IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE

PREPARED UNDER THE DIRECTION OF THE MINERAL RESOURCES COMMITTEE OF THE IMPERIAL INSTITUTE, WITH THE ASSISTANCE OF THE SCIENTIFIC AND TECHNICAL STAFF

THE PLATINUM METALS

BY
A. D. LUMB, A.R.S.M., F.G.S., Assoc. Inst. M.M.
LATELY OF THE SCIENTIFIC AND TECHNICAL DEPARTMENT, IMPERIAL INSTITUTE

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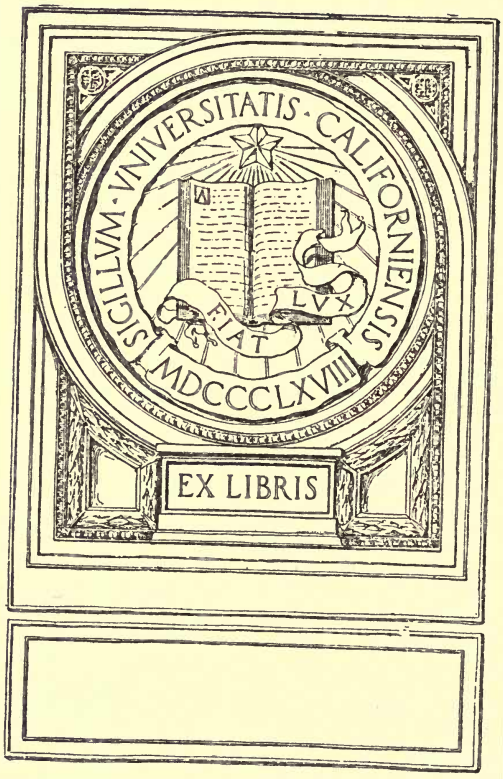
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IMPERIAL INSTITUTE

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A special staff is engaged in the collection, critical revision and arrangement of all important information respecting supplies of minerals especially within the Empire, new methods of usage and other commercial developments.

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PREFACE

THE Mineral Resources Committee of the Imperial Institute has arranged for the issue of this series of Monographs on Mineral Resources in amplification and extension of those which have appeared in the *Bulletin of the Imperial Institute* during the past fifteen years.

The Monographs are prepared either by members of the Scientific and Technical Staff of the Imperial Institute, or by external contributors, to whom have been available the statistical and other special information relating to mineral resources collected and arranged at the Imperial Institute.

The object of these Monographs is to give a general account of the occurrences and commercial utilisation of the more important minerals, particularly in the British Empire. No attempt has been made to give details of mining or metallurgical processes.

HARCOURT,

Chairman Mineral Resources Committee.

IMPERIAL INSTITUTE, LONDON, S.W.7.
July 1920.

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THE PLATINUM METALS

CHAPTER I

PLATINUM METALS: THEIR OCCURRENCES, CHARACTERS AND USES

INTRODUCTION

THE metals which comprise the Platinum group are the following: Platinum, Palladium, Iridium, Osmium, Ruthenium and Rhodium.

Up to the year 1914 Russia produced over 90 per cent. of the world's supply of platinum, the Republic of Colombia, South America, ranking next in importance with about 5 per cent. Owing, however, to the war and to the chaotic conditions brought about by the revolution, the output of Russia has considerably decreased, and although the Colombian production has been steadily increasing, the increased demand in connection with munition manufacture caused a somewhat serious shortage during the latter stages of the war, which was especially felt in the United States. As a result much exploratory work has recently been carried on in an endeavour to discover new deposits of importance; but up to the present, although several fresh occurrences have been brought to light, results have on the whole been disappointing.

OCCURRENCES

Platinum usually occurs in nature as native metal alloyed with one or more of its allied metals in the form of very fine grains more or less flattened; sometimes in the form of irregular nuggets; and occasionally, though rarely, in small cubic crystals. It is sometimes coated with a black layer of iron

oxide, which may be magnetic, in which case it is not easily recognizable. When unrefined it is referred to as "crude" platinum.

With the exception of a certain amount of the platinum metals, obtained from the refining of copper and gold bullion, particularly from the copper-nickel deposits of Sudbury, Ontario, about 99 per cent. of the whole supply is derived from alluvial deposits. Several occurrences of platinum *in situ* are known, but so far few are of commercial importance: however, in view of the indications of exhaustion shown by some of the placer deposits, notably in Russia, the exploration of primary ores is now receiving more attention and practical results have already been achieved in Russia and in Spain.

The mother rocks from which the deposits are derived, in the large majority of known cases, consist of basic and ultra-basic igneous rocks, including peridotites, pyroxenites and dunites. The two first are composed of iron magnesian silicates, pyroxene, augite and hornblende with olivine, chromite, ilmenite and magnetite: the dunites consist principally of olivine with some chromite. These rocks are often found to have undergone more or less alteration to serpentine. In addition, platinum has been found in quartz veins, notably at the Boss Mine, Nevada, and in a few known cases it has been derived from formations in schistose, or altered sedimentary rocks.

When present in serpentine, platinum is usually disseminated through the rock in fine particles. It seldom occurs in a lode formation. In sedimentary rocks it usually occurs in sandstones. In cases where alluvial deposits have been derived from the basic igneous rocks, the associated minerals are usually chromite, magnetite, ilmenite, iridium and osmiridium. In sedimentary deposits the metal is commonly associated with quartz, copper, nickel, silver and palladium.

