THE

Geology and Mineral Products

.....OF.....

MISSOURI.

BY

ARTHUR WINSLOW, STATE GEOLOGIST.

FROM "MISSOURI AT THE WORLD'S FAIR."

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Principal Mineral Products

IN THE YEAR

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THE State of Missouri is located in the central portion of the United States, in that region known as the Mississippi valley. It is bounded on the east by the Mississippi river, on the south by the lines 36° and 36° 30′ of north latitude, and on the west by the meridian which passes through the mouth of the Kansas river at latitude 39° 7′, and longitude 94° 37′. Thence the boundary line follows the Missouri river in a northwesterly direction to a point at about latitude 40° 34⅔′, longitude 95⅓°. This is the northwestern corner of the State, and thence the northern boundary line extends eastwards approximately along the line of same latitude to the Des Moines river, which it intersects at longitude 91¾°, about 25 miles above the mouth of that stream. The area of the State, according to the figures of the eleventh census of the United States, is 69,415 square miles.

PHYSIOGRAPHY.

Generally speaking, the whole State is an incised plain; no great mountain ranges traverse it. The maximum difference of absolute elevation within the whole area is only 1,500 feet; the local and relative differences are still less, and do not exceed 700 feet. More closely speaking, the following four topographic divisions may be recognized: (1.) A plain or prairie country. (2.) A plateau country. (3.) A highland or semi-mountainous country. (4.) An alluvial or swamp country.

(1.) The Prairie Country.—The prairie country of the State is principally represented in the northern portion, and in that part north of the Missouri river; it also occupies, however, nearly all of the two tiers of counties south of that stream which extend along the Kansas line. Adjacent to the Missouri river and to other large streams this country loses its prairie features and is rugged and characterized by steep, timbered slopes and bluffs adjacent to and bordering the flood plains of these streams. Away from the channels, however, the country assumes the character of a broad plain, sometimes flat, but generally undulating. In fact the local differences of elevation often amount to 100 feet or more, but the slopes are so gentle that the country does not lose the aspect of a plain. The growth of trees is here not abundant, excepting along the streams. It must, however, be understood that, though a comparatively level and treeless country, it is of a very different type from the great flat plains of Western Kansas.

(2.) The Plateau Country.—The plateau country of the State occupies the central southern part, south of the Missouri river. This is the area known as the Ozark Mountains, and is essentially a dome-shaped uplift, with very gentle quaquaversal slopes. It differs from the prairie country chiefly in its greater relative altitude, and in that it is not covered by a protecting and modifying coat of glacial material. As a result the land is more pronouncedly sculptured. The valleys are cut deeper, and the slopes are more abrupt; the area is made up of a series of long ridges and hills, divided by deep narrow valleys, often of cañon-like dimensions. Timber is abundant, but, on the other hand, the land is generally less fertile than that of the northern portion of the State. Near the crest of the Ozarks the type of topography is not nearly so pronounced, and we have here quite a large expanse of undulating country; thence, in all directions, however, the streams cut deeper and deeper, and the profile becomes more serrated.

(3.) The Highland Country.—What we term for convenience the highland or semi-mountainous country, lies in Southeastern Missouri, and includes what we have named the St. Francois mountains. These are a series of knobs and domes of Archean porphyry and granite which rise to altitudes of from 1,700 to 1,800 feet, A. T., and some 700 feet above the surrounding valleys. The whole area covered by these mountains is not over 1,000 square miles. These are distinguished from the Ozark mountains, so called, in form, structure and age. They are among the oldest elevations in America. They are not arranged by groups and ranges, but their distribution seems to be quite adventitious. The country is decidedly a timbered one, but a large part of the timber has been removed for railway and furnace uses. The valleys are underlain by Cambrian limestone, and are generally cultivated.

(4.) The Alluvial Country.—The alluvial or swamp country occupies the extreme southeastern corner of the State; it is the alluvial or flood plain of the Mississippi river and its tributaries. It is almost entirely a low-lying and flat expanse, though in the western part it is traversed by a long, low ridge of


GEOLOGICAL MAP
OF THE
State of Missouri,
SHOWING
The Distribution of the
Principal Mineral Products
IN THE YEAR
1892.
Scale 40 Miles = 1 Inch.
Prepared by
THE MISSOURI GEOLOGICAL SURVEY
TO ACCOMPANY THE PAPER
OF ARTHUR WINSLOW, STATE GEOLOGIST,
ON THE
GEOLOGY AND
MINERAL
PRODUCTS
OF MISSOURI.
LEGEND
Pleistocene
Tertiary
Pennsylvanian
Mississippian
Devonian
Cambrian & Silurian
Algonkian
Archean
Missouri River
Mississippi River
Hannibal
St. Joseph
Kansas City
Sedalia
Moberly
Springfield
St. Louis
Ste. Genevieve
Cape Girardeau
COAL
LEAD
ZINC
IRON

Tertiary sands and clays. This area is in large part subject to overflow, though portions are not reached by any ordinary floods. It is mostly heavily timbered, especially in the swampy portion, and large amounts of lumber are shipped out annually. It also contains great tracts of prairie and cleared country of extreme fertility, and many flourishing towns and settlements have been built up within its borders.

GEOLOGY.

Nine geologic formations or systems, representing so many periods of geologic time are found in the State. These are, beginning with the oldest, the Archean, Algonkian, Cambrian, Silurian, Devonian, Carboniferous, Tertiary and Pleistocene.

The Archean.—The rocks of Archean age in Missouri consist chiefly of granites and porphyries or felsites. They occur exclusively in the southeastern part and constitute the hills described on the preceding page as the St. Francois mountains. The porphyries are of varying color, from light gray, pink, red and brown to almost black. They are generally massive, but frequently brecciated, and are sometimes banded, with the flow structure well developed. The texture varies from the vitrophyric to the microgranitic. The most important ores occurring in these rocks are the specular iron ores of Iron mountain. The granites are irregularly distributed over the Archean area. They are intimately associated with the porphyries and seem to grade into the latter in places; elsewhere they are extremely coarse, and, in some instances, the quartz and feldspar are in masses six and eight inches across. They are of gray, pink and red colors. Some black mica is found as an accessory mineral. About the only ore of economic value found in these rocks is the silver-bearing galenite of the Einstein mines, in Madison county.

The Algonkian.—The Algonkian rocks are represented at only a few localities in the vicinity of Ironton, associated with Archean rocks. The most noteworthy and extensive exhibit is on the summit of Pilot Knob. Here the formation is represented by beds of conglomerate or breccia and of felsitic appearing slate. A bed of specular ore, some 30 feet in maximum thickness, constitutes one of the members of the series here. The fragments of the breccia consist of porphyry and, though sometimes rounded, are generally sub-angular. The matrix of the conglomerate and the material of the slates is also felsitic and the texture is similar to that of the porphyry. The slate is fissile and cleavable in places, but is elsewhere massive. It is, in large part, highly ferruginous. The bed of iron ore is near the bottom of this series of rocks and is of elliptical outline and changes in character towards the margin by lessening in iron contents or "leaning out" as the miner expresses it. These Algonkian beds probably began forming immediately after the Archean rocks were consolidated. They must have originally spread over a wide area. Denudation before or during early Cambrian times has left only a few remnants. The maximum thickness now to be seen is under 200 feet. The presence of these beds and the fact that only these remnants should be left is significant of the vast interval of time that must have elapsed between the Archean and Cambrian periods.

