	....	....	....	...	......	....	.....	....	....

(*b*) From *Uebersicht der Production des Bergwerks-Huetten und Salinen Betriebes in dem Bayerischen Staate.* In 1886 there were also produced 123 tons of sulphur valued at $3075, and in 1890 260.4 kilos silver, valued at $8450.

THE MINERAL PRODUCTION OF BAVARIA—*Continued.*

Year.	Gypsum.		Iron Ore.		Iron Pyrites.		Kaolin.		Limestone.		Lithographic Stone.		Manganese Ore.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1881	45,229	$25,141	75,580	$90,194	988	$2,962	11,023	$33,201	120,931	$28,435	7,925	$277,375	70	$70
1882	26,624	12,376	74,131	93,347	1,305	3,915	9,645	29,068	98,650	29,597	8,101	283,535	151	151
1883	31,310	10,923	79,328	94,729	2,028	6,083	8,450	24,295	129,874	34,977	8,703	304,605	180	180
1884	31,960	11,166	119,388	148,342	1,726	3,667	10,770	28,021	106,127	36,951	7,308	254,870	200	150
1885	36,168	11,752	129,688	147,671	1,384	2,838	12,105	27,443	124.866	37,635	2,976	86.982	254	402
1886	35,109	11,320	102,655	123,182	1,098	2,306	12,325	20,316	111,969	36,261	4,802	100,070	423	550
1887	29,348	9.349	95,778	101,339	1,467	3,485	13,831	19.654	136,391	45,815	6,543	200,255	309	302
1888	33,873	10,388	117,919	121,811	1,384	3,113	15.115	20,517	159,111	57,151	8,676	303,660	262	486
1889	29,972	9,054	130,935	137,352	1,761	4,402	19,335	19,992	146,658	45,790	15,999	559,965	170	467
1890	32,631	9,562	153,768	155,867	1,741	4,138	18,635	22,773	182.616	50,593	11,485	401,975	187	562
1891	30,197	10,407	149,653	150,720	1,933	4,833	18,320	19,284	224,185	61,431	8,775	219,375	260	650
1892	24,517	12,764	146,392	149,004	1,945	4,862	18,085	17,232	233,417	64,716	8,650	216,262	137	275
1893	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Year.	Ocher and Mineral P'ts.		Petroleum.		Quartzsand.		Salt, Rock.		Sandstone.		Slate.		Soapstone.		Whetstone.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1881	3,740	$30,506	......	....	31,330	$32,315	860	$5,454	12,295	$10,094	1,093	$6,893	652	$8,769	170	$20,343
1882	5,655	12,351	......	....	35,560	36,990	922	5,840	27,143	27,283	1,428	9,496	727	9,214	133	16,260
1883	1,947	9,491	62	$1,500	38,792	34,278	1,008	6,336	76,993	63,955	1,436	9,391	715	12,950	192	22,963
1884	3,331	8,949	82	2,255	37,366	32,566	874	5,448	59,765	81,665	1,455	10,289	576	9,841	154	17,181
1885	2,994	9,770	32.5	812	52.583	47,795	938	5,953	66,302	50,678	1,873	13,139	681	20,357	148	17,968
1886	4,912	20,077	23.7	653	27,375	23,687	967	6,109	44,212	51,232	1,637	11,746	799	22,769	127	14,858
1887	4,906	12,310	......	....	35,599	29,732	789	5,066	44,986	50,089	1,495	11,019	975	27,812	143	16,759
1888	4,866	10.802	......	....	41,540	36,803	931	5,867	50,491	91,893	1,223	9,725	1,111	31,745	158	18,602
1889	4,396	11,293	......	....	11.964	4,415	896	5,535	51,876	71,321	1,162	10,191	1,190	30,778	45	5,589
1890	6,855	27,116	......	....	27,936	7,735	665	4.236	237,030	312,679	1,127	9,742	1,351	26,075	88	2,188
1891	5,710	14,750	....,.	....	32,974	11,271	1,042	6,638	221,575	307,117	1,433	12,127	1,145	22,930	109	2,075
1892	8,877	20,773	......	....	32,381	10,963	955	6,115	246,193	319,562	1,463	13,005	1,271	20,343	147	2,802
1893	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....

Year.	Zinc and Lead Ore.		Iron, Pig.		Iron, Cast, 1st Fusion.		Iron, Cast, 2d Fusion.		Iron, Bar.		Iron, Sheet.		Iron, Wire.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1881	767	$20,082	37,280	$480,017	1,848	$81,054	28,928	$1,425,061	61,812	$2,256,491	3,652	$208,557	3,355	$144,971
1882	1,562	45,704	41 110	521,656	1,015	44,307	33,397	1,633.178	67.315	2,512,621	3,945	193,603	3,313	144,903
1883	2,408	70,442	53,375	665,606	215	9,432	37,178	1,813,029	56.386	1,896,588	3,968	187,021	2,931	119,763
1884	3,756	64,084	64,836	710,744	264	11,308	42,223	1,907,949	54,447	1,731,360	3,857	167,755	2,713	105,130
1885	220	3,900	62,723	666,682	361	13,330	40,285	1.865,273	60,990	1,902,344	2,913	114,104	2,844	95,672
1886	1,629	32,250	39.634	416,491	73	2,939	39.510	1,807,471	55,809	1,507,365	1,977	72,443	2,010	64,076
1887	....	....	36,794	389,943	161	4,840	43,392	1,968,362	69.264	1,971.219	2,052	76,153	2,321	72,543
1888	3,388	59,292	49,171	513,452	2.2	66	45,985	2.116,978	80,983	2,463,361	2,663	105,606	2,604	79,699
1889	4,392	84,140	59,345	678,324	115	3,561	51.574	2,449,864	82,760	2,713.478	3,740	176,553	7,509	209,192
1890	1,127	22,548	66,517	863,565	187	7,459	53,567	2,671,410	68.684	2,567,147	3,511	161,161	4,983	166,573
1891	....	....	76,552	883,823	213	7,999	52,257	2,523,427	64,742	2,187,057	282	12,519	1,644	46,080
1892	....	....	77.598	898,302	334	12,521	48,212	2,249.683	64,646	2,020,865	592	22,349	1,008	28,035
1893	....	....	......	....	......	....	......	....	......	....	......	....	......	....

Year.	Steel.		Lead.		Salt.		Sulphate of Alumina.		Sulphate of Soda.		Other Sulphates and Alum.		Sulphuric Acid.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1881	2,113	$79,561	......	....	44,384	$490,252	3,918	$124,250	......	....	1,022	$38,526	1,612	$31,000
1882	377	28,009	......	.......:	44,227	491,264	3,285	87,500	......	....	967	40,570	1,589	27,120
1883	12,599	520,340	......	....	45,559	504,626	4,875	101,915	......	....	892	34,745	1,154	9,376
1884	13,604	541,921	......	....	43,038	478,773	......	....	......	....	443	19,573	1,156	19,652
1885	466	21,948	......	....	41,989	466,822	......	....	600	$7,376	423	19,605	7,785	87,436
1886	6,854	232,089	......	....	42,636	475,233	......	....	131	1,310	479	22,681	8,026	85,137
1887	13,202	411,131	......	....	42,411	472,203	......	....	201	1,837	684	27,510	8,105	82,705
1888	6,492	191,817	1.337	$20,653	42,321	409,545	......	....	243	2,047	634	23,431	7,323	73,700
1889	18.809	457,997	1,963	114,875	41,713	397,517	......	....	299	2,637	753	32,470	7,487	72,789
1890	47,917	1,438,886	1,989	125,533	40,718	444,977	......	....	404	3,521	833	43,044	7,914	79,226
1891	67.088	1,834,077	......	....	40,629	439,614	......	....	466	3,800	662	29,198	7,520	70,500
1892	70,790	1,887,673	......	....	41,352	444,192	......	....	516	4,617	612	29,597	6,566	62,192
1893	......	....	......	....	......	....	......	....	......	....	......	....	......	....

MINERAL PRODUCTION OF PRUSSIA. (*a*) (METRIC TONS ; 4 marks=$1.)

Year.	Alum Shale. (*m*)		Antimony Ore.		Arsenic Ore.		Asphalt.		Boracite.		Coal. (*b*)		Lignite. (*b*)	
1852	61,631	$11,169	11	$723	723	$3,080	......	......	....	......	5,148,994	$6,392,519	1,771,258	$1,199,424
1853	59,329	15,743	15	617	454	1,818	......	......	....	......	5,728,009	7,660,854	1,837,423	1,205,796
1854	52,091	19,796	13	808	308	1,429	......	......	....	......	6,799,734	10,432,434	1,892,568	1,249.216
1855	48,566	10,592	14	1,159	688	2,636	......	......	....	......	8,134,163	14,375,495	2,074,422	1,385,160
1856	47,993	8,863	60	3,624	266	879	......	......	....	......	8,842,831	16,337.455	2,342,777	1,620.376
1857	*e*29,374	7,764	44	2,101	1,026	3,784	......	......	....	......	9,456,852	17,590,005	2,747,610	1,816,651
1858	*e*32,417	9,384	52	2,775	1.073	3,360	......	......	....	......	10,399,826	19,162,171	2,919,985	2,191,583
1859	32,260	9,994	15	1,121	1,733	5,969	......	......	....	......	9,703,531	16,329,653	3,064,656	2,211,683
1860	55,398	13,165	12	856	2,129	7,650	......	......	....	......	10,638,843	15,973,749	3,165,907	2,228,893
1861	21,316	11,864	22	1,677	1,981	5,525	......	......	....	......	11.759,500	16,356,244	3,320,574	3,279,247
1862	16,879	9.263	73	4,277	332	5,255	......	......	....	......	13,088,390	16,923,780	3,807,050	2,499,300
1863	17,001	255,005	106	2,270	519	8,004	......	......	....	......	14,304,575	17,520,798	4,026,204	2,735,363
1864	......	......	99	2,970	877	8,511	......	......	....	......	16,547,745	20,655,249	4,649,521	3,188,839
1865	......	......	102	3,062	1,227	9,253	4	$16	....	......	18,542,115	29,274,682	5,021,446	3,552,198
1866	66,329	8,575	79	2,011	581	3,707	......	......	....	......	18,628,543	26,184,843	4,900,433	3,444,230
1867	......	......	45	1,105	768	4,707	......	......	....	......	21,028,556	29,368,454	5,513,878	3,925.685
1868	......	......	55	1,412	809	4,502	......	......	....	......	22,731,533	30,822.066	5,602,323	3,874,687
1869	......	......	24	582	1,132	4,606	......	......	....	......	23,761,094	33,596,493	6,014,688	4,143,952
1870	......	......	15	343	1,043	4,126	......	......	....	......	23,316,237	34,528,968	6,116,521	4,334,940
1871	......	......	10	249	445	3,337	......	......	....	......	25,967,044	45,685,976	6,876,245	5,224,498
1872	27,096	21,945	19	540	649	1.005	......	......	....	......	29,523,776	63,839,121	7,449,637	5,967,843
1873	27,475	40,175	17	540	3,445	8,613	17,250	45,375	....	......	32,347,909	88,541,314	7,987,832	6,963,907
1874	32,537	37,082	11	416	2,347	5,869	23,263	91,902	....	......	31,938,683	89,351,131	8,716,649	7,866,962
1875	32.227	12,032	15	624	2,303	20,725	20,500	61,500	....	......	33,419,299	63,648,140	8,340,259	7,391,355
1876	26,571	9,682	24	926	1,407	10,550	20,000	50,000	...	......	34,466.249	56,645,556	8,985,122	7,874,927
1877	36,019	12,713	23	892	631	3,384	26,000	140,000	36	$4,481	33,672,025	46,669,938	8,636,598	7,291,908
1878	22,535	10,482	34	1,027	592	6,456	26,000	140,000	80	3,029	35,500,167	44,511,402	8,841,366	6,997,774
1879	15,059	5,978	30	922	616	15,403	26,000	65,000	70	6,562	37,674,648	43,723,201	9,278,353	7,198,851
1880	18,254	5,732	52	1,552	695	10,434	29,000	72,500	80	9,958	42,172,944	52.654,267	9,874,888	7,541,442
1881	17,084	6,399	57	2,394	443	6,645	15,905	46,442	77	14,017	43,780,545	54,243,490	10,412,153	7,817,248
1882	22,283	6,610	42	1,168	451	6,765	12,996	26,494	86	16,984	47,097,376	58,181,123	10,798,091	7,392,681
1883	10,734	3,463	33	714	225	3,369	20,411	33,605	151	18,506	50,611,018	63,830,714	11,826,630	7,939,888
1884	11,745	3,771	16	355	1,196	19,857	19,005	28,157	153	25,554	51,867,646	65,142,453	12,055,697	7,983,086
1885	5,453	1,504	14	240	1,487	24,343	19,401	28,995	121	14,797	52,879,004	65,720,501	12,387,284	8,092,681
1886	2,247	1,285	....	......	670	11,235	15,829	20,647	118	10,648	52,482,799	64,438,905	12,565,405	8,002,941
1887	150	214	....	......	323	4,972	10,561	18,479	123	12,417	54,548,283	65,977,149	12,696,487	7,968,053
1888	211	304	....	......	1,198	18,097	10,747	25,348	148	12,149	59,475,351	72,979,734	13,207,888	8,039,837
1889	343	494	....	......	1,882	26,080	12,310	41,805	111	8,350	61,436,991	83,145,265	14,205,047	8,832,033
1890	911	648	....	......	2,183	27,728	14,533	50,079	176	13,260	64,373,816	119,880,961	15,468,434	9,967,812
1891	2,163	963	....	......	2,169	25,864	11,217	36,021	150	11,073	67,528,015	131,806,263	16,739,984	10,892,089
1892	2,460	1,087	....	......	1,202	12,229	12,665	35,956	168	12,953	65,442,558	117,677,458	17,219,033	11,913,033
1893	......	......	....	....	......	......	......	......	....	......	......	......	......	......

Year.	Cobalt Ore.		Copper Ore.		Epsom Salt.		Graphite.		Iron Ore. (*b*)		Iron Pyrites.		Kainit. (*c*)	
1852	233	$16,376	62,154	$455,912	......	......	178	$472	392,443	$603,684	1.772	$9,399	......	......
1853	12	5,652	62,713	461,565	......	......	56	420	426,923	719,151	......	......	......	......
1854	14	6,676	62,239	499,204	......	......	34	273	755,082	1,139,393	......	......	......	......
1855	10	4,534	63,940	524,790	......	......	12	108	784,555	1,267,584	5,603	12,663	......	......
1856	6	3,882	71,581	474,239	......	......	24	183	1,080,304	1,628,554	6,718	15,420	......	......
1857	3	1,761	60,416	471,027	......	......	41	......	1,238,408	1,830,976	10,625	23,998	......	......
1858	1	767	66,665	645,845	......	......	28	177	1,084,003	1,862,050	12,135	30,813	......	......
1859	......	......	71,399	626.056	......	......	49	348	754,394	1,183,888	14,366	31,778	......	......
1860	0.3	17	83,321	674,797	......	......	9	69	790,730	1,198,643	22.944	51,489	......	......
1861	1	72	94,905	540,464	......	......	14	47	998,451	1,295,772	26,252	63,543	......	......
1862	1	75	112,376	579,449	......	......	285	1,646	1,213,861	1,603,818	22,312	48,411	......	......
1863	1	291	128,482	651,366	......	......	....	......	1,370,502	1,875,411	34,699	72,078	......	......
1864	143	1,470	141,099	700,546	......	......	....	......	1,432,918	2,123,962	48,397	76,990	......	......
1865	0.2	37	143,365	789,050	......	......	3	17	1,724,207	2,945,679	53,321	89,720	......	......
1866	......	......	147,777	784,208	......	......	....	......	1,611,331	2,858,423	55,178	228,136	......	......
1867	23	12,313	174,642	958,650	......	......	1	15	2,384,982	3,872,556	95,351	340,010	......	......
1868	25	8,371	294,822	1,168,011	......	......	33	745	2,712,284	4,200,150	115,235	421,304	......	......
1869	27	6,764	214,507	1,258,316	......	......	51	1.011	2,895,569	4,813,704	91,791	325,935	......	......
1870	16	3,762	204,148	1,191,993	......	......	....	......	2,676,401	4,657,344	115,992	288,033	......	......
1871	18	4,228	214,014	1,341,878	......	......	....	......	2,920,275	6,359,355	135,524	352,584	......	......
1872	219	14.547	278,348	1,183,581	25	$7,500	....	......	3,671,368	8,541,930	149,349	457,692	......	......
1873	286	13,820	285,009	1,781,032	17	7,282	....	......	3.550,005	8,349,225	128,138	696,863	......	......
1874	254	35,757	255,296	1,562,987	18	6,954	....	......	2,540,886	4,981,238	126,797	607,085	......	......
1875	200	19,789	259,442	1,652,842	31	8,559	....	......	2,594,423	4,825,203	123,972	644,112	......	......
1876	158	19,076	300,279	1,736,230	35	4,990	....	......	2,572,250	4,336,659	110,802	526,805	......	......
1877	70	5,233	336,947	1,857,961	......	......	....	......	2,753,486	4,330,728	100,920	376,034	1,077	$5,387
1878	46	2,955	366,432	2,051,880	......	......	....	......	2,955,872	4,931,847	95,751	306,626	15,026	59,031
1879	49	3,074	391,553	2,434,335	5	8	....	......	3,153,091	4,988,606	100,427	273,545	41,181	136,958
1880	48	2,974	473,295	2,931,621	1,251	2,159	....	......	3,679,320	6,282,982	112,238	290,381	118,219	360,737
1881	33	2,052	515,359	3,521,436	2,543	4,971	....	......	3,933,314	6.674,546	124,925	319,423	160,325	541,118
1882	66	3,311	558,851	3,609,143	3,472	7,599	38	204	4.027,473	7,079,702	157,961	450,047	141,272	508,009
1883	98	4,869	604,407	3,943,686	30	45	....	......	4,118,331	6,876,869	148,717	338,020	230,071	777,423
1884	67	2,030	583,582	4,459,692	80	120	....	......	4,186,075	6,443,012	149,428	322,803	203,120	722,402
1885	59	1,326	611,337	4,744,172	27	54	....	......	3,925,783	5,509,586	115,195	232,977	195,391	731,368
1886	19	808	486,771	3,552,619	9,806	19,195	....	......	3,555,493	4,680,848	104,371	199,895	178,171	616,213
1887	11	343	497,571	3,582,865	20,305	37,995	....	......	3,833,764	5,446,854	99,554	188,901	174,924	600,799
1888	33	992	521,873	4,310,018	11,152	21,899	....	......	4,145,254	6.385,003	99,305	186,533	257,557	933,537
1889	503	2,739	563,863	4,467,187	8,959	17,047	....	......	4,375,283	7,856,097	107,955	195,405	279,984	1,011,055
1890	651	10,739	587,722	4,978,543	6,688	14,311	....	......	4,243,399	7,899,970	111,291	216,961	308,660	1,095,891
1891	576	9,209	578,256	5,149,521	6,421	13,896	....	......	3,903,811	6,207,238	119,100	213,457	399,007	1,421,727
1892	534	14,550	557,172	5,073,704	8,518	18,423	....	......	4,081,306	6,388,537	104,346	184,851	448,095	1,562,839
1893	......	......	......	......	......	......	....	......	......	......	......	......	......	......

MINERAL PRODUCTION OF PRUSSIA—*Continued.*

Year.	Other Potash Salts.		Lead Ore.		Manganese Ore.		Nickel Ore.		Petroleum.		Quicksilver Ore.		Rock Salt.	
1852	....	....	14,085	$478,380	327	$4,680	23	$11,250	......	....	....	......	....	....
1853	....	....	16,233	677,834	475	6,270	45	3,090	......	....	....	......	....	....
1854	....	....	20,837	870,626	351	5,304	52	3,183	......	....	....	......	....	....
1855	....	....	23,153	1,058,845	465	5,769	44	2,973	......	....	....	......	....	$4,636
1856	....	....	30,131	1,313,253	547	7,479	29	1,378	......	....	....	......	....	2,112
1857	....	....	30,437	1,288,311	1,119	16,139	15	866	......	....	....	......	....	34,746
1858	....	....	34,254	1,346,326	1,614	21,600	12	1,803	......	....	....	......	25,824	90,410
1859	....	....	41,111	1,504,103	1,987	28,899	12	1,781	......	....	....	......	20,538	42,174
1860	....	....	44,742	1,749,860	2,015	26,756	7	1,323	......	....	....	......	34,123	84,232
1861	....	....	42,321	1,765,858	1,910	23,560	12	1,624	......	....	....	......	44,222	89,661
1862	....	....	46,031	1,712,854	1,778	22,101	14	1,085	......	....	....	......	69.789	149,829
1863	....	....	56,670	2,046,333	463	8,521	49	3,542	......	....	....	......	82,334	1,235,020
1864	....	....	61,042	2,296,299	906	12,577	18	934	......	....	204	$1,718	106,503	340,471
1865	....	....	57,808	2,085,588	662	8,712	13	1,335	......	....	269	1,581	86,416	94,141
1866	....	....	61,648	2,253,699	2,259	....	6	1,509	......	....	121	1,510	122,228	....
1867	....	....	91,564	3,580,420	51,639	402,012	388	7,440	......	....	36	671	137,341	269,508
1868	84,100	$208,629	885,849	3,534,925	27,135	264,876	81	5,293	......	....	23	225	89,284	135,748
1869	109,400	252.609	951,016	3,823.721	18,068	174,020	37	2,926	......	....	12	225	77,694	119,901
1870	146,250	307,734	98,858	3,828,384	11,786	101,314	3	366	......	....	4	285	65,196	121,490
1871	160,150	328,467	922,767	4,668,586	12,641	116,027	6	2,675	......	....	70	47	73,658	140,512
1872	197.525	539.115	90.168	3,219,822	17,621	173,723	13	4,635	......	....	2	44	79,839	165,603
1873	163,600	400,286	96,568	4,394,229	16,472	223,572	17	3,128	38	$6,210	....	......	78,774	198,789
1874	127,990	244,316	99,603	4,531,571	12,187	156,470	305	3,806	38	6,210	....	......	76,898	150,252
1875	162,661	300,718	107,878	5,204,348	12,059	133,885	222	8,853	38	6,210	....	23	80,408	133,603
1876	193,546	356,943	112,844	5,025,978	8,942	94,559	361	10,851	45	7,258	....	15	80,628	121,634
1877	287,122	544,249	134,582	5,420,759	5,289	46,686	221	4,154	......	....	....	20	85,910	123,782
1878	292,856	564,155	139,986	5,015,991	4,407	39,865	11	1,775	......	....	....	......	110,758	160,345
1879	306,995	643,086	137,621	4,364,027	5,006	39,235	143	2,838	47	3,263	14	101	142,857	212,892
1880	282,254	657,865	142,874	4,541,472	9,753	84,025	158	3,728	256	12,800	29	175	165,075	240,569
1881	385,107	879,508	148,790	4,653,856	11,086	82,377	7	483	2,871	105,505	....	......	207,858	309,812
1882	553,029	1,235,457	157,236	4,867,468	4,670	35.152	15	1,718	5,989	147,876	....	......	210,130	324,173
1883	609,742	1,254,595	149,445	4,286,163	4,574	29,608	15	1,422	2.495	63,529	....	......	208,241	315,634
1884	585,016	1,383,189	141,108	3,706,752	7,751	44,914	31	1,467	3,633	95,710	....	......	197,247	278,795
1885	529,539	1,378,096	140,337	3,621,167	14,696	84,690	11	693	2,695	85,941	....	......	205,492	265,703
1886	514,254	1,343,654	140,165	3,849,642	25,045	184,443	15	1,106	2,671	102,012	....	......	214,022	263,218
1887	625,419	1,650,172	141,930	3.892,011	36,534	237,958	18	2,090	2,552	97,944	....	......	194,131	236,477
1888	723,181	1,845,535	143,383	4,024,001	27,308	153,385	9	336	2,770	98,441	....	......	188,692	225,914
1889	689,341	1,832,275	148,773	4,242,952	44,006	225,397	17	872	3,059	104,495	....	......	251,849	286,308
1890	708,467	1,937,579	148,615	4,349,864	40,131	181,696	33	409	2,249	84,545	....	......	250,351	303,086
1891	617,638	1,712,988	140,123	4,000,998	36,860	181,899	185	1,452	2,498	76,050	....	......	283,924	321,893
1892	501,748	1,439,801	141,660	3,462,955	31,388	106,087	529	4,500	1,585	41,925	....	......	245,550	253,628
1893	....	....	....	....	....	....	....	....	......	....	....	......	....	....

Year.	Silver and Gold Ore.		Zinc Ore.		Antimony and Alloys.		Arsenic Products.		Bismuth.		Cadmium, Kilos.		Cobalt Prod.	
1852	......	....	181,048	$760,532	6	$1,542	100	$8,060	......	......	......	....	254	$60,370
1853	......	....	162,333	1,028,737	6	1,176	143	7,788	......	......	......	....	161	36,462
1854	......	....	178,929	1,452,951	18	4,117	83	5,210	......	......	......	....	154	29,696
1855	......	....	214,365	1,600,582	20	4,282	56	3,298	......	......	......	....	124	22,734
1856	......	....	226,625	1,622,589	15	2,932	134	8,632	......	......	......	....	105	16,395
1857	......	....	218,890	2,289,041	22	3,964	206	12,513	......	......	......	....	77	14,201
1858	......	....	244,363	99,381	19	3,180	246	15,992	......	......	......	....	10	2,818
1859	......	....	278,277	1,143,843	9	2.228	220	14,085	......	......	......	....	9	2,244
1860	......	....	303,596	1,169,867	7	1,540	281	18,144	......	......	......	....	10	2.325
1861	......	....	328,682	1,073,061	10	3,000	305	18,082	......	......	1	$300	7	1,797
1862	0.2	$1,938	326,107	1,319,253	60	18,750	224	14,658	......	......	101	252	......	....
1863	1	4,417	285,613	1,261,231	60	12,000	263	7,276	......	......	124	309	......	....
1864	0.1	175	305,879	1,715,650	62	19,500	226	14,388	......	......	113	311	......	4
1865	1	355	326,945	1,712,572	60	11,700	233	16,428	......	......	88	242	......	....
1866	0.4	156	343,703	1,755,711	60	9,200	136	8,973	......	......	69	140	......	....
1867	83	3,179	343,467	1,995,400	60	11,700	231	14.144	......	......	30	68	113	15,987
1868	11	8,531	3,665,826	1,894,134	60	11,700	162	10,257	......	......	5	12	132	18,289
1869	265	55,702	400,536	2,119,659	60	11,700	211	11,213	0.004	$18	......	....	104	14.302
1870	27	48,701	363,583	1,727,946	......	....	90	5,401	0.0035	14	......	....	106	13,929
1871	184	40,695	3,306,969	1.070,737	6	1,226	117	7,500	......	......	708	5,250	145	18,150
1872	11	14,834	411,811	2,123,601	9	2,256	65	3,777	......	......	1,475	15.000	200	17,574
1873	6	17,216	441,612	3,100,130	3	998	216	12,750	......	......	1,066	5,700	8	11
1874	6	25,438	443,526	2,735,185	......	....	215	16,153	......	......	1,265	4,949	8	4,656
1875	6	17,987	465,210	3,157,205	......	....	171	14,272	......	......	1,918	8.006	11	3,013
1876	5	24,854	531,315	3,237,304	......	....	134	11,165	......	......	1,779	7,228	11	314
1877	5	25,368	575,147	2,771,614	93	12,267	110	7,961	......	......	2,022	6,049	11	95,000
1878	2	7,103	595,839	2,846,117	125	14,353	209	14,121	......	......	2,490	7,010	13	81,250
1879	2	9,034	589,255	2,010,569	150	17,343	326	18,427	......	......	3,114	7,191	14	82,500
1880	3	12,028	631,827	2,977,238	265	44,668	265	15,046	......	......	3,327	7,564	18	87,500
1881	122	29,504	659,211	2,394,294	257	35,078	112	8,743	......	......	3,367	6,807	16	81,250
1882	115	19,568	693,369	2,964,603	176	24,879	251	14,264	......	......	3,671	8,634	27	80,552
1883	96	14,210	676,796	2,214,619	128	17,920	58	2,867	......	......	2,419	5,380	21	85,000
1884	67	9,178	631,235	1,950,819	143	19,688	370	19,531	......	......	2,768	5,768	21	87,500
1885	59	9,140	679.787	1,907,913	149	18,458	522	28,505	......	......	3,267	6,394	34	90,873
1886	77	10,390	704,216	1,926,065	120	14,701	446	21,102	......	......	4,964	9,234	34	125,000
1887	74	13,975	899.679	2,500,875	45	5,456	599	28,515	0.0315	119	7,310	12,124	33	126,750
1888	63	10,306	666.700	3.431,958	69	8,183	842	43,939	......	......	4,794	5,714	36	132,375
1889	77	7,851	707,537	4,414,114	161	18,645	846	43,165	......	......	5,067	4,436	38	188,585
1890	152	13,594	757,862	5,843,854	115	16,899	817	41,108	......	......	4,187	3,789	40	197,440
1891	131	20,610	792,351	6,230,590	165	23,750	812	41,379	......	......	2,797	2,468	44	198,740
1892	4	11,498	797,698	5,294,549	210	23,106	592	22.739	......	......	3,200	2,850	54	239,909
1893	......	....	....	....	......	....	......	....	......	......	......	....	......	....

THE MINERAL PRODUCTION OF PRUSSIA—*Continued.*

Year.	Copper. (*f*)		Copper Pig. (*l*)		Gold, Kilos.		Iron, Pig. (*j*)		Lead, Pig. (*g*)		Litharge. (*g*)	
1852	....	....	1,549	$712,994	3.680	$2,520	161,294	$4,167,692	6,785	$550,922	......	....
1853	....	....	1,660	817,332	4.370	3,045	204,997	6,073,619	7,348	762,070	......	....
1854	....	....	1,624	853,239	3.220	2,197	254,171	8.263,639	10,891	1,129,726	......	....
1855	....	....	1,650	933,089	2.530	1,728	292,904	9,490,802	11,110	1,362,135	......	....
1856	....	....	1,712	1,022,348	2.990	2,099	353,638	12,094,801	12,286	1,309,441	......	....
1857	....	....	1,598	960.964	6.326	4,311	386.092	12,208,156	13,284	1,400,960	......	....
1858	....	....	1,597	905,565	....	....	413,343	11,657,592	14,126	1,324,930	......	....
1859	....	....	1,747	852,564	10	6,186	396.892	9,927,774	15,231	1,405,238	......	....
1860	....	....	1,965	999,318	9	5,664	394,710	8,930,517	17,114	1,612,835	......	....
1861	....	....	2,274	1,087,796	4	2,449	449,339	10,473,692	20,758	1,816,129	......	....
1862	....	....	2.582	1,201,712	0.15	102	526,077	11,105,848	23,147	2,101,856	......	....
1863	....	....	2,681	1,266,020	0.23	154	636,679	13,359,215	24.739	2,341,502	......	....
1864	....	....	2,824	1,350,020	0.17	77	....	....	27,277	2,525,740	......	....
1865	....	....	2,481	1,367,650	0.07	31	771,903	15,981,302	29,884	2,611,023	......	....
1866	....	....	3,231	1,402,986	....	....	803,552	15,980,650	31,869	2,876,698	......	....
1867	....	....	3,724	1,512,186	3	1,891	915,667	17,150,859	43,785	4,008,059	......	....
1868	....	....	4,141	1,661,453	18	11,680	1,053,255	19,488,597	48,801	4,385,147	......	....
1869	....	....	4,448	1,678,329	18	11,624	1,180,529	21,959,762	53,283	4,831,267	......	....
1870	....	....	4,664	1,703,871	12	7,183	1,155,541	22,271,246	53,907	4,685,328	......	....
1871	....	....	5,161	2,992,302	164	109,758	1,297,940	26,872,008	53,043	4,851,527	......	....
1872	....	....	7,005	3,104,494	257	172,977	1,457,335	43,172,824	54,007	5,164,622	......	....
1873	....	....	7,751	2,891,255	306	207,445	1,573,902	45,378,944	59,677	6,558,128	......	....
1874	....	....	6,252	2,703,659	219	148,386	1,280,268	28,751,473	64,335	6,689,657	......	....
1875	....	....	7,212	3,188,431	177	121,639	1,398,337	26,872,620	65,412	7,066,077	......	....
1876	....	....	7,985	3,140,114	125	86,980	1,324,339	21,839,493	70,207	7,287,858	......	....
1877	248	$25,501	8,193	3,122,654	150	107,672	1,421,667	21,925,937	78,353	7,828,306	2,534	$238,979
1878	243	24,127	9,073	3,142,694	232	161.576	1,568,061	22,622,707	75,001	6,054,255	3,359	258,376
1879	555	52,744	9,607	2,917,998	144	200,884	1,639,676	22,460,862	76,013	5,304,371	3,143	204,497
1880	988	73,125	13,604	4,535,507	316	220,406	2,052,671	32,540,465	79,337	5,852,322	2,548	174,126
1881	1,079	104,286	14,624	4,809,791	211	147,082	2,172,909	32,724,665	81,656	5,652,949	3,203	215,045
1882	886	78,884	14,886	5,165,739	82	57,205	2,467,548	37,450,638	86,811	5,909,904	2,739	176,831
1883	545	46,996	16,189	5,483,579	102	71,111	2,575,978	35,767,565	84,809	5,113,514	3,859	223,596
1884	300	25,981	16,675	5,051,096	146	102,208	2,618,897	32,993,522	88,460	4,711,144	3,573	185,656
1885	343	22,339	17,424	4,375,628	130	90,860	2,664,874	30,770,375	87,216	4,546,408	3,126	185,656
1886	402	26,180	17,798	3,831,852	122.29	85,579	2,563,027	25,659,973	86,341	5,162,572	3,171	181,328
1887	406	43,213	18,381	4,033,202	82.38	57,646	2,863,618	31,511,881	88,807	5,253,101	3,727	214,800
1888	992	86,802	18,900	6,403,726	195.95	137,158	3,098,757	33,208,058	89,847	5,742,938	3,208	201,237
1889	263	25,267	21,668	6,163,804	179.37	125,498	3,218,719	40,936,507	90,809	5,759,053	2,373	151,494
1890	793	66,026	21,779	6,430,001	127.67	89,795	3,288,369	49,127,521	91,133	5,712,706	2,907	190,453
1891	547	43,150	21,236	6,102,910	100.31	69,790	3,288,441	43,832,358	87,372	5,286,817	2,246	142,510
1892	625	24,630	21,559	5,383,722	115.82	81,067	3,439,081	42,515,551	87,983	4.607,369	2,634	153,143
1893	....	....	....	....	....	....	....	....	....	....	......	....

Year.	Manganese and Alloys.		Nickel and Alloys.		Paint, Mineral.		Salt, Common. (*h*)		Silver, Kilos.		Sulphur.		Sulphuric Acid.	
1852	....	....	10	$16,593	......	......	118,604	$1,075,088	9,852	$440,308	12	$1,128	....	....
1853	....	....	9	10,068	......	......	122,556	1,078,508	10,381	464,598	38	2,568	....	....
1854	....	....	43	101,727	......	......	122,538	1,105,242	12,160	552,387	23	1,491	....	....
1855	....	....	73	83,515	......	......	122,068	1,112,398	11,486	514,080	27	1,831	....	....
1856	....	....	159	242,742	......	......	126,860	1,156,515	12,652	565,470	28	1,823	....	....
1857	....	....	91	163,965	......	......	141,388	1,280,390	13,570	610,953	......	....	....	....
1858	....	....	195	217,073	......	......	124,831	1,194,778	14,189	633,635	529	9,667	....	....
1859	....	....	189	215,625	......	......	100,216	988,889	16,012	714,624	240	14,315	....	....
1860	....	....	322	331,003	......	......	96,524	949,334	17,579	782,533	233	14,035	....	....
1861	...	....	237	267,000	......	......	113,479	1,089,235	19,158	855,540	110	5,793	....	....
1862	....	....	220	345,750	......	......	123,075	1,142,836	23,078	1,028,390	374	17,157	....	....
1863	....	....	375	438,104	......	......	118,377	978,128	23,016	1,016,855	310	14,850	....	....
1864	....	....	337	348,675	......	......	118,982	945,283	25,977	1,163,020	90	4,368	....	....
1865	....	....	321	304,950	......	......	118,060	949,974	25,645	1,968.088	102	4,875	....	....
1866	....	....	321	279,200	......	......	124,662	978,189	28,859	1,297,379	151	7,530	....	....
1867	....	....	371	289,692	......	......	174,484	999,695	46,102	2,067,341	178	7,833	....	....
1868	....	....	49	70,499	......	......	167,718	1,001,473	53,326	2,388,401	......	....	....	....
1869	....	....	29	57.901	......	......	170,019	1,078,181	58,304	2,590,752	11	396	....	....
1870	....	....	43	65,598	......	......	169,001	1,049,247	62,631	2,806,043	6	241	....	....
1871	....	....	89	145,614	......	......	136,334	1,188.926	66,130	3,112,616	4	178	32,370	$786,544
1872	....	....	133	228,133	......	......	194,118	1,253,995	81,277	3,616,321	18	923	32,752	779,758
1873	....	....	270	392,739	......	......	191,128	1,285,588	115,960	5,057,806	1	68	31,504	686,684
1874	....	....	184	324,848	......	......	215,283	1,460,590	113,487	4,874,658	188	9,104	41.757	794,993
1875	....	....	237	416,231	......	......	217.926	1,400,993	112,371	4,705.208	198	9,787	69,985	1,359,302
1876	....	....	300	508,813	......	......	224,393	1,407,304	108,657	4,274,959	337	16,473	71,766	1,205,830
1877	....	....	76	136,325	70	$1,400	227,561	1,401,223	111,574	4,499.275	1,198	47,715	67,021	1,188,304
1878	0.6	$615	75	110,000	30	750	218,303	1,323,521	128,786	4,833,394	729	27,489	78,369	1,281,149
1879	3	3,085	110	52,325	50	750	230.741	1,376,232	134,309	4,994,484	1,239	46,421	94,628	1,445,636
1880	2	2,035	105	128,747	127	2,063	244,998	1,491,711	138,939	5,336,265	1,529	43,858	106,285	1,480,775
1881	4	4,209	82	119.970	130	2,617	247,006	1,515,163	145.201	5,528,289	2,571	86,201	189,593	2,561,132
1882	5	4,584	121	191,080	185	1,286	251,679	1,542,791	161,520	6,147,975	3,365	112,942	215,468	2,799,680
1883	12	8,550	109	188,750	184	2,883	258,199	1,578,957	172,865	6.451,223	3,753	124,346	224,980	2,813,398
1884	11	8,600	126	187,500	186	2,646	258,854	1,545,991	184,876	6,898,462	3,803	124,863	259,896	2,890,038
1885	7	7,925	145	183,842	161	2,225	255.517	1,481,153	195,035	6,975,541	3,190	96,099	255,092	2,569,083
1886	7	5,525	169	192,500	234	2,863	270,937	1,516,421	215,758	7,226,319	3,373	96,125	259,468	2,293,369
1887	12	9,375	254	254,500	322	3,067	267,811	1,453,831	233.131	7.660.294	2,050	56,339	287,954	2,297,267
1888	14	10,225	288	292,000	687	17,769	268,463	1,412,453	259,504	8,213,973	2,270	59,338	297,062	2,349,371
1889	16	10,800	282	299,104	1,158	30,617	268,363	1,588,690	256.324	8,070,353	2,132	58,751	319,574	2,524,332
1890	24	14,833	434	466,783	1,659	33,885	271,615	1,721,098	260,824	9,046,966	1,603	40,098	340,512	2,746,565
1891	33	19,425	594	689,405	1,813	35.863	265,549	1,675,428	277,546	9,254,830	1,721	46,528	343,826	2,938,186
1892	39	21,825	747	747,312	2,082	40,320	264,896	1,695,904	301,374	8,786,415	1,850	49,828	360,156	2,722,789
1893	....	....	...	....	......	......	....	....	......	....	......	....	....	... ..

THE MINERAL PRODUCTION OF PRUSSIA—*Continued.*

Year.	Sulphates.										Tin.		Zinc.	
	Copper.		Iron.		Nickel.		Zinc.		Mixed.					
1852	......	....	......	....	......	......	......	....	5,914	$308,493	......	....	34,721	$2,427,117
1853	......	....	......	....	......	......	......	....	6,094	303,074	......	....	34,673	3,021,678
1854	......	....	......	....	......	......	......	....	5,294	232,304	......	....	36,873	3,609,175
1855	......	....	......	....	......	......	......	....	5,108	233,784	......	....	38,254	3,915,391
1856	......	....	......	....	......	......	......	....	4,773	188,983	......	....	38,326	4,526,518
1857	......	....	......	....	......	......	......	....	5,901	264,950	......	....	43,611	5,154,568
1858	......	....	......	....	......	......	......	....	5,802	249,814	......	....	52,777	5,286,636
1859	......	....	......	....	......	......	......	....	6,411	275,470	......	....	49.282	4,407.112
1860	......	....	......	....	......	......	......	....	6,773	270,894	......	....	55,346	4,568,272
1861	......	....	......	....	......	......	......	....	5,342	212,252	......	....	58,573	4,724,123
1862	......	....	......	....	......	......	......	....	5,052	199,984	......	....	59,765	4,765,282
1863	......	....	......	....	......	......	......	....	5,265	192,328	......	....	60,310	4,750,134
1864	......	....	......	....	......	......	......	....	4,992	167,424	......	....	59,246	5,419,101
1865	......	....	......	....	......	......	......	....	5,091	170,626	......	....	51,483	5,194,022
1866	......	....	......	....	......	......	......	....	5,403	170,040	......	....	60,149	5,703,210
1867	......	....	......	....	......	......	......	....	7,084	265,220	......	....	73,781	5,986,800
1868	......	....	......	....	......	......	......	....	4,062	151,965	......	....	66,006	6,040,997
1869	......	....	......	....	......	......	......	....	4,278	166,208	......	....	69,721	6,343,258
1870	......	....	......	....	......	......	......	....	4,302	172,278	......	....	63,919	5,349,427
1871	......	....	......	....	......	......	......	....	2,129	96,006	......	....	53,103	5,265,226
1872	......	....	......	....	......	......	......	....	2,017	152,527	......	....	53,054	5,821,623
1873	......	....	......	....	......	......	......	....	3,748	291,324	......	....	62,562	7,051,268
1874	......	....	......	....	......	......	......	....	3,748	264,536	......	....	70,177	7,133,016
1875	......	....	......	....	......	......	......	....	4,518	322,025	......	....	74,117	7,696,478
1876	......	....	......	....	......	......	......	....	3,004	210,152	88	$11,501	83,041	8,682,306
1877	1,474	$144,831	1,800	$24,070	......	......	253	$7,743	7	333	......	....	94,744	8,429,426
1878	2,050	173,811	1,892	25,615	......	......	92	5,570	......	....	......	....	94,637	7,924,337
1879	2,504	204,889	2,247	27,340	......	......	292	8,601	60	2,388	......	....	96,484	7,434,007
1880	2,556	252,584	2,672	32,766	......	......	464	12,481	76	3,250	......	....	99,490	8,453,187
1881	2,385	220,423	5,255	58,179	......	......	352	8,121	436	13,258	......	....	105,345	7,902,949
1882	2,176	195,912	5,237	55,941	......	......	435	8,778	367	13,553	......	....	113,272	8,975,729
1883	2,517	253,299	4,872	51,629	......	......	567	11,189	411	14,631	......	....	116,644	8,417,178
1884	3,120	317,726	5,158	49,610	......	......	692	14,290	300	10,906	77	38,750	125,183	8,519,129
1885	2,587	230,913	4,801	46,713	......	......	683	11,854	254	7,993	120	52,500	128,911	8,452,750
1886	1,980	142,759	4,435	41,282	......	......	660	10,298	280	7,706	200	90,000	130,815	8,627,483
1887	1,808	123,951	6,481	52,782	26	$1,250	721	11,373	252	7,506	200	87,500	130,445	9,145,913
1888	1,618	134,252	8,517	63,032	28	1,250	772	10,417	175	5,406	220	34,375	133,280	10,894,501
1889	1,700	173,474	7,245	51,174	27	1,250	1,417	2,293	243	7,268	340	51,850	135,972	12,333,522
1890	2,182	217,051	6,384	39,905	26	8,250	1,944	28,458	281	8,302	......	....	139,056	15,574,109
1891	1,285	109,032	7,682	51,344	45	14,000	2,405	36,723	223	6,723	238	107,778	139,147	15,616,909
1892	1,338	95,056	7,778	41,692	44	14,000	2,748	40,886	167	5,506	644	290,720	139,725	13,743,287
1893	......	....	......	....	......	......	......	....	......	....	......	....	....	....

(*a*) From *Zeitschrift für das Berg-, Hütten-, u. Salinenwesen.* The production of quicksilver, in kilos, was, in 1864-68, 2718, 25,645, 986, 537, 402 ; in 1871, 124 ; in 1872, 45, and in 1877, 20. Of selenium, in tons, in 1859-61, 1871, and 1879, respectively, 3, $247 ; 1, $56 ; 2.5, $181 ; and 5, $405. Of uranium products the values were for 1877, $2058; 1880, $2675; 1881, $3330; 1882, $1230; 1883, $69. For 1848-51 the production was as follows for the minerals mentioned :

Year.	Coal.		Lignite.		Copper Ore.		Iron Ore.		Lead Ore.		Zinc Ore.	
1848	3,508,483	$5,028,502	1,222,654	$718,771	36,393	$246,969	402,020	$554,610	23,005	$303,964	127,396	$288,424
1849	3,633,324	5,142,731	1,321,247	785,224	35,198	254,214	393,336	551,675	23,268	290,788	128,743	500,238
1850	4,146,487	5,988,288	1,331,270	789,551	40,452	243,799	532,928	600,841	26,504	388,575	147,840	663,783
1851	4,526 909	6,245,116	1,512,504	921,303	49,414	283,524	485,509	577,586	12,338	434,811	150,950	520,899

The apparent decrease in tonnage of lead ore in 1851 is due to the fact that in 1848, 1849, and 1850 the weight of the "Knottenerze" of Bleiberg near Commern is taken, while for the other years the weight of the dressed ore is given.

(*b*) The figures for coal, lignite, iron ore, and alum shale to the year 1860, inclusive, are given in "Tonnen," an old Prussian measure. We have converted them to metric tons by multiplying by 0.1996 for coal, 0.1506 for lignite, and 0.3521 for iron ore and alum shale.

(*c*) From 1862-67, inclusive, under rock salt are included kainit and other potash salts. From 1868-72, inclusive, kainit is included with potash salts.

(*e*) Does not include 1883 and 2052 tons reported in centners respectively in 1857 and 1858.

(*f*) Matte and black copper. Included in "Pig Copper" until 1877.

(*l*) Includes matte and black copper until 1877.

(*g*) Litharge is included with lead from 1852-76, inclusive.

(*h*) From 1852-57, inclusive, converted from lasten—1 lasten=2 metric tons.

(*i*) Copper, iron, nickel, and zinc sulphates are included in mixed sulphates from 1852-76, inclusive.

(*j*) From 1852 to 1860, inclusive, the figures given do not include castings direct from ore.

(*m*) The German reads : *Vitriol und Alaunerze.* See note (*b*).

THE MINERAL PRODUCTION OF SAXONY.(*a*) (IN METRIC TONS). (4 marks=$1.)

Year.	Arsenopyrites.		Bismuth, Cobalt, and Nickel Ores.		Coal.		Lignite.		Iron Ore.		Manganese Ore.		Pitch-Blende.		Tin Ore.	
	Tns	Val.	Tns.	Value.	Tons.	Value	Tons.	Value.	Tons.	Value.	Tons	Value	Tns	Value	Tns	Value.
1878	22	$279	206	$120,703	3,088,334	$5,503,728	559,518	$454,387	8,963	$18,814	33	$523	2	$1,292	85	$27,988
1879	24	274	211	124,401	3,310,614	5,653,224	590,899	455,944	14,090	35,258	27	365	2	1,205	97	34,802
1880	10	165	214	114.142	3,622,352	6,351,845	590,119	467,084	19,291	50,423	723	1,772	3	1.386	105	46.498
1881	67	412	222	126,714	3,707,745	6,415,897	600,708	474,745	19,951	62,063	433	1,530	4	2,694	115	55,614
1882	34	511	236	134,451	3,792,437	6,363,302	618,736	468,598	21.895	66,318	265	896	3	2,938	99	53,089
1883	33	444	251	132,145	4,088,664	7,058,009	648,044	496,309	20,959	63,995	388	2,211	2	3,279	88	42,699
1884	22	300	50	130,408	4,131,899	7,040,185	688,551	521,351	20,949	57,158	622	4,278	3	4.239	95	40,389
1885	43	751	47	131,023	4,150,525	7,395,555	731,796	553,083	17,827	51,862	482	2,346	4	4,999	99	45,805
1886	58	1,092	44	118,639	4,249,023	8,049,752	733,918	536,010	12,097	35,581	422	2,511	12	18,150	86	46,271
1887	14	350	50	133,254	4,293,417	8,803,985	766,732	559,222	11,680	30,524	469	1,812	3	8,815	76	40,839
1888	25	308	64	143,829	4,359,085	9,133,269	839,968	616,583	12,349	31,197	329	1,503	2	5,113	84	45,335
1889	28	412	53	124,936	4,234,713	9,459,988	849,522	628,182	15,806	37,310	555	1,739	6	6,896	62	29,629
1890	1	27	187	153,402	4,150,842	10,289,151	848,053	634,739	10,808	28,079	792	3,008	5	3,552	60	29,267
1891	....	.....	291	148,379	4,366,819	10,957,819	864,376	657,733	14,159	36,912	2,046	4,717	....	......	50	22,758
1892	....	.....	476	179,561	4,212,875	9,939,670	927,860	674,682	12,895	23,945	1,638	3,699	....	......	49	18,945
1893	....	.....	.....	....	4,330,733	10,146,287	....	....	......	....	.....	......	....	......	....	....

Year.	Wolfram Ore.		Mixed Ores. (*b*)		Other Minerals. (*c*)		Total.
	Tns	Val.	Tons.	Value.	Tns.	Val.	Value.
1878	13	$484	24,918	$1,009,135	432	$2,810	$7,140,142
1879	27	874	23,001	1,008,838	932	3,934	7,319,119
1880	32	1,498	24,406	1,091,952	628	3,039	8,129.801
1881	48	3,470	28,802	1,110,618	2,125	5,474	8,259,101
1882	41	4,585	27,416	1,238,852	515	2,847	8,336,387
1883	55	5,944	28.623	1,185,731	1,142	4,554	8,995,320
1884	40	5,925	28,876	1,296,611	919	3,864	9,104,708
1885	27	4,878	28,422	1,153,511	2,797	9,567	8,103,629
1886	31	5,095	29,809	1,095,735	2,225	8,634	9,909,969
1887	40	4,785	25,661	1,026,148	1,923	13,198	10,622,932
1888	39	4,232	29,523	1,029.831	3,033	12,471	11,023,671
1889	39	4,389	30,698	1,028,291	2,516	13,841	11,335,613
1890	37	5.722	31,498	1,163,737	2,250	18,249	12,328,933
1891	42	8,212	31,909	1,164,205	3,136	16,891	13,017,902
1892	37	8,108	30,231	1,025,078	3,212	15,256	11,888,706
1893	....	.....	......	....	.....	......	....

METAL CONTENTS OF THE MIXED ORES TREATED AT THE ROYAL SMELTING WORKS AT FREIBERG.(*a*) (IN METRIC TONS.)

Year.	Total of Mixed Ores.		Arsenic.	Copper.	Gold.	Lead	Nk'l and Cobalt.	Silver	Sulphur.	Zinc.
	Tons.	Dollars.	T'ns	T'ns	Kilos.	Tons	T'ns	Kilos.	Tons	Tns
1883	28,623	1,185,731	538	30	0.045	4,237	0.6	32,984	4,136	52
1884	28,876	1,296,611	540	25	0.027	3,894	0.5	36,388	4,032	65
1885	28,422	1,153,511	.....	.....	......	......	.....	......	.....	....
1886	29,809	1,095,735	.....	.....	......	......	.....	......	.....	....
1887	25,661	1,026,147	.....	.....	......	......	.....	......	.....	....
1888	29,523	1,029,831	375	4	......	3,458	1.3	31,746	4,407	77
1889	30,698	1,028,291	558	13	0.074	3,479	2.6	33,278	4,720	196
1890	31,498	1,163,737	528	16	0.184	3,583	2.97	34,151	4,935	151
1891	31,528	1,159,029	462	18	0.286	4,253	0.97	34,499	4,619	318
1892	30,015	1,023,215	415	13	0.0496	4,163	0.55	34,908	4,208	338
1893	....	....	.....	.....	......	......	.....	......	.....	....

PRODUCTS SOLD BY THE ROYAL SMELTING WORKS AT FREIBERG AND THE BLUE-COLOR WORKS AT SCHNEEBERG.(*a*) (IN METRIC TONS.)

Year.	Arsenic Products. (*d*)	Bismuth.	Cobalt (*e*) Products.	Copper Sulph	Gold.	Lead Prod. (*f*)	Lead, Sheet	Lead, Shot.	Lead, other Mf'es of. (*g*)	Nickel Speiss.	Silver.	Sulphuric Acid (*h*)	Other Chemicals. (*i*)	Zinc and Zinc Gray.
	Tons.	Tons.	Tons.	Tons.	Kilos.	Tons.	Tons.	Tons.	Tons.	Tons.	Kilos.	Tons.	Tons.	Tons.
1875..	778	2.4	518	1,332	151.367	2,995	244	128	543	6	43,286	11,636	622	226
1876..	694	3.8	404	1,540	151.110	3,584	285	111	484	....	29,215	9,291	872	188
1877..	717	1.8	436	1,162	177.885	3,475	350	94	515	13	34,065	12,612	732	255
1878..	1,020	1.1	397	1,545	137.265	3.853	455	111	685	7	36,709	11,531	807	321
1879..	981	2.6	440	1,479	171.225	5,252	254	105	716	6	41,041	11,365	853	276
1880..	866	1.3	424	1,321	136.955	5,082	98	74	655	43	44,659	14,897	1,165	158
1881..	1,125	1.2	439	1,534	159.450	3,484	522	50	783	20	39,134	14,107	1,010	134
1882..	1,235	1.8	429	1,399	281.600	4,364	679	71	876	5	50,986	14,718	1,086	145
1883..	1,233	2.2	393	1,621	343.000	4,112	597	82	951	16	58,947	15,527	1,159	209
1884..	1,230	0.6	380	1,616	394.550	3,970	809	67	1,077	56	60,309	16,243	1,194	94
1885..	1,244	2.3	379	1,778	466.950	2,246	864	168	1,247	20	79,950	14,979	1,174	188
1886..	1,125	3.4	387	1,698	587.975	2,628	671	282	1,199	28	59,783	13,399	1,274	40
1887..	1,156	2.0	416	2,065	587.077	2,335	801	404	1,033	40	89,265	14,867	1,415	46
1888..	1,058	2.2	438	2,102	581.957	4,237	674	299	573	....	93,077	15,534	1,070	180
1889..	1,066	2.1	449	2,217	462.140	4,861	1,094	210	407	61	81,327	15,682	874	1
1890..	1,342	1.9	453	2,404	778.155	4,393	1,330	248	612	35	84,201	16,653	1,082	210
1891..	1,170	2.5	416	1,750	949.657	4,159	1,200	193	179	56	83,513	13,832	726	207
1892..	1,075	2.0	407	1,975	778.406	6,054	565	187	356	49	94,830	10,860	932	212
1893..	....	....	....	......	....	......	......	......	......	....	....	....	....	....

(*a*) From *Jahrbücher für das Berg- und Hüttenwesen im Königreiche Sachsen.* (*b*) See the appended table of Metal Contents of Mixed Ores Treated at the Royal Smelting Works at Freiberg. (*c*) Fluorspar, barytes, mineral paint, etc. (*d*) Including arsenious acid, red, yellow, and white glass, and metallic arsenic. (*e*) Product of the blue-color works at Schneeberg. (*f*) Including soft lead, antimonial lead, litharge, etc. (*g*) Lead pipe, etc. (*h*) Including sulphuric acid of various sorts. (*i*) Copperas, sodium sulphate, etc.

THE MINERAL INDUSTRY OF GREECE.

By E. Grohmann.

The accompanying table of production shows clearly the bad effects which the fall in prices of the chief metals has had upon the mineral industry of Greece. The English coal strike also contributed to this by increasing the freight charges. The chief sufferers from low prices were the zinc producers and the lead works of Laurium, while the increase in freight affected the iron-ore mines of Laurium and of Seriphos. The high exchange of gold, which stood at 160% (one franc, gold=1.60 drachma), somewhat lessened the bad effects of low prices.

One of the chief smelting works, Laurium, treated exclusively the old slags and dump-heaps. The slags are nearly all worked out, and of the dump-heaps only the poorer portions remain, viz., those containing 3% to 4% lead and 70 to 100 grams silver per ton. Concentrating works capable of treating 1000 tons of raw material per day were completed during 1893. There were about 6700 tons produced from these old dumps during the year, the rest of the lead, or a little more than half, being obtained from new workings, from which only the purest galena was exported. The average silver contents of the lead was about 2000 grams per ton. Since their erection to the end of 1893 the Laurium works have smelted 283,800 metric tons of lead, of the value of $31,860,000.

The Laurium mines have also produced considerable quantities of zinc ores. Since 1875 to the end of 1893 there have been exported from these mines 555,000 metric tons of calcined calamine, of the value of $12,265,600. There has been a gradual decrease in the production of zinc ores in the last few years, due to the exhaustion of old workings, but there exist several deposits which only require to be properly developed to yield large quantities.

Since 1881 manganiferous iron ore, containing 33% to 40% iron and 12% to 18% manganese, which (if it contained 4% to 6% lead) had been used only as flux, has been exported. It is estimated that, altogether, about 200,000 tons have been consumed as flux, while to the end of 1893, 1,065,880 tons, of the value of $2,679,500, have been exported.

Iron Ores of Seriphos.—The iron mines of Seriphos are very ancient. The Romans used the island as a colony for convicts, who were made to work the mines. Exploitation was commenced in 1870, but there were only 42,000 tons produced up to 1880. Since then a French company has operated the mines, and has exported the following quantities:

Year.	Total Exports, Net Tons.	Exports to United States Net Tons.	Year.	Total Exports, Net Tons.	Exports to United States Net Tons.
1881	5,150	....	1888	18,150	6,950
1882	6,250	....	1889	37,750	18,775
1883	28,100	4,800	1890	89,470	36,460
1884	21,645	13,185	1891	76,350	19,980
1885	7,350	3,900	1892	142,445	41,440
1886	32,640	26,300	1893	67,670	....
1887	51,215	45,380	Total	544,135	217,170

These ores contain hematite ores: 46% to 48% iron, 2% to 3% manganese, 2.5% to 4% silica, and 0.02% phosphorus; limonite ores: 50% to 53% iron, 4% to 8% silica, and 0.035% to 0.04% phosphorus. Good ports allow large steamers to load rapidly.

Silver Ores of Milo.—Silver was discovered in Milo and in the neighboring islands of Kimolo and Polino about ten years ago. In 1890 the Government prevented a company, having a concession to work lead-silver mines, from further exploiting these silver deposits and ordered an examination by Government engineers, who found in several places lenticular masses of heavy spar, intermixed clay, surrounded by clay and decomposed trachyte. These masses are imbedded in fresh trachyte. The heavy spar, clay, and trachyte carry silver. It is estimated that there are no less than 10,000,000 tons of this ore. The silver is unevenly distributed and the ore is not rich, averaging about 164 grams per ton (5½ oz.). Some assays have given as much as 4000 grams per ton.

The engineers being of the opinion that large quantities of ore averaging 250 grams per ton could be profitably worked, the Government in February, 1893, offered to grant a lease to the highest bidder to mine 150,000 tons within fifteen years. It was easy to foretell that under these conditions and with the low price of silver no one would undertake to mine eight-ounce ore.

Magnesite.—This mineral holds an important position. Its occurrence in nature as magnesium carbonate appears to be rather limited, and nowhere else can it be found in such workable quantities as in Greece. The composition of the ore is as follows: Magnesium carbonate, 96% to 98%; silica, 1% to 1.5%; alumina, 0.5% to 2%; calcium carbonate, 0.5% to 1.5%; iron carbonate, 0.3% to 0.5%. The manufacture of bricks from burnt magnesite was first carried out in Styria, Austria, but for some years past there has been an establishment at Eubea. After many experiments and difficulties on account of the high temperature necessary (above the melting point of platinum) to burn the magnesite to a tenacious substance, they succeeded about the middle of 1893 in carrying on the operations continuously. The maximum compressibility of magnesia is at 1800° C., with a diminution of 80% in volume. The "Chamotteskine" and "Dinas bricks" used in the construction of the furnace (Hoffmann's circular) were unable to withstand the heat; now the magnesium bricks are used. The sp. gr. of these compact bricks is 2.64, and their composition is: Magnesium carbonate, 93.25% to 96.25%; calcium carbonate, 1.5% to 3%; silica, 1.5% to 2.5%; iron oxide and alumina, 0.75% to 1.25%.

Emery.—Emery is found in several of the Greek islands, but chiefly in Naxos, where it has been exploited for a long while, and occurs in bowlders in crystalline limestone of the Archæan age. These mines could very easily compete with those of Asia Minor between Smyrna and Ephesus, as they are purer, containing, before undergoing any cleaning, 68% to 70% corundum, against 65% of the Smyrna deposits. The old method of fire-setting is still used on account of the difficulty of boring, even with the hardest steel. The price of emery in blocks at the coast of Naxos is 65f. per metric ton. Loads of at least 300 tons can be obtained, but on account of the bad ports it is difficult and expensive to ship such large blocks. Between the years 1869 and 1886 the quantity of Naxos emery produced was 41,344 metric tons, valued at $1,809,220. From 1869 to 1889 the Government supplied emery at the fixed price of 218–80f. at Naxos. Since then the competition of the Smyrna mines has brought the price down, as stated above, to 65f.

MINERAL PRODUCTION OF GREECE. (*a*) (IN METRIC TONS.) (1 drachma=20 cents.)

Year.	Blende.		Calamine, Calcined.		Chrome Ore		Emery.		Gypsum.		Iron Ore.		Iron Ore, Manganiferous.	
1883..	3,880	....	*c*39,852	....	......	......	2,222	....	426	......	*b*33,938	....	56,803	....
1887..	7,761	$144,800	33,136	$628,400	212	$3,040	2,200	$96,272	90	$1,620	51,215	$66,580	114,540	$335,074
1888..	10,900	224,600	32,505	645,400	200	2,920	2,200	96,272	90	1,620	18,150	22,506	106,200	280,600
1889..	5,400	168,900	27,615	725,400	596	7,748	2,200	96,272	85	1,530	37,850	47,312	98,645	224,660
1890..	2,310	84,220	32,850	1,056,800	800	9,600	11,111	....	98	1,764	90,470	113,088	126,620	329,240
1891..	2,870	102,440	25,800	811,200	200	2,400	936	18,720	100	1,800	76,350	96,200	108,733	262,486
1892..	2,800	75,160	24,769	624,160	470	17,934	1,479	19,227	110	1,800	142,445	185,178	157,756	371,190
1893..	2,727	47,480	19,862	385,300	1,820	20,800	2,449	31,837	133	2,180	67,670	81,200	121,352	281.540

Year.	Lead Ore, Argentiferous.		Lead, Argentiferous.		Lead Dust.		Lignite.		Magnesite.		Manganese Ore	
1883..	....	....	9,612	....	....	....	8,200	....	3,642	. ....	400	....
1887..	1,616	$87,830	12,922	$1,343,888	....	....	5,500	$11,000	7,000	$25,200	500	$3,500
1888..	2,620	132,048	14,543	1,483,676	....	....	6,500	13,000	300	21,080	1,475	10,620
1889..	1,330	63,840	13,567	1,387,900	....	....	5,560	11,120	1,200	4,320	10,660	70,356
1890..	3,250	159,380	13,787	1,441,600	2,549	$25,400	8,500	17,000	8,734	27,949	13,547	93,474
1891..	3,946	154,683	14,528	1,462,970	1,900	19,000	10,700	21,400	5,223	15,669	13,453	86,099
1892..	2,380	74,720	15,958	1,410,780	1,129	9,800	11,500	23,000	10,100	28,400	11,716	84.120
1893..	4,625	97,122	14,534	1,156,900	1,913	17,800	12,134	24,268	8,815	24,680	5,250	36,760

Year.	Millstone, No.		Puzzolan.		Sea Salt. (*d*)		Silver Ore.		Sulphur.	
1883..	24,148	......	37,000	....	13,860	....	......	....	......	....
1887..	......	$7,000	28,980	$25,680	17,000	$272,000	4,864	$38,912	1,346	$43,072
1888..	......	7,640	28,500	25,640	17,500	280,000	2,927	25,717	1,670	53,440
1889..	......	7,000	47,928	43,134	19,455	311,280	1,356	10,305	1 552	44,696
1890..	......	6,000	44.284	39,855	18,000	288,000	......	....	2,044	65,020
1891..	......	5,200	34,727	31,248	19.772	316,352	......	....	1,498	46,120
1892..	......	5,200	30,800	27,720	21,600	345,600	......	....	1,664	46,592
1893..	......	8,000	32,348	29,100	18,329	293,264	......	....	2,400	67,380

(*a*) The figures for 1887–93, inclusive, furnished by Mr. E. Grohmann of Seriphos; for 1883 from *L'Industrie Minérale en Grèce*, Athens, 1893. There are no official statistics for 1884, 1885, and 1886. The figures for gypsum, lignite. millstones. puzzolan, salt, and sulphur are the sale returns. The figures for all the other substances are the quantities exported. Of substances not included in the above, there were sold: Silver, 1890, 200 kilos, $6000; soft lead, 1890, 27 tons, $1700; 1892, 76 tons, $4370. Exported: Copper ore, 1890, 150 tons, $5250; magnesia bricks, 1893, 1275 tons, $25,500. (*b*) Contained from 4% to 6% lead. (*c*) Of this 2601 tons were raw calamine. (*d*) Government monopoly.

ITALY.

By N. Pellati.

Few European countries have shown a greater increase in mineral production during the last twenty-five years than Italy. In 1860 the total value of the output was a little less than 25,000,000 lire ($5,000,000), and in 1891 the amount had increased to 80,000,000 lire ($16,000,000), or more than threefold. In 1892 the value had fallen to 76,000,000 lire ($15,200,000), but the decrease for that year was in value, not in quantity. This is a remarkable growth, and it is, therefore, interesting to note the items which have contributed to the gain, and which may be briefly enumerated as follows:

1. The zinc ores of Sardinia, the output of which was insignificant up to 1865, but in 1892 was valued at 13,000,000 lire ($2,600,000).

2. Sulphur, the production of which was valued at 19,000,000 lire ($3,800,000) in 1860, increased, with some fluctuations, to 45,000,000 lire ($9,000,000) in 1891. In 1892 this value dropped to 39,000,000 lire ($7,800,000), the fall being due to lower prices, since the actual product increased 23,000 tons.

3. The silver and silver-lead ores of Sardinia increased in value of output from 3,000,000 lire ($600,000) in 1860 to 10,000,000 lire ($2,000,000) in 1877; since that year the value has fluctuated between $1,200,000 and $1,500,000. Although the quantity mined has increased recently, the value has diminished.

4. The quantity of copper ore mined increased from 32,624 tons in 1860 to 102,427 tons in 1892, and the value from 658,315 lire ($131,663) to $550,000.

5. The quicksilver produced in 1860 was 34 tons; in 1892 it was nearly ten times as much, being 325 tons, valued at $305,500, although less than in 1891.

6. Iron ore is one of the products which have not shown a gain. The output reached its highest point, a value of 5,000,000 lire ($1,000,000), in 1881, but has since declined to 2,000,000 lire ($400,000). The ore mined is exported, chiefly to England and Belgium, though a little has been sent to the United States.

7. Boracic acid is a product of some importance. Like iron ore, this has not increased. The highest point reached was in 1868, when the value was 5,000,000 lire ($1,000,000); in recent years it has varied from $300,000 to $400,000.

8. While Italy has no true coal, there are mines of lignite, the production of which increased steadily, from 30,000 tons in 1860 to 400,000 tons in 1889, though it has since declined to 300,000 tons in 1892.

The notable increase in production has been accompanied by a corresponding improvement in the conditions under which mining is carried on. The reports of the producers showed at the end of 1866 that the power employed for hoisting and other purposes amounted in all to barely 1000 horse-power, most of which was derived from hydraulic motors. In 1892 there were at work in the mines 252 steam engines and 28 hydraulic motors, capable of furnishing a total of 5156 horse-power. To take one branch of the industry alone, in 1864 there was in the sulphur mines of Sicily only a single shaft worked by steam-power. Last year there were sixteen vertical shafts and eleven inclines provided with hoisting engines, with a total of 441 horse-power. During the same period the power employed in pumping increased from 120 horse-power to 566 horse-power.

In recent years some extensive works have been executed for freeing mines from water. The most notable of these is the great drainage adit of the Monteponi mines in the island of Sardinia, which has been driven for a distance of 6000 meters and drains the mines to a depth of 50 meters.

Great progress has also been made in ore dressing, especially in lead and zinc ores. In the mines of Sardinia prior to 1868 the dressing was done by hand or with the rudest and simplest appliances. These have given way to plants of improved designs. At the Malfidano mines last year 76,000 tons of 15% zinc ore were concentrated to 17,000 tons of 35% ore and 240 tons of 60% galena, carrying over 500 grams of silver to the ton. At the Monteponi mines there is a plant of almost equal efficiency. The ore-dressing works of Montevecchio, San Giovanni, Monte Narba, and others are also worthy of note.

Important progress has been made in quarrying and preparing building stone. In marble the value of the product has increased in twenty years from 11,000,000 to 25,000,000 lire ($2,200,000 to $5,000,000). Equal advances have been made in the production of pozzolano, of volcanic tufa, of hydraulic cement, and of clay and other materials for ceramic work.

While Italy is not especially an iron country, the value of its products in iron and steel is considerable, having reached 86,000,000 lire (or over $17,000,000) in 1889; since then it has declined on account of commercial depression.

Notable advance has also been made in the conditions under which miners are required to work. The mining laws put in force in recent years provide for the proper ventilation of mines, for the care and management of engines and boilers, and for the safety of hoisting apparatus. The conditions under which women and minors may be employed are also strictly regulated. The Government has gone further, and has provided for the insurance of miners against disabilities resulting from accident and old age, and has also required the establishment of hospitals for cases of accident and sickness, and of schools for the instruction of children. Very full reports are required from all mine operators as to the condition of the workings with respect to ventilation, safety, and other matters. Especial pains have been taken to encourage the formation of co-operative associations among the miners.

The latest statistics attainable show that last year the number of men killed by mining accidents was only 1 per 1000 employed, a ratio which is believed to be lower than that of any other European country.

MINERAL PRODUCTION OF ITALY. (*a*) (IN METRIC TONS).

Year.	Alum.		Alunite.		Antimony Ore.		Asphaltum.		Boracic Acid.		Copper Ore.		Gold Ore.		Graphite.	
	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$
1860	723	52,512	3,788	....	19	......	5,300	5,900	......	....	32,624	131,663	5,623	50,382	84	1,008
1861	725	52,600	3,800	....	76	......	5,500	6,100	1,678	268,480	29,540	121,959	2,888	42,301	500	2,000
1862	705	51,520	3,627	....	......	......	5,100	5,700	1,207	193,120	22,937	111,736	2,030	43,686	500	2,000
1863	712	52,028	3,684	....	......	......	5,400	6,000	1,294	207,040	12,693	95,144	4,022	27,027	500	2,000
1864	712	52,028	3,694	....	.....,	......	5,200	5,800	515	82,400	20,258	119,827	10,381	47,130	500	2,000
1865	713	52,072	3,700	....	......	......	5,600	6,200	6	960	22,853	113,258	4,797	41,158	500	2,000
1866	643	48,992	3,025	....	250	10,000	5,300	5,900	622	99,520	25,859	322,428	9,190	79,953	728	2,912
1867	680	51,796	3,415	....	250	10,000	5,500	6,100	2,551	408,160	25,856	286,877	9,190	79,953	728	2,912
1868	712	52,028	3,694	....	250	10,000	5,800	8,800	6,804	1,088,640	25,115	227,109	9,190	79,953	728	2,912
1869	660	50,250	3,235	....	250	10,000	7,100	20,600	2,405	384,864	24,298	228,510	9,190	79,953	728	2,912
1870	652	49,080	3,193	....	250	10,000	5,600	7,280	1,615	258,464	25,078	250,006	9,190	79,953	728	2,912
1871	645	49,780	3,045	....	250	10,000	7,000	16,080	3,732	597,168	27,476	235,274	10,947	75,196	600	2,400
1872	667	50,784	3,300	....	250	10,000	8,500	22,000	2,749	403,952	26,370	212,323	8,847	65,711	3	35
1873	669	51,076	3,300	....	250	10,000	3,520	19,560	1,847	295,552	26,763	193,444	5,789	26,707	600	2,400
1874	......	....	3,663	....	250	10,000	551	3,227	1,868	298,960	26,823	201,189	1,788	7,831	50	200
1875	......	....	3,966	....	200	8,000	1,327	6,565	2,461	393,824	26,649	301,756	2,704	25,054	30	120
1876	129	10,320	5,340	....	200	8,000	3,197	82,950	2,546	407,448	23,330	293,797	6,253	42,708	886	6,202
1877	2,050	102,500	4,132	....	490	23,000	7,744	18,053	2,697	431,520	24,173	362,104	7,453	50,278	861	6,027
1878	2,930	117,200	2,235	....	600	21,600	6,979	49,232	3,443	551,008	22,682	318,337	8,804	64,416	800	4,000
1879	2,100	75,600	3,864	38,640	470	20,120	12,173	95,675	2,506	400,896	20,751	222,146	9,700	83,305	1,327	6,465
1880	......	....	4,936	49,360	540	21,600	6,260	51,494	3,087	494,152	30,181	350,464	11,757	119,706	1,327	6,465
1881	1,400	42,400	8,068	80,680	600	23,725	9,380	66,970	2,659	425,456	26,257	332,991	12,190	95,034	3,443	30,987
1882	......	....	10,840	108,400	1,450	65,700	8,332	27,340	3,025	484,198	24,065	397,068	12,202	91,198	4,147	37,323
1883	......	....	8,530	68,240	2,027	58,295	6,739	47,270	3,158	505,264	23,947	413,972	10,486	69,001	4,200	37,800
1884	......	....	1,650	13,200	1,714	59,476	17,350	91,040	2,517	337,410	27,482	440,388	15,037	89,361	4,000	36,000
1885	2,950	83,200	6,000	36,000	2,887	80,195	13,728	61,356	1,761	190,188	27,236	317,151	11,106	99,691	4,000	36,000
1886	5,320	39,960	6,000	36,000	1,738	39,991	17,943	77,650	3,063	306,280	25,162	220,013	10,759	106,530	4,000	32,000
1887	2,260	57,500	6,000	6,000	848	21,166	18,507	83,984	2,879	305,163	43,826	243,878	11,134	116,983	1,572	3,419
1888	1,380	31,581	6,050	6,050	507	13,249	20,064	101,022	2,603	260,250	47,088	324,367	10,638	97,632	1,390	2,889
1889	1,380	30,120	5,600	28,000	563	20,014	29,844	108,206	2,473	247,310	48,214	268,306	10,932	101,685	1,531	2,144
1890	1,290	26,276	5,000	5,500	891	65,742	45,125	240,778	2,824	301,424	50,378	371,541	8,296	104,320	1,735	4,656
1891	1,029	20,080	4,000	3,840	891	65,742	28,180	135,780	3,831	444,780	53,059	565,867	7,729	93,276	2,415	6,593
1892	1,695	36,050	4,000	3,840	621	45,672	34,580	168,184	2,560	321,910	102,427	552,288	6,612	94,696	1,650	3,778
1893	......	....	......	....	......	......	....	....	......	....	....	....	......	....	......	......

Year.	Iron Ore.		Iron Pyrites.		Lead Ore. (*b*)		Lignite.		Manganese Ore.		Manganiferous Iron Ore.		Mercury.	
	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$
1860	82,708	206,184	1,960	3,293	10,407	603,159	30,280	70,223	652	12,822	....	....	34	29,952
1861	82,719	194,676	2,200	4,400	15,493	646,504	33,531	76,966	523	9,507	....	....	24	20,608
1862	105,228	243,158	5,000	6,000	16,134	674,641	43,381	86,294	1,742	16,229	....	....	26	22,126
1863	137,447	298,603	4,600	11,040	17,458	757,308	36,189	88,878	725	6,916	....	....	22	18,629
1864	134,482	286,147	4,750	5,178	10.524	468,014	38,210	77,040	723	8,878	....	....	26	21,194
1865	142,145	273,679	2,169	5,206	17,248	814,082	37,490	86,246	580	6,960	....	....	26	22.792
1866	154,467	318,685	2,281	5,064	21,594	928,873	50,319	119,125	722	7,452	....	....	20	17,264
1867	141,210	287,927	2,281	5,064	28,350	1,253,027	42,476	98,660	688	8,372	....	....	15	13,804
1868	116,816	230,432	2,564	6,196	31,019	1,536,724	51,386	124,177	672	8,180	....	....	18	15,464
1869	111,739	211,642	2,692	6,708	31,063	1,559,204	56,201	125,121	770	10,780	....	....	24	22,016
1870	89,248	157,334	2,702	6,787	26,352	1,315,559	58,770	132,839	640	8,960	....	....	47	43,673
1871	85,517	147,870	3,956	9,104	22,454	1,076,354	80,336	178,612	792	10,148	....	....	36	41,116
1872	163,339	280,896	4,254	10,296	25,716	1,249,608	93,555	222,549	1,143	12,758	....	....	27	34.082
1873	259,418	494,317	5,380	12,520	22,814	1,443,898	116,884	298,183	3,153	58,237	....	....	31	49,602
1874	279,583	802,354	3,350	8,520	27,120	1,644,814	127,473	335,865	3,220	60,826	3,500	7,000	32	55,500
1875	227,547	607,758	4,190	13,080	30,681	1,622,211	116,955	298,482	3,811	66,675	20,000	100,000	82	121,044
1876	231,790	590,726	4,460	11,757	32,404	1,725,883	116,399	242,868	6,909	63,289	23,245	96,699	99	147,711
1877	229,732	556,287	5,090	15,704	36,910	2,075,862	120,588	242,728	6,812	58,597	8,000	27,200	111	152,767
1878	189,721	457,437	3,242	8,469	36,512	1,967,094	124,117	245,092	6,655	48,256	6,470	15,851	124	118,204
1879	186,857	420,221	3,355	9,410	41,301	1,660,064	131,318	257,452	5,705	35,070	1,388	2,776	132	131,571
1880	289,058	621,606	4,663	11,353	37,153	1,816,233	139,369	262,676	6,475	42,158	20,471	65,507	116	115,940
1881	421,065	921,187	5,785	13,340	39,533	1,636,875	134,582	249,959	8,767	46,860	30,000	96,000	128	115,166
1882	242,083	579,473	6,521	17,283	47,854	1,677,106	164,737	284,052	6,978	69,638	30,000	96,000	140	111,773
1883	203,582	489,883	6,620	19,345	46,116	1,585,663	214,421	337,280	11,384	54,896	9,000	28,800	206	156,788
1884	225,368	522,945	7,948	22,944	47,386	1,442,088	223,322	340,071	835	7,845	....	....	267	202,939
1885	200,955	425,057	11,372	32,007	41,734	1,171,662	190,413	301,560	1,802	11,294	....	....	237	175,500
1886	209,082	458,491	17,149	30,445	40,773	1,428,248	243,325	360,750	5,561	32,065	....	....	251	185.973
1887	230,575	505,530	18,470	37,165	38,325	1,388,630	327,665	500,572	4,434	22,665	.......,	....	244	204,588
1888	177,157	399,866	14,633	29,532	35,178	1,382,011	366,794	534,515	3.630	15,600	....	....	339	338,615
1889	173,489	377,446	17,022	49,299	36,894	1,412,470	390,320	571,631	2,203	10,360	....	....	385	454,890
1890	220,702	483,203	14,755	37,719	32,187	1,301,539	376,326	581,254	2,147	10,414	....	....	449	583,994
1891	216,486	553,437	19,868	54,118	30,233	1,196,846	289,286	441,170	2,429	12,919	....	....	330	356,400
1892	214,487	554,431	27,670	71,987	33,310	1,139,098	295,713	426,073	1,243	8,359	4,622	8,320	325	305,500
1893	....	....	....	....	....	....	....	....	......	......	....	....	....	....