Platinum has been found in certain varieties of the copper ores tetrahedrite and bournonite. It has occasionally been located in shales and in coal, although not in recoverable quantities. In the latter case, in an Australian coal, it is associated with vanadium [1/p. 992].

Several cases are known of platinum being present in meteor-

ites, two well-authenticated instances having been reported from Mexico. Platinum has been shown to exist in meteoric iron from New South Wales.

Crude platinum, as recovered, contains from 70 to 90 per cent. of the metal, and, as mentioned above, is really an alloy of platinum with one or more of the allied metals, the chief impurities consisting principally of iron and copper.

The table on the next page gives the analyses of typical samples of crude platinum from the Urals, California, British Columbia, and other places.

Platinum also occurs in combination with arsenic in the mineral *Sperrylite* ($PtAs_2$), in the form of minute octahedral crystals. The colour of this mineral is tin white, its lustre is metallic and brilliant, its hardness varies from 6 to 7, and its specific gravity is 10·6. The mineral is brittle and breaks with a conchoidal fracture. It is very rare, and is interesting as being the only mineral of platinum known besides the native metal. It occurs associated with sulphide minerals of magmatic origin in gabbros and diabases, notably in the nickeliferous pyrites of Sudbury, Canada, and in the copper ores of the Rambler Mine, Laramie, Wyoming.

It is probable that the palladium, which is also found in these deposits, is similarly present in the form of an arsenide, but such a mineral has not yet been definitely proved to exist.

The following is an analysis of a sample of sperrylite: platinum, 54·47 per cent.; rhodium, 0·76 per cent.; palladium, trace; arsenic, 42·23 per cent.; antimony, 0·54 per cent. [3/p. 69].

Properties of the Platinum Metals

Platinum.—The colour is white with a greyish tinge. When pure it is very malleable and ductile. Its coefficient of expansion is less than that of all other metals. Platinum fuses at about 1750° C., but the presence of impurities lowers the melting-point. Its specific gravity is 21·5, and its hardness is from 4 to 5. Its electric conductivity is low, being 13·4 at 0° C. [4/p. 398].

Platinum is not acted upon by either nitric, sulphuric or

Composition of Native Platinum and Osmiridium

Locality.	Pt.	Fe.	Pd.	Rh.	Ir.	Os.	Cu.	Os-Ir.	Remarks.
Platinum	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Urals 1*	76·22	17·13	1·87	2·50	tr.	—	0·36	0·50	Magnetic grs.
Urals 2	73·58	12·98	0·30	1·15	2·35	tr.	5·20	2·30	Magnetic grs.
Urals 3	81·34	11·48	0·32	2·14	2·42	tr.	1·13	0·57	Non-magnetic.
Urals 4	78·94	11·04	0·28	0·86	4·97	—	0·70	1·96	Non-magnetic.
Urals 5	86·50	8·32	1·10	1·15	—	tr.	0·45	1·40	Non-magnetic.
Borneo	82·60	10·67	0·30	—	0·66	—	0·13	3·80	Gold, 0·20 per cent.
Brazil	72·62	tr.	21·82	—	0·88	—	—	—	Sand, 0·42 per cent.
Granite Cr., B.C.	68·19	7·87	8·26	3·10	1·21	—	3·09	14·62	Gangue, 1·69 ; non-magnetic.
Granite Cr., B.C.	78·43	9·78	0·09	1·70	1·04	—	3·89	3·77	Gangue, 1·27 ; magnetic.
Chocó, Col.	86·20	7·80	0·50	1·40	0·85	—	0·60	0·85	Sand, 0·95.
Chocó, Col.	84·30	5·31	1·06	3·45	1·46	1·03	0·74	—	Gold, 1·0 ; sand, 0·61.
California	85·50	6·75	0·60	1·00	1·05	—	1·40	1·10	Gold, 0·8 ; sand, 2·95.
California	79·85	4·45	1·95	0·65	4·20	—	0·75	4·95	Gold, 0·55 ; sand, 2·69.
Oregon	51·45	4·30	0·15	0·65	0·40	—	2·15	37·30	Sand, 3 ; gold, 0·85.
Fifield, N.S.W.	75·80	10·15	tr.	1·30	1·30	—	0·41	9·30	Gold, nil ; sand, 1·12.
" Australia "	61·40	4·55	1·80	1·85	1·10	—	1·10	26·00	Gold, 1·2 ; sand, 1·4.
Currumbin, Q.	26·12	27·17	—	—	—	—	2·51	40·02	Sand, 1·33.
Osmiridium									
Urals	10·08	tr.	tr.	1·51	55·24	27·23	tr	—	Ru, 5·85 (*Nevyanskite*).
Urals	0·14	0·63	—	1·65	43·94	48·85	0·11	—	Ru, 4·58 (*Nevyanskite*).
California	—	—	—	2·60	53·50	43·40	—	—	Ru, 0·50 (*Nevyanskite*).
" Australia "	—	—	—	3·04	58·13	33·46	0·15	—	Ru, 5·22 (*Nevyanskite*).
Currumbin, Q.	3·00	—	—	—	62·00	33·00	—	—	Sand, 2·00 (*Nevyanskite*).
Tasmania	0·37	0·30	0·21	33·80		57·09	tr.	—	Ru, 8·19; Au, ·04 (*Siserskite*).
Platiniridium									
Condalo, Brazil	55·44	4·14	1·49	6·86	27·79	tr.	3·30	—	
Native Iridium									
Urals	19·64	—	0·89	—	76·80	—	1·78	—	

Reference—Pt., platinum ; Fe., iron ; Pd., palladium ; Rh., rhodium ; Ir., iridium ; Os., osmium ; Cu., copper ; Os-Ir., osmiridium ; Ru., ruthenium.