The Cambrian.—The Cambrian system is represented in Missouri by a succession of beds of magnesian limestone and sandstone. These occupy the southern-central and southeastern portions of the State, and are particularly well developed in the Ozark mountains. In the St. Francois mountain region beds of conglomerate are found at the base of the formation consisting largely of porphyry, granite boulders and pebbles derived from the Archean hills. As the results of recent work, three main divisions of this system are provisionally recognized. These are, from the bottom upwards, as follows: (1) The La Motte sandstone, to which horizon the conglomerate above referred to may be assigned. (2) The Gasconade limestone. (3) The Roubidoux sandstone. This last is probably equivalent to the old "Saccharoidal" sandstone. The exact upper limit of this system is not yet defined; but, probably, it will be drawn below what has been called the First magnesian limestone. The maximum thickness of the whole system is about 800 feet. The strata of this formation are comparatively undisturbed. They are largely represented in the dome-shaped arch already referred to, known as the Ozark Uplift. Minor gentle flexures traverse this arch in places. The rocks have been eroded both by surface and subterranean waters, and, hence, local settling of the strata is quite frequent. This might lead to the idea that great flexing had taken place in places; but such is not the case. The principal mineral product of economic value in these rocks are the lead ores of Southeastern Missouri and the iron ores of the central and southern portions of the State.

The Silurian.—The outcrops of rocks of Silurian age are confined almost entirely to the eastern border of the State, where they are frequently exposed from Marion to Cape Girardeau counties. No exposures of these rocks have been found in the western part of the State, and it is probable, even, that they do not occur there beneath the overlying rocks. This system is divided into an upper and a lower series, the two aggregating about 600 feet in thickness. They consist of a succession of limestones and shales of varying character. Areally the rocks of this system are not prominent in Missouri, neither do they contain minerals of great economic value.

The Carboniferous.—The Carboniferous system is divided into two series, the lower is known as the Mississippian or Lower Carboniferous, the upper as the Pennsylvanian or Coal Measures. This formation occupies well-nigh the whole northern and western portions of the State. The Mississippian division is composed chiefly of massive beds of limestone, often crystalline and highly fossiliferous. Thick beds of chert, shale and sandstone are, however, often included, the last two especially in the lower portion.

The aggregate thickness is over 1,000 feet. This is the great lead and zinc bearing formation of Southwestern Missouri. Excellent building stone is also derived from the limestone beds, and they furnish the best grades of quicklime.

The rocks of the Pennsylvanian series overlie the Mississippian somewhat unconformably. A period of sub-areal erosion, over at least part of the latter formation, must have intervened. The series consists, in the lower part, of sandstones and shales, the latter partly arenaceous, with some limestone and coal. Higher up limestones and coals are more abundant, and the latter are more regular in distribution. At the top of the series, the limestones are most abundant. This is the great coal-bearing formation of the State. The strata of this series, as well as those of the preceding member of the Carboniferous, are practically horizontal with but a slight dip to the west and northwest. Local departures from this rule exist, however. The aggregate thickness of the series is in the vicinity of 2,000 feet.

The Tertiary.—The Tertiary rocks are confined to the narrow ridge in Southeastern Missouri referred to on page 14. This is bounded by the alluvial plains of the Mississippi river. It consists of unconsolidated beds of clay and sand and lignite, covered by a stratum of chert gravel. The exhibited thickness is in the vicinity of 100 feet. How much the beds extend beyond this we are unable to say at present.

The Pleistocene.—In the Pleistocene we include all of what are known as the glacial deposits of the State, as well as the more recent Quaternary formations represented by the residuary loams and clays which cover the ground in the uplands, and the alluvial deposits of the plains along the larger streams.

The glacial deposits cover the entire northern half of the State approximately down to the Missouri river. The materials are the usual clays, sands and boulders, which we will not attempt here to classify. Along the Missouri and Mississippi rivers are thick deposits of loess, capping the bluffs on both sides of the stream and sometimes fifty feet or more in depth. The alluvial plains along the rivers are of varying width, the maximum width on one side of the Missouri river being about eight miles. They constitute land of extreme fertility and large crops of corn and wheat are annually produced upon them.

THE MINERAL PRODUCTS.

The territory occupied by the State of Missouri has been known as a mineral producing area for nearly 200 years. Penicaut, one of Le Sueur's party, which ascended the Mississippi river in the year 1700, refers to a mine west of the Mississippi and west of Ste. Genevieve, whence the Indians got their supply of lead. This is the earliest reference which we have, and, as Carr says, it indicates with reasonable certainty the date when the French began to make use of the mineral resources of the region. Since that time the State may be considered a continuous ore producer up to the present date. Iron mining was begun about the year 1815; coal was probably discovered in the earliest explorations; we find records of its existence in 1804; in 1840, 8,903 tons were mined, and from that time the production was continuous. Zinc was mined with lead ores for many years, but it was not utilized until 1869. Since then the growth of production has been rapid.

Missouri's principal mineral products are zinc, in the production of which she ranks first in the country; lead, in which she is second only to Colorado, and iron. In addition, she is a large producer of coal, her clays have a national reputation, and she has a great variety of excellent building and ornamental stones. Among the minor products are quicklime, glass sands, copper and barytes. A large number of the more common classes of mineral waters are scattered over the State. The distribution, character and conditions of occurrence of these various materials of economic value we will now proceed to briefly describe.

ZINC.

Zinc may be considered Missouri's distinctive product. In it she ranks first among the States as a producer, and between one-third and one-half of the total zinc yield of the country comes from her mines. She thus stands as a source of supply for the whole country, and her zinc ores are even tentatively seeking the foreign market.

The zinc region of the State is the extreme southwest, and this particularly in the counties of Jasper, Newton and Lawrence. These are the centers of production, nearly eight-tenths of the annual product coming from Jasper county alone, and ninety-six one-hundredths from the three. The ore is mined on a commercial scale in seven other counties. Zinc is, however, widespread in the State and is known to occur in greater or less, but still considerable, quantities in as many as fifteen more counties.

Zinc ore is known to have been mined in the past in Washington, Wright, Christian, Howell and Webster counties, and the following table shows the amounts mined in different counties in the year 1892:

Dade	103 tons.
Barry	192 "
Green	899 "
Jefferson	2,075 "
Newton	8,343 "
Lawrence	13,861 "
Jasper	106,014 "
Total zinc ore mined during 1892..	131,487 tons.

The ore principally mined is the sulphide of zinc, or sphalerite, commonly known as "jack," which occurs in several varieties, distinguished chiefly by color and known by the names of jack, rosin jack and black jack. It is the most abundant ore in the Jasper district. It is the most valuable of the three classes, and is now rated at about $22 per ton. The so-called "silicate" ores are of two varities, *i. e.*, the true silicate, or calamine, and the carbonate, or smith-

sonite, and they are difficult to distinguish by the eye. These ores are produced most abundantly about Aurora and Granby, and constitute the zinc ore of the Valle mines in the northeastern corner of St. Francois county; they are generally found near the surface in the shallower workings. They do not contain so large a proportion of zinc as does the sphalerite, which latter contains about sixty-seven per cent, while the true silicate has fifty-four per cent, and the carbonate fifty-two per cent. They, hence, bring a lower price and now sell at about $15 per ton.

Geologically the zinc ores occur in nearly all of the Paleozoic formations of the State, but outside of the ores from the Valle mines, those mined at the present date come almost exclusively from what has been described as the Mississippian formation, or from a great series of limestones and cherts, which immediately underlie the Coal Measures, or Pennsylvanian rocks. It is not to be understood, however, that these ores are co-extensive with this series, for these same rocks abound about St. Louis, and yet they are there practically destitute of zinc. Their development in this formation, on a scale of commercial importance, seems confined to the southwestern part of the State, for some reason which we do not clearly understand, but which we are trying to find out. The ores do not occur in these rocks in sheets or beds, as does the coal in the Coal Measure rocks; if so it would be a very simple matter to successfully direct prospecting and further development. Unfortunately for the progress of mining, however, the ore is of irregular distribution, sometimes in thin sheets in crevices in the massive limestones; sometimes in great chambers; sometimes buried in clay and a mass of loose material which can be excavated by pick; sometimes disseminated through solid, brecciated rock which has to be blasted down; sometimes lining cavities with drusy crystals.