(*a*) *Authorities:* For 1860–80, inclusive *Natizie Statistiche sulla Industria Mineraria*, Rome, 1881; for 1881–90, *Relazione generale sul Servizio Minerario;* for 1890–92, *Revista del Servizio Minerario*, and for the metallurgical products in 1884, *Oesterreichische Zeitschrift für Berg- u. Hüttenwesen*, 1887, p. 601. $1 = 5 lire. In 1876–82

MINERAL PRODUCTION OF ITALY—*Continued.*

Year.	Nickel Ore.		Petroleum.		Salt, Rock.		Salt, Saline.		Silver Ore.		Sulphur.		Zinc Ore.	
1860	......	......	5	$880	13,200	$33,600	8,800	$62,680	......	......	157,599	$3,826,980	162	$489
1861	257	$5,905	4	640	13,800	36,000	8,275	59,425	......	......	165,883	4,016,166	168	521
1862	60	1.599	4	640	13,500	34,800	9,347	66,071	......	......	165,485	4,012,225	157	832
1863	......	......	8	1,280	14,040	36,960	9,157	64,893	......	......	182,571	4,429,008	265	1,177
1864	7	208	10	1,600	14,200	37,600	9,196	65,165	......	......	180,610	4,284,839	202	1,782
1865	700	12,600	315	13,200	14,100	37,200	8,524	60,968	......	......	171,587	3,892,753	732	8,291
1866	58	1,524	138	7,448	14,000	36,800	11.084	65,287	......	......	198,204	4,745,645	4,492	79,374
1867	58	1,524	110	7,680	13,600	35,200	8,900	57,450	......	......	199,072	4,809,374	6,443	108,995
1868	58	1,524	51	4,440	13,100	33,200	8,900	57,450	......	......	201,333	4,997,055	51,012	687,997
1869	58	1,524	20	3,200	13,600	35,600	8,900	57,450	......	......	200,719	5,255,663	80,524	1,144,302
1870	58	1,524	12	1,920	13,486	34,745	8,900	57,450	......	......	203,874	4,873,241	92,833	1,133,000
1871	90	1,080	38	2,000	13,725	35,700	8,900	57,450	15	$10,178	199,728	5,046,130	56,426	828,968
1872	220	1,901	46	1,920	13,440	34,560	8,900	57,450	15	10,178	239,167	5,954,661	80,861	1,166,023
1873	1,264	15,225	65	2,240	12,733	31,732	11,400	81,510	137	62,510	274,201	6,804,197	79,036	1,053,173
1874	970	17,400	84	2,560	13,258	33,832	11,600	80,092	266	154,897	251,259	7,060,804	64,716	754,402
1875	2,489	44,616	113	3,120	12,943	32,572	10,000	61,430	394	181,086	207,420	5,764,326	61,968	776,872
1876	1,476	21,747	402	9,920	14,700	39,600	8,616	54,388	249	126,646	276,041	6,603,508	66,034	878,649
1877	1,065	8,520	408	10,800	14,516	38.864	10,109	59,618	661	194,352	260,325	5,372,345	88,844	900,020
1878	130	1,300	602	12,400	14,234	49,738	11,213	64,625	1,041	271,914	305,142	6,110,534	62,703	631,251
1879	......	......	402	10.000	17,735	54,226	10,427	64,223	1,409	319,122	376,316	7,295,507	73,411	781,003
1880	......	......	283	17.719	......	......	......	......	1,801	445,832	359,663	7,293,119	85,287	925,764
1881	......	......	172	15,308	19,523	59,620	11,744	75,758	1,444	447,790	373,160	8,381,593	72,176	938,369
1882	......	......	183	17,369	18,800	63,952	10,225	54,358	1,449	347,979	445,918	9,328,508	91,366	903,906
1883	......	......	225	11,677	18,900	64,629	9,937	53,666	1,510	334,795	446,508	8,478,640	100,574	1,288,226
1884	......	......	396	27,090	17,600	62,106	10,227	55,178	1,626	373,466	411,037	7,304,406	104,974	1,268,918
1885	......	......	270	22,011	17,204	61,558	10,678	57,625	1,485	392,478	425,547	6,992,826	107,887	1,331,828
1886	......	......	219	18,226	18,394	60,263	10,881	62,301	1,639	288,280	374,343	5,592,456	107,548	1,382,392
1887	......	......	208	15,344	18,788	56,185	10,412	59,170	1,892	434,729	342,215	4,738,839	93,143	1,251,412
1888	......	......	174	11,126	18,424	56.327	11,325	78,095	2,005	384,684	376,538	5,002,603	87,310	1,431,888
1889	......	......	177	10,200	18,475	57,298	10.015	54,028	1,997	349,733	371,494	4,930,575	97,059	1,651,555
1890	......	......	417	24,121	17,099	51,660	9,879	67,799	1,750	420,195	369,239	5,653,058	110,926	2,450,529
1891	......	......	1,131	68,420	31,285	75,890	9,258	53,390	2,006	394,697	395,528	8,905,091	120,685	2,544,121
1892	......	......	2,548	150,900	15,504	49,619	8,217	38,455	1,680	345,898	418,555	7,844,333	129,731	2,722,099
1893	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Year.	Antimony.		Asphaltum.		Boracic Acid.		Borax.		Briquettes.		Copper.	
1884	270	$54,000	......	......	......	......	......	......	......	......	400	$112,000
1885	240	41,560	......	......	......	......	......	......	......	......	1,615	676.789
1886	198	27,986	......	......	......	......	......	......	......	......	2,239	700,555
1887	22	2,818	......	......	......	......	......	......	421,014	$2,455,217	3,197	970,839
1888	......	......	......	......	......	......	......	......	502,249	2,871,444	5,332	2,113,865
1889	197	56,013	......	......	2,473	$247.310	......	......	520,450	3,303,180	6,904	2,449.200
1890	182	54,716	10,302	$80,594	1,874	187,400	950	$114,000	576.050	3 664,740	6,406	2,504,365
1891	218	37,714	9,375	66,020	1,775	177,500	2,056	267,280	644,005	4,099,570	5,977	2,243,229
1892	315	53,822	9,270	78,570	1,089	130,680	1,471	191,230	612,069	3,883,650	6,039	2,159,469
1893	......	......	......	......	......	......	......	......	......	......	......	......

Year.	Gold, Kilos.		Iron, Pig.		Iron, Wrought.		Lead.		Petroleum, Refined.	
1884	191	$92,875	18,405	$368,100	120,129	$4,324,844	15,000	$900,000	......	......
1885	209	125,688	15,991	319,820	140,734	5,629,360	16,461	987.660	......	......
1886	195	105,547	12,291	245,820	161,633	6,465,320	19,508	1,487,528	......	......
1887	234	126,985	12,265	220,950	172,834	9,843,840	17,795	1,100,000	......	......
1888	187	101,265	12,538	284,440	176,769	8,285,571	17,481	1,180,000	......	......
1889	216	113.969	13,473	424,619	181,623	10,068,679	18,165	1,235,220	......	......
1890	206	108,836	14,346	425.784	176,374	9,769,728	17,768	1,137,152	350	$42,000
1891	284	166,839	11.930	315,209	152,668	7,996,459	18,500	1,139,600	813	74,448
1892	330	204,579	12,729	411,258	124,273	6,278,691	22,000	1,144,000	1,573	154,495
1893	......	......	......	......	......	......	......	......	......	......

Year.	Salt, Sea.		Silver, Kilos.		Steel.		Sulphate of Alumina.		Sulphur, Refined.	
1884	338,653	$745,037	31,191	$1,154,667	4,645	$464.500	......	......	......	......
1885	410,255	......	33,346	934,056	6,370	382,200	630	$14,800	......	......
1886	353,852	......	33,839	1,082,848	23,760	1,425,600	440	8,160	......	......
1887	391,548	861,406	33,387	1,100,000	73,262	......	1,980	34,000	74,686	$1,448,571
1888	382,593	801,706	34,891	1,098,254	117,785	5,601,293	2.825	43,722	74,474	1,417,083
1889	420,625	539,789	33,505	1,005,150	157,899	7,037,167	2,667	61,248	107,421	2,068,931
1890	442,010	899,851	34,248	1,164,432	107,676	5,821,481	2,553	58,430	105,660	2,213,171
1891	347.274	613,555	37,600	1,203,200	75,925	3,948.766	859	17,108	154,611	4,393.278
1892	395,269	800,831	43,000	1,281,400	56,543	2,756,499	1,890	40,450	182,630	4,595.280
1893	......	......	......	......	......	......	......	......	......	......

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there were also produced 764 tons of tin ore, $2268, and in 1880–81, respectively, 1000 and 3000 tons of sulphate of strontium, valued at $10 per ton. (*b*) Includes mixed or argentiferous lead ores. (*c*) From 1882 no returns for alum were given among the mineral products, and only from 1885 were they included with the metallurgical products. (*d*) Includes the value of 73,262 tons of steel.

MINERAL IMPORTS OF ITALY. (*a*) (METRIC TONS.)

Year.	Coal. (*d*)	Iron, Scrap.	Iron and Steel. (*b*)	Machinery.	Marble and Alab'st'r R'gh.	Marble, W'kd	Ores, Various. (*e*)	Sulphur. (*c*)
1862	446,093	166	60,777	3,720	1,001	......	2,090	1,282
1863	390,391	2,459	85,339	3,614	1,707	......	1,198	775
1864	554,632	166	83,956	4,820	671	......	308	929
1865	456,039	225	79,042	7,820	509	......	3,237	283
1866	524,042	265	62,993	6,937	778	......	418	93
1867	515,943	2,530	68,492	7,247	299	......	6,872	628
1868	580,388	2,488	68,188	6,757	587	......	6,723	536
1869	649,803	3,434	103,086	9,537	836	......	299	289
1870	641,722	5,237	99,119	7,953	505	......	359	349
1871	791,389	8,524	99,724	9,453	585	......	357	253
1872	1,037,409	19,703	93,057	13,299	1,079	......	312	240
1873	959,532	9,243	98,953	18,351	1,075	......	974	277
1874	1,030,816	14,507	127,238	17,313	1,882	103	502	217
1875	1,059,591	14,709	129,117	13,908	1,480	111	819	256
1876	1,454,223	23,367	115,308	14,466	1,211	105	882	219
1877	1,329,549	17,828	135,782	15,162	1,403	143	941	289
1878	1,325,245	18,309	125,703	12,968	1,381	125	2,917	332
1879	1,523,676	58,186	123,156	12,356	1,499	167	3,182	317
1880	1,737,746	53,999	139,682	19,120	1,582	141	190	219
1881	2,073,315	52,057	183,666	24,528	509	188	232	154
1882	2,180,020	70,374	251,433	32,025	505	213	354	466
1883	2,351,092	80,765	255,156	33,559	255	178	695	40
1884	2,605,051	81,856	241,152	33,917	787	204	1,090	55
1885	2,957,436	78,156	255,957	37,283	4,189	198	6,531	45
1886	2,927,092	115,705	241,861	33,766	1,232	293	3,806	57
1887	3,583,143	174,129	310,772	43,904	704	253	5,161	32
1888	3,872,905	164,571	196,908	36,229	410	303	4,148	30
1889	3,999,117	157,228	154,233	37,241	388	396	6,613	24
1890	4,354,847	168,043	101,284	31,651	476	277	6.607	28
1891	3,916,685	137,233	80,488	23,077	296	266	7,346	20
1892	3,877,571	145,723	80,889	22,392	216	379	16,497	50
1893	....	....	....	......	......	......	......	......

MINERAL EXPORTS OF ITALY. (*a*) (METRIC TONS.)

Year.	Coal. (*d*)	Iron Sc'p	Iron and Steel. (*b*)	Machinery.	Marble and Alabaster	Marble M'f'es	Ores, Various.	Sulphur. (*c*)
1862	4,539	4	652	60	20,545	....	16,803	145,530
1863	3,595	26	537	122	39,762	....	14,236	152,763
1864	5,682	10	1,680	82	21,903	....	27,477	143,393
1865	2,974	11	635	70	41,681	....	2,925	145,316
1866	1,879	33	929	92	50,495	....	43,645	179,544
1867	2,068	1,474	679	176	56,828	....	77,087	192,593
1868	3,934	1,759	994	161	70,091	....	59,608	176,426
1869	2,551	1,884	1,883	141	50,227	....	151,732	170,531
1870	11,389	138	1,674	587	55,037	....	136,289	174,318
1871	12,350	232	1,102	1,542	58,143	....	117,017	172,471
1872	3,587	1,866	1,221	371	53,696	....	250,678	182,655
1873	4,189	1,544	4,544	501	64,149	....	246,368	203,051
1874	3,559	334	1,685	320	73,510	22,970	294,880	174,562
1875	7,511	243	976	151	63,983	22,882	286,497	216,675
1876	5,475	505	718	257	48,306	19,979	301,376	195,280
1877	3,668	234	820	307	55,064	17,820	359,509	210,327
1878	3,896	267	779	285	46,822	24,537	262,902	218,326
1879	9,228	281	923	381	51,530	48,377	315,036	242,271
1880	9,069	277	1,519	441	71,893	37,182	523,258	287,149
1881	9,526	277	933	557	52,987	44,454	399,258	289,365
1882	11,663	130	918	800	66,870	43,747	365,183	273,747
1883	8,094	317	921	823	59,374	57,268	368,038	288,380
1884	6,223	149	985	819	61,139	53,340	286,952	277,210
1885	8,592	187	1,372	765	58,452	53,314	291,732	289,257
1886	7,413	119	864	895	52,641	55,513	295,783	300,881
1887	8,084	431	968	861	55,010	55,083	281,421	279,628
1888	6,114	161	1,004	829	53,961	52,954	245,504	323,790
1889	9,360	125	692	1,467	63,915	63,189	333,314	331,902
1890	7,098	59	889	1,189	68,820	58,313	286,889	328,708
1891	13,322	143	576	1,104	69,474	53,958	327,326	269,377
1892	12,919	256	683	1,076	78,404	57,917	272,278	291,081
1893	......	.....	......	......	......	....	....	....

(*a*) From *Annuario Statistico Italiano.* (*b*) Pig and wrought. (*c*) Raw, refined, and flowers of sulphur. (*d*) Al kinds of fuel. (*e*) Iron, copper, zinc, lead, tin, manganese, and cobalt ores. The zinc ore exports were in 1886, 82,134; 1887, 82,541; 1888, 90,674; 1889, 107,066; 1890, 80,759; 1891, 104,656; 1892, 119,286 tons. The iron ore exports were in 1886, 193,480; 1887, 171,553; 1888, 130,743; 1889, 183,281; 1890, 186,676; 1891, 202,309; 1892, 124,755 tons. The lead ore exports were in 1886, 5860; 1887, 10,337; 1888, 7747; 1889, 7439; 1890, 8266; 1891, 7328; 1892, 6695 tons. The copper ore exports were in 1886, 9315; 1887, 11,769; 1888, 9872; 1889, 9034; 1890, 9894; 1891, 10,116; 1892, 12,719 tons.

EXPORTS OF SULPHUR FROM SICILY TO VARIOUS COUNTRIES. (*f*) (IN METRIC TONS.)

Year.	Australia and India.	Austria.	Belgium.	England and Malta.	France.	Germany. (*g*)	Greece.	Italy and Dependci's.	Holland.	Norway & Sweden.	Portugal.	Russia.	Spain.	Turkey.	Un'd States and Canada.	Other Countries.	Total.
1883	....-	....	8,975	59,518	70,049	12,799	......	76,228	.....	.....	....	....	.....	.....	93,095	37,310	357,974
1884	.....	....	6,123	41,305	67,884	12,682	......	67,510	.....	.....	....	....	.....	.....	103,415	39,295	338,214
1885	.....	....	10,914	35,105	63,255	15,115	......	54,313	.....	.....	....	....	.....	.....	90,691	64,126	333,519
1886	.....	....	6,102	33,704	55,500	16,142	......	55,200	.....	.....	....	....	.....	.....	84,666	96,022	347,336
1887	.....	....	5,734	37,380	59,710	16,098	......	57,972	.....	.....	....	....	.....	.....	68,347	83,882	329,123
1888	913	8,936	6,726	39,865	55,321	14.115	6,831	55,155	1,366	3,231	12,575	19,901	7,046	1,115	134,526	453	368,075
1889	345	9,778	8,464	39,031	67,894	18,312	10,502	51,878	1,293	6,487	14,445	17,152	7,938	3,047	114,288	798	371,652
1890	1,679	9,930	7,241	29,420	74,624	13,912	15,151	47,373	1,596	5,313	18,929	14,288	6,556	8,155	109,558	638	364,363
1891	336	11,102	5,241	25,772	58,339	11,249	11.266	47,285	2,037	2,215	7,309	12,642	7,727	2,972	99,439	1,227	306.158
1892	1,954	9,519	5,573	24,997	77,394	16,413	12.847	40,898	2,466	3,626	11,241	13,284	9,627	3,055	89,996	1,042	323,932
1893	.....	....	....	....	....	....	......	....	.....	.....	....	....	.....	.....	....	......	....

(*f*) From *Revista del Servizio Minerario nel* 1892, p. 43. (*g*) Includes exports to Austria from 1883 to 1887.

MERCURY PRODUCTION OF THE MONTE AMIATA MINES AND EXPORTS FROM ITALY (*h*)
(IN METRIC TONS.)

Year.	Prod.	Exp.	Year.	Prod.	Exp.	Year.	Prod.	Exp.	Year.	Prod.	Exp.	Year.	Prod.	Exp.	Year.	Prod.	Exp.	Year.	Prod.	Exp.
1860..	4	....	1865..	4	....	1870..	16	47	1875..	80	106	1880..	116	146	1885..	237	305	1890..	449	450
1861..	4	....	1866..	3	....	1871..	20	55	1876..	97	97	1881..	128	161	1886..	251	284	1891..	330	550
1862..	4	1	1867..	5	5	1872..	21	74	1877..	106	77	1882..	140	244	1887..	244	364	1892..	325	262
1863..	4	....	1868..	5	8	1873..	25	71	1878..	121	83	1883..	206	216	1888..	339	267	1893..	....	....
1864..	4	1	1869..	6	5	1874..	30	82	1879..	130	128	1884..	267	362	1889..	385	394			

(*h*) From *Le Miniere di Mercurio del Monte Amiata*, Firenze, 1890.

JAPAN.

THE mineral industry in Japan, which is a very ancient one, has now nearly reached the end of the period of transition, during which the old methods, dating back to the fifteenth and sixteenth centuries, and even earlier, have been abandoned, and in their places modern machinery and modern metallurgical systems of working have been adopted. The copper mines of Ashio; the gold, silver, and lead mines of Sado; the sulphur mines of Atosanobori; the coal mines at Miike and elsewhere, are all worked with approved appliances, and the results are apparent in their increasing output. The Japanese workmen are generally good miners and readily adapt themselves to new methods, especially under the charge of their own mining engineers and managers, who are careful students of foreign plans and improvements.

The petroleum industry in Japan has shown some improvement during the year, and the Government has undertaken a thorough examination of the oil-producing districts, which will, it is hoped, be followed by new developments of importance, although it is too early yet to predict the final results. Meantime the production has so increased as to lessen the imports of foreign oil.

The coal production of Japan is increasing more rapidly than any other branch of the mineral industry, and the supply already exceeds, by a considerable amount, the demand for home consumption. With characteristic shrewdness and enterprise the Japanese coal operators are pushing their exports, and coal from the Miike, the Takesima, the Namasuka, the Chikuzen, and other mines is already well known in Eastern ports, and the better grades are finding a considerable market for steamship use, their cheapness largely making up for their inferiority to the Welsh steam coal brought from England.

The iron industry of Japan grows slowly, although the demand for iron and steel is steadily increasing. Recently the Government ordered an investigation into the value and extent of the iron ore deposits, with a view to encourag ing their development and to the introduction of the manufacture of steel. The extent of the deposits is considerable, and as there is an abundance of cheap fuel, there ought to be no obstacle to the establishment of an iron industry of considerable magnitude. The railroad system of the country is being steadily extended, and the Government is preparing to spend large sums in shipbuilding, so that there will undoubtedly be a growing demand for iron and steel.

MINERAL PRODUCTION OF JAPAN. (*a*) (IN METRIC TONS.)

Year.	Antimony.	Arsenic.	Coal. (*d*)	Copper. (*e*)	Copper Sulphate.	Copperas	Gold, Kilos	Graphite.
1881	394	10.22	910,094	4,809.73	55.94	948.95	305.068	49
1882	2,504	10.94	944,173	5,660.84	62.83	512.60	272.191	10
1883	2,407	9.79	1,019,576	6,828.72	30.78	391.53	301.242	2
1884	1,492	76.50	1,158,290	8,959.36	44 20	383.12	275.115	2
1885	2,686	8.65	1,314,506	10,624.67	41.24	371.63	274.555	4,231
1886	2,416	7,25	1,396.334	9,852.01	82.91	469 79	465.378	3,837
1887	1,566	7 92	1,774,412	11,151.86	27.40	897.36	521.552	1,084
1888	1,484	6.16	2,039,992	13.480 92	6.53	1,150.30	630.291	5,211
1889	1,944	9.55	2,427,071	16,383.55	65.19	943.00	769.855	4,123
1890	3,224	113.21	2,650,277	18,259.69	27.33	954 76	727.765	4 601
1891*b*	2,286	......	3,226,975	19,186,00	. . .	573.08	721.910	2.479
1892	*g*2,814	38.00	3,175,670	20,726.72	....	....	700 519	600
1893	....	....	....	....	....	....	....	....

Year.	Iron.	Lead.	Manganese.	Petroleum, Liters.	Silver, Kilos	Sulphur. (*f*)	Tin.
1881	16,255	261.56	1 51	2,651.676	17,892 327	703.84	20.07
1882	12,299	234 95	156.87	3,081,278	17,409.811	3,430.11	17.90
1883	14,854	292.29	151.67	3,253,211	24 172,505	6,995 28	20.92
1884	11,955	87.63	125 85	933 559	22,941.253	4.313 39	28 18
1885	6,824	90.65	123.61	1,100,296	23,877 172	4.989.17	41.79
1886	13,870	237.07	405.08	2.025,770	33,743 237	6 498.57	64.28
1887	15,391	388.63	312.73	1,326,241	35,679 803	10 866.94	96 34
1888	18,341	403.20	815.42	5,412,440	42,812.665	23,021.65	82.61
1889	21,333	606.47	947.50	7,422,098	43,042.742	19,158.81	53.22
1890	22,594	780.95	2,612.09	7,634,784	52,935.991	26,775 80	47.83
1891*b*	18,641	814.91	3,249.49	8,408,567	58,816.816	22,105.26	44.71
1892	*h*16,748	911.36	5,018.25	11,164,674	60,237.848	*i* 21,403.82	41.29
1893	....	....	....	....	....	....	......

MINERAL IMPORTS AND EXPORTS OF JAPAN. (*a*) IN METRIC TONS.)

Year.	Imports. (*m*)												
	Brass.		Coal.		Iron		Kerosene.	Lead.		Nickel.		Quicksilver	
1887	4.00	$1,087	11,828	$65,275	6,586.55	$118 369	$1.871,428	1 383.03	$108,835	23.93	$20,381	41.54	$54,819
1888	150 95	89,740	4,376	29,880	20,907.54	397,165	3,519,255	2,171.97	201,252	12.31	14,134	49.43	73,134
1889	7.34	4.090	4,556	40,015	9,885.36	164,148	4,587,135	1 931.14	173,487	61.38	85.340	64.94	105,416
1890	6.59	2,947	11,587	110,497	10,512.47	185,948	4,950,256	971.14	85,425	84.97	118,423	64.49	102,833
1891	94.81	48.238	15,110	142,918	12,287.82	199,209	4,535,720	1,221.38	104,028	8.99	9,651	69 85	105,660
1892	243.66	*j*204405	......	....	62,313 *k*	3,740,219	....	*l*7,077.00	759,033	.....	....	66.48	95,546
1893	......	....	......	....	....	....	....	....	....	.....	....	.....	....

Year.	Imports—*Continued.*				Exports. (*q*)							
	Tin.		Zinc.		Antimony.		Coal.		Copper.		Sulphur.	
1882	......	....	......	....	1,147	$101,110	329,898	$1,177,343	2,748	$829,455	1.163	$31,224
1883	......	....	......	....	1,853	140,243	395,815	1.357,936	2,382	725.551	5,664	119,764
1884	......	....	......	....	997	73.848	527,651	1,809,932	5,224	1,386,800	3,346	66.645
1885	......	....	......	....	2,296	183.290	591.055	1.975,967	8,162	1,825,066	7,539	137,932
1886	......	....	......	....	1,994	154,319	681.665	2.208,549	9,635	2,148,839	4,801	72,550
1887*c*	52 43	$31,238	319.86	$24,995	2,074	163,878	716.284	2.337.806	8,614	2.031.515	8.845	136 022
1888*c*	84.54	51,502	227.57	24,115	1,322	153,320	990.992	3,186,039	9,722	3,518,787	6,991	120,903
1889*c*	101.47	58,812	291.76	31 154	1,512	238 833	1,070 788	4,346,640	10,182	2.878.969	20 273	313,323
1890	127.08	69,281	546.15	69,716	1,716	349,961	1,234,127	4,796.090	19,567	5.352,314	18,801	263,283
1891	128.38	71.721	336.96	42,762	1,859	232,499	1,259,782	4,749,734	17,464	4.877,090	19,149	284,831
1892	104.79	62,984	......	....	*n*1229	163,309	*o*1300,068	4,577,106	*p*18013	4,870,501	.....	....
1893	......	....	......	....	......	....	....	....	....	....	.....	....

(*a*) From *The Mining Inaustry of Japan*, Tokio, 1893. Yens are converted at the rate of 1 yen = $1. (*b*) Fiscal year 1891-92; there were also produced this year 246 tons of iron pyrites. (*c*) In 1887, 1888, and 1889 the imports of antimony were respectively 5.85, 7.12, and 0.25 tons, valued at $1011, $1810, and $78. (*d*) The greater part of the coal produced in Japan comes from Honshiu and Kiushiu (Central and Southern Japan), and the reserves in these fields, at depths not exceeding 500 ft. below sea level, are estimated at 600,000,000 tons. The Honshiu coal is mostly lignite and of inferior quality. That from Kiushiu, in which are the more productive fields, is bituminous, of good quality. (*e*) The most important copper mines in Japan are those at Ashio, which are equipped with modern mining, ore dressing, and smelting machinery, and produce at present about one-third of the total output of the country. These mines have been worked, according to authentic records, since 1610; they are now owned and operated by Mr. Furukawa Ichibei. They produced 294 tons of copper in 1882; 655 tons in 1883; 2315 tons in 1884; 4142 tons in 1885; 3638 tons in 1886; 3032 tons in 1887; 4128 tons in 1888; 4902 tons in 1889; 5862 tons in 1890; and 6099 tons in 1891. (*f*) The most important producer of sulphur in Japan is the Atosanobori mine at Kushiro, in Hokkaido, about 50 miles from the sea. About one-half of the total output of sulphur in Japan in 1890 was derived from this mine, which is equipped with a good plant, and has largely increased its production since 1887. (*g*) Includes 42 tons metal, 1341 tons sulphide, 1431 tons ore. (*h*) Includes steel. (*i*) In 1892 there were also produced 2268 tons of iron pyrites. (*j*) Includes $53,826 for sundries, quantity not given. (*k*) Includes iron and steel manufactures. (*l*) Including sheets and pipes. (*m*) Other metal wares, valued at $147.923. (*n*) Antimony sulphide. (*o*) Includes 716 tons coke. (*p*) Includes crude, refined, and scrap. (*q*) Exported in 1892 and not on table: Minerals, 61.288 kilos, $110,131; lead, 4 8 tons, $419; brass and brass wire, 49.96 tons, $73,013; copper, sheet and wire, 9.47 tons, $31,680; iron manufactures, $44,806; bronze manufactures, $213,522; sundry manufactures, $43,007.

NORWAY.

The mining statistics of Norway were in 1866 incorporated in the official statistics of that country, an innovation due less to the prominence of the mining industry than to the expectation of its development and the intention to promote it. Previous to that year only fragmentary records are available.

In the beginning of the sixteenth century the Government induced German miners to settle in the country, and it promulgated the first mining regulations, which were framed after the German pattern. During the next two centuries the industry advanced considerably.

Norway's chief silver mine, Kongsberg Sólvvœrk, was opened in 1623, and operated on a far greater scale than now, through many vicissitudes from considerable profits to frequent losses. Its maximum output, in 1833, was 41,000 marks of fine silver, or more than $400,000 in value; its aggregate production from 1830 to 1870 was 887,950 marks of fine silver, or about $5,103,800 in value.

The fragmentary records of the production of copper before 1866 are as follows, in metric tons, centners being converted at the rate of 1 centner = 50 kilos.

	Output.	Export.	
		Copper.	Copper. Ore.
1781	650	....	....
1791	495	....	....
1821–26 average	385	. ..	....
1827–29 “	340	....	....
1830–35 “	380	320	....
1836–40 “	675	467	960
1841–45, average	625	510	13
1846–50 “	545	475	6
1851–55 “	562	509	305
1856–60 “	562	536	658
1861–65 “	521	450	770

In 1870 hardly one-third of the output of copper ore was smelted in Norway, two-thirds being shipped to England to be treated. Considerably more than half of the copper industry in Norway was then conducted by foreign capital.

Of copper sheets there were imported, yearly, in 1851–55, 24.4 tons; in 1856–60, 54.2; and in 1861–65, 179. Adding the importation of other wrought copper and of copper in alloys, the consumption of copper in Norway appeared equal to the production, apart from the copper in the exported ores.

The number of employees in the copper industry was, in 1865, 984, and in 1870, 1054, of whom 210 worked at the smelters.

MINERAL PRODUCTION OF NORWAY.*—*Continued on opposite page.* (In metric tons.)

—*Continued on opposite page.*

Year.	Apatite.		Cobalt Ore.		Copper Ore.		Feldspar.		Iron Ore.		Nickel Ore.	
	Tons.	Value.	Tons.	Value†	Tons.	Value†	Tons.	Value†	Tons.	Value†	Tons.	Value†
1866	....	......	85	$20,600	13,885	$151,300	....	....	24,580	$49,700	3,600	$36,000
1867	....	....	30	7,500	15,285	139,200	.... ..	....	18.785	37,500	3,600	36,100
1868	....	... ...	5	4,368	14,795	155,584	....	....	19,895	39,000	6,885	71,552
1869	....	......	30	14,456	15,710	177,112	.. ..	....	16,800	30,264	4,720	49,192
1870	....	....	10	4,056	16,785	159,536	....	....	21,155	38,584	3,780	39,416
1871	....	....	25	13,520	17,730	170,040	....	....	7,165	14 144	5,975	99,736
1872	....	....	65	35,152	17.940	291,616	....	....	32,980	90.168	7,665	127,660
1873	....	....	75	40,560	18.500	269,672	....	....	28,960	81.848	23,725	342,680
1874	....	......	65	35,100	8,880	158,210	....	....	29,805	73,060	22,030	365,530
1875	....	.....	60	32,500	12,410	170,544	....	....	28 805	71,500	34.850	674,700
1876	2,070	$59 020	95	49,400	13,940	291,460	4,300	$22,360	20,535	43,160	42,550	406,900
1877	2 406	69 740	105	52,000	17,565	252,278	2,000	10,504	17,265	36,140	18,695	157,300
1878	2,863	83.382	105	52,000	12,220	202,006	4,143	21,504	11 880	25.012	3,800	35,100
1879	2,035	52.936	108	52,000	10,478	166,504	5,534	28,808	8 060	16,640	4,548	30,680
1880	7,945	206,570	87	45,500	10,102	165,750	8,069	41,964	6,715	13.780	11,150	84,500
1881	8,992	233,792	80	41,600	10,181	170,040	11,729 -	45,734	6.210	12,610	12.731	96.200
1882	15,338	218,556	99	52,000	11,262	222.910	6,957	287,144	1,950	3,640	14,010	101,580
1883	9,884	308,386	84	14,326	12.955	172,176	10,591	41,394	2,128	4,160	15,226	110,578
1884	6,460	184,730	90	12,922	12,395	171,600	6,889	26,858	......	....	12,398	91,130
1885	1,605	43,810	101	13,702	12,385	127.036	6,434	21,736	200	438	10,217	78,234
1886	1,719	39,572	123	11,960	12 264	102,206	8,196	27,716	....	.. .	5.618	42,536
1887	4,821	119,080	57	4,160	13,250	86,554	5.923	23,088	1,904	2.834	4,283	31,460
1888	4.797	112,242	84	8,060	15,439	220,190	9,162	40,482	1.385	2,080	5,459	39,780
1889	10,665	240,994	152	14,300	16,614	150,072	10,995	51,454	800	1,456	7,099	46 020
1890	11,119	260,182	213	19,500	18,769	186,680	11,850	55,458	1.300	2,340	8,181	48,360
1891	4,258	94,120	....	.	20,939	185,120	12,257	55,900	1,464	2,600	12,839	....
1892	...	......	....	....	....	....	....	....	....	.. ....	... .	... ...
1893	...	...		...	.... .	..... .	. ....		....	... .	.....	....

Year.	Pyrites, Iron and Copper.		Silver Ore.		Zinc and Lead Ore.		Arsenic.		Cobalt.		Copper.	
	Tons.	Value†	Tons.	Value†	Tons.	Value†	Tons.	Value.	Tons.	Value†	Tons.	Value.†
1866	56,305	$324,900	812	$127.300	....	....	....	....	*a*10	$8,200	500	$185,900
1867	70,840	388.100	773	136,300	2,925	$26,300	..... .	....	....	....	505	172,700
1868	63,225	356,824	758	150,176	5,755	53.872	......	....	....	4.732	505	170.248
1869	70,155	394,368	748	135,600	3.630	34,008	....	....	*b*14.50	15,938	550	185,432
1870	66,620	354,952	977	146,432	2,480	23,192	....	....	*b*27.50	4.420	535	163.176
1871	90,355	519.688	827	121,472	1,125	11,752	....	....	*b*20.50	16 640	647	201.968
1872	98 850	674,960	737	105.248	995	10,400	.... .	....	*b*30.00	36,920	676	294,528
1873	63,740	389,480	742	111,904	380	3,952	....	....	*b*41.00	37,180	530	231,816
1874	49,170	305,500	702	123,734	250	2,600	....	....	*b*44.50	28.600	409	159,380
1875	46.795	304,980	702	132,704	.... ..	....	....	....	*b*39.50	24.700	280	120,120
1876	26,430	203,710	770	169,182	....	....	1.90	$182	8.80	58,500	565	233,792
1877	20,280	174.954	915	180.440	....	....	.... ..	....	8.97	58.500	831	299,936
1878	55.495	379,860	1,148	191,932	....	....	....	....	12.04	72,800	1,005	377,988
1879	50,318	362,882	875	188,760	....	....	....	...	10.90	57.200	753	227,786
1880	59,495	404.320	885	170,820	....	....	....	....	10.60	52,000	892	270,660
1881	70,558	489,450	1,190	189,800	......	...	3.30	312	8.10	49,400	936	270,400
1882	77,315	544,440	1,264	235,040	300	3,900	3.60	338	14.10	59,800	719	236,080
1883	65,090	358.280	1,406	241.220	200	2.340	1.60	104	6.88	21,502	670	170,300
1884	71,277	396,604	1,310	256,360	571	6,656	2.30	182	6 21	18,122	641	173,800
1885	65,255	286,078	1,264	269,880	300	3,510	1.50	104	6.58	19,266	676	129,200
1886	49,919	256,230	1,023	187,980	....	....	....	....	6.56	16,900	455	87,100
1887	53,222	213.590	919	171,600	....	....	. ....	....	4.50	11,700	310	63,960
1888	55,902	291.928	1,117	163,280	1,540	18,200	....	. ....	6.20	16,900	299	96,200
1889	59,051	252.720	1,636	171,200	3,278	29,744	2.50	208	3.70	9.880	435	101,400
1890	58.669	262.600	1,311	161,460	3,941	35,620	....	....	2.60	7,020	466	120.900
1891	49,048	209,560	1,277	149,890	498	4,550	... ..	....	7.00	18,200	677	....
1892	....	....	... ...	....	.. ..	.... ..	....	....	....	....	....	....
1893	....	. ...	....	....	....	....	....	....	....	....	....	....

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* For the years 1866–90, from *Tabeller vedkommende Norges Bergværksdrift*, Christiania, 1874–92; for 1891, from *Meddelelser fra det statistiske Centralbureau*, Vol. XI., No. 5. † The first two years converted from specie daler, and the others from kroner : 1 specie daler = $1; 1 krone = 26c.

Of iron (pig and castings) Norway produced in 1781, 8215 metric tons (164,300 centners); in 1792, 2380 tons (47,600); in the period 1813–17, on an average 3450 tons (69,000); in that of 1821–25, 5320 tons (106,400); in that of 1827–29, 6300 tons (126,000); in that of 1830–35, 6300 tons (126,000); in 1836–40, 7600 tons (152,000); in 1841–45, 10,230 tons (204,600); in 1846–50, 9745 tons (194,900); in 1851–55, 9860 tons (197,200); in 1856–60, 9305 tons (186,100); and in 1861–65, 8075 tons (161,500). The yearly steel production

MINERAL PRODUCTION OF NORWAY—*Concluded.* (In metric tcns.)

Year.	Iron, Pig and Castings.		Iron, Bar and Steel.		Nickel.		Silver (Fine).		Sulphur.		Zinc (White).	
	Tons.	Value†	Tons.	Value†	Tons.	Value†	Tons.	Value†	Tons.	Value.	Tons.	Value.
1866......	6,320	$96,780	4,160	$259,800	65	$31,000	3.64	$143,500	....	....	....	....
1867 . ..	7,145	99,400	3,710	231,100	60	30.600	3.62	142,000	....	....	....	....
1868......	4.755	69,056	1,815	143,520	58	48.768	4.15	171,704	....	....	....	....
1869......	3,985	58.968	1,190	118,664	49	58,240	4.00	163,280	....	....	....	....
1870......	3,975	57,512	1,110	110,136	55	48,328	3.70	150,696	....	....	....	....
1871......	2,620	40,976	1,210	132,912	47	95,264	3.70	152,256	....	....	....	....
1872......	1,565	43,368	1,080	193,752	55	114,191	3.70	152,464	....	....	....	....
1873	1,395	44,688	1,080	195,624	93	190,736	3 65	149,344	....	....	....	....
1874......	1,961	29.120	589	91,000	136	464,620	3.55	145,600	....	....	....	....
1875	2,231	37,180	478	67,600	254	824,200	3.30	135,200	....	....	....	....
1876......	870	15,990	443	89,700	332	670.800	4.00	154,648	....	....	....	....
1877......	1,292	24,440	379	59,400	141	253,600	4.45	167,696	....	....	15	$1,456
1878......	737	10,348	583	83,720	71	109,564	4.70	164,736	....	....	8	780
1879......	1,400	25,480	370	61,568	46	74,100	4.27	152,464	....	....	9	910
1880	932	14,040	653	72,800	68	114,400	4.78	170,560	6.17	$260	8	780
1881......	1,189	18.460	975	87,100	79	130,780	5.16	183,040	5.80	208	8	780
1882......	740	9,620	673	80,080	104	167.700	5.93	208,000	6.00	260	20	2,002
1883	1,031	16.068	952	78,250	107	150.800	6.08	211,900	1.43	78	11	708
1884......	1,174	15,080	666	46,540	105	107,900	6.83	237,380	.55	26	4	260
1885......	....	....	539	33,956	132	133,900	7.32	247.000	....	....	4	260
1886......	....	....	323	23,400	94	84.500	7.12	218,400	....	....	....	....
1887	698	87,800	379	25,180	93	72,800	*c*6.87	200,200	....	....	....	....
1888	799	9,360	441	22,100	66	52,000	*c*5.96	172,900	....	....	....	....
1889	287	3,583	537	30,160	69	50,440	*c*5.35	157,300	....	....	....	....
1890......	517	6,708	691	38,480	71	45,500	*c*5.08	161,876	....	....	....	....
1891......	421	5,252	593	35,776	91	68,458	*c*4.68	....	....	....	....	....
1892......	....	....	....	....	....	....	....	....	....	....	....	....
1893	....	....	....	....	....	....	....	....	....	....	....	....

(*a*) Cobalt speiss. (*b*) Chiefly calcined cobalt ore (Zaffer) In 1873, 1874, and 1875 there were also produced respectively 120, 230, and 175 tons of chrome ore. (*c*) Contained 9.868, 19.176, 18.684, 22.549, and 11.000 kilos of gold in 1887, 1888, 1889, 1890, and 1891, respectively.

amounted to 80 tons (1600 centners) in the period 1861–62, and to 232 tons (4640) in 1863–65.

In 1865 the iron industry employed 1700 men, 400 of whom were working in the mines; in 1870 the number had decreased to 654, of whom 194 were mine workers.

MINERAL IMPORTS OF NORWAY.* (IN METRIC TONS.)

Year.	Cement.	Coal.	Copper Sheet.	Iron.						Potas. Nitrate	Salt.	Zinc Sheet.
				Bar.	M'n'f.s.	Pig.	Plates.	Rails.	Steel.			
1861....	680	†1,442,100	110	4,165	2.280	3,175	575	...	50	85	†627,700	70
1862....	665	†1,249,300	135	3,725	5,490	3,490	450	210	80	85	†778.000	215
1863....	....	†1,220,700	170	4,430	3,665	3,350	730	75	85	170	†761,300	140
1864 ...	1,480	†1,611,200	215	6,205	4.255	4.935	750	5,780	70	230	†633,000	200
1865....	1,555	†1,587,500	265	4,730	4,445	4,980	1,250	1,185	90	135	†740.600	250
1866....	1,170	†1,739.600	275	7,260	5,270	4,935	1.975	1,895	310	255	†801,200	225
1867....	1,410	†2,082,200	495	7,285	5,035	5,045	1,765	945	95	185	†670,200	325
1868....	1,405	†2,118,700	510	6,150	5.035	4,035	1,165	560	120	185	†784,800	230
1869 ...	1,700	‡1,872,600	405	5.735	4,490	3,180	850	130	120	175	†778,400	225
1870 ...	1,381	235.447	467	6,920	4,935	5,417	1,683	3,863	202	207	137,576	210
1871....	7,750	227,531	497	6,122	4.546	5,466	2 153	1,790	176	148	81,392	246
1872. ..	3,563	244,104	506	8,513	4,647	5,734	2,096	994	111	237	137,172	248
1873....	1,645	242,748	583	9,597	5.365	6,545	1,481	2,065	238	379	94,345	277
1874....	1,473	302,504	934	13,945	7,455	8,442	2,501	10,215	361	261	148,173	390
1875 ..	2.032	381,851	958	15.694	9,006	14,071	2,379	12,386	498	353	114,549	384
1876....	2,152	335,426	1,021	12,592	8,115	9,247	2,193	11,457	376	224	92,262	512
1877....	2,490	452,204	969	19,352	8,397	19,226	2,565	11,385	436	446	143,334	453
1878....	2,806	405.838	713	10.230	5,766	7,752	2,711	4,791	357	313	84.568	452
1879....	5,703	423.028	865	11,878	6,982	8,144	1,523	7,722	398	190	105,097	468
1880....	5,895	462,293	755	13.886	7,341	5,765	1,994	3,232	420	369	101,286	596
1881....	5,348	476,716	963	15,965	7,043	10,114	3,244	4.566	696	175	133.817	600
1882....	7,142	523,737	932	15,030	7,618	8,583	4,191	2,837	629	280	129,979	648
1883....	3,117	564,066	931	17.218	7,336	10,433	7,121	1,558	650	164	101,492	657
1884....	6,685	575,450	1,487	16,217	8,548	10,298	5.405	2,331	687	280	119,489	593
1885....	7.200	660.908	1,176	10,398	10.112	10.395	5,606	1,092	859	326	89,028	670
1886....	8,709	643.605	968	17,021	9,138	10,707	3,749	3,558	796	228	110,401	726
1887....	8,262	622,748	924	17,032	7,402	12,791	3.650	1,488	890	380	122.093	707
1888....	9,106	717,394	909	21,822	9,332	15,612	7,965	3,695	1,289	265	123,093	799
1889....	11,928	819.512	1,040	26.731	10,566	19,080	10,289	3.324	2,074	156	158,586	707
1890....	14,184	766,995	1,477	17,531	11,924	18,227	9,034	4,330	2,184	320	122,280	702
1891....	....	....	....	....	....	....	....	....	....	....	....	...
1892....	....	....	....	....	....	....	....	....	....	....	....	...
1893....	....	....	....	....	....	....	....	....	....	....	....	...

MINERAL EXPORTS OF NORWAY.*

Year.	Apatite.	B'ld'g Stone.	Chr'me Ore.	Copper Ore.	Crude B'rytes	F'ldspr	Iron Ore.	Limestone.	Nickel Ore.	Silver Ore.	Whetstones.	Zinc Ore.
1861	175	**3,300	415	1,335	2,080	450	335	†1,000	215	....	§451,000	......
1862	95	......	325	660	5,700	550	1,160	†200	910	....	§178,000	120
1863	(a)	......	495	1,240	6 110	150	395	†1,000	600	....	§286,700	......
1864	......	......	130	230	6,120	500	2.490	†300	2,185	....	§225,000	......
1865	(a)	......	....	400	22,310	350	2 235	†1,000	1,715	....	§145,800	......
1866	......	......	590	3,280	35,880	150	5,720	†1,200	1,370	....	§112,000	160
1867	......	**100	....	15,100	71,370	410	6,015	†700	1,315	.. ....	§12,400	185
1868	......	......	....	6,000	68,245	1,035	10.310	....	820	....	§10,300	150
1869	......	325	210	11,435	64,465	530	15,980	1,600	685	....	§191,000	700
1870	......	332	281	29,865	49,524	1,333	17.117	140	533	....	69	936
1871	......	385	6	33,791	58,082	1,073	2,983	50	8	.. ....	119	656
1872	123	2,044	....	25,311	65,174	2,330	15 028	141	876	......	114	1,374
1873	1,211	2.819	....	26,500	64.108	2,843	18.697	96	3,882	.... ..	119	569
1874	1,632	2.498	....	11,880	69,875	2,821	28,823	74	6,465	....	....	......
1875	959	3.515	....	15,712	40.132	3 660	21.646	92	6,143	....	132	......
1876	2,070	5.485	....	17,325	34,313	4.328	14,161	361	5,995	....	3	......
1877	2,405	6,987	....	8,084	36,203	2,020	6,010	980	530	....	133	......
1878	2,863	8,248	....	3,296	40,692	4,143	1,167	322	601	....	132	......
1879	2,035	21.925	....	4,353	46,492	5,534	510	261	1,276	....	238	.....
1880	7,915	21,505	.... ..	7,966	65,258	8 069	136	162	1,693	217	16	......
1881	8,992	26,027	.. ....	6.983	61,679	11,729	170	227	1,104	259	24	......
1882	15,338	22,382	....	5.592	61,097	6,957	411	263	1,435	290	47	6
1883	9,884	28.584	. ....	4,068	59,417	10,591	5,744	192	823	170	170	......
1884	6,460	26,661	....	4,675	68,303	6,889	741	519	1,123	375	39	1,330
1885	1,605	29,234	100	4,028	50,605	6,434	1,376	602	13	392	162	......
1886	1,791	40,351	60	4,413	51,349	8,196	20'	397	478	828	44	150
1887	4,821	35,827	129	2,212	54,512	5,923	2,510	408	662	219	178	108
1888	4,797	42,073	20	4,434	58,963	9 162	382	473	5 .0	361	206	670
1889	10,665	43,163	310	4,823	63 217	10,995	1,143	483	270	348	78	2,875
1890	11,119	54.623	100	1,233	54,851	1 ,850	370	555	....	368	149	3,444
1891	......	......	....	....	....	... ...	....	....	....	.... .	....	......
1892	......	......	....	....	....	....	....	....	....	....	....	......
1893	......	......	..	....	..	... ..	...	....	...		....	....

Year.	Chrome Salts.	Cobalt	Copper	Iron.						Nickel.
				Bar Iron.	Castings.	Plates.	Nails.	Pig & Scrap.	Steel.	
1861	70	15	560	1,465	75	55	25	20	....	....
1862	165	30	465	1,240	45	35	15	45	20	... .
1863	75	10	405	2 170	150	30	30	500	10	....
1864	40	15	490	1,235	95	10	10	80	195	35
1865	90	20	330	490	40	35	90	560	220	140
1866	.....	....	380	2,835	20	35	125	170	125	20
1867	125	....	450	2,375	70	60	200	295	155	30
1868	....	5	655	735	20	85	105	685	240	35
1869	.....	10	310	1,330	50	75	50	100	210	85
1870	15	....	474	1,100	50	79	131	1,029	233	139
1871	58	7	716	801	71	104	365	831	202	89
1872	77	18	490	303	117	101	401	2,410	209	54
1873	119	36	467	158	195	107	420	630	128	132
1874	22	49	446	22	223	132	781	468	115	100
1875	....	39	158	54	353	97	806	239	97	216
1876	....	49	365	122	152	53	1,016	30	123	178
1877	....	49	339	109	159	85	947	50	102	162
1878	....	53	418	325	58	80	642	49	219	64
1879	....	51	540	87	76	22	575	14	238	35
1880	....	59	404	455	81	10	2,079	699	222	81
1881	....	48	376	155	96	51	2.354	1,070	244	41
1882	....	38	248	145	166	8	2,530	856	222	126
1883	....	44	82	65	409	8	3,933	1,361	276	73
1884	....	46	244	93	124	13	5,370	1,186	158	293
1885	....	57	270	7	152	12	5,598	1,825	83	404
1886	....	50	370	361	122	1	6,923	1,066	90	197
1887	....	44	314	103	75	....	8,149	4,144	109	361
1888	. .....	39	389	249	96	2	8,246	2,055	264	191
1889	....	76	310	140	174	10	8,578	2,013	120	181
1890	....	96	557	23	224	1	9,788	3,610	178	171
1891	....	... ..	....	....	....	....	....	....	....	....
1892	....	....	....	....	....	....	....	....	....	....
1893	.....	....	....	....	....	....	...	....	....	....

* From *Tabeller vedkommende Norges Bergværksdrift.* Christiania, 1874-92. ** Cubic feet. † Barrels. § Pieces. (*a*) Also reported in 1865, 90 tons cobalt ore, and in 1863, 15 tons lead ore.

Of iron pyrites the yearly or average production was in 1861, 2700 tons (54,000 centners); in 1863, 11,000 tons (220,000); and in 1865, 30,100 tons (602,000). The number of laborers employed during the period increased from 60 to 543.

The nickel-ore production increased from the period 1861–65 during 1866–70, the number of employees increasing from 81 to 127. The production of cobalt lead decreased to a very small quantity, and that of chrome ore was discontinued for a time between 1865–70.

PORTUGAL.

It has proved a difficult matter to secure the mineral returns from this kingdom, and we are indebted to the courtesy of the American Minister for such statistics as we have used here. The mineral output of Portugal is quite small, the most important item being copper ore, of which a little less than 100,000 tons, valued at $751,875, were produced in 1892. This shows a decline in output since 1882, owing to the increased expense of production, declining grade of ore, and lack of improved methods in the industry. The greater part of this ore, which is largely copper pyrites, is exported without treatment. Among the other products salt is the most important, the exports varying from 100,000 to almost 200,000 tons per year, though they also have been declining in the past ten years. The small amounts of manganese and iron ore which are produced are exported to England.

In the imports of gold and silver bullion and specie there has been a wide variation in the amount taken annually. In 1886 the value of both was $9,422,900, and in 1890 but $3,994,000. In the coal imports an increase is shown which, though not very great, indicates growing activity in manufacturing. This is also noticeable in the inports of wrought and cast iron and machinery, both of which have increased considerably, the former over 100%, and the latter nearly 600%, since 1880. As but a small portion of this material is again exported, the greater part must go into the industries of the country.

Among the minor minerals gold quartz was produced valued in 1889 at $342, 18 tons of tin ore in 1892, 12 tons of asbestos in the same year, and 100 tons of ocher in 1889. A little bituminous schist, nickel, and zinc ore are also found, but appear to be merely sample lots which have not led to any permanent exploitation.

THE MINERAL PRODUCTION, IMPORTS, AND EXPORTS OF PORTUGAL.

(IN METRIC TONS; 1 milreis=$1.)

Year.	PRODUCTION.												IMPORTS. (x)	
	Antimony Ore.		Coal.		Copper Ore.		Iron Ore.		Lead-Silver Ore.		Manganese Ore.		Bull. and Specie (w)	
													Gold.	Silver.
1880	......	....	....	....	....	....	....	....	......	....	....	....	$2,545.500	$13,100
1881	......	....	....	....	....	....	....	....	......	....	....	....	2,849,300	32,800
1882	815	$55,474	16,490	$53,007	*t*137,946	$1,393,920	24,451	$30,096	2,183	$79,876	*u*17,336	$173.987	796,000	54,300
1883	......	....	....	....	....	....	....	....	......	....	....	....	3,432,900	70,500
1884	2,293	130,223	12,168	40.338	110,190	1,345,850	7,318	5,403	1,233	43,605	9,241	81,386	2,441.500	51,300
1885	2,062	107,117	15,236	50,375	68.763	730,903	10,272	24,512	1,115	30,536	7,103	63,939	3,247,400	83,100
1886	......	....	....	....	....	....	....	....	......	....	....	....	8,747,700	675,200
1887	......	....	....	....	....	....	....	....	......	....	6,812	....	5,027,000	
1888	......	....	....	....	....	....	....	....	......	....	5,638	....	6,064,000	
1889	1,509	142,892	20,539	55,496	181,529	435,136	1,588	1,588	1,308	43,506	5,893	79,556	8,505,000	
1890	......	....	....	....	....	....	....	....	......	....	....	....	3,994,000	
1891	......	....	....	....	....	....	....	....	......	....	....	....	....	
1892	996	80,810	17,931	53,462	*v*99,667	751,785	11,330	4,532	1,099	28,125	3,399	23,632	....	
1893	......	....	....	....	....	....	....	....	......	....	....	....	....	

Year.	IMPORTS—*Continued.*						EXPORTS. (x)					
	Coal.		Wrought and Cast Iron.		Machinery.		Copper Ore.		Iron Manufactures.		Salt.	
1880	317,054	$1,485,000	22,932	$883,000	1,954	$922,000	179,023	$1,725,200	492	$83,000	192,285	$300,700
1881	321,554	1,198.000	35,587	897,000	2,200	528,000	154,600	1,401,000	1,311	69,000	126,054	200,000
1882	380,880	1,426,000	27,612	840,000	1,622	333,000	163,950	1,249,000	372	51,000	113,985	168,000
1883	404,520	1,510,000	37,938	882,000	2,628	480,000	136,783	1,236.000	785	104,000	188,095	279.000
1884	428,249	1,631,000	46,137	931,000	3,006	619,000	107,528	987,000	752	95,000	116,413	175.000
1885	394,211	1,420,000	39,744	899,000	3,184	568,000	52,416	483,000	387	54,000	80,850	121,000
1886	432,945	1,530,000	42,595	825,000	3,285	569,000	81,394	738,000	323	46,000	117,776	175.000
1887	446,408	1,507,000	50,545	897,000	4,104	692,000	90,211	815,000	364	41,000	183,156	276,000
1888	482,244	1,533,000	55,381	994.000	4,719	840,000	96,984	862,000	523	53,000	172,568	259,000
1889	558,999	1,873,000	49,535	1,131,000	7,223	1,121,000	79,770	997,000	625	63,000	190,137	285,000
1890	599,718	2,024,000	43,835	1,164,000	7,555	1,294,000	114,065	1,001,000	575	57,000	110,934	167,000
1891	....	....	....	....	....	....	....	....	......	....	....	....
1892	....	....	....	....	....	....	....	....	......	....	....	....
1893	....	....	....	....	....	....	....	....	......	....	....	....

(*s*) *Annuario Estatistico de Portugal* for 1882, 1884, and 1885; *Inquerito Industrial*, Vol. I., for 1889; United States Consul General at Lisbon for 1892. The total value of the mineral production for 1851–55 was $279,838; 1856–60, $873,411; 1861–65, $3,984,693; 1866–70, $5,629,615; 1871–75, $5,755,459; 1876–80, $5,429,889; 1881, $1,392,093; 1882, $1,786.915; 1883, $2,869,533; 1884, $1,647,061; 1885, $1,007,398; 1889, $763,515. In 1889 the products of the smelting works were: Antimony regulus, 30,429 kilos, $10,157; copper (98% fine), 5 tons, $1193; copper matte (30% cu.), 32 tons, $2389; cement copper, 7003 tons, $530,000; copper slags, 72,333 tons, $17,200—total, 79,403 tons, $560,882. There were also produced of gold quartz in 1882, 1885, and 1889, respectively, 222 tons, $554, 18 tons and 13 tons, $342; of tin ore in 1889, 6 tons, $1513, and in 1892, 18 tons, $4583; of asbestos in 1889 and 1892, 12 tons, $378, and 17 tons, $306; of ocher in 1889, 100 tons, $1333; of gold in 1884, 1885, and 1889, 3.7 kilos, 6.8 kilos, and 3 kilos, $1774; of bituminous schist in 1882, 1884, and 1885, 670 tons, 35 tons, $256. and 25 tons, $15, and of zinc ore in 1892, 25 tons, $300. (*t*) Includes 125 tons cobalt and nickel ore, and also 132,283 tons copper pyrites, valued at $424,72. (*u*) Includes 124 tons ferro-manganese, valued at $848. (*v*) There were also produced 151 tons copper-lead ore, valued at $1737. (*w*) This column represents the imports of bullion and specie, less the exports. In 1891 the exports exceeded the imports by $21,534,000. (*x*) From British Statistical Abstracts. From *Annuario Estatistico de Portugal and Inquerito Industrial*, Vol. I., we obtain the following exports of native products: Antimony ore: 1882, 815 tons; 1884, 2293 tons, $130,223; 1885, 2062 tons, $107,117; 1889, 1524 tons, $143,539. Lead ore: 1882, 306 tons; 1884, 629 tons, $25,463; 1885, 356 tons, $15,185; 1889, 1258 tons, $40,606. Copper ore: 1882, 156,734 tons; 1884, 110,190 tons, $1,345,850; 1885, $68.763 tons, $730,903; 1889, 2336 tons, $30,208. Iron ore: 1882, 24,451 tons; 1884, 7318 tons, $5403; 1885, 10,272 tons, $24,512; 1889, 1588 tons, $1588. Manganese ore: 1882, 17,326 tons; 1884, 9236 tons, $81,199; 1885, 7103 tons, $63,939; 1889, 5893 tons, $79,556. Auriferous quartz: 1882, 222 tons; 1885, 18 tons; 1889, 13 tons, $343, and in 1884, 3.7 kilos gold. In 1889, 12 tons of asbestos and 6 tons of tin, valued, respectively, at $378 and $1513.

RUSSIA.

The mineral industry of Russia during 1893 still suffered to some extent from the unfavorable conditions imposed upon it by the scarcity and short crops of 1890–91. There has been a partial recovery, it is true, and an increase in some special branches, but the year was not, upon the whole, favorable to any great increase of production or to the development of new resources.

The first exception which is to be noted is the increase in the production of manganese ores in the Caucasus. This has resulted partly from the growing demand for such ores everywhere in the production of steel, and partly from the extension of railroad lines, making the transportation of the ores to shipping ports easier and cheaper.

The other exception is the petroleum industry, which continues to grow rapidly. The area of production has not been extended, but the continued new developments in the Baku oil fields have increased production and afforded a larger surplus for export than ever before. In fact, the latter seems to be now limited only by the facilities afforded for transportation. The railroad which carries the Baku oil to the shipping port at Batoum, on the Black Sea, is still insufficient in spite of improvements made in its grades and carrying capacity, and it will probably be supplemented by pipe lines on the American pattern.

The Russian oil producers have practically completed the formation of a union which will place the entire output of the wells under the control of a committee of the leading producers. Reports have been current of negotiations between this union and the American Standard Oil Company for a division of the petroleum trade of the world. These reports have been denied by officers of the Standard Oil Company, but it is not unlikely that some agreement has been or will be made, at least as to the trade of Western Europe. Meantime the sale of Russian oil is steadily pushed in the markets of the East, where it has taken a large part of the trade from American producers.

Some explorations have been made of copper and lead deposits in Russian Turkestan, on the line of the Trans-Caspian Railroad, which is becoming an important commercial line; but no considerable workings have been begun.

It is expected that the new commercial treaty with Germany, which has been concluded since the close of 1893, will enable the German ironmakers to compete for Russian trade more actively than they have done; but the increased demand for iron and steel, which is probable for several years to come, will enable the Russian works to maintain their present output.

MINERAL PRODUCTION OF RUSSIA. (*a*) (IN METRIC TONS.)—*Continued on opposite page.*

Year.	Asbestos.	Asphalt.	Chrome Iron Ore.	Clay, Porcelain.	Coal.	Cobalt Ore, Kilos.	Glauber's Salt.	Graphite.	Iron Pyrites.	Manganese Ore.	Petroleum.		
											Naptha.	Lighting Oil.	Benzine.
1855	......	......	......	......	155,512	......	......	......	......	......	......	......	......
1860	......	......	......	......	299,901	......	......	......	......	......	......	......	......
1865	......	......	......	......	382,162	......	......	......	......	......	9,122	......	......
1870	......	......	......	......	694,782	......	......	......	......	......	27,919	......	......
1873	......	......	......	......	1,173,546	......	......	......	......	......	68,474	......	......
1874	......	......	......	......	1,291,723	......	......	......	......	......	85,388	......	......
1875	......	......	......	......	1,701,192	......	......	......	......	......	134,007	......	......
1876	......	......	......	......	1,824,574	......	......	......	......	......	168,893	......	......
1877	......	......	......	......	1,789,133	......	......	......	......	......	205,100	......	......
1878	......	......	......	......	2,524,291	......	......	......	......	......	251,216	......	......
1879	......	......	......	......	2,921,935	......	......	......	......	......	352,065	......	......
1880	......	......	......	......	3,291,555	......	......	......	......	......	352,426	......	......
1881	......	......	......	......	3,488,901	......	......	......	......	11,238	663,786	210,330	......
1882	......	......	......	......	3,765.957	......	......	......	......	14,431	828,327	269,087	......
1883	......	......	......	......	3,972,192	......	......	......	......	17.052	990,166	248,082	812
1884	......	......	......	......	3,925,107	......	......	......	......	22,134	1,479,769	333,168	2,473
1885	......	......	......	......	4,623,056	......	......	......	......	60,532	1,906,646	559,347	673
1886	......	......	......	......	4,570,869	......	......	......	......	74,400	1,974,739	619,475	1,004
1887	......	......	......	6,088	4,528,104	1,245	......	......	......	58,207	2,736,648	755,260	3,968
1888	......	......	7,221	7,609	5.179,478	950	......	......	......	32,680	3,187,208	853.736	2,361
1889	......	......	4,156	4,593	6,206,166	*b*13,268	......	......	......	78.031	3,314,898	1.048,193	1,820
1890	......	......	2,370	......	6,007,457	15,000	......	......	......	182,468	3.984,247	1,146,172	2,046
1891	11,839	140,394	30,966	52.022	6,233,025	......	39,320	1,638	183,531	113,081	4,756,417	1,249,592	......
1892	......	......	......	......	......	......	......	......	......	......	......	......	......
1893	......	......	......	......	......	......	......	......	......	......	......	......	......

MINERAL IMPORTS AND EXPORTS OF RUSSIA.(*d*) (IN METRIC TONS: 1 ruble=77c.)

Year.	Imports.												
	Cement and Clay.		Coal and Coke.		Copper.	Iron.			Lead.	Petroleum.		Salt.	
						Bar and Sheet.	Pig.	Rails. (*e*)		Light'g Oil.	Raw Nap.		
	Tons.	Dollars.	Tons.	Dollars.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Dollars.
1880	135,386	2,367,750	1.922,373	13,555,850		157,568	243,854	......	......	......	......	148,399	4,743,970
1881	81,525	775.390	1,791,378	11,358,270	8,809	106,208	234,119	14,381	......	21.269	446	186.221	5,489,330
1882	96,868	1,296,680	1,730,721	11,918,060	2,088	109,893	218,886	5,586	......	16,909	255	168,561	5,139,750
1883	112,131	1,467,620	2,267,377	13,965,490	3,653	106,011	237,363	1,933	17,788	6,377	314	155,117	4,506,040
1884	116,459	2,252,250	1,914,098	12,285,350	4,603	79,787	283,865	2,358	17,543	2,974	231	74,796	2,497,880
1885	96,410	1,540,770	1,827,901	11,897,270	3,178	63,522	221,277	2.554	8,467	1,934	25	35,169	862,400
1886	91,148	1,134,980	1,860,115	10,362,660	2,196	77,941	264,008	1,100	13,520	667	1	19.690	485,870
1887	107,230	1,231,230	1,569,016	8,711,780	832	55,215	129,035	393	17,671	246	0.5	7,759	225,610
1888	93,607	980,210	1,728,787	9,979,200	554	65,740	75,199	409	19,868	187	2	11,289	175,560
1889	87,377	972,510	2,070,934	11,651,640	3,968	86,053	116,836	1,687	19,696	265	2	22.947	324.170
1890	114,590	1,096,480	1,739.705	9,570,330	4,393	95,559	126,332	2,458	21,603	247	0	17,191	222,530
1891	102,833	974,820	1,737,607	9,267,720	......	51,171	75,118	442	18,395	311	......	13,628	170,940
1892	......	......	......	......	......	......	......	......	......	......	......	......	......
1893	......	......	......	......	......	......	......	......	......	......	......	......	......

	Imports -*Continued.*					Exports.									
	Steel—Bar and Sheet.	Sulphur.		Tin.	Zinc.	Coal.	Copper.	Iron and Steel.	Manganese.	Petroleum.					Phosphates.
		Raw.	Refined.							Raw Naptha	Light. Oil.	Lubric. Oil.		Napth. Refuse	
												Refin.	Unr'd		
1880	39.207	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1881	10,319	......	......	2,079	2,321	......	229	5,106	......	2,991	2,203	5,063	4,534	1,097	......
1882	4,603	......	......	1,459	2,480	......	3,386	5,801	9,217	1,835	3,746	5,358	6,162	1,269	......
1883	3,784	......	......	1,872	2,434	......	581	4,955	14,275	4.647	23,467	7,441	20,749	989	......
1884	5,536	......	......	1,825	4,015	......	441	5,002	20,439	9,874	64,683	9,907	13,972	7,398	......
1885	4.389	......	......	1,289	2,991	......	331	5,743	42,047	18,498	117,074	10,618	24,412	3,410	......
1886	10,906	7,939	562	1,736	2,692	2,457	206	7.230	55,748	20,503	150,619	12,716	23,787	36,946	11,055
1887	7,366	14,735	1,063	1,818	796	3,145	173	5,941	60,449	17,659	193,604	18,617	27,263	53,754	7,677
1888	9.482	22,332	568	2,354	1,382	15,576	77	3,492	49,839	4,904	448,047	24,827	20,993	73,404	7,346
1889	14,833	19,097	472	2,172	3,998	14,429	74	5,142	56,352	3,680	573,126	25,025	31,560	100,401	8,536
1890	15,087	18,428	465	2,644	5,456	13,672	88	5.001	133,161	12,460	651,387	56,241	18,570	48,917	11,554
1891	10,893	......	......	......	......	......	......	......	......	14,251	739,114	64,799	18,084	51,875	......
1892	......	......	......	......	......	......	......	......	......	4,855	789,876	89,091	12,351	41,753	......
1893	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

(*a*) Authorities: *Reports prepared for the World's Columbian Exposition*, St. Petersburg, 1893, for 1825–70; *Annales des Mines*, 1885, for 1873–80, as well as for chrome iron in 1888–90, porcelain clay in 1887–89, and cobalt ore in 1887, 1888, and 1890; Russian official figures for 1881–91; *Catalogue of the Russian Section at the Chicago Exposition* for gold in 1892.

(*b*) Exclusive of 3079 kilos cobalt matte. (*c*) Crude gold.

MINERAL PRODUCTION OF RUSSIA.(*a*)—*Continued.* (IN METRIC TONS.)

Year.	Lubricating Oil.	Phosph't's.	Salt.	Cobalt	Copper.	Gold, Kilos. (*c*)	Iron—Pig.	Iron Mfrs.	Lead.	Platinum, Kilos.	Quicksilver.	Silver, Kilos.	Steel.	Sulphur	Tin.	Zinc.
1825	......	......	......	....	3,325	3.882	157.978	......	......	180	......	18,673	......	....	....	......
1830	......	......	342,676	....	3,866	6,273	182,953	......	694	1,753	......	20,999	......	....	....	......
1835	......	......	368,550	....	3,944	6,437	172,008	......	696	1,720	......	19,853	......	....	....	2,514
1840	......	......	434,889	....	4,121	7,502	185,610	......	891	1,523	......	19,738	......	....	....	2,739
1845	......	......	908,713	....	4,173	21,409	187,266	......	916	770	......	19,525	......	....	....	3,569
1850	......	......	406,699	....	6,447	23.816	227,556	......	675	164	......	17,494	......	....	....	2,606
1855	......	......	516,936	....	6,201	27,011	250.788	......	1,816	16	......	18,018	......	....	....	1,107
1860	......	......	429,688	....	5,194	24,423	335,258	......	1,093	999	......	17,527	......	....	....	1,838
1865	......	......	501,864	....	4.144	25,814	299,438	......	1.633	2,227	......	17,756	......	....	....	3,089
1870	......	......	475,241	....	5.052	35,430	359.531	......	1,649	1,949	......	14,218	......	....	....	3,780
1873	......	......	826,208	....	3,660	33,180	387,940	......	944	1,574	......	9,951	......	....	....	3,378
1874	......	......	769,631	....	3.271	33 230	379,060	......	1,330	2,016	......	11,803	......	....	....	4,128
1875	......	......	622,810	....	3,652	32,721	427,187	......	1,083	1,541	......	9,852	......	....	....	3,988
1876	......	......	717,046	....	3.876	33,672	441,914	......	1,169	1,574	......	11,197	......	....	....	4,626
1877	......	......	474,626	....	3,507	41,033	400,054	......	1,205	1,721	......	11,164	......	....	....	4,635
1878	......	......	781 615	....	3,522	42,164	417,632	......	1,398	2,066	......	11,459	......	....	....	3,646
1879	......	......	818,523	....	3,126	43,148	432,997	......	1,358	2,262	......	11,426	......	....	....	4,321
1880	......	......	779,867	....	3,205	43,311	448,596	......	1,147	2,951	......	10,115	......	....	....	4,390
1881	47,876	......	830,013	....	3,460	36,763	470,052	292,206	985	2,981	......	9,423	293,323	106	10	4.542
1882	29,181	......	1.664,959	....	3.587	36.151	463,087	297,327	571	4,077	......	8,000	247,670	650	5	4,462
1883	49,864	......	1,136.566	....	4.350	35,733	482,274	322,805	542	3,520	......	7,362	222,183	1,161	18	3,809
1884	55,796	......	1,022,521	....	6,211	35.676	510,132	362,230	631	2,233	......	9,652	206,965	755	13	4,313
1885	48,547	......	1,131,791	....	4,715	33,018	528,170	362,281	714	2,587	......	11,239	192,895	1,781	14	4,579
1886	41,384	......	1,194,359	....	4.515	33,437	532,744	363.003	776	4,310	......	13,251	241,791	1,179	17	4,190
1887	65,577	7,053	1,155,280	....	4,983	34,862	613,184	369,400	988	4,502	64	15,362	225,480	1,446	10	3,621
1888	60,826	12.776	1,111,679	....	4,597	35,164	667,737	364,542	798	2.713	165	15,116	222,288	372	19	3,869
1889	51,719	9,982	1,392.599	....	4,793	37,256	740,957	427,786	577	2,632	167	13,840	258,734	95	12	3,681
1890	88,026	......	1,388,365	....	5,718	39,369	927,585	433,178	836	2,841	292	14,544	378,424	161	13	3,768
1891	......	174,967	1,351,187	99	5,456	39,087	1,004,745	448,021	558	4,226	324	13,722	433,487	336	9	3.675
1892	......	......	......	....	....	43,138	......	......	......	......	......	......	......	....	....	......
1893	......	......	......	....	....	......	......	......	......	......	......	......	......	....	....	......

(*d*) The figures for cement, clays, coal, coke, and salt, as well as those for 1891, from British Statistical Abstracts The other figures are from the *Reports prepared for the World's Columbian Exposition*, St. Petersburg, 1893. In 1891 there were 1392 tons of unwrought metals imported.

(*e*) Both steel and iron. The latter were in 1889, 1890, and 1891 respectively 489, 764, and 442 tons; steel rails in 1888, 1889, and 1890, 217, 1198, and 1694 tons.

CONSUMPTION OF PRINCIPAL MINERAL PRODUCTS IN RUSSIA, AND PROPORTION FURNISHED BY DOMESTIC MINES.

Year.	Coal.		Copper.		Iron.		Iron (Cast).		Salt.		Steel.	
	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.
1881......	5,260,551	66.3	12,317	28.1	399,390	73.0	698,914	67.0	1,019,791	81.2	522,816	56.0
1882......	5,447,305	69 1	3,304	108.6	399,228	74 3	670,404	69.1	1,837,397	90.6	404,993	60.6
1883	6,132,003	64.7	7,711	56.4	425,936	75.6.	718,187	66.9	1,289,764	88.1	226,611	97.7
1884......	5,764,874	68.0	10.589	57.0	459,279	78.0	795.617	64.0	1,103,581	92.0	214,331	96.0
1885......	5.999,844	71.0	8,176	57.0	440,652	82.0	726,992	72.0	1,156.680	97.8	198,847	96.0
1886......	6.318,375	72.0	6,552	69.6	433,556	81.0	795,996	66.0	1,205,401	99.8	252,706	95.0
1887......	5,946,626	76.1	5,641	88.3	418,268	88.2	740,454	82.6	1,155,707	99.7	232,607	96.8
1888.....	6,739,176	76.8	5,122	89.7	426,460	85.4	741.094	89.9	1.116,168	99.5	231.562	95.8
1889......	8.059,570	77.0	8,663	55.3	508,565	84.0	855,680	86.3	1,407,205	98.4	274,347	94.2
1890... ..	7,534,331	79.7	10,030	57.0	524,153	82.5	1,051,367	88.1	1,398,134	99.3	394,631	95.7

Gold is produced in the Oural, Siberia, Orenburg, and Finland; platinum in the Oural, and silver in Siberia, the Kirghiz steppes, the Caucasus, and (a small quantity only) in Finland. Lead is produced in Siberia, the Kirghiz steppes, and the Caucasus; tin in Finland and spelter in Poland. Copper is reported from the Oural, the Caucasus, Siberia, Poland, and Finland; manganese ore from the Oural, the Caucasus, Orenburg, and Ekaterinoslav; cobalt ore from the Caucasus; chrome ore from the Oural and Orenburg; sulphur pyrites from the Oural, Toula, Novgorod, and Towsk.

The iron and steel manufacturing districts are found in the Oural, Siberia, Orenburg, Moscow, Poland, South Russia, and Finland. The coal-producing districts of Russia are Taganrog, the Donetz Basin, Kharkov, Bakhmuth, Poland, the Oural, the Kirghiz steppes, Siberia, and Sakhalin.

Rock salt is mined at Orenburg, in Ekaterinoslav, and at Erivan-Karsk, in the Caucasus. The salt from lakes and marshes is contributed by many districts, Astrakhan, the Crimea, Kherson, Bessarabia, Kuban, Daghestan, Baku, Turgai, Ferghana, the Oural, and Western Siberia. The salt factories are found at Perm, Arkangel, Bakhmuth, in Poland and Daghestan, at Yeneseisk, Irkutsk, and in the Trans-Baikal, in Siberia. Sulphur comes from Daghestan and Ferghana; Glauber salts from Tomsk, Tiflis, and Turgai; phosphorite from Podolsk, Kursk, and Kostroma; asbestos from Ekaterinburg; graphite from Yeneseisk, in Siberia. Kaolin is found in Volhynia, Tchernikoff, and the Crimea; quicksilver is produced at one point only, the mines of Zaizewo, owned by Auerbach & Co.

The Baku district is the great producer of petroleum, and also of bitumen and asphalt, but petroleum is also found in Daghestan, Tcheleken Island, the Crimea, Tiflis, Terghana, and Kuban; asphalt at Simbirsk, Kazan, and Kutais; bitumen at Tiflis, and at Bala and Ishim, in Siberia.