* Average percentage of Urals platinum is a little under 80. [2/p. 558.]

hydrochloric acid, but is soluble in aqua regia (1 part of nitric to 2 parts of hydrochloric acid), or in other mixtures liberating chlorine, with the formation of platinum tetrachloride ($PtCl_4$). It is not acted upon by air or moisture, even at high temperatures. It is corroded by caustic alkalis, sulphides, sulphates, phosphates and arsenides, if heated in contact with them. It will not amalgamate with mercury unless sodium is present, in this respect differing from gold and silver.

Platinum, in a finely-divided condition, absorbs large quantities of hydrogen or other gases, which on occlusion become more active : hence its value as a catalytic agent.

Palladium.—This metal resembles platinum, but is sometimes fibrous, the colour being between that of platinum and of silver. It possesses a lower melting-point than platinum—about 1550° C. It is malleable, has a hardness of from 4·5 to 5, and a specific gravity of 11·5. As already stated, palladium, when found in copper ores, is probably present in combination with arsenic. *Porpezite*, a rare mineral, containing gold and up to 10 per cent. palladium, has been identified in gold-bearing veins in Brazil [see p. 54].

Palladium is produced from the refining of copper matte and of base gold bullion from Australia and elsewhere.

Iridium is a brilliant white brittle metal, with a specific gravity of 22·4, and hardness of 6 to 7. Its fusion point is very high—about 2200° C.—and under ordinary conditions it is not attacked by any acid. At 1100° C. it begins to oxidize to a purple oxide. Iridium usually occurs either in crude platinum, or alloyed with osmium, as iridosmine, or as native metal. The bulk of iridium is derived from the platinum placer deposits of the Urals, but the Californian metal is more valuable, on account of its better quality. It is also obtained in small amounts from copper bullion.

Osmium is a hard and brittle metal, bluish-grey in colour. Its specific gravity is 22·5, and it has a very high melting-point, in this respect being the most refractory of the group.

Iridosmine, or *Osmiridium*, an alloy of iridium and osmium, occurs as hexagonal crystals, or flattened grains of lighter colour than platinum. It may contain from 40 to 77 per cent.

of iridium, and from 20 to 50 per cent. of osmium. If the iridium predominates, the alloy is called *Nevyanskite*, and *Siserskite* if the osmium content is high. It is distinguishable from platinum by the brittleness of the flakes. Siserskite gives off a pungent odour, if strongly heated, caused by the volatilization of osmium. Iridosmine has a hardness of 6 to 7, and a specific gravity of 19 to 21.

Ruthenium is a white metal, with a specific gravity of 12·1. It is scarcely acted upon by aqua regia. Ruthenium occurs mainly in small amounts in iridosmine. It is also found in the copper ores of Sudbury and other places. *Laurite* is a very rare sulphide of ruthenium (RuS_2), containing a small amount of osmium, which has only been recognized in the Borneo deposits.

Rhodium is a white metal resembling aluminium, with a specific gravity of 12·1, and a melting-point of about 2000° C. It is ductile and malleable at red heat. In addition to its occurrence in crude platinum, the metal is also contained in small quantities in the sperrylite found in the copper ores of Sudbury, Canada [5/p. 779].

Colloidal Platinum.—This has only recently been detected in ores, and therefore its occurrence might not be detected qualitatively. By destroying its colloidal condition, however, its presence can be discovered in the ordinary ways [2].

Metallurgical Treatment

Crude platinum can be refined either by dry or by wet methods, the following being brief outlines of the two processes:

By the wet method, the crude platinum is dissolved in aqua regia, with excess of hydrochloric acid. Evaporation is continued until the whole of the nitric acid is expelled. By addition of a solution of ammonium chloride, the platinum is then precipitated as ammonium platini-chloride. This precipitate is heated to redness, when chlorine and ammonium chloride are given off, and spongy platinum remains. The last is next granulated, after fusion by the oxy-hydrogen blow-pipe in a small lime furnace. Platinum obtained by this

method may contain small amounts of iridium, rhodium and palladium.

In the dry method, introduced by Delville and Debray, the crude platinum is smelted with galena in a small reverberatory furnace. A portion of the lead is reduced to the metallic state by the iron in the charge, and forms a fusible alloy with the platinum. The osmiridium present settles to the bottom of the furnace, and may thus be removed. Litharge is then thrown in to form more alloy, and some glass to act as a flux. The alloy is cupelled, and the residual platinum is then melted in a lime furnace with the oxy-hydrogen flame. The platinum thus obtained often contains iridium and rhodium.

A combination of these two methods is also sometimes employed [4/p. 403].