The reasons for the peculiar conditions of occurrence of these zinc ores are chiefly assignable to structural considerations, and to the nature of the country rock of the region in which they are found. We have there a series of layers of limestone, and of chert or "flint," piled upon each other, varying in thickness from a few feet to twenty and more. These have existed for a very long time, and the limestones have been subjected to the solvent action of waters percolating through them. These percolating waters have by degrees produced channels along planes of fracture, which have been developed into subterranean passages, have dissolved away whole layers of limestone, allowing the overlying insoluble chert beds to break down, and to partially fill the cavities with their fragments. The clays, so abundant in some deposits, are probably the residues of dissolved limestones, all of which latter have more or less clay in their make-up. In these cavities, in the residuary clays and around the broken rock fragments, the zinc ores have been deposited; brought there in solution, perhaps, by the very waters which have dissolved the limestones, possibly by waters issuing from great depths. That is, the zinc may have been originally disseminated in minute quantities throughout the surrounding limestone rock, and have been concentrated through the medium of the dissolving waters; it may have been similarly collected from overlying beds, or it may possibly have been brought to its present position from a deep source in ascending waters. This is a problem which we are still trying to solve, and which is of vital importance to the successful development of our mining industry.

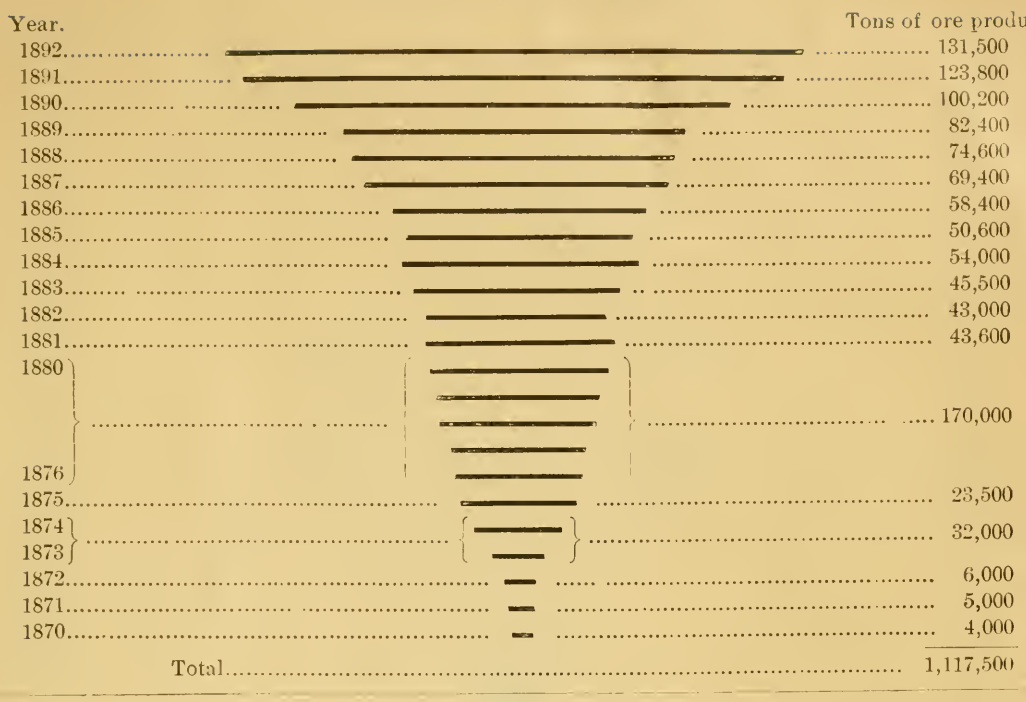
Zinc mining in the State is of very recent origin. Zinc ore was taken out along with the lead ore at the Valle mines, and thrown aside on the dumps for many years, but not until 1869 did it become an article of shipment. In the southwest, zinc mining may be considered to have begun in the year 1870, when the Granby mines began to work it. With the increased use of zinc since that time for galvanizing and other purposes, the production has increased rapidly and constantly. During the past sixteen years the price of spelter in New York has varied from 7 cents per pound in 1875 to 4.34 cents in 1885, and to 5.05 cents in 1891.

Concerning the production of zinc ore in Missouri during past years, figures of any kind are difficult to obtain, and exact figures are in many cases unattainable. The table on following page is compiled from figures derived from many different sources, supplemented by estimates where figures were not attainable.

The grand total is 1,117,500 tons of ore produced up to and including the year 1890. This, at $22 per ton, is equal to $24,585,000.

That the zinc output of the State has reached its maximum rate, no one maintains. That the productive area is in any way exhausted of ore, there is no reason to think. On the contrary, we look for a continued discovery of fresh deposits as prospecting advances. That much of the mining of these ores in the past has been crude and wasteful is true, and it still remains so to a great extent. Improvements are, however, being introduced both in the mining and milling of the ores. These factors of success should be given more attention in the future. Professional knowledge should be applied to the problems presented, to the methods of excavating, of draining, of hoisting, of concentrating; the small, single-handed, hand-to-mouth practices of the past are enormously wasteful and should give way to large projects systematically and scientifically directed.

ZINC ORE PRODUCTION IN MISSOURI.



LEAD ORES.

Lead ranks next to zinc in prominence as a Missouri metal, and her production is only second to Colorado's in the United States. Lead, like zinc, is widely distributed over the State, is known to occur in thirty or more counties, and was mined during the past year in fourteen. Much of the lead ore occurs associated directly with the zinc ores, and the two are mined together; but elsewhere the lead is by itself. The counties which are at present the principal lead producers are: St. Francois, Madison, Washington and Jefferson, in the southeast, and Jasper, Lawrence, Newton and Greene in the southwest. Of the total lead produced nearly one-half comes from St. Francois county, and nine-tenths comes from the four counties of St. Francois, Madison, Jasper and Lawrence.

The distribution of lead mining among the counties of the State is shown in the following table, as well as the amount of pig lead produced by the several counties during the past year:

PRODUCERS IN PAST YEARS.

Crawford.	Morgan.	Camden.
Wright.	Cooper.	Benton.
Christian.	Texas.	Moniteau.
Hickory.	Webster.	Saline.