The important share which the Asiatic possessions of Russia, Siberia and the Trans-Caspian, and the border districts of the Oural and the Caucasus, contribute to its mineral production will be noted.

The work on the Trans-Siberian Railroad, which is now well begun, and a large part of which will be completed during the next ten years if the plans of the Government are carried out, will have a notable effect on the mineral industry of the Russian Empire. In the precious metals Siberia has furnished an important part of the supply for many years, having contributed in 1890—excluding the Oural district, which belongs administratively to European Russia, although the eastern slopes of the mountains are geographically in Asia—71% of the gold and 96% of the silver output of Russia. That district supplied also 72% of the lead and 8% of the copper. Both the gold and silver production are capable of considerable increase. The silver mines of the Tomsk and Semipalatinsk districts in Western Siberia, and of the Nertchinsk district in Eastern Siberia, are at present worked only in a very limited way on account of the high cost of fuel and supplies, but the ore deposits known are sufficient to furnish a very much greater output when the railroad is so far completed as to transport these necessities to the reduction works. The placer workings, which at present supply nearly all the gold, can be much extended when more labor and cheaper supplies are attainable. In the older districts, such as those of Tomsk, Yeniseisk, Irkutsk, the upper tributaries of the Lena, and in the Trans-Baikal, only the richer deposits have been touched, because under present conditions no others will pay for working. On the upper tributaries of the Amour there are placers which have hardly been touched as yet on account of the difficulty of reaching them.

It is, however, not in the precious metals, but in coal and iron, that the Trans-Siberian line will produce the greatest results. The Siberian production is at present insignificant, but important deposits of coal have been located and worked, though only to a very small extent, in the northern slopes of the Altaï Mountains, especially in the Kouznetsk Basin, in the valleys about the sources of the Obi and the Tom, on the upper Irtish and the Angara, and at the southern end of Lake Baikal. An extensive coal bed is also found on the middle Amour, while the coal beds of the Oussouri Basin, near the Pacific Ocean, are already worked on a considerable scale and find a market in supplying steamers at Vladivostok. There are also beds of lignite of good quality on the Kirghiz steppes. The silver smelting works near Semipalatinsk have been supplied with excellent coke made from coal mined at a point not far distant.

Iron ores of good quality and remarkably free from phosphorus have been found in the Altaï Basin, to the west of Lake Baikal, at several points in the Trans-Baikal, and in the foothills of the Jablonnovoï Mountains.

A considerable production of salt from the salt lakes of the southern steppes is also possible when the demand requires it and transportation is furnished.

At present a beginning has been made of a geological survey of Siberia, and a corps of mining engineers has been organized as a part of the staff on each division of the railroad. This work is considered by the Government as of especial importance in connection with the building of the Siberian line.

It may also be stated that a survey has been ordered of the petroleum deposits of the island of Sakhalin (or Saghalien, as it is spelled on many maps), where some shallow borings have revealed the presence of oil. Should these deposits prove extensive, they will become, from the geographical position of the island, an important factor in the Eastern trade.

SPAIN.

By Roman Oriol.

Progress in the mining industry throughout the peninsula during 1893, though unceasing, was slow, from lack of a spirit of association and because capitalists here find it easier and more profitable to invest in the money and stock markets than in mining enterprises. The small share of attention bestowed by legislators, until quite recently, upon the means of developing this industry has also rendered its progress much slower than it might have been with the natural condition of the Spanish soil. But public sentiment, the needs of the industrial community, and the difficulties due to the absence of advantageous commercial treaties with most of the nations with which Spain's export trade is mainly carried on, have pointed out the necessity for greater solicitude regarding the material interests of the country. The mass meeting held at Bilbao early last December by representatives of the principal industries of Cataluña, Asturias, Vizcaya, and the other Basque provinces, to protest against the projected treaties with Germany, Italy, and England, was an unmistakable evidence of the new turn in Spanish politics.

Among the new enterprises to the credit of the year 1893 are the companies organized for the exploitation of coal in the Castilian provinces of León and Palencia, ready transportation between which and the important consuming center of Bilbao was expected in the opening to traffic of the one-meter-gauge railway from Robla to Valmaseda in 1894. Mining in Andalusia has been encouraged with capital from Bilbao, now in search of argentiferous lead in the Province of Córdoba, now in preparing iron mines in the Province of Almería.

Under the protective tariff of 1892 have cropped up some new and desirable features, for the most part in the northern—the chief manufacturing—provinces of the kingdom. In Vizcaya two companies have been formed—the Tubos Forjados, for the manufacture of wrought-iron pipe (by a process different from that of Mannesmann, discarded as impracticable here), and the Alambres del Cadagua, for wire rope of every description. The new Compañia de Asturias, in the province of the same name, is establishing extensive works at Sama de Langreo for the construction of rolling stock for mines and economical railways; hard by it a screw factory is being equipped; and Cataluña has begun to make moldings and frames, toys, etc., competing favorably with the cheap German articles.

Shipbuilding, which made such a notable stride in the large armored cruisers ordered at the Astilleros del Nervión for the Spanish Government,—one of which, the Maria Teresa, launched in 1893, is now (January, 1894) receiving her heavy armament at El Ferrol,—is about to enter upon a new era. There are rumors of a fusion, to be effected in 1894, of the extensive iron works on the banks of the Nervión, for the reorganization of the shipyards there on a scale to permit the building of ships in competition with England and France, hitherto the chief sources of supply of vessels for the merchant navy of Spain.

Bituminous Coal.—Although nothing of unusual importance occurred during 1893 in relation to the production of coal in Spain, certain it is that the returns at hand show a slight increase over those for 1892, and all the probabilities point to a rapid augmentation of the output at no distant day.

In Asturias washeries and means of transportation have been established at the Turón Valley mines, which are this year to be placed on the productive list, the Bilbao Stock Company of the Hulleras del Turón having already completed extensive preparatory work. The Fábrica de Mieres Company has continued the preparatory work at the Cadabal group, which alone is expected to produce 150,000 tons annually.

The aggregate yield of the four groups worked in Asturias by this company in 1893 was 225,000 tons. The Unión Hullera y Metalúrgica de Asturias Company is completing the washeries at Sama and Maria Luisa, and will show a greatly increased output when able to deliver its coal at the port of Avilés by the Soto del Rey and Ciaño-Santa Ana Railway, to be opened to traffic in 1894.

The Asturian coal producers shipping more than 100,000 tons annually are the Fábrica de Mieres, the Hullera Española (Aller mines), and the Unión Hullera y Metalúrgica.

In the Province of Córdoba the Rio Tinto Company has given up work at the La Perdiz and El Conejo mines, in the Belmez coal basin, after reaching a depth of 100 meters; but to offset this the Compañia Minera y Metalúrgica de Peñarroya and the Ferrocarriles Andaluces Company continued operations, and extracted 136,000 and 153,136 tons of coal, respectively, in 1893. The Madrid, Taragoza and Alicante Railway Company has purchased and will soon commence working the Belmez mines, Santa Isabel and Padre Murillo; and important explorations are being undertaken by Messrs. Hill, Delprat, Ferdinand & Carr of Córdoba in the small coal basin of Hornachuelos, from which they extracted 800 tons in 1893.

PRODUCTION OF BITUMINOUS COAL AND LIGNITE IN SPAIN.
(In metric tons.)

Provinces.	Bituminous.		Provinces.	Lignite.	
	1892.	1893.		1892.	1893.
Oviedo	781,620	810,000	Guipuzcoa	14,800	11,000
Córdoba	250,000	310,000	Barcelona	6,536	7,000
Palencia	148,204	149,850	Baleares	8,000	9,000
Sevilla	106,218	103,660	Lérida	5,000	4,000
Ciudad Real	79,000	88,000	Ternel	895	750
Gerona	34,143	40,300	Gerona	930	600
León	25,000	30,000	Santander	700	550
			Logroño	150	1,200
Total	1,424,185	1,531,810	Total	37,011	34,100

Lignite.—The lignite industry continues at a low ebb, notwithstanding the existence of some very important basins, particularly in the Provinces of Ternel, Barcelona, and Guipuzcoa; but lack of means of transportation in the first, and of capital in all, renders their development impossible.

Quicksilver.—Exploitation at the Almadén mines continued regularly during the year 1893, and without any accident worthy of mention. But in order that the twelfth level can be pushed with the necessary dispatch, the directing engineer must be able to purchase drills suitable for the work, as machine drilling is necessary for Almadén to be capable of meeting the requirements of the quicksilver markets of the world.

Besides Almadén there are the quicksilver mines of Mieres and Lena (Asturias), from which were taken 14,000 tons of ore, carrying an average of 1% of quicksilver, and those of Granada, which produced but 380 tons. Exploration of the Miñera cinnabar mines, in the Province of León, commenced in 1893, gave promising results; and similar work was prosecuted at La Vallina cinnabar mines (Asturias), the ore of which carries an average of 0.75% of quicksilver.

The quicksilver treated at the Almadén furnaces in 1892 and 1893, respectively, constituted an aggregate of 44,804 and 44,729 flasks, of 34.507 kilos each, as follows: January, 7738 and 7232; February, 7433 and 6431; March, 6996 and 7045; April, 6347 and 7662; October, 606 and 2604; November, 7262 and 6601; December, 8422 and 7154 flasks. The total production of quicksilver in Spain during the years 1892 and 1893 was 48,740 and 48,457 flasks, of 34.507 kilos each, respectively.

Lead.—The statistics of lead mining in Spain for the year 1893 indicate a healthy condition, with somewhat of an increase as compared with those for the year immediately preceding, thanks in part to the abundance of our lead deposits, but particularly to the high rates of exchange on foreign gold, which, while they were ruinous to the imports, operated favorably upon our export trade. Lead mining in the peninsula is undergoing a gradual transformation, analogous to that heretofore effected in the iron industry, namely, the substitution of wealthy and judiciously organized companies in the place of individuals. This new order of things renders possible the exploitation on a much larger and more remunerative scale the deposits already worked to depths of from 300 to 400 meters, as, for instance, the Compañia de Aguilas in the Provinces of Almería, Mazarrón, and Badajoz; the Real Compañia Asturiana, in various provinces; the Metalúrgica de Mazarrón; the Escombrera-Bleiberg; the English companies at Linares (Jaen); that of El Horcajo (Ciudad Real); the lessees of the Arayanes mine at Linares; the Anglo-Vasca and the Posadas (Córdoba); the California Mauchega (Ciudad Real). The majority of these companies are operated by foreign capital.

The argentiferous district of Mazarrón has changed but little since Don Fernando B. Villasante described it in his excellent work.* The Talia mine has decreased in value; the yield of the Trinufo, in some months of 1893, ran as high as 1000 tons of galena; Santa Ana held its own; San José is in a critical situation; while San Cárlos, San Vicente, Convenio, and others still less important offer hopes for the future.

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* *La Industria Minero-Metalúrgica de Mazarrón*, por D. F. B. Villasante, Cartagena, 1892.

PRODUCTION OF LEAD ORE.
(In metric tons.)

Provinces.	1892.	1893.
Murcia	146,186	160,000
Jaen	104,000	97,000
Almería	34.000	35,000
Badajor	30,000	48,000
Ciudad Real	22,000	23,500
Guipuzcoa	1,829	1,450
Granada	1,675	1,600
Córdoba	1,700	1,500
Navarra	812	120
Baleares	380	310
Toledo	145	430
Huelva	130	350
Total	342,857	369,260

In this table there has been no attempt to classify the ores as argentiferous or non-argentiferous. Tolerably satisfactory returns have been received from the following works. The Santa Elisa, belonging to the Compañia Metalúrgica de Mazarrón, and among the most important in Spain, produces regularly some 21,000 tons of lead and 10,000 kilos of silver annually. The old La Cruz Company's yield in 1893, as in 1892, was approximately 15,000 tons of lead and 6000 kilos of silver, besides a quantity of shot and cannon balls. The Peñarroya works, where the Compañia Minera y Metalúrgica of the same name treats the galena from Aznaga, Berlanga, etc., produced 17,500 tons of lead and 23,000 kilos of silver in 1893; and at the Renteréa works (Guipuzcoa) the Real Compañia Asturiana produced 5500 tons of lead and 10,000 kilos of silver in the same year.

The total production of metallic lead throughout the peninsula in 1892 and 1893 was 175,124 and 188,500 tons, respectively.

Silver.—The only silver ores exploited to-day in Spain are those of the Hiendelaencina district, in the Province of Guadalajara. The Nueva Santa Cecilia, a Spanish company organized with French capital, produced in 1893 a large quantity of sulpho-arseniurets and sulpho-antimoniurets of silver. Silver is also obtained from the argentiferous galenas of El Horcajo (Ciudad Real), the Sierra Almagrera (Almeria), Mazarrón (Murcia), etc. From these remarks it will be perceived that the argentiferous wealth of Spain, once so famous among the Carthagenians and Romans, has materially diminished in modern times; nor is gold now found in any appreciable quantity in the Spanish Peninsula.

The aggregate production of silver in 1892 and 1893 was 85,500 kilos and 90,000 kilos, respectively.

Zinc.—Although calamine and blende deposits have been worked in various Spanish provinces, the production may be regarded as confined almost exclusively to the Province of Santander. These ores are chiefly treated by the Real Compañia Asturiana at Arnao (Asturias) and Auby (France), and are also exploited or purchased by the Vieille Montagne, Stolberg, Westphalia, and other foreign companies, Belgian for the most part. The total production of calamine and blende in Spain was 49,566 tons in 1892 and 51,410 tons in 1893.

The Real Compañia Asturiana's zinc metallurgical establishment at Arnao, the only one in Spain, produced 6000 tons of that metal in 1893, as against 5925 tons in 1892.

Other minerals are produced in many of the provinces, but in quantities so insignificant as to justify the briefest mention only, viz.:

Antimony, the decline in the price of which has completely discouraged the mines; asphalt; sulphur, but little worked owing to the impossibility of competing with the Sicilian article; kaolin (807 tons in 1892 and 1827 tons in 1893); fluorspar (48 tons in 1893); tin (less than 100 tons); steatite (5000 tons); manganese (9480 tons exported in 1893); arsenical pyrites (200 tons); common salt (adequate statistics unobtainable); Glauber salts; hydraulic lime (32,775 tons in 1893, as against 49,808 tons in 1893, at Zumaya, in the Province of Guipuzcoa), etc.

Iron.—The iron-mining returns for 1893 show but a slight improvement as compared with those for the year immediately preceding, the increased output of the Bilbao mines having been offset by a decrease in other provinces, particularly that of Murcia. The Province of Vizcaya exported 4,036,054 tons of iron ore in 1893, but little short of the unusually large shipments of 1891 and 1887; 3,918,544 tons were shipped in 1892. Murcia, one of the provinces which take the lead in exporting ores to the United States, shipped 300,000 tons in 1893, against 476,375 tons in 1892, of which 413,764 tons were through its chief seaport, Cartagena. In these last figures were included what in Cartagena are called *hierros secos* (literally "dry irons"), carrying 50% of metallic iron, and *hierros manganetiferos*, carrying in some cases as high as 24% and even 28% of manganese, though the classes ordinarily exported do not average higher than from 8% to 14% of manganese and from 30% to 35% of iron. The important Pedroso iron mines, in the Province of Sevilla, have been purchased, for a royalty of 0.75 pesetas ($0.15) per ton extracted, by Messrs. William Baird & Co. of Glasgow, they advancing without interest the sum of 3,000,000 pesetas, to be reimbursed at the rate of three-fourths of said royalty. Upon the reimbursement being completed, the purchasers pay over the entire amount of the royalty. Preparations are being made at the mines for work on an extensive scale, and the ore will be transported to the shipping port, Sevilla, 90 kilometers distant, by the Mérida and Sevilla standard-gauge railway. Spain undoubtedly abounds in deposits of good iron ore which require only capital for their exploitation on a proper scale.

PRODUCTION OF IRON ORE.
(In metric tons.)

Provinces.	1892.	1893.
Vizcaya	4,200,000	4,600,000
Murcia	476,376	300,000
Santander	360,000	300,000
Almería	170,300	115,000
Malaga	70,000	55,000
Oviedo	60,000	65,000
Navarra	14,911	13.890
Guipuzcoa	13,555	18,650
Other provinces	40,000	30,000
Total	5,405,142	5,497,540

The chief centers of iron smelting are still the provinces of Vizcaya and Asturias, and there also are the largest factories for the construction of machinery. The Sociedad de Altos Hornas y Fabricas de Hierro de Bilbao produced the following shares of the amounts contained in the foregoing table of production: Cast iron, 90,333 tons; pig iron, 49,000 tons; steel, 20,000 tons.

The Sociedad Vizcaya, likewise at Bilbao, produced 104,678 tons of cast iron in 1892 and 102,700 in 1893; 22,413 tons of pig iron in 1892 and 23,254 tons in 1893; and 24,000 tons of steel.

The Fábrica de Mieres Company (Asturias) produced 19,000 tons of cast iron at Mieres, and 6000 tons of cast iron and 14,500 tons of rolled iron at Quiros, in 1893; in which year the latter establishment was equipped with shops and forges for the manufacture of structural iron. The Fábrica de Mareda y Gijón Company completed in 1893 a blast furnace to supply ingots for its wire works.

Work has gone forward regularly at the leading shops of Bilbao—those of the Aurrerá Company, of Dentso, Zorroza, Miravallas, and others; but the development of these interests has been materially retarded by the uncertainty concerning the projected treaties.

PRODUCTION OF IRON AND STEEL.
(In metric tons.)

Provinces.	Pig Iron.		Wrought Iron.		Steel.	
	1892.	1893.	1892.	1893.	1892.	1893.
Vizcaya	195,000	200,000	71,308	72,149	46,600	60,000
Oviedo	46,865	55,000	41.687	40,000	9,300	10,500
Guipuzcoa	....	....	2,800	2,800	490	600
Navarra	1,293	1,400	3.300	3,250	100	100
Alava	3,660	3,450	3,200	3,150	....	....
Santander	511	600	....	....	....	....
Total	247,329	260,450	122,295	121,349	56,490	71,200

Copper.—The production of copper ore in Spain is confined almost exclusively to the Province of Huelva, the supplies from all other sources—León, Granada, etc.—being really insignificant. At the head of the producers is the Rio Tinto Company, which in 1892 produced 1,402,063 tons and in 1893 1,325,080 tons of pyrites, averaging, respectively, 2.82% and 3.02% of copper. The ore exported by this company in 1892 amounted to 473,065 tons, and in 1893 to 504,696 tons, carrying almost uniformly 3.43% of copper. The production of sulphate of copper, only 405 tons in 1892, reached 3164 tons in 1893; but this increase was offset in the production of sulphuric acid absolute by a decrease from 4056 tons in 1892 to 1524 tons in 1893. Tharsis, second in the order of producers, and the best managed company in Huelva, took out of the mines of the same name and those of Calañas 504,706 tons of pyrites in 1892 and 490,000 tons in 1893, against 585,422 tons in 1891, on account of which steady diminution the company has recently purchased, for £60,000, the Lagunazo mines, with which it will be able to regain its normal output in 1894. Sotiel-Coronada, conducted by the Spanish engineer Don Antonio Gonzalez de Nicolás, produced in 1893, from underground works exclusively, 92,000 tons of pyrites, as against 102,000 tons in 1892. Of this yield 25,000 tons represented *negrillos*, or ore rich in copper, which were exported, the remainder having been treated on the spot with the following result: 106 tons of copper precipitated, firsts, carrying 90% of copper; 1907 tons seconds, carrying 72% to 80% of copper—total, 2093 tons, against 2460 tons in 1892. This Portuguese concern has made marked progress, both economically and technically, since Señor Gonzalez assumed the exclusive management. The Bede Metal and Chemical Company, Limited, of Newcastle-on-Tyne, working La

Cabezas del Pasto and Las Herrerias mines at Puebla de Guzmán, and El Jorga at El Cerro de Andévalo, produced from the first two 44,300 tons of pyrites in 1893, as against 49,913 tons in the year immediately preceding; and from La Jorga 40,590 tons in 1893, as against 382,727 tons in 1892.

The Compañia del Buitrón—or, more correctly, Mr. Hill of London—produced in 1893 only 13,031 tons of pyrites, or 2000 tons more than in the previous year. At his Poderosa and Concepción mines all work is suspended save the operation of utilizing the escaping waters by the cementation process. The Companhia Mineira of San Miguel extracted in 1893, from the mine of the same name, pyrites that produced 715 tons of copper precipitate, as against 908 tons in 1892. The Peninsular Copper Mining Company, Limited, which exploits the Peña de Hierro mines, north of Rio Tinto, has almost entirely abandoned open-air work, and turned to precipitation from the escaping waters of the mine until more ready means of transportation to the port of Huelva can be obtained. The returns at hand warrant me in setting down as follows:

PRODUCTION OF COPPER IN THE PROVINCE OF HUELVA.
(In metric tons.)

	1892.	1893.
Ore, 2.50% of copper	2,300,000	2,200,000
Copper precipitate, .75% of copper	29,000	26,500
Matte, .45% of copper	16,385	15,500

As to the rest of Spain, it may be added that the Province of León produced in 1892 ore rich in copper to the amount of 1437 tons, and in 1893 1300 tons; the Province of Granada, 1257 tons in 1892, and 1220 tons in 1893; and the Province of Gerona in 1893, as a beginning, produced 80 tons.

THE MINERAL PRODUCTION OF SPAIN. (*a*) (IN METRIC TONS; $1=5 Pesetas.)

Year.	Alum Ore.		Antimony Ore.		Asphalt.		Coal.		Copper Ore.		Copper Ore, Argent.		Iron Ore.	
1856	106	$12,540	24	$1,060	12	$4,900	91,355	$244,569	80,354	$809,926	....	....	69,124	$137,326
1857	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1858	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1859	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1860	8,938	17,876	60	....	63	....	321,773	....	146,003	....	....	....	173,503	....
1861	8,142	16,785	116	2,900	2,417	15,717	331,055	827,637	151,289	680,838	8	....	130,259	211,671
1862	7,644	6,879	85	2,117	1,166	7,580	360,246	990,675	227,719	1,028,152	....	....	213,192	347,937
1863	8,179	8,178	85	1,700	894	....	401,301	1,010,128	245,637	781,751	....	....	222,676	245,667
1864	9,043	9,044	74	2,808	3,835	3,824	387,904	1,259,060	211,389	890,361	....	....	253,121	417,123
1865	7,588	7,587	28	1,083	795	795	461,396	1,356,693	273,184	1,278,894	....	....	191,684	331,598
1866	7,288	7,285	....	....	2,663	3,712	393,105	852,757	279,527	1,007,954	....	....	180,131	244,646
1867	21,600	21,600	....	....	326	738	511,550	970,134	237,488	575,056	116	$11,278	254,481	323,184
1868	16,200	16,200	30	750	1,004	2,576	529,058	932,255	227,731	667,068	95	1,750	385,553	531,269
1869	13,250	13,250	75	453	955	2,178	550,403	1,115,734	306,619	731,517	223	9,763	311,345	425,182
1870	14,720	14,720	80	1,007	477	1,070	621,848	1,300,143	395,398	1,231,447	397	14,503	436,586	558,255

Year.	Iron Pyrites.		Kaolin.		Lead Ore.		Lead Ore, Argentiferous.		Lignite.		Manganese Ore.	
1856	....	....	....	....	233,974	....	....	$3,092,916	701	$1,796	9	$512
1857	....	....	....	....	....	....	....	....	....	....	....	....
1858	....	....	....	....	....	....	....	....	....	....	....	....
1859	....	....	....	....	....	....	....	....	....	....	....	....
1860	....	....	....	....	315,712	....	1,106	....	17,531	....	28,863	....
1861	....	....	....	....	337,513	$2,985,597	20,006	1,432,142	22,292	44,584	14,071	105,535
1862	....	....	....	....	277,845	4,077,412	....	....	28,696	64,566	6,460	68.448
1863	....	....	....	....	269,599	3,438,831	40,339	1,268,845	50,302	115,500	14,660	38,575
1864	....	....	....	....	274,588	3,949,216	25,111	1,101,898	38,526	97,832	22,246	84,590
1865	....	....	....	....	271,318	3,239,730	19,323	943,174	34,455	86,110	24,864	115,857
1866	....	....	....	....	267,494	4,117,050	31,312	1,165,354	39,559	96,461	39,624	488,140
1867	25	$250	400	$800	337,093	3,745,107	30,417	1,490,568	37,640	96,500	33,722	147,821
1868	500	5,000	700	1,400	317,670	4,432,084	28,908	1,401,910	41,765	114,786	43,193	203,278
1869	1,825	6,287	500	1,000	278,374	4,938,258	33,440	1,599,634	39,420	119,469	29,402	143,934
1870	1,460	5,110	450	860	318,945	4,980,716	33,248	1,542,443	40,095	119,967	16,823	117,140

Year.	Mercury Ore.		Nickel and Cobalt Ore.		Peat.		Phosphates.		Quartz. Aurif'rous		Salt.		Schists.	
1856	19,524	$2,346	10	$2,430	1,836	$1,836	....	....	....	....	....	....	....	....
1857	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1858	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1859	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1860	8,041	....	3	....	130	....	....	....	....	....	391,692	$5,562,478	....	....
1861	6,894	16,736	....	....	....	....	....	....	50	$1,500	201,775	5,774,120	....	....
1862	16,115	459,286	3	232	....	....	....	....	....	....	182,203	5,927,738	....	....
1863	16,862	498,062	18	462	....	....	....	....	....	....	187,271	6,629,008	400	$800
1864	19,800	620,399	....	....	....	....	....	....	....	....	152,659	6,001,592	....	....
1865	16,425	659,706	....	....	....	....	12,800	$27,776	....	....	199,309	6,136,610	....	....
1866	18,547	760,750	....	....	....	....	9,304	20,189	46	....	201,108	6,198,677	....	....
1867	19,756	839,080	122	9,760	34	42	2,133	4,628	....	....	176,238	5,733,572	....	....
1868	24,017	1,112,832	1	172	494	741	3,950	7,506	....	....	176,339	4,547,424	1,335	5,340
1869	28,084	1,219,278	83	616	2,150	4,388	18,000	39,060	39	1,662	170,216	3,752,698	120	498
1870	23,744	1,013,683	22	2,372	150	3,750	27,978	83,934	5	196	139,058	946,545	....	....

Year.	Silver Ore.		Steatite.		Sulphate of Soda.		Sulphur.		Tin Ore.		Topaz.		Zinc Ore.	
1856	37,773	....	....	....	398	$6,873	233	....	18	$435	9	$540	18,293	$497,535
1857	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1858	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1859	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1860	4,330	....	....	....	17,557	....	23,045	....	7	....	....	....	108,802	....
1861	3,005	$368,196	....	....	11.691	29,228	23.149	$188,190	1,888	22,660	1	290	24.744	324,367
1862	2,524	309,172	....	....	5,022	12,554	13,639	101,116	101	14,143	1	466	41,104	534,355
1863	3,062	301,160	....	....	8,090	20,225	11,982	42,972	61	13,315	1	130	48,124	512,353
1864	1,818	277,342	....	....	11,822	7,910	9.788	36,190	63	15,650	41	886	80,222	777,110
1865	1,135	171,601	....	....	7,667	3,834	10,708	37,906	93	10,336	1	607	70,158	812,650
1866	1,703	235,483	....	....	9,911	18,422	16,242	58,052	30	5,613	649	602	73,423	765,428
1867	1,648	161,718	800	$400	11,177	22,310	10,597	36,900	20	4,268	1	600	86,822	945,862
1868	3,464	235,784	....	....	9,117	12,129	14,575	47,986	24	5,058	1	606	131,407	1,535,974
1869	2,931	194,071	1,720	3,440	17,540	17,810	12,501	41,755	24	7,742	1	692	113,485	1,402,749
1870	2,679	177,790	....	....	7,975	7,325	15,156	50,099	28	2,533	....	1,605	113,583	1,456,315

(*a*) The figures for 1856–70, inclusive, and for the fiscal year 1892–93 (this latter advance sheets of the Government publication), were kindly furnished by Sr. D. Federico de Botella y de Hornos, Chief Inspector General of the Mining Bureau; for 1871–90, inclusive, and for the fiscal year 1891–92, from *Estadistica Minera de España.* Of other mineral products are reported: Gold ore, 876 tons between 1871 and 1882; jet, 819 tons between 1871 and 1875, the output in 1890 being 57 tons, $5403; limestone, in 1889 and 1890, respectively, 6295 tons, $6295, and 5217 tons, $5217; nickel ore, 807 tons between 1872 and 1881, the output in 1890, 1891, and 1892 being, respectively,

MINERAL PRODUCTION OF SPAIN—*Continued.*

Year.	Alum Ore.		Antimony Ore.		Asphalt.		Clay.		Coal.		Cobalt Ore.		Copper Ore.	
1871..	14,720	......	155	......	....	....	......	......	589,724	....	4	......	498,206	....
1872..	13,620	......	312	......	....	....	......	......	687,791	....	48	......	507,340	....
1873..	11,670	......	163	......	....	....	......	......	658,745	....	4	......	333,086	....
1874..	9,850	......	22	......	....	....	......	......	709,155	....	82	......	560,341	....
1875..	8,800	......	......	......	....	....	......	......	666,806	....	89	......	802,633	....
1876..	9,600	......	33	......	5	....	......	......	720,410	....	115	......	899,721	....
1877..	8,800	......	2	......	458	....	......	......	652,362	....	433	......	1,387,123	....
1878..	10,330	......	31	......	237	....	18,276	......	649,670	....	100	......	1,391,035	....
1879..	8,675	......	35	......	642	....	21,377	......	667,866	....	110	......	1,470,945	....
1880..	10,675	......	11	......	584	....	22,077	......	825,790	....	129	......	1,476,209	....
1881..	6,775	$3,387	14	$172	106	$184	......	......	1,171,410	$2,509,786	102	$13,720	1,455,892	$3,226,215
1882..	8,180	4,090	30	1,290	493	802	......	......	1,165,517	2,775,937	40	5.234	1,720,853	3,779,519
1883..	4,620	2,310	45	1,530	275	492	......	......	1,044,480	2,318,231	19.4	2,486	2,455,036	5,472,464
1884..	6,843	3,403	1,095	10,880	243	480	......	......	952,970	1,952,613	.....	....	2,271,060	5,066,304
1885..	7,513	3,756	150	1,350	284	528	......	......	919,440	1,620,389	.....	....	2,199,125	4,872,457
1886..	7,000	3,500	8	162	159	261	......	......	977,559	1,637,334	132	17,200	2,376,381	5,273,435
1887..	3,800	5,700	322	686	183	366	......	......	1,021,254	1,686,056	436	13,914	3,154,901	3,665,881
1888..	....	......	440	4,309	150	300	5,379	$213	1,014,720	1,660.647	68	5,476	3,202,416	3,842,899
1889..	1,420	2,130	456	14,087	387	878	540	896	1,124,436	2,248,873	141	4,876	*c*3,136,997	15,819,925
1890..	....	......	821	25,352	43	97	180	360	1,212,088	2,424,177	112	4,368	*d*3,016,855	11,180,171
1891*b*	536	2,680	564	16,304	312	640	72	144	1,296,460	2,282,433	.....	....	*e*2,481,166	2,562,462
1892*b*.	550	2,750	183	759	668	1,381	120	180	1,458,660	2,309,911	24	72	2,237,707	2,274,421
1893..	....	......	......	......	....	....	......	......	....	....	.....	....	....	....

Year.	Copper Ore, Argentiferous.		Fluorspar.		Graphite.		Iron Ore.		Iron Pyrites.		Kaolin.		Lead Ore.	
1871..	491	....	......	......	....	......	585,763	....	540	....	.....	......	402,789	....
1872..	334	....	......	......	....	......	721,468	....	600	....	.....	......	373,844	....
1873..	335	....	......	......	....	......	811,926	....	....	....	.....	......	218,536	....
1874..	203	....	......	......	....	......	423,401	....	....	....	.....	......	227,560	....
1875..	162	....	......	......	....	......	520,095	....	....	....	.....	......	304,478	....
1876..	92	....	......	......	....	......	884,568	....	....	....	.....	......	*f* 345,337	....
1877..	....	....	......	......	....	......	1,578,150	....	....	....	.....	......	*f* 301,696	....
1878..	107	....	......	......	....	......	1,703,051	....	....	....	.....	......	300,407	....
1879..	87	....	......	......	....	......	1,754,295	....	....	....	.....	......	*f* 311,627	....
1880..	101	....	......	......	....	......	3,565,338	....	....	....	.....	......	*f* 290,167	....
1881..	80	$ 220	......	......	....	......	3,502,681	$1,890,413	....	....	446	$2,062	*g*342.968	$9,097,834
1882..	50	10,000	......	......	....	......	4,726,293	2,353,400	....	....	80	480	341,818	8,989,823
1883..	50	2,000	......	......	....	......	4,526,279	2,530,626	....	....	1,040	5,600	280,061	7,025,888
1884..	8	120	......	......	....	......	3,907,266	2,182,253	....	....	680	4,680	331,164	7,399,269
1885..	3,624	4,933	20	$120	....	......	3,933,298	2,371,210	....	....	880	6.080	263,825	6,067,494
1886..	51	64	2,000	2,000	....	......	4,166,946	2,849,501	....	....	946	5,788	342,200	8,556,207
1887..	....	....	......	......	....	......	6,796,266	4,104,945	....	....	749	5,247	335,624	7,050,588
1888..	....	....	5	96	36	$ 319	5,609,876	3,365,925	....	....	490	3,434	356,545	7,843,990
1889..	818	1,636	9	162	107	1,204	5,710,639	6,852,764	165,230	$537,327	691	6,500	172,315	4,824,838
1890..	334	2,576	5	97	95	1,064	6,546,495	7,855,794	163,825	532,760	1,938	22,065	*h*161,925	4,532,994
1891*b*.	....	....	2	36	58	318	4,931,689	4,906,615	221,000	706,937	640	4,340	129,365	3,063,733
1892*b*.	....	....	48	......	....	......	5,426,036	4,080,326	213,772	106,906	1,485	4,366	*r*161,942	3,393,528
1893..	....	....	......	......	....	......	....	....	....	....	.....	......	....	....

Year.	Lead Ore, Argentiferous.		Lignite.		Manganese Ore.		Mercury Ore.		Phosphates.		Salt.		Silver Ore.	
1871..	25,787	....	43,768	....	15,269	....	21,025	....	23,661	....	38,233	....	13,265	....
1872..	34,381	....	33,211	....	32,726	....	21,939	....	45,847	....	54,397	....	6,944	....
1873..	36,505	....	20,691	....	18,055	....	19,655	....	20,987	....	48,205	....	50,651	....
1874..	60,340	....	14,828	....	11,069	....	24,177	....	21,070	....	34,127	....	33,306	....
1875..	33,580	....	27,184	....	14,710	....	28,956	....	1,220	....	28,582	....	36.380	....
1876..	34,302	....	32,303	....	5,658	....	26,324	....	7,911	....	144,715	....	35,588	....
1877..	37,408	....	24,817	....	5,703	....	26,766	....	15,500	....	118,877	....	33,331	....
1878..	38,922	....	22,657	....	3,837	....	22,483	....	15,267	....	90,679	....	32,171	....
1879..	42,536	....	22,814	....	4,846	....	25,919	....	17,672	....	82,095	....	32,812	....
1880..	30,852	....	21,338	....	5,034	....	26,336	....	24,713	....	105,921	....	29,999	....
1881..	24,655	$934,281	38,472	$67,960	8,207	$69,125	23,919	$19,080	20,179	$60,537	150,389	$334,240	8,907	$184,433
1882..	22,425	975,394	30,738	74,508	5,668	45,579	27,037	198,168	21,070	63,210	112,582	271,399	18,349	355,830
1883..	24,548	787,658	26,270	58,614	4,182	23,340	22,581	1,045,654	44,750	111,875	117,930	276,278	22,531	441,656
1884..	26,047	824,820	26,380	56,135	851	9,233	24,683	1,129,347	35,705	71,410	112,317	272,103	5,982	118,572
1885..	22,879	704,226	26,464	58,635	4,045	16,575	25,801	1,236,998	19,350	79,245	117,304	296,532	4,857	28,002
1886..	23,246	937,157	23,873	79,023	400	1.455	25,286	1,232,653	11,839	23,678	124,851	334,824	1,531	37,652
1887..	147,794	4,484,363	17,051	36,084	1,460	7,482	26.422	1,112,599	21,963	13,266	405,394	1,452,148	185	12,195
1888..	183,441	5,503,230	21,846	41,307	2,807	14,596	27.847	1,183,047	4,532	3,170	*i*413,886	1,448,610	134	7,756
1889..	321,480	9,803,224	29,319	46,911	8,187	81,875	30,373	1,245,568	9,000	10,800	745,406	2,087,139	19,090	25.199
1890..	332,739	10,146,545	26,307	42,090	9,872	98,722	34,580	1,492.960	48	96	615,727	1,813,931	3,574	26,028
1891*b*.	195,063	1,263,693	32,870	41,127	9,002	60,575	33,333	1,670,945	2,190	3,210	27,070	102,984	4,099	74,799
1892*b*.	176,720	2,769,015	21,053	27,392	90	90	37,373	1,861,153	760	1,107	*s*45,871	147,892	1,299	257,015
1893..	....	....	....	....	......	....	......	....	......	....	....	....	......	....

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12 tons, $168, and 75 tons, $225 (the latter including cobalt ore), and 30 tons, $897; ocher, in 1889, 1890, and 1891, respectively, 1 ton, 305 tons, and 334 tons, $3, $2112, and $667; peat, 3601 tons between 1873 and 1885; arsenical pyrites, 442 tons, $1031, in 1892. Wolfram ore in fiscal year 1891–92, 20 tons, $985; 1892–93, 16 tons, $810; antimony in 1882–84, 20 tons, $4918, and lead and antimony in 1886 and in 1891, respectively, 260 tons, $14,040, and 190

MINERAL PRODUCTION OF SPAIN—*Continued.*

Year.	Steatite.		Sulphate of Barium.		Sulphate of Soda.		Sulphur Ore.		Tin Ore.		Topaz of Hinojosa, Kil.		Zinc Ore.	
1871	....	....	1,021	....	10,148	....	16,624	....	17	....	0.7	....	107,380	....
1872	....	....	1,011	....	10,172	....	20,425	....	3	....	0.7	....	89,371	....
1873	....	....	....	....	8,827	....	19,355	....	47	....	....	....	101,010	....
1874	....	....	....	....	4,592	....	19,881	....	18	....	0.6	....	106,477	....
1875	....	....	....	....	8,154	....	20,000	....	3	....	0.4	....	100,174	....
1876	....	....	800	....	17,366	....	37,358	....	1	....	0.1	....	107,063	....
1877	....	....	518	....	16,066	....	34,787	....	7	....	0.5	....	70,951	....
1878	....	....	636	....	5,680	....	27,757	....	350	....	0.2	....	71,558	....
1879	....	....	955	....	2,850	....	26,860	....	4	....	0.1	....	60,980	....
1880	....	....	800	....	6,340	....	30,281	....	1	....	....	....	50,521	....
1881	....	....	800	$800	4,200	$8,200	32,691	$108,872	....	....	....	....	42,911	$229,725
1882	....	....	800	800	13,525	13,700	40,037	183,626	0.23	$50	....	....	57,353	385,762
1883	....	....	205	143	1,015	2,810	54,964	787,664	....	....	....	....	54,193	281,793
1884	100	$200	1,250	750	1,735	1,780	43,967	314,304	....	....	....	....	49,838	265,519
1885	200	400	150	90	3,190	2,770	38,328	383,910	....	....	....	....	45,509	239,183
1886	100	200	13	8	3,155	3,655	45,669	373,318	....	....	....	....	39,810	229,185
1887	199	435	....	....	2,504	3,893	48,050	110,957	5	726	....	....	69,012	357,700
1888	738	2,401	5,535	11,583	177	467	*j*132,880	78,340	115	18,026	280	$407	74,353	382,435
1889	2,664	8,364	487	3,896	522	2,349	30,810	78,140	55	9,984	288	1,913	71.774	574,185
1890	3,106	9,692	335	2,680	332	1,494	29,639	76,669	51	9,254	337	2,423	81,398	651,184
1891	2,411	11,826	555	2,558	220	290	29,647	77,082	80	8,054	147	3,048	53,547	382,561
1892	2,950	13,635	701	3,001	310	465	24,722	59,647	243	5,291	104	2,360	62,963	375,130
1893	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Year.	Alum.		Arsenic and Arsenical Comp'ds.		Asphalt.		Cement.		Coke.		Copper.		Iron, Pig.	
1871	444	....	....	....	331	......	14,462	....	....	....	5,841	....	....	....
1872	400	....	....	....	430	......	14,204	....	....	....	4,955	....	....	....
1873	330	....	....	....	....	......	11,944	....	....	....	8,946	....	....	....
1874	800	....	....	....	....	......	7,862	....	....	....	5,054	....	....	....
1875	352	....	....	....	....	......	8,000	....	....	....	6,632	....	....	....
1876	384	....	....	....	6	......	14,370	....	....	....	9,372	....	44,491	....
1877	352	....	....	....	322	......	13,420	....	....	....	11,221	....	46,919	....
1878	413	....	....	....	230	......	14,902	....	....	....	15,327	....	66,763	....
1879	347	....	44	....	6	......	18,121	....	....	....	20,421	....	68,742	....
1880	427	....	63	....	507	......	18,301	....	....	....	23,676	....	85,939	....
1881	271	$8,807	....	....	56	$634	18,573	$75,508	....	....	23,478	$3,822,348	114,394	$1,746,448
1882	327	10,660	50	$3,300	300	3,296	26,941	98,822	....	....	22,849	3,910,098	120,064	1,692,376
1883	185	5,920	81	5,508	160	1,590	26,170	114,825	....	....	32,156	5,520,528	139,920	1,728,882
1884	274	9,316	109	4,284	100	1,234	33,718	104,883	....	....	45,556	6,159,534	124,363	1,603,830
1885	451	14,432	96	8,175	155	1,402	29,582	88,517	....	....	42,161	7,592,770	159,225	1,824,710
1886	560	14,000	77	6,560	117	1,060	31,945	81,044	....	....	41,870	7,562,684	57,728	*k*2,487,276
1887	304	7,600	....	....	164	1,314	30,363	73,492	134,536	$2,158,175	55,762	7,804,680	288,634	*m*7,927,256
1888	233	5,644	50	4,005	23	178	31,538	97,494	188,607	724,234	70,719	10,089,417	252,116	*m*7,260.928
1889	1	25	56	4,480	335	1,341	124,586	355,553	162,043	657,761	54,887	8,312,259	197,874	*n*2,532,787
1890	....	....	60	7,501	23	188	135,988	388,109	191,238	772,995	64,373	9,540,468	170,782	*n*2,732,634
1891	....	....	62	3,968	280	3,640	129,721	336,380	43,341	211,197	*l*50,435	5,365,686	119,605	*n*1,646.866
1892	....	....	85	5,466	655	8,491	129,379	321,062	29,379	140,277	43.047	4,702,040	134,299	1,875,223
1893	....	....	....	....	....	......	....	....	....	....	....	....	....	....

Year.	Iron, Wrought.		Steel.		Lead.		Lead, Argentiferous.		Mercury.		Silver, Kilos.	
1871	....	....	217	....	80,696	....	11,321	....	1,151	....	8,205	....
1872	....	....	272	....	88,924	....	12,624	....	1,262	....	6,978	....
1873	....	....	216	....	85,305	....	14,407	....	929	....	6,404	....
1874	....	....	171	....	86,432	....	19,826	....	1,257	....	12,743	....
1875	....	....	149	....	107,765	....	11,887	....	1,426	....	5,914	....
1876	33,900	....	....	....	113,212	....	14,283	....	1,334	....	3,320	....
1877	43,977	....	....	....	80,822	....	....	....	1,292.	....	9,240	....
1878	44.722	....	....	....	89,567	....	....	....	1,503	....	9,670	....
1879	44,620	....	....	....	75.067	....	15,050	....	1,611	....	7,040	....
1880	49,021	....	....	....	68,437	....	11,371	....	1,388	....	6,590	....
1881	3,602	$220,896	....	....	82,982	$5,026,178	7.690	$1,020,680	1,812	$1,609,226	24,220	$918,979
1882	5,553	319,826	....	....	81,040	4,530,075	7,299	938,736	1,705	1,535,232	6,898	1,746,668
1883	2.304	121,589	....	....	89,313	4,644,271	9.999	1,269,875	1,667	1.497,723	54,335	1,968,705
1884	1,906	98,983	373	$50,908	70,384	3 577,559	12,920	1,239,610	1,564	1,399,232	26,301	957,561
1885	1,901	108,859	361	50,708	79,986	4,234,075	9,629	954,514	1,694	1,523,670	31,026	1,104,562
1886	*k*	*k*	20,261	534,567	94,895	5,010,622	11,047	825,628	1,846	1,660,306	39,066	1,927,011
1887	*m*	*m*	*m*	....	119,932	5,442,915	67,775	5,376,035	1,949	1,887,744	93,113	4,374,907
1888	*m*	*m*	*m*	....	161,462	9,687,720	73,376	6,457,088	1,865	2,001,433	65,000	2,321,751
1889	61,613	2,957,424	49,124	1,964,960	100,090	5,985,392	76,732	7,980,207	1,975	2,124,472	50,000	1,700,000
1890	61,444	2,949,355	75.255	3.100,491	91,628	5,611,855	86,325	8,377,779	1,813	2.239,547	52.000	1,770,496
1891	74,475	3,078,850	59,988	2,424,533	74,820	4,163,512	91,158	7,098,905	1,749	1,696,512	54,809	1,748,317
1892	63,218	2,851,882	65,926	2,652,393	69,146	3,447,458	82,568	5,855,720	2,087	1,854,618	60,859	1,889,531
1893	....	....	....	....	....	....	....	....	....	....	....	....

MINERAL PRODUCTION OF SPAIN—*Continued.*

Year.	Sulphate of Barium.		Sulphate of Soda.		Sulphur.		Zinc. (*p*)	
1871.	.....	......	1,826	......	2,405	....	3,166	....
1872.	.....	......	1,449	......	2,964	....	2,940	....
1873.	.....	......	1,703	......	2,622	....	2,993	....
1874.	.....	......	395	......	3,118	....	3,295	....
1875.	.....	......	801	......	3,056	....	3,831	....
1876.	100	......	885	......	5,906	....	4,349	....
1877.	500	......	853	......	5,542	....	3,780	....
1878.	636	......	462	......	4,664	....	3,775	....
1879.	955	......	208	......	4,270	....	3,800	....
1880.	780	......	460	......	5.144	....	4,221	....
1881.	800	$8,000	229	$3,664	6,018	$154,983	7,032	$585,360
1882.	800	8,000	900	14,400	7,207	184,257	7,310	609,896
1883.	205	2,619	31	620	11,129	310,990	6,843	581.196
1884.	1,250	7.500	283	4,528	9,211	219,327	4.295	485,360
1885.	150	900	140	2,240	8,350	241.490	4,247	450,142
1886.	13	136	325	6,500	9,041	226,713	4,327	475,404
1887.	63	1,008	53	1,078	8,371	174,351	28,579	721,422
1888.	*o*28	70	22	432	5,054	101,464	26,173	785,118
1889.	*o*60	720	223	2,682	8,352	187,926	27,475	895,788
1890.	.....	......	128	1,536	9,855	221,737	39,276	1.318,260
1891*b*	.....	......	170	1,530	9,700	164,900	26,031	834,743
1892*b*	.....	......	163	1,463	5,353	93,939	*t*26,475	885,375
1893.	.....	......	......	......	......	....	....	....

MINERAL IMPORTS OF SPAIN (*u*) (IN METRIC TONS; 5 pesetas=$1.)

Year.	Asphalt and Pitch.		Carbonates, Alkaline.		Chemical Products.	Coal.	Coke.	Coal.	Coke.	Gold Bars, Kilos.		Gold Coin.
1881	....	....	......	....	$2,775,800	983,112		$4,129,000		......	....	....
1882	....	....	......	....	2,952,600	1,108,104		4,654,000		......	....	....
1883	....	....	......	....	3.010,200	1,262,677		5,808,400		......	....	....
1884	....	....	......	....	3,176,200	1,342.000		5,368,200		......	....	....
1885	....	....	......	....	3.045,000	1,317,000		5,005,600		......	....	....
1886	....	....	......	....	3,170,400	1,407,000		5,206,800		......	....	....
1887	....	....	......	....	3,162,600	1,382,000		5,114,400		......	....	....
1888	....	....	......	....	2,873,000	1,488,000		6,251,400		......	....	....
1889	....	....	......	....	3,320,600	1,615,000		8,074.800		......	....	....
1890	....	....	......	....	4,555,200	1,718.000		8,932.000		......	....	....
1891	36,430	$728,621	23,159	$1,019,037	2,855,200	1,634,400	228,926	$8,825,006	$1,236,002	1,922	$1,191,640	$4,766
1892	25,682	513,635	23,213	1,109,393	....	1,688,537	175,872	9,020,169	940,983	7,738	4,797,560	3,936
1893	33,608	672.164	25,649	1,128,571	....	1,484,097	268,193	8,014,112	1,410,045	2,203	1,365,860	1,008

Year.	Iron, Pig.		Iron, Bars.		Machinery.		Petroleum, Crude.		Silver Bars, Kilos.		Silver Coin.	Soda Nitrate.	
1881.	......	....	......	....	22,389	$5,675,600	4,415	$22,800	....	....	....	......	....
1882.	......	....	......	....	25,455	6,496,000	5,174	1,257,800	....	....	....	......	....
1883.	......	....	......	....	22,125	5,638,400	6,452	1,546,400	....	....	....	......	....
1884.	......	....	......	....	23,670	5,846,600	6,502	1,667,000	....	....	....	......	....
1885.	......	....	......	....	17,767	4,377,200	6,046	2,408,400	....	....	....	......	....
1886.	......	....	......	....	16,640	4,180,400	7,147	1,844,400	....	....	....	......	....
1887.	......	....	......	....	16,021	4,027,400	6,520	1,693,800	....	....	....	......	....
1888.	......	....	......	....	17,097	4,317.000	5,353	3,616,600	....	....	....	......	....
1889.	......	....	......	....	26,622	6,730,400	6,267	1,595,600	....	....	....	......	....
1890.	......	....	......	....	32,295	8,216,600	4,879	2,229,000	....	....	....	......	....
1891.	34,609	$484,533	18,013	$776,996	30,611	7,760,400	54,821	2,192,863	544,901	$21,796.040	$487,916	15,816	$949,007
1892.	30,022	420,312	10,177	478,206	*v*6,297	1,609,381	44,656	1,786,241	97,468	3,898.720	1,000,719	18,335	1,099,917
1893.	23,348	328,784	6,970	343,303	*v*2,795	649,686	54,942	1,977,925	394	14,184	3.827,308	18,998	1,139,923

Year.	Steel.		Sulphur.		Tin Plate.		Tin Ingots.	
1891..................	45,002	$1,876,979	7,125	....	2,659	$265,929	625	$312,867
1892..................	31,637	1,214,953	8,568	$222,759	2,433	293,341	813	406,580
1893..................	15,143	717,841	6,330	162,186	2,986	268,794	1,004	395,362

tons, $11,003; tin in 1871, 1873 1875, and 1880, respectively, 2, 2, 1, and 12 tons; powdered alabaster in 1876 and 1877, respectively, 1600 and 1800 tons; superphosphates in 1889, 968 tous, $50,357. Iu 1892–93, sulphuric acid 885 tons; sulphate of copper, 1817 tons, $181,685. (*b*) Fiscal years 1891–92, and 1892–93. (*c*) Includes 7102 tons of copper and cobalt ore, $170,448. (*d*) Includes 5077 tons of copper and cobalt ore, $121,848. (*e*) Includes copper and cobalt ore, 1770 tons, $42,480, and 1777 tons, $42,648, respectively, in 1891 and 1892. (*f*) Includes lead-zinc ore amounting respectively to 65,237, 3, and 120 tons. (*g*) Includes 30 tons of lead-zinc ore, $1200. (*h*) Includes 50 tons of lead-copper ore, $500. (*i*) Includes salt obtained from salines. (*j*) Includes iron pyrites. (*k*) Includes wrought iron. (*l*) Includes 269 tons of fine copper, 28,672 tons of copper precipitate, and 17,849 tons of copper matte. (*m*) Includes soft iron, steel, and wire. (*n*) There were also produced in 1889, 1890, and 1891, respectively, 1,934 tons, $116,040, 1524 tons, $94,488, and 3,645 tons, $230,094 of wire. (o) Sulphate of calcium. (*p*) Iucludes for the years 1887–92 calcined calamine. The productiou of spelter amounted to 11,476, 5117, 5640, 5919, 5656. 5925 and 5972 tons, respectively, during the years 1887–92. (*q*) Sulphate of magnesia. (*r*) The production of Arrayanes is missing. (*s*) Rock and common salt; the production of Correvieja is missing, as well as that of the province of Cadiz, which amounted to 62.486 tons, but the value of which is unknown.(*t*) Includes 483 tons of calcined calamine from the province of Ternel, the value of which is not known. (*u*) Authorities: For imports: British Abstracts for 1881–90, and *Revista Minera* for 1891 and 1892 and Dr. Roman Oriol for 1893. For exports: *Estadistica Minera de España* for 1871–90, and *Revista Minera* for 1891–92, and Dr. Roman Oriol for 1893. (*t*) Other exports were: Coal in 1891, 1892, and 1893, 11,460 tons, $61,888, 14,390 tons, $77,706, and 8387 tons, $45,290; copper matte in 1886, 1891, 1892, and 1893, 10,414 tons. $93,734, 24,487 tons, $284,055, 30,222 tons, $350.591, 28,130 tons, $286,302; gold bullion and coin in 1883–86 to the value of $1,196,009, in 1891, 1892, and 1893, $114,576, $95,336, and $114,298 (respectively 181.8 153.8, and 127.9 kilos); silver bullion and coin in kilos, in 1877 and 1878, 3000 and 32,200, and from 1883 to 1893, respectively, 20,972, $819,912; 11,599, $440,762; 23, $819,961; ———, $819,961; ———, ———; 23, $888,767; 70. $2,621,209; 25, $1,010,456; 101,509.5, $4,060,380; 2,237,458, $8,349,832; 705,703, $2,540,521; salt in 1892 and 1893, 232,234 tons, $700.702, and 200,924, $602,772; tin in 1871 and 1872, 1 and 1 tons, in 1882, 13 tons, $3,795; in 1885 and 1886, 6 tons, $2617 and 4 tons, $1,908; in 1888–90, 6 tons, $3328; 12 tons, $6061, and 7 tons, $3573. (*v*) Engines and boilers only.

MINERAL EXPORTS OF SPAIN. (*u*) (IN METRIC TONS; 5 pesetas=$1.)

Year.	Antimony Ore.		Copper Ore.		Iron Ore.		Iron Pyrites.		Lead-Silver Ore.		Manganese Ore.		Phos-phates.	
1871	20	......	247,223	....	391,436	....	......	......	1,168	....	23,868	......	33,417	......
1872	46	......	271,484	....	745,803	....	......	......	3,384	....	29,800	......	45,559	......
1873	...	......	255,969	....	800,381	....	......	......	4,662	....	29,056	......	11,842	......
1874	25	......	289,877	....	711,127	....	464	......	8,146	$19,309	41,937	......	100	......
1875	...	......	362,478	....	336,604	....	......	......	9,954	....	13,954	......	19,193	......
1876	145	......	453,781	....	638,497	....	......	......	23,810	....	13,129	......	12,922	......
1877	160	......	512,250	....	1,277,423	....	......	......	12,533	....	7,740	......	15,747	......
1878	212	......	436,295	....	1,807,029	....	......	......	15,094	....	6,215	......	17,766	......
1879	40	......	451,009	....	1,071,016	....	......	......	12,090	....	8,820	......	15,126	......
1880	52	......	501,425	....	2,932,998	....	......	......	12,513	....	11,552	......	19,486	......
1881	40	......	450,370	....	3,088,703	....	......	......	9,687	....	5,698	......	45,639	......
1882	46	$2,714	571,441	$8,000,174	4,025,234	$12,075,702	......	......	12,599	1,058,293	3,357	$67,140	42,873	$85.746
1883	68	4,033	564,565	3,951,955	4,225,827	7,606,589	......	......	15,409	1,001,618	4,533	46,691	55,773	111,545
1884	445	26,281	617,958	3,707,747	3,967,607	7,145,693	......	......	14,077	910,560	4,677	40,222	49,928	59,070
1885	187	13,192	785,892	3,929,461	3,796,943	6,454,805	......	......	17,558	1,943,181	3,960	35,644	22,612	45,225
1886	27	1,878	671,897	3,762,625	4,187,526	7,118,795	6,390	$11,503	12,640	1,234,127	1,201	12,012	13,113	26,227
1887	27	6,090	766,801	6,134,408	5,222,270	9,400,446	......	......	13,780	1,557,740	1,460	14,600	21,439	42,878
1888	367	21,997	825,046	6,600,360	4,464,385	8,928,769	......	......	10.993	1,080,168	2,387	23,870	2,802	5.604
1889	254	15,265	762,249	5,793,099	5,051,613	11,113,549	121,928	243,856	12,646	1,193,616	8,187	81,875	8,520	17,040
1890	596	35,813	680,274	5,170,110	5,708,810	12,559,383	163,825	327,651	12,952	993,365	5,570	52,360	20	40
1891	550	33,039	661,762	5,029,398	4,343,834	8,687,768	283,721	567,443	19,405	730,016	3,885	36,520	1,935	3,870
1892	307	18,435	512,015	3,891,325	4,773,827	9,547,255	454,451	908,982	10,613	890,315	10,410	97,854	1,740	3,480
1893	87	16,515	174,934	4,391,500	4,646,877	8,564,379	399,880	800,560	12,048	1,016,821	9,480	96,993	.....	....

Year.	Zinc Ore.		Copper Precipitate.		Iron, Pig.		Lead.		Quicksilver.		Zinc, Bar, and Sheet.	
1871	33,807	....	3,604	....	....	....	45,099	....	586	....	1,531	....
1872	43,503	....	3,684	....	....	....	44,855	....	1,369	....	1,030	....
1873	46,562	....	4,449	....	....	....	32,780	....	1,218	....	1,992	....
1874	66,169	....	4,417	....	....	....	83,289	$93,275	1,376	....	1,336	....
1875	42,778	....	......	....	....	....	91,738	....	1,716	....	1,178	....
1876	60,081	....	......	....	....	....	93,806	....	971	....	2,805	....
1877	65,968	....	11,564	....	....	....	110,051	....	1,776	....	223	....
1878	37,332	....	......	....	81	....	88,068	....	1,372	....	103	....
1879	29,625	....	20,435	....	106	....	104,831	....	2,171	....	1,712	....
1880	36,414	....	20,778	....	3,725	....	92,399	....	1,097	....	2,095	....
1881	39,774	....	24,390	....	22,304	....	110,177	....	1,780	....	1,743	....
1882	38,701	$387,010	22,694	$4,357,352	12,108	$211,892	115,167	9,679,431	1,067	$1,109,674	1,620	$165,271
1883	45,556	175,944	23,976	4,836,222	30,131	494,153	128,793	10,787,738	517	465,278	1,402	140,166
1884	35,580	234,602	19,609	2,810,793	23,186	375,609	118,266	6,433,377	1,193	1,192,600	677	67,723
1885	33,045	248,376	26,930	3,502,686	18,250	246,380	117,248	7,370,013	1,014	1,014,889	906	81,742
1886	29,873	202,617	27,014	3,242,348	49,420	642,461	114,471	7,891,937	541	541,414	1,075	96.754
1887	27,253	181,947	41,093	5,066,267	115,543	1,512,576	131,651	9,901,751	1,334	1,602,157	1,800	180.000
1888	32,004	199,413	45,080	5,570,017	96,801	1,465,775	129,593	8,840.500	1,104	1,204,322	1,089	102,373
1889	36,108	212,525	53,589	5,610.772	69,238	1,456,066	134,795	9,671,500	1,974	2,211,454	2,494	274,386
1890	47,025	275,841	63,306	6,149,452	69,218	1,254,501	140,660	13,348,710	989	1,747,364	2,046	209,074
1891	39,581	238,391	32,270	4,195,221	66,657	1,066,514	145,741	11,411,326	1,886	2,112,150	2,044	212,643
1892	39,574	240,796	36,862	4,768,135	43,412	694,992	153,859	13,225,703	1,644	1,840,978	2,161	224,873
1893	30,814	203,372	18,658	3,496,283	31,230	499,693	155,829	10,756,053	1,560	1,746,845	2,486	248,638

MINERAL PRODUCTION OF CUBA. (*a*) (IN METRIC TONS.)

Year.	Asphaltum	Copper Ore.	Copper, Cement	Iron Ore.	Mang. Ore.	Year.	Asphaltum	Copper Ore.	Copper, Cement	Iron Ore.	Mang. Ore.
1884......	3,349	....	67.32	23,877	....	1889.....	763	....	35.70	304,406	700
1885......	467	21	18.00	101,600	....	1890.....	....	....	....	... .	22,161
1886......	2,066	....	45.00	112,755	46	1891.....	....	....	....	....	22,341
1887......	961	....	57.00	92,910	5	1892.....	....	....	....	....	18,000
1888......	645	22	40.22	204,425	1,924	1893.....	....	....	....	....	13,922

(*a*) From *Estadistica Minera de España.* Also reported: Petroleum, 283 and 300 kilos, respectively, in 1884 and 1886; naphtha, 34 kilos, in 1884.

SWEDEN.

The mineral industry of Sweden has shown no considerable changes during the year, the most important being an increase of nearly 50% in the exports of iron ore, which was chiefly due to the development of the Gelliwam deposits in Swedish Lapland and the establishment of a market for the ores in England, where their value is recognized. The increase in production in the district named has followed very closely upon the completion (early in 1892) of a Government railroad from the mines to a shipping port.

While ores of gold, silver, copper, lead, and zinc, and some coal, are mined in this country, and the output of building stone and cement is of considerable value, the iron and steel industry is by far the most important in the country, and is that which is best known to the outside world. The Swedish iron ores are remarkably free from phosphorus and sulphur, and for many years Swedish iron has been in demand for special purposes in all the manufacturing countries of the world. While this demand has, to some extent, been diminished by the increasing use of steel everywhere, the exports of blooms and bar iron have been fairly well maintained.

The Swedish iron masters during 1893 have been affected, like their brethren all over the world, by a depression in trade which has shown itself more in low prices than in a decrease in output. According to the statements of their representatives, there is but little opportunity to meet the low prices by a decrease in costs of production, which have already, it is claimed, been brought down to almost the lowest possible point. The Association of Swedish Ironmakers not long ago asked for a reduction of freight rates on the system of railroads owned by the Government, to assist in meeting this reduction.

Swedish iron and steel men have always had a reputation for enterprise in the adoption of improved methods, and accordingly one of the papers which attracted especial attention in the metallurgical section of the Engineering Congress in Chicago in July, 1893, was that of Prof. Richard Akermann on the "Bessemer Steel Process in Sweden," in which some valuable improvements were described. A later improvement, which has been described by the inventor, Mr. J. L. Sebenius, in a communication to the American Institute of Mining Engineers and in a recent number of the *Engineering and Mining Journal* (April 21, 1894), is a rotary mold for casting ingots, in which centrifugal force is very ingeniously applied to the expulsion of gases and the consolidation of the metal before it cools.

MINERAL PRODUCTION OF SWEDEN.(*a*) (IN METRIC TONS.)

Year.	Alum	Cement. (*e*) Value.	Coal. (*b*)	Cobalt Ore. (*c*)	Copper Ore.	Fire Clay.	Gold Ore.	Iron Ore	Iron Bog Ore.	Iron Pyrites	Mang. Ore.	Nickel Ore	Plumbago.	Pyrolusite (Powder'd)	Red Ocher.	Silv'r and Lead Ore.	Zinc Ore.
1861	1,004	....	30,222	.....	......	....	......	429,067	9,146	.....	....	2,550	24	......	....	......	7,209
1862	912	....	29,768	.....	......	....	......	429,586	10,678	.....	....	2.790	38	......	....	......	8,518
1863	857	....	29.604	.....	......	....	......	448,129	5,504	.....	51	3,223	86	......	....	......	9,033
1864	815	....	27,826	.....	......	....	......	464,088	7,603	.....	102	5,103	29	......	....	......	14,248
1865	798	....	33,031	.....	......	....	......	496,562	20,302	.....	255	5.250	11	......	....	......	25.949
1866	806	....	34,096	.....	......	....	......	483,145	8,157	.....	361	2,483	15	......	....	......	20,841
1867	758	....	34,654	.....	......	....	......	484.664	17,787	.....	186	2,219	....	......	....	......	18.790
1868	816	....	43,461	.....	......	....	......	535,359	10,804	.....	334	2.094	57	......	....	......	23.831
1869	1,410	....	45,780	.....	......	....	......	591,732	6,257	.....	547	1.450	14	......	....	......	31,741
1870	771	....	35,805	58	68,649	....	......	616,712	13,748	268	701	3,704	38	......	....	12,218	28,146
1871	705	....	40,674	.....	63,987	....	......	646,778	15,761	640	389	3,884	47	......	....	11,973	32,172
1872	705	....	37,565	41	60,245	....	......	720,008	12,422	565	254	5,142	56	......	....	9,581	33,236
1873	584	....	49,123	17	38,509	....	......	827,127	5,362	2,551	306	3,786	66	......	....	9,850	27,444
1874	550	$34,992	55,719	41	28.834	....	......	922,117	4,298	3,845	641	4,530	39	51	.....	12,201	28,198
1875	494	59.669	62,605	74	29,792	....	......	807,502	14,935	3,015	850	7,789	39	149	.....	11,139	31,642
1876	473	93,257	75,406	101	28,029	....	......	787,602	9,002	1,807	672	7,563	26	119	.....	9,422	35,523
1877	409	108,000	91,620	153	28,344	....	......	733,381	5,422	1,777	819	6,053	72	81	.....	8,919	39,966
1878	396	108,000	90,425	726	26,006	....	......	672,535	4,913	17	391	393	62	95	.....	9,017	40,795
1879	262	97,649	99,699	223	28,509	....	......	642,510	2,854	638	320	......	36	13	.....	14,665	43,817
1880	262	130,311	98,343	331	29,385	....	......	770,134	5,209	1,482	1,386	......	44	21	.....	12,990	43,460
1881	258	134,700	114,992	556	29,352	....	......	820,938	5 199	1,356	1,659	2	39	30	.....	11,768	43,811
1882	299	157,909	139,683	516	25,766	....	......	891,016	1,847	1,531	1,673	269	35	34	.....	13,720	46,255
1883	202	203,477	149,110	177	25,681	....	2,583	881,738	3,385	1,609	4,043	857	30	17	.....	13,955	45,347
1884	206	198,036	160,714	56	24,087	....	48	907,249	2,303	1,037	3,662	3,105	26	34	.....	15,921	44,893
1885	191	162,247	169,707	137	21,495	....	340	871,171	2,190	1,869	6,091	2,212	19	43	.....	14,862	48.589
1886	217	162,495	166,054	164	20,883	....	876	867,579	4,900	1,462	7,192	515	26	268	.....	14,913	49,571
1887	152	183,974	164,774	231	20,653	....	1,404	902.213	973	2,506	8,659	85	26	121	1,380	15,616	46,241
1888	655	304,620	169,006	143	19,170	71,406	930	956,357	3,183	1,333	9,690	969	20	188	1,237	11,680	49,972
1889	705	....	186.719	266	19,952	96,781	980	983,609	2,295	158	8,645	289	16	231	1,550	16,577	59,381
1890	981	....	187,512	145	20,670	126,003	1,457	940,429	812	1,134	10,698	616	14	45	1,534	14,986	61,843
1891	542	....	198,033	244	21,823	134,909	2,680	985,255	2,150	1,659	9,079	483	17	192	1,468	15,044	61,591
1892	356	....	199,380	53	24,069	123,096	3,463	1,291,933	1,650	1,249	7,832	......	15	172	1,090	19,803	54,981
1893	......	....	....	.....	......	....	......	....	......	.....	....	......	....	......	.....	......	......

Year.	Brass	Cobalt Oxi. Kilos	Copper. (*d*)	Copperas.	Copper, Hammer'd	Copper, Sulph'te	Gold, Kilos.	Iron.			Steel.			Mf'rs of Iron and Steel.	Lead.	Silver, Kilos	Sulphur.	Sulphuric Acid.
								Pig.	Bloom.	Bar.	Bessemer.	Siemans Martin.	Other.					
1861	130	......	1,530	510	448	29	....	169,731	....	144,881	......	......	.....	17,260	259	938	193	......
1862	114	......	1,697	422	354	......	....	199,577	....	128,206	......	......	.....	16,052	442	1,129	195	......
1863	129	......	1,889	386	308	40	3.56	186,805	....	124,956	......	......	.....	17,006	478	1,141	283	......
1864	119	......	1,689	415	270	14	26.03	241,398	....	137,661	......	......	.....	19,838	565	1,296	407	......
1865	106	......	1,850	453	220	75	15.09	226,619	....	148,434	......	......	.....	19,784	479	1,140	422	......
1866	140	......	1,906	418	216	54	4.34	230,173	17,072	166,799	......	......	.....	19,335	288	1,057	448	......
1867	98	......	1,995	421	178	96	8.63	253,538	18,165	170,471	......	......	.....	18,486	410	1,144	418	......
1868	99	......	2,052	405	236	93	8.92	263,089	17,500	172.021	......	......	.....	18,311	393	1,299	443	......
1869	137	......	2,201	183	212	100	9.08	292,134	26,802	179,622	......	......	.....	18,800	513	1,236	468	......
1870	111	......	1,864	392	273	131	10.19	300,338	31,229	193,806	......	......	.....	20,816	374	1,191	473	......
1871	156	......	1,421	651	368	97	6.07	298,761	30,058	187,693	......	......	.....	27,050	89	974	335	......
1872	204	......	1,365	623	243	124	6.52	339,409	31,233	172,733	......	......	.....	32,715	43	743	326	......
1873	228	......	1,112	463	224	104	5.68	345,720	64,725	175,383	15,678	......	1,308	37,880	24	706	352	......
1874	254	......	960	469	219	161	3.21	327,852	64,404	167,644	21,303	123	1,522	34,308	56	740	273	......
1875	244	......	955	405	221	198	4.18	350,539	68,711	189,854	19,371	33	1,983	38,244	55	737	260	......
1876	223	......	901	219	285	286	6.18	352.466	107.360	212,423	20,993	158	2,918	39,496	43	798	191	......
1877	255	......	732	199	272	177	4.32	344.536	104,523	224,818	16,095	2,789	2,468	39,493	32	851	146	......
1878	277	......	1,087	361	266	93	9.72	340,857	107,801	197,960	19,306	3,608	3.004	36,826	44	1,268	123	......
1879	311	......	813	130	165	175	3.35	342,547	116,097	209,556	20.733	4,769	2,129	27,706	44	1,355	284	......
1880	281	......	1,092	422	275	142	5.31	405,713	125,151	221.060	30,013	5,892	1.549	32,509	197	1,312	256	......
1881	269	......	1,015	395	209	......	1.71	430.042	136,668	250,222	39,328	8,643	1,741	37,964	382	1,177	143	......
1882	280	......	804	390	260	......	17.32	398,945	152.246	262,925	47,358	9,942	1,430	43,409	243	1.531	345	......
1883	308	......	748	401	266	......	37.47	422,627	141,304	259,544	50,878	13,110	1,826	43,988	91	1,714	244	......
1884	377	......	660	389	308	......	19.73	430,534	146,897	271,799	50.297	15,325	1,764	43.914	364	1,817	239	......
1885	336	......	627	437	352	......	47.74	464,737	178,806	266,482	52,021	23,365	1,786	42,676	267	2,326	261	......
1886	274	......	528	418	255	21	67.34	442,457	165,656	237,130	54,121	22,361	1,749	41,055	197	1,939	99	......
1887	271	......	920	387	259	158	83.44	456,625	172,921	255,383	68,199	41,898	1,468	49,251	282	5,834	54	......
1888	227	3,305	754	513	279	197	75.802	457,052	238,132	253,090	68,620	44,712	1,205	59,680	328	4,649	64	1,725
1889	323	6,434	579	516	366	507	73.579	420.665	226,071	274,734	80,324	55,487	2,010	74,066	254	4,294	21	1,934
1890	275	7,020	617	500	363	636	87.664	456.103	225,632	281,833	94,247	72,985	2,055	78,998	310	4,555	42	2,124
1891	293	6,260	543	419	308	612	109.580	490,913	224,651	280,430	92,985	78,197	1,592	72,438	299	5,748	23	2,184
1892	302	7,138	745	476	314	580	87.626	485,664	235,426	273,510	82,422	76,556	.....	......	799	5,211	46	......
1893	......	......	....	......	......	......	....	....	....	....	......	......	.....	......	...	......	...	......

(*a*) From *Bidrog till Sveriges Officiela Statistik*, *Bergshandteringen*, and *Tullkomitens Betänkande*, II., *Bilaga* 1, *Stockholm.* 1891. There were also produced of allanite 20 and 14 tons in 1890 and 1891; of cerite. 39 and 28 tons in 1887 and 1888; $7,768 worth of marble in 1887–91; of litharge, 66 tons in 1890–92; of nickel matte, etc., 586 tons in 1889–91. (*b*) From 1888–92, converted from cubic meters by multiplying by 0.78. (*c*) In 1887, 1888, and 1889 there were also produced 376, 258, and 177 kilos of concentrated ore. (*d*) For 1888–91 the reports of 1891 and 1892 give slightly different figures. In 1892 there was also an output of 16 tons of cement copper. (*e*) These statistics are all in tons, except for cement, which is in values; 1 krone=27 cents.

MINERAL IMPORTS AND EXPORTS OF SWEDEN.(*e*) (1 krone = 27c.)

Years.	Imports.							
	Coal and Coke. (*g*)		Iron and Steel. (*h*)		Iron M'f'e.	Machinery.	Mineral Oil.	
1879	860,696	$2,663,820	....	$743,310	$982,260	$1,060,830	13,564	$642,870
1880	1,141,214	4,121,010	....	1,040,040	882,900	1,414,260	12,415	657,180
1881	1,080,688	3,501,360	....	1,186,920	1,049,760	1,911,330	16,891	912,060
1882	1,230,321	4,293,810	....	950,130	1,533,330	2,138,940	17,862	936,360
1883	1,249,264	4,384,800	....	1,153,710	2,485,620	2,535,570	19,091	1,022,220
1884	1,377,725	4,394,520	42,065	969,300	2,331,990	2,670,840	23,617	1,261,160
1885	1,491,574	4,567,590	42,565	1,454,220	2,441,070	2,678,400	24,698	1,318,950
1886	1,456,570	4,274,100	43,437	1,065,420	2,378,160	2,258,280	27,801	1,408,590
1887	1,480,433	4,350,780	36,269	661,500	2,347,920	1,967,760	27,641	1,037,340
1888	1,682,949	5,597,910	45,732	1,525,230	2,593,890	2,528,280	26,015	1,112,130
1889	1,955,971	7,558,380	33,692	1,093,770	2,476,440	3,335,040	45,287	2,181,330
1890	1,972,411	8,774,830	38,353	1,112,940	2,325,780	3,995,190	38,227	1,854,090
1891	2,092,062	8,358,660	36,037	1,131,300	2,645,170	3,831,300	41,837	1,667,790
1892	2,078,711	6,970,216	40,167	1,085,163	....	2,752,110	....	....
1893 *i*	2,072,900	....	....	....	....	1,958,970	....	....

Year.	Antimony, Crude.		Asphaltum.		Calcium Chloride		Cement.		Gypsum.		Saltpeter.		Salt.		Sulphur.	
1891	83.78	$2,432	2,382	$35,583	1,128	$48,709	896	$11,123	1,331	$17,972	4,491	$363,809	......	$492,482	4,402	$154,523
1892	58.10	10,981	1,981	21,400	1,083	43,884	719	8,940	1,207	16,295	5,301	572,520	95,505	478,509	7,416	240,283
1893	......	......	......	....	.....	....	....	....	.....	....	.....	....	......	....	.....	....

Years.	Exports.										
	Glass.		Iron Manufactures. (*f*)		Iron, Pig.		Machinery.	Steel. (*f*)		Zincblende.	
1879	2,451	$195,750	166,399	$6,650,738	34,569	$526,985	$316,440	8,549	$1,086,037	20,696	$262,911
1880	2,966	247,320	194,178	9,533,430	61,585	1,075,680	684,180	8,155	517,860	18,166	230,850
1881	2,677	247,590	203,257	8,801,190	55,469	898,560	745,740	7,170	1,239,030	15,422	208,170
1882	3,173	242,190	223,203	10,544,580	55,732	1,053,270	697,410	9,784	607,500	22,459	303,210
1883	4,051	303,210	210,988	10,494,630	52,313	988,740	703,620	10,887	676,080	25,940	350,190
1884	3,958	295,650	213,449	9,971,100	54,426	1,028,700	651,780	9,820	1,325,700	18,946	255,690
1885	4,124	335,880	203,097	8,897,580	47,527	866,160	550,800	.....	....	28,055	378,740
1886	2,685	244,350	195,772	8,068,950	58,139	941,760	741,150	.....	....	25,280	341,280
1887	4,006	352,620	225,876	8,788,230	49,285	718,470	625,860	.....	....	26,423	356,670
1888	4,041	442,530	228,912	8,235,540	49,099	702,540	730,620	.....	....	25,322	341,820
1889	4,907	431,460	245,979	10,255,950	79,378	1,223,640	707,940	.....	....	24,018	324,270
1890	5,287	447,660	227,422	9,752,940	60,125	1,107,270	825,930	.....	....	31,903	430,650
1891	6,084	554,850	208,037	8,760,960	63,096	1,022,220	873,990	.....	....	31,168	420,660
1892	....	......	......	....	57,502	923,583	......	.....	....	29,482	398,011
1893 *i*	....	......	......	....	59,831	....	......	.....	....	26,772	......

Year.	Cement.		Cobalt.		Copper Ore.		Iron Ore.		Silver, Kilos.		Soda.	
1891	14,322	$154,671	7,306	$13,808	181	$3,423	174,148	$470,200	2,058	$87,794	1,610	$43,476
1892	25,128	271,382	......	....	162	3,066	320,071	864,193	......	....	1,491	28,186
1893 *i*	....	....	......	....	......	....	484,020	....	......	....	......	....

(*e*) From British Statistical Abstracts, and *Bidrag till Sveriges Officiela Statistik: Utrikes Handeln.*

(*f*) Steel, after the year 1884, is included in "Iron Manufactures."

(*g*) Unit of measure is cubic meter.