The electrolytic process of gold-refining was introduced to treat platiniferous gold. In the gold chloride, or Wohlwill method, iridium and osmiridium are insoluble, and remain with the anode slime. Platinum and palladium, if nearly pure, are also insoluble, but when present alloyed with gold and silver, pass into the solution and remain there. In a hot bath it is stated that the platinum present should not exceed 50 gm. per litre. According to T. K. Rose, a cold bath containing only 20 gm. per litre causes a certain quantity of platinum to be deposited with the gold [6].

H. F. Keller, in " Platinum, the Most Precious of Metals " (*Journal of the Franklin Institute*, November 1912) deals fully with the extraction and refining of platinum.

Platinum-Refining Agencies

The following contains a list of the principal firms engaged in the refining of platinum metals :

In England : Johnson, Matthey & Co., Ltd., Lees & Sanders, Warstone Smelting Works, Sheffield Smelting Works, Johnson & Sons. (This is the list of the Ministry of Munitions.)

In France : Legende et Cie., Compagnie Internationale du Platine, Lyon Allemand, Lecht Lyonnais, Henrique Marrett, Bonnen, Hesse Fils.

In Germany: W. C. Heraeus, G. Siebert, F. Eisennad & Co.

In the United States: Baker & Co., American Platinum Works (N.T.), Irvington Smelting and Refining Works, J. Bishop & Co., H. A. Wilson & Co., Belais & Cohn, Kastenhuber & Lehrfeld, Roessler & Hasslacher Chemical Co., Wildberg Bros., and others handling scrap.

According to Russian information about 25 per cent. of the Russian output before the war was refined in Germany. In Russia there are practically no platinum-refining facilities [7].

The Uses of Platinum and its Allies

Platinum.—In the chemical industry platinum is largely used for catalyzers in the manufacture of sulphuric, acetic and nitric acids; for stills for the final concentration of sulphuric acid; and in the electro-chemical industry.

In the making of "contact" sulphuric acid a "contact mass" is charged into the chambers of the plant. This is formed by soaking asbestos, or anhydrous magnesium sulphate, with platinic chloride solution, and baking the mass to drive off the chlorine. The contact mass usually contains from 7 to 8 per cent. platinum, in a very finely-divided state. In the making of acetic acid from a mixture of air and alcohol vapour, platinized asbestos is used. For the catalyzer used in the conversion of ammonia into nitric acid a very fine-meshed platinum gauze is used; this is strengthened at its edges with platinum-iridium wire. One ounce of platinum is required for the production per annum of 25 tons of catalytic acid, or of 40 tons of nitric acid from ammonia.

In the finely-divided state all the other metals of the platinum group, especially palladium, have also the facility of absorbing great quantities of certain gases, and can be used as catalysts.

Owing to its high melting-point, and to the resistance to the action of acids at high temperatures, platinum is largely used for chemical ware in the form of crucibles, dishes, etc. Platinum crucibles are indispensable in the chemical analysis of rocks.

In the electrical industry platinum is largely used for contact points, in telegraph and telephone apparatus, in magneto-contacts, and in the construction of the thermo-couples of pyrometers. In the manufacture of jewellery, especially in the crown-setting of diamonds, platinum has been much used in the place of gold: alloyed with a little iridium it can be worked into delicate designs, which are durable. During the war, however, when platinum was largely wanted in the making of munitions, its use in jewellery manufacture was much restricted. Platinum was formerly largely used in dentistry. In photography potassium platino-chloride is required for producing platinotype prints. In the form of barium platino-cyanide it is used in X-ray photography as a coating for the projecting screen.

Platinum is required in the manufacture of certain parts of chronometers, theodolites and watches; also for standard weights and measures, and for various types of self-lighting lamps [2/p. 561].

Palladium has its chief value as a substitute for platinum, in palladium-gold alloys, which are used extensively in dentistry, for jewellery and for chemical ware. It is also utilized in the manufacture of astronomical instruments and watches, also for plating metal ware [1/p. 1002]. The use of palladium as a catalyzer is well known.

Iridium, when pure, is of small value, being difficult to manipulate on account of its brittleness. It is principally used in alloy with platinum for hardening purposes. Jewellers' platinum usually contains 10 per cent. iridium, and in the electrical industry an alloy composed of from 15 to 50 per cent. iridium is usually employed. Alloys with up to 10 per cent. of iridium are ductile and malleable, but with over that amount are hard and difficult to work.

The metal is used in the manufacture of fountain-pen points, for which purpose the grains require careful selecting [8/p. 106]; also for standard weights and for contact points. Iridium black, an oxide, is of value as a pigment for china-ware [1/p. 1001].

Iridium is suitable for sharp surgical instruments, and gold needles with soldered iridium ends are employed for stitching

wounds. It is also used in photography. Iridium is of greater scarcity than platinum, hence its greater value.

Osmium.—There is now little or no market for osmium. It was formerly in considerable use for the manufacture of incandescent lamps. Osmic acid is used for staining anatomical preparations in microscopic work. On account of the poisonous nature of its vapour the extraction of osmium is costly and dangerous.

Ruthenium is also of little or no commercial value. Both these metals possess the disadvantages of being brittle and easily oxidized.