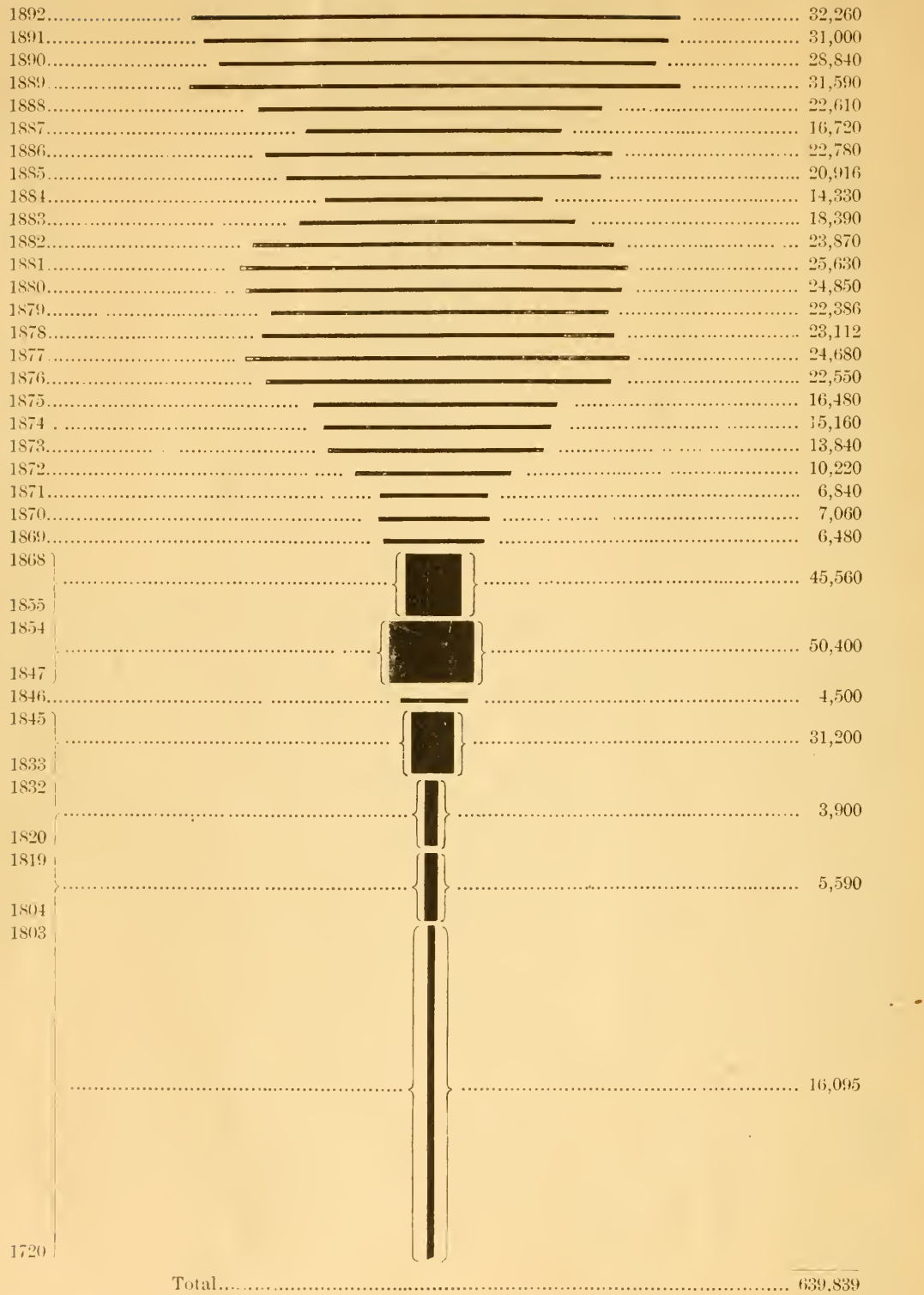
PRODUCERS IN 1892.

	Tons.		Tons.
Perry	4	Madison	2,865
St. Francois	15,430	Jefferson	268
Washington	1,166	Franklin	98
Miller	16	Cole	23
Greene	264	Barry	55
Lawrence	3,719	Dade	64
Newton	812	Jasper	7,476
Total production pig lead in 1892			32,260

Lead is mined in two forms. One is the familiar galenite or sulphide of lead, the other the cerussite, or carbonate of lead, known as "dry bone." The latter is generally a direct product of the decomposition of the former, and is found near the surface, while the former is reached at depths. The galenite is the more common and the more valuable ore, it containing about eighty-seven per cent of lead, while the carbonate contains only about seventy-eight per cent. Very little of the latter is now produced. The average price at which galenite was sold at the mines, in 1892, was a little over $44.00 per ton.

The lead ores of the southwest, being immediately associated with the zinc ores, occur in the same formation as the latter, namely in the Mississippian limestones, and the conditions of occurrence are essentially the same. Both the galenite and the cerussite are found here; the former, however, in greatest abundance. The lead ores of the southeast, however, occur in much older rocks, in what are known as the Cambrian limestones, and little zinc ore is found associated with them, excepting at the Valle mines and others in that vicinity. The conditions under which they are found are also remarkably different from those of the ores of the southwest. The latter occur in a more or less concentrated state, in large crystals, in cavities, or in irregular deposits, whereas these southeastern ores are found through solid limestone rock, generally in small crystals, in a disseminated condition, and hence are called "disseminated ores," in contradistinction to the concentrated ores of the southwest. Moreover, they occur in certain layers or strata of limestone, and, hence, may be considered in a stratified condition, though

Pig Lead Production in Missouri.



the ore is not found co-extensive with the limestone rock in which it occurs at any point. The lead ores of Mine La Motte, Doe Run and Bonne Terre are such. The ore is here exclusively galenite as at present mined. The carbonate was extensively dug during the earlier years of mining, from shallow surface deposits, but, at the greater depths at which mining is now carried, this ore is not found.

Lead is recognized as the metal which has been longest mined in the State. Up to quite recent date, however, this mining was confined to the southeastern part. As already stated we find mention of lead mining as early as the year 1700. In 1723, Mine La Motte, in Madison county, was discovered, and mining of the surface ores was begun, and has been intermittingly continued ever since. The "Old Mines" near Potosi, in Washington county, were discovered in 1726, and the Mine Renault, in the same county, about the same date. In 1763, the Mine à Burton, also near Potosi, was discovered, and about the year 1800 a number of mines in St. Francois county were opened. The Valle mine, in St. Francois county, was discovered in 1824, and the Perry mine about the same time; the Virginia mines, in Franklin county, in 1834; the Avon mines, in Ste. Genevieve, in 1848. Mining on a large scale was begun at the St. Joe mines, in St. Francois county, as late as 1868, while the Doe Run mines were not opened until 1888. About the earliest record of mining on a commercial scale in the southwest is in 1850, where it is recorded that about 100,000 pounds of lead were produced in Newton county. The Granby mines in the same county began operations about the year 1854. Concerning the production of pig lead in Missouri, we have compiled and estimated from various sources the figures of the table on page 19.

From this table we see that, during the past two decades, fully two-thirds of the total output has been produced. The average price of lead up to the end of the year 1803 is estimated to have been 5 cents; from 1804 to 1854, 4 cents; from 1855 to 1874, 7 cents; from 1875 to 1890, 4 cents. The average price of lead in the New York market in 1873 was 6.32 cents per pound; from this it declined, with fluctuations, to 3.61 cents in 1878, and from that date it has risen, with fluctuations, to 4.35 cents in 1891. Despite these fluctuations, however, the production in the State has continued to increase, as is exhibited in the table. Applying various approximate values for the different periods to the different products up to 1892 inclusive, the value of the product is, in round numbers, $56,000,000.

The future of lead mining in the State is a question of considerable moment to its industrial growth. A comparison of the production of the year 1892 with that of 1891 shows an increase of 1,260 tons for the latter year, or about 4 per cent. Will this rate of increase be maintained, and for how long? An increase of lead production in the southwest will undoubtedly accompany the increase of zinc production which we have already stated is probable; but as only about a fourth of the production of lead is from that region, it is evident that we must look to a vigorous sustenance of the industry in the southeast for the rate to be increased, or even maintained. For this we cannot rely entirely upon the mines which are now the largest producers; they must be supplemented by the discovery of new ore bodies, and by the opening of new mines. Prospecting is now in progress in various sections of this region, and much success has attended some of the operations. The work of the Geological Survey in the district is not far enough advanced for specific predictions to be ventured here; that within the great untouched areas of the formations containing these ores extensive and yet undiscovered ore bodies exist, is, however, probable.

IRON ORES.

Iron mining in the State is confined to a portion lying south of the Missouri river and east of the marginal line of the Coal Measure. Within this area mining has been prosecuted during the past year in the following seven counties:

	Tons.		Tons.
St. Francois	79,000	Dent	24,800
Crawford	13,800	Howell	300
Phelps.....	1,300	Iron	7,000
Franklin.....	300		
Total production of iron ore during 1892 ...			126,500

During preceding years iron ores have been mined to a considerable extent in nine other counties as follows:

Stoddard.	Washington.	Madison.
Bollinger.	Callaway.	Oregon.
Wayne.	Butler.	Camden.