(*h*) Unwrought and partly unwrought.

(*i*) From *Teknisk Tidskrift*, Feb. 3, 1894.

MISCELLANEOUS COUNTRIES.

The accompanying tables of miscellaneous statistics give the mineral imports and exports of Denmark, Holland, Roumania, and Switzerland, and the imports of Egypt and Shanghai.

Denmark can hardly be considered as a mineral-producing country, since only a little iron ore and pyrite and stone have been mined there, and these in such small quantities as to be unimportant. As a producer of peat, however, it takes a prominent place, its bogs extending over 90 square miles, or about 4% of its total area. Holland also is a producer of peat, and of coal and some other products. The production and manufacture of peat in these and other countries will be found under the subject head of "Peat." In 1892, 96,144 tons of coal, of which 56,584 tons came from the Government mine at Kokrade and 39,560 tons from the mine at Neupricke Bleijerheide, were produced in Holland.

Roumania is not a mineral-producing country, but the adjoining kingdoms of Servia and Bulgaria yield coal and other minerals to some extent, Servia in 1891 having an output of 100,263 tons of coal.

The table of imports at Shanghai does not show any material increase, but mining in China has been gaining steadily, though slowly, for some years past. The output of gold in China is given under the subject "Gold." H. Mandl & Co. of Tientsin have furnished the following information: "In the Provinces of Yunnan, Izechnan, and parts of Hunan rich copper ores are found. Iron occurs in Hunan, Kwangtung, Shensi, Shansi, and Honan. Coal is abundant in nearly all of the northern provinces, and is mined and sold in near-by towns. The method of working is crude in the extreme, consisting simply of sinking a shaft and working until water drives the laborers out. The oldest and most important mine in the empire is at Kaeping, about four miles north of Tientsin, and is connected with the latter town by a railroad which continues to a coal wharf at Tongku, on the Peiho River. This mine has been developed with modern machinery. The main shaft reaches a depth of 1200 ft., passing through five seams of coal, which altogether are about 100 ft. thick. In 1893 there were produced 350,000 tons, worth 300 tael (78c. to 90c.) per ton."

In Switzerland the mining industry is of little importance, the only considerable mines being the iron mines in the Jura Mountains. Two blast furnaces are operating in this section, producing about 10,000 tons of pig iron per annum, and employing some 2000 persons. Coal is found in small quantities in the canton of Zurich, where 128 persons are employed in mining it. The annual output, however, does not exceed 3000 tons. The salt industry at Schweizerhalle is important and employs a large number of people.

MINERAL IMPORTS AND EXPORTS OF DENMARK. (*a*) (IN METRIC TONS; 1 krone=27 cents.)

	IMPORTS.								EXPORTS.	
Years.	Coal.		Glasswares.		Iron and Steel Wares.		Petroleum and Other Oils.		Coal.	
1884....	1,266,604	$3,898,530	2,896	$850,500	64,187	$5,285,250	20,781	$1,113,210	134,555	$414,180
1885....	1,327,062	3,977,100	2,900	886,140	54,690	4.304,340	19,024	994,410	136,216	441,450
1886....	1,270,184	3,703,860	2,495	553,770	48,022	3,534,840	24,618	1,035,990	114,998	353,970
1887....	1,304,160	3,802,950	2,801	609,390	55,517	4.352,940	21,303	932,040	124,356	382,860
1888....	1,466,803	4,990,140	2,662	632,340	62,284	4.476,330	25,131	1,269,810	125,588	447,660
1889....	1,566,609	6,344,730	2,853	712,530	69,066	5,376,240	29,193	1,543,860	151,290	637,200
1890....	1,500,715	6,077,970	2,836	731,970	69,472	5,624,100	28,784	1,492,020	143,284	603,450
1891....	1,614,943	6,278,850	3,016	693,630	78,987	5,827,950	38,738	1,793,340	167,964	690,130
1892....	....	....	....	....	....	....	....	....	....	....
1893....	....	....	....	....	....	....	....	....	....	....

EXPORTS—*Continued.*

Year.	Iron and Steel Manufactures.		Petroleum & Other Oils.		Stone and M'f's Thereof.	
1884	8,932	$879,120	2,041	$213,300	67,554	$266,220
1885	5,316	567,540	1,819	250,020	58,457	216,810
1886	4,664	518,130	1,372	89,640	46,763	197,100
1887	7.086	596,700	1,641	97.200	52,571	290,520
1888	4,887	514,620	1,716	108,810	57,670	427,950
1889	7,523	716,310	2,891	178,200	67,100	561,060
1890	9,343	983,610	3,862	243,270	66,622	385,560
1891	14,302	1,091,880	7,930	492,480	68,825	363,420
1892	......	....	......	....	....	....
1893	......	....	......	....	....	....

MINERAL IMPORTS OF EGYPT. (*a*) (L1 Egypt.=$5.)

Year.	Coal.	Copper, Bronze and Zinc, Wro't and Unwrought	Iron and Manufactures of.	Machinery	Petroleum.
1881	$1,895,845	$524,135	$738,060	$892,640	$717,020
1882	1,520,930	232,080	508,555	823,690	564,785
1883	1,697,165	318,470	481,610	710,260	481,880
1884	2,435,460	514,040	1,167,400	801,610	721,775
1885	2,253,250	631,905	928,605	803,935	785,755
1886	1,821,430	426,425	1,113,345	660,015	693,005
1887	2,036,710	490,080	1,115,075	2,524,875	807,315
1888	2,208,300	283,745	1,238,310	1,305,175	595,010
1889	2,204,915	223,670	1,336,015	519,715	869,740
1890	2,457,475	302,520	1,323,730	937,660	655,055
1891	2,369,225	524,215	2,344,410	837,455	721,190
1892	....	....	....	....	....
1893	....	....	....	....	....

MINERAL IMPORTS AND EXPORTS OF HOLLAND (*a b*) (IN METRIC TONS; 1 gulden=40 cents.)

IMPORTS.

Years.	Coal.		Copper Ore.		Copper, Raw.		Guano.		Iron, Pig.	Iron Manuf'res
1880....	3,081,100	$12,322,400	68,552	$4,387,200	5,103	$2,041,200	21,776	$1,393,600	$7,845,600	$28,980,400
1881....	3,109,000	12,435,200	72,110	4,614,800	5,409	2,163.600	16,698	1,068,800	10,227,200	37,989,600
1882....	3,143,000	12,572,400	74,248	4,751,600	4,598	1,839,200	22,832	1,461,200	13,150,400	42,938,000
1883...	3,432,000	13,727,600	59,637	3,816,800	5,271	2,108,400	9,380	600.400	11,535,200	33,963,200
1884....	3,404,000	13,614,400	72,473	4,638,400	5,887	2,354,800	16,345	1,046,000	8,661,200	31,822,400
1885....	3,557,000	14,229,600	80,035	5,122,400	8,115	3.246,000	19,061	1,220,000	7,352,800	28,086,800
1886....	3.584,000	14,336,800	74,962	4,797,600	7,087	2,834,800	16,496	1,055,600	5,310,000	28,303,600
1887....	3,650,000	14,599,200	92,768	5,937,200	8,886	3,554,400	19,521	1,249,200	7,042,400	23,080,800
1888....	4,056,000	16,222,800	92,319	5,908,400	4,770	1,908,000	20,058	1,283.600	9,015.200	23,763,200
1889....	4,059,000	16,235,200	89,400	5,721,600	21,853	8,741,200	14,161	906,400	9,862.000	22,831,200
1890....	3,883,000	15,533,200	91,700	5,868,800	21,961	8,784,400	14,482	926,800	8,867,600	21,492,400
1891....	4,511,000	18,044,000	91,343	5,846,000	22,827	9,130,800	16,511	1,585,200	7,544,800	25,598,800
1892....	....	....	....	....	....	....	....	....	....	....
1893....	....	....	....	....	....	....	....	....	....	....

	IMPORTS.										EXPORTS.	
Year.	Petroleum.		Potash, Pearl-ash, Soda, etc.		Saltpeter, Unrefined.		Spelter, or Zinc.	Steel and Manuf'es	Tin, Unwrought.		Copper, Unwrought.	
1880	49,311	$4,931,200	21,816	$2,268,800	18,042	$2,165,200	$2,485,600	$7,837,200	6,461	$2,584,400	4,519	$1,807,600
1881	54,351	5,435,200	20,442	2,126,000	23,400	2,808,000	4,043,600	8,786,000	8,354	3.341,600	4,802	1,920,800
1882	59,810	5,981,200	20,690	2.151,600	33,310	3,997,200	3,556,800	15,871.200	7,094	2,837,600	5,271	2,108,400
1883	67,790	6,779,200	24,457	2,543,600	30,507	3,660,800	3,420,400	14,697,200	9,364	3,745,600	3,388	1,355,200
1884	74,784	7,478,400	28,587	2,973,200	34,288	4,114,400	3,353,600	18,590,800	9,280	3,712,000	4,308	1,723,200
1885	77,228	7,722,800	31,378	3,263.200	23,716	2,846,000	3,861.600	17,548.000	9,258	3,703,200	6,550	2,620,000
1886	84,626	8,462,400	31,461	3,272,000	27,946	3,353,600	3,994,800	24,945,200	8,522	3,408,800	4.763	1,905,200
1887	90,127	9,012,800	34,045	3.540,800	43,104	5,172,400	4,262,800	24,854,800	9,942	3,976,800	6,594	2,637,600
1888	89,811	8,981,200	35.111	3.627,200	32,444	3,893,200	3,804,000	22,542,000	12,110	4,844,000	4,186	1,674,400
1889	98,830	9.885,200	37,395	3,839,200	59,336	7,120,400	4.274,400	16,988,400	10,941	4,376,400	16,588	6,635,200
1890	103,817	10.381,600	38,830	4,038,400	46,528	5,583,200	4,684,000	17,257,600	9,276	3,710,400	16,223	6,489,200
1891	114,008	3,234,400	39,051	4,061,200	53,370	6,404,400	4,164,800	13,756,400	11,944	4,777,600	18,768	7,507,200
1892	....	....	......	....	......	....	....	....	....	....	....	....
1893	....,..	....	......	....	......	....	....	....	....	....	....	....

(*a*) From British Statistical Abstracts. (*b*) Colonial produce is included under head of "Domestic Produce in Holland."

MINERAL EXPORTS OF HOLLAND—*Continued.*

Year.	Guano.		Iron, Pig.	Iron Manufactures.	Saltpeter, Unrefined.		Spelter, or Zinc, Unwrought.		Steel and Manufactures.		Tin, Unwrought.	
1880	26,485	$1,695,200	$7,266,000	$19,767,200	17,730	$2,127,600	15,032	$924,000	36,500	$5,358,000	9,438	$3,775,200
1881	20,930	1,339,600	9,453,600	26,206,800	23,495	2,819,200	23,590	1,903,200	14,576	2,577,200	8,447	3,378,800
1882	24,031	1,538,000	12,440,800	25,658,000	30,154	3,618,400	17,270	1,120,400	43,635	10,669,600	6,204	2,481,600
1883	17,234	846,800	9,938,000	19,135,200	27,735	3,328,400	19,372	1,290,400	21,500	5,057,200	7,432	2,972,800
1884	12,675	811,200	7,966,800	19,875,600	29,149	3,498,000	20,064	1,564,400	27.197	7,663,600	8,213	3,285,200
1885	13,034	834,000	6,702,000	18,503,600	22,957	2,754,800	26,366	2,138,800	42,521	10,180,000	8,885	3,554,000
1886	13,606	870,800	4,316,400	19,073,600	27,801	3,336,000	37,271	2,822,000	48,016	12,994,400	8,523	3,409,200
1887	17,806	1.139,600	6,249,200	18,525,200	32,135	3,856,000	31,935	2,717,200	59,131	15,976,000	8,965	3,586,000
1888	13,996	895,600	8,100,400	17,740,000	33,098	3,971,600	24,669	2,466,800	48,672	14,219,200	9,203	3,681,200
1889	14,025	897,600	8,400,400	15,496,000	53,660	6,439,200	27,094	2,709,600	46,533	9,124,000	9,126	3,650,400
1890	14,215	909,600	7,547,600	15,928,800	44,609	5,353,200	27,437	2,743,600	50,807	8,447,600	10,498	4.199,200
1891	......	....	6,097,200	17,001,600	46,223	5,546,800	......	....	41,041	7,140,800	10,671	4,268,400
1892	......	....	....	....	......	....	......	....	......	....	......	....
1893	......	....	....	....	......	....	......	....	......	....	......	....

MINERAL IMPORTS AND EXPORTS OF ROUMANIA. (*a*) (IN METRIC TONS; 5 lei=$1.)

Years.	IMPORTS.								EXPORTS.	
	Coal.		Iron, Unwrought.		Iron and Steel Rails.		Iron, Tin Plates.		Petroleum.	
1882....	62,024	$558,200	8,769	$350,800	6,344	$444,200	2,432	$291,800	14,152	$360,000
1883....	131,157	1,180,400	13,968	558,800	29,201	2,044,000	3,325	399,000	17,624	355,400
1884....	143,702	1,293,400	10,965	438,600	11,464	802,600	3,784	454,200	22,253	466,200
1885....	139,042	1,251,400	10,208	408,400	11,864	830,400	2,264	271,600	20,986	462.400
1886....	154,948	1,051,400	11,765	470,600	28,065	1,964,600	3,246	389,400	15,099	329,400
1887....	169,693	830,800	9,590	383,600	7,221	505,400	2,853	342,400	16,132	324,200
1888....	203,144	1,003,800	9,328	373,200	9,298	650.800	2,683	322,000	18,126	362,600
1889....	195,143	969,000	9,914	276,600	6,722	470,600	4,315	517,800	18,668	373,800
1890....	243,813	1,216,400	8,465	338,600	12,806	896,400	4.000	480,000	11,774	235,400
1891....	336,383	2,160,400	9,706	388,342	21,242	1,487,000	4,627	555,200	18,087	362,400
1892....	....	....	....	....	....	....	....	....	....	....
1893....	....	....	....	....	....	....	....	....	....	....

MINERAL IMPORTS OF SHANGHAI. (*e*) (IN METRIC TONS.)

Years.	Copper	Iron.	Lead.		Kerosene.	Quicksilver.	Steel.	Tin.		Yellow Metal and Nails.	Zinc in Sheets.
			Pig	Sheets.				Slabs.	Plates.		
	Tons.	Tons.	Tons.	Tons.	Cases. (*f*)	Kilos.	Tons.	Tons.	Tons.	Tons.	Tons.
1889........	1,747	49,627	6,660	147	1,506,532	58.834	1,058	2,124	480	216	106
1890........	604	40,960	6,167	67	1,820,449	62,315	1,669	2,237	520	326	287
1891........	1,631	73,688	4,516	51	2,921,169	52,090	1,740	2,198	614	260	179
1892........	1,571	59,468	5,366	52	2,092,567	90,024	1,265	2,440	725	53	283
1893........	1,577	48,386	4,799	49	2,559,500	31,460	929	2,170	479	263	267

(*e*) From Alex. Bielfeld's Reports, Shanghai. Tons converted from piculs. (1 picul=0.06 metric ton.) (*f*) 1 case holds 10 gallons.

MINERAL IMPORTS AND EXPORTS OF SWITZERLAND. (*a*) (IN METRIC TONS; 1 franc=20 cents.)

Years.	IMPORTS					EXPORTS.					
	Chemical Products.	Coal and Coke.		Iron and Steel.		Chemical Products.		Dyes, Coal Tar.		Iron Manufactures.	
1885........	$3,139,600	740,242	$3,293,200	98,782	$4,704,000	6,396	$680,400	620	$1,131,400	1,935	$555,600
1886........	3,494,000	748,503	3,337,400	97,297	4,654,400	6,528	772,600	712	1,291,400	2,378	662,600
1887........	3,906,800	812,561	3,629,800	124,130	6,004,000	5,653	535,800	872	1,385,200	1,883	662,600
1888........	3,784,800	827,202	3,872,400	127,241	6,299,400	5,378	516,688	932	1,364,800	2,132	741,600
1889........	4,115,400	914,014	4,629,000	137,946	7,074,200	6,785	592,200	1,159	1,669,600	2,918	867,200
1890........	4,407,000	993,612	6,092,800	154,632	8,576,600	7,591	548,000	1,338	1,785,000	3,317	1,047,200
1891........	4,331,400	1,060,625	6,616,500	166,870	8,654,800	8,298	554,500	1,542	1,958,200	1,957	855,600
1892........	....	....	....	....	....	......	....	......	....	......	....
1893........	....	....	....	....	....	......	....	......	....	......	....

(*a*) From British Statistical Abstracts.

THE UNITED KINGDOM.

During the year 1893 the mineral and metallurgical industries of Great Britain suffered severely by strikes in the important branches of coal and iron. While in the latter the output was greater than during the preceding year, when the strike had seriously curtailed production, it was still much below 1891. The decline in the coal production was enormous, and wholly unprecedented in the history of the trade. In 1892 a falling off of about 4,000,000 tons, due to labor disturbances, seriously interfered with the various industries of the country, and about the same time there was added the trouble from striking spinners. In 1893 this was followed by another and even more serious strike among the coal miners, which resulted in reducing the output from 181,786,871 gross tons in 1892 to 164,325,975 gross tons in 1893, inflicting an almost irreparable injury to the many industries dependent upon this fuel for their motive power. The actual decline in production represents only the smallest part of the loss which Great Britain has sustained, as both the domestic and foreign trade which it was unable to fill has been taken by other nations. Under the subject head of "Coal" are tables and diagrams showing the production and consumption in this country as compared with others. Since 1882 there has been a steady decline in the production of iron ore and a corresponding increase in its imports. At present the latter amounts to 30% of the production, as against 17% in 1883. It is noteworthy that the rapid growth of the chemical industry in the United Kingdom has been due to the adoption of the Solvay and Mond ammonia process, as described elsewhere in this volume, and the production of iron pyrites has even decreased, while there has been no corresponding increase in the imports of either pyrites or brimstone. The increase which has taken place in the output of oil shale indicates a steady growth notwithstanding the competition of petroleum.

The result of the industrial depression caused by the coal strike is shown in the reduction which has taken place in many of the exports. While not amounting to a large percentage in any single item, the total adds up to a loss which, both direct and indirect, it will take many years to recover from. Altogether, however, the output and foreign trade of Great Britain shows a much healthier general tone than was expected during even the latter part of the year.

MINERAL PRODUCTION OF THE UNITED KINGDOM OF

	Alum Shale.		Arsenic.*		Arsenical Pyrites.		Barytes.		Bauxite.		Clays.†	
	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$
1860...	no returns	....	1,626	64,000	no returns	....	13,573	48,750	no returns	....	517,005	1,105,750
1861...	"	....	1,474	54,375	"	....	11,639	not given	"	....	701,926	1,159,005
1862...	"	....	915	4,100	"	....	10,130	"	"	....	867,800	1,363,995
1863...	"	...	1,468	6,000	"	....	no returns	....	"	....	834,122	1,327,210
1864...	"	....	643	2,375	"	....	508	1,835	"	....	1,133,862	1,841,575
1865...	"	....	841	3,020	"	....	6,880	24,980	"	....	1,144,382	1,869,580
1866...	"	....	1,135	6,505	"	....	1,783	....	"	....	1,168,575	1,962,875
1867...	"	....	2,292	20,560	"	....	11,289	39,035	"	....	1,198,633	2,948,250
1868...	"	....	3,354	48,550	"	....	14,468	43,640	"	....	1,029,077	1,588.850
1869...	"	....	2,603	57,320	"	....	6,085	17,075	"	....	1,219,672	2,250,000
1870...	"	....	4,116	88,695	"	....	6,622	18,855	"	....	1,219,672	2,250,000
1871...	"	....	4,216	77,595	"	....	5,602	17,695	"	....	1,275,574	2,375,000
1872...	"	....	5,257	89,820	"	....	9,242	35,390	"	...	1,219,672	2,250,000
1873..	"	....	5,538	114,270	"	....	10,438	39,965	"	....	1,814,262	3,281,500
1874...	"	....	6,371	137,190	"	...	14,610	61,505	"	....	2,476,861	3,900,795
1875...	"	....	5,144	155,870	13,160	not given	15,804	70,445	"	....	3,057,763	3,769,785
1876...	4,592	not given	4,297	140,460	13,161	"	23,948	122,395	"	....	4,036,223	3,721,120
1877...	20,059	"	4,888	152,105	5,429	"	21,401	144,740	2,808	not given	3,009,699	2,951,155
1878...	6,843	"	5,073	134,500	3,698	"	22,804	183,430	3,482	"	2,755,937	3,389,355
1879...	4,164	"	5,582	170,900	2,639	"	19,667	105,340	3,717	"	2,925,677	3,585,715
1880...	6,805	"	5,832	217,490	5,273	"	18,780	66,920	3,527	"	3,112,750	8,178,250
1881...	7,787	"	6,257	225,350	14,556	"	21,647	119,470	7,839	"	2,440,789	6,001,050
1882...	8,580	5,275	7,591	245,740	12,770	58,070	23,690	139,350	8,527	29,385	2,903,100	3,857,855
1883...	8,424	5,180	7,747	267,565	1,321	5,460	21,730	132,825	13,699	50,540	2,900,129	3,533,785
1884...	1,992	1,225	8,035	289,205	1,791	5,715	20,391	146,780	8,700	21,400	2,739,902	3,336,980
1885...	2.362	1,460	8,262	284.285	1,942	7,865	26,583	151,480	9,178	18,285	2,572,693	3,004,670
1886...	3,041	1,870	5,109	164,010	4,999	38,745	25,554	129,090	8,397	12,390	2,429,628	2,916,050
1887...	2,628	1,615	4,694	162,290	4,436	16,025	25,220	133,095	4,237	5,200	2,453,262	2,952,060
1888...	2,017	1,240	4,700	175,985	5,412	21,200	25,604	130,735	9,824	24,165	2,604,805	3,267,095
1889...	4,257	2,615	4,836	191,300	7,814	36,585	25,256	141,190	9,300	27,450	3.086,028	4,140,870
1890...	6,525	4,010	7,395	303,635	5,198	22,070	25,769	148,420	11,716	28,815	3,362,447	4,495,830
1891...	5.564	3.420	6.147	292.965	5.179	21.850	27.317	160.600	10.939	16 140	3.274.855	4.719.480
1892...	2,969	1,825	5,196	218,430	4,569	24,940	24,637	146,415	7,440	9,300	3,153,824	4,446,875
1893...	....	....	....	....	....	....	....	....	....	....	....	....

* White arsenic, crude and refined, produced from arsenical pyrites not included in the next column.

	Iron Ore.		Iron Pyrites.		Lead Ore.		Manganese ore.		Ochre and Umber.		Oil Shale.	
	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$
1860	8,155,749	12,334,645	137,893	420,695	90,541	6,183,745	947	15,480	607	4,345	no returns	....
1861	7,333,807	11,511,855	127,186	398,575	92,183	5,681,245	932	14,625	3,065	15,080	....	....
1862	7,686,211	11,998,695	100,047	291,065	96,874	5,957,000	....	....	not given	25,000	....	....
1863	9,250,758	16,204,450	96,940	310,175	92,780	5,967,650	....	... .	4,497	23,880	....	....
1864	10,229,888	16,835,720	96,006	290,485	95,981	6,748,025	508	not given	2,362	10,890	....	....
1865	10,072,505	16,624,020	116,067	355,870	92,098	5,765,670	....	....	no returns	....	....	....
1866	9,823,455	15,595,490	137,622	389,660	92,540	5,806.140	....	....	5,114	15,245	....	....
1867	10,185,338	16,050,490	118,805	337,265	94,964	5,790,330	821	16,160	5,582	29,040	....	....
1868	10,335,941	15,983,000	77,738	268,180	96,797	5,753,840	1,728	38,250	6,802	31,860	....	....
1869	11,697,189	18,662,800	77,193	205,115	98,455	5,945,150	1,584	39,285	5,802	24,715	....	....
1870	14,606,238	24,756,100	59,386	180,130	99,785	6,001,045	4,917	97,495	4,923	21,305	....	....
1871	16,602,673	38,352,860	62,989	324,935	95,523	5,778,850	5,639	114,790	708	6,950	....	....
1872	16,855,740	38,874,370	65,980	197,350	85,345	5,730,825	7,901	194,325	3,382	41,135	....	....
1873	15,832,868	37,868,380	59,831	177,425	74,705	5,659,535	8,813	288,830	6,472	27,050	532,687	1,310,235
1874	15,088,295	36,590.845	57,129	191,130	77,451	5,120,535	5,873	146,000	7,239	47,390	368,694	906,865
1875	16,080.422	29,877,050	48,823	175,680	79,021	6,010,740	3,258	79,530	5,403	35,925	449,587	1,000,000
1876	17,117,676	34,128,525	49,610	219,350	80,393	6,090.390	2,843	48,915	3,867	22,390	620,798	1,599,265
1877	16,966,455	33,733,340	44,668	141,130	82,175	5,619,760	3,087	39,790	5,157	22,440	713,204	1,754,250
1878	15,984,180	28,047,535	30,157	95.495	78,618	4,007.140	1,612	15,605	4,487	20,190	801,633	1,971,760
1879	14,615,468	24,812,175	20,608	59,180	67,973	3,443,700	829	7,575	4,039	17,185	797,206	1,960,870
1880	18,322,543	32,929,030	32,227	115,020	73.429	4,081,840	2,886	28,005	6,226	57,560	851,539	2,094,510
1881	17,732,066	31,005,340	44,327	150,165	65,763	3,281,625	2,931	32,105	8,097	61,430	973,964	2,395,635
1882	18,327,563	28,896,425	25,820	72,295	66,067	2,963,050	1,573	19,535	9,018	81,805	1,047,815	1,553,425
1883	17,668,014	25,611,905	28,125	87,335	57,413	2,374,555	1,308	14,880	17,447	129,795	1,187,090	1,498,380
1884	16,402,443	22,316,375	29,581	90,695	55,378	2,007,775	924	7,150	9,342	94,880	1,543,770	1,933,900
1885	15,670,736	19,848,595	30,350	92,585	52,143	2,038,000	1,716	12,055	13,546	117,295	1,799,436	2,236,510
1886	14,341,325	17,567,575	28,283	82,875	54,296	2,356,475	12,972	54,465	12,595	110,925	1,756,839	2,179,815
1887	13,312,763	16,166,775	22,441	63,410	52,408	2,145,685	14,000	55,550	8,429	78,945	1,434,515	1,775,425
1888	14,829,905	17,506,585	23,876	56,510	52,099	2,191,915	4,413	9,670	7,697	66,935	2,110,509	2,595,350
1889	14,784,566	19.241,340	18,009	40,555	49,260	2.148,235	8,997	32,390	10,666	77,660	2,047,890	2,518,575
1890	14,066,681	19,632,225	16,281	35,330	46,399	2,030,820	12,646	33,665	19,381	87,375	2,248,516	3,041,845
1891	12.987.159	16.779.300	15,716	40.010	44.578	1.783.915	9,632	31.065	13.825	100.515	2 399.826	3.535.885
1892	11,494,809	14,853,160	14,142	34,785	40,668	1,482,420	6,176	22,170	12,326	83,910	2,123,585	2,612,420
1893	....	....	....	....	....	....	....	....	....	....	....	....

NOTE.—In addition to the above, small quantities of the following minerals are occasionally produced, viz., steatite, and uranium ore. A very large quantity of stone used for building and other purposes is also ascertained, but the value in 1890 was estimated to be upwards of $43,540,000. Details concerning the mineral

GREAT BRITAIN AND IRELAND. (IN METRIC TONS.)

Coal.		Cobalt and Nickel Ore		Copper Ore.		Copper Precipitate.		Fluor-spar.		Gold Ore.‡		Gypsum.		
Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	
81,354,873	100,053,370	6.09	1,270	240,576	7,535,665	no returns	......	no returns	...	....	......	no returns	......	1860
85,006,283	104,544,015	.81	120	235,282	7,135,075	"	......	"	....	....	......	"	......	1861
82,976,671	102,047,920	....	.....	227,846	6,083,875	"	......	"	....	816	75,000	"	......	1862
87,706,842	102.864,725	....	.....	214,405	5,502,770	"	......	"	....	391	7,500	"	......	1863
94,308,986	115,989,840	....	.....	218,122	5,777,355	"	......	1	60	2,374	......	"	.....	1864
99,759,613	122,688,230	....	.....	201,549	4,639,690	"	......	56	230	4,350	......	"	......	1865
103,296,618	127,038,175	....	.....	183,333	3,795,590	"	......	2	10	2,973	...	"	......	1866
106,213.603	130,625,725	1.88	75	161,143	3,498,465	"	......	....	....	3,294	26,600	"	......	1867
104,831,996	128,926,445	....	.....	159,914	3.210,515	"	......	61	210	1,211	5,000	"	......	1868
109,188,664	134,284,410	....	.....	132,083	2,599,560	"	......	....	....	....	......	"	......	1869
112,241,539	138,038,990	.61	135	108,447	2,189,255	"	......	....	....	....	......	"	......	1870
119,275,832	176,028,040	5 08	1,090	98,721	1,935,590	"	......	52	130	....	......	"	......	1871
125,521,862	231,555,715	1.02	100	93,491	2,218,890	"	......	81	120	....	......	"	......	1872
130,789,643	241,275,245	.3	60	81,503	1,713,540	61	not given	....	...	....	......	67,208	not given	1873
128,665,356	232,081,860	....	.....	79,808	1,682,070	178	"	643	1,585	....	......	62,115	"	1874
135,491,837	233,286,350	....	.....	72,701	1,667,070	214	"	365	940	32.52	500	66,135	"	1875
136,323,939	234,719,040	.36	.....	80,551	1,585,930	783	"	342	1,150	....	90	62,753	92,855	1876
136,379,640	234,814,940	27.44	1,210	74,340	1,311,355	638	"	224	185	....	......	75,120	110,860	1877
134,786,031	232,071,110	101	3,085	57,013	1,007,170	541	"	398	665	....	......	76,136	112,360	1878
135,912.531	234,010,685	119	4,165	51,869	886,915	368	"	1,285	2,110	.2	....	63,467	93,665	1879
149.378,744	312,309,990	49.8	1,485	52,972	953,340	335	"	466	1,750	.1	125	76,689	125,650	1880
156,711,911	327,641,635	65.05	1,550	53,418	950,285	597	"	379	1,270	.05	90	80,802	116,645	1881
159,065,550	220,592,045	38.6	1,205	53,676	1,033,690	434	18,290	147	1,345	....	.....	103,542	290,715	1882
166,421,545	230.270,715	49.8	865	47,047	729,520	540	18,505	91	1,265	.4	500	101,183	216,075	1883
163,393,136	217,230,915	67.08	1,185	42,412	547,135	428	15,930	590	3,650	....	......	111,724	227,205	1884
161,963,736	205.697,040	111	2,110	36,835	398.815	140	5,745	430	2,455	....	......	113.915	238,765	1885
160,100,752	190,729,650	102	2,630	18,503	192,835	419	14,155	284	2,060	....	......	120,796	222,310	1886
164,777,514	195,464,150	157	4,500	9,228	104,910	285	15,375	288	1,925	.86	1,045	122,763	241,465	1887
172,721,042	214,856,380	155	3,730	15,380	304.900	425	32,695	142	765	3,907	136,500	132,215	294,990	1888
179,816,998	280,877,130	158	4,840	9,177	132,920	286	15,565	302	2,055	6,328	53,730	134,527	269,095	1889
184,594,850	374,769,985	85.37	1,300	12,333	139,005	351	23,350	272	1,260	584	2,070	142,592	289,955	1890
188.519,767	370.499.080	Nil.	.....	8,981	101,070	327	21.775	143	935	14.348	62,000	154,195	300,190	1891
184,713,640	330,252,255	......	.....	6,092	57,965	274	15,560	174	940	10,151	45,840	149,915	291,135	1892
....	....	......	.....	....	....	....	....	....	.....	.....	......	....	....	1893

† China clay, potter's clay, fuller's earth, etc., but exclusive of ordinary clays. ‡ Auriferous quartz.

Phosphate of Lime.		Salt.*		Slates and Slabs.		Sulphate of Strontia.		Tin Ore. ("Black Tin.")		Wolfram.		Zinc Ore.		
Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	Tons.	$	
30,492	300,000	1,596.726	4,025,615	no returns	....	....	....	10,634	3,744,135	19.31	95	15,807	198,155	1860
38,118	375,000	961,942	2,484,365	"	....	....	....	11,831	3,627,800	6.09	145	16,029	155,565	1861
no returns	....	997,690	2,331,295	"	....	....	....	14,359	4,215,910	12.2	315	7,620	80,250	1862
"	....	938,893	2,116,925	"	....	....	....	15,405	4,819,925	13.2	335	13,153	149,840	1863
"	....	953,207	2,168,740	"	....	....	....	15,460	4,629,845	2.53	70	15,310	222,810	1864
"	....	983,155	2,297,330	"	....	....	....	15,943	4,337,175	2.03	55	18,135	262,390	1865
"	....	1,010,174	2,981,640	"	....	....	....	15,327	3,659,730	......	.. ..	12,979	213,275	1866
37,607	351,500	1,417,800	4,184,815	"	....	....	....	13,872	3,473,670	10.16	310	13,710	206,700	1867
38,118	357,500	1,538,657	4,636,135	"	....	....	....	14,182	3,871.025	9.15	335	12,990	195,970	1868
no returns	....	1,270,492	3,437,500	"	....	....	....	14,966	5,139,025	25.4	1,615	15,788	246,830	1869
35,574	250,000	1,513,867	3,723,625	"	....	....	....	15,483	5.011,785	51.8	3,265	13,809	205,290	1870
37,100	255,000	1,530,409	3,764,300	"	....	....	....	16,539	5,154,170	20.3	1,140	18,027	281,650	1871
35,574	250,000	1,320,964	3,273,740	"	....	....	....	14,500	6,230,675	89	4,965	18,847	369,755	1872
no returns	....	1,814,263	4,462,500	"	....	....	....	15,129	5,284,175	50.8	2,635	16,231	305,830	1873
152,114	1,951,450	2,344,390	5,766,065	154,481	not given	....	....	14,269	3,941,550	33.5	2,725	17,106	240,975	1874
254,222	3,140,000	2,354,625	5,791,610	155,795	"	....	....	14,224	3,678,030	46.8	1,910	24,371	375,550	1875
262,382	3,125,000	2,310,522	5,683,140	159,459	"	....	....	13,912	3,004,615	23.4	860	24,000	450,710	1876
70,137	1,000,000	2,779.836	7,522,250	174,961	"	....	....	14,374	2,863,815	15.23	750	24,806	430,755	1877
54,885	750,000	2,726,912	6,707,325	171,812	"	....	....	15,292	2,653,685	10.16	500	25,855	402,825	1878
34,521	368,750	2,600,308	6,395,920	145.204	"	....	....	14,905	2,933,040	13.2	600	22,564	407,655	1879
30,100	354,750	2,688,361	5,612,500	155,194	"	....	....	13,963	3,365,710	1.01	45	28,000	492,730	1880
32,016	433,140	2,315,896	5,745,550	165,002	"	....	....	13,109	3,487.220	54.9	2,720	36,109	550,215	1881
50,362	488,000	2,170,472	3,076,580	513,055	6,462,750	... ..	....	14,275	4,029,235	58.9	3,735	33,069	467,855	1882
50,393	508,645	2,362,863	3,348,800	506,227	6,231.660	......	......	14,706	3,675,945	113	7,215	30,215	464,475	1883
52.716	519,880	2,370.945	3,391,715	493,626	5,870,100	11,610	114,220	15,365	3.346,270	65	5,520	25,982	370,145	1884
30,492	250,000	2,243,875	3,903.075	476.642	5,878,860	9,961	24,500	14,612	3,311,950	380	23,995	25,072	335,000	1885
20.328	157,500	2,177,338	3,710,8[illegible]0	463,687	5,535,845	13,825	28,750	14,465	3,901,510	142	11,160	23,535	338,795	1886
10,056	79,150	2,229,917	3,661,600	471,946	5,594,090	15,418	37,920	14,422	4,394,155	54.9	6,345	25,862	380,910	1887
22,870	216,560	2,343,305	3,504,145	479,522	5,287,675	7,180	17,660	14,607	4,473,325	61	8,125	26,841	484,920	1888
20,328	191,250	1,978,407	4,451,820	465,951	5,240,715	6,074	14,940	14,033	3,646,065	.53	40	23,582	484,625	1889
18,295	147,500	2,182,045	5,500,070	441,473	5,136,175	10,444	25,690	15,155	3,912,460	106	8,340	22,402	549,450	1890
10.164	100,000	2,077.072	4.884.120	421.829	4.835.000	8,193	20,150	14.726	3,676.200	140	16.705	22.580	567.225	1891
12,396	111,250	1,988,024	4,307,005	424,975	5,129,610	5,147	6,330	14,588	3,672,825	127	15,000	24,264	520,080	1892
....	....	....	....	....	....	....	....	....	....	......	......	......	....	1893

* Rock salt and salt obtained from brine.

antimony ore, bismuth ore, bog-iron ore (used for purifying gas), jet, lignite, petroleum, plumbago, silver ore, annually raised, besides chalk, ordinary clay, gravel, etc., the total quantity of which cannot be accurately output will be found in the *Mineral Statistics of the United Kingdom*, published annually.

PRODUCTION OF CERTAIN METALS IN THE UNITED KINGDOM. (*a*) (IN METRIC TONS.)

Year.	Fine Copper	Metallic Lead	White Tin.	Zinc.	Silver from Lead, Kilos.
1854	20,224	65,054	6,072		17,319
1855	21,643	66,603	6,098		17,420
1856	24,654	74,328	6,278		19,039
1857	17,660	68,498	6,690		16,519
1858	14,693	69,422	7,033	3,522	17,649
1859	15,925	64,208	7,216	3,757	17,926
1860	16,230	64,355	6,804	4,428	15,149
1861	15,582	66,710	7,571	4,487	17,655
1862	15,086	70,163	8,614	2,186	21,269
1863	18,480	68,340	10,170	3,897	19,654
1864	13,521	68,180	10,273	4,106	19,871
1865	12,083	68,282	10,203	4,533	22,470
1866	11,320	68,495	10,154	3,244	19,721
1867	10,391	69,562	8,842	3,811	24,977
1868	9,977	72,181	9,452	3,774	25,901
1869	8,427	74,460	9,920	4,573	25,788
1870	7,292	74,623	10,367	4,000	24,321
1871	6,383	70,188	11,078	5,047	23,606
1872	5,796	61,411	9,716	5,276	19,496
1873	5,326	55,127	10,035	4,544	16,669
1874	5,007	59,740	10,005	4,543	15,787
1875	4,668	58,376	9,771	6,823	15,108
1876	4,771	59,612	8,639	6,750	14,986
1877	4,559	62,410	9,655	6,384	15,418
1878	4,017	58,971	10,271	6,412	13,022
1879	3,519	52,481	9,688	5,645	10,343
1880	3,722	57,882	9,064	7,279	9,161
1881	3,938	49.383	8,757	15,192	9.560
1882	3,521	51,153	9,308	16,394	11,548
1883	2,297	44,130	9,459	13,826	10,665
1884	3,405	40,732	9,731	10,081	10,097
1885	2,818	38,405	9,484	9,938	9,936
1886	1,496	40,129	9,465	9,036	10,088
1887	903	38,511	9.434	9,920	9,930
1888	1,480	38,194	9,392	10,166	9,964
1889	920	36,187	9,058	9,546	9,490
1890	941	34,140	9,752	8,692	9,043
1891	731	32,733	9,503	9,037	8,673
1892	503	30,016	9,419	9,500	8,436
1893	....	....	....	....	....

MINERAL IMPORTS OF THE UNITED KINGDOM. (*b*) (IN METRIC TONS; £1=$5.)

Year.	Alkali.		Brimstone.		Copper Ore.		Copper Regulus and Precipitate.		Copper, Unwrought and Part Wrought.		Chemical Products.
1891	4,428	$252,020	21,769	$647,485	90,423	$3,664,550	125,323	$16,507,525	44,958	$11,819.550	$6,845,365
1892	2,857	207,580	26,499	738,905	93,399	2,926,865	136,328	16,450,530	35,626	8,279,710	7,511,470
1893	4,456	395,520	26,171	623,985	82,099	2,429,660	120,621	14,164,700	42,694	9,571,560	6,798,645

Year.	Glass of All Sorts.		Guano.		Iron Ore.		Iron, Bar, Angle, Bolt, and Rod.		Iron, Girders, Beams & Pillars		Iron Manufactures.	
1891	76,659	$9,045,205	24,003	$693,210	3,231,750	$12,267,035	78,674	$3,757,935	75,227	$2,549,400	157,540	$13,823,605
1892	81,111	9,351,095	28,323	947,165	3,841,369	13,584,100	77,137	3,461,295	75,781	2,512,870	146,093	12,660,590
1893	87,069	9,701,095	18,606	473,605	4,131,323	13,960,140	66,880	2,965,165	73,480	2,277,755	153,130	12,757,555

Year.	Steel, Unwrought.		Lead, Pig and Sheet.		Nitrate of Soda.		Paraffine.		Petroleum, Liters.		Phosphate of Lime and Rock.	
1891	8,572	$437,840	172,456	$10,688,370	123,998	$5,249,090	28,418	$4,025,170	494,378,537	$13,426,840	260,906	$3,141,975
1892	6,587	312,430	185,725	9,882,180	121,486	5,100,960	28,074	3,748,520	492,754,491	12,234,530	319,187	3,328,445
1893	9,079	452,490	194,252	9,276,075	88,169	4,030,985	39,025	4,067,500	577,151,861	12,742,885	328,461	2,972,185

Year.	Pyrites, Iron, Copper, or Sulphur.		Quicksilver.		Saltpeter.		Silver Ore.	Tin. in Blocks, Ingots, Bars, or Slabs.		Zinc, Crude, in Cakes.		Zinc Manufactures.	
1891	626,148	$5,631,235	2,135	$2,537,515	14,163	$1,255,105	$18,831,695	28,661	$12,825,370	59,455	$6,647,525	20,483	$2,571,980
1892	614,142	5,317,530	1,939	1,980,920	15,666	1,339,655	15,160,845	29,942	13,719.070	53,643	5,512,955	19,263	2,315,400
1893	622,684	5,327,035	1,787	1,705,930	12,323	1,069,370	15,354,110	34,093	14,460,535	57,842	5,036,985	18,739	1,991,745

(*a*) From *Mineral Statistics of the United Kingdom.* (*b*) Imports for home consumption. From *Accounts Relating to Trade and Navigation of the United Kingdom.* For the imports and exports of the United Kingdom from 1877-92, inclusive, see THE MINERAL INDUSTRY, Vol. I.

MINERAL EXPORTS OF THE UNITED KINGDOM. (*a*) (METRIC TONS.)

DOMESTIC PRODUCE.

Year.	Alkali.		Brass and Manufactures.		Cement.		Coal, Coke, Cinders, and Fuel.		(*b*) Coal, etc., for St'm'rs.	Coal Products. (*c*)	Unwrought, in Ingots.	
1891..	316,383	$11,676,405	5,793	$2,583,030	585,242	$5,703,485	31,584,570	$94,475,390	8,673,933	$7,849,570	35,928	$9,823,740
1892..	299,018	10,597,200	5,498	2,272,685	500,546	4,514,550	30,944,282	84,053,790	8,738,591	6,661,365	42,972	10,307,220
1893..	296,481	9,290,785	5,877	2,274,925	444,898	3,724,630	29,512,740	72,440,770	8,257,207	6,376,190	28,802	6,836,765

Y'r.	Copper, Wrought or Manufactured.		Mixed or Yellow Metal.		Earthenware.	Glass of All Sorts.	Hardware and Cutlery.	Implements, Tools & Parts.	Iron, Pig.		Iron, Bar, Angle, Bolt, and Rod.	
1891	16,425	$5,384,245	66,650	$19,140,560	$9,791,720	$5,067,085	$12,637,875	$6,557,865	853,580	$11,027,835	220,617	$7,314,500
1892	16,478	4,864,985	74,[illegible]9	18,817,645	9,523,560	4,426,525	10,973,630	6,310,245	779,402	9,873.725	176,206	5,738,410
1893	17,277	4,862,605	60,889	15,113,255	9,117,405	3,830,360	10,240,210	6,123,905	853,391	9,861,870	151,329	4,649,800

Year.	Iron, Railroad of All Sorts.		Iron and Steel Wire and M'f's Excpt Tel. Wire		Iron Hoops, Sheet, Boiler, Armor.		Iron, Galvanized Sheets.		Tin, Plates and Sheets.		Iron, Cast and Unwrought, and Manufactures.	
1891...	713,553	$19,263,820	68,603	$5,715,635	160.000	$6,252,705	166,541	$11,550,540	455,598	$35,833,275	370,778	$24,032,005
1892...	475,538	11,236,110	48,112	3,969,575	142,373	6,318,035	159,649	10,385,340	401,866	26,651,080	325.059	21,811,445
1893...	567,823	12,564,820	37,735	3,270,845	141,851	6,097,395	169,407	10,230,920	385,339	24,961,380	285,095	18,844,510

Y'r.	Old Iron for Remanufacture.		Steel, Unwrought.		M'f's of Steel or Steel and Iron Combined.		Total of Iron and Steel.		Lead, Pig, Sheet, Piping, and Manuf'res.		Locomotives.	Mining Machinery.
1891	112,856	$1,771,845	152,874	$8,660,365	17,311	$2,962,475	3,292,312	$134,385,000	49,010	$3,412,395	$8,086,270	....
1892	108,202	1,638,080	151,532	8,703,270	15,491	2,503,770	2,783,381	108,828,840	59,098	3,542,550	4,918,760	....
1893	120,461	1,666,825	172,497	8,519,745	18,826	2,397,665	2,903,753	103,070,775	49,723	2,766,375	4.260,295	$2,064,395

Year.	Salt, Rock, White.		Telegraph Wire and Apparatus.	Tin, Unwrought.		Zinc or Spelter, Unwrought and Wr'ght.	
1891................	682,078	$2,982,040	$7,170,100	5,249	$2,457,460	7,798	$808,665
1892................	664,668	2,696,310	4,549,585	5,738	2,720,335	9,974	894,880
1893................	646,389	2,522,645	5,328,835	6,848	3,031,590	9,895	795,470

FOREIGN PRODUCE.

Year.	Chemical M'f's and Products.	Copper, Unwrought and Part Wrought.		Glass of All Sorts.		Guano.		Iron, Bar, Angle, Bolt, and Rod.	
1891......	$808,890	11,874	$3,290,605	5,229	$504,765	1,073	$52,290	57,034	$2,282,105
1892......	1,083,545	11,261	2,797,665	4,516	460,360	1,961	60,000	47,225	1,914,320
1893......	983,625	13,050	3,066,395	4,702	431,235	1,472	63.680	28,533	1,195,305

Year.	Steel, Unwrought.		Iron and Steel Manufactures.		Petroleum, Liters.		Quicksilver.		Saltpeter.		Tin, in Blocks, Ingots, Slabs, or Bars.	
1891......	4,291	$230,795	29,750	$2,367,790	4,370.092	$267,855	1,928	$2,222,845	1,219	$111,715	14,856	$6,694,470
1892......	3,004	147,390	38,761	2,638,255	9,010,298	527,005	1,713	1,662,885	1,574	131,335	16,627	7,665,500
1893......	4,983	246,410	47,830	2,936,630	5,988,157	341,625	1,293	1,200,085	1,326	110,055	19,377	8,441,810

(*a*) From *Accounts Relating to Trade and Navigation of the United Kingdom.* For the imports and exports of the United Kingdom from 1877–92, inclusive. see THE MINERAL INDUSTRY, Vol. I. (*b*) Coal, etc., shipped for the use of steamers engaged in the foreign trade. This not being an export in the ordinary acceptation of the term, the value thereof is not given in the returns. (*c*) Including naphtha, paraffine, paraffine oil, and petroleum.

THE UNITED STATES.

THE statistics given in the accompanying table are compiled from returns courteously furnished by nearly every producer in the United States. There are, however, a few substances included in this list whose statistics are of little value. Thus the quantity of building stone quarried at the great permanent quarries of the country is easily ascertained, and undoubtedly the record of this has great value, but there is a very large quantity of building stone used in the vicinity of temporary quarries, or even picked up on the surface of the ground without quarrying, which cannot be estimated with any degree of accuracy either as to quantity or value, and statistics which ignore this or estimate it are misleading.

The same is true in a great measure of lime, which is burned at an innumerable number of places where no records are kept or can be obtained. Marl is also in the same category, as is shown in our report of marl mined in New Jersey, in which about 10% is returned by the mining companies and 90% is estimated by the State Geological Survey as produced by the farmers. Until the local machinery for collecting these returns can be greatly improved such statistics can have but little value.

We have omitted altogether the article "Mineral Water," which has heretofore appeared in the United States mineral statistics. Of the so-called mineral waters it is well known that a majority are simply unusually pure or non-mineral waters,—in fact, are much less mineral than most of the river and spring waters supplied to our great cities,—while some are actually "artificial mineral waters," though sold as "natural." This is especially the case with many of the table and medicinal waters. On the other hand, of the true mineral waters, such as brine and a few others, their mineral ingredients are already included in the list of mineral products. It is manifestly absurd to swell the values of our mineral production with such irrational and deceptive items.

The determination of the values of mineral products as reported in statistical works is far from satisfactory.

We have thus far reluctantly followed the methods adopted in the statistical books of the United States Government in obtaining the values of the minerals and mineral products at various places, in some cases at the mines, in other cases in the great markets, and in various degrees of manufacture. We have followed this illogical and absurd method, even to the extent of adding together these incongruous items to arrive at a total value of the products of the industry, but we hope in future volumes to adopt a more rational basis of valuation.

The mineral production of the United States declined heavily in 1893, though not to the extent generally expected during the last six months of the year. The decline in prices was more severe than in quantities, and it is safe to say that the values reached at the close of the year—which were much below the averages which are used in these tables—were the lowest ever touched in this country. The year 1894 will bring values down to a point not only below anything reached in 1893, but in many things below the costs in European countries for the same articles. These prices are far below the normal, but they foreshadow also what the future may bring forth. The productive industries of this country have in many instances outgrown the home market, and in times of forced economy in consumption, as at present, they overstock it to such an extent that the most economical producers can alone supply the demand. The consequences are seen in prices much below the average cost of all our works, and which measure very nearly the actual cost at the most closely managed.

These periodical ebb tides in prices measure the progress made in industrial technology, and they force on producers the necessity and demonstrate the possibility of extending our markets. The tables giving the production of minerals and mineral products show that the United States is much the most important mineral producer in the world; that the growth of this industry has been phenomenally rapid; that while continuing to pay higher wages than any other country in the world we have steadily lowered costs of production until to-day, in coal, iron, steel, copper, nickel, and many other substances we produce more cheaply than any other country. These facts naturally direct the attention of the industrial world to the conditions which have rendered them possible, and as a consequence we find American engineers, American processes, American machinery, tools, and appliances in demand in every country on account of their superiority. Now, when it is further demonstrated that we can compete with the world in costs, our American industry possesses a deeper interest for its rivals in other countries.

The mineral industry lies at the foundation of our national prosperity and our international commerce, and this yearly demonstration of the limitless natural resources of the country, and of the intelligence, enterprise, and industry of its people, is well calculated to attract the attention of the whole world.

The description of the several substances included in these tables, and the accounts of where and how they occur in nature, of the methods by which they are obtained, and the uses to which their products are applied, are given in the several subject articles in this and in the first volume of THE MINERAL INDUSTRY.

MINERAL PRODUCTS OF

Calendar years

No.	Products.	Customary Measures.	1880.			1881.		
			Quantity.		Value at Place of Production	Quantity.		Value at Place of Production
			Customary Measures	Metric Tons.§		Customary Measures	Metric Tons.§	
	NON-METALLIC.							
1	Asbestos	Short tons†	150	136	$4,312	200	181.4	$7,000
2	Asphaltum	" "	444	403	4,440	2,000	1,815	8,000
3	Barytes (crude)	Long tons‡	20,000	20,327	80,000	20,000	20,327	80,000
4	Borax	Pounds	3,860,748	1,751	289,870	4,045,405	1,835	303,365
5	Bromine	"	404,690	184	114,752	300,000	136	75,000
6	Building stone	....	....	....	18,356,055	....	....	20,000,000
7	Cement	Bbls., 300–400 lb.	2,072,943	....	1,852,707	2,500,000	....	2,000,000
8	Coal, anthracite	Long tons	23,449,742	23,832,768	38,680,250	28,512,516	28,978,237	64,152,000
9	Coal, bituminous *c*	" "	42,307,400	42,998,445	59,123,340	50,279,840	51,101,101	62,849,000
10	Cobalt oxide	Pounds	7,251	3.2	....	8,280	3.3	....
11	Corundum	Short tons	1,044	947	29,280	500	454	80,000
12	Chrome ore	Long tons	2,288	2,325	27,808	2,000	2,033	30,000
13	Feldspar	" "	12,500	12,704	60,000	14,000	14,228	70,000
14	Flint	" "	20,000	20,376	80,000	25,000	25,408	100,000
15	Fluorspar	Short tons	4,000	3,629.7	16,000	4,000	3,629.7	16,000
16	Grindstones	....	....	....	500,000	....	....	500,000
17	Gypsum	Short tons	90,000	81,818	400,000	85,000	77,273	350,000
18	Infusorial earth	" "	1,833	1,664	45,660	1,000	909	10,000
19	Lime	Bbls., 200 lbs.	28,000,000	2,545,454	19,000,000	30,000,000	2,727,272	20,000,000
20	Limestone for iron flux	Long tons	4,500,000	4,572,000	3,800,000	6,000,000	6,096,000	4,100,000
21	Manganese ore	" "	5,761	5,855	86,415	4,895	4,974	73,425
22	Marls	Short tons.	1,000,000	907,441	500,000	1,000,000	907,441	500,000
23	Mica	Pounds	81,669	37	127,825	100,000	45	250,000
24	Millstones	....	....	....	200,000	....	....	150,000
25	Mineral paints	Long tons	3,604	3,662	135,840	6,000	6,097	100,000
26	Mineral waters	Gallons	2,000,000	....	500,000	3,700,000	....	700,000
27	Natural gas	....	*a*	....	....	*a*	....	....
28	Novaculite	Pounds	420,000	190.5	8,000	500,000	226.8	8,580
29	Ozokerite (refined)	"	*a*	....	....	*a*	....	....
30	Petroleum *j*	Bbls., 42 gals	26,286,123	3,678,202	24,183,233	27,661,238	3,869,936	25,448,339
31	Phosphate rock	Long tons	211,377	214,228.7	1,123,823	266,734	271,089.7	1,980,259
32	Plumbago	Pounds	....	....	*e* 49,800	400,000	181	30,000
33	Potters' clay	Long tons	25,783	26,204	200,457	25,000	25,408	200,000
34	Pyrites	" "	2,000	2,032	5,000	10,000	10,163	60,000
35	Precious stones	....	....	....	100,000	....	....	110,000
36	Rutile	Pounds	100	*45.4	400	200	*90.8	700
37	Salt	Bbls., 280 lbs	5,961,060	757,944	4,829,566	6,200,000	793,285	4,200,000
38	Slate (for pigment)	Long tons	1,000	1,016	10,000	1,000	1,016	10,000
39	Soapstone	Short tons	8,441	7,657.8	66,665	7,000	6,352	75,000
40	Sulphur	" "	600	543.5	21,000	600	543.5	21,000
41	Talc (fibrous)	" "	4,210	3,729	54,730	5,000	4,537	60,000
42	Zinc-white	" "	10,107	9,171.5	763,738	10,000	9,083	700,000
	Total value of non-metallic mineral products		....	....	$165,440,966	....	....	$209,477,668
	METALLIC.							
43	Aluminum, value at N. Y.	Pounds	*a*	....	....	*a*	....	....
44	Antimony, value at S. Fran.	Short tons	50	45.3	$10,000	50	45.3	$10,000
45	Copper, value at N. Y. *h*	Pounds	60,480,000	27,441	11,491,200	71,680,000	32,523	12,175,600
46	Gold, coining value	Troy ounces	1,741,500	*54,165	36,000,000	1,676,300	*52,137	34,700,000
47	Pig-iron, value at N. Y.	Long tons	3,835,190	3,897,835	101,466,500	4,144,252	4,211,130	87,029,334
48	Lead, value at N. Y.	Short tons	97,825	88.770	9,782,500	117,085	106,248	11,240,160
49	Nickel, value at N. Y. *i*	Pounds	233,893	106.0	257,282	265,668	120.5	292,235
50	Platinum (crude)	Troy ounces	100	....	400	100	....	400
51	Quicksilver, value at S. F.	Flasks, 76½ lbs.	59,926	2,033.4	1,797,780	60,851	2,117.6	1,764,679
52	Silver, coining value	Troy ounces	30,320,000	*943,036	39,200,000	33,077,000	*1,028,787	43,000,000
53	Tin	Pounds	....	....	....	....	....	....
54	Zinc, value at N. Y.	"	23,239	21,088	2,277,432	26,800	24,319	2,680,000
	Total value of metallic mineral products		....	....	$201,283,094	....	....	$192,902,408
	Total value of non-metallic mineral products		....	....	165,440,966	....	....	209,477,668
	Estim. value of mineral products, unspecified *g*		....	....	6,000,000	....	....	6,500,000
	Grand total		....	....	$372,724,060	....	....	$408,880,076

* Kilograms.

† Short ton = 2000 lbs. ‡ Long ton = 2240 lbs. § Metric ton = 2204 lbs.

(*a*) Not reported.

(*b*) Including aluminum in alloys.

(*c*) Including brown coal and lignite.

(*e*) Value of crude product.

THE UNITED STATES.

1880 to 1892.

1882.			1883.			1884.			
Quantity.		Value at Place of Production	Quantity.		Value at Place of Production	Quantity.		Value at Place of Production	No.
Customary Measures.	Metric Tons.		Customary Measures.	Metric Tons.		Customary Measures.	Metric Tons.		
1,200	1,083.4	36,000	1,000	907	30,000	1,000	907	30,000	1
3,000	2,722	10,500	3,000	2,722	10,500	3,000	2,722	10,500	2
20,000	20,327	80,000	27,000	27,441	108,000	25,000	25,408	100,000	3
4,236,291	1,922	338,903	5,600,000	2,541	504,000	7,713,303	3,409	539,931	4
250,000	113	75,000	301,100	137	72,264	281,100	128	67,464	5
....	....	21,000,000	....	....	20,000,000	....	....	19,000,000	6
3,250,000	....	3,672,750	4,190,000	....	4,293,500	4,000,000	....	3,720,000	7
29,132,596	29,608,441	65,547,500	31,636,029	32,152,806	73,432,000	32,653,998	33,187,367	65,307,000	8
58,548,429	59,504,760	73,185,000	64,865,861	65,925,341	77,838,000	65,938,151	66,989,773	69,235,000	9
11,653	5.2	....	1,096	0.5	....	2,000	0.9	....	10
500	454	80,000	550	499	100,000	600	544	108,000	11
2,500	2,541	50,000	3,000	1,049	60,000	2,000	2,033	35,000	12
14,000	14,228	70,000	14,100	14,330	71,112	10,900	11,077	55,112	13
25,000	25,408	100,000	25,000	25,408	100,000	30,000	30,489	120,000	14
4,000	3,629.7	20,000	4,000	3,629.7	20,000	4,000	3,629.7	20,000	15
....	....	700,000	....	....	600,000	....	....	570,000	16
100,000	90,909	450,000	90,000	81,818	420,000	90,000	81,818	390,000	17
1,000	909	8,000	1,000	909	5,000	1,000	909	5,000	18
31,000,000	2,818,181	21,700,000	32,000,000	2,909,090	19,200,000	37,000,000	3,363,636	18,500,000	19
3,850,000	3,911,600	2,310,000	3,814,273	3,875,301	1,907,136	3,401,930	3,456,361	1,700,965	20
4,532	4,060	67,980	6,155	6,255	92,325	10,180	10,346	122,160	21
1,080,000	914,700.5	540,000	972,000	882,032.6	486,000	875,000	794,010.9	437,500	22
100,000	45	250,000	114,000	52	285,000	147,410	67	368,525	23
....	....	200,000	....	....	150,000	....	....	150,000	24
7,000	7,114	105,000	7,000	7,114	84,000	7,000	7,114	84,000	25
5,000,000	....	800,000	7,529,423	....	1,119,603	10,215,328	....	1,459,143	26
....	....	215,000	....	....	475,000	....	....	1,460,000	27
600,000	272.2	10,000	600,000	272.2	10,000	800,000	362.9	12,000	28
a	....	....	*a*	....	....	*a*	....	....	29
30,510,830	4,268,608	24,065,988	23,449,633	3,289,513	25,790,252	24,218,438	3,392,479	20,595,966	30
332,077	337,499.8	1,992,462	378,380	384,558.9	2,270,280	431,779	438,829.9	2,374,784	31
425,000	193	34,000	575,000	261	46,000	*a*	....	....	32
30,000	30,489	240,000	32,000	32,522	250,000	35,000	35,571	270,000	33
12,000	12,195	72,000	25,000	25,408	137,500	35,000	35,571	175,000	34
....	....	150,000	....	....	207,050	....	....	222,975	35
500	*227	1,800	550	*249.7	2,000	600	*272.4	2.000	36
6,412,373	820,448	4,320,140	6,192,231	791,794	4,251,042	6,514,937	833,583	4,197,734	37
2,000	2,032	24,000	2,000	2,032	....	....	2,032	2,000	38
6,000	5,435	90,000	8,000	7,259.5	150,000	10,000	9,074.4	200,000	39
600	543.5	21,000	1,000	908.3	27,000	500	454.2	12,000	40
6,000	5,444.6	75,000	6,000	5,444.6	75,000	10,000	9,074.4	110,000	41
10,000	9,083	700,000	12,000	10,899.0	840,000	13,000	11,797.3	910,000	42
....	....	223,408,023	....	....	235,519,564	....	....	212,697,759	
a	....	....	83		875	150	....	1,350	43
60	54.5	12,000	60	54.5	12,000	60	54.5	12,000	44
92,267,109	41,863	16,143,500	117,705,742	52,951	7,995,000	148,149,966	67,218	18,148,250	45
1,572,186	*48,899	32,500.000	1,451,249	*45,137	30,000,000	1,489,949	*46,341	30,800,000	46
4,623,232	4,698,822	106,336,429	4,595,510	4,666,495	91,910,200	4,097,869	4,164,786	73,761,624	47
132,890	120,590	12,624,550	143,957	130,632	12,322,719	139,897	126,948	10,537,042	48
281,616	128	309,777	58,800	26.7	52,920	64,550	29.3	48,412	49
200	....	600	200	....	600	150	....	450	50
52,732	1,833.0	1,487,042	46,725	1,626.0	1,253,632	31,913	1,110.5	936,327	51
36,197,695	*7,125,849	46,800,000	35,733,622	*1,111,415	46,200,000	37,744,605	*1,173,962	48,800,000	52
....	....	....	....	....	....	....	....	....	53
33,765	30,639	3,646,620	36,872	33,459	3,311,106	38,544	34,976	3,422,707	54
....	....	219,860,518	....	....	203,059,052	....	....	186,468,162	
....	....	223,408,023	....	....	235,519,564	....	....	212,697,759	
....	....	6,500,000	....	....	6,500,000	....	....	5,000,000	
....	....	449,768,541	....	....	438,578,616	....	....	404,165,921	

(*g*) Including fire-clay, common brick-clay, terra cotta, building sand, glass sand, limestone used as flux in lead-smelting, limestone used in glass-making, iron where used as flux in lead-smelting, tin ore, iridosmine, nitrate of soda, carbonate of soda, sulphate of soda, native alum, mineral soap, strontia, and pumice-stone.

(*h*) Including copper matte from imported pyrites, except in 1881, for which no returns are available for matte.

(*i*) Including nickel in copper-nickel alloy and in exported ore and matte.

(*j*) The production of petroleum stated in gallons is calculated in kiloliters, and converted to metric tons, by multiplying by 0.88. This, of course, gives a result only approximately correct, as the specific gravity of the various kinds of oil varies.

MINERAL PRODUCTS OF

Calendar years

No.	Products.	Customary Measures.	1885.			1886.		
			Quantity.		Value at Place of Production	Quantity.		Value at Place of Production
			Customary Measures	Metric Tons.§		Customary Measures	Metric Tons.	
	NON-METALLIC.							
1	Asbestos..............	Short tons†....	300	272.2	$9,000	200	181.4	$6,000
2	Asphaltum	" "	3,000	2,722	10,500	3,500	3,176	14,000
3	Barytes (crude)...........	Long tons‡....	15,000	15,245	75,000	10,000	10,163	50,000
4	Borax.....................	Pounds........	7,471,404	3,381	448,284	9,094,172	4,126	454,700
5	Bromine..................	"	320,000	145	92,800	428,334	194.3	141,350
6	Building stone....	....	....	....	19,000,000	....	....	19,000,000
7	Cement	Bbls.,300–400lb.	4,150,000	....	3,492,500	4,500,000	....	3,990,000
8	Coal, anthracite.	Long tons......	34,241,047	34,800,338	76,698,000	34,865,576	35,435,067	76,145,000
9	Coal, bituminous *c*	" "	66,303,427	67,386,423	84,205,009	67,509,684	68,612,386	80,507,000
10	Cobalt oxide..............	Pounds........	8,423	3.8	....	8,689	3.9	... .
11	Corundum................	Short tons.....	600	544	108,000	645	655	116,190
12	Chrome ore	Long tons......	2,700	2,744	40,000	2,000	2,033	30,000
13	Feldspar..................	" "	13,600	13,822	68,000	14,900	15,143	74,500
14	Flint......................	" "	30,000	30,489.9	120,000	30,000	30,489	120,000
15	Fluorspar...	Short tons.....	5,000	4,537.2	22,500	5,000	4,537.2	22,000
16	Grindstones	....	....	... .	500,000	....	... .	250,000
17	Gypsum	Short tons.....	90,405	82,186	405,000	95,250	86,434	428,625
18	Infusorial earth...........	" "	1,000	909	5,000	1,200	1,089	6,000
19	Lime.	Bbls., 200 lbs...	40,000,000	3,636,363	20,000,000	42,500,000	3,901,996	21,250,000
20	Limestone for iron flux....	Long tons......	3,356,956	3,410,667	1,678,478	4,717,163	4,794,194	2,830,297
21	Mauganese ore	" "	23,258	23,637	190,281	30,193	30,686	277,636
22	Marls.	Short tons. ...	875,000	794,010.9	437,500	800,000	725,953	400,000
23	Mica......................	Pounds	92,000	42	161,000	40,000	18.1	70,000
24	Millstones	....	....	....	100,000	....	....	140,000
25	Mineral paints............	Long tons......	3,950	4,014	43,575	15,800	16,058	285,000
26	Mineral waters...........	Gallons........	9,148,401	....	1,312,845	8,950,317	....	1,284,070
27	Natural gas...............	....	....	....	4,857,200	....	....	10,012,000
28	Novaculite	Pounds........	1,000,000	453.7	15,000	1,160,000	526.3	15,000
29	Ozokerite (refined)........	"	*a*	....	....	*a*	....	....
30	Petroleum *j*	Bbls., 42 gals..	21,847,205	3,060,311	19,198,243	28,064,841	3,931,277	19,996,313
31	Phosphate rock...........	Long tons......	437,856	445,006.1	2,846,064	430,549	437,579	1,872,936
32	Plumbago	Pounds........	327,883	149	26,231	415,525	188.3	33,242
33	Potters' clay	Long tons.....	36,000	36,587	275,000	40,000	40,653	325,000
34	Pyrites	" "	49,000	49,800	220,500	55,000	55,895	220,000
35	Precious stones...........	....	....	....	209,900	....	....	119,056
36	Rutile	Pounds........	600	*272.4	2,000	600	*272.4	2,000
37	Salt..	Bbls., 280 lbs...	7,038,653	901,089	4,825,345	7,707,081	986,115	4,825,345
38	Slate (for pigment)........	Long tons......	1,975	2,007	24,687	3,000	3,048	30,000
39	Soapstone.................	Short tons.....	10,000	9,074.4	200,000	12,000	10,899	225.000
40	Sulphur..................	" "	715	648.8	17,875	2,500	2,268.5	75,000
41	Talc (fibrous).............	" "	10,000	9,074.4	110,000	12,000	10,889	125,000
42	Zinc-white..	" "	15,000	13,624.5	1,050,000	18,000	16,344	1,440,000
	Total value of non-metallic mineral products...		. ...	....	$243,101,308	....	....	$247,208,210
	METALLIC.							
43	Aluminum, value at N. Y.	Pounds.... ...	283	283 lbs.	$2,550	3,000	1.7	$27,000
44	Antimony, value at S. Fran.	Short tons.....	50	45.3	10,000	35	31.7	7,000
45	Copper, value at N. Y. *h*..	Pounds........	170,094,182	77,175	18,292,999	162,241,535	73,612	16,630,660
46	Gold, coining value	Troy ounces...	1,538,376	*47,847	31,801,000	1,881,250	*58,512	34,869,000
47	Pig-iron, value at N. Y....	Long tons......	4,044,524	4,110,572	64,712,400	5,683,326	6,521,940	95,195,760
48	Lead, value at N. Y.......	Short tons.....	129,412	117,434	10,469,431	135,629	123,075	12,667,749
49	Nickel, value at N. Y. *i*....	Pounds........	277,904	126	179,975	214,992	97.5	127,157
50	Platinum (crude)..........	Troy ounces...	250	....	187	50	... .	100
51	Quicksilver, value at S. F..	Flasks, 76½ lbs.	32,073	1,116.6	979,189	29,981	1,043.3	1,060,000
52	Silver, coining value... .	Troy ounces...	39,910,279	*1,241,321	51,600,000	39,445,312	*1,226,859	51,321,500
53	Tin	Pounds........	....	....	....	....	....	....
54	Zinc, value at N. Y........	"	40,688	36,931	3,539,856	42,641	38,694	3,752,408
	Total value of metallic mineral products......		....	....	$181,587,587	....	....	$215,658,334
	Total value of non-metallic mineral products...		....	....	243,101,308	....	....	247,208,210
	Estim. value of mineral products, unspecified *g*		....	....	5,000,000	....	....	5,000,000
	Grand total..		....	... .. .	$429,688.895	....	.. ..	$467,866,544

* Kilograms.

† Short tons = 2000 lbs. ‡ Long tons = 2240 lbs. **§ Metric tons = 2204 lbs.**

(*a*) Not reported.

(*b*) Including aluminum in alloys.

(*c*) Including brown coal and **lignite.**

(*e*) Value of crude product.

THE UNITED STATES—*Continued.*

1880 to 1892.

1887.			1888.			1889.			No.
Quantity.		Value at Place of Production	Quantity.		Value at Place of Production	Quantity.		Value at Place of Production	
Customary Measures	Metric Tons.		Customary Measures.	Metric Tons.		Customary Measures.	Metric Tons.		
150	136.1	$4,500	100	90.7	$3,000	30	27.2	$1,800	1
4,000	3,629.5	16,000	53,800	48,811	331,500	51,735	46,955	171,537	2
15,000	15,244	75,000	20,000	20,326	110,000	19,161	19,473	106,313	3
7,601,115	3,448	380,055	6,813,443	3,091	408,800	7,273,132	3,299	454,571	4
199,087	90.3	61,717	307,386	139.5	95,290	418,891	190	125,667	5
....	....	25,000,000	....	....	25,500,000	....	....	42,809,706	6
6,692,744	....	5,674,377	6,503,295	....	5,021,139	7,000,000	....	5,000,000	7
37,591,246	38,205,259	84,558,000	41,637,110	42,317,208	89,027,000	35,420,209	35,998,760	57,313,000	8
79,350,990	80,647,105	99,103,000	88,247,002	89,688,424	98,664,000	87,898,265	89,334,004	97,125,000	9
5,769	2.6	....	7,491	3.4	....	12,955	6.9	....	10
600	544	108,000	589	535	91,620	2,245	2,038	105,565	11
3,000	3,049	40,000	1,500	1,524	20,000	2,000	2,032	30,000	12
10,200	10,366	56,100	8,700	8,842	50,000	6,970	7,083	39,370	13
32,000	32,522	185,000	30,000	30,489	175,000	11,113	11,294	49,137	14
5,000	4,537.2	20,000	6,000	5,453.8	30,000	9,500	8,621	45,835	15
....	....	224,400	....	....	281,800	....	....	439,587	16
95,000	86,207	425,000	110,000	99,819	550,000	267,769	242,985	764,118	17
3,000	2,722	15,000	1,500	1,361	7,500	3,466	3,154	23,372	18
46,750,000	4,242,286	23,375,000	49,087,000	4,451,814	24,543,500	68,474,668	6,213,672	33,217,015	19
5,377,000	5,464,806	3,226,200	5,438,000	4,529,334	2,719,000	6,318,000	6,421,172	3,159,000	20
34,524	35,087	333,844	29,198	29,674	279,571	24,197	24,592	240,559	21
600,000	544,465	300,000	300,000	272,232	150,000	139,522	126,608	63,956	22
70,000	31.8	142,250	48,000	21.7	70,000	49,500	22.4	50,000	23
....	....	100,000	....	....	81,000	....	....	35,155	24
20,000	20,326	310,000	24,000	24,391	380,000	32,307	32,924	463,766	25
8,259,609	....	1,261,463	9,578,648	....	1,679,302	12,780,471	....	1,748,458	26
....	....	15,817,500	....	....	22,629,875	....	....	21,097,099	27
1,200,000	544.4	16,000	1,500,000	681	18,000	5,982,000	2,714	32,980	28
a	....	....	43,500	19.7	3,000	50,000	22.7	2,500	29
28,278,866	3,961,257	18,877,094	27,612,025	3,867,848	17,947,620	35,163,513	4,925,647	26,963,340	30
480,558	488,005	1,836,818	448,567	455,892	2,018,552	550,245	559,233	2,937,776	31
416,000	188.7	34,000	400,000	182	33,000	....	....	*e*72,662	32
43,000	43,702	340,000	36,750	36,750	300,000	294,344	299,150	635,578	33
52,000	52,849	210,000	54,331	55,218	167,658	93,705	95,275	202,119	34
....	....	163,600	....	....	139,850	....	....	188,807	35
1,000	*454	3,000	1,000	*454	3,000	1,000	*454	3,000	36
8,003,962	1,228,953	4,093,846	8,055,881	1,030,743	4,374,203	8,005,565	1,030,702	4,195,412	37
2,000	2,032	20,000	2,500	2,540	25,000	2,000	2,032	20,000	38
12,000	10,899	225,000	15,000	13,612	250,000	12,715	11,538	231,708	39
3.000	2,722	100,000	*i*	....	....	450	408	7,850	40
15,000	13,611	160,000	20,000	18,148	210,000	23,746	21,549	244,170	41
18,000	16,344	1,440,000	20,000	18,149	1,600,000	16,970	15,390	1,357,600	42
....	....	$288,331,764	....	....	$299,988,780	....	....	$301,775,088	
18,000	10.2	$59,000	19,000	8.6	$65,000	*b*47,468	21.5	97,335	43
75	68.9	15,000	100	90.7	20,000	115	104.3	28.000	44
185,246,000	84,049	21,115,916	233,729,000	106,047	34,194,170	244,729,000	111,038	28,646,300	45
1,596,500	*49,655	33,136,000	1,604,927	*49,917	33,167,500	1,590,869	*49,480	32,886,744	46
6,417,156	6,521,940	121,925,800	6,489,738	6,595,715	107,000,000	7,603,640	7,727,809	120,000,000	47
160,700	145,827.5	14,463,000	180,555	163,843	15,924,951	182,967	166,031	16,137,689	48
205,566	93.3	133,200	204,328	92.5	127,632	217,663	99	130,598	49
448	....	1,838	500	....	2,000	500	....	2,000	50
33,997	1,183	1,436,000	33,250	1,125.7	1,413,125	26,484	921.6	1,190,500	51
41,269,240	*1,283,588	53,941,800	45,783,632	*1,423,999	59,206,700	51,354,851	*1,596,999	66,396,988	52
....	....	....	....	....	....	....	....	....	53
50,340	45,680.5	4,782,300	55,903	50,729	5,500,855	58,860	53,412	5,791,824	54
....	....	$250,909,854	....	....	$256,623,933	....	....	271,307,978	
....	....	288,331,764	....	....	299,988,780	....	....	301,775,088	
....	....	5,000,000	....	....	5,000,000	....	....	10,000,000	
....	....	$544,241,618	....	......	$561,612,713	....	....	583,083,066	

(*g*) Including fire-clay, common brick-clay, terra cotta, building sand, glass sand, limestone used as flux in lead-smelting, limestone used in glass-making, iron where used as flux in lead-smelting, tin ore, iridosmine, nitrate of soda, carbonate of soda, sulphate of soda, native alum, mineral soap, strontia, and pumice-stone.

(*h*) Including copper from imported pyrites, except in 1881, for which no returns are available.

(*i*) Including nickel in copper-nickel alloy and in exported ore and matte.

(*j*) The production of petroleum stated in gallons is calculated in kiloliters, and converted to metric tons, by multiplying by 0.88. This, of course, gives a result only approximately correct, as the specific gravity of the various kinds of oil varies.