Rhodium is of small commercial use. It is used principally in alloy with platinum. An alloy containing 10 per cent. rhodium is used for some thermo-couples of pyrometers, and in the making of laboratory utensils.

Platinum Alloys.—Platinum forms alloys with a number of metals, but only a few are of industrial importance [4/p. 400]. Platinum and iridium form a hard and elastic alloy, which is unaffected by air, and takes a high polish. Alloyed with 10 per cent. iridium platinum is used for one of the wires in thermo-couples of pyrometers; and with 10 to 20 per cent. iridium for making standard measures of length and weight.

Platinum and copper form various alloys. An alloy with 18·75 per cent. copper, called "coopers' gold," takes a high polish and closely resembles 18-carat gold.

An alloy of platinum and silver containing 66 per cent. silver is used as a standard of electrical resistance. An alloy containing 20 to 30 per cent. silver is used in dentistry.

Platinum alloys with lead, zinc and other metals at low temperatures; it is usually recovered from these alloys by cupellation.

Platinum alloys with steel in all proportions. With 10 per cent. platinum, rusting is prevented. A very elastic metal is produced by alloying platinum with from 5 to 10 per cent. gold.

The melting-point of silver is raised by alloying it with platinum, but its thermal conductivity is lowered.

The following table gives the composition of the principal platinum and palladium alloys [2/p. 561]:

—	Pt.	Cu.	Ag.	Au.	Ni.	Pd.	Other Constituents.
	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.
Jewellery alloys:							
Platinum alloy .	1	0–1	2–5	—	—	—	
Platinor . .	2	5	1	—	1	—	Brass 2.
Palladium alloy .	—	—	—	—	—	9	Rhodium 1.
Mock gold . .	7	16	—	—	—	—	Zinc 1.
Mock gold . .	1	—	1	—	6	—	Brass 1.
Mock gold . .	1	4	—	—	—	—	
Coopers' pen metal:	4	1	3	—	—	—	
Watch alloy .	—	13	11	18	—	6	
Watch alloy .	—	25	4	—	1	70	
Watch alloy .	63	18	—	—	17	—	Cadmium 1.
Platinum bronze .	1	—	—	—	90	—	Tin 9.
Dentists' alloy .	5	—	—	3	—	4	
Dentists' alloy .	7	—	3	2	—	—	
Dentists' alloy .	6	—	1	2	—	—	
Dentists' alloy .	—	—	—	4	—	1	
Palladium alloy .	—	—	2	—	—	3	

Alloy Substitutes for Platinum

On account of the scarcity and high price of the platinum metals, much attention has lately been directed towards the discovery of suitable substitutes.

In the electrical industry an alloy of 3 parts of palladium and 2 parts of silver is in use, also an alloy of nickel and chromium. *Platinite*, an iron-nickel alloy, containing 46 per cent. nickel and 0·15 per cent. carbon, has the same co-efficient of expansion as glass, and, when coated with copper, is used to replace the platinum connection wires of incandescent lamps. Tungsten is sometimes used for certain ignition devices. For cathodes an alloy of 90 per cent. gold and 10 per cent. copper can be used to replace platinum; the same alloy, if electrically coated with platinum, and then carefully polished and burnished, is suitable for platinum anodes.

For platinum chemical laboratory ware, there are several substitutes, such as fused quartz; various iron, chromium, and nickel-chromium alloys; *palau*, a gold-iridium alloy marketed in California; *rhotanum*, a general name for gold-palladium

alloys containing from 60 to 90 per cent. of gold, which are suitable for most chemical purposes, except for use with hot concentrated nitric acid, and for electrolytic anodes; *amaloy*, which is a complex alloy containing nickel, chromium, tungsten, etc., highly resistant to corrosion and to cold nitric and sulphuric acids [9/p. 600].

In the jewellery trade platinum has been replaced by an alloy of 90 per cent. palladium and 10 per cent. rhodium. For certain surgical work various *stellite* alloys, containing cobalt and chromium, and hardened by the addition of tungsten and molybdenum, are valuable substitutes for platinum, and are not affected by antiseptic solutions. In dental work pins are now made of tungsten coated with palladium [10/p. 549]. For most technical purposes an alloy of tungsten and nickel with gold or silver is used in Germany; it may be cast, rolled or forged, is acid-resisting, and capable of taking a high polish [11]. *White gold*, another substitute for platinum, contains fine gold, from 75 to 85 per cent.; pure nickel, from 10 to 18 per cent.; and zinc, from 2 to 9 per cent. *Illium*, a chromium-nickel-copper alloy reported recently as the discovery of S. W. Parr, of Illinois, is a substitute for gold or platinum, costing only 25 cents per ounce. It is stated to have been a "50 per cent. standard of success." The alloy withstands hot or cold, strong or diluted acid, can be both cast and machined, and is already used largely in the manufacture of calorimeter bombs [12].

The results of researches made to discover substitutes for platinum, and undertaken by the National Dental Association of America, are described at length by F. A. Fahrenwald, in a paper read in January 1916 before the American Institute of Mining Engineers.

Scrap Platinum

A considerable amount of platinum in the form of old and worn articles is now collected for return to the refineries, where it is re-treated, and sold again as new metal. The trade in scrap platinum has been particularly active in the United

States, official statistics showing that in 1916, 49,400 oz. of refined platinum were recovered.