Geologically, the iron ores occur associated with the rocks of nearly every formation in the State, from the Archean to the Pleistocene, but the manner of their occurrence in these formations is quite different. The iron ores of the Archean and Algonkian formations are the most widely known and have yielded the bulk of the product to date. These are the familiar specular ores of the Iron Mountain and Pilot Knob mines. They are Missouri's best ores with the largest percentage of iron and are mostly of Bessemer grade. The ore at Pilot Knob occurs in a great sheet in Algonkian rocks, while at Iron Mountain it occurs in tongue-like masses or veins penetrating the porphyry in an irregular manner. Another class of ore, known as detrital ore, occurs at both points and consists of boulders scattered through the superficial material over the surface, or along the contact between the porphyry and overlying Cambrian limestones and sandstones. The mode of origin of the massive ore in the porphyry is a somewhat obscure question; it was probably deposited from a solution of iron in water, either in cavities existing in the porphyry or by replacement of the original materials of the rock with iron from such solutions. The immediate origin of the detrital ore is a simple question; that over the present surface having accumulated through the decomposition of the porphyry since Paleozoic times, while that between

the limestone and porphyry was accumulated in a similar manner before the deposition of the rocks of that series.

In the second class of ores are the specular and red hematites of Crawford, Dent and Phelps counties, which have been sources of large supply during past years. These are also excellent ores, but the iron content is not so high nor is the percentage of Bessemer grade so large as with the specular ores of the porphyries. These ores occur generally in stratified rocks of Cambrian age, and are frequently closely associated with the sandstones of that formation; they are also found in the Mississippian formation. Their mode of occurrence is peculiar, they having evidently accumulated in cavities formed in the limestones. Thus, at the Cherry Valley mine, in Crawford county, we have a great depression, like an inverted cone, from which half a million tons of ore have been taken. The sandstone beds, which flank the sides of this cone, and the remnants of such beds which occur in the ore body, dip towards the center of the cavity, indicating that, from the solution of a great layer of limestone, a cavity was formed into which the overlying and insoluble sandstones sank as the roof of the cavity collapsed. In this cavity waters accumulated bearing iron in solution, which was leached from the surrounding rocks, and there the air oxidized the iron contents and caused its deposition. By a long continuation of this process the great body of ore has accumulated.

The third class of iron ores of noteworthy importance are the limonites of the southern and extreme southeastern counties. These are comparatively low in iron content, averaging about forty-seven per cent, and are generally non-Bessemer. They are, however, very abundant, and deserve more consideration than they have received. The ores mined in Howell county are of this class. The mode of occurrence of these ores, and the manner in which they have been formed, are similar to those of the last class. They occur in the limestones and sandstones of the Cambrian system, and have apparently accumulated in cavities in these rocks, like the former. They occur in an earthy and porous condition, mixed with chert and other foreign materials, and also as pipe stem ore which has accumulated, like stalactites, from drippings of chalybeate waters; the latter is generally the better ore.

From what has been said concerning the occurrence of these ores, it is evident that they are of uncertain distribution, and their existence at any point, is, in a certain sense, adventitious. They are not confined to any one stratum, as is coal, nor to any one formation. They exist where the rocks and the conditions of erosion and deposition were favorable for their accumulation. They can only be discovered by detailed examination over each area. There are few general laws governing their distribution to guide one.

The earliest iron mining in the State was in 1815, on Shepherd mountain, in Iron county, and the next was in Crawford county, at the Harrison-Reeves bloomery, in 1820. At the Meramec mine, in Phelps county, mining was begun as early as the year 1826. The Meramec furnace was built in the year 1828, but the first blast furnace erected in Missouri was by Eversol, Perry and Ruggles, in 1823 to 1824, between Potosi and Caledonia. At Iron Mountain, mining did not begin until 1844, when surface ore was dug by the American Iron Mountain Company. The first iron ore was smelted there in 1848, when furnace No. 1 was put in blast. Soon after 1858, on the completion of the Iron Mountain Railway to Pilot Knob, the first shipments were made. In 1869, the present Iron Mountain Company was organized. The last iron made at Iron Mountain was in 1887, and up to that date the total amount of pig made there was 192,731 tons. The total amount of ore mined at Iron Mountain up to the year 1892 is, approximately, 3,500,000 gross tons. Pilot Knob was first entered in 1835, but little work was done until 1847. In 1848 the first furnace was built. About 1853 the Pilot Knob Iron Company was organized. The total amount of ore which has been mined at Pilot Knob to date is about 1,500,000 tons, and, in addition, about 107,000 tons have been taken from Shepherd Mountain and adjacent points.

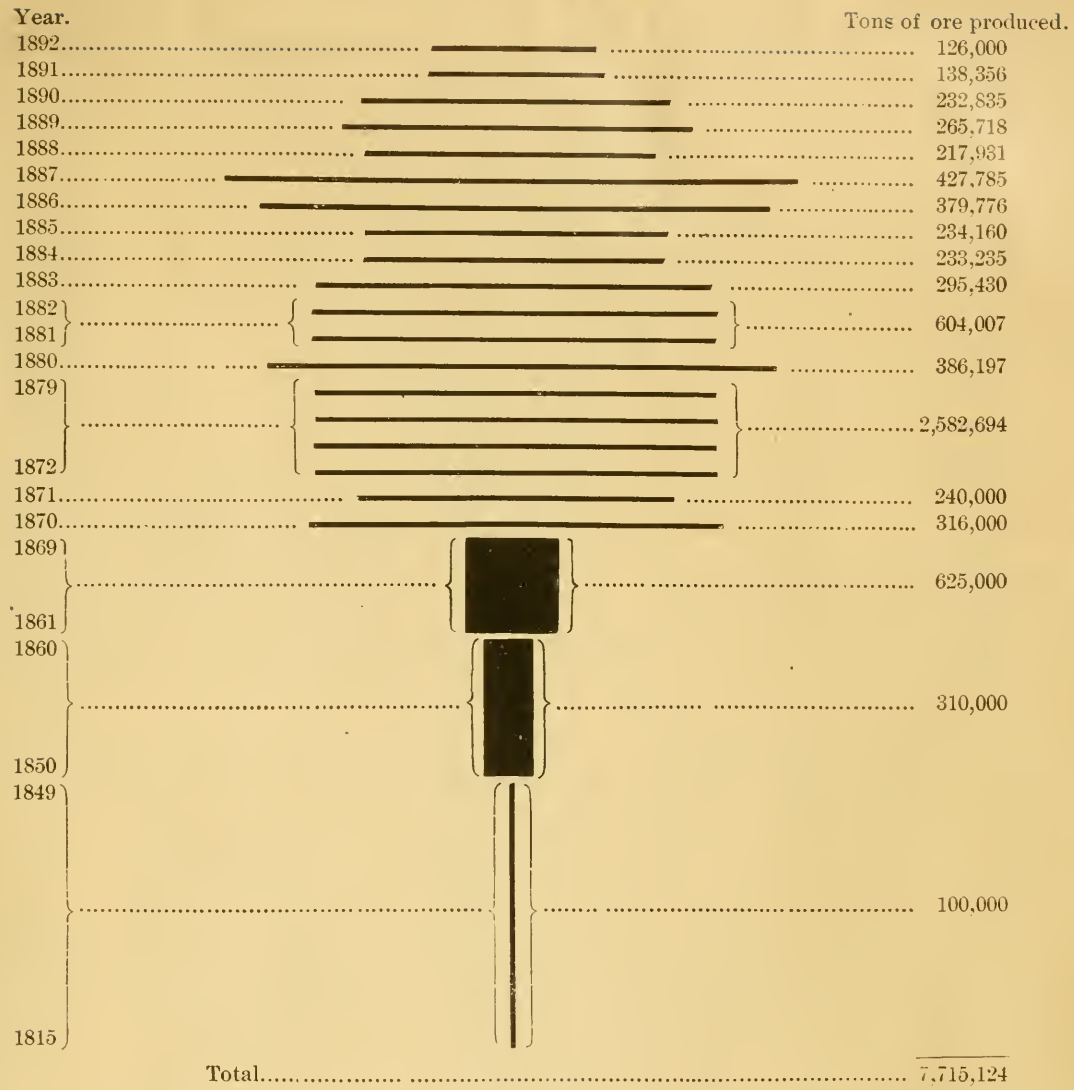
In Franklin county, a few deposits were worked between the years 1855 and 1860, and supplied the old Franklin furnace near Moselle, which was erected in 1859. In Crawford county, the Scotia iron furnace was erected in 1849; the Benton Creek mine was opened in 1873, and the Steelville, Grover and Iron Ridge banks were operated about the same time. Cherry Valley was not opened until 1878. In Dent county, the Simmons Mountain and a few other banks were operated in 1874. In Phelps county, the Meramec, Buckland and Beaver Creek banks were operated in the same year.