MINERAL PRODUCTION OF

Calendar years

No.	Products.	Customary Measures.	1890.			1891.		
			Quantity.		Value at Place of Production	Quantity.		Value at Place of Production
			Customary Measures	Metric Tons.		Customary Measures	Metric Tons.	
	NON-METALLIC.							
1	Asbestos.	Short tons†	71	64.3	$4,560	66	59.8	$3,960
2	Asphaltum	" "	40,841	37,061	190,416	45,054	40,884	242,264
3	Barytes (crude)	Long tons ‡	21,911	22,180	86,505	31,069	31,576	118,363
4	Borax	Pounds	11,889,828	5,394	760,770	11,830,000	5,367	768,950
5	Bromine	"	387,847	176	104,719	368,786	167	73,757
6	Building stone				47,000,000			47,294,746
7	Cement	Bbls.,300–400 lb.	8,000,000		6,000,000	8,222,792		6,680,951
8	Coal, anthracite	Long tons	41,502,357	42,180,257	66,395,772	45,249,492	45,988,594	76,019,145
9	Coal, bituminous *c*	" "	97,849,081	99,447,339	108,708,000	106,129,033	107,862,538	118,864,516
10	Cobalt oxide	Pounds	6,788	3		7,200	3.3	
11	Corundum	Short tons	1,970	1,789	89,395	2,265	2,055	90,230
12	Chrome ore	Long tons	3,599	3,657	53,985	1,372	1,396	20,580
13	Feldspar	" "	8,000	8,130	45,200	10,000	10,163	50,000
14	Flint	" "	13,000	13,212	57,400	15,000	15,245	60,000
15	Fluorspar	Short tons	8,250	7,486	55,328	6,320	5,735	38,000
16	Grindstones				450,000			476,113
17	Gypsum	Short tons	182,995	166,057	574,523	208,126	188,862	628,051
18	Infusorial earth	" "	2,532	2,298	50,240			21,988
19	Lime	Bbls., 200 lbs	60,000,000	5,444,646	35,000,000	60,000,000	5,444,646	35,000,000
20	Limestone for iron flux	Long tons	5,521,622	5,611,790	2,760,811	5,000,000	5,081,650	2,300,000
21	Manganese ore	" "	25,684	26,103	219,050	23,416	23,898	239,129
22	Marls	Short tons	153,620	139,401	69,880	135,000	122,505	67,500
23	Mica	Pounds	60,000	27.1	75,000	75,000	34	100,000
24	Millstones				23,720			16,587
25	Mineral paints	Long tons	45,732	46,478	661,992	47,562	48,430	658,478
26	Mineral waters	Gallons	13,907,418		2,600,750	18,392,732		2,996,259
27	Natural gas				18,742,725			15,500,084
28	Novaculite	Pounds			69,909	1,375,000	628	150,000
29	Ozokerite (refined)	"	350,000	158.9	26,250	50,000	23	3,000
30	Petroleum *j*	Bbls., 42 gals	45,822,672	6,418,765	35,365,105	57,024,891	7,978,923	34,214,935
31	Phosphate rock	Long tons	510,499	518,835	3,213,795	587,988	597,589	3,651,150
32	Plumbago	Pounds			*e*77,500	1,506,065	684	75,350
33	Potters' clay	Long tons	350,000	355,715	756,000	400,000	406,532	900,000
34	Pyrites	" "	111,836	113,652	273,745	109,319	111,105	317,280
35	Precious stones				118,833			235,300
36	Rutile	Pounds	400	*181.6	1,000	300	304	800
37	Salt	Bbls., 280 lbs	8,776,991	1,127,092	4,752,286	10,233,701	1,300,107	5,639,083
38	Slate (for pigment)	Long tons	2,000	2,032	20,000	2,000	2,032	20,000
39	Soapstone	Short tons	13,670	12,404	252,309	16,514	14,985	243,981
40	Sulphur	" "	*a*			1,200	1,089	39,600
41	Talc (fibrous)	" "	41,354	37,526	389,196	53,054	48,143	493,068
42	Zinc-white	" "			1,600,000			1,600,000
	Total value of non-metallic mineral products				$337,696,669			355,913,198
	METALLIC.							
43	Aluminum, value at N. Y.	Pounds	*b*61,281	27.8	61,281	168,075	76	$126,056
44	Antimony, value at S. Fran.	Short tons	129	117	40,756	455	413	45,500
45	Copper, value at N. Y. *h*	Pounds	265,878,000	120,607	30,930,800	297,600,000	135,027	38,522,500
46	Gold, coining value	Troy ounces	1,588,880	*49,418	32,845,000	1,604,840	*49,915	33,175,000
47	Pig-iron, value at N. Y.	Long tons	9,202,702	9,352,983	151,200,410	8,279,870	8,415,079	140,757,790
48	Lead, value at N. Y.	Short tons	161,754	146,780	14,266,703	202,000	183,303	17,574,000
49	Nickel, value at N. Y. *i*	Pounds	200,332	91	130,216	120,848	55	72,509
50	Platinum (crude)	Troy ounces	600		2,500	450		3,150
51	Quicksilver, value at S. F.	Flasks, 76½ lbs.	22,926	797.8	1,203,615	22,926	777.13	1,037,381
52	Silver, coining value	Troy ounces	54,500,000	*1,695,102	70,485,714	58,330,000	*1,814,226	75,416,565
53	Tin	Pounds				125,198	56.8	25,085
54	Zinc, value at New York	Short tons	67,342	57,789	7,474,962	80,263	72,834	8,058,405
	Total value of metallic mineral products				308,641,957			314,813,941
	Total value of non-metallic mineral products				337,696,669			354,273,449
	Estim. value of mineral products, unspecified *g*				10,000,000			10,000,000
	Grand total				656,338,626			679,087,390

* Kilograms.

† Short tons = 2000 lbs. ‡ Long tons = 2240 lbs.

(*a*) Not reported.

(*b*) Including aluminum in alloys.

(*c*) Including brown coal and lignite, and anthracite mined elsewhere than in Pennsylvania.

(*e*) Value of crude product.

THE UNITED STATES—*Continued.*

1880 to 1893.

No.	Product.	Customary Measures.	1892.			1893.		
			Quantity.		Value at Place of Production.	Quantity.		Value at Place of Production.
			Customary Measures	Metric Tons.		Customary Measures	Metric Tons.	
1	Asbestos	Short tons	100	91	$5,000	120	109	$6,000
2	Antimony Ore	“ “	850	771	51,000	850	771	41,000
3	Asphaltum and asph't rock	“ “	47,040	42,675	254,016	34,944	31,701	174,720
4	Barytes (crude)	“ “	28,476	25,833	142,380	26,632	24,161	133,160
5	Bauxite	“ “	9,800	8,891	49,000	11,041	10,106	55,205
6	Borax	Pounds	12,538,196	5,687	940,365	8,699,000	3,946	652,425
7	Bromine	“	379,480	172	64,512	348,399	158	87,100
8	Building Stone	....	....	....	44,589,500	....	....	*f*40,000,000
9	Cement, hydraulic	Barrels of 300-	8,211,181	....	5,999,150	7,503,385	....	5,180,797
10	Cement, Portland	400 lbs.	547,440	....	1.153,600	596,531	....	1,152,839
11	Coal, anthracite	Long tons	46,850,405	47,352,696	89,727,982	48,044,834	48,818,356	93,091,670
12	Coal, bituminous (*c*)	“ “	114,220,101	116,059.045	124,230,532	113,436,871	115,263,204	118,595,834
13	Coke	Short tons	12,010,829	12,204.203	23,421,117	9,792,330	9,949,986	14,688,495
14	Cobalt oxide	Pounds	8,600	*3,900	6,450	3,893	*1,766	3,500
15	Copperas	Short tons	13,250	12,021	110,272	16,000	14,515	95.440
16	Copper sulphate	Pounds	....	....	....	54,000,000	24,492	1,822,500
17	Corundum	Short tons	1,504	1,364	139,994	1,747	1,585	140,589
18	Chrome ore	Long tons	1,650	1,677	16,500	1,620	1,646	16,000
19	Feldspar	“ “	16,000	16,258	80,000	17,000	17,274	85,000
20	Flint	“ “	37,000	37,596	185,000	38,000	38,612	190.000
21	Fluorspar	Short tons	9,000	8,165	54,000	9,700	8,800	63,070
22	Grindstones	“ “	....	....	304,800	45,580	41,350	345,920
23	Gypsum	“ “	256,259	232,458	695,492	250,000	226,799	562,500
24	Infusorial earth and tripoli	“ “	1,323	1,200	41,950	1,709	1,550	46,800
25	Lime	Barrels, 200 lbs.	70,000,000	6,350,200	38,500,000	*f*60,000,000	5,443,164	30,000,000
26	Limestone for iron flux	Long tons	4,560,000	4,633,416	2,097,600	3,750,000	3,810,375	2,250,000
27	Magnesite	Short tons	1,402	1,272	9,814	1,143	1,037	8,000
28	Manganese ore	Long tons	19,117	19,425	129,586	9,150	9,297	60,000
29	Marls	Short tons	125,000	113,400	65,000	110,000	99,792	55.000
30	Mica	Pounds	75,000	34	100,000	75,000	34	100,000
31	Millstones	....	....	....	20,000	....	....	18,000
32	Mineral Paints	Long tons.	50,000	50,805	650,000	....	....	546,000
33	Natural gas	....	....	....	14,800,000	....	....	14,000,000
34	Onyx	Cubic feet	3,500	....	40,000	2,175	....	28,750
35	Ozokerite (refined)	Pounds	130,000	59	7,800	None.	....	....
36	Petroleum	Bbls., 42 gals.	50,512,136	7,000,982	30,229,128	50,349,228	6,978,403	30,223,505
37	Phosphate rock	Long tons	902,723	917,257	3,322,021	981,340	997,140	3,434,690
38	Plumbago (crude)	Short tons	900	816	3.506	1,500	1,365	7,500
39	Plumbago (refined)	Pounds	1,398,363	634	87,902	896.603	406	39,503
40	Potters' clay	Long tons	450,000	457,349	1,000.000	393,000	399,327	830,000
41	Precious stones	....	....	....	188,000	....	....	200,000
42	Pyrites	Long tons	106,250	109,957	357.000	95.000	96,526	285,000
43	Salt	Barrels, 280 lbs.	11,784,954	1.542,133	5,900,000	11,435,487	1,452,388	5,717,743
44	Slate (for pigment)	Short tons	3,400	3,085	21,000	3,000	2,721	18,000
45	Slate (for roofing)	In squares	953,000	....	3.396,625	871,500	....	2,780.600
46	Slate (other kinds)	....	....	....	750,500	....	....	737,400
47	Soapstone	Short tons	23,208	21,054	423,449	20,100	18,235	366,825
48	Soda, natural	“ “	3,300	2,994	16,500	2,500	2,268	12,500
49	Soda, natural sulphate	“ “	1,680	1,524	8.400	90	82	450
50	Sulphur	“ “	1,825	1,656	54,750	1,344	1,219	26,880
51	Talc (fibrous)	“ “	41,925	38,034	472,485	36,500	33,113	337,625
52	Venetian red	“ “	4,205	3,815	89,335	3,830	3,475	81,475
53	Whetstones (*g*)	Gross pounds	1,090,000	....	107,580	900,000	....	105,925
54	Zinc, white	Short tons	27,500	24,946	2,200,000	25,000	22,678	1,875.000
	Total non-metallic	....	....	....	397,310,587	....	....	371,376,935
	METALLIC.							
55	Aluminum, value at N. Y. *b*	Pounds	295.000	134	191,750	312.000	142	202,800
56	Antimony, value at S. Fran.	Short tons	200	181	36,000	350	318	63.000
57	Copper, value at N. Y.	Pounds	325,500,000	147,647	36,716,400	322,585,500	146,324	34,677.940
58	Gold, coining value	Troy ounces	1,596,375	*49,652	32,997.071	1,739,081	*54,091	35,950,000
59	Pig iron, value at N. Y.	Long tons	8,977,869	9,122,413	134,668,035	7,043 384	7,156,782	93,888,309
60	Lead, value at N. Y.	Short tons	205,630	186,548	16,450,400	193,928	175,931	14,467,029
61	Nickel (fine)	Pounds	96,152	*43.614	57,691	25,893	*11,745	12,429
62	Platinum (crude)	Troy ounces	350	*11	1,750	300	*9.3	9.300
63	Quicksilver, value at S. F.	Flasks, 76½ lbs.	27,993	971	1.119,720	30,164	1,046	1,108,527
64	Silver, coining value	Troy ounces	65,000,000	*2,022,195	84.038,500	60,500,000	*1,881,732	78,220,450
65	Spiegeleisen and ferroman.	Long tons	179,131	182,015	*h* 6,647,290	81,118	82,424	2,893,229
66	Tin	Pounds	143,400	65	29,827	None.	....	....
67	Zinc, value at New York	Short tons	84,082	76,279	7,785,993	76,255	69,178	6,214,782
	Total metallic	....	....	....	320,740,427	....	....	267,707,795
	Est. prod'ts. unspecified	....	....	....	*f* 7,500,000	....	....	*f* 6,000,000
	Grand total	....	....	....	725,521,014	....	....	645,084,730

(*f*) Estimated. (*g*) Includes scythestones and novaculite. (*h*) Value taken as average of spiegel-eisen and ferromanganese, assuming production to have been one-third ferromanganese. (*i*) Including nickel in copper-nickel alloy and in exported ore and matte. (*j*) The production of petroleum stated in gallons is calculated in kiloliters, and converted to metric tons, by multiplying by 0.88. This gives an approximate result, the specific gravity of the various kinds of oils varies.

MINERAL IMPORTS OF THE UNITED STATES.

Year.	Aluminum. (b)			Antimony, Crude and Regulus. (d)			Antimony, Ore. (d)				Asbestos. (d)		
	Lbs.	Kilos.	Value.	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.	Total Value.	Total.	Unm'n-ufact'd.	Manu-fact'ed.
1870	....	......	$98	1,227,429	576	$164,179	....	......	....	$164,179	$7	....	$7
1871	....	......	341	1,015,039	460	148,264	....	......	$2,364	150,628	12	....	12
1872	....	......	......	1,933,306	877	237,536	....	......	3,031	240,567	....	....	....
1873	2	1	2	1,166,321	529	184,498	....	......	2,941	187,439	18	$18	....
1874	683	310	2,125	1,253,814	569	148,409	....	......	203	148,612	152	152	....
1875	434	197	1,355	1,238,223	562	131,360	6,460	3	609	131,969	5,783	4,706	1,077
1876	139	63	1,412	946,809	429	119,441	8,321	4	700	120,141	5,881	5,485	396
1877	131	59	1,551	1,115,124	506	135,317	20,004	9	2,314	137,631	3,221	1,671	1,550
1878	251	114	2,978	1,256,624	570	130,950	20,351	9	1,259	132,209	3,908	3,536	372
1879	284	129	3,423	1,380,212	626	143,099	34,542	15	2,341	145,440	7,828	3,204	4,624
1880	341	155	4,042	2,019,389	917	265,773	25,150	11	2,349	268,122	9,736	9,736	....
1881	517	235	6,071	1,809,945	821	253,054	841,730	381	18,199	271,253	27,786	27,717	69
1882	567	257	6,459	2,525,838	1,146	294,234	1,114,699	506	18,019	312,253	15.739	15,235	504
1883	426	193	5,079	3,064,050	1,390	286,892	697,244	316	11,254	298,146	24,612	24,369	243
1884	595	270	8.146	1,779,337	807	150.435	231,360	105	6.489	156,924	49,940	48,755	1,185
1885	439	199	4,736	2,579,840	1,170	207,215	215,913	98	7,497	214,712	73,643	73,026	617
1886	452	205	5,369	2,997,985	1,360	202,563	218,366	99	9,761	212,324	135,125	134,193	932
1887	1,260	572	12,119	2,553,284	1,158	169,747	362,761	164	8,785	178,532	140,845	140,264	581
1888	1,349	612	14,086	2,814,044	1,276	248,015	68,040	31	2,178	250,193	176,710	168,584	8,126
1889	998	453	4,840	2,676,130	1,213	304,711	146,309	66	5,568	310,279	263,393	254,239	9,154
1890	2,051	930	7,062	3,315,659	1,494	411,960	611,140	277	29.878	441,838	257,879	252,557	5,342
1891	3,921	1,779	c7,635	3,258,701	1,498	388,850	1,433,531	650	36,232	425,082	358,461	353,589	4,872
1892	....	......	c	3,950,864	1,792	392,761	192,344	87	7,338	400,099	269,642	262,433	7,209
1893	....	......	c	....	......	....	116,495	53	4,753	....	184,999	175,602	9,397

Year.	Asphaltum. (d)			Barium Sulphate. (f)						Bauxite. (b)			Brass and Mf's of, Value.
	Short Tons.	Metric Tons.	Value.	Man'f'c'd Lbs.	Metric Tons.	Value.	Unm'f'd, Lbs.	Metric Tons.	Value	Lbs.	Metric Tons.	Value.	
1870	488	443	$13,072	1,684,916	764	$12,917	....	......	......	....	......	......	....
1871	1,301	1,180	14,760	1,385,004	628	9,769	....	......	......	....	......	......	....
1872	1,474	1,337	35,553	5,804,098	2,632	43,521	....	......	......	....	......	......	....
1873	2,314	2,099	38,298	6,939,425	3,147	53,759	....	......	......	....	......	$44,995	....
1874	1,183	1,073	17,710	4,788,966	2,172	42,235	....	......	......	....	......	86,820	....
1875	1,171	1,062	26,006	2,117,854	960	17,995	....	......	......	....	......	45,725	....
1876	807	732	23,818	2,655,349	1,204	25,325	....	......	......	....	......	20,875	$235,411
1877	4,532	4,112	36,550	2,388,373	1,083	19,273	....	......	......	....	......	345	248,831
1878	5,476	4,968	35,932	1,366,857	619	10,340	....	......	......	....	......	685	....
1879	8,084	7,334	39,635	453,333	206	3,496	....	......	......	....	......	7,080	....
1880	11,830	10,732	87,889	4,924,423	2,334	37,374	....	......	......	....	......	14,737	409,905
1881	12,883	11,687	95,410	1,518,322	688	11,471	....	......	......	....	......	9,795	558,643
1882	15,015	13.621	102,698	562,300	255	3,856	....	......	......	12,008,101	5,446	30,525	....
1883	33,116	30,042	149,999	411,666	187	2,489	....	......	......	10,592.552	4,805	19,533	494,052
1884	36,078	32,740	145,571	3,884,516	1,761	24,671	5,800,816	2,531	$8,044	10,066,496	4,566	25,188	463,368
1885	18,603	16,877	88,062	4,095,287	1,857	20,606	7,841,716	3,557	13,567	20,510,540	9,303	41,378	404,310
1886	32,565	29,543	108,528	3,476,691	1,577	18,338	6.588,872	2,988	8,862	15,988,807	7,252	33,223	410,903
1887	31,108	28,221	97,377	4,057,831	1,842	19,769	10,190,848	4,622	13,205	10,824,749	4,910	29,809	379,331
1888	36,615	33,217	84,060	3,821,842	1,733	17,135	6,504,975	2,950	9,037	20,899,516	9,480	40,761	195,821
1889	61,705	55,979	138,885	3,601,506	1,633	22,458	13,571,206	6,156	7,660	28,945,674	13,149	60,292	175,311
1890	73,345	66,538	223,891	3,125,670	1,417	16.453	9,629,172	4,367	13,133	27,503,730	12,475	46,137	215,371
1891	14,725	13,358	229,350	3,813,760	1,729	22,041	11,043,200	5,009	4,505	17,936,504	8,135	46,252	277,533
1892	98,581	89,433	336,868	3,111,360	1,411	15,419	6,247,360	2,834	7,418	12,804,253	5,808	57,948	235.782
1893	76,996	69,854	196,314	2,265,121	1,028	11,179	6.681,920	3,031	7,612	11,431,678	5.185	28,217	215,657

Year.	Cement. (g)			Nitrate of Soda.			Bicarbonate Soda.			Caustic Soda.		
	Barrels.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.
1870	....	....	$18,057	31,122,795	14,166	$752.604	15,014,628	6,811	$347,530	20,804,681	9,437	$653,790
1871	....	....	52.103	50,290,377	22,812	1,254,965	18,998,399	8,618	421,177	27,952,469	12,636	877,710
1872	....	....	172,339	35,817,597	16,250	934,118	13,530,188	6,138	374,231	29,992,599	13,608	1,037,328
1873	....	....	209,097	59,757,241	27,107	1,469,243	10,571,049	4,795	369,867	28,171,629	12,781	1,269,142
1874	....	....	286,429	61,978,316	28,114	1,338,141	11,873,182	5,386	435,454	34,282,189	14.637	1,516.132
1875	....	....	261,741	52,105,826	23,636	968,855	6,853,588	2,109	231,754	37,669,885	17,090	1,419,292
1876	....	....	247,200	51,887,218	23,537	1,055,357	4,482,911	2,034	125,857	32,093,691	14,559	1,107,200
1877	....	....	201,074	54,246,531	24,607	1,324,299	3,765,165	1,708	98,277	33,375,447	15,412	1,043,933
1878	....	....	184,086	42,258,855	19,126	973,223	3,693,494	1,675	92,917	33.178,762	15,052	1,015,554
1879	....	....	212,719	76,285,858	34,607	1,324,299	2.392,719	1,086	60,701	45,767,366	20,761	1,209,469
1880	....	....	373,264	68,043,426	30,868	1,830,396	7,716,289	3,500	133,264	43,693,333	19,822	1,056,497
1881	....	....	441,512	126,613,909	57.432	2,909,368	1,791,330	813	56,808	50,500,802	22,908	1,155,215
1882	370,406	67,206	683.684	150,297,385	68,178	2,045,127	2,115,891	960	53,535	60,802,359	27,581	1,336,497
1883	832,996	151,139	1,321,225	128,333,230	58,212	2,469,013	2,041,103	926	51,099	65.593,102	29,754	1,436,450
1884	499,369	90,606	763,810	145,825,237	66,104	2,218,217	1,863,057	845	38,432	70,871,734	32,151	1,628,684
1885	617,409	112,023	840,191	89,573,975	40,632	1,332,969	3.033,498	1,376	54,352	79,880,338	36,237	1,659,936
1886	916,153	166,227	963,262	139,381,060	63,226	2,373,068	3,417,803	1,551	59,967	79,726,941	36,168	1,553,158
1887	1,506,721	273,379	1,469,185	163,776,049	74,290	2,253,806	1,803,183	818	31,603	89,162,856	40,446	1,651,337
1888	1,843,814	334,542	1,733,733	154,834,445	70,233	2,168,607	1,502,096	681	22,709	81,620,366	37,026	1,370,552
1889	h1,745,624	316,726	1,705,100	169,746,583	76,998	2,500,137	1,124,065	509	18,443	75,418,604	34,213	1,253,072
1890	h2,567,126	465,779	3,175,159	293,007,228	132,938	3,090,900	916,355	416	16.962	88.345,462	40,075	1,882,728
1891	h2,991,236	542,820	4,411,330	219,712.640	99,663	2,579,930	1,500,663	681	26,936	68,154,226	30,918	1,700,532
1892	h2,440,705	442.801	3,378,331	213,456,320	96,815	2,933,174	1,466,595	665	25,874	54,384,120	24,670	1,339,500
1893	h2,674,449	485.198	3,476,169	257,626,880	116,889	3,673,537	1,380,426	526	23,136	52,116,492	23,641	1,171,878

MINERAL IMPORTS OF THE UNITED STATES—*Continued.*

Year.	Sal and Ash Soda.			Other Soda Salts.			Nitrate of Potash.			Muriate of Potash.		
	Lbs.	Metric Tons.	Dollars.	Lbs.	Metric Tons.	Dollars.	Lbs.	Metric Tons.	Dollars.	Lbs.	Met. Tons.	Dollars.
1870	149,245,792	67,700	2,327,720	105,158	48	1,386	4,759.968	2,159	173,731	1,235,946	561	127,333
1871	174,065,704	78,957	2,669,474	619,782	281	10,231	5,072.381	2,301	208,423	2.170,473	984	284,809
1872	164,764,752	74,738	3,119,324	927,024	421	14,283	4,409,789	2,000	207,242	6,995,825	3,174	346,529
1873	215,680,880	97,834	5,261,009	364,406	165	7,534	10,681,948	4,846	498,932	8,886,852	4,031	337,240
1874	180,330,438	81,801	7,679,555	294,993	134	5,242	8,280,341	3,756	392,515	8,831,331	4,006	352,806
1875	198,559,205	90,068	3,912,457	187,877	85	4,327	9,457,954	4,290	380,286	13,159,522	5,969	374,011
1876	185,577,166	84,181	3,217,062	176,166	80	2,894	7,507,213	3,405	279,634	11,549,733	5,239	333,337
1877	219,280,164	99,467	3,473,317	262,569	119	3,340	10,322,255	4,682	382,091	16,164,862	7,332	473.805
1878	227,946,540	103,243	3,306,990	341,618	155	6,276	8,126,384	3,686	332,162	21,584,874	9,791	503,739
1879	245,599,656	111,433	3,175,714	417,476	190	5,884	9,243,193	4,193	282,088	23,958,425	10,870	471,969
1880	307,065.268	139,315	4,704,438	728,629	330	13,106	12,762,545	5,789	498,959	27,530,294	12,491	681,768
1881	287,516,778	130,357	3,525,084	3,204,484	1,454	26,487	13,041,704	5,916	487,916	27,205,496	12,343	737,878
1882	331,388,943	150,348	4,009,237	9,968,465	4,522	66,197	10,451,272	4,741	391,532	45,925,535	20,832	1,004,831
1883	327,121,598	148,441	3,931,278	9,434,953	4,280	56,310	11,884,592	5,391	395,443	32,732,473	14,850	743,940
1884	288,610,304	130,944	3,396,011	9,411,103	4,269	53,412	10,262,228	4,655	303,561	39,814,102	18,062	591,343
1885	303,148,263	137,493	3,387,351	4,443,355	2,015	28,386	11,838,354	5,370	314,380	44,794,335	20,319	687,033
1886	301,963,864	137,000	3,244,700	10,593,355	4,805	40,770	10,132,805	4,597	278,859	47,062,984	21,349	723,010
1887	280,777,373	127,388	2,843,892	16,171.131	7,335	51,665	9,601,381	4,355	264,560	40,891,063	18,547	597,588
1888	299,756,473	126,001	2,887,534	19.205,872	8,712	70,417	7,240,636	3,285	191,894	66,955,744	30,375	989,915
1889	307,256,243	139,400	2,937,084	17,686,879	8,023	98,353	9,822,848	4,455	270,008	68,059,738	30,875	1,015,263
1890	360,521,656	163,562	4,176,422	21,664,033	9,827	132,443	13,563,798	6,153	408,460	63,773,938	28.929	978,024
1891	347,822,902	157,800	4,509,611	16,226,334	7,360	114,955	15,292,057	6,937	469,591	78,144,810	35,450	1,220,119
1892	361.648,637	164,073	4,698,379	40,954,822	18,580	284,853	13,012,087	5,900	382,771	70,227,971	31,900	1,098,267
1893	348,972,506	158,321	3,982,772	29,872,509	13,553	205,790	13,374,016	6,066	369,274	74,663,116	38,407	1,192,516

Year.	Chromate and Bi-chromate of Potash.			Chloride of Lime.			Chrome Ore. (*d*)			Chromic Acid. (*d*)			Clays or Earths, including Kaolin.		
	Lbs.	Met. Tons	Value.	Lbs.	Met. Tons.	Value.	Long Tons.	Met. Tons	Value.	Lbs.	Kil's	Val.	Long Tons.	Met. Tons.	Value.
1870	1,235,946	561	$127,333	24,202,766	10,981	$467,459	......	.....	....	....	.....	$8	......	......	....
1871	2,170,475	984	223,529	32,111,839	14,569	635,910	......	.....	....	....	.....	5	......	......	....
1872	1,174,274	532	220,111	35,043,050	15,900	930,953	......	.....	....	514	233	49	......	......	....
1873	1,121,357	498	178,472	43,920,383	19,924	1,259,970	......	.....	....	922	418	276	......	......	....
1874	1,387,051	629	218,517	39,184,641	17,777	1,027,644	......	.....	....	44	19	13	......	......	....
1875	1,417,812	643	183,424	48,443,540	21,975	1,059,371	......	.....	....	45	20	22	......	......	....
1876	1,665.011	755	175,795	46,934,185	21,290	850,216	......	.....	....	120	55	45	......	......	....
1877	2,471,669	1,121	264,392	47,592,989	21,590	711,601	......	.....	....	13	5	10	......	......	....
1878	1,929,670	875	211,136	49,576,396	22,490	602,201	......	.....	....	32	14	35	......	......	....
1879	2,624,403	1,190	221,151	61,026,447	27,682	661,325	......	.....	....	....	.....	.....	......	......	....
1880	3,505,740	1,590	350,279	70,047,541	31,777	994,359	......	.....	....	5	2	3	......	......	....
1881	4,404,237	1,998	402,088	86,952.887	39,444	822,510	......	.....	....	124	55	89	......	......	....
1882	2,449,875	1,113	261,006	93,619,703	42,467	847,564	......	.....	....	52	23	42	......	......	....
1883	1,990,140	903	208,681	103,348,329	46,880	1,350,838	......	.....	....	290	131	338	23,463	23,841	$200,680
1884	2,593,115	1,176	210,677	93,451,223	42,391	1,651,237	2,677	2,720	$73,586	....	.....	120	29,285	29,756	223.284
1885	1,448,539	657	92,556	94,301,180	42,777	1,337,485	12	12	2,239	....	.....	39	26,541	26,968	215,887
1886	1,985,809	901	139,117	102,249,640	46,382	1,418,023	3,356	3,410	43,721	....	.....	101	32,504	33,027	261,504
1887	1,722,465	781	120,305	103,086,679	46,762	1,686,742	1,404	1,427	20,812	....	.....	5,571	42,482	43,166	293,194
1888	1,755,489	796	143,312	101,172,022	45,893	1,625,799	4,440	4,511	46,735	....	.....	281	45,843	46,581	308,943
1889	1,580,385	717	127,263	96,571,074	43,807	1,517,402	5,474	5,562	50,782	....	.....	2,974	46,829	47,582	320.966
1890	1,304,185	592	113,613	105,696,046	47,745	3,314,548	4,353	4,423	57,111	....	.....	634	53,383	54,242	367,223
1891	755,254	343	53,897	108,880,831	49,389	1,632,127	4,560	4,633	108.764	634	287	203	62,598	63,606	471,785
1892	1,193,972	541	94,708	109,888,561	49,846	1,962,084	4,930	5,009	55,589	772	347	204	75,283	76,495	605,022
1893	979,706	444	78,981	98,618,347	44,735	1,843,410	6,354	6,456	58,629	3,708	1,682	641	73.390	74,571	564,547

Year.	Coal. (*f*) Anthra.	Coal. (*f*) Bitumin.	Total.	Total.	Total.	Coke. (*j*)			Cobalt Oxide. (*k*)		
	Short Tons.	Short Tons.	Short Tons.	Metric Tons.	Value.	Short Tons.	Metric Tons.	Value.	Lbs.	Kilos.	Value.
1870	....	466,615	466,615	422,406	....	....	....	....	....	....	$5,019
1871	1,087	482,168	483,255	438,408	....	....	....	....	....	....	2,766
1872	436	543,270	543,706	493,250	....	....	....	....	....	....	1,920
1873	2,487	515,230	517,717	468,674	....	....	....	....	1,480	671	4,714
1874	527	547,110	547,637	496,816	....	....	....	....	1,404	636	5,500
1875	154	489,119	489,273	443,877	....	....	....	....	678	308	2,604
1876	1,598	448,707	550,305	417,589	....	....	....	....	4,440	2,013	11,180
1877	705	555,313	556,018	504,419	....	....	....	....	10,752	4,877	11,056
1878	176	641,586	641,762	582,206	....	....	....	....	2,860	1,297	8,693
1879	545	544,881	545,426	494,810	....	....	....	....	7,531	3,418	15,208
1880	9	528,435	528,444	479,404	....	5,047	4,579	$18,406	9,819	4,453	18,457
1881	1,351	731,318	732,669	664,677	....	15,210	13,798	64,987	21,844	9,908	13,837
1882	40	891,208	891,248	808,540	....	14,924	13,539	53,244	17,758	8,054	12,764
1883	567	723,434	724,001	656,814	....	20,634	18,628	113,114	13,067	5,927	22,323
1884	1,621	918,697	920,318	834.912	....	14,483	13,147	36.278	25,963	11,776	43,611
1885	5,567	887,286	893,153	810.268	....	20,876	18,938	64,814	16,162	7,331	28,138
1886	8,553	964,209	972,762	882,490	....	28,124	25.514	84,801	19,366	8,784	29,543
1887	4,392	952,931	957,323	869,391	....	35,320	32,042	100,312	26,882	12,193	39,396
1888	17.312	1,246,149	1,263,461	1,146,212	....	35,201	31,934	107,914	27,446	12.449	46,211
1889	29,528	1,148,431	1,177,959	1,068,644	....	28,608	25,953	88,008	41,455	18,802	82,322
1890	19,316	939.168	958.484	869,537	....	20,808	18,877	101,757	33,338	15,121	63,202
1891	16,676	1,525,972	1,542,648	1,399,490	....	50,753	46,043	223,184	35,483	16,094	60,630
1892	....	1,144,499	1,144,499	1,038,290	$3,747,140	24,482	22,210	86,350	32,833	14,775	60,067
1893	....	1,108,061	1,108,061	1,005,233	3,566,930	33,165	33,699	99,683	28,164	12,775	41,105

MINERAL IMPORTS OF THE UNITED STATES—*Continued.*

Year.	Fine Copper in Ore.			Copper Ingots, Old, Etc.			Manuf's Value.	Total Value.	Cryolite.			Earthen, Stone and Chinaw'e
	Lbs.	Met. Tons.	Value.	Value.	Met. Tons.	Value.			Long Tons.	Metric Tons.	Value.	
1870	1 936,875	879	$134,736	$260,543	118	$32,349	$487,258	$655,343	....	....	....	....
1871	411,315	187	42,453	373,449	169	46,222	676,510	765,185	....	....	$71,058	....
1872	584,878	265	69,017	3,786,978	1.718	758,584	1,060,409	1,888,010	....	....	75,195	....
1873	702,006	318	80,132	12,587,194	5,709	2,524,576	971,682	3,576,190	....	....	84,228	....
1874	606,266	275	70,633	1.485,641	674	277,739	175,909	524,281	....	....	28,119	....
1875	1.337,104	606	161,903	478,949	217	69,504	59,843	291,250	....	....	70,472	....
1876	538,972	244	68,922	264,156	120	39,926	33,635	142,483	....	....	103,530	$3,923,094
1877	76,637	35	9,756	263,029	119	34,034	41.987	85,777	....	....	126,692	4,039,890
1878	87,039	39	11,785	198,750	90	31,589	36.729	80,103	....	....	105,884	....
1879	51,959	24	6,199	126,157	57	13,456	44,539	64,194	....	....	66,042	....
1880	1,165,283	529	173,712	4,138,752	1,878	634,518	135,167	943,397	....	....	91,366	6,595,539
1881	1,077,217	488	124,477	1,178,196	534	152,587	289,263	566,327	....	....	103,529	6,799,654
1882	1,473,109	668	147,416	755,228	343	92,107	79,278	318,801	3,758	3,818	51,589	....
1883	†	†	203,948	632,039	287	69,225	381,713	654,886	6,508	6,613	97,400	7,077.816
1884	3,228,966	1,465	313,820	195,378	88	17,055	200,382	531,257	7,390	7,508	106,029	5,088,655
1885	3,607,952	1.637	356,274	574,514	261	43,617	94,702	494,593	8,275	8,408	110,750	4,685,658
1886	4,795.050	2,175	346,781	531,789	241	40,381	126,722	513,884	8,230	8,362	110,152	5,401,375
1887	3,935,432	1,785	199,696	212,539	96	15,086	107,100	321,882	10,328	10,494	138,068	6,139,014
1888	5,216,583	2,366	411,299	107,946	49	6,392	77,944	495,635	7,388	7,507	98,830	6,505.280
1889	5,190,252	2,354	311,277	122,998	56	11,041	92,762	495,080	8,603	8,741	115,158	6,763,753
1890	6 017,041	2,729	394,864	663,676	201	57,014	127,527	579,405	7,129	7,244	95,405	7,724,289
1891	11,690,312	5,303	875,855	3,154,557	1,431	276,263	513,611	1,665,729	8,296	8,430	76,350	8,752,163
1892	8,107,582	3.677	499,574	1,724,772	782	131,608	96,627	727,809	8,155	8,286	73,847	8,987,111
1893	7,723,387	3,504	467,988	5,536,690	2,510	488,710	83.752	1,040.450	9,574	9,728	126,688	8,769,831

Year.	Emery, Grains. (*b*)			Emery, Rock. (*b*)			Emery, Pulverized. (*b*)			Other M'f'res. (*b*)	Total Value.	Guano.		
	Lbs.	Met. Tons	Value.	Long Tons.	Met. Tons.	Value.	Lbs.	Met. Tons	Value.			Long Tons.	Metric Tons.	Value.
1870	....	.....	....	742	754	$25,335	644,080	292	$29,531	....	$54,866	.... ..	....	....
1871	....	....	....	615	625	15,870	613,624	278	28,941	....	44,811	......,	....	....
1872	....	.....	....	1,641	1,667	41,321	804,977	365	36,103	....	77,424	....	....	....
1873	610,117	277	$20,706	755	767	26,065	343,828	156	15,041	$107	70,919	....	....	....
1874	331,580	150	16,216	1,281	1,302	43.886	69,890	32	2,167	97	62,366	....	....	....
1875	487,725	221	23,345	961	976	31,972	85,853	39	2,990	20	58,327	....	....	....
1876	385.246	145	18,999	1,395	1,417	40,027	77,382	35	2,533	94	61,653	23,082	23,453	$784.718
1877	343,697	156	16,615	852	866	21,964	96,351	44	3,603	....	42,182	22,503	22,865	836,179
1878	334,291	152	16,359	1,475	1,499	38,454	65,068	30	1,754	34	56,601	....	....	....
1879	496,633	225	24,456	2,478	2,518	58.065	133,556	61	4,985	....	87,506	....	....	....
1880	411,340	141	20,066	3,400	3,455	76,481	233,855	106	9,202	145	105,894	17,546	17,827	245,869
1881	454,790	206	22,101	2,884	2,930	67,781	177,174	80	7,497	53	97,432	30,534	31,026	527,842
1882	520,214	236	25,314	2,765	2,810	69,432	117,008	53	3,708	241	98,695	....	....	....
1883	474,105	215	22,767	2,447	2,486	59,282	93,010	42	3,172	269	85,490	29,339	29,810	598,710
1884	143,267	165	5,802	4,145	4,212	121,719	513,161	233	21,181	188	148,890	24,210	24,600	423,344
1885	228,329	104	9,886	2,445	2,485	55,368	194,314	88	8,789	757	74,800	16,508	16,712	432,198
1886	161,297	73	6,910	3,782	3,842	88,925	365,947	166	24,952	851	121,638	13,344	13,559	302,154
1887	367,239	167	14,290	2,078	2,111	45,033	*m*114,380	52	6,796	2,090	68,209	10.195	10,358	252,265
1888	430,397	195	16,216	5,175	5,258	93,287	....	.....	....	8,743	118,246	7,381	7,500	125,112
1889	503,347	228	18,937	5,234	5,318	88,727	....	....	....	111,302	218,966	15,992	16,249	314,001
1890	534,968	243	20,382	3,867	3,929	97,939	....	.....	....	5,046	123,367	4,981	5,061	60,135
1891	90,658	41	3,729	2,530	2,571	67,573	....	.....	....	....	71,302	11,937	12,129	199,044
1892	566,448	257	22,586	5,280	5,365	95,625	....	.....	... .	2,412	120,623	3,073	3,122	46,014
1893	516,953	234	20,073	5,066	5,147	103,875	....	.....	....	3,819	127,767	5,951	6.045	97,890

Year.	Phosphates, Crude or Native.			All Ot'r Fertilizers.	Glass and Glassw'e	Gold and Silver in Coin and Bullion.		Gold and Silver in Ore.		Graphite, Unmanufactured. (*n*)			Manufactured
	Long Tons.	Met. Tons.	Value.	Value.	Value.	Gold.	Silver.	Gold.	Silver.	Cwts.	Met. Tons.	Value.	Value
1870	......	......	....	....	....	$10,430,561	$15,259,199	....	....	80,795	4,104	$266,291	$833
1871	......	......	....	....	....	5,841,948	16,962,467	....	....	51,628	2,623	136,200	3,754
1872	......	......	....	....	....	11,113.290	10,068.714	....	....	96,381	4,896	329,030	...,..
1873	......	......	....	....	....	20,537,254	9,212,185	....	....	157,539	8,003	548,613	......
1874	......	......	....	....	....	7,422,806	7,830,998	....	....	111,992	5.689	382,591	......
1875	......	......	....	....	....	14,348,781	8,547,367	....	....	46,492	2,361	122,050	......
1876	......	......	....	....	$4,175,301	23,676,096	10,795,238	....	....	50,589	2,570	150,709	17,605
1877	......	......	....	....	4,109,348	11,629,655	12,141,560	....	....	75,361	3,828	204,630	18,091
1878	......	......	....	....	....	10,477,859	18,389,884	....	....	60,244	3,060	154,757	16,909
1879	......	......	....	....	....	78,767,941	14,425,017	....	....	65,662	3,336	164,013	24,637
1880	......	......	....	....	5,969,976	73,644,698	11,631,025	....	....	109,908	5,583	278,022	22,941
1881	......	......	....	....	6,439,492	60,398,620	8,595,645	....	....	150,927	7,667	381,966	31,674
1882	......	......	....	....	....	13,402,528	9,098,385	....	....	150,421	7,641	363,835	25,536
1883	45,830	46,568	$424,343	$919,001	7,288,184	22,055,961	14,153,357	....	....	154,893	7,868	361,949	21,721
1884	15,471	15,720	218,584	921,723	7,350,419	27,957,657	15,504,777	....	....	144,086	7,319	286,393	1,863
1885	37,756	38,364	428.906	988,236	6.053,134	23,642,826	17,771,241	....	....	110,462	5,611	207,228	......
1886	30,837	31,333	310,413	1,447,336	6,756,403	41,309,181	17,221,465	....	....	83,368	4,237	164,111	......
1887	24,197	24,586	206,933	792,620	7,686,186	44,889,299	16,772,614	$14,028	$4,228,107	168,841	8,577	331,621	......
1888	34,337	34,890	303,974	870,041	7,986,554	10,960,773	15,907,969	71,168	5,684,093	184,013	9,347	353,990	......
1889	34,692	35,250	398,460	928,973	7,152,782	12,004,632	19,219,262	Bro.t'p.	7,580,196	177,381	9,011	378,057	......
1890	31,298	31,802	253,432	595,518	8,083,366	20,230,090	22,426,119	149,366	8,356,412	255,955	13,002	594,746	......
1891	28,843	29,307	213,771	1,296,807	8,263,006	44,970,110	18,192,750	233,269	9,717,443	212,360	10,788	555,080	......
1892	19,610	19,916	106,957	882,675	8.510,551	17,450,946	21,726,252	714,110	9,726,704	233,540	11,864	667,775	......
1893	21,727	22,077	112,504	1,012.340	6,822,852	72,762,389	18,274,804	578,186	9.490,892	288.820	14,672	865,379	......

MINERAL IMPORTS OF THE UNITED STATES—*Continued.*

Year.	Iridium. (*d*)	Iron Ore.			Iron, Pig, Scrap, Spiegel, and Ferromanganese. (*p*)			Bar Iron. (*p*)			Castings, Boiler, Hoop, Sheet, Taggers. (*p*)		
	Val.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Met. Tons.	Value.
1870	.....	....	....	....	*a*328,032	333,313	$5,581,471	68,104	69,200	$3,028,213	*d*24,346	24,738	$1,548,979
1871	.....	....	....	....	415,960	422,657	8,642,390	109,433	111,194	5,024,686	23,182	23.555	1.507,672
1872	.....	....	....	....	512,700	520,954	14,887,313	79,978	81,265	4,837,532	15,540	15,790	2,110,178
1873	$429	....	....	....	235,310	238,898	8,243,606	55,583	56,478	4,481,614	17,574	17,857	1,691,119
1874	275	....	....	....	90,882	92,345	2,688,190	23,996	24,342	1,936,793	7,393	7,512	1,123,251
1875	500	....	....	....	100,785	102,407	2,305,113	24,591	24.987	1,729,743	3,913	3,976	655,199
1876	180	....	....	....	86,804	88,201	2,031,961	23,798	24,181	1,532,361	1,742	1,770	224,870
1877	311	....	....	....	69,432	70,549	1,487,366	27,260	27,699	1,477,224	1,248	1,268	130,805
1878	.....	....	....	....	72,062	73,222	1,585,609	29,720	30,198	1,515.598	817	830	100,285
1879	425	284,141	288,655	$687,467	543.840	552,596	8,919,424	43,607	44,309	1,780,736	5,930	6,025	571,144
1880	.....	493,408	501,352	1,436.809	1,320,750	1,342,014	29,703,091	113,380	115,205	5,721,828	33,047	33,579	1,990,318
1881	1,730	782,887	795,491	2,222,652	599,948	609,607	11,628,537	42.696	43,383	2.075,161	9,070	9.216	699,179
1882	7,307	589.655	599,148	1,640,564	687,115	698,177	12,633,152	70,732	71,871	3,304,967	19,138	19,446	1,143,795
1883	495	490,875	498,778	1,207,991	386,934	393,163	6,760,862	42,329	43,010	1,914,474	9,033	9,178	723,751
1884	.....	487,820	495,674	1,133,678	194,608	207,741	3,685,048	36,605	37,194	1,588,464	24,296	24,687	1,310,037
1885	5,852	390,786	396,169	801,293	162,523	165,139	2,728,923	31,474	31,981	1,401,213	26,360	26,784	1,254,317
1886	.....	1,039,433	1,056,168	1,912,437	451,043	458.304	6,656,820	29,148	29,617	1,250,456	20,767	21,101	1,034,603
1887	3	1,194,301	1,213,529	2,206,958	807,460	820,460	12,212,650	36,218	36,801	1,400,005	51,864	52,699	1,982,361
1888	2	587,470	596,928	1,313,589	251,215	255,259	3,651,850	31,744	32,255	1,119,107	*c*60,140	61,109	*c*2,140,150
1889	.....	853,573	867,316	1,852,392	188,388	191,421	3,344,593	29,570	30.046	1,097,132	*c*41.867	42,541	*c*1,858,852
1890	.....	1,246,830	1,266,904	2,854,118	191,232	194.310	4,535,526	24,034	24,421	1,002,480	*c*30,218	30.708	*c*1,515,225
1891	.....	912,864	927,561	2,456,546	67,179	68,260	1,432,455	18,099	18,390	770,858	*c*12,753	12,958	*c*781,557
1892	.....	806,585	819,571	1,795,644	99,348	100,947	2,023,428	19,728	19,594	776,927	71,756	72,909	3,195,684
1893	.....	526,951	535,435	906,687	60,667	61,644	1,321,899	14,896	15,138	603,985	76,647	77,878	3,276,537

Year.	Steel Ingots, Billets, Blooms, Slabs, Sheets, etc			Tin and Terne Plates.			Rails.			Total.	Lead, Ore and Dross. (*d*)		
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Value.	Lbs.	Metric Tons.	Val.
1870	14,024	14,250	$2,013,577	66,659	67,732	$7,628,871	288,802	293,452	$9,678,305	$32,489,198	5,973	2.7	$176
1871	o18,644	18,944	2,829,066	82,968	84,304	9,946,373	505,538	513,667	19,132,359	57,866,299	316	0.14	10
1872	o20,687	21,021	3,185,457	85,628	87,006	13,893,450	473,974	481,604	22,705,025	75,617,677	32,331	14.6	1,425
1873	o18,994	19,300	2,230,843	97,177	98,741	14,240,868	231,046	234,766	13,692,292	60,005,538	....	....	.. ..
1874	*o*12,198	12,394	2.447,345	79,787	81,071	13,057,658	96,705	98,262	7,234,578	37,652,192	....	....	......
1875	o12,396	12,595	2,157.766	91,054	92,520	12,098,885	17,364	17,644	1,108,251	27,363,101	13,206	6	320
1876	8,584	8,716	1,433,979	89,946	91,394	9,416,816	256	260	6,603	20,016.603	....	....	......
1877	6,029	6,126	1,001,328	112,478	114,289	10,679,028	31	31	1,559	19,874,399	1,000	0.45	20
1878	5,155	5,238	879,098	107,864	109,600	9,069,967	9	9	435	18,013,010	....	....	......
1879	4,777	4,854	785,979	154,250	156,733	13,227,659	39,417	40,052	1,008,747	33,331,569	....	....	......
1880	9,090	9,236	1,421,521	158,049	160,533	16,518,113	259,543	263,722	9,192,901	80,483,365	....	....	......
1881	*o*68,796	69,903	3,578,166	183,005	185,951	14,886,907	344,930	350,483	11,114,487	61,655,077	5,981	2.7	97
1882	*o*218,338	221,850	7,642,302	213,987	217,432	17,975,161	200,112	203,334	6,481,039	67,075,125	21,698	9.84	500
1883	76,957	78,916	2,373,883	221,233	224,794	18,156,773	34,799	35,359	1,068,840	48,714,297	600	0.27	17
1884	21,973	22,327	1,310,362	216,183	219,663	16,858,650	2,829	2,874	69,779	38,211,800	419	0.19	13
1885	30,105	30,590	1,249,123	228,597	232,277	15,991,152	2,188	2.223	56,694	31,144,552	4,218	1.91	57
1886	149,336	151,740	3,298,707	257.686	261,835	19,495,564	41,588	42,257	887,433	41,630,779	715,588	325	9,699
1887	310,552	315,552	6.543,935	283,831	288,401	18,699,145	137,829	140,048	2,988,531	56,420.607	153,731	69.7	21,487
1888	103,577	105.244	2,822,870	297,871	302,667	19,752,180	60,960	61,941	1,525,558	42,308,256	88,890	40	2,468
1889	72,808	73,980	1.989,837	323,274	328,479	21,726,707	6,217	6,317	163,339	42,027,742	328,315	149	7,468
1890	28,636	29,097	1,578,286	329,435	334.739	23,670,158	204	207	5,035	44,540,413	493,463	224	12,947
1891	34,685	35,243	1,673,214	327,868	333,147	25,900,305	253	257	8,405	41,983,626	105,898	48	6,721
1892	30,586	31,081	1,591,092	268.472	272,793	17,102,487	347	352	10,607	33,882,447	127,873	58	9,932
1893	26,868	27,300	1,293,834	253,485	257,564	15,559,423	2,888	2,922	57,584	29,667.364	*w*	....	......

Year.	Lead, Pig and Bars.			Sheets, Pipe, and Shot.			Old and Scrap.			Manufacturer's N. E. S.	Total Values. (*q*)
	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.		
1870	85,895,724	38,966	$3,530,837	141,681	64	$6,879	3,756,785	1,704	$150,379	10,444	$3,548,336
1871	91,496,715	41,505	3,721,096	86,712	39	4,209	2,289.688	1,038	94,467	8,730	3,734,045
1872	73,086,657	33,156	2,929,623	15,518	7	859	4,257,778	1,932	171,324	20,191	2,952,098
1873	72,423,641	32,855	3,233,011	525	0.24	62	3,545,098	1,608	151,756	21,503	3,254,576
1874	46,205,154	20,955	2,231,817	30,219	13.6	1,349	395,516	180	13,897	36,484	2,269,650
1875	32,770,712	14,867	1,559,017	58	0.025	4	382,150	173	13,964	25,774	1,585,115
1876	14,329,366	6,500	682,132	20,007	9.1	1,204	265,860	121	9,534	27.106	710,442
1877	14,583,845	6,815	671,482	16,502	7.4	1,242	249,645	113	8,383	1,041	673,785
1878	6,717,052	3.047	294,233	15.829	7	963	106,342	48	3,756	113	295,309
1879	1,216,500	552	42,983	3,748	1.7	209	42,283	19	1,153	930	44,122
1880	6.723,706	3,050	246,015	1,120	0.5	54	213,063	97	5,262	20,976	268,198
1881	4,322,068	1,961	159,129	900	0.4	65	123,018	56	2,729	111,890	276,443
1882	6.079,304	2,758	202,603	1,469	0.66	99	220,702	100	5,949	62,139	268,070
1883	4,037,867	1,832	130,108	1,510	0.67	79	1,094,133	496	31,724	86,703	222,856
1884	3.072,738	1.394	85,395	15,040	6.7	630	160,356	73	4,830	127,949	245,711
1885	5,862,474	2,659	143,103	971,951	441	22.217	4,866	2.2	106	466,755	636,962
1886	17,582,298	7,975	491,310	27,357	12.5	1,218	24,726	11	882	559,284	1,061,617
1887	7,716,783	3,500	219,779	27,941	12.7	1,286	136,625	62	4,323	364,740	608,165
1888	2,582,236	1,172	69,891	23,103	10.35	1,202	33,100	15	904	407,839	585,723
1889	2,773,622	1,258	76,243	35,859	16	1,417	50,816	23	1,494	425,144	511,176
1890	19,336,233	8,771	593,671	68,314	31	3,338	*v*	....	....	1,210,387	1,821.837
1891	3,392,562	1,539	104,184	334,179	151	12,406	*v*	....	....	2,744,122	2,867,633
1892	1,549,771	749	110,593	90,153	40	6.207	*v*	....	....	....	4,569,176
1893	3,621,525	1.643	141,405	56,678	26	2,914	*v*	....	....	....	6,608,639

MINERAL IMPORTS OF THE UNITED STATES—*Continued.*

Year.	Manganese.						M'ble and Stone, & Ma'f's of.	Metals, Comp's & Ma'f's of.	Mica.(*r*)	Mineral Subst's N. E. S.	Nickel (*b*)	Oil, Mineral.		
	Ore.			Manufactured.										
	Long Tons.	Met. Tons.	Value.	L'ng Tons	Met. Tons	Value	Value.	Value.	Value.	Value.	Value.	Gallons.	Liters.	Value.
1870	......	......	....	.....	.....	......	....	....	$6,124	....	....	....	....	....
1876	......	......	....	.....	.....	......	$1,037,074	$863,218		....	$10	1,511,306	5,720,293	$265,687
1877	......	......	....	.....	.....	......	863,218	922,098	13,085	....	10,346	752,425	2,747,998	110,944
1878	......	......	....	.....	.....	......	....	....	7,930	....	16,684	....	....	....
1879	......	......	....	.....	.....	......	....	....	9,274	....	13,399	....	....	....
1880	......	......	....	.....	.....	......	965,244	1,462,282	12,562	....	66,069	17,524	66,238	2,877
1881	......	......	....	.....	.....	......	925,516	1,568,317	5,839	....	122,130	455	1,722	120
1882	......	......	....	.....	.....	......	....	....	5,175	....	143,660	....	....	....
1883	......	......	....	.....	.....	......	920,810	2,054,373	9,884	$87,256	132,484	139,983	529,836	3,555
1884	......	......	....	.....	.....	......	931,652	2,264,144	27,555	90,746	129,733	1.127,083	4,266,008	25,513
1885	......	......	....	.....	.....	......	851,258	2,039,876	28,685	109,659	64,166	413.195	1,563,941	13,812
1886	......	......	....	.....	.....	......	965,268	2.939,992	43,107	191,233	141,546	280,461	1,061,545	12,778
1887	......	......	....	.....	.....	......	901,742	3,091,992	63,240	145,325	205,232	382,977	1,449,566	14,108
1888	......	......	....	.....	.....	......	964,298	3,167,608	21,806	122,023	138,290	247,904	938,316	9,425
1889	4,135	4,202	$72,391	153	153	$6,000	1,219,595	3.616,416	91,826	109,042	156,331	711,410	2,692,687	32,661
1890	33,998	34,545	509,704	156	158	7,196	1,338,177	5,616 609	146,975	106,999	376,279	627,039	2,373,341	45,352
1891	28,624	29,087	371,594	201	204	9,024	1,312,856	7,445,640	110,442	183,175	321,163	1,362,288	5,156,259	62,222
1892	58,364	......	830,046	208	.....	10,305	1,525,271	6,470,918	100,846	275,615	426,817	909,885	3,443,913	49,487
1893	67,717	68,807	860,832	.....	.....	......	1,637,165	6,325,307	120,864	261,639	384,628	523,800	1,842,583	31,801

Year.	Ozokerite. (*d*)			Paints and Colors.	Palladium, Manufactured		Platinum, Man'fact'd.		Platinum, Ore, Sponge, Plate		Platinum, Vases, Retorts, etc.		Precious Stones.	
	Lbs.	Met. Tons	Value.	Value.	Weight, Grams.	Value	Kilos.	Value	Kilos.	Value.	Kilos	Value.	Rough &Uncut	Cut.
1870	....	.....	....	....	....	......	3.67	$648	692.93	$99,984	96.70	$16,294	$9,442	$1,769,828
1871	....	.....	....	....	....	......	.26	48	770.42	108,244	136.36	22,470	993	2,349,738
1872	....	.....	....	....	....	......	1.70	310	651.07	91,472	132.50	21,816	92,093	2,934,288
1873	....	.....	....	....	....	......	.17	43	504.16	90,771	.05	9	216,850	2,956,190
1874	....	.....	....	....	....	......	.65	132	684.32	123,293	292.40	59,698	213,250	2,163,091
1875	....	.....	....	....	....	......	.78	173	750.67	141,188	85.19	18,082	244,438	3,235,663
1876	....	.....	....	$922,149	....	......	.03	6	735.67	141,207	34.34	7,421	207,082	2,411,968
1877	....	.....	....	937,758	....	......	.04	11	417.03	81,925	84.35	18,611	123,297	2,113,892
1878	....	.....	....	....	....	.....	1.03	241	611.47	120,121	227.31	50,133	99,679	2,973,919
1879	....	.....	....	....	....	......	.27	73	753.47	166.178	139.81	34,209	123,047	3,875,804
1880	....	.....	....	1,121,122	....	......	3.82	964	1,000.59	217,144	173.43	41,827	178,567	6,705,692
1881	....	.....	....	1,119,596	....	......	1.19	290	1,375.74	273,343	95.55	21,292	285,005	8,330,061
1882	....	.. ..	....	....	....	......	7.96	1,731	1,417.41	285,731	232.16	48,452	542.366	8,353,512
1883	565,658	256	$29,332	1,355,439	....	......	.015	4	1,407.71	298,799	392.34	92,967	373,397	8,550,818
1884	617,992	280	69,626	1,233,827	....	......	......	......	1,290.63	289,898	333.96	83,112	375,564	6,534,139
1885	1,056,438	479	123,976	1,179,579	....	......	.015	3	1,184.66	285,239	65.44	17,473	318,767	6,326,881
1886	800,496	363	71,220	1,231,220	82.87	$694	.09	25	1,453.12	356,020	338.07	83,752	300,226	9,306,074
1887	718,769	326	59,084	1,283.646	690.96	5,417	.21	61	1,751.16	438,516	229.08	58,925	286,072	10,731,534
1888	1,164.940	528	89,131	1,213,910	6,188.73	46,564	.056	15	2,424.29	565,459	199.97	52,295	296,197	10,259,049
1889	1,078.725	489	86,682	1,315,411	12,195.46	96,008	1.00	299	2,342.08	548,350	157.17	44,879	204,450	12,123,448
1890	1,669,241	757	142,333	1,452,509	1,181.13	1,037	.75	39	2,563.02	702,093	322.30	159,057	513,611	12,540,646
1891	1,869,241	847	149,539	1,378,970	....	......	.012	49	2,204.35	972,989	66.59	26,228	975,772	11,769,663
1892	1,250.000	567	150,000	1,366.844	....	......	......	......	1,774.96	505,852	170.63	53,763	1,032,869	13.427,774
1893	1,744,905	792	133,111	1,294,857	....	......	.. ...	1,412	1,940.85	534,235	......	69.823	802.075	10,022,271

Year.	Pyrites.			Salt. (*i*)			Sulphur, Crude. (*s*)			Flow'rs Sulph.			Refined. (*s*)		
	Long Tons.	Metric Tons.	Av.Sulp. % Cont's.	Lbs.	Met. Tons.	Value.	Long Tons.	Metric Tons.	Value.	L'g Tns	M. Tns	Value	L'g T'ns	Met. T'ns	Value
1870	....	....	....	638,255,726	289,509	$1,305,067	27,379	27,820	$829,677	76	77	$3,927	157	160	$6.528
1871	....	....	....	558,724,372	253,433	1,155,772	36,131	36,712	1,213,202	65	66	3,514	92	93	4,328
1872	....	....	....	515,870,037	231,995	1,101,462	25,379	25,789	764,798	36	37	1,822	57	58	2,492
1873	....	....	....	727,506,249	329,991	1,780,401	45,533	46,266	1,301,000	55	56	2,924	36	37	1,497
1874	....	....	....	785,669,705	356,374	2,101,997	40,989	41,648	1,260,491	51	52	2,694	57	58	2,403
1875	....	....	....	719,943,406	326,551	1,749,651	39,683	40,321	1,259,472	18	18	891	.....	.....	......
1876	....	....	....	710,744,358	321,388	1,615,584	46,434	47,181	1,475,250	41	41	2,114	44	44	1.927
1877	....	....	....	803,050,112	364,257	1,592,771	42,962	43,653	1,242,888	116	118	5,873	1,171	1,190	36,962
1878	....	....	....	766,923,489	347,871	1,546,903	48,102	48,875	1,179,769	159	162	7,628	149	151	5,935
1879	....	....	....	810,046,604	367,431	1,682.723	70,370	71,503	1,575,533	137	139	6,509	69	70	2,392
1880	....	....	....	850,714,403	385,877	1,728,507	87,837	89,251	2,024,121	123	125	5,516	158	160	5,262
1881	11,927	12,119	35	941,803,333	427,195	1,900,609	105,096	106,788	2,713,485	98	99	4,226	71	72	2,555
1882	29,818	30,298	35	729,069,538	330,700	1,561,131	97,504	99,074	2,627,402	159	162	6,926	58	59	2,196
1883	35,811	36,397	36	1,447,406,276	656,530	2,635,273	94,539	96,061	2,288,946	79	80	3,262	115	117	8,487
1884	44,250	44,962	36	878,816,823	398,624	1,520,685	105,112	106,804	2,242,697	178	180	7,869	126	128	4,765
1885	50,000	50,850	38	880,579,875	399,424	1,576,753	96,839	98,398	1,941,943	120	122	5,351	114	116	4,060
1886	60,000	60,966	38	792,437,314	359,443	1,450,634	117,538	119,440	2.237,989	212	215	8,739	116	118	3,877
1887	60,000	60,966	38	712,444,544	323,160	1,267,111	96,881	98,441	1,688,360	278	282	9,980	83	84	2,383
1888	81,000	82,304	42	663,530,095	301,973	1,030,198	120,104	122,037	1,927,336	60	61	1,921	27	.....	734
1889	100,000	101,610	43	503.629,902	228,342	944,213	135,935	138,123	2,068,208	282	286	8,184	10	10	299
1890	115,000	116,852	43	527,835,772	239,322	932,905	131,096	133,206	2,147,481	*o*188	183	5,139	*o*10	10	299
1891	130,000	132,093	44	463,455,263	210,220	793,115	116,971	118,854	2,675.192	206	....	6,762	10	10	1,997
1892	210,000	213,381	43	456.613,733	207,213	768,415	100,721	102.342	2,189,307	158	....	5,439	26	25	4,106
1893	194,934	198.072	725	332.039,120	150.113	569,626	107.601	109.333	1,903,191	241	245	5,746	43	44	1,017

MINERAL IMPORTS OF THE UNITED STATES—*Continued.*

Year.	Tin. (*h*)						Zinc. (*t*)				
	Block Tin.			Tin, Terne Plate& Taggers Tin.			Sheet, Block, Pig, and Old.			Man'fs Net Value.	Total Value.
	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.		
1870	9,150,662	4,151	$2,042,887	149,312,800	67,727	$7,628,871	18,768,808	8,513	$925,357	$21,696	$947,053
1871	11,938,640	5,415	2,938,409	174,274,576	79,019	9,490,778	18,805,861	8,530	917,598	26,320	943,964
1872	11.424,672	5,182	3,033,837	181,174,224	82,179	10,736,906	22,507,191	10,209	1,116,409	58,688	1,175,077
1873	14,612,528	6,628	3,938,032	207,955,072	94,327	15,906,446	17,962,040	8,147	1,047,105	58,813	1,103,918
1874	13,041,504	5,916	3,199,807	174,032,320	78,939	13,322,976	9,610,405	4,359	627,983	48,304	676,287
1875	14,525,248	5,228	3,329,487	172,547,118	78,266	12,557.630	9,354,965	4,243	546,305	26,330	572,635
1876	10.435,600	4,733	1,816,506	197,927,509	89,778	10,226,802	5,558,682	2,521	354,390	18,427	372,817
1877	10,999,408	4.919	1,783,765	222,307,980	100,838	9,818,069	2,608,227	1,183	145,065	2,496	147,561
1878	14,431,088	6,545	2,167,350	242,646,871	110,063	9,893,639	2,526,804	1,146	127,134	4.892	132,026
1879	16,007,712	4,261	2,301,944	278,544.822	126,346	10,248,720	2,531,016	1,148	106,344	3,374	109,718
1880	32,480,662	14,733	6,153.005	369,435,844	167,573	16,524,590	*c*10,448,681	4,739	516,678	*a*	575,678
1881	19,168,352	8,694	3,971,756	377.072,728	171,037	14,641,057	8,187,993	3,714	328,212	*a*	328,212
1882	22,124,928	10,036	5,204,251	439,746,895	199,466	16,550.834	30,320,128	13,753	1,240,117	*a*	1,240,117
1883	42,201,780	19,142	9,505,949	742,807,258	336,932	27,194,574	8,695,898	3,944	319,890	75,467	395,359
1884	25,203,379	11,422	4,706,273	484,245,265	219,650	16,858,650	4,330.416	1,954	147,349	78,370	325,919
1885	23,535,488	10,675	4,497,499	512.056,092	232,265	15,991,152	3,086,683	1,400	95,319	30.480	125,799
1886	29,531,355	13,393	6,728,908	577,217,362	261,821	17,495,564	4,791,521	2,173	150,101	48,278	198,379
1887	29,344,553	13,311	6,921,948	635,792,760	288,391	18,699,145	9,525,070	4,319	309,744	44,703	354,447
1888	34,294,135	15,555	8,802,854	667,231,988	302,652	19,752,180	3,520,194	1,597	137,714	18,270	155,984
1889	35,177,648	15,956	7,044,939	724,135,688	328,463	21,726,707	1,928,480	875	81,078	66,312	147,390
1890	33,821,319	15,341	6.869,645	737,935,079	334,722	23,670,158	2,112,626	958	107,017	53,469	160,486
1891	41,146,123	18,663	8,091,363	734,425,267	333,030	25.900,305	814,218	369	41,369	18,424	59,793
1892	46,821,958	21,238	9,415,889	601,378,109	272,781	17,102,487	*x*410,896	186	23,307	22,709	46,016
1893	40,184,556	18,228	8,007,292	567,806,461	257,552	15,559,423	*x*425,998	193	22,931	20,756	43,687

(*a*) From *Summary Statements of the Imports and Exports of the United States* and *Mineral Resources of the United States*, and several figures for 1893 kindly furnished by Mr. J. V.Whitney, acting Chief of Bureau of Statistics. When not otherwise expressed. all years are calendar. All fiscal years end June 30. The following substances not given in the above table were imported in 1893: Bromine, 780 lbs., $234; plaster of paris, unground, 164,300 long tons, $180,263; ground, 1368 long tons, $22,643; calcined, 2565 long tons, $18,316; ocher and ochery earths, dry, 6,126,006 lbs., $53,943; ground in oil, 51,804 lbs.. $3321; spiegeleisen and ferromanganese, 37,457 long tons, $879,731; quicksilver, 30,191 lbs., $12,507; talc, 2,720,528 lbs., $12,825. (*b*) Fiscal years to 1886. (*c*) In 1891 unmanufactured only; in 1893 3286 lbs., $2168, crude and alloys of any kind in which aluminum is the component material of chief value was, imported; and manufactures not specially provided for, $2244 and $3301 in 1892 and 1893. (*c*) Six months. (*d*) Fiscal years to 1885. (*f*) Fiscal years to 1884. (*g*) Fiscal years to 1883. (*h*) Custom house returns for these years are given in pounds, which are reduced to barrels of 400 lbs. for convenience of comparison. (*i*) Fiscal years to 1882 excepting chromate and bichromate of potash, which are fiscal years to 1885. (*j*) Fiscal years. (*k*) Fiscal years to 1887. (*l*) Fiscal years to 1882; 1883, eighteen months, ending Dec. 31. (*m*) Six months only; since classed with "grains." (*n*) Fiscal years to 1888. (o) Fiscal year. (*p*) Fiscal year for 1870. (*q*) In the years from 1887 on is included the value of lead in ores from Mexico. which amounted in 1887 to 15,488 short tons; 1888 to 28,636 tons; 1889 to 25,570 tons; 1890 to 18.124 tons; 1891 to 23,867 tons; 1892 to 39,608 tons; and 1893 to 29,370 tons. (*r*) Fiscal years. (*s*) Fiscal years to 1887. (*t*) Fiscal years to 1883. The imports of zinc oxide were: 1886, dry, 2.526389 lbs., in oil, 79,788; 1887, dry, 4,961,080, in oil, 123.216; 1888. dry, 1,401.342. in oil, 51,985: 1889, dry, 2,686,861, in oil, 66,240; 1890, dry, 2,631,458, in oil, 102,298; 1891, dry, 2,839,351, in oil, 128.140. (*v*) Included with pig and bars. (*w*) Amount of lead contained in silver ore was 58,069,401 lbs., $985,324; that contained in other ore and dross, 13,686 lbs., $354. In 1893 were imported: Litharge, 42,582 lbs., $1310; red lead, 838,152 lbs., $26,885; lead white and white paint containing lead. 682,912 lbs., $33,973. (*x*) Does not include sheets, which amounted in 1893 to 25,373 lbs., $1789. N. E. S., not elsewhere specified.

MINERAL EXPORTS OF THE UNITED STATES.

Year.	As-best's (*b*)	Brass and Man'frs	Cement. (*c*)		Chemicals Drugs, Medicines	Coal. Anthra. Short Tons.(*d*)	Coal. Bitum. Short Tons.(*d*)	Total. Short Tons.	Total. Metric Tons.	Copper Ore. (*f*) (*g*)		
	Value	Value.	Bbls.	Value.	Value.					Lbs.	Metric Tons.	Value.
1870	......	....	31,175	$61,490	....	*e*135,628	119,638	255,266	231,577	*h*2,150,176	975	$537,505
1871	......	....	25.575	51,858	....	150,719	149,385	300,104	272,245	*h*6,097,840	2,766	727,213
1872	......	....	39,686	69,218	....	290.714	158.268	448,982	407,317	3,983.168	1,707	101,752
1873	......	....	27,873	52,848	....	383,241	271,547	654,778	594,015	5,068,224	2,299	170,365
1874	......	....	41,349	69,080	....	450,141	404.868	855,009	775,644	1,492.512	676	110,450
1875	......	....	64.087	98,630	....	354,095	227,570	581.665	527,686	*h*5,746,160	2,606	729,578
1876	......	....	53,827	77,568	....	378.485	257,760	636,245	577,201	1,714,048	777	84,471
1877	......	....	78,341	97,923	....	469,045	360,264	829,309	752,349	2,400,384	1,088	109,451
1878	......	....	82,507	98.334	....	351,424	381,539	732,963	664,944	3,690.064	1,674	169,020
1879	2,335	....	60,657	74,097	....	433,345	309.120	742,465	673,562	2,583,840	1,172	102,152
1880	7,848	....	41....	52,584	....	439,740	249,359	689,099	625,150	2,421,776	1,099	55,763
1881	30,785	....	57,555	83,598	....	517,672	213.961	731,633	663,737	1,115,296	506	51,499
1872	18,923	....	67,030	100,169	....	620,200	352,038	972,238	882,034	2,904,832	1,316	89,515
1883	17,865	....	109,113	177,531	....	624,750	518,617	1,143,367	1,037,263	30,593,920	13,877	2,097,490
1884	30,846	....	76,452	123,566	....	726,925	723,816	1,450.741	1,316,112	75,425,280	34,213	4,366,910
1885	36,068	....	72,828	113,555	....	724,368	604,001	1,328,369	1,205.096	77,878,080	35,325	3,878.956
1886	29.303	....	83.247	123.687	....	747,211	610,154	1,357,365	1,231,402	46.762.240	21,210	2,341,164
1887	10,191	....	63,520	97,771	....	924,543	791,127	1,715,670	1,301,754	56,143,360	25,467	2,774.464
1888	2,910	....	100,070	147,309	....	1,095,886	963,717	2.059,603	1,868,472	89,035,520	40,387	6,779,294
1889	120	....	89,995	142,298	....	960,548	1,047,369	2,007,917	1,821,582	102,672,640	46,572	8,226,206
1890	......	....	86,963	152,295	....	889,361	1,434,914	2.324,275	2.108,582	54,116,160	24,547	4,413,067
1891	17,847	....	83,607	130,371	....	967,181	1,807,202	2,774.383	2,516,920	86,477,440	39.225	6,565,620
1892	......	$438,486	....	....	$6,618,827	851,639	1,645,686	2.497.325	2,265,573	113.113.616	51.308	6.479,758
1893	......	741,317	....	....	7,001,179	1,333,287	2,325.591	3.658.878	3.319,334	93,527,950	42,424	4,257,128

MINERAL EXPORTS OF THE UNITED STATES—*Continued.*

Year.	Copper, Pig, Sheet, Old.			Manu-fact'r's Value.	Total Value.	Earthen, Chinaw'e	Glass-ware.	Gold and Silver in Coin and Bullion. (*p*)		Gold and Silver in Ores. (*j*)	
	Lbs.	Met. Tons.	Value.			Value.	Value.	Gold.	Silver.	Gold.	Silver.
1870	2,214,658	1,005	$385,815	$118,926	$1.042,246	....	....	$53,103,745	$27,846,083	....	....
1871	581,650	264	133,020	55,198	915,431	....	....	44,915,975	32,524.495	....	....
1872	267,868	122	64,844	121,139	287,735	....	....	68,638,125	32,048,799	....	....
1873	38,958	17	10,423	78,288	259,076	....	....	25,496,118	38,076,207	....	....
1874	503,160	229	123,457	233,301	467,208	....	....	43,149,091	29,577,984	....	....
1875	5,123,470	2,324	1,042,536	43,152	1,815,266	....	....	53,413,947	25,889,567	....	....
1876	14,304,160	6,488	3,098,395	343,544	3,526,410	....	....	31,231,739	25,122,736	....	....
1877	13,461,553	6,109	2,718,213	195,730	3,023,394	....	....	18,982,638	29,336,929	....	....
1878	11,297,876	5.125	2,102,455	217,446	2,488,921	....	....	8,655,948	18,209,252	....	....
1879	17,200,739	7,802	2,751,153	79,900	2,933,205	....	....	4,115,446	21,710,552	....	....
1880	4,206,258	1,907	667,242	126,213	849,218	....	....	3,062,459	12,983,442	....	....
1881	4,865,407	2,207	786,860	38,036	876,395	....	....	2,603,543	17,063,274	....	....
1882	3,340,531	1,515	565,295	93,646	748,456	....	....	38,721,079	17,317,055	....	....
1883	20,097,567	9,016	2,265,340	174,378	4,537,208	....	....	6,048,770	25,794,670	....	....
1884	30,405,159	13,792	3,888,759	112,505	8,368,174	....	....	40,948,246	29,563,748	....	....
1885	36,285,032	16,459	3,883,342	124,709	7,887,007	....	....	11,417,207	33,280,542	....	....
1886	19,553,421	8,870	1,968,772	76,386	4.386,322	....	....	41,281,276	27,040,290	....	....
1887	12,471,393	5,657	1,247,928	92,064	4,114,456	....	....	9,444,426	27,644,988	$87,604	$924,105
1888	31,706,527	14,382	4,906,805	211,141	11,897,240	....	....	34,526,449	29,880,403	125,153	637,766
1889	16,816,410	7,627	1,896,752	86,764	10,209,702	....	....	50,933,460	40,694,230	14,813	629,000
1890	10,971,899	4,977	1,365,379	139,949	5.918,395	....	....	24,063,074	26,539,789	32,094	1,126,697
1891	*i*69,279,024	31,425	8,844,304	293.619	15,703,543	....	....	79,086,581	27,692,879	100,918	1,090,514
1892	*i*30,515,736	13,742	3,438.048	245,064	....	$245,731	$938,154	76,532,056	35,975,834	9,262	1,592,931
1893	*i*138,984,128	63,043	14,213,378	462,136	....	151,308	971.503	79,767,354	46,230,439	....	....