World's Output of Platinum

According to J. L. Howe, the estimated limits of the total world-production of crude platinum, up to January 1917, were as follow [13]:

	In oz. (troy)	
	Minimum.	Maximum.
Russia	7,115,482	10,128,308
Colombia	700,000	735,000
Borneo	175,000	200,000
United States	10,000	12,000
Canada	9,000	10,000
Miscellaneous	9,000	10,000
Total	8,018,482	11,095,308

On the other hand, James M. Hill [14] states that possibly 5,000,000 oz. was the total world's production to June 1917, which he distributes according to the uses made of it as follows:

	Oz.
Chemical and physical apparatus	1,000,000
Electrical devices	250,000
Catalyzing	500,000
Dental uses	1,000,000
Jewellery	1,000,000
Minor uses and hoarded (balance)	1,250,000

It is difficult to obtain exact figures of the annual production of crude platinum. This is particularly so in the case of Russia, where there appears to have been a tendency for private enterprises to keep their published outputs as low as possible, in order to avoid registration. The discrepancy between the official and actual figures of production in Russia is variously estimated at from 20 to 60 per cent.

The table on the next page is compiled from the sources considered most reliable.

The market value of platinum has risen considerably since 1880. In that year the price was 12*s.* 7½*d.* per oz. troy, in 1890 it was 25*s.* 3*d.*, and in 1900, 63*s.* 1½*d.* The average prices

World's Production of Crude Platinum

(In troy oz.)

—	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.
Borneo and Sumatra [3]	—	—	200	200	†	†	†	†	—
Burma [8]	—	38	57	58	37	18	9	4	—
Canada [1]	—	—	—	18	—	23	15	57	39
Colombia [5]	10,000	12,000	12,000	15,000	17,500	18,000	25,000	32,000	27,030
Madagascar [6]	13	3	—	—	—	—	—	—	—
New South Wales [2]	332	470	610	442	244	56	82	259	—
Russia [4]	176,334	187,008	177,596	157,735	157,182	119,789	78,682	50,000*	—
United States [3]	390	628	721	483	570	742	750	605	—
Victoria [7]	—	184	—	127	—	—	—	—	—

Canada.—The recoveries of platinum at the works of the International Nickel Company in New Jersey for the years 1910–1912 were 258, 666 and 497 oz. respectively, chiefly from Canadian matte.

Russia.—The *actual* productions of platinum as quoted in *Mineral Industry* in oz. were: 1910, 300,000; 1911, 280,000; 1912, 300,000; 1913, 275,000; 1914, 240,000; 1915, 124,000; 1916, 90,000; 1917, 50,000.

* Estimated.

† Estimates not available.

[1] *Mineral Production*, Mines Dept., Canada. Figures are for alluvial production only, and far below *actual* production figures, not including Ontario production from nickel matte, for which only incomplete information is available. [See p. 25.]

[2] *Annual Rept. Dept. of Mines.*

[3] *U.S.A. Mineral Resources*, 1917, *Geol. Surv.*

[4] *Mineral Industry.* These are *official* figures for production; *actual* production is much greater than these.

[5] *Mining Journal*, November 30, 1918, p. 700, and *Mineral Industry.*

[6] *Mines and Quarries Reports*, Home Office.

[7] *Dept. of Mines Reports* (platinum obtained from copper matte).

[8] *Records of Geol. Survey, India.*

in London and New York for the years 1910–1919 were as shown on the accompanying tables:

Average price in pounds per troy oz. of refined metals of the platinum group in London

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Platinum Metals	9·1	8·6	9·5	9·5	8·1	10·9	10–14·5	14·5	20	24

1910, 1915, 1916 and 1917—*Metal Market Year Book.*
1911, 1912, 1913 and 1914—*Mining Magazine.*

Average price in dollars per troy oz. of refined metals of the platinum group in New York

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Platinum	33	43	46	45	45	50	84	103	106*	114
Iridium	—	—	—	—	65	83	94	150	—	—
Iridosmine	—	—	—	—	33	35	45	80	—	—
Palladium	—	—	—	—	44	56	67	110	—	—

1910, 1914, 1915, 1916 and 1917—*U.S. Geol. Surv. Mineral Resources.*
1911, 1912, 1913, 1918 and 1919—*Eng. and Min. Journ.*, vol. 107, No. 2, p. 77.

* The price was fixed on May 14, 1918, at $105.

CHAPTER II

SOURCES OF SUPPLY OF PLATINUM AND ALLIED METALS

(*a*) BRITISH EMPIRE

THE outputs of platinum metals in different parts of the British Empire are shown in the table on p. 14.

EUROPE

UNITED KINGDOM

There is no known occurrence of platinum in the United Kingdom, but there has always been much trade done there in the platinum metals, England having been the second largest importer of the big consuming nations. The following were the importations of Russian platinum for five periods since 1863:

Period	*Oz.*
1863–1880	512,005
1881–1890	167,999
1891–1900	437,645
1901–1910	259,111
1911–1915	71,624

[15/p. 923]

The above figures do not include receipts of platinum for seven different years since 1863, for which there are no records.

The table on the next page gives a summary of total imports of platinum metals for the years 1910–1918, with the countries of origin.