The table on the following page shows the growth and decline of Missouri's iron production from its beginning to the present.

The total amount of iron ore produced to date is, thus, 7,715,124 tons; from different values applied to different periods we obtain as the value of this total product the sum of $30,050,612.

The decline in Missouri's iron product is in sharp contrast to the increase in production of her other minerals, and calls for serious consideration. In 1880, she ranked sixth in the Union; in 1890, tenth; in 1891, thirteenth, and she now probably ranks still lower. This sudden fall is to be attributed, in large part, to the cessation of work at the Pilot Knob mine, which was practically abandoned last year. That the well-known deposits of specular ores in the State can no longer play the important part in the iron industry that they have in the past seems unfortunately probable. If the industry is to be maintained other sources of supply must be developed. Among the most promising fields for future activities, observations lead one to point to the limonites of the southern part of the State, which have heretofore remained practically unnoticed. That they are lower in iron contents and inferior in grade to the high-class ores used in the past, is not disputed. But that

IRON ORE PRODUCTION IN MISSOURI.



they are so much so as to be of no practical use is not the case. Their distribution, quantities and qualities have been determined by recent work of the State Geological Survey and a report just distributed deals at length with these ores. That they will bear shipment does not seem probable, but their development will probably best be by the establishment of furnaces and the production of pig within the mining region itself.

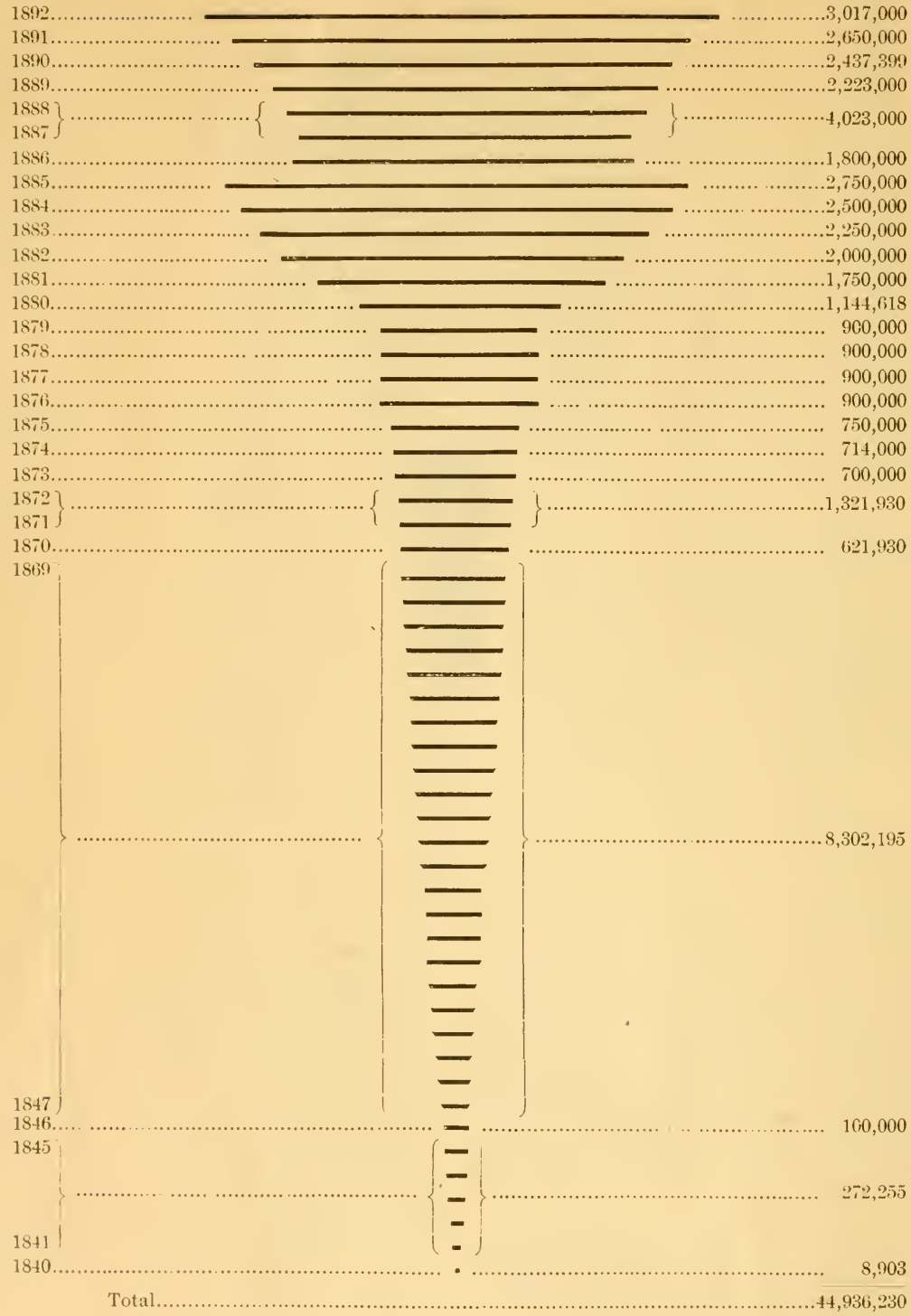
COAL.

Of the four prominent mineral products of Missouri, coal, iron, zinc and lead, coal is the most widespread, and is, doubtless, the most important when measured either by tons or by values. Its mode of occurrence is also the simplest.

The coal within the Coal Measure or Pennsylvanian area lies in beds or sheets, between similar beds of limestone, shale or clay, piled one upon the other to thicknesses of many hundreds of feet. Thus coal beds are sometimes near the surface, and are sometimes buried at great depths. They are sometimes continuous over areas of many square miles, and sometimes dwindle from a workable to an insignificant thickness within the same square mile. The greatest development of coal beds in the State is over the marginal area, as is indicated by the distribution of coal mines; here the beds are also nearer the surface, which makes them more accessible. In the extreme northwestern counties there is less available coal of workable thickness, though we have there the greatest accumulation of Coal Measure rocks, (a thickness of about 2,000 feet).

Just what is "workable thickness" is, of course, a variable term. In Pennsylvania a bed less than three feet thick was not considered workable, and would not compete with other beds five and more feet thick. In Missouri beds as little as eighteen inches thick

Coal Production in Missouri.



are extensively worked with profit, in fact as much as one-fourth of the annual production is from beds not over two feet thick. The reasons for this are in the conditions of the trade and in the manner of occurrence of the coal. The greatest thickness of any one coal bed in the State maintained over a considerable area, is about five feet; that is of a coal bed within the area of what we may term the regular Coal Measures. Beyond the margin of this formation, however, there are isolated deposits of coal of more limited superficial area, but of great vertical dimensions. These are familiarly known as "coal pockets." The coal in these pockets sometimes has the phenomenal thickness of fifty and even seventy feet. These deposits have frequently given rise to false hopes and illusions. The supply of coal which any one of them can yield is always comparatively small and will never warrant very large outlay for the development. The area of the Coal Measures of Missouri is, approximately, 23,000 square miles, distributed over fifty-seven counties in whole or in part. Coal pockets occur in many other counties. It occupies nearly the entire half of the State north of the Missouri river and extends south of that stream along the western border of the State in a strip nearly fifty miles wide. It thus occupies almost exclusively what we have termed the prairie country of the State.