Year.	Iron, Pig. (*k*)	Iron, Bar. (*k*)					Iron, Boiler, Band, Hoop, Scroll, and Sheet. (*k*)			Iron, Steel Ingots, Bars, Sheets, and Wire. (*k*)		
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1870	1,390	1,412	$50,127	228	232	$26,024	69	70	$7,793	21	21	$5.755
1871	2,080	2,113	111,033	182	185	16,754	64	65	7,906	7	7	2,538
1872	1,318	1,339	69,331	37	37	4,532	173	175	21,077	29	29	8,146
1873	9,020	9,165	140,683	308	313	33,767	97	98	10,657	8	8	3,955
1874	14,320	14,551	414,728	1,965	1,998	173,168	163	165	24,522	301	306	26,691
1875	7,802	7,928	489,362	5,323	5,409	392,420	200	203	22,732	58	59	16,830
1876	3,397	3,452	181,663	8,398	8,533	607,921	103	105	10,374	60	61	13,208
1877	6,859	6,969	89,029	2,874	2,920	194,775	201	204	35,723	67	68	15,661
1878	2,934	2,981	140,148	2,519	2,560	133,373	232	235	24,549	70	71	15,892
1879	1,144	1,163	85,949	991	1,007	58,987	657	667	48,056	49	50	9,084
1880	1,871	1,901	70,496	342	347	31,426	250	254	27,417	132	134	35,568
1881	6,158	6,257	184,364	445	452	32,325	164	167	14,473	195	198	46,495
1882	5,576	5,666	186,221	756	768	60,628	146	148	14.962	447	454	89,076
1883	3,768	3,828	111,414	107	109	72,054	*e*157	159	15,721	*d*367	373	76,447
1884	3,840	3,902	92,036	832	845	52,872	460	467	45,907	*c*2,355	2,393	296,072
1885	6,227	6,327	123,605	833	846	48,048	456	463	34,254	3,059	3,108	312,080
1886	8,849	8,991	161,072	809	822	44,999	1,151	1,170	77,045	4.186	4,253	380,408
1887	6,796	6,905	129,918	860	874	54,485	425	432	36,359	4,648	4,723	408,516
1888	14,374	14,605	256,563	587	596	40,749	2,183	2,218	199,478	6,727	6,835	558,108
1889	13,573	13.793	227,048	778	790	52,341	339	344	29,540	8,738	8,879	689,784
1890	16,341	16,604	266,107	1,068	1,085	97,317	609	619	48,168	10,721	10,894	886.244
1891	14,945	15,186	258,000	1,341	1,363	85,382	506	514	34,019	12,516	12,718	940,375
1892	15,427	15,675	282,290	963	979	60,463	31	31	1,762	15,291	15,537	1,027,541
1893	24,570	25,545	379,254	1.842	1,872	94,219	255	259	10,487	17,079	17,354	1,033,757

Year.	Iron—*Continued.*				Lead, Man'fs. (*m*)	Marble, Stone & Man'fs.	Mica.	Nickel.	Petroleum (1=1000 in quantities and values).					
	Rails.								Crude.		Naphtha.		Illuminating.	
	Long Tons.	Met. Tons.	Value.	Total Value. (*e*)	Values.	Value.		Value.	Gallons	Value	Gallons	Value	Gals.	Value.
1870	801	814	$65.081	$11,002,902	$28,315	....	From 1883–88 small quantities of mica were exported, amounting in the aggregate to $5682.	....	10,403	$2,237	5,423	$565	97,903	$29,864
1871	220	224	17,445	19,005,090	79,880	....		....	11,279	2,171	8,397	896	132,179	33,493
1872	87	88	7,167	8,747,106	48.132	....		....	16,364	2,761	8,688	1,307	118,260	29,456
1873	1,265	1,285	104,054	11,119,831	13,393	....		....	19,644	2,665	10,250	1,267	207,596	41,358
1874	341	346	25,356	13,180,654	302.044	....		....	14,431	1,428	10,617	997	206,563	30,169
1875	1,749	1,777	101,557	17,385,738	429,309	....		....	16,537	1,739	14,049	1,392	203,679	28,169
1876	1,002	1,018	57,109	13,454,574	102,726	....		$203.150	25,343	3,344	13,253	1,502	220,832	44,089
1877	5,289	5,374	243,811	14,468,039	49,835	....		8,200	28,773	3,267	19,566	1,939	307,374	51,366
1878	8,328	8,462	324,986	13,969,275	314,904	....		2,452	24.050	2,170	13,432	1,077	306,213	36,856
1879	*b*6,293	6,394	233,514	13,074,235	280,771	....		....	28,602	2,069	19,525	1.368	365,597	32,812
1880	958	973	47,212	15,156,703	49,899	....		4,120	36,748	2,772	15,115	1,345	286,132	29,048
1881	610	620	41,427	18,216,121	39.710	....		39,480	40,430	3,089	20,655	1,981	444,667	42,123
1882	2,996	3.044	208,228	22,348,834	178,779	....		19,674	45,011	3,373	16,970	1,304	428,425	37,636
1883	2,308	2,345	134,670	22,716,040	43,108	....		22,093	59,019	4,439	17,365	1,195	440,151	39,470
1884	6,034	6,131	223,535	19,290,895	135,156	....		22,429	79,679	6,103	13.676	1,133	433,851	39,451
1885	7,757	7,883	278,392	16,622,411	123,466	....		11,773	81,436	6,041	14,739	1,161	445,881	39,476
1886	2,644	2,687	87,308	14,865,087	136,666	....		51,353	76,346	5,068	14,475	1,265	485,121	39,013
1887	549	558	22,746	16,235,922	140,065	....		46,709	80,650	5,142	12,382	1.049	485,242	37.007
1888	8,908	9,051	232,002	19,578,489	194,216	....		39,576	77.549	5,455	13,481	1,083	455,045	37,236
1889	9.325	9,474	309,825	23,712,814	161,614	....		100	85,190	6.134	13,984	1,208	551,769	41,215
1890	16,948	17,221	577,916	27,000,134	181,030	....		471	96,573	6,535	12,462	1,051	550,873	39,826
1891	11,239	11,420	363.488	30,736,442	173,887	....		184,728	96,723	5,366	11,424	868	531,445	34,880
1892	7,982	8,110	256,325	27,900,862	154,375	$765,165		....	104,397	4,696	16,393	1,038	589,418	31,827
1893	20,876	21,212	595,988	30,159,150	508,090	964,616		....	115,091	3,966	16,343	1,003	711,828	31,796

MINERAL EXPORTS OF THE UNITED STATES—*Continued.*

Year.	Petroleum (*n*)—*Continued.*						Platinum.				Quicksilver.		
	Lubricating.		Res. & All Oth's.		Paraffine.		Manufactures		Scrap.				
	Gallons	Value.	Gallons	Value.	Lbs.	Value.	Kilos.	Value.	Kilos.	Value.	Pounds.	Metric Tons.	Value.
1870	7	$3	....	....	2	$0.4	....	....	....	....	....	....	....
1871	240	92	101	$10	37	5	....	....	....	....	....	....	....
1872	438	180	568	57	*a*	14	....	....	....	....	....	....	....
1873	1,503	517	1,377	118	*a*	42	....	....	....	....	....	....	....
1874	993	270	2,505	118	*a*	65	....	....	....	....	....	....	....
1875	938	266	2,324	170	*a*	110	....	....	....	....	....	....	....
1876	1,158	370	2,864	239	*a*	222	....	....	....	....	....	....	....
1877	1.914	578	4,256	391	*a*	163	....	....	....	....	....	....	....
1878	2,526	699	3,127	221	1,735	156	....	....	....	....	....	....	....
1879	3,169	713	4,828	273	3,634	302	....	....	....	....	....	....	....
1880	5,607	1,142	3,178	199	4,234	392	....	....	3.45	$600	....	....	....
1881	5,054	1,166	3,756	197	5,370	437	....	....	26.55	4,222	....	....	....
1882	8,822	2,034	4,265	275	9,121	579	88.68	$19,244	....	....	....	....	....
1883	10,108	2,193	6,503	465	16,562	1,124	88.16	21,600	36.76	6,250	....	....	....
1884	11,985	2,443	5,303	328	19,757	1,412	72.32	18,587	6.27	1,130	....	....	....
1885	12,979	2,659	5,714	335	25,349	1,868	....	....	37.43	7,000	....	....	....
1886	13,948	2,689	1,994	110	27,432	1,844	15.25	4,048	10.69	2,000	....	....	....
1887	20,583	3,559	2,989	141	33,135	2,049	8.30	2,200	93.59	17,500	....	....	....
1888	24,510	4,215	1,871	116	34,751	2,104	....	....	....	....	....	....	....
1889	27,903	4,639	1,858	97	40,965	2,288	....	....	31.10	6,500	....	....	....
1890	32,091	4,767	1,831	92	59,693	2,920	....	....	116.90	45,835	....	....	....
1891	33,210	5,000	1,003	61	65,076	3,979	....	....	43.59	12,900	....	....	....
1892	34,027	5,131	403	38	69,876	4,160	....	....	....	....	269,104	122	$133,626
1893	35,645	5,069	543	35	98,061	4,553	....	....	....	....	1,272,271	577	539,385

Year.	Salt. (*c*)			Tin, Man'f's Value.	Zinc Ore and Oxide. (*c*)			Zinc Sheets, Pigs, Bars. (*c*)			Manuf's Value.	Total Value.
	Lbs.	Metric Tons.	Value.		Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.		
1870	16,695,952	7,573	$119,582	....	1,712,032	777	$81,487	110,157	50	$10,672	....	$92,159
1871	6,728,736	3,052	47,115	....	1,077,552	488	48,292	76,380	35	7,823	....	56,115
1872	2,385,765	1,082	19,978	....	412,834	187	20,880	62,919	29	5,726	....	26,606
1873	4,106,088	1,862	43,777	....	26,208	12	2,304	73,953	33	4,656	....	6,960
1874	1,772,792	804	14,701	....	285,600	130	20,037	43,566	20	3,612	....	23,649
1875	2,637,264	1,196	16,273	....	345,296	157	20,659	38,090	17	4,245	$1,000	25,904
1876	2,856,784	1,296	18,378	....	1,139,936	517	66,259	134,542	60	11,651	4,333	82,243
1877	3,683,176	1,671	20.133	....	719,936	327	34,468	1,419,922	643	115,122	11,118	150,708
1878	4,055,912	1,840	24,968	....	1.797,600	815	84,831	2,545,320	1,154	216,580	567	300,978
1879	2,649.760	1,202	13,612	....	1,195,920	543	40,399	2,132,949	987	170,654	....	211.053
1880	1,242,024	563	6.613	....	618,128	280	18,388	1,737,776	788	154,817	....	174,205
1881	2,545,400	1,154	14,752	....	2,130,240	966	16,437	1,382,853	628	116,941	....	133,378
1882	2,356,760	1,069	18,265	....	710,750	322	16,487	1,159,949	526	823,384	....	837,871
1883	4,188,317	1,899	27,072	....	235,200	107	9,292	125,594	58	8,616	....	17,908
1884	3,987,008	1,808	26,935	....	813,120	369	22,867	136,804	62	10,606	3,097	36,570
1885	4,216,174	1,912	27,326	....	697,080	316	20,297	171,577	78	11,638	9,704	41,639
1886	4,828,863	2,290	29,580	....	2,981,440	1,352	49,455	917,229	416	75,192	13,526	138,173
1887	4,685,080	2,145	27,177	....	526,400	239	17,286	136,690	62	9,017	16,789	43,092
1888	5,359,235	2,431	32,986	....	510,720	232	18,034	62.234	28	4,270	19,098	41,402
1889	5,378,450	2,440	31,405	....	2,997,120	1,359	73,802	879,785	399	44,049	35,732	153,543
1890	5,927,022	2,235	30,079	....	8,664,320	3,930	195,113	3,925,584	1.780	126,291	23,587	344,991
1891	5,242,280	2,378	29,510	....	13,071,840	5,935	149,435	4,294,656	1,948	278,182	38,921	466,538
1892	....	....	....	$204,429	2,058,560	....	41,186	12,494,335	5,667	669,549	166,794	877,529
1893	....	....	....	258,449	109,760	....	1,271	7,278,874	3,302	403,590	248.382	653,243

(*a*) From *Summary Statements of the Imports and Exports of the United States* and from *Mineral Resources of the United States*. All are calendar years except where otherwise stated. All fiscal years end June 30. (*b*) Fiscal years to 1888. (*c*) Fiscal years to 1883. (*d*) Fiscal years to 1884. (*e*) Includes bituminous. (*f*) Fiscal years to 1882–83, eighteen months ending Dec. 31. (*g*) Ore, so called, is mostly matte, and during 1891 and 1892 matte exports averaged about 55% fine copper. (*h*) Evidently errors in quantities. (*i*) Sheets are not included these years, but are reported with manufactures. (*j*) Only approximately correct. The Bureau of Statistics reports only the value of silver ores exported, but a much larger amount of silver leaves the country in copper matte which is classified as copper ore and no record is kept of its silver contents. In the above table the value of silver in copper matte so far as could be ascertained from the Director of the Mint has been added to the value of silver ores, the values being calculated at the commercial rate each year. The gold in copper matte exported is not included in the exports of gold given in the above table. (*k*) Fiscal years to 1879. (*l*) Includes all manufactures of iron and steel as classified by Census Bureau. (*m*) Fiscal years to 1886. (*n*) Fiscal years to 1871. (*p*) Total exports of coin and bullion; that is, includes both domestic and foreign. N. E. S., not elsewhere specified.

MINERAL EXPORTS OF FOREIGN PRODUCE FROM THE UNITED STATES. (*a*)

Year.	Asphaltum or Bitumen (Crude).			Brass and Mf's of.	Cement.			Chemicals.								
								Salts of Potash. (*b*)			Chloride of Lime.			Nitrate of Soda.		
	Long Tons	Met. Tons	Value	Value.	Lbs.	Met. Tons	Value.	Lbs.	Kilos.	Value	Lbs.	Kilos.	Value	Long Tons.	Met. Tons	Value.
1890	......	.....	......	$1,072	3,533,000	1,603	$14,219	31,055	14,081	$627	1,900	862	$54	88	89	$4,478
1891	398	404	$4,530	5,097	4,055,002	1,839	17,297	....	......	......	......	......	......	104	106	2,984
1892	84	85	2,513	8,702	8,614,537	3,907	32,371	....	......	.....	......	......	......	214	217	8,355
1893	378	384	4,838	3,430	5,710,675	2,590	20,202	109,778	49,794	8,322	2,566	1,164	231	2,428	2,467	105,624

Year.	Chemicals—*Continued.*									Clays or Earths of All Kinds, including China Clay.			Coal, Bituminous.		
	Caustic Soda.			Sal Soda and Soda Ash.			All Other Salts of Soda.								
	Lbs.	Met. Tons	Value.	Lbs.	Kilos.	Value.	Lbs.	Kilos.	Value.	Long Tons.	Met. Tons.	Value	Long Tons.	Met. Tons	Value
1890	1,832,563	831	$40,188	74,153	33,635	$1,324	56,209	25,344	$683	41	41	$332	843	856	$9,689
1891	2,693,103	1,222	72,382	84,152	37,944	1,150	76,640	34,557	1,162	52	53	572	1,239	1,259	12,005
1892	1,408,986	639	37,872	46,876	21,266	725	63,591	28,844	942	60	61	514	127	127	1,310
1893	1,738,138	788	45,183	216,274	98,100	3,060	68,759	31,189	1,135	175	178	1,531	9	9	126

Year.	Copper.							Earthen, Stone and China-ware.	Fertilizers.						
	Copper Ore. Fine Copper Therein.			Pigs, Bars, Ingots, Old, & Other Unm'fd.			Mnf'es of.		Guano.			Phosphates, Crude or Native.			Other Fert'z's
	Lbs.	Met. Tons	Value.	Lbs.	Met. Tons	Value.	Value.	Value.	Tons.	Met. Tons	Value	Long Tons.	Met. Tons	Value	Value.
1890	1,636,058	742	$87,494	233,824	106	$20,368	$28,631	$18,562	1	1	$45	......	.....	......	$69,720
1891	2,082,708	945	78,514	534,949	243	43,637	15,185	19,144	......	.....	......	115	117	$1,150	52,190
1892	707,739	321	38,088	1,274,410	578	97,364	6,711	11,458	1	1	44	......	.....	......	....
1893	1,012,267	459	81,187	1,007,554	457	80,236	20,546	15,657	6	6	275	......	.....	......	222

Year.	Glass and Glass-ware.	Gold-bearing Ores N. E. S.	Gold and Silver, Manufactures of.	Graphite.			Iron Ore.			Iron and Steel, and Tin Plate, Etc.					
										Pig Iron.			Scrap Iron and Steel, fit only to be remanufact'd.		
	Value.	Value.	Value.	Long Tons.	Met. Tons	Value	Long Tons.	Met. Tons	Value	Long Tons.	Met. Tons	Value	Long Tons.	Metric Tons.	Value.
1890	$17,115	$34	$5,808	......	.....	......	......	.....	......	451	458	$6,363	657	667	$6,932
1891	6,814	6,484	39,927	36	37	$2,500	......	.....	......	226	230	2,980	370	376	3,539
1892	12,761	13,272	69,314	......	.....	......	31	31.5	$211	133	135	1,544	340	345	6,164
1893	11,366	17,057	17,308	164	166	5,615	......	.....	......	35	36	350	117	119	1,800

Year.	Iron and Steel, and Tin Plate—*Continued.*											
	Bar Iron, Rolled or Hammered.			Railway Bars of Iron or Steel, or in Part of Steel.			Ingots, Blooms, Slabs, Billets and Bars of Steel, and Steel in Forms N. E. S.			Steel Plate and Taggers, Wire Rods, Wire and Wire Rope, and Structural Iron or Steel.		
	Lbs.	Met. Tons.	Value	Long Tons.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.	Lbs.	Metric Tons.	Value.
1890	56,006	25	$888	....	....	....	....	....	....	360,049	164	$10,587
1891	76,896	35	1,151	19	19	$462	5,516	2	$485	412,620	187	12,306
1892	93,883	43	1,268	100	102	2,433	39,794	18	1,938	296,023	132	9,525
1893	7,067	3	148	1,243	1,263	24,297	181,111	82	10,232	336,682	153	8,503

Year.	Tin Plates, Terne Plates, and Taggers Tin.			Manufactures of.	Lead and Manufactures of.	Marble and Stone, and Manufactures of.	Metal Compositions and Manufactures.	Mineral Substances.	Oil, Mineral.			Paints and Colors
	Lbs.	Met. Tons.	Value.	Value.	Value.	Value.	Value.	Value.	Gals.	Liters.	Value	Value.
1890	917,462	416	$28,294	$88,474	$737,489	$3,338	$170,934	$200	......	....	......	$6,329
1891	1,164,742	528	41,637	110,324	1,743,739	6,436	96,737	1,114	40	151	$17	5,626
1892	548,134	249	16,433	83,260	3,348,124	1,892	105,904	16	310	1,173	247	3,492
1893	1,256,393	560	36,542	164,721	5,478,182	10,736	91,624	2,591	4,771	18,060	1,045	10,271

Year.	Platinum, Unmanufact'ed.			Precious Stones.	Salt.			Silver-bearing Ores.	Sulphur or Brimstone (Crude).			Tin in Bars, Blocks, Pigs, or Grain, or Granulated.			Zinc or Spelter, M'f'res
	Lbs	Kilos.	Value	Value.	Lbs.	Met. Tons.	Value	Value.	Long Tons.	Met. Tons.	Value	Lbs.	Met. Tons.	Value	Value.
1890	....	......	......	$36,716	4,034,292	1,830	$5,157	$74.214	......	......	......	....	......	......	$192
1891	....	....	......	33,433	1,096,400	497	1,270	212,624	50	51	$1.545	44,900	20	$2,000	778
1892	1	½	$83	5,956	3,542,113	1,607	4,687	305,640	......	......	3	55,532	25	11,212	44
1893	1	½	35	311,660	1,155,217	524	2.897	69,027	65	66	1,360	310,266	141	63,580	570

(*a*) From *Summary Statements of the Imports and Exports of the United States.* (*b*) This includes chlorate of potash, muriate of potash, nitrate of potash, and all other potash.

ASSESSMENTS LEVIED BY MINING COMPANIES FROM 1887 TO 1894.

Name and Location of Company.	Levied in 1887.	Levied in 1888.	Levied in 1889.	Levied in 1890.	Levied in 1891.	Levied in 1892.	Levied in 1893.	Total to Jan. 1, 1894.
Alliance, Utah			30,000		40,000			150,000
Allouez, Mich		80,000	40.000	40,000	40,000			1,440,000
Alpha, Nev	30,000	52,500	26,500	42,250	15,000	36,750	10,000	220,000
Alta, Nev	100,000	108.000		54,000	30,000	27,000	25,200	3,476,800
Anchor, Utah	70,000	105,000	15.000		150,000		90,000	560,000
Andes, Nev	50,000	50,000	25,000	25,000	30,000	25,000		?
Argenta, Nev			10,000					335,000
Atlantic Con	10,000							70,000
Baltimore. Nev		75,000	50,000	20,000				145,000
Belcher, Nev	52,000		104,000	104,000	104,000	78,000		3,160,000
Belle Isle, Nev	35.000			15,000		30,000	20,000	230,271
Bellevue-Idaho, Idaho	31,250	18,750	12,500	16,037				104,787
Benton Con., Nev	27,000	108,000						556,000
Best & Belcher, Nev	153,200	100,800	75,200	149,485	100,800	50,000	75,600	2,480,475
Bodie Con., Cal	100,000	100,000	75,000	50,000			40,000	715,000
Bodie Tunnel, Cal	25,000	25,000		25,000	25,000	25,000		202,906
Brunswick Con., Cal					20,000	20,000		40,000
Bullion, Nev	90,000	50,000		25,000	50,000	100,000	25,000	2,940,000
Bulwer Con., Cal	20,000	20,000	50,000		15,000		10,000	155,000
Butte Queen, Cal						4,000		6,000
Caledonia Silver. Nev	15,000	15,000			150,000			3,185,000
California, Cal						6,000		12,000
Centennial Eureka, Utah		30,000						30,000
Central North Star, Cal							10,000	10,000
Challenge Con., Nev		25,000	25,000	50,000	50,000	45,200	15,000	237,500
Chollar, Nev	112,000	112,000	112,000		168,000	112,000	61,600	1,881,600
Cœur d'Alêne, Idaho		25,000						25,000
Commonwealth, Nev		50,000				30,000		190,000
Comstock, Nev	15,000							30,000
Concord, N. C	3,000	3,000						6,000
Concordia, Nev		75,000						75,000
Confidence, Nev	12,480			18,720	18,720	49,920		1,608,270
Con. Califor. and Virgin., Nev.						108,000	6,220	1,614,530
Con. Imperial, Nev	125,000	25,000	25,000	75,000	150,000	26,500		2,076,500
Con. New York, Nev			25,000	45,000	30,000	20,000	25,000	145,000
Con. Pacific, Nev	9,000		15,000	6,000				198,000
Courier, Idaho	5,000							10,000
Crocker, Ariz	15,000	25,000	20,000	25,000	20,000	5,000	5,000	180,000
Crown Point, Nev		150,000	100,000		150,000	100,000	80,000	2,805,000
Del Monte, Nev		25,000	20,000	20,000	29,050	20.000		120,000
Derbec Blue Gravel, Cal						10,000	5,000	15,000
Diana, Nev		10,000				8,000		83,000
East Best & Belcher, Nev				25,000	45,000	20,000		?
East Sierra Nevada, Nev			10,000		10,000			20,000
Eureka Con., Nev			50,000					550,000
Exchequer, Nev	20,000	40,000	25,000	50,000	25,000	45,000	15,000	700,000
Felice, Ariz	20,000							20,000
Fisher, Ariz	20,000							20,000
Flowery, Nev		20,000						130,000
Found Treasure, Nev	6,000	18,000	12,500	45,000		50,000		131,500
Gold Flat, Cal						11,000	2,000	13,000
Goodyear, Mont						2,000	4,183	17,183
Gould & Curry. Nev	162,000	140,400	91,800	60,400	64,800	76,400	80,200	4,688,400
Grand Prize, Nev		25,000	120,000	25,000				785,000
Hale & Norcross, Nev	112,000			56,000	168,000	168,000	56,000	5,646,800
Hartery Con., Cal				5,000	5,000			27,000
Hartshorn, S. Dak				6,250				6,250
Hayward Group, S. Dak				2,000				2,000
Head Centre & Tranq., Nev.								22,824
Heath, Idaho	20,000	5,000						25,000
Hector, Cal			45,000					45,000
Hidden Treasure, Cal							1,000	1,000
Himalaya, Utah	1,800	900			1,800	1,800		10,800
Holmes, Nev				25,000				345,000
Honorine, Utah			12,500		12,500			50,000
Hudson Bay, Cal							10,000	10,000
Huron, Mich	120,000							280,000
Independence, Nev						5,000		345,000

ASSESSMENTS LEVIED BY MINING COMPANIES FROM 1887 TO 1894—*Continued.*

Name and Location of Company.	Levied in 1887.	Levied in 1888.	Levied in 1889.	Levied in 1890.	Levied in 1891.	Levied In 1892.	Levied in 1893.	Total to Jan. 1, 1894.
Iron Hill, S. Dak.		36,250	15,000	20,625	15,000			169,375
Jack Rabbit, Cal.						15,000	13,000	113.000
Jackson, Nev.							10,000	247,500
John Duncan, Mich.			2,000					4,000
Julia Con., Nev.	16,500				11,000		5,000	1,479.000
Justice, Nev.	31,500	52,200			26,250	42,000	30.000	3,555,000
Kearsarge, Mich.	50,000							190.000
Kentuck Con., Nev.					36,750	31,500	10,500	77.500
Keystone, Nev.	10,000							240.000
Keyes, Nev.		95,500	30,000					125,000
Kingman Silver, Ariz.					5,000			5.000
King of the West, Idaho.	30,000	15,000						45.000
Kossuth, Nev.	10,800	10,800						433,000
Lady Washington, Nev.		27,000			21,400			128.400
La Plata, Nev.			3,000					3.000
Locomotive, Ariz.	75,000	25,000	10,000	5,000				115,000
Lone Star Con., Cal.						5,000		12.500
Manhattan, Nev.	200,000							250.000
Martin White, Nev.			25,000	50,000	50,000	50,000	25,000	1,325,000
Mayflower, Cal.	150,000	175,000	35,000					470.000
Mexican, Nev.	50,400	50,400	50,400	25,200	50,400	75,600	75,600	2,993,760
Michigan Gold, Mich.						10,000		40,000
Mikado, Mich.	9,200	6,000						15,200
Milwaukee, Mont.					2,500			12,500
Missoula Placers, Mont.	2,000							4,000
Modoc Chief, Idaho.						5,000		975.000
Mollie Gibson, Colo.						10,000		20,000
Montreal, Utah.						750		4,500
Mono, Cal.	100,000	25,000	62,500	12,500	12,500			772,500
Mount Terry, S. Dak				750				750
Navajo, Nev.	50,000	30,000	10,000	15,000	15,251	20.000	20,000	555,521
Nevada Queen, Nev.	130,000		70,000		15,000	25,000	25.000	265,000
North Belle Isle, Nev	100,000	50,000	100,000	20,000	50,000	20,000	38,075	513,075
North Bonanza, Nev.	15,000	15,000	10,000					240,000
N. Commonwealth, Nev.		30,000	30,000	25,000	25,000		10,000	120,000
North Comstock, Nev.	10,000							10,000
North Extension, Nev.	25,000							25,000
North Gould & Curry, Nev.			20,000		30,000	10,000	10,000	290,000
North Occidental, Nev.				6,000				13,000
North Peer, Ariz.		5,000	5,000	5,000				21,000
Occidental Con., Nev.	25,000	45,000	50,000	75,000	25,000	50,000	55,000	323,990
Ophir, Nev.	50.400	50,400	50,000	50,000	50,000	50,000	100,000	4,410,640
Original Keystone, Nev.						10,000		250,000
Overman, Nev.	28 800		57,600	28,800	79,340	126,720	60,000	4,096,400
Paradise Valley, Nev.		25.000						57,000
Pennsylvania Con., Cal.						2,750		36,050
Peer, Nev.			20,000	10,000	15,000	20,000	10,000	210,000
Peerless, Nev.	25,000	25,000	96,000	25,000	10,000	5,000	5,000	405,000
Phil Sheridan, Nev.	20,000	10,000	35,000					65,000
Pine Hill, Cal.							3,000	7,000
Potosi, Nev.	145,600	112,000	10,000	55,400	112,000	56,000	84,000	1,825,600
Queen Bee, S. Dak.				3,000				3,000
Rainbow, S. Dak.						1,250		4,250
Ropes, Mich.							20,000	20,000
Sampson, Utah.	25,000	100,000						288,257
San Francisco, Cal.	22,000							22,000
Savage, Nev.	168,000	112,000	112,000		112,000	112,000	112,000	793,800
Scorpion, Nev.	20,000	10,000	120,000	90,000		5,000		410,000
Seg. Belcher & Mides, Nev.		25,000	50,000	80,000	50,000	25,000	35,000	290,000
Seg. Iron Hill, Dak.	2,500							8,750
Sierra Nevada, Nev.	100,000	75,000	100,000	71,910	80,000	55,000	45,000	6,401,910
Silver Hill, Nev.			43,200	43,200	30,000	16,200	5.400	1,987,200
Silver King, Ariz.		50,000		30,000	60,000	25,000		165,000
Siskiyou Con., Cal.					8,000	7,000	9,000	24,000
Stanard, Cal.				50,000				100,000
St. Mary's, Copper, Mich.							2,000	2,000
Summit, Cal.		5,000	2,500					120,000
Taylor Plumas, Cal.	4,000	6,000			10,000			20,000
Telegraph, Cal.						975		3,575
Teresa, Mex.						20,000	60,000	140,000
Tioga Con., Cal.		10,000						295,000
Triumph, Idaho.	10,000							20,000
Trojan, Nev.		10,000	10,000					370,000
Tuscarora, Nev.		5,000	10,000					15,000
Union, Utah.		1,000						7,000
Union Con., Nev.	75,000		75,000	50,000	80,000	50,000	45,000	2,450,000
Utah Con., Utah.							25,000	425,000
Wall Street, Mont.						900		1,500
Waterloo, Cal.							30,000	30,000
Weldon, Ariz.	20,000		10,000	10,000	10,000	5,000	10,000	65,000
Wood River, Idaho					3,000			3,000
W. Y. O. D., Cal.					22,500			22,500
Yellow Jacket, Nev.			60,000			156,000	90,000	5,874,000

DIVIDENDS PAID BY AMERICAN MINES. (1 = $1000; total, full amount.)

Company.	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893.	Total.
Adams, S., L., Colo	83	218	240	15	....	....	....	75	8	....	$634,500
Alaska-Treadwell, G., Alaska (*a*)	....	....	....	....	....	....	....	450	300	375	1,525,000
Alice, S., G., Mont	150	125	75	....	25	25	95	75	....	....	975,000
Alma, G., Ida	....	....	....	....	....	15	....	....	....	....	60,000
Alturas, G., Ida	....	....	95	....	113	....	....	....	....	....	262.250
Amador, G., Cal.(*b*)	....	....	....	....	....	....	31	....	....	....	31,250
American & Nettie, G., Colo	....	....	....	....	....	150	....	45	30	....	225,000
American Belle, S., C., Colo	....	....	....	....	....	....	....	50	....	....	50,000
American Coal, Md	....	....	....	....	....	....	....	90	90	90	270.000
American Turquoise, N. M.	....	....	....	....	....	....	....	....	....	60	60,000
Amy & Silversmiths, Mont	....	....	205	43	....	....	....	....	....	....	247,530
Anaconda, G., Colo	....	....	....	....	....	....	....	....	13	....	12,500
Argyle, G., Colo	....	....	....	....	....	....	....	....	20	....	20,000
Aspen, S., Colo	....	....	....	....	80	280	200	100	100	100	860,000
Atlantic, C., Mich	40	20	40	40	120	80	100	40	....	....	700,000
Aurora, I., Mich	....	....	....	150	....	....	....	200	100	200	650.000
Badger, S., Can	....	....	....	....	....	....	38	....	....	....	37,500
Bald Butte, G., Mont	....	....	....	....	....	....	23	30	20	100	172,500
Ballarat Smuggler, G., Colo	....	....	....	....	....	....	....	6	....	....	6,000
Bangkok-Cora Belle, S., Colo	....	....	....	....	....	3	42	....	....	....	44,510
Bannister, S., Mont	....	....	....	....	....	....	24	72	6	....	102,000
Bassick, S., G., Colo	100	....	....	....	....	....	....	....	....	....	400,000
Bates-Hunter, G., Colo	....	....	....	....	....	....	....	68	....	....	67,500
Belden, M., N. H	....	....	....	....	....	....	....	....	45	60	105,000
Bellevue, S., L., Ida	....	88	63	38	....	....	....	....	....	....	187,500
Best Friend, S., Colo	....	....	....	....	....	....	....	70	20	....	90,000
Big Bend, G., Cal	72	30	66	48	....	....	....	....	....	....	258,000
Bimetallic, S., G., Mont	....	....	....	....	....	....	290	840	200	190	1,630,000
Bodie Cons., G., Cal	350	50	....	....	....	....	....	....	....	....	1,602,572
Bonanza King, S., Cal	150	10	....	....	....	....	....	....	....	....	185,000
Boreel, Colo	....	....	....	....	....	....	....	....	....	60	83,000
Boston & Montana, C., S., Mont	....	30	180	....	400	500	625	500	....	....	2,075,000
Brooklyn Lead, L., S., Utah	....	....	20	25	....	....	....	....	....	....	127,000
Brotherton, I., Mich	....	....	....	....	....	....	....	....	40	80	120.000
Bull-Domingo, L., S., Colo.(*c*)	....	....	....	....	....	....	20	29	4	....	53,000
Bulwer, Cons., G., Cal	....	....	....	....	....	....	....	....	15	....	190,000
Bunkerhill & Sullivan, S., L., Ida	....	....	....	....	20	....	....	....	....	....	150,000
Buxton, So. Dak	....	....	....	5	....	....	....	....	20	....	25,000
Caledonia, G., Dak	....	20	20	....	16	80	56	....	56	....	192,000
California, G., Colo	32	....	....	....	....	....	20	....	....	....	116,500
Calliope, S., Colo	....	....	....	....	....	50	85	5	....	....	140,000
Calumet & Hecla, C., Mich	1300	1700	1000	1000	2000	2000	2000	2000	2000	2000	40,850.000
Carbonate Hill, S., L., Colo	10	....	....	....	....	....	....	....	....	....	80,000
Carlisle, G., N. M.(*d*)	....	....	....	....	175	....	....	....	....	....	175,000
Catalpa, S., L., Colo	30	....	....	....	....	....	....	....	....	....	270,000
Centennial-Eureka, S., G., L., Utah	....	....	....	....	....	....	150	330	90	188	765,000
Central, C., Mich	40	30	40	40	70	40	20	20	40	....	2,010,100
Champion, G., Cal	....	....	....	....	....	....	27	43	41	41	150,800
Charleston, P., S. C	....	....	....	....	....	....	....	....	....	140	140,000
Chrysolite, S., L., Colo	50	....	....	....	....	....	....	....	....	....	1,650,000
Clay County, G., Colo	....	....	....	....	....	....	8	48	....	....	56,000
Cleopatra	....	....	....	....	....	....	....	....	....	450	450,000
Cœur d'Alêne, S., L., Ida	....	....	....	....	....	70	160	80	72	30	340,000
Colorado Central, S., Colo	....	60	111	83	83	55	...	14	55	28	502,661
Colorado Fuel, Colo	....	....	....	....	....	178	189	252	67	67	752,700
Commonwealth, S., Nev	....	....	....	....	....	....	20	....	....	....	20,000
Confidence, S., Nev	....	....	....	....	175	25	....	....	....	....	199,680
Cons. Cal. & Va., S., G., Nev.(*f*)	....	....	65	1118	1118	756	162	216	....	....	3,682,000
Con. New York, S., G., Nev	....	....	....	....	....	....	....	....	....	10	10,000
Consolidation Coal, Md	....	....	....	....	....	....	....	....	205	....	205.000
Contention, S., Ariz	63	....	....	....	....	....	....	....	50	....	2,637,500
Cook's Peak, S., L., Colo	....	....	....	....	....	....	....	55	60	....	114,532
Copper Bell, S., Mont	....	....	....	....	....	....	....	14	....	....	13,500
Copper Queen, C., S., Ariz	200	....	....	....	140	70	210	....	140	300	1,560,000
Coptis, S., Nev.(*g*)	....	....	....	....	....	10	5	60	15	10	100,000
Cortez, S., Nev	....	....	....	....	....	....	173	250	95	45	735,000
Cosmopolitan, S., Utah	25	....	....	....	....	....	....	....	....	....	75,000
Crescent, S., L., Utah	....	30	30	18	....	....	....	....	....	....	238.000
Daly, S., L., Utah	....	....	....	375	488	450	450	450	450	188	2,850,000
Deadwood-Terra, G., So. Dak.(*h*)	....	....	....	100	....	....	....	50	100	....	1,150,000
Deer Creek, S., G., Idaho	....	....	....	....	10	10	....	....	....	....	20,000
De Lamar, S., G., Ida	....	....	....	....	....	....	....	150	272	450	872,000
Derbec, G., Cal	60	40	40	20	....	30	30	20	....	....	260,000
Dexter, S., Nev	....	....	....	....	....	....	....	50	80	115	245,000
Dunkin, S., L., Colo	10	....	....	30	100	40	....	....	....	....	390,000
Dunstone, G., S., L., Mont	....	....	....	....	6	....	....	....	....	....	6,000
Eclipse, L., S., Colo	....	....	....	20	....	....	....	....	....	....	20,000
Elkhorn, S., L., Mont	....	35	55	20	....	....	125	300	303	225	1,157,500
Empire, G., Mont.(*i*)	....	....	....	71	....	....	....	....	....	....	70,500
Enterprise, S., G., Colo	....	....	....	....	....	....	....	250	450	125	825,000
Eureka Cons., S., L., Nev	....	....	....	50	88	....	38	50	13	....	5,004,500
Evening Star, S., L., Colo	....	....	....	....	13	25	....	....	....	....	1,450,000
Father de Smet, G., Dak	200	200	....	....	....	....	....	....	....	....	1,125,000
Franklin, C., Mich	80	40	80	40	160	80	80	80	160	120	1,160,000
Freeland, S., Colo	....	80	60	....	....	....	....	....	....	....	190,000
Garfield, S., G., Nev	....	....	13	13	25	....	....	....	....	....	85,000
Glengarry, S., G., Mont	....	....	....	....	....	....	....	10	....	....	10,000

DIVIDENDS PAID BY AMERICAN MINES—*Continued.*

Company.	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	Total.
Golconda, S., G., Ida					120						120,000
Golden Fleece, Colo										144	144,000
Golden Reward, G., Dak					20				60	60	125,000
Gold Rock, G., Colo								29			28,750
Granby, Z., Mo						20					20,000
Granite, S., L., Ida					8	20					28,400
Granite Mountain, S., G., Mont		580	1020	2000	1600	2400	2400	1400	520		12,120,000
Great Western, C., Cal								25	137	25	391,338
Hale & Norcross, S., G., Nev					224						1,822,000
Hecla, Cons., S., L., Mont	195	195	135	30	100	180	123	180	90	60	1,890,000
Helena & Frisco, S., Mont							79	190	20		300,000
Helena M. & R. Co., Mont	36	138	60								197,970
Helena & Victor, S., Mont								20			70,000
Holmes, S., Nev			75								75,000
Homestake, G., So. Dak	306	525	575	300	300	188	150	150	150		4,943,750
Honorine, S., Utah	13	50	25	38							125,000
Hope, S., Mont		36		25	50				100	175	508,252
Horn Silver, S., L., Utah	1200					50	200	200	200	230	4,880,000
Hubert, G., Colo					18	5					247,000
Idaho, G., Cal	226	270	271	140	357	178	29	93	42	105	5,505,350
Ideal, S., L., Colo			15								15,000
Illinois, S., N. M				25		20	20				65,000
Iron Hill, S., Dak			112	44							156,250
Iron Mountain, S., Mont							50	25		30	245,000
Iron Silver, S., L., Colo	100	200	300	300	300	100					2,500.000
Ivanhoe, Colo						10					10,000
Jackson, G., S., Nev	10	15	20			5		5			55,000
Jay Gould, G., S., Mont				95	226	74	22				459,000
Jay Hawk, S., G., Mont.(*j*)									33		33,375
Jumbo, G., Colo				33							33,000
Kearsarge, C., Mich							80				80,000
Kennedy, G., Cal								360	500	480	1,072,000
Kentuck, S., G., Nev	21		3								1,350,000
Lady Franklin, N. M				100							100,000
Lake Superior, I., Mich									400		400,000
Last Chance, S., Colo									650		650,000
Leadville, S., L., Colo	20	20	40	20					12	12	316,000
Lexington, G., Colo									36		36,000
Lexington, S., Mont.(*k*)	320					64					609,000
Little Chief, S., L., Colo	40	20					20				820,000
Little Rule, S., Colo							100	120			220,000
Maid of Erin, S., L., C., Colo.(*l*)				105	409	385	454	419	140	150	2,060,847
Mammoth, Utah				20	50	130	470	320			990,000
Manhattan, S., Nev		13	25								437,500
Martin White, S., Nev			50								140,000
Maryland Coal, Md								84	84		168,000
Mary Murphy, S., Colo				70							175,000
Maxfield, S., L., Utah								36	18		117,000
May Flower Gravel, G., Cal								75	25	120	220,000
May-Mazeppa, S., L., Colo							70	110			180,000
Mercur, G., Utah										50	50,000
Metropolitan, I., Mich						350	250	350			1,637,500
Minas Prietas, S., Mex							50				50,000
Minnesota, I., Minn								840	840	495	2,745,000
Mollie Gibson, S , Colo								1000	1700	1230	3,930,000
Monitor, So. Dak						38	7		22		77,500
Mono, G., Cal			13								12,500
Montana Limited, G., S., Mont		123	617	719	413	206	178	83			2,685,287
Morning Star, S., L., Colo	25	25	125	75				50			925,000
Morning Star Drift, G., Cal								23	83	72	177.600
Moulton, S., Mont	80	150	90	60					30		440,000
Mount Diablo, S., Nev		30			40	40	20	30		30.	240,000
Mount McClellan, S., Colo								13			12,540
Mount Pleasant, Cal	15	30		45							180,000
Napa, Q., Cal						30	40	40	70	70	590,000
Navajo, S., G., Nev	50	50				40					229,950
New Guston, S., Colo					100	188	170	440	124		1,210,000
New Hoover Hill, G., N. C		37									37,200
Newton, Cal								10			10,000
North Banner, Cons., G., Cal								20			20,000
North Belle Isle, S., G., Nev					200						230,000
North Commonwealth, S., G., Nev								25			25,000
North Star, G., Cal					150	100		50	50	100	450,000
Omaha, G., Cal							13		7	43	62,900
Ontario, S., Utah	900	975	900	900	900	900	1650	900	750		13,175 000
Original, S., C., Mont	30		3	12	6	3					138,000
Oro, G., S., L., Colo							95				95,000
Oro Grande, G., Cal	175	15									188,860
Osceola, C., Mich	63			100	150	50	225	150	150	100	1,847,500
Pacific Coast Borax. B., Cal								180	180	63	422,500
Pamlico, Nev					21	12			12		189,080
Pandoro, Mont								3	3		6,000
Paradise Valley, S., Nev	50			10							160,000
Parrott, C., S., Mont				54	144	144	252	360	216	138	1,569,000
Peacock, N. M			50								50,000
Petro, S., Utah								18			17,500
Pharmacist, G., Colo									24	84	108,000

DIVIDENDS PAID BY AMERICAN MINES—*Continued.*

Company.	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	Total.
Pittsburgh, G., Nev	....	....	....	....	30	....	....	....	....	....	29,850
Pleasant Valley, C., Utah	....	....	....	....	....	....	....	....	....	20	593,056
Plumas Eureka, G., Cal	....	105	53	18	70	123	....	70	25	53	2,696,294
Plutus, S., Colo	....	....	20	....	....	....	....	....	....	....	20,000
Plymouth, Cons., G., Cal	600	575	300	375	80	....	....	....	....	....	2.280,000
Poorman, G., Colo	....	....	....	....	25	15	85	....	....	....	125,000
Poorman, S., Ida	....	....	....	....	....	....	....	....	57	....	56,935
Quicksilver, Q., Cal.(*m*)	13	....	118	129	283	193	257	118	....	....	2,475,082
Quincy, C., Mich	280	180	240	800	360	280	320	400	350	300	6,670,000
Red Cloud, S., L., Ida	....	....	....	....	....	....	20	80	70	10	180,000
Reed & National, S., G., Colo	....	....	....	....	....	....	45	....	....	....	45.000
Rescue, N. M	....	....	....	....	....	....	....	....	12	....	12,000
Retriever, So. Dak	....	....	....	....	....	....	....	13	....	....	12,500
Rialto, G., Colo	....	....	....	....	....	....	....	32	18	....	50,250
Richmond, Cons., S., L., Nev	68	68	135	68	....	....	....	34	....	14	4,386,780
Rico-Aspen, Colo	....	....	....	....	....	....	....	....	....	50	50,000
Robinson, S., Colo	....	....	10	....	....	....	....	....	....	....	585,000
Rocky Fork Coal, Mont	....	....	....	....	....	....	....	100	100	....	200,000
Rooks, G., Vt	21	30	....	....	....	....	....	....	....	....	61,000
Running Lode, Colo	....	....	....	....	....	....	5	25	6	1	27,000
Russell, G., Cal	....	....	....	30	....	....	....	....	....	....	30,000
Saint Joseph, L., Mo	40	66	184	90	....	....	....	....	....	....	1,974,000
Security. G., Colo	25	25	....	....	....	....	....	....	....	....	56,000
Sheridan S.., G., Colo	....	....	....	....	....	....	....	75	....	....	300.000
Sherwood, Z., Mo	....	....	....	3	....	....	....	....	....	....	3,000
Sierra Bella, S., N. M	30	....	....	....	....	....	....	....	....	....	30,000
Sierra Buttes, G., Cal	15	31	76	76	15	....	....	25	36	31	1,584,933
Sierra Nevada, Ida	....	....	....	....	20	20	....	....	....	....	40,000
Silent Friend, S., L., Colo	....	....	....	....	....	....	....	60	....	....	60,000
Silver Cord, S., L., G., Colo	....	....	....	....	....	45	....	....	....	....	265,000
Silver King, S., Ariz	50	200	225	175	....	....	....	....	....	....	1,950,000
Silver Mining of Lake Valley, N. M	....	....	....	....	25	25	180	80	....	....	310,000
Silverton, S., Colo	32	....	48	....	....	....	....	....	....	....	80,000
Small Hopes, S., Colo	800	888	775	600	....	25	25	....	38	25	3,225,000
Standard, G., Cal	75	....	....	20	50	....	....	10	40	19	3,711,160
Syndicate, Cal	60	12	....	....	....	....	....	....	....	....	72,000
Tamarack, C., Mich	....	....	....	....	640	440	590	800	600	690	3,670,000
Teal & Poe, S., L., N. M	....	....	....	....	....	....	....	9	....	....	9,000
Trinity River, Colo	....	....	....	....	....	....	....	....	....	28	27,500
United Verde, C., S., Ariz	60	....	....	....	....	....	30	....	30	435	562,500
Utah, Utah	....	....	....	....	....	....	....	....	15	5	20,000
Valencia, M., N. H	19	19	4	....	....	....	....	....	....	....	41,250
Victor, G., Colo	....	....	....	....	....	....	....	....	....	120	120,000
Viola Limited, S., L., Ida	....	....	38	38	94	....	....	....	....	....	337,500
Ward, Cons., S., Colo	....	....	....	....	....	20	....	....	....	....	20,000
Webb City, Z., Mo	....	....	....	....	....	4	....	....	....	....	4,400
Whale, Colo	....	....	....	....	....	....	....	5	....	....	5,000
Woodside, S., Utah	....	....	....	....	....	25	....	....	....	....	25,000
W. Y. O. D., G., Cal	....	....	....	....	....	....	....	6	36	24	48,000
Yankee Girl, S., Colo.(*n*)	....	....	300	187	....	....	125	260	....	....	1,665,000
Yosemite, S., Utah	....	....	....	....	....	....	....	....	5	....	5.000
Young America, G., Cal	....	....	165	....	10	....	....	....	....	....	175,000

(*G*) Gold; (*S*) Silver; (*L*) Lead; (*I*) Iron; (*C*) Copper; (*Q*) Quicksilver; (*B*) Borax; (*Z*) Zinc; (*M*) Mica.

(*a*) Formerly the Alaska Mining and Milling Company, reorganized in 1891 as the Alaska-Treadwell Gold-mining Company; the dividends credited for 1891 and 1892 are the payments of the latter company. The Alaska Mining and Milling Company paid $700,000 previously.

(*b*) Amador Gold-mining Company, Limited.

(*c*) Bull-Domingo Mining and Leasing Company, which acquired possession of the Bull-Domingo mine from the Phœnix Lead Company in 1890 under terms of a lease.

(*d*) Reconstructed into the Golden Leaf, Limited, of Montana.

(*e*) Cœur d'Alêne Silver-Lead Mining Company, operating the Poorman mine in the Cœur d'Alêne district, Idaho.

(*f*) Previous to the consolidation in August, 1884, the California had paid $31,320,000 in dividends and the Consolidated Virginia $42,390,000.

(*g*) Formerly the Young America South Mining Company, reorganized as the Coptis in 1891.

(*h*) Previous to consolidation, the Deadwood paid $275,000 and the Terra $75,000.

(*i*) Reconstructed as the Golden Leaf, Limited.

(*j*) Jay Hawk and Lone Pine Consolidated Mining Company, Limited.

(*k*) Société Anonyme des Mines de Lexington.

(*l*) Maid of Erin Silver Mines, Limited, formerly Henriette and Maid Consolidated Mining Company. The dividends for 1887, 1888, 1889, and 1890 were paid by the old company, and those for 1891 and 1892 by the new company.

(*m*) Including dividends paid on preferred stock and common stock.

(*n*) Yankee Girl Silver Mines, Limited, formerly Yankee Girl Mining Company. The above statement includes the payments by both the old and new companies.

(*o*) Enterprise Mining Company, of Rico, Colo.; there is also an Enterprise Mining Company in Aspen and one in Leadville.

(*p*) Poorman Mines, Limited, operating the Poorman Mine at Silver City, Idaho, which paid large dividends in 1865 and 1866.

PRICES OF COAL STOCKS AT NEW YORK DURING 1893.

Name of Company.	January.		February.		March.		April.		May.		June.	
	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.
American Coal	......	......	......	......	94.00	90.00	......	......	90.00	......	......	......
Col. & Hocking Coal	29.38	18.00	24.00	18.50	21.00	15.50	20.50	11.00	12.00	7.50	9.50	8.00
“ “ “ pref	55.00	40.00	......	......	......	......	......	......	......	......	......	......
Col. C. & I.	24.38	19.50	25.75	20.75	23.00	19.25	22 00	18.00	18.00	14.00	15.50	12.00
Col. Coal, Fuel & Iron	64.50	57.25	72.00	64.00	70.00	64.50	69.25	60.00	60.00	40.25	46.00	36.50
“ “ “ “ pref	111.50	107.00	111.00	107.50	108.00	105.00	......	......	......	......	80.00	......
Consolidation Coal	31.00	30.00	......	......	29.00	......	......	......	26.00	......	27.00	......
Del. & Hudson Canal	139.00	131.50	137.25	124.00	130.50	125.00	133.00	126.50	127.00	120 00	123.25	119.00
D., L. & W. R. R.	156.50	148.75	155.38	142.25	147.50	137.25	148.25	140.63	142.50	134.75	149.38	137.25
Hocking Valley	32.13	28.50	30.88	27.63	29.50	25.00	29.00	26.25	26.00	21.00	22.00	19.00
“ “ pref	73.75	71.00	74.00	69.00	72.00	69.00	70.00	69.50	68.50	62.00	69 00	60.00
Hunt. & Broad Top	40.38	36.00	38.75	33.50	37.88	35.50	37.00	36.00	36.50	35.00	35.50	35.00
“ “ pref	56.00	54.25	55.00	49.00	53.00	50.50	52.00	51.00	51.75	51.00	51.50	50.00
Lehigh Coal & Nav	54.13	52.75	54.38	51.00	52.00	51.00	53.50	51.50	51.75	50 50	51 50	49.75
Lehigh Valley	61.25	56.75	61.00	44.50	49.38	44.00	49.38	47.50	48.50	45.50	47.38	39.75
Mahoning Coal	......	......	......	......	100.00	......	......	......	......	......	......	......
Maryland Coal	27.75	23.75	26.50	......	26.00	22.00	29.00	26.00	......	......	......	......
Morris & Essex	155.00	151.00	154.75	153.25	163.00	150.00	152.50	148.75	149.00	145.00	148.88	142.00
New Central Coal	11.88	10.75	11.88	9.50	9.50	......	......	......	8.50	......	......	......
N. J. C. R. R.	132.75	122.88	130.00	118.00	121.00	114.25	122.00	115.00	114.75	104.50	111.00	99.88
N. Y., Susq. & West	21.38	17.25	20.38	15.75	19.13	16.13	19.13	16.00	16.50	13.75	14.50	12.00
“ “ “ pref	73.38	68.50	70.00	64.00	72.00	65.00	72.50	67.00	67.00	56.00	56.00	53.00
Norfolk & Western R. R.	9.75	9.50	9.50	8.00	8.00	7.75	8.00	......	8.00	7.00	6.25	......
“ “ pref	39.50	37.00	37.50	34.50	32.75	31.00	32.75	29.50	30.25	26.00	28.00	20.00
Pennsylvania Coal	......	......	......	......	300.00	......	......	......	290.00	......	295.00	290.00
“ R. R.	55.38	54.38	55.13	52.25	54.13	52.88	54.63	53.50	54 00	50.75	51.13	50.00
Phila. & Reading R. R.	52.72	48.75	51.50	25.00	28.00	22.38	30.00	22.88	26.13	15.63	18.63	12.88
Tennessee C. & I.	37.38	33.50	36.00	25.75	29.25	25.00	27.50	19.00	20.75	16.13	18.00	12.00
“ “ pref	101.00	97.50	103.00	100.00	......	......	88.00	84.00	76.00	75.00	75.00	70.50

Name of Company.	July.		August.		September.		October.		November.		December.	
	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.
American Coal	......	......	......	......	......	......	90.00	......	......	......	......	......
Col. & Hocking Coal	8.00	5.00	6.25	5.50	10.50	7.50	10.38	8.00	9.25	7.25	9.38	7.25
“ “ pref	......	......	......	......	20.00	......	......	......	15.00	......	......	......
Col. C. & I.	12.50	7.00	9.88	6.00	11.00	8.75	14.00	10.00	11.00	9.00	......	......
Col. Coal, Fuel & Iron	38.00	20.00	23.50	19.00	27.50	20.75	28.00	23.00	25.00	23.00	26.75	22.50
“ “ “ pref	......	......	......	......	80.00	......	70.00	......	......	......	60.00	......
Consolidated Coal	......	......	......	......	......	......	......	......	......	......	......	......
Del. & Hudson Canal	121.00	102.75	114.00	107.50	121.25	111.75	131.88	119.00	138.63	128.50	136.50	127.50
D., L. & W. R. R.	147.13	127.00	141.00	130.50	150.00	135.25	171.50	146.50	175.00	165.75	168.25	157.75
Hocking Valley	20.75	14.50	17.25	11.75	21.50	17.00	23.50	19.25	22.75	20.75	22.25	18.38
“ “ pref	......	......	59.50	55.00	......	......	60.00	......	......	......	65.00	......
Hunt. & Broad Top	35.63	29.00	33.00	32.00	36.00	33.00	36.00	34.50	35.00	34.50	35.00	32.25
“ “ pref	50.88	48.00	48.50	45.88	50.00	46.50	50.00	49.50	51.00	50.00	51.75	50.25
Lehigh Coal & Nav	50.00	46.88	47.75	46.88	51.00	47.75	52.00	48.50	52.50	50.50	53.13	50.00
Lehigh Valley	41.00	30.50	38.25	29.88	34.00	30.00	38.63	31.50	43.63	38.00	40.63	33.25
Mahoning Coal	......	......	......	......	......	......	......	......	......	......	......	......
Maryland Coal	57.50	......	55.00	......	......	......	60.00	......	62.00	......	......	......
Morris & Essex	142.50	140.00	138.50	136.50	146.00	140.00	150.00	145.25	154.50	150.00	152.25	149.00
New Central Coal	7.00	......	6.50	......	......	......	9.38	9.00	9.00	8.63	9.00	......
N. J. C. R. R.	104.38	84.00	101.00	89.50	112.13	99.88	120.75	106.00	120.50	115.00	118.00	112.00
N. Y., Susq. & West	13.50	8.00	12.50	9.00	15.00	12.25	16.88	13.00	18.50	15.75	17.75	13.88
“ “ “ pref	55.00	42.00	47.50	37.00	46.75	40.50	49.50	41.25	52.50	47.50	49.00	41.00
Norfolk & West. R. R.	5.13	......	6.25	6.00	6.00	......	......	......	......	......	......	......
“ “ pref	20.50	16.50	22.88	20.00	24.25	23.63	22.00	20.00	21.50	19.75	22.63	19.00
Pennsylvania Coal	......	......	......	......	......	......	......	......	......	......	276.00	......
“ R. R.	51.00	46.50	50.00	48.25	51.38	50.25	52.00	50.00	51.75	49.75	50.13	46.63
Phila. & Reading R. R.	15.00	12.00	18.13	12.25	21.38	14.38	23.75	15.88	23.00	19.50	21.88	17.00
Tennessee C. & I.	16.75	10.50	15.00	10.25	16.38	13.75	17.00	14.00	16.00	15.00	17.63	14.00
“ “ pref	......	......	59.00	......	61.00	......	......	......	......	......	......	......

Mining and Coal Stocks.

The stocks of the coal and coal railroad companies on Wall Street as a rule showed no special features during the year, but followed the course of the general stock market, as shown in table on opposite page. In the earlier months of the year there was, in most of them, a gradual decline, due to the general feeling of uncertainty which then prevailed, and the growing weakness of the market. In June the decline was sharply accentuated, and in July most stocks reached their lowest point. From August on there was a gradual recovery. This course of the market can be exemplified by taking Morris & Essex, which is a guaranteed stock, not liable to any change in the dividend rate, and dependent for its value on the solvency of the guarantee company, which no one has ever doubted. This stock brought its highest price, 155 in January, went down to 145 in May and 140 in July, and recovered to 152 in December.

Of the anthracite stocks, Reading naturally showed the greatest depression on account of the uncertainty attending the reorganization. Lehigh Valley declined on its separation from the Reading, probably on account of fears of the renewal of competition among the anthracite companies, which have not been justified by the event. Pennsylvania Coal Company ranged from 276 to 295; but the sales of this closely held stock are so few that they hardly fix a definite price.

The bituminous coal stocks on the New York markets are generally of a more speculative character than the anthracite securities. They followed, however, the same general course, but did not recover to the same extent. Norfolk & Western preferred, for instance, was 39½ in January, fell to 16½ in July, and only reached 22⅝ in December. Tennessee Coal & Iron, which sold for 37⅜ in January, dropped to 10½ in July, and recovered to 17⅝ in December. The bituminous coal stocks, however, are not a prominent feature on Wall Street, and in most cases—as in the first noted above—do not depend on coal for their entire value, but are affected by other traffic conditions.

FLUCTUATIONS OF MINING STOCKS AT NEW YORK DURING 1893.

No.	Name and Location of Company.	Par Value	Jan.		Feb.		March.		April.		May.		June.		July.		Aug.	
			H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.
1	Alice, Mont........	25	....	....	....	....	.50	....	....	....	....	....	....	....	.30	....	....	....
2	Alpha, Nev........	100	....	....	....	....	....	....	....	....	....	....	....	....	.20	....	....	....
3	Alta, Nev..........	100	....	.27	.25	.30	.25	....	.25	.20	....	....	....	....	.20	....	....	....
4	American Flag, Col	100	....	....	....	....	....	....	....	....	....	....	....	....	.02	....	....	....
5	Andes, Nev........	100	.45	....	.47	....	....	....	.55	....	.70	....	....	....	....	....	....	....
6	Barcelona, Nev....	25	.08	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	Belcher, Nev.......	100	1.25	....	1.25	1.00	....	....	1.45	1.20	1.35	....	....	....	....	....	....	....
8	Belle Isle, Nev.....	100	.10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	Belmont, Cal.......	1	.30	.20	.22	.20	.23	.22	.23	.20	.20	....	....	....	....	....	....	....
10	Best & Belcher, Nev	100	1.55	1.35	1.85	1.35	1.75	1.50	1.85	1.35	1.90	1.70	1.00	....	....	....	....	....
11	Bodie Cons., Cal...	100	.30	.25	....	....	.30	.20	.40	.25	.35	....	.37	.25	....	....	....	....
12	Breece, Colo.......	25	.15	....	....	....	.40	30	....	....	....	....	....	....	....	....	....	....
13	Brunswick, Cal....	5	.11	.09	.10	.07	.07	.05	.10	.07	.06	.05	.05	.04	.05	.04	.04	....
14	Bullion, Nev.......	100	1.30	1.10	.95	.70	....	....	.70	.55	....	....	....	....	....	....	....	....
15	Bulwer, Cal........	100	.20	....	....	....	.15	....	....	....	.25	....	....	....	....	....	....	....
16	Caledonia, Dak....	100	1.15	1.00	1.25	1.00	1.00	....	....	....	....	....	....	....	....	....	....	....
17	Castle Creek, Ida..	100	....	....	....	....	.03	....	....	....	....	....	....	....	....	....	....	....
18	Chollar, Nev.......	100	.80	.60	.80	.60	.70	.65	.85	.65	1.35	....	....	....	....	....	....	....
19	Chrysolite, Colo....	50	.22	.21	.23	.20	.22	.21	.23	.21	....	....	.23	....	....	....	....	....
20	Comstock Tun., Nev	100	.16	.06	.13	.09	.16	.10	.10	.09	.11	.08	.09	.06	.08	.06	.07	.06
21	Comstock B'ds. Nev	......	.15	....	.17	.14	.14	....	.15	.14	.15	.14	....	....	....	....	.06	....
22	Comstockscrip, Nev	......	....	....	.25	....	....	....	....	....	....	....	....	....	....	....	....	....
23	Con. C. & Va., Nev.	100	3.00	1.90	3.00	2.55	2.90	2.45	2.95	1.00	3.00	2.25	2.00	1.70	1.85	1.20	1.45	1.10
24	Cons. Imp., Nev...	100	....	....	....	....	....	....	.10	....	....	....	....	....	....	....	....	....
25	Crown Point, Nev.	100	.75	.70	.85	.55	....	....	1.15	.80	1.15	....	....	....	....	....	....	....
26	Deadwood Ta., Dak	25	1.75	1.60	1.70	....	....	....	....	....	....	....	1.50	....	....	....	.75	....
27	El Cristo. Rep. of C.	2	.60	.20	.55	.40	.51	.45	.48	.35	.33	.24	....	....	....	....	....	....
28	Exchequer, Nev...	100	.32	.29	.35	.20	....	....	.30	....	.20	....	....	....	....	....	....	....
29	F. de Smet, Dak...	100	.21	....	....	....	....	....	.25	.20	....	....	.15	....	....	....	....	....
30	Gould & Curry, Nev	100	1.10	.90	1.05	.85	.95	....	.90	.55	1.05	.85	....	....	....	....	....	....
31	Hale&N'cross, Nev.	100	1.40	.95	1.45	.90	1.40	.90	1.30	1.00	1.30	1.05	....	....	....	....	.65	....
32	Homestake, Dak...	100	....	....	....	....	14.75	....	14.75	13.00	....	....	....	....	....	....	....	....
33	Horn Silver, Utah.	25	3.36	3.15	....	....	3.40	3.20	....	....	3.00	2.90	....	....	2.75	2.00	....	....
34	Independence, Nev.	100	.10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
35	Iron Hill, Dak......	10	....	....	....	....	.50	....	....	....	....	....	....	....	....	....	....	....
36	Iron Silver, Colo...	20	.50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
37	Jackson, Nev......	100	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
38	Julia Cons., Nev....	100	....	....	.16	.10	....	....	....	....	....	....	....	....	....	....	....	....
39	Kentuck, Nev......	100	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
40	Kingst'n&Pike, Ont	......	....	....	....	....	....	....	....	....	....	....	.15	....	.15	....	....	....
41	Lacrosse, Colo.....	10	....	....	....	....	.05	.04	.05	.03	.05	.04	.05	.03	.05	.04	.07	.04
42	Leadville, Colo.....	10	.30	.20	.20	.18	.19	.18	.19	.17	.17	.15	.19	.15	.16	.12	.13	.10
43	Little Chief, Colo..	50	.20	....	.22	.20	.22	.20	.21	.19	.20	.16	....	....	.18	....	....	....
44	Mexican, Nev......	100	....	....	2.00	1.45	1.95	1.55	1.85	1.35	2.65	2.30	1.20	1.05	1.10	.75	....	....
45	Mono, Cal.........	100	.20	....	....	....	....	....	.30	....	.25	.20	....	....	....	....	....	....
46	Moulton, Mont.....	5	....	....	....	....	....	....	....	....	....	....	.35	.30	.35	....	....	....
47	M'te Cri'to, Rep. of C	......	....	....	3.30	2.75	3.55	3.15	3.15	3.10	3.15	3.00	....	....	....	....	....	....
48	Navajo, Nev.......	100	....	....	....	....	.20	....	.15	.10	....	....	....	....	....	....	....	....
49	N. Belle Isle, Nev..	100	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
50	Ontario, Utah......	100	15.25	14.00	16.00	15.00	15.00	....	18.00	15.50	....	....	16.00	15.50	12.50	7.00	....	....
51	Ophir, Nev.........	100	2.50	1.90	3.25	1.90	2.00	1.80	2.85	1.75	3.70	2.90	1.80	1.60	.90	....	.90	.40
52	Or'l. & Miller, Nev.	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
53	Overman, Nev.....	100	....	....	....	....	....	....	....	....	.40	.35	....	....	.30	....	....	....
54	Phœnix Lead, Colo	1	....	....	....	....	....	....	....	....	....	....	....	....	.15	....	....	....
55	Phœnix of Arizona.	100	....	....	.46	.15	.20	.15	.32	.12	.16	.02	.12	.10	....	....	....	....
56	Plymouth, Cal.....	50	.80	.60	.65	....	1.00	.75	....	....	.50	....	....	....	....	....	....	....
57	Potosi Nev........	100	....	....	1.90	1.50	....	....	....	....	2.90	2.60	....	....	....	....	.75	....
58	Quicksilver, Cal., c.	100	....	....	....	....	3.00	2.00	....	....	2.88	....	....	....	....	....	....	....
59	Quicksilver, Cal., p.	100	....	....	....	....	14.00	....	....	....	....	....	....	....	....	....	1550	....
60	Robinson, Colo.....	50	....	....	.30	....	.35	.32	.35	....	....	....	....	....	....	....	....	....
61	Santiago, Rep. of Col	......	....	....	.02	....	....	....	....	....	....	....	....	....	....	....	....	....
62	Savage, Nev.......	100	1.25	1.14	1.00	.95	1.00	.60	1.35	.46	1.40	1.25	....	....	....	....	.44	....
63	Scorpion, Nev......	100	....	....	.16	.14	....	....	....	....	....	....	....	....	....	....	....	....
64	Sierra Nevada, Nev	100	2.00	1.30	1.70	1.20	1.25	1.00	1.50	1.00	1.05	....	....	....	....	....	....	....
65	Silver Cord, Colo...	10	.30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
66	Silver Hill, Nev....	100	.15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
67	Silver King, Ariz...	100	.30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
68	Small Hopes, Colo.	20	....	....	....	....	.85	.75	.85	....	....	....	....	....	.30	....	....	....
69	Standard Con., Cal.	100	1.50	....	1.50	....	1.55	1.40	1.45	1.40	1.35	....	1.25	....	1.45	1.30	....	....
70	Sullivan Con., Dak.	3	....	....	1.00	....	....	....	....	....	....	....	....	....	....	....	....	....
71	Sutro Tunnel, Nev.	100	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
72	Syndicate, Cal.....	......	....	....	.10	....	....	....	....	....	....	....	....	....	....	....	....	....
73	Tornado, Con......	......	.07	.04	.07	.04	.06	.04	.06	.05	....	....	....	....	....	....	....	....
74	Union Cons., Nev..	100	....	....	1.15	1.00	1.00	.65	1.15	.80	1.50	....	.95	....	....	....	.80	....
75	Utah, Nev.........	100	....	....	.25	.20	....	....	.30	....	1.35	....	....	....	....	....	....	....
76	Ward Cons., Colo..	10	.10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
77	Yellow Jacket, Nev	100	.85	.55	.90	.60	.65	.55	1.35	.35	1.35	1.15	1.75	1.00	....	....	....	....
	Total shares sold..	......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

FLUCTUATIONS OF MINING STOCKS AT NEW YORK DURING 1893—*Continued.*

Sept.		Oct.		Nov.		Dec.		Sales.	No.
H.	L.	H.	L.	H.	L.	H.	L.		
....	....	....	....	.35	.30	....	....	2,000	1
....	....	....	....	....	....	....	....	100	2
....	....	....	....	.80	.45	....	....	1,800	3
....	....	.05	....	.06	....	....	....	1,100	4
....	....	....	....	....	....	....	....	600	5
....	....	....	....	....	....	....	....	100	6
....	....	....	....	1.70	.50	....	....	2,195	7
....	....	....	....	....	....	....	....	600	8
....	....	....	....	....	....	....	....	13,720	9
.60	.50	1.55	.55	3.50	2.00	2.25	....	7,555	10
....	....	.25	.20	....	....	.30	.25	2,350	11
....	....	....	....	....	....	....	....	310	12
.04	.02	.06	.04	.07	.04	.07	.06	57,300	13
....	....	....	....	.80	.75	....	....	2,100	14
....	....	....	....	....	....	....	....	700	15
....	....	....	....	....	....	....	....	4,110	16
....	....	....	....	....	....	....	....	1,000	17
....	....	.35	....	....	....	....	....	2,750	18
....	....	....	....	....	....	....	....	13,100	19
.05	....	.08	.06	.10	.08	.09	.07	102,380	20
....	....	....	....	.10	....	....	....	20,000	21
....	....	....	....	....	....	....	....	300	22
1.10	....	3.00	1.65	5.00	3.00	4.15	2.75	12,060	23
....	....	....	....	....	....	.12	.10	3,100	24
....	....	....	....	....	....	....	....	2,150	25
....	....	....	....	....	....	....	....	505	26
.15	....	....	....	....	....	....	....	63,100	27
....	....	....	....	....	....	....	....	3,200	28
....	....	....	....	....	....	....	....	900	29
....	....	1.30	....	1.80	1.25	1.15	.75	3,580	30
.45	....	.55	.45	1.20	1.00	.95	.78	3,675	31
....	....	....	....	....	....	....	....	475	32
2.60	2.10	3.00	2.75	2.70	....	2.75	....	5,837	33
....	....	....	....	....	....	....	....	200	34
....	....	....	....	....	....	....	....	100	35
....	....	....	....	....	....	....	....	100	36
....	....	....	....	.45	....	....	....	200	37
....	....	....	....	....	....	....	....	4,200	38
....	....	....	....	.30	...	....	....	200	39
....	....	....	....	....	....	....	....	400	40
.04	....	.12	.03	.06	.05	.04	....	23,700	41
.12	.11	.13	.10	.14	.12	.14	....	46,887	42
....	....	....	....	....	....	....	....	6,300	43
.60	....	1.05	.60	1.85	1.15	1.25	.85	8,135	44
....	....	....	....	.35	....	....	....	1,100	45
....	....	....	....	....	....	....	....	1,300	46
....	....	....	....	....	....	....	....	62,950	47
....	....	....	....	....	....	....	....	600	48
....	....	....	....	1.05	....	....	....	1,100	49
8.00	7.00	6.50	....	7.13	....	....	....	3,618	50
.95	.85	1.75	.85	2.75	1.15	1.90	1.40	8,290	51
....	....	....	....	.04	.02	....	....	700	52
....	....	....	...	.70	....	....	....	600	53
....	....	....	....	....	....	....	....	300	54
.60	.45	.50	.40	.59	.47	.60	.50	69,250	55
....	....	....	....	.65	.60	....	....	2.000	56
....	....	.60	.45	1.25	1.20	.75	....	2,425	57
....	....	1.50	....	1.50	....	1.63	....	2,100	58
....	....	....	....	....	....	1200	....	300	59
....	....	....	....	....	....	....	....	400	60
....	....	....	....	....	....	....	....	100	61
....	....	....	....	1.20	1.15	....	....	3,150	62
....	....	....	....	....	....	....	....	800	63
.50	....	.95	.50	2.70	1.15	1.60	1.00	5,140	64
....	....	....	....	....	....	....	....	300	65
....	....	....	....	....	....	....	....	200	66
....	....	....	....	....	....	....	....	300	67
....	....	....	....	....	....	....	....	3,900	68
....	....	....	....	....	....	....	....	2,760	69
....	....	....	....	....	....	....	....	600	70
....	....	....	....	.02	.01	....	....	200	71
....	....	....	....	....	....	....	....	300	72
....	....	....	....	....	....	....	....	11,500	73
....	....	.40	.30	1.80	1.05	1.25	.80	4,370	74
....	....	.15	....	.40	....	.25	....	1,025	75
....	....	....	....	....	....	....	....	1,100	76
....	....	.55	....	1.35	1.05	1.30	1.05	5,650	77
....	....	....	....	....	....	....	....	624,617	

Once, trading in mining shares was a pursuit and vocation with many people; to-day, it is merely an incident—and, we may add, an incident of small importance to anybody. The investing public exhibits no interest in such securities, in so far as concerns the buying or selling of them in the stock exchanges, and to the true speculator they offer little for his peculiar talents. Thus, even as a form of gambling the buying of mining stocks has become unpopular. And all this has been brought about by the growing knowledge of the public generally as to what constitutes legitimate mining operations.

It is almost making use of a euphemistic expression to speak of the "New York Mining Stock Market." Such a phrase conveys an impression of importance which the mining stock market of this city does not possess. Transactions during the past six years have been growing smaller and the course of the market has been a steady decline. The total sales in 1893 were 624,617 shares. For the preceding five years the total yearly sales were as follows: 1,527,371 shares in 1892; 2,522,660 shares in 1891; 3,925,926 shares in 1890; 4,114,480 shares in 1889, and 11,689,388 shares in 1888.

During the past year the trading was very uninteresting. Not only were transactions small in volume but prices were low. There were no violent fluctuations and the only attempt at a "boom" was late in the year, when the usual manipulation of the Comstocks took place, based on the possible results of the "Rule" explorations in the Consolidated California and Virginia. The prices of the silver stocks, with the exception of Horn Silver, naturally show a considerable decline, and gold stocks did not inspire confidence.

FLUCTUATIONS OF PRICES OF MINING STOCKS AT BOSTON DURING 1893.

Name and Location of Company.	Par Value.	Jan.		Feb.		March.		April.		May.		June.	
		H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.
Allouez, Mich	25	.90	.70	.75	......	.75	......	.60	......	.60	.40	.45	.35
Arnold, Mich	25	1.00	......	.50	......	.50	......	.50	......	.40	.35	.20	......
Atlantic, Mich	25	10.25	9.00	10.25	9.00	9.75	9.25	9.50	8.75	8.00	7.00	7.50	7.00
Bonanza, C. & M	10	.30	.27½	......	......	......	......	......	......	.29	......	......	......
Bost. & Mont.. Mont	25	34.50	32.25	34.50	31.50	32.00	30.63	31.25	23.25	24.00	19.50	22.50	17.38
Butte & Boston, Mont	25	12.00	10.50	11.75	10.25	11.00	10.00	10.25	8.75	8.50	6.25	7.50	6.00
Cal. & Hecla, Mich	25	320.00	295.00	310.00	300.00	318.00	305.00	315.00	294.00	300.00	285.00	290.00	280.00
Catalpa, Colo	10	.15	......	......	......	......	......	......	......	......	......	......	......
Centennial, Mich	25	8.25	7.25	9.00	7.50	9.25	7.88	9.75	8.00	9.00	6.00	6.50	2.50
Central, Mich	25	......	......	......	......	......	......	......	......	......	......	......	......
Copper Falls, Mich	25	7.50	......	......	......	......	......	7.38	7.00	......	......	......	......
Dunkin, Colo	25	......	......	......	......	......	......	.14	......	.14	......	......	......
Franklin, Mich	25	13.50	12.50	13.50	12.00	13.25	12.25	13.00	12.00	12.00	11.00	12.50	9.50
Humboldt, Mich	25	.26	......	......	......	......	......	......	......	......	......	......	......
Hungarian, Mich	25	......	......	......	......	.15	......	......	......	......	......	......	......
Kearsarge, Mich	25	12.75	11.38	12.50	10.50	11.00	9.00	9.50	6.50	7.50	6.50	7.00	6.00
Lake Superior Iron	....	25.00	......	......	......	25.50	......	30.00	......	26.50	25.00	......	......
Mesnard, Mich	25	......	......	......	......	.50	......	.50	......	.50	......	......	......
Napa, Cal	2	6.00	5.50	......	......	......	......	......	......	......	......	......	......
National, Mich	25	1.00	......	1.25	......	1.13	......	1.00	......	1.00	.75	......	......
Ontario, Utah	100	......	......	......	......	......	......	......	......	......	......	......	......
Osceola, Mich	25	37.50	35.00	37.63	35.00	36.75	34.88	35.00	31.00	30.00	26.00	27.50	24.25
Pontiac, Mich	25	.30	......	......	......	.25	.15	......	......	......	......	......	......
Quincy, Mich	25	144.00	135.00	138.00	132.00	135.00	128.00	130.00	120.00	118.00	110.00	112.25	105.00
Ridge, Mich	25	......	......	......	......	......	......	......	......	......	......	......	......
Santa Fé, N. M	10	.06	.02	......	......	.05	......	.05	......	.05	......	.02	......
Tamarack, Mich	25	162.00	152.00	164.00	158.00	165.00	160.00	163.00	155.00	155.00	137.00	143.00	137.00
Tamarack, Jr., Mich	25	20.00	......	20.00	18.00	24.00	18.00	23.00	19.05	17.00	16.00	15.50	14.00
Wolverine, Mich	25	1.75	1.38	2.75	1.50	2.75	2.50	2.75	2.50	2.75	2.00	2.13	2.00

	July.		August.		September.		October.		November.		December.		Sales.
	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	
Allouez, Mich	.40	......	......	......	.40	.35	.35	......	.35	.25	.50	.45	9,981
Arnold, Mich	......	......	......	......	......	......	......	......	.60	......	......	......	1,400
Atlantic, Mich	8.00	6.00	......	......	10.00	8.00	10.25	8.50	12.00	9.00	12.75	11.00	8,209
Bonanza, C. & M	......	......	......	......	......	......	......	......	.20	......	.20	......	800
Bost. & Mont., Mont	19.50	10.00	20.25	17.00	22.75	22.00	26.50	20.75	27.00	24.00	30.25	26.25	138,137
Butte & Boston, Mont	6.50	5.00	6.50	5.00	8.75	6.50	8.88	7.00	10.00	7.63	11.00	8.75	69,959
Cal. & Hecla, Mich	280.00	247.00	270.00	249.00	280.50	256.00	281.00	272.50	296.00	280.00	305.00	297.00	6,005
Catalpa, Colo	......	......	.10	.09	.07	.06	......	......	......	......	......	......	4,600
Centennial, Mich	4.25	1.50	2.50	2.00	3.75	2.00	3.50	2.25	3.50	2.50	4.50	3.00	53,500
Central, Mich	......	......	......	......	......	......	......	......	15.00	12.50	......	......	350
Copper Falls, Mich	......	......	......	......	......	......	......	......	......	......	......	......	350
Dunkin, Colo	......	......	......	......	......	......	......	......	......	......	......	......	400
Franklin, Mich	10.50	9.13	9.50	8.50	12.00	10.00	11.50	9.00	12.00	9.75	12.63	10.00	13,101
Humboldt, Mich	......	......	......	......	......	......	......	......	......	......	......	......	100
Hungarian, Mich	6.25	5.13	5.50	5.00	8.00	6.00	7.88	6.00	8.75	6.50	10.00	7.75	14,848
Kearsarge, Mich	......	......	......	......	......	......	......	......	......	......	......	......	200
Lake Superior Iron	......	......	......	......	......	......	......	......	20.00	......	......	......	555
Mesnard, Mich	......	......	......	......	......	......	......	......	......	......	......	......	1,200
Napa, Cal	4.00	......	4.00	......	4.00	......	......	......	4.63	......	......	......	1,395
National, Mich	......	......	......	......	......	......	......	......	......	......	1.00	.75	1,038
Ontario, Utah	9.75	......	......	......	......	......	......	......	......	......	......	......	10
Osceola, Mich	25.25	20.00	23.00	22.00	27.00	24.00	29.00	25.00	30.50	27.75	32.00	28.50	30,179
Pontiac, Mich	......	......	......	......	......	......	......	......	......	......	......	......	567
Quincy, Mich	107.50	80.00	100.00	92.00	110.00	100.00	108.00	100.00	115.00	105.00	126.00	116.00	2,894
Ridge, Mich	......	......	......	......	......	......	......	......	.25	......	......	......	200
Santa Fé, N. M	......	......	......	......	......	......	......	......	......	......	......	......	3,900
Tamarack, Mich	140.00	119.00	130.00	120.00	148.00	130.50	137.00	125.00	146.00	131.00	166.00	147.00	7,560
Tamarack, Jr., Mich	......	......	11.00	......	18.00	13.00	19.00	15.00	20.00	16.75	21.00	18.00	7,382
Wolverine, Mich	1.50	.75	1.25	1.00	2.00	1.00	1.50	......	3.00	1.25	3.13	2.00	23,940
Total	......	......	......	......	......	......	......	......	......	......	......	......	403,760

The market for copper stocks in Boston during the year 1893 did not prove as satisfactory as was generally expected. The low price of ingot copper in the early months, together with the limited demand both at home and abroad, had a tendency to reduce values, and the lowest prices for the year were recorded during the months of July and August. In the latter part of the year there was a marked improvement in this respect, although as a rule prices did not reach the limit of 1892. The old investment companies have been enabled to pay their usual dividends as a general thing. There were several attempts made to get up a boom in the speculative stocks listed on the market, but they proved short lived, were not remunerative to the projectors, and were soon abandoned. The year closed with nothing especially favorable in the outlooks. It is a general opinion that the production of copper will be fully up to the demand and that no material advance can be made over present rates. If, however, the present price of ingot can be maintained the large producing mines will earn sufficient to keep up the present rates of dividends, and some which have not heretofore been in condition to make returns to the stockholders may be enabled to do so.