The platinum market in London was controlled by the Government from January 1916 to December 1918, Johnson, Matthey & Co., Ltd., acting as buyers. On December 26, 1916, platinum was declared contraband.

About 7 per cent. of the Russian and one-half of the Colom-

Imports of Platinum Metals, wrought and unwrought, into United Kingdom
(in troy oz.)

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.
From British countries . .	24	1,011	1,100	—	—	—	28	458	265
From foreign countries :									
Russia	4,167	2,579	461	1,778	—	7	—	—	—
Germany . . .	5,837	8,786	1,669	50	3	—	—	—	—
France	35,149	30,449	33,969	33,149	12,592	1,878	1,666	632	596
United States . . .	494	794	644	3,623	257	1,265	191	2,716	—
Colombia . . .	2,037	4,909	4,552	3,725	2,296	139	—	—	—
Other foreign countries .	454	—	158	315	40	59	79	—	362
Total: foreign countries . .	48,138	47,517	41,453	42,640	15,188	3,348	1,936	3,348	958
Grand total, oz. . . .	48,162	48,528	42,553	42,640	15,188	3,348	1,964	3,806	1,223

bian outputs were sold to England during the war, as well as most of the Australian and Indian production. Much of this metal was refined in the United States.

According to J. E. Orchard [17], the commercial control (financial) of the world's output of platinum of 267,233 oz. of 1913 was divided as follows: France, 74 per cent.; Russia, 18 per cent.; United States, 4 per cent.; British Empire, 2 per cent.; other countries, 2 per cent.; whilst the political control (territorial) was divided as follows: Russia, 93 per cent.; Colombia, 6 per cent.; other countries, 1 per cent.

ASIA

India

Traces of platinum and iridium have been noticed in association with the gold obtained from native workings at Bonai City. The gold occurs in a deposit of iron oxide, which forms the cementing material in a hard stratum of quartz pebbles. The oxide is separated by pounding, and then washed away to extract the gold. The proportion of platinum to gold is probably less than 1 to 20.

Platinum occurs, associated with gold, in the gravels of the Irawaddy River in Burma. A small quantity of platinum is obtained at Myitkyina by the Burma Gold Dredging Company. During the years 1911–13, 152 oz. were won by this company. In 1915 the output was 17·7 oz., and in 1916, 9·25 oz. In 1917, 4 oz. only were produced [18]. Owing to the cessation of the gold-dredging operations at Myitkyina, Burma has ceased to produce platinum, the quantity recovered during the year 1918 being only 0·31 oz. [90].

It has also been located with iridosmine in the auriferous gravels of the rivers draining the slopes of the Patkoi Ranges, both on the Assam and Burma sides [19].

AFRICA

Rhodesia

Platinum has recently been located in the Gwelo district, about 6 miles north-east of Indiva siding, where it occurs in the great dyke of norite, which is here about 4 miles

wide. A. E. V. Zealley, the late assistant Government geologist, made this occurrence the subject of a special report [20].

The country rock is a serpentinized dunite. The deposit is capped by a ferruginous siliceous gossan from 4 to 5 ft. wide, which may be traced on the surface for about 100 ft., and is comparable to a fissure vein. The gossan consists largely of hæmatite and chalcedony, with occasional veinlets of copper and nickel minerals. Although the presence of platinum in the ore could not be detected by panning, the possibility of its occurrence on geological grounds was considered, and a sample of concentrate from an unstated amount of ore was forwarded to the Imperial Institute for analysis. The sample was found to contain platinum to the amount of 1 dwt. 20 gr. per ton. A report on the further development of this deposit is awaited with interest.

A sample of concentrate from an unstated amount of material from the gem-bearing gravels of Somabula Forest, Gwelo district, was received at the Imperial Institute from the Director of the Geological Survey of Southern Rhodesia in November, 1918. On analysis this sample yielded the following per ton: platinum, 3 oz. 12 dwt.; osmiridium, 7 oz. The concentrate also contained a large proportion of gold. As shown by the latest information available, the deposits, although undoubtedly rich, appear to extend over a limited area. According to an analysis made at the Imperial Institute, a sample of chromite from Southern Rhodesia (Selukwe) contained 0·17 per cent. copper and nickel oxides, and a trace of platinum [21].

H. B. Maufe [22] has stated that as the River Umtebekwe drains two areas of ultra-basic rock containing chromite, it might be expected to contain alluvial platinum, as well as gold, and, as a matter of fact, platinum has actually been discovered in a reef in the Great Dyke (norite), at the head of the Umtebekwe valley.

The presence of platinum was recently reported at Willoughby's Halt, 12 miles south of Gwelo.

Union of South Africa

Cape Colony [23].—Platinum is present in varying quantities in the copper-nickel deposits at Insizwa, situated in the Cape

Province, close to the boundary between East Griqualand and Pondoland.

The rock formation consists of a basin-shaped mass of intrusive norite, averaging from 2,000 to 3,000 ft. in thickness, and lying in the shales and sandstones of the Beaufort Series of the Karroo System.

The ore body consists of sulphides of copper and nickel, in association with pyrrhotite, the minerals occurring disseminated near the basal margin of the intrusive in olivine picrite. Gold and silver are also present in small quantities.

The average copper and nickel contents in the ore are each about 4 per cent., and the platinum content averages from 2 to 3 dwt. per ton, the platinum being unequally distributed through the ore [24/p. 14].