During the year 1892 there was mined, according to the State Mine Inspector's figures, 3,017,000 tons, distributed in the thirty-three counties as follows:

	Tons.		Tons.
Macon	685,335	Bates	659,924
Lafayette	347,600	Randolph	297,011
Ray	272,948	Henry	137,258
Putnam	134,984	Vernon	119,036
Barton	108,784	Caldwell	38,333
Linn	35,588	Audrain	29,792
Grundy	28,670	Boone	21,058
Callaway	16,551	Montgomery	16,039
Adair	14,820	Johnson	10,485
Sullivan	8,800	Dade	6,881
St. Clair	5,405	Saline	4,440
Cedar	4,181	Cooper	3,666
Chariton	2,312	Nodaway	1,850
Cole	1,548	Carroll	1,380
Livingston	1,000	Schuyler	766
Pettis	433	Ralls	280
Miller	127		

Total amount of coal mined during 1892... 3,017,285

Coal digging was probably practiced by early settlers for forge uses, and similar small local purposes. From such beginnings the coal industry grew, and it is thus impossible to set a definite date for its birth. One of the earliest references is that of Captain Pike in 1806, who speaks of fine seams of coal far up the Osage river. In the report of the Lewis and Clarke expedition, performed during the years 1804 to 1806, the existence of coal in the State is also mentioned. According to a congressional report, there was mined in the State in the year 1840, 8,903 tons of coal. From other sources we learn that there was weighed at the city scales of St. Louis in 1846 about 70,000 tons, the great advance being ascribed to the increase in the business, and the number of founderies and factories in the city. Between the years 1850 and 1860 a large amount of coal was mined in St. Louis county, but we have as yet obtained no figures indicating the amount produced. In 1860, coal was mined for shipment at Carbon, Macon City, Bevier, Lexington and St. Louis. The product at Lexington supplied most of the steamboat trade. The first coal mined on the Missouri Pacific Railway, we are informed by Prof. G. C. Broadhead, was in 1867, by the Pacific Coal Company, near Center Town, in Cole county, and was from a pocket. Mines in Johnson county were opened soon after this.

From the recorded statistics of production, combined with estimates where exact data were not attainable, the table of coal produced to date has been compiled. (See preceding page.)

From this table it is seen that the total amount of coal thus far produced is, in round numbers, 45,000,000 tons; this, at a valuation of $1.50 per ton, represents $67,500,000.

REVIEW.

This completes what will here be said concerning the four prominent mineral products of Missouri. Reviewing this we see that of these there has been produced, up to and including the year 1892, the following amounts:

	Production in 1892		Total produced to date.	
	Tons.	Values.	Tons.	Values.
Zinc ore...	131,487	$2,862,475	1,117,500	$24,585,000
Pig lead....	32,260	2,194,029	639,839	56,000,000
Iron ore...	126,500	234,607	7,715,124	30,050,612
Coal	3,017,285	3,825,828	44,936,230	67,500,000
Total...	3,307,553	$9,116,939	54,408,693	$178,135,612

Referring to the tables accompanying the preceding pages we see that lead has been produced for the longest period, iron for the next greatest, coal next, and zinc last. That the value of the coal product is the greatest and is represented by a very large bulk, which is significant as indicating the amount of traffic which a coal industry gives rise to; that the value of pig lead product is next, but is represented by an almost insignificant bulk as compared with coal; that the value of the zinc product is third, but is represented by a somewhat larger bulk than lead, due to the fact that the tonnage is of ore and not of spelter; that the value of the iron ore produced is least of all, but is represented by a comparatively large bulk. The productions of zinc, coal and lead have increased, and this more rapidly with the zinc than with any one of the others. The production of iron in the State was large and increasing between the years 1870 and 1887, but it has fallen off alarmingly during the past few years. The value at present of the annual production of coal, zinc and lead are not very widely separated, being about four, three and two millions of dollars respectively; while the iron product represents a value of less than one-quarter of a million.

That Missouri has prominent rank as an ore producer is evident from comparisons made with other States of the Union. Of these products, her lead, zinc and coal are articles of traffic and export, as are

also her clays and limes, and her supplies of these are large. They are thus sources of direct income, and, in addition, supply home needs. In other materials for domestic consumption the State is also splendidly endowed, and, as her population increases, and her local industries develop, the full value of these possessions will become more and more appreciated.

CLAYS AND SHALES.

Missouri possesses in great abundance clays suitable for all ordinary uses, such as the manufacture of common, fire and ornamental brick, for paving brick, sewer pipe, drain tile and pottery. In addition, she possesses large quantities of superior fire clays, which have, so far, been principally used for the manufacture of fire brick, glass house pots and gas retorts. Recent work of the State Geological Survey is further developing the fact that there are also large deposits of clays suitable for the manufacture of stoneware and china. So far as investigations have gone to date, the following is a list of the counties in the State which contain clays of the characters specified:

Fire Clays.—St. Louis, Franklin, Crawford, Phelps, Morgan, Cooper, Henry, Warren, Callaway, Audrain, Randolph, Greene and Clay.

Stoneware Clays.—Stoddard, Scott, St. Louis, Moniteau, Cooper, Morgan, Henry, Cass, Vernon, Barton, Jasper, Christian, Polk, Monroe, Shelby.

China Clays and Kaolin.—Cape Girardeau, Bollinger, Iron, Jefferson, Oregon, Howell, Morgan.

The clays for common uses are derived chiefly from the loess, or from residuary products of rock decay. Paving brick is manufactured largely from Coal Measure shales, as is also much of the sewer pipe and drain tile. Fire brick, pots and retorts are made largely from the Coal Measure clays, especially in the works of St. Louis. Various proportions of what are known as "rock clays" are, however, mixed with these. Some fire clays, stoneware and china clays of the State occur in pockets in older rocks, from the Cambrian up to the Mississippian. They are hence of doubtful age, though of comparatively recent formation. They are altogether peculiar deposits, both as regards the conditions of occurrence, as well as the character of the material.

The common clay products used in ordinary building purposes are manufactured in all the larger towns of the State. Excellent paving brick are produced at Moberly, in Randolph county. There are large sewer pipe works at St. Louis and Kansas City. Fire brick and other refractory clay products are made on a large scale in St. Louis; also at Fulton in Callaway county, and Mexico and Vandalia in Audrain county and in Montgomery county. Potteries are operated in St. Louis, Kansas City, Henry county and at a few other points in the State.

Missouri clays have a high reputation, especially the fire clays. The products, as well as the raw material, have been shipped to all parts of this country and to foreign countries also, such as Mexico, South America and Africa. They are destined to have a great development in the future, and will be the basis of a large industry.

BUILDING STONES.

Missouri is abundantly supplied with building stones for all ordinary home uses, and shipments are made from many of her quarries to foreign points. In this list are included limestone, marble, sandstone and granite, and, for ornamental purposes, Mexican onyx. Among the limestones, the most prominent source of building material, are the Mississippian beds which are quarried about St. Louis, near Springfield in Greene county, in Dade county, at Carthage in Jasper county, about Hannibal in Marion county, about Louisiana in Pike county. This stone is of a light gray color, coarse-grained, crystalline and often takes a fine polish. From some of the quarries it can be obtained in blocks of almost any dimensions required. Fine joints sometimes traverse this rock in a horizontal direction, known as "Crows feet" or "suture joints." These, though not directly impairing the strength of the stone, are lines of attack and will become lines of weakness with long exposure.