The London Mining Stock Market in 1893.

The year 1893 has been an extremely bad one for stockholders and company promoters—perhaps the worst on record. A combination of causes is to be found for this depression, the chief one being the general distrust of public companies on the part of investors. Confidence has been entirely shaken by the Baring failure, the Liberator frauds, and the exposures of the trust companies. We have always had our mining swindles, but experience of losses in that quarter was never sufficient to open the investors' eyes to the illusory promises of promoters; it required an exposure of the methods of a higher and more trusted class of financiers to arouse suspicion and to awaken the public to the fact that mining investments are perhaps the most uncertain of all. At the present time it is almost impossible to get any one to look at a mining proposition, and the few new companies that have been floated publicly during the year have been launched only with the greatest difficulty with the aid of underwriters. In many cases promoters have preferred to raise money privately rather than try to interest the public. Speculation is dead, and people put their money into gilt-edged, readily marketable securities.

There was a period of great stringency in the money market during the summer months, and many stockholders had difficulties in meeting their obligations. This was brought about largely by the Australian crisis, and in a smaller degree by the American monetary reaction. The settlements in June and July were times of the most acute anxiety, and many good houses went under. For several months afterward speculation was at a very low ebb, and the volume of transactions was phenomenally small. There were no buyers and sellers, and the appearance on the market of a small quantity of shares caused quite unexpected and unauthorized movements in values. During December a return toward healthier things took place, and many shares returned to their real values, but the volume of business continued very small.

The general tendency in the London mining stock market has been the continued advance in the importance of South African investments, with a decline in American and Australian stocks. Indian gold mining has come to the front, and during the year has claimed attention in city circles. Of the new companies floated during the year the most important are those connected with Mashonaland, Matabeleland, and South and East Africa. Most of these are exploration companies, and nothing has been done as yet to develop and open up the country. The war against the natives carried on by the British South Africa Company occupied attention during the latter half of the year, and the English pioneers are by no means out of the wood yet. The future is full of promise, and a few years will see the south and east of Africa developed into another Transvaal. In the mean time the Witwatersrand output of gold has gone on steadily increasing, and, as detailed elsewhere, rather by the application of improved machinery and the McArthur-Forrest recovery process than by the opening up of new mines.

A very serious blow was given to the mining market toward the end of June by the closing of the Indian mints to the free coinage of silver. The action of the Indian Government was quite unexpected, and consequently caused a severe panic not only in silver mining stocks, but in a smaller degree throughout the whole of the mining stock market. Of American dividend payers Elkhorn suffered the most, dropping from £1 2s. 6d to 9s. in a few weeks. At the present time this stock shows some signs of recovery, for after staying at 9s. for five months, it is creeping up again slowly, and now stands at 11s. De Lamars fell from £1 3s. to 16s. and stayed there for several months, after which a turn for the better came until now they have advanced past par again. Jay Hawks and Poormans suffered, but not so much. The "Gresham House" group were given a great shock by the fall in silver. None of them was in a healthy state before, and now their future is very gloomy and uncertain. New Montana is struggling against lawsuit costs as well as overcapitalization and the fall in the price of silver; Yankee Girl is on the point of vanishing altogether; American Belle is in a state of suspense; and New Guston and Maid of Erin are far from prosperous. The Yankee Girl property is being sold by the debenture holders, as the shareholders will not subscribe for a reconstruction. It is true that the New Montana stock has had a boom during November and December, and the price went up from 1s. to 9s. on receipt of news of a discovery of a new vein, but in well-posted circles this action is attributed to a rig on the part of the inside holders who desire to sell out at a profit, and there is not much real hope for any increased dividends or a return of prosperity to the company. The one of this group with most promise is New Guston, for with decreased expenses and the application of improved machinery, a dividend should be paid even with the present low price of silver.

A *résumé* of the principal operations and alterations in American mining stocks managed in London is given in the following paragraphs:

In September the English company the Poorman Mines, Limited, was consolidated with the American companies the South Poorman Company and the Idaho Milling Company. Before the consolidation the product of the Poorman mines was treated by the Idaho Milling Company, while the output of the South Poorman mines was shipped elsewhere. Additional milling capacity is being provided by the Poorman Consolidated, so as to treat the product of both sets of mines. There appears to be a good deal of delay in providing the new machinery, and some uncertainty exists as to the time when operations will continue on the proper scale. In the mean time the shares of the consolidated company are very little dealt in here.

The La Plata Company has ceased operations at its mine in Colorado, and has since constituted itself as an exploration company. Mr. Niness has been dispatched to the Mozambique territory in East Africa to prospect for gold reefs, and has already become one of the pioneers in that country. The company has exceedingly good prospects before it.

Golden Feather Channel and Golden Gate of California have made pretty much the same record this year as in previous years. The whole season was occupied by Colonel MacLaughlin in clearing away the débris of the winter and the surface soil, and then closing down for the winter with excellent reports for the next season. Golden Gate has been reconstructed with a view of obtaining additional capital, in order to purchase additional claims through which the continuation of the ledge runs. There is a good deal of sham speculation in the shares of these companies on the Stock Exchange, but there are no signs of dividends and no people to deceive by the so-called operations.

The Richmond Consolidated Mining Company has continued during the year to pay small dividends derived from the income from tributers, but practically the career of this celebrated mine is at an end. During the greater part of the year there has been very little buying of the shares, as it was generally supposed that the company would be wound up soon. In October, however, the directors announced that they intended to buy a new property with their remaining funds. Buyers of the stock thereupon came forward freely and the price of the shares is now 11s. No information has yet been published as to the nature of the new property.

The Valley Gold Mining Company, formed two years ago to work gold gravels in Holcomb Valley, San Bernardino County, California, failed in obtaining results, owing to a deficient and variable water supply. Additional money was raised during the summer to purchase a Bucyrus shovel and amalgamator and to improve the water supply. This plant is now working and obtains 55c. per cubic yard.

The Palmarejo Mining Company has been in monetary difficulties during the year. In the spring the directors forced on the shareholders the raising of £50,000 more capital to pay off debenture interest, and offered as an alternative the confiscation of the property by the debenture holders. At the same time the shareholders determined to appoint a committee of inspection with the intention of investigating the methods and transactions of the directors. This, however, ended in nothing but the engagement of a mining expert to report on the present value of the property in the interest of the shareholders. So far nothing more has been heard of, and no report has been made public.

The Golden Leaf Company, working mines in Montana and New Mexico, has practically ceased work. In the spring the directors announced that though their mines had been operated at a profit during 1892, they considered it unadvisable to continue, owing to the pockety nature of the mines and the present price of silver. They recommended that the £12,000 remaining should be devoted to the purchase of new mines. These propositions were not received favorably by the shareholders, and the disagreement was so great that practically nothing has been done since. At the time of writing the company is negotiating for the acquisition of new mines, but no decision has been arrived at.

The New Eberhardt Company closed its Eberhardt mine, in Nevada, in June, but continues work on the Monitor. The directors state that they are negotiating for a mine in South Africa, but matters are practically at a standstill.

The Silver Mines of La Luz, Mexico, have been reconstructed, after severe internal dissensions among the directors and leading shareholders, under the title of La Yesca Gold and Silver Mines. The new owners have not yet done anything at the mines.

The Big Creek Mining Company decided on June last to suspend operations at its antimony mines near Austin, Nev., owing to the continued fall in the price of the metal. It is now taking out only enough ore to pay the expenses of the caretakers.

The shares of the Alaska-Treadwell Mining Company have been steadily advancing during the year from £1 17s. 6d. in January to £2 15s. in December, owing to the decreased expenses and increased output. The market for the shares is naturally a restricted one.

The New Viola Company was reconstructed in July under the name of the Pearl Mining Company. The company was formed three years ago to work silver-lead mines near Camas, Idaho, but it was soon found that the mines were absolutely worthless. The company therefore ceased work, and has now bought the Pearl silver-lead mine near Silverton, Colo.

Toward the close of the year the stock of the Rajah Gold Mining Company, Lake of the Woods, fell to almost a nominal value on the publication of the report of a mining expert who examined the property in the autumn on behalf of the English shareholders. It is now generally considered that it is idle to continue working the property, owing to its extreme poverty and patchiness.

The Flagstaff Mining Company, Utah, whose shares have been practically valueless for some time, has been reconstructed. The English directors and chief shareholders determined to get rid of the managing director at the mine, Professor Vincent, as they consider that he carried on operations solely for his own benefit, and not for the benefit of the shareholders. The directors of the new company have perfect faith in the mine if worked properly.

The Ruby Mining Company, working silver mines in Nevada, has been wound up voluntarily. The reason was a want of necessary capital for development, together with the continued fall in the price of silver.

The Idaho Mining Company has ceased operations at its mine, and has been reconstructed into an exploring company. It is said that a new property has already been found.

The following companies have been reconstructed in addition to those before mentioned : New Calaveras Mining Company and the Amador Mining Company into Jackson Goldfields, Limited.

Of new companies formed during the year to work American properties the Harquahala was the most important, and it was the only new one which has obtained a quotation on the Stock Exchange. It was floated in July by the Mining and Financial Trust of London, which was responsible also for the Elkhorn and De Lamar companies. The property is in Arizona, and the nature of the mine is fairly lean quartz reefs. The new company managed things so well that a dividend was paid in November, but its property has experienced a set-back by the fact that a new shaft is being sunk on account of the old one having proved unsafe. It is expected that operations will be resumed in February. Two other properties offered for public subscription were the Fisk Gold Mining Company, to take over the Fisk Mining and Milling Company of Colorado ; and the Hall mines, to work the group of mines in Kootenai, British Columbia. A large block of shares of the new Denver company, the Springdale Gold Mining and Milling Company, has been placed on the market here during the year. Prominent among companies privately subscribed for is the Bonanza Gold Mining Company to work the Nelson mines, California, promoted by the Poorman circle. The McArthur-Forrest syndicate has publicly floated the Mexican Gold Recovery Company to work its process in Mexico.

The following is a list of all the new companies registered during the year 1893. It should be stated that many are reconstructions of old companies, and many are companies formed privately to carry on old mines without asking the public to subscribe, while many may never get beyond the stage of registration.

Aztec gold mines, £100,000 in £1 shares, to work Aztec gold mines in Colorado; Bonanza gold mines, £130,000 in 5s. shares, to work the Nelson gold mines, Sierra County, California; California Milling and Mining Company, £75,000 in 10s. shares, reconstruction of New California; Catalina gold mines, £25,000 in 2s. and 6d. shares, to work mines in Pinol County, Arizona; Chemical and Electrolytic Syndicate, £39,000 in £5 shares, to work Lyte and Lunges patents; Churnababi Mining and Milling Company, £48 in £1 shares, to work a mine in Mexico; Consolidated Nitrate Company, £160,000 in £1 shares, to work nitrate beds in South America; Fisk gold mine, £200,000 in £1 shares, to work Fisk mine, Gilpin County, Colorado; Flagstaff Company, £240,000 in £1 shares, a reconstruction, Utah; Gas Desulphurization Company, £15,100 in £10 shares, to work the Hood-Solomon process; General Electrolytic Company, £24,000 in £1 shares, to acquire any patent rights of any electrolytic process; General Metallurgical Company, £5000 in £1 shares, to work J. M. Stuart's process of gold extraction; Golden Eagle Syndicate, £20,000 in £10 shares, to work the Golden Eagle claim, Vancouver Island; Harquahala Gold Mining Company, £300,000 in £1 shares, to work a gold mine in Arizona; Harvey Steel Company of Great Britain, £180,000 in £10 shares, to work the Harvey process in Great Britain; Lake View Mining Syndicate, £12,000 in £10 shares, to work mines, etc., in Canada; Malacato Syndicate, £12,000 in £500 shares, to work mines in Mexico; Mexican Asphalt, Pitch, and Oil Wells, £75,000 in £1 shares, to acquire properties in Mexico; Mexican Gold and Silver Recovery Company, £200,000 in £1 shares, to work the McArthur-Forrest process in Mexico; Mexican Lands Company, £10,000 in £1 shares, to develop lands and mines in Mexico; Missouri Mining and Land Syndicate, £6000 in £1 shares, to acquire and work lands and mines in Missouri; Natashquen, £3000 in £1 shares, to work magnetic sands in Canada; New Calaveras Gold Mining Company, £25,000 in 5s. shares, to work Calaveras mines in Angel's Camp, California; New Cyanide Gold Recovery Company, £5000 in £1 shares, to work C. M. Pielsticker's patent; New Jersey Metal Refining Works, £50,000 in £10 shares, to take over the New Jersey Extraction Works; New London Estates Company, £75,000 in 2s. 6d. shares, to take over the Parker gold mines in North Carolina; Newfoundland Mineral Syndicate, £5000 in £1 shares, to prospect for asbestos, etc., in Newfoundland; Phi Kappa Mining Company, £6000 in £1 shares, to acquire the Phi Kappa mines, Custer County, Idaho; Picacho gold (gravel) mines, £200,000 in £1 shares, to work properties in Mexico; Santo Nino Mining Company, £25,000 in £50 shares, to work mines in Mexico; Slate Creek Gravel Gold Company, £100,000 in £1 shares, to work mines in Sierra County, California; Sonora Smelting Company, £48 in £1 shares, to carry on smelting at Sonora, Mexico; Storm Cloud Syndicate, £100 in £1 shares, to acquire gold mines at Prescott, Ariz.

THE MINING SCHOOLS OF THE UNITED STATES.

The age of ignorant empiricism and of charlatanry has passed away, and exact knowledge is now directing the operations of industries upon which the greatness of nations and the prosperity and happiness of their people depend. In the old days brute strength and skill in the use of the sword gave nations desolating victory. To-day pre-eminence in the knowledge and skill necessary to make well and cheaply the material from which swords are fashioned makes nations prosperous and irresistible, and renders the sword useless. Exceptional elasticity and strength in a blade was then the mysterious result of an accidental combination of materials, and its value would purchase to-day many tons of a better steel, for we now know what imparts elasticity and strength, and science has taught us how to reproduce in any quantity a material possessing any desired properties.

The possession of that knowledge which is the accumulated experience of preceding workers enables the captains of industry to-day to accomplish, in everyday routine, the miracles of the past, and there can be no surer foundation for the industrial prosperity of a nation richly endowed by nature than to equip an army of workers with this knowledge which has built up the industry of its rivals.

The mining schools of the United States are equipping this army to achieve the marvels which are the admiration and wonder of the world. It is fitting, therefore, that they should find place in a work which aims to record the achievements of the industry and to elucidate the conditions which promote its prosperity. Foremost among these mining schools must be mentioned the technical press. The one course of lectures which every mining student and every one engaged in the active work of the industry must follow is the current record of the efforts and achievements in the industry.

The technical paper is the indispensable supplement as well as the inspiration and helpful ally of the mining school; the necessary beacon light to guide the men who make the industry. It is the menstruum in which the experience of a profession is crystallized into an art. Without it no man can keep pace with the progress in the arts it represents, and its records are necessary to enable the most gifted and experienced to compete successfully with their rivals. With increasing intelligence and knowledge it becomes constantly more valuable and indispensable to the worker, and its lectures are followed by a steadily increasing number of students. The weekly records of the whole mineral industry given in the *Engineering and Mining Journal* are studied by a vastly greater number than follow the lectures of all the mining schools in the world. This voice is heard to the utmost ends of the earth, and it places within the reach of every one in the industry the experience of all. It is the greatest of the mining schools.

Mining Schools in the United States and Canada.

1. Arizona School of Mines.
2. Agricultural and Mechanical College of Texas.
3. Armour Institute.
4. School of Mines, Columbia College.
5. Case School of Applied Science.
6. University of California.
7. Colorado State School of Mines.
8. State School of Mines, Dakota.
9. University of Idaho.
10. University of Illinois.
11. Kingston School of Mining and Agriculture, Ontario.
12. Lafayette College.
13. Lehigh University.
14. Massachusetts Institute of Technology.
15. Michigan Mining School.
16. University of Minnesota.
17. Missouri School of Mines.
18. Montana School of Mines.
19. McGill University, Canada.
20. New Mexico School of Mines.
21. Ohio State University.
22. Pennsylvania State College.
23. University of Pennsylvania.
24. Vanderbilt University.
25. Washington University of St Louis, Mo.
26. University of Wyoming.

ARIZONA SCHOOL OF MINES.

The Arizona School of Mines, at Tucson, Ariz., was founded in June, 1891, and Dr. Theo. B. Comstock selected as its director. For two years the school was conducted as a branch of the Agricultural School in what was known as the University of Arizona. Since May, 1893, when Dr. Comstock was made president of the University, the School of Mines has been continued under his direction as a department of the University.

Mining and metallurgy constitute the leading features, but departments of civil, mechanical, and electrical engineering have also been established. The course in mining and metallurgy embraces mine surveying and exploration, mathematics, assaying, physics, mining administration, ore dressing, and other essential studies. Much time is spent in practical work in these branches. The school has ample facilities for illustrating the various processes employed in mining work, the principal methods of ore concentration, and metallurgical treatment by the various modern processes, including electrolytic processes. The assay laboratory is fully equipped for crucible work, scorifying and cupelling, and for retorting mercury from amalgam.

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS.

The Agricultural and Mechanical College of Texas, at College Station, has no separate department of mining, but metallurgy is taught in connection with the chair of chemistry and mineralogy, the course requiring thirty-six weeks, including seventy-two recitations and practical work in assaying.

ARMOUR INSTITUTE.

The Armour Institute in Chicago has a department of mining and metallurgy, under the charge of Prof. Herman Haupt, Jr. The course of study includes advanced chemistry, metallurgy, geology, the study of ores and ore deposits, assaying and blow-pipe analysis, drawing, and a study of the most approved metallurgical methods of extracting metals. The theoretical training is supplemented by field work in mine surveying, topography, prospecting, practical geology, and instruction in mining law. The course also includes instruction in mechanical engineering. Applications of electricity to mining and metallurgy are studied in the department of electrical engineering.

SCHOOL OF MINES, COLUMBIA COLLEGE.

This school, situated in New York City, is the oldest and most important of the mining schools in this country. In 1864 it was established, largely through the efforts of Prof. Thomas Egleston, and organized as a private undertaking, Columbia College lending the support of its name and faculty but assuming no pecuniary responsibility. From this small beginning it has grown rapidly and secured large appropriations for its support. To-day the real estate, building, and equipment for its sole use are estimated as worth over $1,000,000. Including the money spent on its maintenance the school enjoys the use of an endowment of about $3,500,000, and fully $1,000,000 more will be required before contemplated additions can be carried into effect.

It is estimated that the average cost of the instruction of each student in the School of Mines, including interest at 5% on the value of the plant, is about $840 per year. The tuition fee charged is $200 per annum, and this is sometimes remitted in the case of deserving applicants. Formerly free tuition was granted to all deserving applicants, amounting on an average to 20% of the total number enrolled, but of late it has been found necessary to limit this to the students of the three higher classes, and to a number not to exceed 10% of the total students in the school. A large proportion of those applying for admission are rejected, and of those entering less than 40% succeed in graduating. In spite of this the present accommodations have been outgrown and it is proposed to erect new buildings in July, 1894, and have them ready for occupancy by October, 1895.

The School of Mines gives instruction also in engineering, in chemistry, in architecture, etc.; but as it was organized as a school of mines, these additions to the original curriculum are not allowed to interfere with the thoroughness of the instruction given to the students of mining.

The faculty of the School of Mines, arranged by departments, omitting those which give little or no instruction in mining, metallurgy or geology, is as follows:

Department of Mining: Henry S. Munroe, professor; Robert Peele, Jr., adjunct professor; Edward B. Durham, assistant.

Department of Geology: James Furman Kemp, professor; Charles A. Hollick, tutor; Gilvert Van Ingen, assistant.

Department of Mineralogy and Metallurgy: Thomas Egleston, professor; Alfred J. Moses, adjunct professor mineralogy; Joseph Struthers, tutor in metallurgy; Lea McI. Luquer, tutor in mineralogy; Gustav J. Volckening, assistant in metallurgy; Herbert P. Whitlock, assistant in mineralogy.

Department of Chemistry: Charles F. Chandler, professor; Pierre de P. Ricketts, professor analytical chemistry; Charles E. Colby, adjunct professor organic chemistry; James S. C. Wells, instructor qualitative analysis; Ferdinand G. Wiechmann, instructor chemical philosophy; Louis H. Landy, tutor general chemistry; Henry C. Bowen, tutor quantitative analysis; Hermann T. Vulti, tutor quantitative analysis; Alexander R. Cushman, assistant qualitative analysis; Delancey W. Ward, assistant organic chemistry; Edmund H. Miller, assistant assaying.

Department of Physics: Ogden N. Rood, professor; William Hallock, adjunct professor; Holbrook Cushman, instructor; Reginald Gordon, Henchel C. Parker, tutors; C. C. Trowbridge, Asa S. Inglehart, Herbert T. Wadi, assistants.

Department of Mathematics: J. Howard Van Amringi, professor; Jasper T. Goodwin, adjunct professor; Thomas S. Fiske, instructor; James Maclay, tutor; Henry S. Curtis, Edwin M. Blake, Arnon L. Squires, assistants.

Department of Mechanics: R. S. Woodwan, professor; Michael I. Pupin, adjunct professor; Joseph C. Pfister, tutor.

Department of Mechanical Engineering and Drawing: Frederick R. Hutton, professor; Ralph E. Mayer, Ira H. Woolson, instructors; Elisha D. Hurlbut, Jr., Luther E. Gregory, Francis A. Provst, assistants.

Department of Electrical Engineering: Francis B. Crocker, professor; George Francis Sever, instructor; William H. Frerdman, tutor.

Department of Civil Engineering: William H. Burr, professor; James L. Greenleaf, adjunct professor; Andrew E. Foye, tutor; G. R. Tuska, assistant.

Department of Botany: Nathaniel L. Britton, professor; Carlton G. Curtis, assistant.

Department of Biology: Henry F. Osborn, professor; E. B. Wilson, adjunct professor; Bashford Dean, instructor; Arthur Willey, tutor; H. E. Crampton, assistant; Alexis A. Julien, instructor in microbiology; John S. Billings, lecturer in hygiene.

In both the mining and metallurgical courses great stress is laid upon engineering. A solid foundation is laid in mathematics, mechanics, physics, thermodynamics, and much time given to the theory and practice of engineering in the different branches. The geological course is intended to train men for service in State and Governmental geological surveys, and as professors or instructors in geology. The course combines chemistry, physics, botany, zoölogy, mineralogy, geology, paleontology, etc., with instruction in applied science, mining, metallurgy, and economic geology.

The schedule of study for the degrees of Engineer of Mines, Metallurgical Engineer, and Bachelor of Science in Geology embraces geometry, chemistry, botany, drawing, surveying, mineralogy, and physics during the first year, including also special field work in summer. In the second, third, and fourth years advanced courses of the same studies are pursued, the time given to each varying with the course followed. An important branch taken up during the last year by mining and metallurgical students was mining administration.

Summer schools devoted to practical surveying, supplemented by lectures and office work, occupy six weeks between the first and second years, six weeks between the second and third, and three weeks between the third and fourth years—fifteen weeks in all. The instruction in railroad surveying is given in a summer class between the third and fourth years.

The Summer School of Practical Mining is held in June and July, between the third and fourth years, at some mine selected for the purpose, and devotes six weeks to a detailed study of the plant and methods of working, geological work, surface and underground mine surveying, shaft sinking, and the various operations of mining, pumping, ventilating, surface plant, and administration. The students are divided into small squads and assigned each day to a foreman or a working gang of miners for the study of some definite subject. This summer school has been in successful operation since 1877. At least one week is devoted to practical field geology, and time is given to the construction of maps and geological sections from the observations noted.

The school owns a mineralogical collection, consisting of about 26,000 labeled specimens, illustrating the physical characters of minerals. The geological collection of the school consists of over 100,000 specimens, namely: A systematic series of the rocks and fossils characteristic of each geological epoch, numbering over 70,000 specimens; a collection of ores, coals, oils, clays, building materials, and other useful minerals, illustrative of the course of lectures on economic geology; a collection of 5000 specimens of rocks and the minerals which form rocks, to illustrate lectures on lithology; a paleontological series; several hundred maps and diagrams illustrating the course of instruction, with lanterns, microscopes, and over 2000 slides to accompany them.

In the mining museum there are maps of coal and metal mines of several countries and working drawings, diagrams, and photographs of mine and ore-dressing machinery and models of mines, illustrating everything connected with mining.

The lectures on mining are illustrated by over 1600 blue prints from negatives made for the purpose. These prints are collected in scrap-books showing the different courses of lectures, and each student has the use of one of these books for reference during the lecture and for home study. The ore-dressing laboratory contains ore-dressing and sampling machinery.

CASE SCHOOL OF APPLIED SCIENCE.

The Case School of Applied Science, in Cleveland, Ohio, was founded by Leonard Case in 1877, when he endowed it. After his death, in 1880, the school was legally incorporated, and in 1881 instruction was commenced on a limited scale in Mr. Case's residence, awaiting the completion of the college buildings. In 1885 the school moved into its present home, and as it has grown new laboratories and buildings have been added.

The faculty is as follows: Cady Staley, president, and professor of civil engineering; C. F. Mabery, professor of chemistry; H. F. Reid, professor of physics; C. H. Benjamin, professor of mechanical engineering; C. S. Howe, professor of mathematics and astronomy; F. M. Comstock, professor of English language and literature; J. W. Langley, professor of electrical engineering; A. S. Wright, professor of French and German; A. W. Smith, assistant professor of metallurgy and analytical chemistry; F. H. Neff, assistant professor of civil engineering; D. C. Miller, assistant professor of physics; A. A. Skeels, instructor in mathematics and physics; J. B. Bayliss, instructor in French; C. W. Trumbull, instructor in surveying and mathematics; W. B. Lippincott, instructor in mathematics and drawing; R. H. Fernald, instructor in mechanical engineering; W. O. Quayle, instructor in organic and applied chemistry; N. M. Hill, instructor in general chemistry; H. P. Fairfield and L. O. Burwell, assistants in machine shop.

The courses pursued in the school are civil, mechanical, electrical, and mining engineering, physics, chemistry, architecture, and general science. The fee for tuition and incidental expenses is $100 per year, text books, stationery, and other items amounting to about $25 more. Degrees in mechanical, electrical, mining, and civil engineering are conferred on those who follow their respective studies one year longer than the regular course or are engaged in professional work for three years. The roster for the various studies gives a thorough preliminary grounding during the first year, while in the second specialization commences and is carried on through the remainder of the course. Field work, excursions, and visits to works are included in the studies, and throughout the course special stress is laid on practical work in the various branches.

UNIVERSITY OF CALIFORNIA.

The University of California, which is a part of the public educational system of the State, consists of colleges devoted to various courses of study, some being located in Berkeley, the university seat, others in San Francisco, and a third, the Lick astronomical department, at Mount Hamilton. The colleges at Berkeley include mechanics, mining and civil engineering, and chemistry, with other branches. The college of mining requires a four-years course, conferring the degree of B. S. After an additional period of professional work and examination upon subjects selected by the faculty the degree of E. M. is given. During the first two years of the course the time is largely devoted to lectures and recitations, but in the third year chemistry, mining, and their allied branches are studied, both from lectures and from practical laboratory work. The faculty of the College of Mining is composed of the following professors: Martin Kellogg, president; I. Shingham, dean, mathematics; S. B. Christy, mining and metallurgy; F. G. Hesse, mechanical engineering; J. Le Conte, geology; A. Putzker, German; B. H. Randolph, military science; W. B. Rising, chemistry; F. Slate, physics; Frank Soule, civil engineering; G. C. Edwards, associate, mathematics; A. C. Lawson, associate, geology and mineralogy; F. V. Paget, associate, French and Spanish; M. W. Haskell, assistant, mathematics; H. Kower, assistant, drawing; E. O'Neil, assistant, chemistry; J. H. Senger, assistant, German; H. Whiting, assistant, physics.

COLORADO STATE SCHOOL OF MINES.

The School of Mines of Colorado was established by the legislature in 1874 and located at Golden. The school now consists of a number of large and fully equipped buildings, having lecture rooms, laboratories, and workrooms. Tuition is free, students paying only for material used or broken.

There are four full courses of study—civil, mining, and electrical engineering, and metallurgy. Students graduating in any of these courses receive full degrees. The studies during the first two years are the same for all courses, but the third year the elective studies are commenced, that of mining requiring mathematics, civil engineering, electricity, mining, chemistry, metallurgy, and drawing. During the fourth year the same studies are pursued, but in more advanced lines, taking up all of the principal features of mining work. The course in metallurgy follows the same general lines but requires more attention to subjects relating directly to metallurgical practices. In all courses practical work is carried on by the students, and frequent examinations are made of mining and metallurgical operations in the vicinity.

STATE SCHOOL OF MINES.

The State School of Mines at Rapid City, So. Dak., has for its object testing ores on a working scale, investigating metallurgical processes, and making assays and analyses. It investigates new mineral discoveries and helps to develop and bring before the public the mineral resources of the State, and also gives, collatively, special instruction in assaying, chemistry, and similar studies. The officers of the school are as follows: Dr. V. T. McGillycuddy, president, and professor of civil engineering; Walter P. Jenney, dean, and professor of mining, metallurgy, and geology; C. A. Fenner, professor of chemistry; Frank Lindall, instructor in assaying.

UNIVERSITY OF IDAHO.

The department of mining and metallurgy in the University of Idaho, at Moscow, in that State, was started only a short time ago and has hardly been completely organized. Prof. C. W. McCurdy, formerly with the high school at Winona, Minn., takes the chair of chemistry, and Prof. J. E. Ostrander, formerly instructor in civil engineering at Lehigh University, takes the chair of civil engineering. At present no distinct chair of mining and metallurgical engineering has been appointed. The main building of the University is now under construction and will be completed in April. Provision has been made for chemical laboratories, and assay, draughting, and lecture rooms for the engineering departments. It is the intention of the Board of Regents to give prominence to the Mining School, and to this end it will be fully equipped with the apparatus, models, and other materials necessary.

UNIVERSITY OF ILLINOIS.

The College of Engineering in the University of Illinois, Urbana, Ill., provides several courses in engineering, among them a four-years course in mining. The studies followed in the first two years are the same as with other engineering branches, but in the third year special attention is given mining, mineralogy, assaying, surveying, and similar studies. In the fourth year ore dressing, chemistry, and mining and metallurgical studies are followed. The course consists in lectures, laboratory and shop work, and, whenever practicable, field practice or visits to works in operation. The faculty consists of the following professors: T. J. Burrill, acting regent, botany; N. Clifford Ricker, dean, architecture; S. W. Shattuck, mathematics; Ira O. Baker, civil engineering; A. N. Talbot, municipal engineering and mechanics; F. F. Frederick, industrial art and design; W. J. Baldwin, mining engineering; C. W. Scribner, mechanical engineering; George W. Myers, mathematics; D. W. Shea, electrical engineering and physics; George W. Parker, woodwork; Rufus Anderson, iron work, J. M. White, architecture; C. D. McLane, general engineering drawing; A. L. Kenhmsted, electrical engineering; J. D. Phillips, mechanical engineering drawing.

KINGSTON SCHOOL OF MINING AND AGRICULTURE.

The Kingston School of Mining and Agriculture at Kingston, Province of Ontario, Canada, has a four-years course of mining and confers the degree of Engineer of Mines (E. M.) upon those who pass the final examination. During the first two years the usual academic studies are followed, including introductions to those of the succeeding two years. The latter years embrace full studies of chemistry, assaying, geology, mineralogy, mining engineering and ore dressing, metallurgy, drawing, materials and construction, mechanics, and surveying. The faculty consists of the following professors: William L. Goodwin, chemistry; William Nicol, mineralogy, metallurgy, and assaying; Willet G. Miller, lecturer on geology and petrography; William Hamilton Merritt, lecturer on economic geology of Ontario and the discovery and winning of minerals; R. Carr Harris, engineering; William Mason, lecturer on freehand, mechanical, and office drawing, topography, and surveying; T. L. Walker and Dr. Isaac Wood, laboratory demonstrators.

An important branch added to this school is that providing for mine foremen, assayers, prospectors, and mining men in general, and special eight-weeks courses of instruction in chemistry, mineralogy, geology, lithology, discovery and winning of ores, blowpipe analysis, assaying, drawing, and such advanced work as may be chosen.

LAFAYETTE COLLEGE.

The Pardee Scientific Department of Lafayette College, at Easton, Penn., was established in 1866 by Ario Pardee. The department includes two general scientific and three engineering courses—civil, mining, and electrical engineering. The course in mining engineering requires four years' study and leads to the degree of Engineer of Mines (E. M.). In the first two years the same studies are followed by all three engineering courses, but in the third year the elective mining course begins, taking up mechanics, drawing, surveying, mining, chemistry, geology, and assaying. In the fourth year more advanced studies are followed and much time is spent in practical work. This last feature is an essential part of the course, during both the college year and the summer vacation.

LEHIGH UNIVERSITY.

Lehigh University, South Bethlehem, Penn., was established in 1865 by Hon. Asa Packer of Mauch Chunk. The course in mining engineering and metallurgy requires four years of study, conferring the degree of B. S. In order to secure the higher degree of E. M. an additional year is required. The roster for this course embraces modern languages, drawing and construction, chemistry, mineralogy, geology, astronomy, applied mechanics, surveying, metallurgy, and mining. Field and practical work form an essential part of the course.

The faculty consists of the following professors: R. A. Lamberton, president; Henry Coppée, English literature, international and constitutional law, and the philosophy of history; W. H. Chandler, chemistry; B. W. Frazier, mineralogy and metallurgy; H. W. Harding, physics and electrical engineering; C. L. Doolittle, mathematics and astronomy; M. Merriman, civil engineering; S. Ringer, modern languages and literature and history; E. H. Williams, mining engineering and geology; J. F. Klein, mechanical engineering; W. A. Robinson, secretary, Greek language and literature; E. M. Hyde, Latin language and literature; Rev. E. Worcester, mental and moral philosophy.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

This Institute, in Boston, has been one of the leaders in introducing the modern experimental method of teaching, by which the student carries on actual work and draws conclusions from the results obtained. The Institute has been equipped from its beginning with laboratories in pursuance of this plan. In 1865 a laboratory for general chemistry was erected; in 1869 a physical laboratory; in 1871 a mining and metallurgical laboratory; an engineering laboratory in 1873; shop work, on the Russian system, in 1876; a biological laboratory in 1876; one on applied mechanics in 1881; one for electrical work in 1883; and in the same year one for civil engineering work.

The student in mining and metallurgy receives a thorough training, based upon a foundation of mathematics, chemistry, and physics. These subjects are followed at the same time with courses in surveying, mineralogy, geology, mining, ore dressing, metallurgy, steam engineering, and hydraulics. Other studies included in this course are French, German, English composition, history, political economy, and business law. Both the Institute and its work are widely known, from the high standing of its faculty and the excellent records made by its graduates.

MICHIGAN MINING SCHOOL.

The Michigan Mining School at Houghton, Mich., is the only school in the country devoted exclusively to mining engineering. Two courses are given, one of three and one of four years, leading respectively to the degrees of B. S. and E. M. The second course is separated into two divisions: (1) that giving more attention to engineering work, and (2) that in which more time is given to chemistry. The preliminary examination requires a thorough grounding in the usual academic courses. The course of study during the first year includes mathematics, physics, drawing, chemistry, mineralogy, and surveying. In the second year the same studies are continued, and metallurgy, petrography, mechanics, geology, and practical shopwork are added. In the third and fourth years, in addition to these studies, ore dressing, electricity, mine accounting, hydraulic and structural work, assaying, and similar advanced branches are taken. In this course 67% of the time is devoted to practical and 33% to theoretical work. The faculty of the Mining School is as follows: M. A. Wadsworth, director, professor mineralogy, petrography, and geology; George A. Koenig, professor of chemistry, A. E. Haynes, secretary, professor mathematics and physics; Edgar Kidwell, professor mechanical and electrical engineering; F. F. Sharpless, professor of metallurgy; F. W. Denton, professor of civil and mining engineering.

UNIVERSITY OF MINNESOTA.

The School of Mining and Metallurgy of the University of Minnesota, at Minneapolis, forms a part of the College of Engineering, Metallurgy, and the Mechanical Arts, an organization embracing all the technical courses of the university. The school has been in operation two years. Required and elective work, outside the professional lines of mining and metallurgy, are provided. The course in assaying and ore testing requires one year, as also does the course in metallurgy, while that in mining occupies a portion of the time for two years.

Lectures in mining and metallurgy are illustrated with various pieces of mining machinery, samples of metallurgical products, and a full series of drawings, blue prints, and photographs. A building and machinery are being erected which will enable the school to instruct its students in the practical methods of ore testing on a commercial scale.

MISSOURI SCHOOL OF MINES.

The Missouri School of Mines is situated in the town of Rolla, about 110 miles west of St. Louis. It was established in 1870 by an act of the legislature, to form a branch of the University of Missouri, established in 1839. The faculty is as follows: Richard H. Jesse, president of the university; Walter B. Richards, director and professor of mathematics; William H. Seamon, professor of chemistry; Harry K. Landis, professor of mining and metallurgy; Elmo G. Harris, professor of engineering; Austin L. McRae, professor of physics; Thomas L. Rubey, secretary of faculty, instructor; Paul J. Wilkins and Thomas G. Poats, instructors. The following courses of instruction are pursued: I. Mining and metallurgy. II. Chemistry and assaying. III. Civil engineering. IV. Academic department. Students also pursue special courses in assaying, surveying, and electricity. Degrees conferred in the four-year courses are: Bachelor of Science (B. S.), in mining engineering, chemistry, civil engineering, and mathematics and physics. The degrees of Engineer of Mines (E. M.) and Civil Engineer (C. E.) are conferred upon those who, having received the degree of B. S., after three years of work in their profession have demonstrated their fitness for the degree.

A mining and metallurgical laboratory is now being equipped with apparatus of working size. Visits to mines and metallurgical establishments form a necessary part of the course. The course in chemistry and assaying requires four years and embraces practical work, lectures, and a large amount of original work by the student. In engineering courses special stress is laid on practical field work. In all of the departments the usual academic courses are followed in connection with the special subject of study, both mathematics and physics being carried through the entire four-years course.

MONTANA SCHOOL OF MINES.

The School of Mines of the College of Montana, at Deer Lodge, Mont., has a four-years course leading to the degrees of Mining Engineer, Civil Engineer, and Analytical and Applied Chemistry. The entrance examinations require a good knowledge of the usual academic branches. In the mining course the first year is given to mathematics, chemistry, botany, and some elective studies. The same studies, only more advanced, are taken in the second year, metallurgy and mineralogy being added. In the third and fourth years the studies relating directly to mining engineering are engaged in. An important part of the course in each year is the practical work required of the student, both in the workshop and the field.

M'GILL UNIVERSITY, CANADA.

The department of engineering instruction at McGill University, Montreal, Canada, has been greatly enlarged during the past few years, increasing both its faculty and its equipment. The department includes civil, mining, mechanical, and electrical engineering and practical chemistry. The faculty is as follows: H. T. Bovey, dean, civil engineering; B. J. Harrington, chemistry, mineralogy, and assaying; C. H. McLeod, surveying and geology; G. H. Chandler, practical mathematics; C. A. Carns-Wilson, electrical engineering; John T. Nicolson, mechanical engineering; H. L. Calhuder, experimental physics; W. A. Carlyle, instructor in mining and metallurgy; R. S. Lea, instructor in mathematics and drawing; Henry Bamford, associate, civil engineering; N. N. Evans, instructor in chemistry; P. J. Darey, associate, French; C. E. Moyse, associate English literature; D. P. Penhallow, associate, botany; John Cox, associate, experimental physics; Frank D. Adams, associate, geology and paleontology; L. R. Gugor, instructor in German. There are also a number of assistants and instructors in the various departments.

It is intended that the department of mining and metallurgy shall be fully equipped with a complete laboratory and sets of working models. At present the course follows the usual lines, practical work in summer being regarded as an important feature. During the term the students prepare papers upon the work they were engaged on during the summer.

NEW MEXICO SCHOOL OF MINES.

The New Mexico School of Mines, at Socorro, N. M., was founded in 1889, and is supported by a tax of one-fifth of one mill on all taxable property within the State. The buildings are large and fully equipped for the work carried on within them. The courses of instruction are as follows: I. General inorganic chemistry and qualitative analysis. II. Blow-pipe analysis and determinative mineralogy. III. Qualitative analysis. IV. Stoichiometry, chemical philosophy, and industrial chemistry. V. Organic chemistry. VI. Assaying. VII. General metallurgy. VIII. Mining, mine engineering, ore dressing, and advanced metallurgy. The chemical and metallurgical departments are under the charge of Prof. Floyd Davis, the president of the School, Theodore S. Delay acting as his assistant.

The collegiate year 1893–94 has been the first during which the school has been opened. In the coming year, 1894–95, a complete roster is announced, including mathematics, drawing, and languages, in addition to the courses already named. The course will be of four years' duration, leading to degrees of A. C., E. M., and C. E. Both laboratory, lecture, and field work will be adopted, and particular attention given to the study of practical operation of industrial establishments.

OHIO STATE UNIVERSITY.

The Ohio State University, in Columbus, Ohio, has a department of mining and metallurgy which requires a four-years course of study. This department occupies the eastern part of the large college building and embraces assay rooms, chemical laboratory, and lecture rooms. The course in metallurgy includes mineralogy, metallurgical lectures, and laboratory work, assaying, construction, ore dressing, chemistry, and plans and specifications for works. The mining engineering course consists of the usual studies essential to the mining engineer.

PENNSYLVANIA STATE COLLEGE.

This college, situated in a village of the same name in Centre County, Pennsylvania, consists of six buildings fully equipped and a staff of forty-one professors and instructors, thirteen of them working in strictly technical departments. Optional courses are offered in general science, Latin, agriculture, biology, and civil, mechanical, electrical, or mining engineering.

The mining department, recently organized, is designed to fit students for practical work in geology, mining, and metallurgy by combining instruction with practical work. During the first two years a broad line of study is followed and in the last two years the student devotes himself more exclusively to mining and its cognate branches. The classroom work consists of recitations supplemented by lectures.

The laboratories are well equipped and sufficient hours assigned to draughting, chemistry, and blacksmith work, surveying, assaying, coal washing, mining machinery, designing, and ore dressing. The mining department possesses a large supply of mining tools and machines, an ore-dressing mill, two working models of coal-washing plants, and a typical concentration mill for lead and silver ores. The museums contain very fine mineralogical, geological, and metallurgical collections. A summer-school course is required, for the purpose of visiting mines and other places of interest, giving also field practice in surveying and geology. At the termination of the four-years course the college grants the degree of Bachelor of Science in mining engineering (B. S.). The degree of Engineer of Mines (E. M.) is awarded only after three years of successful professional life, or on the completion of a post-graduate course.

UNIVERSITY OF PENNSYLVANIA.

The Towne Scientific School of the University of Pennsylvania, in Philadelphia, has four branches of engineering studies—chemistry, mining and metallurgy, and civil and mechanical engineering. The full course is five years, conferring degrees of A. C., E. M., C. E., and M. E. A shorter course of four years gives the degree of Bachelor of Science in either branch followed. The course in mining and metallurgy becomes distinctive after the second year. In the fourth and fifth years advanced studies are followed and much practical work carried on in laboratory and field. Excursions are made to various mining and metallurgical plants. The professors of the mining course are as follows: Dr. William Pepper, provost of the university and ex-officio president of the faculty; E. O. Kendall, vice-provost, honorary dean; Thomas A. Scott, mathematics and Flower professor of astronomy; O. Seidensticker, German language and literature; G. F. Barker, physics; H. W. Spangler, Whitney professor of dynamical engineering; E. F. Smith, chemistry; A. W. Goodspeed, assistant, physics; E. D. Cope, mineralogy and geology; E. Marburg, civil engineering. The instructors are A. P. Brown, mining and metallurgy; D. R. Griffith, assistant, mechanical engineering; W. J. Keith, chemistry; J. Ohly, chemistry; J. H. Penniman, English; C. Worthington, civil engineering; A. W. Schramm, electrical engineering; H. W. Huffington and L. E. Picolet, mechanical engineering; W. J. Shields, physics. The lecturers are L. J. Matos, H. W. Jayne, and C. S. Boyer, technical chemistry.

VANDERBILT UNIVERSITY.

Vanderbilt University, Nashville, Tenn., was founded by Cornelius Vanderbilt of New York in 1873. The university is divided into a number of branches, among them being the engineering department, embracing civil, mechanical, and mining engineering. The degree of Bachelor of Engineering (B. E.) is conferred on those who graduate in four years, and the full degree E. M., C. E., or M. E. to those who take an extra year's course and have been engaged in active professional work for not less than three months. During the first and second years the studies are the same for the entire engineering department. In the third year more attention is applied to distinctive mining matters, and during the last two years lecture-room work gives way to practical work in the laboratory and field. The faculty consists of the following professors: L. C. Garland, chancellor; O. H. Landreth, dean; L. C. Garland, physics and astronomy; J. M. Safford, natural history, geology, and mineralogy; W. M. Baskervill, English language and literature; W. J. Vaughn, mathematics; W. L. Dudley, chemistry and metallurgy; J. T. McGill, assistant, chemistry. The adjunct professors are C. L. Thornburg, civil engineering and astronomy; W. T. Magruder, mechanical engineering; E. W. Bemis, economics; John Daniel, practical physics; W. Deering, German; A. Hohlfeld, French; P. A. Rodriguez, Spanish. Assistants are C. S. Brown, English; P. M. Jones, natural history and geology; P. H. Porter, engineering; C. D. Rice, mathematics; W. A. Webb and W. E. Bolles, manual training; J. Ashford, engineer and instructor in machine shops; C. F. Finch, instructor, forge and foundry; P. O'Connor, instructor, wood shop; J. T. Gwathmey, gymnasium and physical exercise.

WASHINGTON UNIVERSITY OF ST. LOUIS, MO.

The department of mining and metallurgy of Washington University was organized in 1871, and is, consequently, among the oldest mining schools in the country. From its early commencement it has required much practical work from its students. The present roster requires that, in addition to visiting and studying the mining and metallurgical plants in the immediate vicinity of St. Louis every Saturday during the term, each student must for three seasons attend a summer school of practical mining and metallurgy, spending about six weeks in the Lake Superior copper and iron regions, in the Colorado gold and silver camps, or in the Missouri lead districts. The course in mining requires four years, and covers the theory and practice of mining and ore dressing, geology, general construction, hydraulic engineering, and analytical chemistry. The course in metallurgy also requires four years, including studies in mechanical engineering and a longer time in chemical analysis. A five-years course is provided for such students as wish to take up both mining and metallurgy. The mining department is under the charge of Prof. H. A. Wheeler, with Arthur Tuttle as his assistant. Dr. W. S. Chaplain is chancellor of the University, and the collegiate departments are in charge of the following professors: J. B. Johnson, civil engineering; J. H. Kinealy, mechanical engineering; F. E. Nipher, electrical engineering; C. R. Sanger, analytical chemistry. Each department has also a number of assistant instructors.

UNIVERSITY OF WYOMING.

This university was founded in 1886, and its present buildings were completed in 1887. The faculty consists of the following professors: A. A. Johnson, president, political science; John D. Conley, vice-president, geology and physics; Aven Nelson, Latin and Greek; Henry Mertz, mental and moral sciences; Burt C. Buffum, horticulture, meteorology, and irrigation engineering; L. C. Colburn, mechanical engineering and mathematics; E. E. Slosson, chemistry; Lieut. E. C. Bullock, military science and tactics; W. C. Knight, mining engineering, assaying, and metallurgy; I. M. Morse, assistant, German and French; C. M. McDonald, principal, academic department; F. J. Neswander, instructor, physiology and zoölogy. The course of the School of Mines is four years, giving the degree of B. S., or, with an additional post-graduate year, the degree of E. M. The first year is given chiefly to elementary training and lectures on mining and geology. In the second year more advanced studies and practical work are pursued. The third and fourth years are given to practical work and a study of mining, mining methods, metallurgy, chemistry, geology, geometry, and surveying.

STATE GEOLOGICAL SURVEYS.

The development of the mineral resources of a State constitutes the most important foundation for its prosperity. The railroad system of the United States, which permitted the reclamation of the wilderness, the building of cities, the establishment of innumerable industries, and the investment of countless millions, owes its development largely to the existence of vast deposits of the useful minerals.

In no other way can the citizens of a State better promote their material interests than in making known the resources which it contains and attracting capital to their development, and unquestionably the best and most economical means of attaining this desired end is by the maintenance of efficient State geological surveys, devoted particularly to the study and description of the economic mineral resources of the State and to showing how they can best be developed and the inducements they offer for the investment of capital in the establishment of various industries. The natural and desirable rivalry among the States can never be satisfied by the results of a general geological survey of the whole country—a survey necessarily devoted chiefly to the elucidation of general scientific problems of only remote economic importance, and which in any event never furnishes the specific economic information necessary to attract the attention of capital. This work cannot be left to the individual, whose interest it often, if not always, is to discourage the establishment of rival mines or works.

It is to profound ignorance of the great importance, from an industrial standpoint, of this means of developing and increasing the wealth of a State that we must attribute the indifference shown to a geological survey in many of the States, though it must also be confessed that some of the surveys have not fully appreciated the importance of giving practical economic value to those who support them. Profound discussions of abstruse points in geology have far less interest to the taxpayer than has a report showing clearly the resources which would justify the establishment of profitable industries.

PROGRESS IN ORE DRESSING IN 1893.

BY ROBERT H. RICHARDS.

FIVE new coal-washing plants were described in 1893, all of which wash the coal by coarse jigs or bedded jigs. One large anthracite breaker has been built, which has no water treatment. For crushing ores three new crushers and four new granulators have been described, and several papers discussing the comparative merits of granulators have appeared. For magnetic concentration two new magnetic concentrators have been described, and two plants for magnetic concentration. For fine concentration five new belt machines and two new circular tables have appeared. An interesting plan for a combination of dry and wet concentration has also been described, and there have been two contributions on the jigging of mine fines. A valuable report upon the anthracite region shows the need of more concentration there.

In reviewing the ore-dressing literature for the year machines will be treated first, then mills and plants, and lastly discussions and comparisons.

The *Lowry Crusher** is of the spindle type, belonging to the same class as the Gates, the Comet, etc. The chief difference is in the position of the fulcrum of the lever, which is below the crushing cone. This machine therefore occupies the same relation to the Gates and the Comet that the Dodge and the Krom breakers do to the Blake, it having the greatest movement on the largest lump of ore. The driving pulley is attached to its shaft by a brake hub, which will slip if a steel hammer gets into the jaws.

The *McCully Rock and Ore Crusher*† is also a machine of the spindle type. The shaft and crusher head are suspended entirely from the top,—the point of least movement or gyration,—thereby diminishing friction to a minimum. The machine is made in nine sizes, from 6 to 150 tons' capacity per day.

The *Cummings Ore Granulating Mill*‡ consists of an annular disc with radial, steep-sided grooves in it, which revolves 1000 turns per minute upon a horizontal axis opposed by a similar stationary disc. The distance apart of these discs is $\frac{1}{8}$ to $\frac{3}{8}$ in. and is regulated by a screw. By this machine $1\frac{1}{2}$ to 2 in. cubes are reduced to $\frac{1}{16}$ in. diameter. Since the plates do not touch, the action is not

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* *Iron Age*, Jan. 5. 1893, p. 12.

† *Engineering and Mining Journal*, Sept. 23, 1893, p. 315.

‡ *Trans. Am. Inst. Min. Eng.*, Vol. XXI., p. 516.

by grinding. A smaller mill than this crushed cement clinker from a 1-in. cube to wheat size at the rate of 20 tons per hour, consuming 50 horse-power, with a cost for renewals of $10 per month.

The *American Rock Breaker*[*] is a jaw crusher with a special toggle and eccentric motion. The fixed jaw is concave cylindrical in surface, and the movable is convex cylindrical; the space between the two is therefore crescent-shaped in horizontal section. In place of the side plates the upper or fixed wearing die is extended down on each side of the lower working jaw, allowing a portion to discharge on each side. The upper end of the movable jaw is attached rigidly to the eccentric box while the lower end is supported on a toggle placed approximately vertical, giving the jaw a rocking or cradle motion. The machine is said to crush 2 to 4 tons per hour, to pass a ¼-in. hole.

The *Buchanan Granulator*[†] is a Blake crusher with the pivot below the jaw and the toggles above the eccentric. It is designed to follow the large jaw crusher and to precede the rolls. It is made in two sizes, 3½ by 30 and 5 by 30. Its capacity is 4 to 8 tons per hour, reduced to ¼ or ¾ in. ring.

The *Griffin Mill*[‡] has a roller with a vertical axis tightly keyed to the lower end of a vertical shaft, which is attached above by a universal joint to a driving pulley. When power is applied the roller revolves with the pulley and swings out of plumb till it meets a ring or die; in this it rolls in the direction opposite to its own rotation, exerting a crushing force of 6000 lbs., suitable for granulating gold ores, etc., giving the grains, it is claimed, in the best possible condition for amalgamation or concentration.

The *Bryan Roller Mill*[§] at the Santa Eduwiges amalgamating silver mill is highly commended. More than fifty other plants are said to have been furnished with it. Four 4-ft. Bryan mills crush from 60 to 100 tons per twenty-four hours preparatory to silver amalgamation.

American Ball Pulverizer.[‖]—This is an anti-friction ball-bearing granulator for either wet or dry grinding. No screens are required. The wearing parts are the upper track, the lower track circle, and the balls. The capacities are said to be: No. 2 machine, 1 ton per hour; No. 3, 50 tons per day; No. 4, 100 tons per day.

The *Sturtevant Mill*[¶] is used for granulating magnetic iron ores at the Croton (N. Y.) magnetic iron mines. The ore is reduced from a 2¾-in. cube to pass a 12-mesh sieve; 20% is returned by the screen to the mill. The screen blocks in the mill are ¼ by 3½ in. The size of the grain may be changed by changing the speed of the mill. With 20-in. mill, 870 revolutions give 80% that will pass through 12-mesh, and 950 revolutions 80% that will pass through 14-mesh. A 12-in. mill will handle 2¾-in. cubes; 15-in. mill will handle 3¼-in. cubes, and 20-in. mill will handle 4½-in. cubes. The form of the particles is approximately cubical, suitable for any concentration. A 20-in. mill will granulate 24 gross tons of roasted ore per hour to 12-mesh with 96 horse-power, and at less than five-eighths of a cent per ton for renewals.

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[*] *Engineering and Mining Journal*, June 24, 1893.

[†] *Ibid.*, April 8, 1893.

[‡] *Ibid.*, June 3, 1893.

[§] *Min. and Sci. Press*, June 3, 1893.

[‖] *Engineering and Mining Journal*, June 24, 1893.

[¶] W. H. Hoffman, *Trans. Am. Inst. Min. Eng.*, Vol. XXI., p. 126.

Granulation of Iron Ore by Crushers and Rolls was described by Axel Sahlin in a valuable paper,[*] comparing graduated crushing for magnetic separators by rock breakers and rolls with direct granulation by the Sturtevant mill. The results in sizes of grains were:

Mesh.	Crushers and Rolls.	Sturtevant Mill.	Mesh.	Crushers and Rolls.	Sturtevant Mill.
10 to 16	21.0%	22.50%	40 to 60	17.5%	29.5%
16 to 24	21.0	21.25	Fines...	20.9	*15.5
24 to 40	7.9	9.25	Loss.....	1.7	2.0

* This figure is too low, as the dust was removed by a fan.

These two papers called out a good deal of discussion, for which the reader is referred to the *Trans. Am. Inst. Min. Eng.*, Vol. XXI., pp. 530, 533.

Magnetic Concentration at the Tilly Foster Mine was described by F. H. McDowell.[†] In 1890 33,204 tons of ore were treated in ten months, at a cost of $2.10 per ton; and in 1891 34,515 tons in nearly ten months, at a cost of $1.99 per ton.

Chase Magnetic Ore Separator.[‡]—There are two methods of working a magnetic machine. 1. Crush all the rock so fine that no magnetite remains attached to quartz. The crushing is expensive and the magnetite concentrates too fine to satisfy the furnace men. 2. Crush coarse and make at once (*a*) clean magnetite, (*b*) attached grains, (*c*) clean quartz. The attached grains being but a small amount, they may be recrushed and the pure magnetite extracted, making but a small proportion of very fine ore. The Chase machine has an endless belt with a drum magnet at one end and a plain roll at the other. This magnet retains the magnetite and attached grains, while the quartz tumbles off over the end. Running crosswise of the belt, above the under part of it, are a set of H section electro-magnets wound alternately oppositely, which brings like poles together. As the belt passes beneath this set of alternate poles the magnetic particles are continually reversed, and in doing so the middlings are shaken out into their hopper, while the pure magnetite is carried forward over its hopper and is then dropped. The machine is adapted to both dry and wet work.

"*La Trieuse*" *Electro-magnetic Oscillating System*[§] is used at Laurium, Greece. Two powerful electro-magnets, whose poles terminate in finger-like ends, mounted in a frame, are swung by a rod with a universal joint from one end of a counterpoise lever over a tray of ore. The current can be let on and put off at will, and graduated in amount to suit the degree of roasting to which the ore has been previously subjected. When the ore has been picked up and is sufficiently clean it is swung over a side hopper and the current shut off. It is a species of hand sorting by a magnet. To work 300 to 1000 kilos of roasted pyrites and blende with 22% Zn. in ten hours requires 2½ to 3 ampères and 40 volts.

Sampler for Wet Pulp[‖] is used in cement works in the southern part of Spain. A conical distributor with its axis vertical is revolved by a propeller which in

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[*] *Trans. Am. Inst. Min. Eng.*, Vol. XXI., p. 521.

[†] *Ibid.*, p. 519.

[‡] *Ibid.*, p. 503.

[§] Hugues Daviot, *Comptes Rendus Mensuels de l'Industrie Minérale*, Sainte Etienne, May, 1893.

[‖] Edmund Baur, *Thon. Ind. Zeitung*, 1893, p. 216.

turn is driven by the falling pulp. Revolving with it are two radial troughs which catch or fail to catch pulp around the base of the distributing cone. The pulp so caught is thrown out by centrifugal force in a circle in which are pockets which catch or fail to catch the pulp.

Dodge's Distributor and Dodge's Sizing Box.[*]—The distributor by a revolving cone delivers even pulp and water for two or more vanners. The sizing box is an hydraulic separator with adjustable area at the point of contest between the upward moving water and the downward falling sand.

The *Bilharz Percussion Table*[†] works upon the same principle as the Rittinger percussion table, but it has an endless belt traveling across the stream. A smooth flat belt is mounted on two large rollers about 4 ft. long, at the ends of the belt frame, about 10 ft. long and 4 ft. wide. The belt frame is mounted on suspending rods and is level in its length, but slopes in its width. Between the end rollers the belt is supported by a plane surface having grooves in it supplied with water from the upper edge to lubricate it and prevent wear. The belt frame receives 150 blows per minute from a cam at one end. The throw is taken up by a spring at the other end. The belt travels lengthwise of the frame at .07 m. per second. Water-sorted ore is fed upon the coming upper corner of the belt, and is washed by water flowing across it as it is carried along by the belt. The ore is delivered separated into its different kinds along the lower margin of the belt, where it is caught in separate spouts. The capacity is 1000 lbs. in ten hours, and the machine is claimed to do very clean work in three mineral separations—galena, blende, and quartz, for example.

Convex Circular Slime Table with Percussion.[‡]—This is a stationary convex table of 4 meters diameter, made of turned cast-iron plates. The pulp runs on in a bent radial direction from the center toward the periphery. This changes the volume and velocity to one-half. The natural separation here takes place into heads and tails, the tails leaving the table first. The heads, however, come under a rotating curved wash-water pipe which separates them according to their gravities. The percussion is applied tangentially to the periphery of the table. The table works 4500 to 5000 kilograms in ten hours and is said to yield galena with 65% to 75% lead and 2% to 3% zinc, blende with 1% to 1.5% lead and 35% to 40% zinc, and tailings with 0.5% to 1% lead and 1.3% to 2% zinc. The advantages claimed are the large capacity, small wear, little repair, ¼ horse-power, simple management, small consumption of water, and small space for the work done. It weighs 5500 kilograms.

The *Johnston Concentrator*[§] is a belt vanner with side shake. The belt frame is suspended by four non-parallel hanging rods. Each rod converges downward toward the one opposite. There results a rocking motion to the belt which breaks up the tendency to form banks on the margins, but is not sufficient to heap up a bank in the center. Small rollers are placed at an angle of 45° along the edges of the belt as guides and also to elevate the edges, rendering a molded edge unnecessary. A canvas or rubber belt is supplied, as desired. The results are said to be very satisfactory.

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[*] *Min. and Sci. Press*, Aug. 5, 1893.

[†] *Engineering and Mining Journal*, May 27, 1893, p. 490.

[‡] W. J. Bartsch, *Berg- und Hüttenmännische Zeitung*, 1893, p. 175.

[§] *Min. and Sci. Press*, May 27, 1893.

Blaisdel Concentrating Belt.[*]—This belt has a molding on the edge at an angle of 60° with the belt, and lies nearly flat upon it when going over the end rollers. It also has, at intervals of two feet, riffles in groups one inch wide. The riffles are $\frac{1}{32}$ in. deep, and are efficient savers of fine sulphurets and of quicksilver. Many of these belts are in use.

The *McGlew Ore Concentrator*[†] is a belt machine with canvas belt provided with rope edges to serve as guides and also as flanges. The belt has a side shake by eccentrics and an end bump by a cam pushing down the slope and a spring returning it against a bumping post. The belt frame rests upon four balls, allowing the gyrating motion. The daily capacity is 10 tons. When worn out the canvas belt can be replaced for $15.

The *Robinson Riffle*[‡] is a flat-bottomed trough with a series of steps or stairs in it. The treads of the steps are 24 in. long, the risers 4 in. high. The bottom of the trough has a grade of 1.25 to 1.50 in. to the running foot, and with those grades the steps have a backward grade of 0.75 to 0.5 in., respectively. This is a very simple, cheap, and efficient concentrator for gold and sulphurets.

In the *Improved Triumph Concentrator*[§] the crank shaft is placed at the head of the concentrator, which arrangement possesses advantages over the older form.

A *Screw Grating for Screening Coal*[‖] is used at the coal mine near Kladno, Bohemia. The bars have strongly developed screw threads of such form that the spaces left between two bars are cut up into a series of circular holes. The simultaneous revolution of all the bars makes the screen a conveyor at the same time. The inventor expects to screen 3300 tons of coal in ten hours with a screen 1.170 m. by 2.370 m. making 80 revolutions per minute, while the diameter of the holes is 136 mm.

The Lührig System of Coal Washing.[¶]—Two hundred Lührig plants are in operation on the Continent and a considerable number in Scotland and Yorkshire. At Motherwell the plant consists of vibrating screens with 2-in. round holes. The over-size from this goes to picking-belts made of open bars. The good coal is loaded on the car from the end of the belt. The small coal dropping through the belt together with the slate is sent to the stone breaker and then joins the under-size from the above screen, going to a hopper containing 100 tons. Thence it is elevated to the top of the washing building, first into a Schmidt spiral sieve, yielding treble nuts, 2 to $1\frac{1}{4}$ in. diameter; double nuts, $1\frac{1}{4}$ to $\frac{7}{8}$; single, $\frac{7}{8}$ to $\frac{5}{16}$; and pea and small, $\frac{5}{16}$ in.

Each size is sent by a chute to its own washer. The upper three sizes are washed on plunger jigs with eccentric piston, making good coal, slate, and fine siftings which are waste. The pea and small sizes are sent to a series of graded pointed boxes, and the discharge from these goes each to its own jig, having a coarse screen and a feldspar-bed yielding slate through the bed and washed coal over the tailboard. The fine coal is sifted in a copper screen with $\frac{1}{64}$-in. holes to separate the fine sludge. The Motherwell plant treats 1500 tons of coal contain-

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[*] *Min. and Sci. Press*, July 15, 1893.

[†] *Ibid.*

[‡] A. B. Paul, *Min. and Sci. Press*, Feb. 25, 1893.

[§] *Min. and Sci. Press*, May 13, 1893.

[‖] Patented by Distl Lusky; described by A. Kás, *Ost. Zeitschrift*, 1893, p. 73.

[¶] *Coll. Guardian*, Feb. 24, 1893, p. 343.

ing 23% ash per day, and yields coal with not over 2½% ash, and dirt with not over 1% of coal in it. The cost of labor was ½d. per ton.

In the *New Coal Washer at Zollern Pit*, near Dortmund, Prussia,[*] the system consists of screening and hand picking for the larger sizes, jigs for the nut sizes, and pointed boxes followed by bedded jigs for the pea sizes, as follows:

Washed pea-coal for coking	from	0. 0	in.	to	0.393	in.	diameter.
Washed nuts	"	0.393	in.	"	0.624	in.	"
" "	"	0.624	in.	"	1.09	in.	"
" "	"	1.09	in.	"	1.75	in.	"
" "	"	1.75	in.	"	3.15	in.	"

Hand-cleaned coal is above 3.15 in. diameter in size. The yield is:

Hand-cleaned coal				
Nut coal				9.8%
Nut coal	1.75	to	3.15	49.0
Nut coal	1.09	to	1.75	6.8
Nut coal	0.624	to	1.09	8.8
Coking pea-coal	0.393	to	0.624	8.8
Dirt and clay	0.	to	0.393	50.0
				10.9

The raw coal contains 12% of dirt; the washed coal, 5.6%. The cost of this washer is $60,000, and it treats 80 tons per hour.

In the *New Coal Washing Plant at New Glasgow, N. S.*,[†] the coal is received upon a flat, shaking screen having an eccentric motion, and with ⅜-in. holes. The oversize goes to a crusher and is elevated back to the screen. The fine coal is sized by a revolving screen into 0 to ⅛ in. diameter, 1⅛ to ¼ in. diameter, and ¼ to ⅜ in. diameter. These sizes are all treated on two-compartment feldspar jigs, arranged with variable stroke. A 100 horse-power engine drives the entire plant. The washed coal is elevated to a storage bin, from which it is taken to the coke ovens. The slate is carried off in cars. The entire plant is automatic. The crude coal contains 17% to 35% ash, and 2½% to 3% sulphur. The washed coal contains 10% of ash, or within 1% of the fixed ash, which is 9%. The sulphur is reduced to 1.35%, which is the organic sulphur, or that combined with aluminum and calcium. The total capacity is 300 tons in ten hours. The cost of washing is somewhat below 5c. per ton in summer and 10c. per ton in winter, an average of 7½c. per year, exclusive of repairs and supplies.

The *Coal Washing Plant of the Standard Coal Company*, Brookwood, Ala.,[‡] was designed by Mr. Walter M. Stein of Philadelphia. A shaking screen yields lump, nut, and washing coal. The former two sizes are sorted by hand by boys on two sorting bands, 73 and 68 ft. long, respectively, and are then sold. The washing coal is screened, yielding a portion too coarse for washing which is crushed and then rejoins the fines. The revolving screen brings the fines into three sizes, which are washed by eleven two-compartment jigs, each capable of handling 5 to 7 tons per hour, removing slate, pyrite, and barite. The amount of water used is very small, as the same water is used over and over. The capacity is 500 tons per day of ten hours. The coal averages 16.79% ash, the washed coal 6.72% ash. Reduction of ash equals 61.93%. The coke made from this coal has 8.89% ash. There is but one other plant of this kind in America—

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[*] *Coll. Engineer*, January, 1893, p. 124.

[†] John Fulton, *Coll. Engineer*, September, 1893, p. 36.

[‡] *Engineering and Mining Journal*, March 25, 1893.

that of the New Glasgow Iron, Coal and Railroad Company, which is operated at Ferona, near Pictou, N. S. Its capacity is 300 tons per twenty-four hours.

In the *Coal Washing Plant at Zenica Bosnien** the coal passes to a grating with 80 mm. spaces. The lump is picked, the good part shipped, and the poor sent to a Blake crusher. The crushed coal and mine fines are elevated to a three-sieve drum with 30, 10, and 4 mm. holes, respectively; 80 to 30 go to rotary picking table; 30 to 10, on skoda jigs; 10 to 4, on skoda jigs; 4 to 0 are settled and the settlings are burned under boilers for power.

Practical Results of the Campbell Coal Washer.†—The table is 8 or 10 ft. long and 30 in. wide. The bottom is of No. 20 galvanized iron, and the sides are of oak. Above the bottom is another sheet of galvanized iron, called the false bottom, perforated with slots, and held ¼ in. above the bottom by strips. Both bottoms are bellied downward lengthwise toward the middle of the table. The table is suspended on hangers, giving a lengthwise movement of 3 to 6 in., allowing it to strike a percussion post. Water is fed at the head, water and coal at the middle. The motion is slow when departing from the bumping post and accelerated rapidly as the bumping post is approached. The table is jarred on the slow return stroke, allowing the slate to settle. When the blow is struck the slate is moved toward the head end, stroke by stroke, while the coal is dropped off the tail end on the return. Each table washes 40 to 45 tons of coal per day, consuming ½ horse-power, using 300 gallons of water per ton of coal. The cost of washing is 2@3c. per ton of coal. One attendant manages 6 machines. The size of the coal treated is: Through ¾ in. on ½ in., 26%; through ½ on ¼, 33%; through ¼ on ⅛, 17%; through ⅛, 24%. Sulphur is reduced from 4.20% to 3.18%; ash, 10.73% to 8.56%.

The *New Breaker No. 5, Lehigh and Wilkesbarre Coal Company,*‡ is one of the latest and most complete in the Pennsylvania anthracite region. It has a capacity of 4000 tons per day, and is a double breaker; that is to say, either side can be worked independently of the other. A car load of mine coal weighing 6337 lbs. yields 4922 lbs. of merchantable coal and 1415 lbs. of refuse. The preparation of this coal is accomplished without the use of washers.

The *Hibernia Concentrating Mill*§ has a 500-ton receiving bin. The machinery consists of one 15 by 24 Buchanan breaker, two 5 by 30 Buchanan double jaw granulators, two sets Buchanan steel rolls 36 by 18 in. and one set 24 by 14 in., two revolving screens 3 ft. by 10 ft., and two hexagonal screens 6 ft. by 10 ft. The electric plant consists of one Edison dynamo giving 100 ampères and 110 volts, and two modified Buchanan magnetic separators fitted with non-magnetic belts over the rolls. Instead of feeding the ore directly upon the rolls, as formerly, the mill works by gravity throughout, except where elevators are used. The tailings are deposited automatically 200 ft. away from the mill. The mill is built in halves. If one half stops, the other half can be speeded to three-quarters total capacity, which is from 200 to 300 tons of crude ore per day.

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* F. Poech, *Oest. Zeit.*, 1893, p. 313.

† *Engineering and Mining Journal*, Feb. 11, 1893.

‡ *Ibid.*, July 29, 1893.

§ *Iron Age*, Aug. 3, 1893, p. 202.

Combined Wet and Dry Concentration.[*]—The coarse work is done by spalling, crushing and jigging with little loss. The table work, however, gives much loss. To overcome this, a combined dry and wet system has been devised: (1) Pulverization in a Krupp-Gruson ball mill, saving the dust. (2) By a centrifugal device consisting of a rotating disc of 45 centimeters diameter, revolving 3000 times per minute on a vertical shaft. The particles are thrown outward against an incoming draught of air. A circular receiver with annular troughs, having a center pipe out through which the dust is drawn by a suction fan, serves to catch the grains, graded according to their momentum. (3) These annular products are sifted, and yield pure pyrite, the concentrates passing through the sieve and the refuse quartz lying on the sieve. The inner rings are usually too poor to work, but with complex ores they need to be sifted. An Australian ore required a sieve from 65 to 200 meshes to the inch, for troughs 1 to 16. The finest sieve ever used was 380 mesh. (4) Wet concentration. The finest portions are worked on Bilharz percussion vanners, and yield poor heads with very little middlings. The sifted products, as well as the dust from the chamber, are also fed on this belt. 2250 kilos Peruvian gold quartz containing pyrite yielded dry 56.40%, wet 17.20%, total 73.60% of the value, assaying 50 grams per 1000 kilos. 2000 kilos Cordillera quartz with pyrite, assaying 43 grams per 1000 kilos, yielded dry 74.80%, wet 5%, total 80.60%. 1500 kilos Transylvania quartz slate, free gold and pyrite, assaying 17 grams per 1000 kilos, yielded dry 65%, wet 28.50%, total 93.50%. The greater part is concentrated by the dry method, which yields very high grade products. That which is to be washed is thoroughly graded for wet treatment before it reaches the water. Two crushers, 6 ball mills, 4 centrifugal separators, and 2 Belhartz tables treat 50 tons in twenty hours.

Ore Dressing in Maiern, Austria.[†]—Concentration of galena and blende. The mine ore fed to a grating yields lump and fines. The lump is picked into clean lump blende; galena and gangue which is sold, and gangue which is waste; blende and gangue which is roasted, crushed with rolls, sized on screens, concentrated with the magnet, and the gangue then washed out on jigs. The mine fines are washed, yielding blende, two grades of impure blende, and two grades of impure galena, which are sold, and gangue which is waste. The two grades of impure blende are roasted, crushed with rolls, sized, treated with a magnet, and then washed to remove the gangue. The sizing is done upon jigging sieves and trommels and the washing is done upon jigs and tables.

Plain versus Corrugated Belts for Vanners.[‡]—Gold ore was crushed and stamped through a 12-mesh screen, then sent to a hydraulic separator, the coarse part jigged and the fine settled in a tank. This fine pulp from the tank was divided, part going to the plain belt and part to the corrugated belt, care being taken to have each belt receive exactly equivalent material. The inclination of both belts was 3½ in. in 12 ft. The minerals contained in the ore were sphalerite, tetrahedrite, pyrite, galena, chalcopyrite, arsenopyrite, and ruby silver. The figures given below are averages for six days, and therefore represent an average day for the machine. In the paper eight other results are also given.

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[*] Pape-Henneberg, *Berg- und Hüttenmännische Zeitung*, 1893, p. 190.

[†] J. Billek, *Oest. Zeits.*, 1893, pp. 39, 51.

[‡] Otto Pfordte, *Transactions American Institute of Mining Engineers*, 1892–93, p. 280.

Plain Belt.				Corrugated Belt.			
Concentrates, Lbs.	Assay, Oz. per Ton.	Contents, Oz.	Tailings, Oz. per Ton.	Concentrates, Lbs.	Assay, Oz. per Ton.	Contents, Oz.	Tailings, Oz. per Ton.
513	121.7	30.7	5.3	792	103.3	43.6	3.8
722	144.5	52.8	4.9	1,120	124.7	67.7	2.7

Averaging all of the results, the author says:

When the plain belt gives,	in quantity,	100, corrugated belt will give	146.3
" " "	in assay,	100, " " "	86.2
" " "	total silver saved,	100, " " "	125.3
" " "	tailings assay,	100, " " "	67.4

*Dressing Tin Ores in Cornwall.**—A complete outline of the present state of tin dressing in Cornwall. Spalling, crushing by machinery, or breaking by hand with hand sorting, gives stuff with 2% of black tin and refuse. The 2% black tin rock is crushed by Cornish stamps, California stamps, or by the Husband pneumatic stamps. From these the pulp runs into stripes 10 meters by ½ meter wide by ½ meter deep, which are in groups. One of them is being filled while another is emptied by shoveling. The upper end yields heads, the middle part middlings, and the lower tails, while the slimes run over the end. The heads, middlings, and tails are run separately upon round, convex, and concave building huddles. The slimes go to hand frames and dead frames. Frames, round pits, slime pits, and keeves are used for the final concentrating, the middlings and tails of the round tables going to pulverizers. The ores are roasted and washed to remove copper sulphates and oxide of iron. The removal of wolfram by sintering with soda ash has proved non-renumerative. Wolfram therefore, as far as possible, is picked out by hand. The final product contains 65% black tin.

Losses in Dressing Cornish Tin Ores.†—Owing to the more finely disseminated condition of the tin stone as the mines get deeper, the stamp screens have been reduced to No. 35 or No. 36, B. W. G., increasing, however, the slimes so that nearly 50% of the slime tin is still lost. The mines of Carn Brea Hill saved 7558 tons of black tin in 1890 and 8234 tons in 1891, while the stream workers in 1890 saved 1302 tons and only 879 tons 16 hundredweight in 1891, owing to the improvements in the dressing works. The tailings, however, still carry away 20% of their original tin, or 8 lbs. per ton. Of the 405,000 tons annually flowing into the Red River this would give 1000 tons of black tin, or £100,000 per annum.

Hicks Double Decker Revolving Frame‡ is a combination of a concave, conical concave slime table above, and a convex conical slime table below. The tailings of the upper table are re-washed on the lower. The machine is used in Cornwall on the tin ores.

Testing Clays.§—This paper describes experiments upon the testing of clays by the washing process for the separation of clay, mica, quartz, and feldspar.

Review of the Methods of Washing Clay.‖—The old established system of freezing and weathering is still much used to-day. Mechanical disintegrators in some

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* L. D. Demaret, *Revue Universalles*, 1893, Vol. XXI., p. 287.

† *Engineering and Mining Journal*, April 1, 1893.

‡ *Ibid.*, p. 295.

§ J. Vogt, *Thom. Ind. Zeitung*, 1883, p. 140.

‖ Hotop, *Thom. Ind. Zeitung*, 1893, pp. 632, 660, 707, 813, 838.

cases succeed, in others not. The methods of separating the coarser parts, of catching the fine clays, allowing them to subside, removing the water, and the subsequent draining, are critically reviewed, referring to the apparatus at present in use.

Natural and Artificial Ore Dressing.[*]—Hoppe reviews at some length the work of von Sparre, Rittinger, and Jarolemek. He criticises them for their tendency to speculate mathematically without sufficient experiment, and concludes by stating that there are three tests which will solve the questions of ore dressing in any case.

Jigging Mine Fines or Unclassed Particles.[†]—Mine fines by jigging alone can yield at least 50% of their non-included grains between 18 mm. and 2 mm., and can also yield pure galena, pure blende, and an enriched intermediate product. The author further says that Munroe's formulæ may do for a "heber wasche," but will not do for a jig any better than the formulæ of von Sparre, Rittinger, and Jarolemek. Only experiment and careful observation can solve the jigging problem.

The Choice of Coarse and Fine Crushing Machinery and of Processes of Ore Treatment.[‡]—This is a valuable contribution to the literature of the subject, discussing the various coarse and fine crushers and giving facts and figures upon them. The paper appeared in the *Transactions of the Federated Institution of Mining Engineers.*

Report of the Commission on Waste of Coal Mining.[§]—The total contents of the anthracite coal fields at the beginning of mining operations are estimated at 19,500,000,000 tons; up to Jan. 1, 1893, there had been mined 902,000,000 tons. The coal won is 30% to 35% of that contained in the area mined, so the total amount exhausted is 2,255,000,000 tons. The amount left in the ground is 17,245,000,000 tons. Assuming that 40% of this can be won, the total available supply is 6,898,000,000 tons. The amount of coal and coal dirt sent to the culm banks since the beginning of mining is estimated at 35% of the production, or 315,700,000 tons.

The saving of a fraction of this loss seems to depend upon two things: (1) The further development of dressing appliances; (2) the further development and introduction of methods of utilizing the fine coal when it has been saved.

The report of this commission is of great value.

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[*] *Zeits. f. Berg. Hütten und Salwesen*, 1893, Vol. XLI., Part I.

[†] Hoppe, *Verein Deuts. Eng.*, Vol. XXXV., p. 1213.

[‡] A. G. Charleton, *North of England Inst. of Mining Engineers*, Dec. 10, 1892.

[§] Eckley B. Coxe, Heber S. Thompson, and William Griffith, Philadelphia, May, 1893.

THE DEVELOPMENT OF VIEWS ON THE ORIGIN OF ORES.

By J. F. Kemp.

The views of the ancients regarding ore deposits belong rather to the curiosities of literature than to the serious records of science. No inconsiderable mining was done by them, especially in those metals which are easy of reduction or are found native, but superstition played a large part in their reasoning on structure and origin, and their insight into the auxiliary sciences was slight. Two writers only are of much moment—Diodorus Siculus (44 B. C.), who wrote a general history and description of the known and accessible countries around the Mediterranean, and Pliny the elder (A. D. 23—79), whose treatise on natural history gives us our most extended acquaintance with the science of the ancients. Both these writers speak of veins as such, especially in connection with gold.*

During the next 1400 to 1500 years little appeared of any moment, for there was hardly any scientific intellectual activity. When, however, attention was directed to the geological and mineralogical phenomena of veins, the awakening transpired in those two time-honored mining districts, Cornwall and Saxony, and in the latter first of all. From 1490 to 1555 Agricola lived near Freïberg, in Saxony, and was a physician. His family name really was Georg Bauer, but as he wrote in Latin he translated it into a classic form.† Surrounded by mining, his attention became directed to the phenomena of minerals and veins, and, being a close observer, he wrote of them with much scientific acumen. He referred veins to filled cracks, which had originated either in the upheavals of mountains or by the dissolving out of cavities by subterranean streams. Into these cavities the ores and gangue minerals filtered as small particles, and then hardened under the influence of heat and cold and by the accession of a third ingredient, that he called or imagined as "rock sap." But he considered them all to have formed at the creation of the world. The value of these views, although somewhat untenable in minor points, comes out with the greater force when we read in his successors, as in his predecessors, that the sun and the planets were strong factors in the origin of ores, and when we note the mixture of astrologic nonsense with alchemic teachings

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* A brief outline of the views of these writers is given in Werner's *Neue Theorie von der Entstehung der Gänge*, Freiberg, 1791, pp. 7-9.

† Agricola's great work is entitled *Bermannus sive de Re Metallica*, Basel. 1530.

which influenced many. Even the great deluge of Noah's time was regarded as a vein-filler by some. Nevertheless, practically all our later views were more or less vaguely foreshadowed and in time took definite shape. This development was aided by the advances in geology, mineralogy, chemistry, and physics, and in the first named especially by the work done in Italy by Steno and others. The dates of the suggestion and advocacy of the several methods of origin may be seen from the following table, which is adapted from Von Herder (*Schrift über den tiefen Meissner Erbstolln,* 27, 1838; Von Cotta, *Erzlagerstätten,* p. 175, 1859):

1. Contemporaneous formation with the walls: Stahl (1700), Zimmermann (1746), Charpentier (1778), Terebra (1785).
2. Lateral secretion: Delius (1770), Gerhard (1781), Lasius (1789).
3. Descension: Baumer (1779), Werner (1791).
4. Ascension by (*a*) Infiltration: Lasius (1789); (*b*) sublimation with steam: Lehman (1753); (*c*) sublimation as gas: Becher ? (1703).

A glance at these dates will show that Werner is the latest of all. The ideas were, almost without exception, advanced in books on mining or kindred practical subjects. Substantially all of the theoretical views held to-day are outlined, except that of replacement.

More extended mention should be made of Abraham Gottlob Werner (1750–1817), who issued, in 1791, when professor at the Freiberg Mining School, his *Neue Theorie von der Entstehung der Gänge* (New Theory of the Origin of Veins). The drift of the book is to establish the filling of veins by precipitation from overlying solutions. It is an extremely interesting little work, and while fuller geological knowledge has made its main thesis seem seldom applicable to-day, it contains many observations and descriptions of structural features which are of much more than mere historical value. Werner's influence upon his contemporaries and upon the German geologists who followed him was remarkable and profound; but it is a curious fact that, however devoted to him his followers were, they soon drew other conclusions regarding origin from their own observation of veins, and in only one or two notable cases since has the "descension" theory received adherence.

Until after 1850, the time of Von Cotta's activity (1808–79), the scene of greatest interest changes to England, except so far as ore deposits were, as a minor feature, concerned in Bischoff's great *Chemical and Physical Geology,* which was issued in 1847. Much attention was directed to these subjects in England in the years following 1825. This led the British Association to appoint a committee, which reported in 1833, on the "State of Knowledge Respecting Mineral Veins."[*] The data recorded especially concern Cornwall, but they also indicate the great interest that was felt regarding terrestrial electrical agencies as a cause of the precipitation of the ores and gangue minerals in veins. The experiments of Fox[†] and Henwood[‡] quickly followed this report. Notwithstanding the inability of the investigators to establish any important electrical agency, the possibility of their influence took a strong hold on even so careful an observer as

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[*] *Proc. Brit. Asso. Adv. Sci.,* Vol. III., p. 1. The report is by John Taylor.

[†] *Trans. Roy. Geol Soc. Cornwall,* V., 415, 1843. The experiments were made in 1836.

[‡] Jamison's *New Philosoph Journal,* XXII., 142, 270. Edinburgh, 1837.

De la Beche. Later experiments by Reich* of the Freiberg Mining Academy, and Barus † of the United States Geological Survey, have left the question still a more or less open one. De la Beche's great monograph on the *Geology of Cornwall, Devon, and Somerset* appeared in 1839. He traced out and plotted the two or three great systems of faults in Cornwall along which the veins lie, discussed the varying richness in different wall rocks, and concluded that the mineral veins had resulted from the filling of fissures in rocks, by chemical deposits from substances in solution in the fissures, such deposits being greatly due to electro-chemical agency. This book was for many years the authoritative treatise in England, and exerted a powerful and eminently beneficial influence.

Many descriptive works of great importance are passed over in this review, because the purpose is briefly to indicate the growth of theoretical views. As the igneous nature of many dike rocks, that are so frequently associated with ore bodies, became appreciated, it was natural to esteem veins as of similar origin. Von Cotta states that such conceptions were widely held in the earlier years of the present century, but they found most definite and authoritative expression from J. Fournet, a distinguished Frenchman, who published in 1856, in the *Comptes Rendus*,‡ a labored endeavor to establish them. The paper is a good example of special pleading, and its propositions, being mostly rejected to-day, are not further considered here.

The great *Chemical and Physical Geology* which Gustav Bischoff brought out in 1847 was a potent factor. The author sought to explain geological phenomena by the laws of molecular action, and thus tended to establish reasonings about the origin of ores upon a definite chemical basis. Breithaupt's monograph on the paragenesis of minerals (1849), *i. e.*, on pseudomorphs, exerted a similar influence.

In 1854 J. D. Whitney published his invaluable *Metallic Wealth of the United States* He brought a wide experience in American and foreign regions to bear on the task and produced a most philosophical and suggestive work. The various theories of origin are discussed, and a scheme of classification suggested which was adopted, almost without change, by subsequent American writers for nearly forty years. Professor Whitney leans more strongly to eruptive methods of origin for certain iron ores than later work has corroborated, but in other respects his views have stood very well.

Of world-wide scope is Von Cotta's *Lehre von den Erzlagerstätten* (1859), (Treatise on Ore Deposits), first published in the magazine *Gangstudien*, II. (Studies in Veins), in 1854. Prime's translation, issued in New York in 1870, placed this admirable work within reach of English readers. It presents an excellent general discussion of the subject, and an encyclopedic description of ore bodies the world over, so far as then known. The author wisely concludes that ore bodies are of endless variety and that one method of origin does not apply to

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* Reich was professor of physics at Freiberg. His experiments were conducted in the neighborhood. Karsten's *Archiv.*, 1840, Vol. XIV.; Poggendorf's *Annalen*, Vol. XLVIII. 287; *Berg- und Hütt. Zeitung*, 1844, 342.

† Monograph III, *U. S. Geol Surv.* and *Amer. Inst. Min. Engineers*, XIII., 417.

‡ *Comptes Rendus*, XLIII., 1097-1105. An excellent abstract will be found in Leonhard's *Jahrbuch* (now the *Neues Jahrbuch*), 1856, 586, 725.

all; but as for veins, he inclines to the belief that they have been precipitated from aqueous solutions, and that the material has mostly come from below. Johann Grimm, in his *Lagerstätten der nutzbaren Mineralien* (Deposits of Useful Minerals), published in 1869, reaches much the same conclusion. Von Groddeck, in his *Lehre von den Lagerstätten der Erze* (Treatise on Ore Deposits), 1879, seeks to draw, from what is known of the original crystallization of minerals in nature, from characteristic occurrences, from their formation in furnaces, and from their artificial experimental production, conclusions as to the development of ore bodies, especially in veins. He leans, if anything, less decidedly than most of his contemporaries to ascending solutions, seeing the possibility of other methods. None the less, too much praise cannot be given to his work, for the writing of which his wide knowledge, his philosophical mind, and his candor eminently fitted him. Phillips's *Treatise on Ore Deposits* (London, 1884) is most valuable in its descriptive portion, but develops less that can be specially cited in its theoretical matter. Kemp's *Ore Deposits of the United States* (1893) aims to trace in a logical sequence, from the least to the most extended, the development of those cavities in rocks which might afford channels for circulations bearing minerals, and then to range these in a table of classification of ore deposits under well-recognized and familiar geological names. With such are grouped those ore bodies which can rightly be referred to an igneous form of origin, or to mere mechanical concentration in moving water. Posepny's essay on the "Genesis of Ore Deposits," which has just been issued in the *Transactions of the Institute of Mining Engineers*, follows in the main much the same line of treatment. The great work of Fuchs and De Launay, *Traité des Gîtes Minéraux et Métallifères* (Treatise on the Deposits of Minerals and Metals), 1893, gives no general discussion of ore deposits, but describes those of each metal by themselves. It is not easy, therefore, to get a general impression of the standpoint of the authors, but it may be said that the work is thoroughly up to date and affords an extended view of the present state of knowledge.

In *résumé* of what has been stated in this necessarily brief outline of general works, it may be added that for many ore bodies there is little doubt as to the method of formation. This is specially true of those forming true beds and of those forming mechanical concentrations. Any good treatise will make these clear. When, however, we come to fissure or other forms of veins, and to metamorphosed ore bodies, there is more or less divergence. The latter are undeniably obscure, and furnish hard problems. In regard to the former, geologists are generally divided between the filling by lateral secretion and by infiltration by ascension, with perhaps rather more holding the latter view. For other forms of ores, such as contact deposits, more or less irregular bodies in limestones, and the like, a method of origin by replacement is justly esteemed. Certain special papers bearing on these particular interpretations may now be briefly noted.

Prof. F. Sandberger of the University of Würzburg has given some new vitality to the idea of lateral secretion. For nearly twenty years he has been working at the problem, and while his later papers show that the theory now holds him, rather than he the theory, he has given the scientific world some important data, and has helped to locate the most probable source of the metals in definite minerals.[*] By investigating large amounts of the dark silicates of wall rocks with refined chemical methods, Sandberger has shown in them the presence of many of the metals, often the very ones found in neighboring veins. But what is true in this way for rocks at the surface also holds for rocks in depth, and whether comparatively cold surface waters are as likely to take insoluble minerals in solution as are the more heated solutions coming from below is not a difficult question to decide. Nevertheless there are cases where the method applies, and an interesting discussion was held at the Butte (Mont.) meeting of the American Institute of Mining Engineers, July, 1877, developing the fact that some of our best men were lateral secretionists.

There has been for twenty years past a growing conviction among mining geologists that a great original cavity was not a prime necessity for the formation of a large ore body, but that a comparatively small supply channel, coupled with replacement of the wall rock, would suffice. This form of origin finds its most extended application in silver-lead deposits in limestones, and such are usually associated with igneous intrusions. It was first extensively developed by Posepny, at the silver-lead deposits of Raibl,[†] in the Austrian province of Kaernthen. In this country it has found extended adoption—Emmons at Leadville,[§] and Curtis at Eureka, Nev.,[‡] have esteemed it the most reasonable explanation in those districts.

According to replacement, the wall rock is supposed to react on the ore-bearing waters in such a way that the ore is precipitated while the rock passes into solution. For a less resistant rock, like limestone, this has many claims to confidence; but it is not so easily explained when applied to more insoluble ones, although cases have arisen wherein even for these it seems the most applicable hypothesis. None the less, there are many points about the chemistry of the process that need further investigation.

While, as stated above, the method of the origin of certain ores by igneous injection has found few modern supporters, a modification of it as applied to masses of iron oxides or sulphides in basic igneous rock has strong claims to confidence. Thus, microscopic study of rock sections has shown that these minerals are universally present in all igneous rocks, though in small amount in all the acidic ones. They are among the first to crystallize. Microscopic work, in this accurate determination of minerals themselves and of their succession in order of formation, has done us a real service; and now that we are greatly increasing our knowledge of their chemical and profound genetic relationship, we may expect other no less significant advances as regards the inclosed ore deposits. In Rhode Island, Minnesota, Sweden, Brazil, and the Adirondacks the passage of basic rocks, of the peridotite, gabbro, and nephelinite families, into masses of iron oxide has been recorded, and there can be little doubt that in this excessively basic development of an already quite basic magma large masses of iron ore can and do originate. Still, in all instances yet recorded, they are highly titaniferous,

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[*] His most important paper is *Untersuchungen über Erzgänge* (Investigations of Mineral Veins), Wiesbaden, 1882; but a long list is cited by A. W. Stelzner in the *Berg. u. Hüt. Jahrb der K. K. Bergakademien zu Leoben und Pribram*, etc., XXXVII., 1889. See also the *Engineering and Mining Journal*, March, 1884.

[†] *Jahrbuch d. K. K. geol. Reichsanst.* (Annual Report of the Austrian Geol. Survey), 1873, XXIII., 317.

[‡] *Monograph VI, U. S. Geol. Survey.*

[§] *Monograph XII., U. S. Geol. Survey.*

and as yet of no great practical value. The same method has been advocated by Vogt of Sweden for bodies of nickeliferous pyrrhotite in connection with diorite.

Widening experience has served to show how frequently igneous rocks are associated with ore bodies, and this association cannot be devoid of significance. In former years the importance of these as stimulators of circulations was not as well appreciated as it deserved, for a moment's consideration will indicate that there is no other natural agent so likely or so well adapted to play this rôle. Nevertheless some of the older writers were so prejudiced in favor of sedimentary rocks as sources of ore and as wall rock, that even the most significant phenomena of an igneous character were overlooked. The daily increasing literature, especially in the West, seldom fails to mention dikes or sheets in the same neighborhood as ores.

For the future the lines of work of greatest promise are in careful investigations of problems in chemistry and structural geology. It is not always easy to bring the reactions within the range of actual experiment in the laboratory, or to find them in nature sufficiently concentrated to yield their secrets to analysis, yet by such investigations the solidest basis of theoretical inference will be laid. The work of Mr. Becker and his associates upon the solutions which were "caught in the act" in or near certain quicksilver mines on the Pacific coast is of great importance in this connection, and further work upon the chemical relations of metallic sulphides and solutions of alkaline sulphides or other salts, and upon the influence exerted on them by attainable temperatures and pressures and by various wall rocks, will be hailed as a welcome addition to our knowledge. Careful observation and record of features of structural geology, both in individual ore bodies and in great groups of the same, will undoubtedly be fruitful of results, and we may hope that even some puzzling varieties, which it has been possible to describe only by very general and indefinite terms, such as stock and stockwork, will in the future reveal their connection with well-understood geological phenomena. Veins and fissures are essentially surface phenomena when compared with the radius of the globe, and can no longer be considered to penetrate to greath depths or the "ewige Teufe (Tiefe)." When the distance from the surface becomes great, the doctrine of "isostasy" of Dutton and the experiments of King and Barus indicate that the rocks become so plastic that any cavity would be kneaded together. We may, however, console ourselves with the reflection that this is below the limit of practicable mining.

It is to be continually and strongly urged that the increasing number of men engaged in mining who have the requisite geological training intelligibly to record the phenomena which come under their daily observation will thus add to our knowledge. Especially in America, with our great variety and extent of ore deposits, should this hold true. Past experience leads us to expect that the specially suggestive and fruitful ideas will be advanced in individual and scattered contributions, which the general treatise then binds into a connected whole and makes available for a wide circle.

ADVANCE IN METHODS OF STONE QUARRYING.

By William L. Saunders.

The art of quarrying—or, more generally speaking, the excavation of rock in open trenches—made its first great advance when gunpowder was introduced in a drill-hole. Prior to that time to remove a ledge of hard rock which was not laminated by seams was a difficult and expensive operation. As many of the rocks of the Old World were soft and of lime formations, the chisel and the hammer enabled the quarryman to build monuments and works of magnitude at an expense perhaps no greater than that involved to-day in the excavation of harder and more durable stone. The Pyramids were built mainly of soft rocks, sometimes protected by an outer layer of gneiss, and in the case of the obelisk we have an illustration of hard gneiss rock quarried without the aid of gunpowder or the steam channeling machine. At one of the old quarries in Egypt an obelisk partly quarried, yet remaining in its natural bed, bears evidence that the ancient Egyptian knew the art of working metals, and actually drilled a hole with, perhaps, a steel tool. A number of holes were drilled side by side, as one postage stamp is separated from another, and when the partitions were broken down the obelisk was formed and ready to be lifted out of the quarry.

The quarries of the ancients, notably those of Italy, were situated on mountainsides, so that only a mere dislodgment was necessary to throw down large masses of stone, which were afterward cut and dressed to proper proportions. Outcroppings of this kind were worked cheaply and do not really require machinery for excavation and lifting. In America the deposits are not so favorably situated, except in localities from which it would not pay to freight the stone. The necessity for machinery is most felt in those excavations which go down into the ground, and which are surrounded and bound in by walls of stone. The cost of transportation cuts so large a figure in the stone business that it becomes a necessity to provide appliances which will enable the quarryman to open that bed of stone which lies nearest the market; hence the rock drill, the channeler, the Knox system, and other modern American appliances have been generally adopted wherever the conditions admit of their use.

Next in line of advance, though several centuries after the introduction of gunpowder, came the channeling machine. Born in Vermont, where the marble quarries were worked in solid deposits, it was almost a necessity that some means be provided whereby a groove or open seam might be cut in the marble for the purpose of releasing it in blocks. A blast of any kind was dangerous in its destruction of valuable stone, and, furthermore, the blast did not enable the quarryman to follow and preserve his best veins. The first steam channeler was built upward of thirty years ago, and consisted mainly of a gang of chisels reciprocated by cams worked by a stationary engine, which was placed on a truck, the whole moving like a locomotive on a track in the quarry. The modern channeler, an invention only a few years old, is a compact, direct-acting machine, built on the principle of a percussive rock drill; that is, the chisels are attached rigidly to the piston-rod of the engine and the blow is direct and rapid.

The Knox system of blasting came after the channeler, and was thought by many to be a substitute for it. Though undoubtedly an improvement of great value to the quarryman, quite equal in importance to the channeler, the Knox system has found its place distinct from the channeler, in some quarries working side by side with it, and in others doing work which could not be done at the same cost with a channeler or with any other machine. The Knox system is a means by which a blast in a drill-hole is made to act in prescribed directions. By cutting the walls of a round hole so that there is a greater area of pressure for the powder to act on one or more sides of the hole, the stone is broken in a straight line and without loss in stock. About 300 of the largest stone quarries in America use the Knox system, and it has saved thousands of dollars in the cost of production.

During the past year an improvement of much value has been made upon the Knox system by what is known as the Githens system. A Knox hole is first drilled round, and then a reamer is used to change the section of the hole so that the effect of the blast may be directed. The Githens system drills in one operation a Knox hole, thus doing in one stage what has heretofore been done in two. Furthermore, a Githens hole is oval-shaped with one axis very much longer than the other, thus insuring a well-directed and reliable break, extending to a greater distance in the quarry than can be accomplished by the old system. The Githens system is the first practical means by which holes have been drilled in one operation, and of the same size and shape as the bit. If the bit is triangular the hole is a triangle, and it is possible with this system to drill a hole in rock of almost any sectional shape. The importance of this in enabling the quarryman to direct the fracture of the stone cannot be overestimated. The day is not far distant when the Githens system will find its way into the most important dimension stone quarries, and so great is the simplicity and economy of the method that it is likely to find a wider application. It is possible to channel by the Githens system by drilling Githens holes on a straight line and interlocking.

Another application of the system is in tunnel driving, where it is now so difficult and costly an operation to make the first or center cut. This cut is made by a series of holes converging, and when blasted the result is a wedge-shaped trench cut into the face of the heading. The purpose of this trench is to provide a release line for subsequent blasts. It is plain that an open seam of perhaps only one-half or three-quarters of an inch in diameter would serve the purpose, and such a seam might be made with a Githens bit.

In looking for a practical example to illustrate the present condition of the art of quarrying one naturally thinks of the Chicago Drainage Canal. Here is a piece of work of great magnitude and importance situated near that great and progressive city of the West where we may expect to find the best modern appliances for quarrying stone. The work on the drainage canal is of special interest from the standpoint of a quarryman, because it is the first application of the channeling process to a case where the stone quarried is of less value than the space which it occupies. In other words, the excavation is not for the purpose of producing stone, but to make an open trench. The outer walls of the canal are cut with channeling machines. These channels are 160 ft. apart and extend to the full depth of the cut.

The Chicago Drainage Canal has been projected primarily to provide an outlet or discharge for the sewage of Chicago, and secondly, to open a waterway for navigation from Chicago to the Mississippi River. Chicago is built upon a tableland elevated but a few feet above the level of the lake on one side and the plain of the Desplaines River on the other. The Chicago River, which has its source north of the city, and which reaches its outlet into Lake Michigan at Chicago, traverses a section of the country which has caused it to incline alternately east and west, as though hesitating whether to discharge into the lake or to follow the open country down through Joliet and into the Mississippi. The Desplaines River follows the Chicago and runs parallel with it; but being several miles to the westward, it turns away from the lake and empties into the Mississippi. The people of Chicago have determined to take their drinking water from the lake, hence they must provide another outlet for sewage. At present the Chicago River, which receives the sewage, is checked, or partly so, in its effort to reach the lake by the pumps at the Bridgeport station, which lift the river water into the Illinois and Michigan Canal, and thence to the Mississippi. The drainage canal is to take the place of this small connecting ditch and is to form an outlet for the Chicago River. As at present projected the canal involves the excavation of 24,000,000 cu. yds. of material, about half of this being rock. This means that we have in this work the largest piece of rock excavation that has ever been attempted in America. The quantity is five times greater than was removed on the New York Aqueduct tunnel, and an engineer has estimated that if the whole of the spoil bank of rock and earth from Chicago's great ditch were used in building pyramids, a half dozen the size of Cheops would rise from the plain.

The rock removed is uniformly Joliet limestone. Illinois stands first in the list in the table prepared for the Eleventh Census showing the relative standing of the States producing limestone for building purposes. Most of this comes from the Joliet region, situated near and along the line of the excavation now being made for the drainage canal. The stone belongs to the dolomite class, is non-crystalline, and differs but little from what is commonly known as limestone so broadly distributed through the Middle States of America and throughout Europe. The stone which underlies the city of London may be fairly compared with this limestone.

The Joliet, and other quarries in the vicinity, produce the stone for building purposes, flagging, etc. Much of the rock excavated on the line of the canal might be transferred and used for these purposes, yet the quantity is so large, and as the effort has been made to get rid of the rock as quickly and as cheaply as possible, no attention has yet been paid to its production as dimension stone. The channeling machines work ahead of the excavation, cutting to a depth of about 12 ft. on each side of the canal. As the depth of the excavation is about 30 ft., the work is done in benches of about 10 ft. in depth each. In other words, after the machines have cut the channels from the top down, the drill-holes are put in and the rock excavated in sections from 10 to 12 ft. deep and covering the entire width of the canal. Afterward the channeling machines are lowered, another cut is made, and the blasting follows as before. Taking any one of these sections and we have in the drainage canal trench an admirable condition of things for dimension-stone quarrying. The stone is horizontally stratified, breaks in square blocks, and after the channels have been cut all of the faces but one are released; hence it would be an easy matter by plugs and feathers, or by the Knox system, to produce regular blocks of marketable building stone. Except in the use of plugs and feathers, or the Knox system, the drainage canal may be closely compared with a dimension-stone quarry, but it serves its best purpose as an illustration of the best modern methods of general rock excavation in open trenches, and in the use of the channeler we have a new feature in this class of work.

Channeling machines cannot, of course, release the walls of a rock-cut as cheaply as they might be released by blasting, hence it might be supposed that the cost of the work—or, rather, the contract prices—would be materially affected by the channeling qualifications. As a matter of fact, but little consideration was given to the channeling by the contractors, and the rock work was let, and is now under way, at from 73c. to 80c. per cu. yd. These figures are exceptionally low, yet it is evident that they are not too low to insure a profit to the contractors. It has been found that the channeling costs about 15c. per sq. ft. of wall channeled, or about 5c. per cu. yd. of rock removed. The contractor, of course, gets some benefit from the channeling, because it releases his bench at the walls, but this benefit does not compensate him for the expenditure, and the only benefit that can be attributed to the use of the channeling process on this work is to the canal itself, in that a substantial, smooth, and intact wall is maintained for wharfage, use as a tow-path or road, etc., and the flow of water is not impeded by jagged or broken walls. Another point of advantage is that no claims are likely to arise for extra work beyond the limits of the canal. It is well known that in tunnel work, notably on the New York Aqueduct, claims were made by the contractors for excavation beyond the neat line because it was found impossible to prevent the breakage or falling in of large quantities of rock, and it is fair to say that the contractor should be paid under such circumstances. It is difficult to tell what the effect of a blast is going to be when the drill-hole is bound in all directions. The release cut made by the channeler prevents any destruction or shattering beyond the limits of the canal itself, and it is safe to say that buildings might be erected close to the bank of the Chicago Drainage Canal without danger.

The only channeling machines in use on this work are of the direct-acting type known as Ingersoll-Sergeant and Sullivan machines. These machines are similar in principle and operation. In cutting capacity they average, perhaps, 100 sq.

ft. of channel per day of ten hours. By this is meant a channel 100 ft. long and 1 ft. deep; or 50 ft. long and 2 ft. deep; or 25 ft. long and 4 ft. deep. Each machine weighs about 10,000 lbs., and comprises a direct-acting engine carrying a gang of chisels attached rigidly to a cross-head which is connected with the piston. A boiler is mounted on the truck, and the whole moves automatically while striking. The price of a channeler complete is $2000.

Twenty Ingersoll-Sergeant machines have been purchased by the contractors, and all of these except one are now at work on the canal; also twenty-five Sullivan machines, seventeen of which are used on Sections 11, 12 and 13, where the Sullivan Company has taken a contract to do the channeling by the square foot, the figures being about 15c. per sq. ft. of channel cut.

The drilling does not differ from that in use elsewhere. Ingersoll-Sergeant and Rand drills are used mounted on tripods, the sizes being from 3 in. to 3⅝ in. diameter of cylinder. The holes are put in from 10 to 12 ft. in depth, and as the rock is not very hard and is free from grit, the progress in drilling is very rapid.

While the channel has its advantages, yet it is questionable whether the engineers will be justified in requiring the contractors to use a channeler as against the Githens system. That this system may be used to disconnect the rock at the wall with equal safety, and that it will insure quite as straight and smooth a cut, there is little reason to doubt. The best engineering work being that which is best accomplished at least expense, it would seem that there can be no objection to the use of the Githens system, provided that by its use the same results may be attained at less expense.

The chief problem against which the contractors have had to contend is in the removal of the broken material. It is an easy matter to dislodge and break up the stone, and this is being done at an exceptionally low figure, but the difficulty is to get rid of it as fast as it is broken. The spoil bank is within 50 ft. of the edge of the canal and there is plenty of room for the rock. At first carts were used to advantage, but after getting down 10 ft. or more they became too expensive, and dump cars were used, pulled up a trestle incline by steam hoists. The cars were in some cases hauled by mules to the foot of the incline, and in others the hoisting rope was carried into the cut. As the work progressed it became necessary to provide something better than these inclines. The stone did not break in such fine pieces, and it was an expensive operation to lift heavy pieces of stone to the height of a dump car. A piece of stone weighing 200 or 300 lbs. could be crow-barred by several men into a skip, but it had to be blasted or broken by sledges before it could be lifted into a dump car. Several hoisting appliances have been introduced, notably the Brown cantilever and the Lidgerwood cable-ways. The cantilever has been more largely adopted than any other means. It consists of what appears to be a single bridge span mounted by central supports, the whole resting upon four-wheel trucks and traveling on a line parallel with the canal. The tracks are laid between the spoil bank and the canal. The truss inclines downward as it reaches over the canal and nearly spans the entire width of the excavation. The other arm of the truss rises above the spoil bank. The hoisting engine, connected with suitable machinery, picks up a loaded skip and lifts it along the line of the truss to any point over the dump. The work is rapid, and it has been computed that by this means the rock is picked up and delivered on the bank for less than 15c. per cu. yd. An objection to this is that it does not handle large blocks, hence much sledging and unnecessary blasting must be done. Furthermore, the cost of a single cantilever is about $28,000, a large investment to make in a machine which will be of little value to the contractor after completing this work.

The cable-way is similar to those used elsewhere, except that the towers with hoisting apparatus and all attachments move on rails laid on each side of the canal. The cost of a cable-way is less than that of a cantilever, and as it is mainly composed of hoisting engines, wire rope, and timber, it may be used elsewhere to advantage. The capacity of a cable-way is nearly if not quite equal to that of a cantilever, and it is possible to lift out larger blocks with the cable. What is really needed to remove this rock most economically is a hoist which will lift blocks of any size within, say, 25 tons, and deposit them at one operation upon the spoil bank. Not only can the stone be removed most cheaply in large blocks, but much of it may afterward be valuable for masonry work, and for this purpose it should be maintained in cubes of large sizes.

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The Opinions of the World

on the

Mineral Industry,

Its Statistics, Technology and Trade.

THE PROFESSIONS AND THE TRADE.

President Grover Cleveland, Executive Mansion, Washington : " I shall always prize the Mineral Industry highly not only for its own sake, but as an evidence of your esteem."

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WINTHROP W. FISK, Mining Engineer and Geologist, Boston, Mass.: "Vol. I. of the Mineral Industry is at hand, and I congratulate you most sincerely on the great success you have made of it, from the binding and general make-up to the vast amount of valuable matter to be found in it. The character of the advertisements shows conclusively the high standing of the *Engineering and Mining Journal*. The early appearance of the first edition of a work of such magnitude is a great credit to the ability and energy of an American institution, and is a worthy adjunct to the leading mining journal of the world."

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C. W. STICKNEY, General Manager, Phi Kappa Mining Company, Limited, Ketchum, Idaho: "I find the Mineral Industry to be the most thorough work of its kind ever attempted in the domain of mining and metallurgy. No one engaged in mining or metallurgy, or expecting to be so engaged, can afford to be without it. It is just what it purports to be, a correct photograph of the present state of the entire mineral industry of the world. I prize it as one of the most valuable of my reference books; for I find it completely filled with important information which one often wants in a hurry, and which is not to be obtained from any other easily accessible source."

JOHN HEARD, Jr., Paris, France: "I am confident of being one of a noble and large community of intelligent men when I bring, among the rest, my thanks and my slight tribute of admiration for what you and your staff, who have been able to accomplish, as it were in a day, what the many handed government idol has been unable to accomplish in much over a year and a day. The volume is a masterpiece of modern co-operation and it would be both interesting and instructive to read an article telling tersely how it was done. The book is a model of its kind. The only question that some little demon (who evidently does not like you) whispers in my ear is—'Ask him about Vol. II.'"

THE PRESS.

The *Republican*, of Denver, Colo.: "It is undoubtedly a very valuable work."

The *Mining Industry*, of Denver, Colo.: "It is a good illustration of business push, energy and ability, and is creditable to the Journal."

The *Post*, of Chicago, Ill.: "It is a very complete and valuable work on the mineral industry of the world from the earliest times to the end of 1892."

The *Engineering*, of London, England: "This publication contains within its 600 pages a wealth of information on the mineral production of all countries."

The *Journal of Commerce*, of New York: "It will prove of great value to all who have occasion to look up any question connected with the production or distribution of minerals."

The *Engineering News*, of New York: "The several technical articles are written by specialists. and the statistical matter bears evidence of careful preparation, and is well arranged."

The *Stationary Engineer*, of Chicago, Ill.: "The book may be considered as a cyclopædia of minerals and will be found most interesting and instructive to those interested in the subject."

The *Chronicle*, of Leadville, Colo.: "The book is of great statistical value and a treasure-house of information for the mining man, the metallurgist and all who are interested in this great industry."

The *Commercial and Financial Chronicle*, of New York: "The work is copiously indexed, and will undoubtedly be used as a standard reference by all seeking facts and statistics on mineral subjects."

The *Oil, Paint & Drug Reporter*, of New York: "It is a volume of over 600 pages, which will be found valuable for reference by all interested in the mineral and metal products of this and other countries."

The *Bulletin of the American Iron and Steel Association*, of Philadelphia, Pa.: "It . . . is one of the most comprehensive and ambitious statistical and technical compilations that has ever appeared in this country."

The *Times*, of Denver, Colo.: "It is much more exhaustive than the federal government's annual statement covering the same great industry, and there is no question as to its being received with more reliance."

The *Popular Science Monthly*, of New York: "It is the most comprehensive work of this nature which has ever been put before the public. . . . Mr. Rothwell is to be congratulated upon the very useful volume."

The *Water and Gas Review*, of New York: "The book is handsomely printed. It will be found an indispensable reference book, and is, as its publishers state, a veritable photograph of the entire mineral industry the world over."

The *Boston News Bureau*, of Boston, Mass.: "The amount of labor and money that has been expended on the work can only be realized by a close examination of the book. It should be in the counting-room of every merchant and banker."

The *Aspen Daily Times*, of Aspen, Colo.: "Its vast amount of statistical information, of great value to those interested in any form of mineral production, is backed by the painstaking authority of the foremost mining journal in the world."

The *Marine Review*, of Cleveland, O.: "The enterprise shown in undertaking a publication of this magnitude is highly commendable, and the comparative promptness with which the results have been presented to the public is especially creditable."

The *Public Opinion*, of Washington, D. C.: "This volume . . . is a wonderful summing up of the facts of what might be called, not as of old, the Iron or the Golden, but the Mineral Age. . . . It is a volume well worthy of the Columbian year."

The *Investors' Guardian*, of London, England: "This is by far the most valuable volume ever published on general mining work. . . . Miners in all parts of the globe will find their intelligence stimulated and their learning increased by the study of this remarkable book."

The *Chemical News*, of London, England: "This most useful work is designated as the Statistical Supplement of the *Engineering and Mining Journal*. . . . This work will meet with a large demand among miners, metallurgists, and consumers of or dealers in metals."

The *Industry*, of San Francisco: "Every engineer, mine owner, economist and what we call 'public man' should have a copy for reference now that this important industry is so classified and arranged that a moment's time discloses the main facts and quantities of the past year."

The *Electrical Review*, of London, England: "It is the most interesting and complete record of the mineral industries of the world. The contributors to this statistical supplement of the *Engineering and Mining Journal* are all competent men, and many of them are men of high standing."

El *Minero Mexicano*, of the City of Mexico: "Con todo probabilidad este tomo es la obra más importante que jamás se ha publicado sobre la estadistica de la industria mineral. . . . Repetimos que esta obra es de mucha importancia y recomendamos su adquisción a todos nuestros lectores."

The *Press*, of New York: "The book is a statistical supplement to that publication (The *Engineering and Mining Journal*). Another volume, entirely new, supplementing the data given in this, will be issued, so that after four or five years the statistics of the mineral industry of the world will be complete in the set."

Glückauf, of Essen-a.-d.-Ruhr, Germany: "Durch seinen ausführlichen interessanten Inhalt, übersichtliche Anordnung und gediegene Ausführung kann das Werk jedem, der sich über die Bergwerksprodukte eines der Länder, vor allem der Vereinigten Staaten Nordamerikas orientieren will, bestens empfohlen werden."

The *Proceedings of the American Society of Civil Engineers*, published in New York: "It must prove of value to all interested in the industry. The work is one which must commend itself, through its admirable arrangement and the value of its statistics, to every mining engineer and to the mining world in general."

The *Independent*, of Helena, Montana: "The most valuable publication of the year, so far as relates to the mineral industry of the world, is a volume just issued by the Scientific Publishing Co., of New York. . . . The publication is one that no mining man who desires to be well informed can afford to be without."

The *Bulletin*, of San Francisco, Cal.: "A vast amount of information is collated and arranged in such an orderly way that it is not only a complete reference book for mineralogists but for the much greater number who will have occasion to search for particular facts cited under the head of some one of the subjects here treated."

The *Review of Reviews*, of New York: "This volume . . . will be indispensable to the chemist, metallurgist, manufacturer, legislator and all in any way concerned with the mineral production of the United States and foreign countries. Its accurate, full and recent tabulations are a monument to modern methods in statistical work."

The *Electrical World*, of New York: "The work contains an interesting statistical article on the use and production of platinum, and information of value to the electrical industries in the sections on electrolytic copper and processes for treating zinc-lead ores, electrical reduction of aluminium, and several other allied subjects."

The *Daily News*, of Denver, Colo.: "It is . . . a perfect summary of both scientific and commercial knowledge of all the mineral resources of America. Its vast amount of statistical information, of great value to those interested in any form of mineral production, is backed by the painstaking authority of the foremost mining journal in the world."

Kritischer Vierteljahresbericht, of Freiberg, Germany: "Diese bedeutende Publikation geht uns so eben bei Schluss dieser Nummer zu und wir wollen nicht verfehlen, unsere Leser auf dieses mit ausserordentlichem Kostenaufwand unter Mitwirkung eines ganzen Generalstabs von Mitarbeitern herausgegebene Werk hiermit vorläufig aufmerksam zu machen."

The *Commercial Weekly*, of Washington, D. C.: "There is no doubt but that this is a rare and reliable statistical record studiously and conscientiously compiled. The Engineering and Mining Journal occupies a high place in the esteem of its readers, and the present compilation of figures and facts relating to the mineral industry, etc., possesses the merit of reliability."

Stahl und Eisen, of Düsseldorf, Germany: "Das Amerikanische *Engineering and Mining Journal* bringt schon seit einer Reihe von Jahren regelmässig am Jahresanfang eine umfangreiche statische Zusammenstellung über das Berg—und Hüttenwesen aller bedeutenden Industrieländer, die sich dadurch auszeichnet, dass sie den Thatsachen auf dem Fusse folgt."

The *Australian Ironmonger*, of Melbourne, Australia: "This is a handsome and important book . . . and is really a monument to enterprise and skill and knowledge of the requirements of the mineral industry. . . . The volume is one of the greatest possible value to all interested in mines and minerals, and it will certainly become a standard work of reference."

The *School of Mines Quarterly*, Columbia College of New York: "Technical articles by competent authorities give the recent progress in each department of mining, metallurgy and chemical industry, forming a valuable work of reference. The tables of itemized cost of production of many of the minerals and metals afford valuable information to all interested in the industry."

The *Queenslander*, of Adelaide, Australia: "Under this title (The Mineral Industry) the editor of the New York *Engineering and Mining Journal* has gathered together a vast store of statistical and other information relating to mining in every part of the world. No mineral is too scarce or insignificant to receive attention, and the result is a rather formidable looking volume of over 600 pages."

The *Southwest*, of Cincinnati, O: "It is a marvelously complete and fresh report, bringing statistics down to the end of last year. . . . For solid information few books will be as valuable to the student as this, of which the *Scientific American* says that it has been compiled with the greatest possible care, and which the *Industrial World* calls an 'encyclopædia of statistical facts.'"

The *Mexican Trader*, of the City of Mexico: "The work bristles with facts, figures and information of all kinds relative to the mineral industry, and pays considerable attention to Mexican mining matters. We intend in future issues to devote considerable space to reproducing portions of the volume in the interest of our mining readers, whom we, however, strongly recommend to purchase the work."

The *Tribune*, of New York: "It is the outgrowth of the annual review which *The Engineering and Mining Journal* formerly printed each year, and which was found of great value for reference, and to people engaged in the various trades . . . the volume is especially valuable for its completeness of statistical information regarding the growth of the various industries, both in this and other countries."

The *Herald*, of Boston, Mass.: "It is a very exhaustive statement of everything pertaining to the mineral productions of the whole world. . . . Too much cannot be said in regard to its value to those who have to do with the common and precious metals. It is a work entirely unique of its kind, and every year the new volumes will increase the value of the work as a complete and authoritative record of all that goes in the name of this line of mineral products."

The *Advertiser*, of Newark, N. J.: "Our mineral industries, as they presented themselves at the close of last year, are treated in the annual statistical number of the *Engineering and Mining Journal* in a way that makes the publication of great value to all interested in this important subject. Not a single mining industry of any value is found wanting in this admirable review of the business, and both the commercial and industrial features of the trade are discussed."

The *North China Daily News*, of Shanghai: "We feel confident that this volume will be welcomed most readily by all who are in any way brought into contact with or affected by mining, and just now it would not be an easy task to say who is excluded from the category. To the producer, manufacturer or merchant it will give much valuable assistance, and the expert practically engaged in mining will particularly appreciate its scope, accuracy and conscientiousness."

The *Chattanooga Tradesman*, of Chattanooga, Tenn.: "It is a magnificent achievement and is a perfect storehouse of useful information, being in reality indispensable as a reference book for all matters pertaining to minerals. The Tradesman ventures frequently into the line of statistical publications, and in the light of this experience can unhesitatingly pronounce this work as a marvel of completeness and an invaluable contribution to statistical and scientific literature."

The *Black Diamond*, of Chicago, Ill.: "The work . . . represents a vast compendium of most useful information and detailed work. Its wealth of information will make it a welcome and most valuable volume of reference. It is a valuable and complete exponent of the industries of the country, and should be upon the library table of all interested in iron, coal, copper, tin or cognate matters. Its compilation is a testimony of and reflects the highest credit upon its author."

The *South African*, of London, England: "Little use is it to glance at the imprint of this work to see that it emanates from America. It is only there that such enormous masses of numerical literature are hurled at the public at the low price of the book before us. It is a statistical supplement to our popular and talented contemporary, the New York *Engineering and Mining Journal*. . . . The amount of information . . . compressed with these flimsy covers is nothing short of wonderful."

The *Electrical Industries*, of Chicago, Ill.: "The various metals and minerals, copper, mica, asbestos, platinum, asphaltum, etc., enter largely into the manufacture of electrical apparatus and the information regarding them contained in this volume will be of great interest and value to the manufacturer, to the dealer and the user. The large number of professional, scientific and practical men who have been employed in the production of this work point to the reliability of the matter it contains."

The *Canadian Mining Review*, of Ottawa, Canada: "A most valuable addition to mining literature is the very comprehensive review of 'The Mineral Industry, its Statistics, Technology and Trade in the United States and Other Countries,' presented in a handsome volume of some 600 pages by our esteemed contemporary the *Engineering and Mining Journal*, of New York. This volume covers so wide a field that we can do no more at present than recommend it most heartily to every reader of the Review."

The *Statist*, of London, England : "Its comprehensive title is 'The Mineral Industry,' and exhaustive statistical information is given, besides facts as to prices, cost of production, etc., of all the minerals and metals. And what is an interesting feature besides is the same information extended to each important country. . . . We have to congratulate Mr. Rothwell, the editor of the Journal, upon his latest comprehensive work, and the manner in which that work has been compiled and, we may add, printed."

The *Wall Street Journal*, of New York : "The annual statistical number of the *Engineering and Mining Journal*, just issued by Mr. R. P. Rothwell, its editor, is a 600 page volume, treating the geography, geology, mineralogy, statistics, metallurgy and economics of every mineral produced in the world that is of commercial value. . . . Statistics . . . are accompanied by elaborate tables, in which are to be found cost of production, It is a book of reference which every broker and banker will find useful."

The *Courier*, Plainfield, N. J : "Within our limited space no adequate account of the detailed information contained in this book or of the enormous labor involved in gathering it can be given. . . . Within our knowledge this information is not to be found in any other one book nor in any half dozen ; no encyclopædia contains one-tenth of it. . . . The book is no one man's work, but is made up of contributions from many of the most prominent mining engineers, metallurgists, and chemists in this and foreign countries."

Revista Minera, Metalúrgica y de Ingeniería, Madrid, España, Junio 24 de 1893 : "En este gran libro de 600 páginas de nutrida impresión no es sólo una estadística de la industria minera y metalúrgica, sino que es al mismo tiempo una historia de las explotaciones de minerales de los más remotos tiempos, así como una exposición de los procedimientios metalúrgicos nuevos y más interesantes, abordando también las cuestiones de tráfico, de coste de producción, marcha de mercados y cuantas pueden interesar á los que en cualquier sentido se ocupan de Minería y Metalurgia.

The *Times*, of New York ; "It is an admirable and remarkably comprehensive collection of valuable statistics, brought down to a time within a very few days of the date of publication. We do not know that any other collection of statistics in this field, even approaching the excellence of the Journal's supplement, has been published in any part of the world. The change of form has enabled the Journal to extend the scope of its supplement and to add many new features. We are confident that the new volume is the most complete and valuable of all publications of this kind."

The *Financial Times*, of London : "We turn for light on the subject to the instructive volume just issued from the office of the *Engineering and Mining Journal*, of New York, which we have already noticed. The paper is recognized as the best mining publication in the world. Its correspondence is extensive and widespread, its information generally impartial and reliable. In its first volume of the work entitled 'The Mineral Industry, its Statistics, Technology and Trade for 1892,' the mining of the past year throughout the world is elaborately reviewed."

The *Morning Call*, of San Francisco : "This handsome volume of over 600 pages is a veritable mine of information on the subject of which it treats. It embraces a complete history of the mineral industry, its statistics, technology and trade in the United States and other countries from the earliest times to the close of 1892. A careful examination of the book shows that the ideas of the editor have been carried out in a manner deserving the highest commendation. Indeed the work is invaluable to all interested in the important subject of which it treats, and no library without it can be called complete."

Le *Bulletin des Mines*, of Paris, France : "Il est regrettable que nous n'ayons pas en France de livre similaire et qu'on y soit obligé, le cas échéant, de consulter un ouvrage, écrit en anglais et ne s'adressant par conséquent qu'à un nombre limité de personnes. Mais la rédaction d'un ouvrage semblable, qui est une véritable enclyclopédie, exige beaucoup de spécialistes compétents, et si la *Scientific Publishing Company*, grâce surtout à l'*Engineering and Mining Journal*, en dispose, nous croyons bien qu'aucune autre publication de Londres ou de Paris ne serait en mesure de rivaliser avec elle à ce point de vue."

The *Chronicle*, of San Francisco: "A volume of particular interest on this coast, and wherever mining of any kind is carried on, is "The Mineral Industry." . . . When the fact is stated that it covers the entire mineral history of the world, an idea of its scope is afforded. The work is the outgrowth of the annual statistical numbers of the *Engineering and Mining Journal*, but, in addition, contains much other data, all of which is drawn from the most authentic sources. Chapters are devoted to all the leading metals, giving in interesting shape the important facts in connection with their discovery, development and use."

Le *Génie Civil*, Paris, France, le 7 Octobre, 1893: "Un Journal de New York, The *Engineering and Mining Journal*, organe des mines et de la métallurgie, a publié la statistique minérale complète des États-Unis et du monde entier pour l'année 1892. L'ouvrage, un beau volume de 600 pages, constitue une véritable encyclopédie des mines et de la métallurgie. On y trouve la monographie de tous les métaux industriels, avec la description et l'indication de provenance de leurs minerais, l'étude des procédés métallurgiques nouveaux, les fluctuations de cours pendant l'année et des considérations économiques tirées de la comparaison de l'offre et de la demande."

The *Dixie*, of Atlanta, Ga.: "Mineral Industry . . . is a work which will be absolutely indispensable to every one interested in any department of the industry, whether as producer, as manufacturer, as merchant dealing in the mineral products, or as consumer. The information it contains has never before been collected, and it has great value to every intelligent man connected with the industry, and the volume will be kept on the desk throughout the year as a necessary book for constant reference. . . . This volume . . . gives the statistics to the end of 1892, or information just a year later and very much fuller than in the report of the United States Geological Survey just issued."

Rand & McNally's Monthly, of Chicago, Ill.: "Volume I. of this laborious work makes an addition to our library that we are not only greatly pleased with, but a feeling, we think, of just pride is added, that such a work comes from the American press, and from an American author. In the United States every man interested in mine-owning and working of mines and minerals will doubtless have this book without delay, and it must find its way into the libraries of thousands of others who desire the complete in their collection of permanent books. That able and thoroughly technical publication, the *Engineering and Mining Journal*, has our congratulations, being a co-operative associate of this work."

The *Florida*, of Ocala, Fla.: "When we first take up this unabridged encyclopædia of the mining industry we are surprised that so much can be put up for so small a price. As the volume opens and the superior quality of the work appears on every page, the wonder grows, and we are convinced that the miner or mining investor who does not have this book ready at hand is of that class which from its money is soon parted; and this work is much more prompt and available than if it had been done by the governmental artisans, who, like all people at a picnic, don't care a custard pie for the needs of a man back in the busy market, who must have some accurate knowledge on which to base his figures for a 'future' sale."

The *Journal of Geology*, Chicago, Ill.: "In conclusion, it may be said that as a piece of statistical work, relating to an industry that is world-wide in its scope, combining accuracy with full detail and systematic arrangement, and issued so soon after the close of the time to which it relates, the Mineral Industry has never been equaled in this country or abroad. . . . In the Mineral Industry we have an epitome of the mining operations of every quarter of the globe, published almost immediately after the close of the time to which they refer, a feat which heretofore would have been declared impossible. . . . The volume will be found of the greatest value to the economic geologist, the miner, the engineer and the business man."

The *Iron and Coal Trades Review*, of London, England: "This volume . . . is without doubt the most important and the most valuable contribution to the literature of the mineral industry ever published, and Mr. Rothwell, the talented editor, is to be heartily congratulated upon its appearance The present volume is only a first installment of the information promised, but its contents is of such a varied and practical nature that by itself it would form an indispensable book of reference. . . . Never before were such valuable data so assiduously collected, and never before was it attempted to collect and publish so promptly the statistics of all the minerals and the chemical industry in the United States and in most of the foreign countries."

The *Science*, of New York: "In the years of 1874–75 and '76, the *Engineering and Mining Journal*, of New York, published the first complete reports of the coal production of the United States, and in 1889, as special government agent for the census, the editor of the Journal, Mr. Rothwell, collected the statistics of gold and silver. The scope was gradually extended until in January, 1892, a magnificent volume of statistics was given to the world and universal encomium heaped upon the Journal and its staff for their wonderful work. Indeed, such was the unstinted praise accorded it, we can but wonder what language will be used for the present volume, no longer a supplementary number in journal form, but a handsome library volume of 628 pages."

The *American Mechanic*, of Chicago, Ill.: "The volume is a statistical supplement of the *Engineering and Mining Journal*, which, as the leading representative of the mineral industry has accumulated a large amount of statistical matter and has created facilities for securing minute and accurate details. These facilities have been attained through financial outlay and no little painstaking and mental labor. The volume of 628 pages before us is replete with stores of valuable information which is not confined to statistics, but is embellished and intensified in interest by illustrated descriptions of mining machinery and operations. . . . The work is one of great usefulness and value, whether regarded as a work of reference or as one containing reliable information upon mineral and metal industries."

The *Report*, of San Francisco, Cal.: "One of the most valuable books recently published, 'The Mining Industry,' has just been issued by the Scientific Publishing Co., of New York. The book . . . is a valuable work of reference. It is crammed full of matter with reference to all branches of the mineral industry, the production, statistics, technology and trade in the United States and other countries from the earliest times to the close of 1892. The editor very truly says that statistics must be fresh to be valuable, and as a consequence everything has been brought up to the latest date possible. In this respect the book differs very essentially from most of the Government publications, in which, too often, so much delay has occurred that the matter when published has lost most of its value."

The *Capitalist*, of London, England: "Mr. Rothwell, the editor of this valuable book, is also the editor of the *Engineering and Mining Journal*, of New York, a periodical of world-wide fame among the mineral interests and their allied and collateral industries. The fame of the journal is founded upon its excellent work, the information gathered together from the four quarters of the earth being exhaustive, and presented in a manner to be useful and instructive. The book now under notice is called a 'statistical supplement' of the Journal, a description which by itself will be sufficient recommendation. In fact, the contents of the volume go far beyond the statistics, good as they are in themselves. . . . Altogether there is a fund of valuable matter for reference which is not to be found in any other book."

L'Echo des Mines et de la Métallurgie, of Paris, France: "Cette publication réunit pour la première fois tous les renseignements sur la production des mines et usines, exportations, importations, statistiques, etc. On y trouve des renseignements précieux sur les métaux et mineraux exploités dans les États-Unis, nous citerons les articles sur l'aluminium, les produits chimiques, charbon et coke, cuivre, étain, zinc, plomb, or et argent. Cette partie, la plus considérable de l'ouvrage, a été traitée avec une très haute compétence par tous les collaborateurs. Cette publication renferme les statistiques du monde entier sur les mines et la métallurgie, et est indispensable aux producteurs et aux consommateurs; elle fait le plus grand honneur a son éditeur, M. Rothwell, qui en a fait une véritable édition de luxe."

The *Industries and Iron*, of London, England: "This volume is a striking example of American journalistic enterprise. Covering 628 pages, in addition to the 115 pages of advertisements, it contains very full mineral statistics compiled with commendable promptitude. The various sections of the work have been intrusted to well-known specialists, the list of contributors including about fifty eminent names. The result of their labors is a complete epitome of our knowledge of the mineral resources of the American continent, with supplementary information relating to other parts of the world. Mr. Rothwell's great work is deserving of very high praise. It constitutes an important work of reference, the value of which is greatly enhanced by the fact that the statistics it contains have been so promptly published."

The *Age of Steel*, of St. Louis, Mo.: "It is in fact a great work, representing a large amount of labor and money and a wealth of information that is practically invaluable to every one interested in any department of the mineral industry, be he producer, manufacturer or merchant. To each and all of these it has a claim on his desk and interest not to be questioned by any practical business man. In accuracy and completeness it is evidently all that painstaking and conscientious bookmaking can make it, while the ground it covers has its only limits in the subjects it handles. It has also a special value as being the first volume of a series that in an annual form will eventually include the mineral statistics and progress of all nations, and be an invaluable encyclopædia of all matters pertaining to mineral industries. If you want to keep abreast of the times, get *it*."

The *Herald-Democrat*, of Leadville, Colo.: "It has usually been the custom of the *Engineering and Mining Journal* to issue each year a statistical number relating to the mineral industry of the world. The vast sources of information at the command of this great journal, its generally accepted accuracy in all that pertains to mining in all its branches, and the universal favor with which its statistics have been received by experts have induced the publishers to undertake the publication of a larger and more complete statistical volume, which is now issued. The title is 'The Mineral Industry; Its Statistics, Technology and Trade in the United States and Other Countries, From the Earliest Time to the End of 1892,' all of which is comprised in a handsome volume of 700 pages, octavo, in which is compressed a vast store of information brought down to the beginning of the present year."

The *Industrial World*, of Chicago: "One of the principal advantages of this work, aside from its riches in knowledge for every-day uses, is its prompt appearance, in which it far outranks the publications issued by the government. . . . Eminent men and experts, extending into a long list, have contributed to the contents. Neither labor nor expense has been spared in the preparation of the volume, which is really an encyclopædia of mineral resources and development in the countries brought under view, with especial elaboration as regards the United States. Moreover, the work will fill a long unoccupied niche in both public and private libraries, and must prove an invaluable adjunct to both. It is a work of reference which any reviewer can conscientiously recommend as well worth the price of its purchase; for its standard of excellence places it in the highest rank of reliability."

The *Railroad Gazette* of New York: "This volume is a result of the development of the annual statistical numbers of the *Engineering and Mining Journal*, of which we have had occasion to speak very favorably before. For some years that journal has collected statistics of the mineral products of the United States and published them promptly at the close of each calendar year, and this publication has been very useful as well for its accuracy as for its remarkable promptness. This work has been compiled, enlarged and collected into the volume now published, in which are given statistics of nearly all of the minerals and metals produced in the United States and in many other countries for the year 1892, and in many cases from early times. The mass of information collected is certainly very great, and the volume is a valuable addition to the library of the scholar, and is a triumph of enterprise."

The *Iron Trade Review*, of Cleveland, O.: "In this volume the *Engineering and Mining Journal* has reached the climax of its splendid achievements in mineral statistics. Its annual statistical numbers have been marvels of completeness and promptness, giving within a short time after the close of each year the figures for production in every line of the mineral industry. And to fullness and timeliness, the Journal has also added accuracy. The great octavo volume that is before us, with its excellent typographical dress, its cloth binding, and its 628 pages of information, covering the whole field of mineral production, is the last evolution of the annual statistical number. The different departments of the work have been put in competent hands, the list of editors including names that will be recognized at once as lending the stamp of authority to whatever is credited to them. The task of bringing out so early in the year so comprehensive a volume is simply stupendous."

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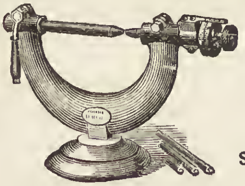

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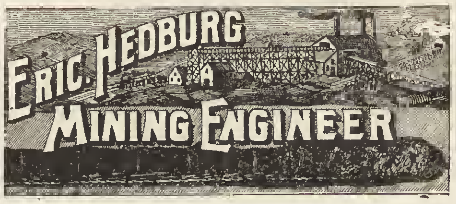

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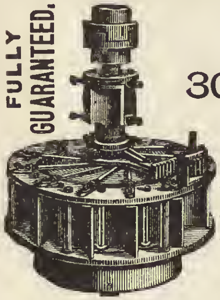

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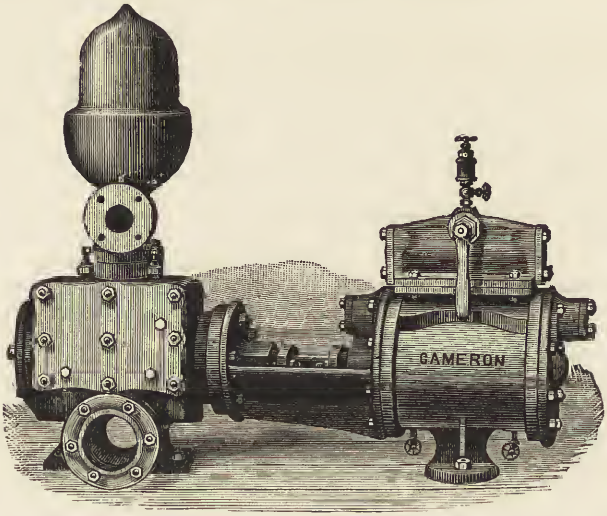

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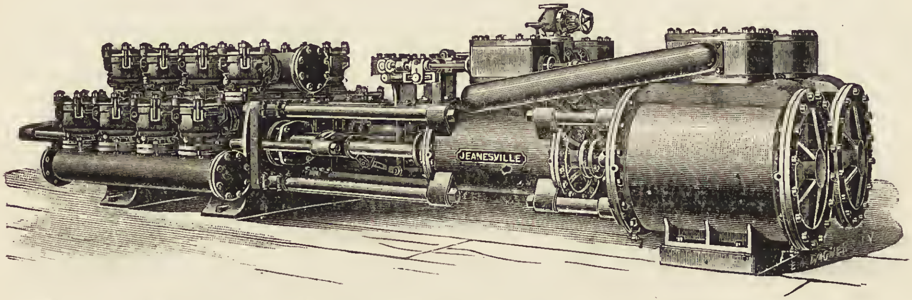

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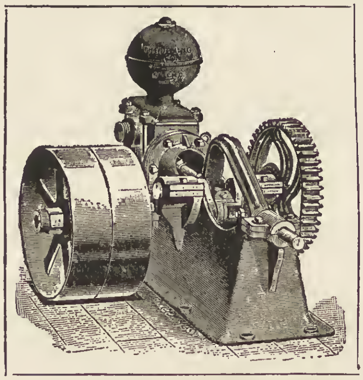

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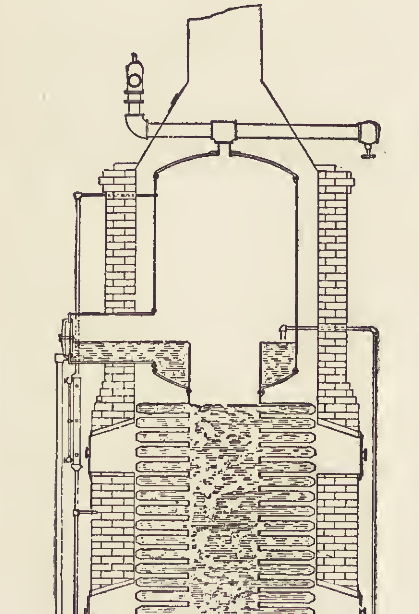

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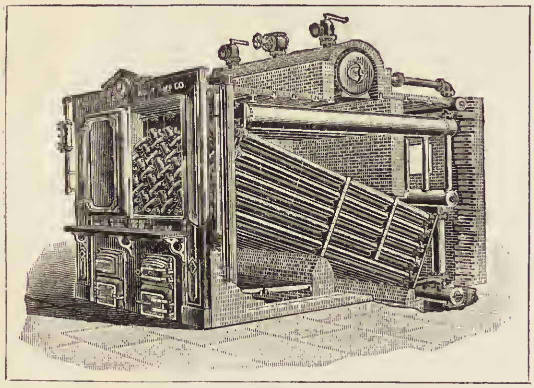

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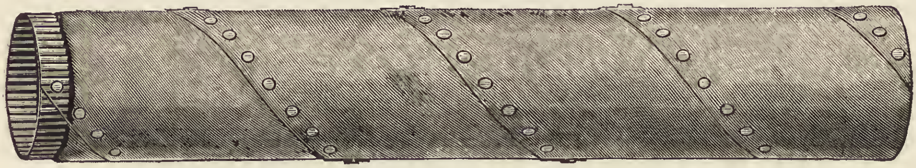

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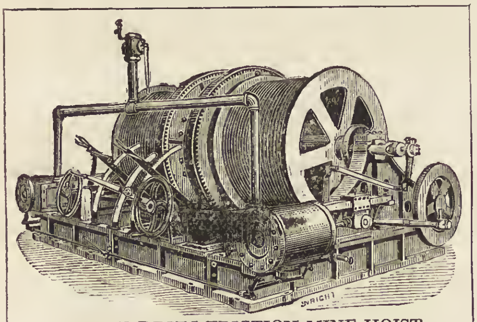

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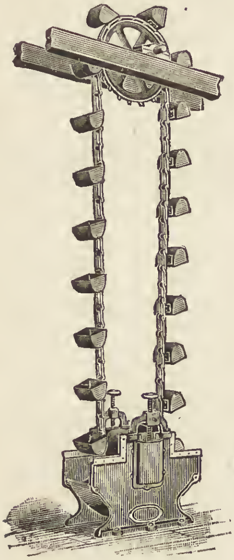

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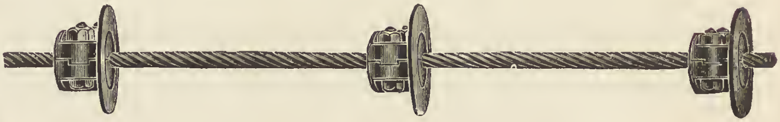

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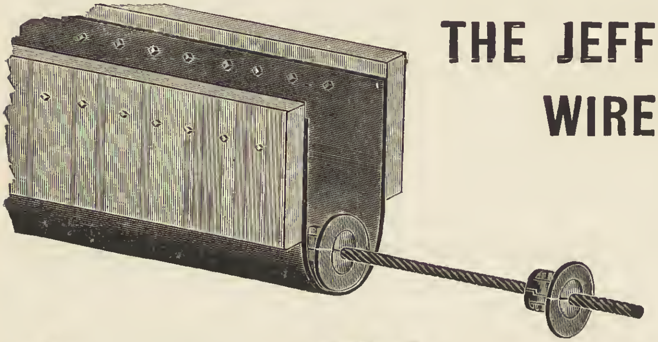

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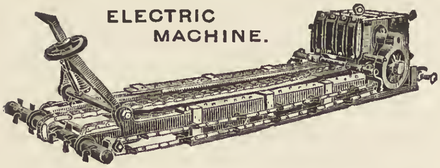

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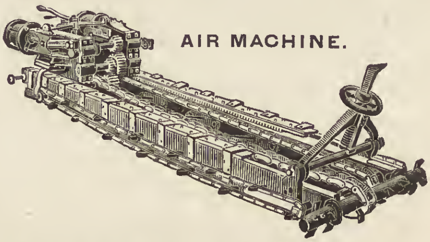

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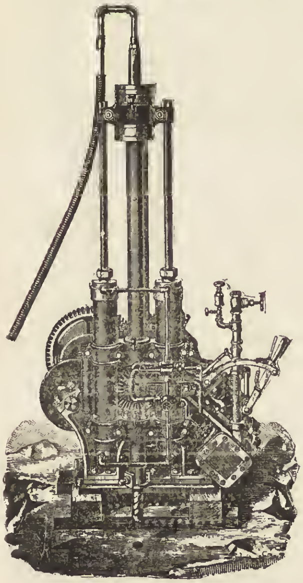

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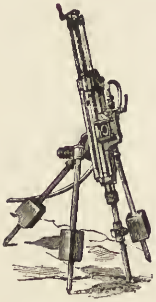

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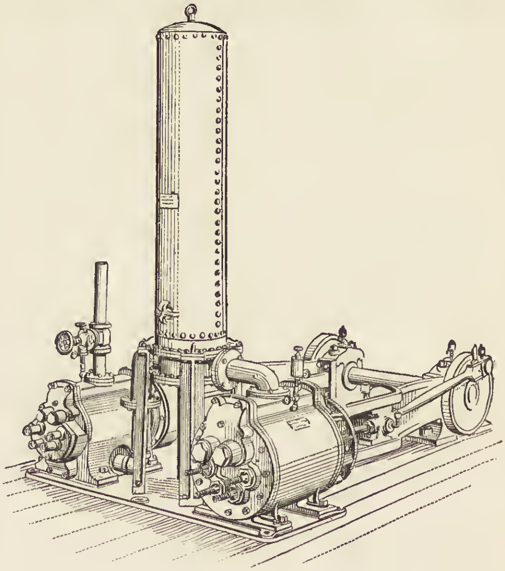

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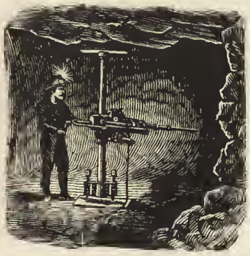

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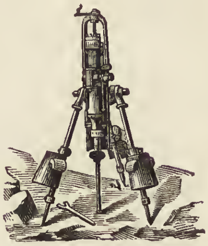

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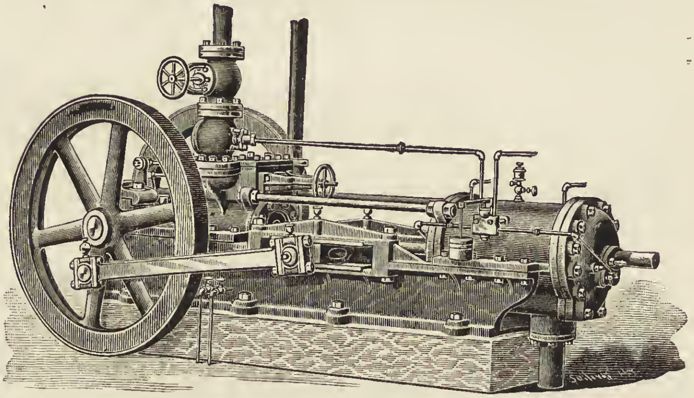

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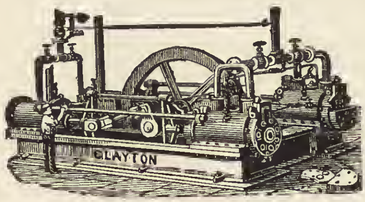

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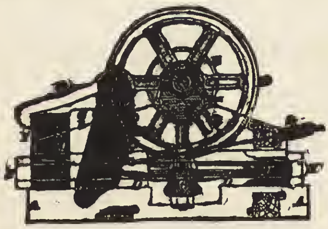

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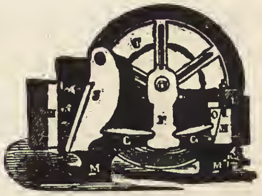

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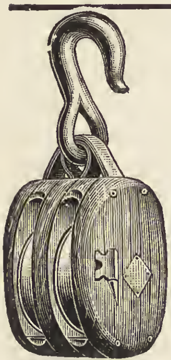

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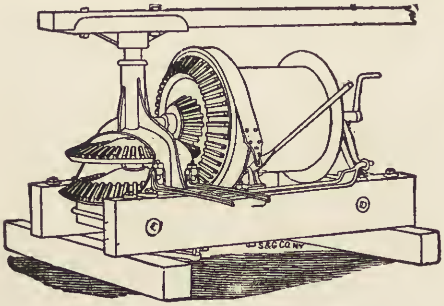

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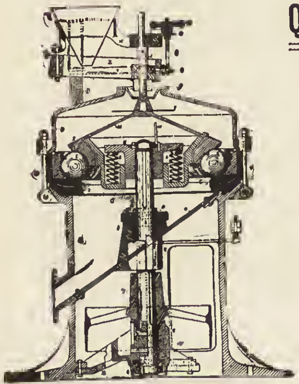

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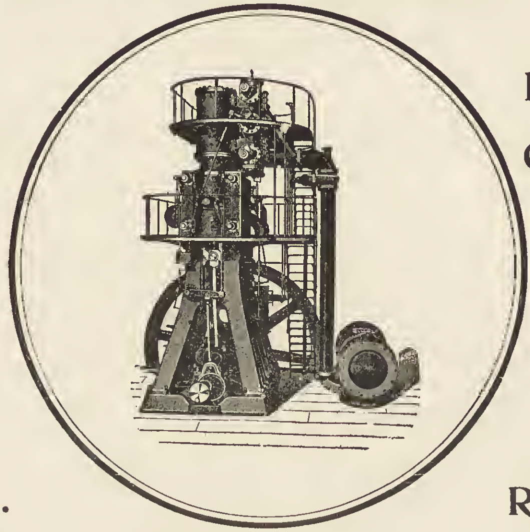

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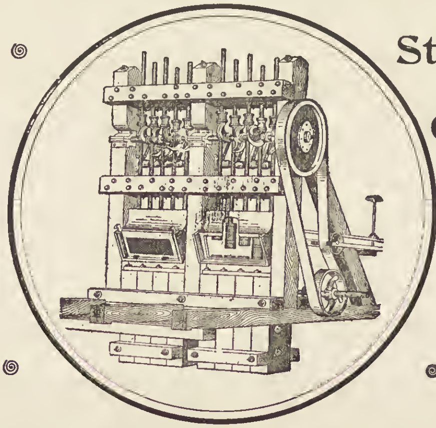

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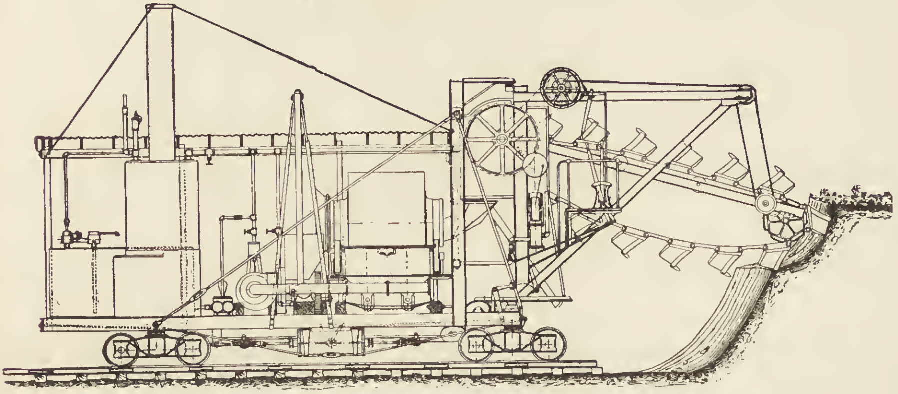

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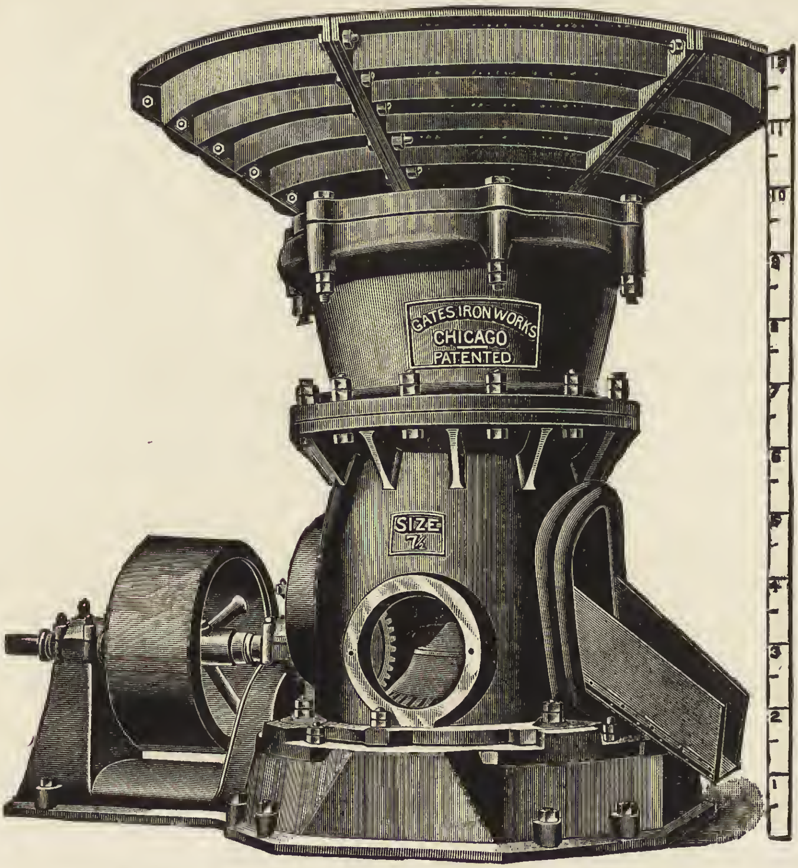

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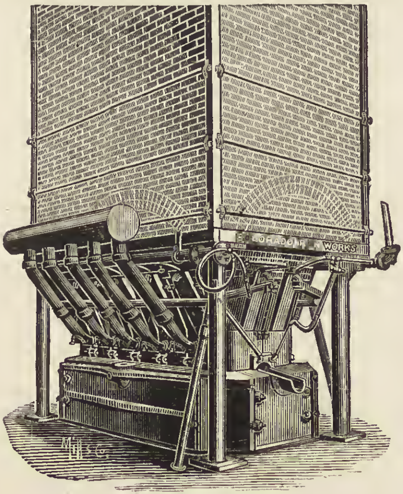

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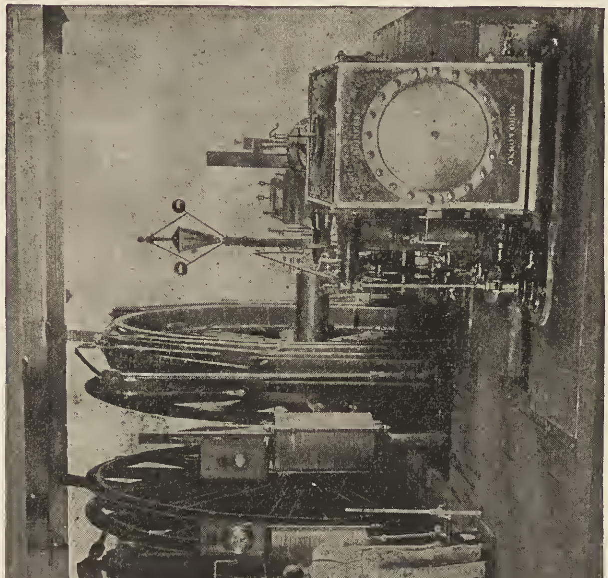

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