The marbles of the State are confined principally to the southeastern portion, to Iron, Madison, Reynolds and Ste. Genevieve counties. Some so-called marble has been found in northern Warren and Montgomery counties. None of this stone has been extensively used so far. The beds in Madison and Iron counties are seldom over a foot thick and are often less. The stone is gray, pink and red colors, often beautifully marked. The Ste. Genevieve county bed is thicker, but not uniform in texture, though often handsomely marked. Quite extensive openings have been made in these latter beds, and some of the product has been shipped to Chicago, but the obstacles in the way of transportation, and other causes, have prevented their extensive development.

The sandstones of Missouri are of excellent quality, and are very abundant at a number of places. Some of the best stone in the State is found in Ste. Genevieve county, a few miles south of the town of that name. The stone was quarried extensively between the years 1873 and 1887. The face at present exposed is about twenty feet high. The stone is of a buffish yellow color. It has been used in the approaches of the Eads bridge over the Mississippi river at St. Louis, in the Iowa State House and in other important structures. Grindstones are also manufactured from this stone. The Warrensburg sandstone, in Johnson county, is operated by a number of quarries in which faces fifty or more feet high are exposed. This stone is extensively used in Kansas City and other places in large and handsome buildings. It is of a uniform light drab and also of a yellowish color. At Miami, Carroll county, is the White Rock quarry. Here a face some sixty feet high is exposed. The stone is similar to that at Warrensburg; large quantities have been quarried

for window and door sills and caps and for other purposes. In Vernon county are a number of deposits of sandstone of good quality, but some is adapted only to interior work.

The onyx of Missouri is of the variety known as Mexican, and is arragonite or carbonate of lime. It has been developed only quite recently, chiefly in Crawford and Pulaski counties. It is also known to occur in Howell, Stone, Barry, Laclede, Camden, Morgan and other counties; nothing more than specimens have been obtained as yet from these counties, however. It is generally of a brown or buff color, though sometimes of a clouded white; it admits of a high polish and is often translucent. It is generally found in caves and is a product of the deposition of lime from percolating waters.

LIMES, SANDS AND GRAVELS.

Of these common materials of construction Missouri has an abundant supply. Limes of the very best grades are manufactured at several points in the State. Large quarries and kilns are operated in and about St. Louis, at Hannibal in Marion county, at Louisiana in Pike county, at Ste. Genevieve, at Cape Girardeau, at Springfield and at Ashgrove in Greene county, at Carthage in Jasper county, and in Callaway county, and at other points in the State. The rock used in all these cases, with the exception of Cape Girardeau, is from the Mississippian series. It is a remarkably pure limestone, especially that quarried at Louisiana.

Sands and gravels are abundant along the streams in all parts of the State, but especially south of the Missouri river. Sand is dredged from the channels of the Missouri and Mississippi rivers at several points. The river bars are also sources of gravel, but the glacial deposits and river terraces of earlier Pleistocene age are perhaps more frequently resorted to. In the vicinity of Pacific, and at other points in Franklin county, beds of gravel occur well above the present flood plains of the stream. These are mixed with a ferruginous clay which becomes very much compacted under wagon or foot travel. Many carloads of this gravel are shipped to St. Louis annually and used for a top dressing along some of the streets and boulevards.

MINERAL WATERS.

Missouri possesses a large number of mineral waters, many of which are of undoubted therapeutic value. They are not confined to any one part of the State, but are most abundant in the central and western portions. These waters have recently received extended study, and, as a result, they are divided into the following five classes:

(1) Muriatic waters, (2) Alkaline waters, (3) Sulphatic waters, (4) Chalybeate waters, (5) Sulphur waters.

The Muriatic waters are essentially brines, and salt is their main and distinguishing constituent. They are among the most abundant in the State, and the volume of their flow at some of the springs is very large. The amount of mineral matter in the different waters varies greatly and ranges as high as 1800 grains to the gallon. In Alkaline waters sodium or magnesium carbonate are the distinguishing constituents. Comparatively few of such waters are recognized in the State, and those examined are not highly mineralized, the maximum amount of mineral matter contained being 95 grains to the gallon. Sulphatic waters contain one or more sulphates as their distinguishing constituents. Very few of these have been discovered. They contain as much as 570 grains to the gallon. The Chalybeate waters are very abundant in the State; they are distinguished by containing ferrous carbonate in solution. The maximum amount of mineral water contained in any examined so far is 150 grains to the gallon. Only two Sulphur waters have been determined. These contain sulphur combined as a sulphide or sulphydrate. The waters analyzed contain about 120 grains to the gallon.

Most of the mineral springs in the State are frequented by people living in the neighborhood and a large number are improved, so as to provide for the care of at least a few guests. Extensive or complete improvements of a sanitarium have been made only at a few places. The most important of these are at Excelsior Springs in Clay county, near Kansas City, at Lebanon in Laclede county, at Pertle Springs in Johnson county, at Sweet Springs in Saline county, at Clinton in Henry county, and at Nevada in Vernon county.

MINOR MINERAL PRODUCTS.

COPPER, BARYTES, GLASS SANDS AND SILVER.

Copper.—Among the minor mineral products copper ore is of quite frequent occurrence, generally in the form of the sulphide, chalcopyrite, or of the carbonate, malachite. The principal occurrences of such ore are Ste. Genevieve, Shannon and Franklin counties. It is found at these places in the magnesian limestones of Cambrian age; the ore follows the stratification planes, but is apparently formed by replacement subsequent to the deposition of the rocks. At the Cornwall mines, in Ste. Genevieve county, extensive mining operations were prosecuted in the past and reduction works were erected. At present no mining of copper ore is done in the State.

Barytes.—In production of barytes, Missouri ranks second in the Union, according to the figures of the 11th census, and her product is credited with being the purest. In 1889 the production was 7,558 tons, valued at $32,715, and in 1892 it was about 10,000, valued at nearly $40,000. This production is distributed over Washington, St. Francois, Miller, Morgan and Jefferson counties. Nearly four fifths coming from the first-named county. The material is obtained largely from the dump piles of old lead mines, it being found in crevices in the limestone associated with the lead ore. At some localties it is dug directly. The product is used chiefly in the manufacture of paint.

Glass Sands.—Sands suitable for the manufacture of plate and other qualities of glass are abundant in the eastern part of the State, especially in Franklin, Jefferson and Ste. Genevieve counties. The formation known as the Saccharoidal sandstone is the chief source of this material. Such sand is dug and shipped at Pacific and Tavern Rock in Franklin county. About 750 carloads, valued at $10.00 per car, were shipped in the year 1892. At Crystal City, in Jefferson county, an equal amount of sand was shipped, and, in addition, the large plate glass works erected at that place were supplied. From this point 180 carloads of plate glass were shipped in 1892, valued at $1,253,000.

Silver.—The only occurrence of silver in Missouri is at the Einstein silver mines on the St. Francois river, in Madison county. Here a nearly vertical vein of quartz occurs traversing the Archean granite and carrying argentiferous galenite. Picked specimens of the latter yielded to the assay all the way from a fraction of an ounce to 184 ounces to the ton and one specimen much exceeded the last figure. The mine was operated some 13 years ago and an incline and shaft were sunk. The mine has been abandoned ever since for causes which are not clearly known. Many are still confident that paying ore exists here.

CONCLUDING REMARKS.

Limitations of space have prevented anything like a full treatment of the many topics included in the preceding article. The attempt has been made to convey in these few pages a clear, but generalized idea of the geology and mineral products of the State of Missouri. The coals, the iron ores and the mineral waters of the State have received quite full treatment in the volumes on these subjects recently issued by the State Geological Survey. A report on the subject of zinc and lead ores is now being prepared by the State Geologist and will be ready for distribution later; reports on other subjects are prepared or are in course of preparation and will be issued from time to time. To these works the reader is referred for more detailed information. In the preceding article the writer has drawn largely from these reports or manuscripts of the survey, but for the figures of production and shipments during the past few years, he is, in addition, indebted to the published reports of the State Mine Inspector, Mr. C. C. Woodson, and of the ex-State Labor Commissioner, Mr. W. C. Hall.