It is not certain in what form the platinum occurs. It does not appear to be present as sperrylite. In the opinion of W. H. Goodchild it may occur in close association with the silver [24/p. 35].

Mining operations have been intermittently carried on here during the last fifty years, the last exploratory work coming to an end in 1911. Operations were, however, resumed early in 1920.

Transvaal.—Small amounts of platinum and its allied metals have from time to time been noticed in black sands from the battery "clean-ups" on the Rand at Klerksdorp and other gold-mining districts, and platinum to the amount of 2½ dwt. per ton is reported to have been present in residual slimes at the Rietfontein mines [25]. A specimen, consisting of about 85 per cent. osmiridium and 15 per cent. platinum, recently received at the Imperial Institute, was stated to have been taken from a compact shale, immediately underlying the banket reef in one of the mines of the Klerksdorp district. In the large majority of the gold mines, however, the platinum metals, if present, appear to exist in such small quantities as to escape detection.

A series of samples of chromite from Kromdaal, near Rustenburg, showed from a mere trace to 1 dwt. of platinum per ton, and one sample of chromite from the Secocoeniland deposits showed as much as 1½ dwt. of platinum per ton [26].

NORTH AMERICA

CANADA

The occurrence of platinum in Canada was first observed in 1862, in the course of gold-mining operations on the Rivière-du-Loup and the Rivière-des-Plantes in the province of Quebec [27/p. 210].

Since that time platinum has been found in a number of localities associated with auriferous gravels, but the crude metal has only been obtained commercially from the Similkameen district in British Columbia. These deposits first attracted attention in 1885. All the workings are alluvial, although the platinum has in several cases been traced to its parent source.

Alberta.—Platinum and gold in minute grains, closely intermixed, are found in the North Saskatchewan River, near Edmonton. In 1918 certain platinum occurrences were examined by the Munitions Resources Commission, visits being paid to Fort Saskatchewan and the Peace River district, in Alberta. These deposits, however, proved to be disappointing. In the former locality, which was carefully tested by drilling, the values of the samples obtained averaged less than 10 cents in gold and platinum per c. yd. of gravel [28/p. 427].

British Columbia.—Platinum, associated with gold, which is the dominant metal, occurs in the Tulameen River and its tributaries, the principal of which is Slate Creek, others being Cedar, Eagle, Bear and Granite Creeks. The metal is present in small rounded grains, or pellets. Chromite is often found intergrown with the platinum, olivine and pyroxene usually occurring in association. The heavy minerals remaining with platinum in the concentrate are titaniferous magnetite, chromite and native copper. The platinum is sometimes magnetic, probably due to the covering of the grains by small particles of magnetite [29].

The following analysis, according to G. C. Hoffmann, is representative of an average sample of crude platinum from the Tulameen River:

	Per cent.		Per cent.
Platinum . . .	72·07	Osmiridium . . .	10·51
Palladium . . .	0·19	Copper . . .	3·39
Rhodium . . .	2·57	Iron	8·59
Iridium . . .	1·14	Gangue (Chromite) .	1·69

Owing to the presence of osmiridium in considerable proportion, the ore is classed as "hard metal," and on that account fetches a higher price. Many of the richer placers have become exhausted, and work is now carried on by a few individuals, principally Chinese, who work during the summer months only. In some cases high benches, 50 to 100 ft. above the creek bottom, are being worked. Much of the platinum and gold is of a coarse texture, with a rough surface, and the latter is sometimes found embedded in quartz. Nuggets are sometimes found encrusted with chromite, and are thus liable to be overlooked. The deposits are therefore not of great age, and the metals have not been transported long distances from their sources.

Kemp is of opinion that the platinum is derived from pyroxenite dykes cutting through peridotites, which outcrop on Olivene and Grasshopper Mountains.

It is of interest to note that some diamonds and rubies have been discovered with the platinum in the Tulameen deposits. They are of good quality, but of small size, and occur in a matrix of dunite [27/p. 210]. American capital dominates the platinum industry in the district. In 1918, at the request of the Imperial Munitions Board, special investigations in this area were undertaken by members of the Geological Survey, and several prospecting bores were put down to bedrock. Full reports of the work done are not yet available, but it is understood that the results are considered to be promising, and to warrant further examination of the district [28/p. 429].

Platinum was in 1918 discovered at Franklin Camp, near Grand Forks, B.C., in the "Black Lead," so-called, which is a mixture of augite, 75·13 per cent.; orthoclase and microcline, 17·06 per cent.; hornblende, 1·47 per cent.; and magnetite, 6·06 per cent., as determined by microscopic measurements on a typical specimen, with accessory minerals, chalcopyrite,

bornite and apatite. A sample of chalcopyrite assayed 0·38 oz. crude platinum per ton. Samples of the "Black Lead" assayed from 0·02 to 0·17 oz. per ton [30].

At Burnt Basin, on the Mother Lode claim, an auriferous quartz vein carries platinum, in amounts varying from a trace to 0·25 oz. per ton. The quartz also contains chalcopyrite, pyrite, galena, sphalerite and molybdenite [30]. Native platinum in small quantities has been found associated with gold in the following localities: Tranquille River, Fraser River, Rock Creek, Yale District, North Thompson and Clearwater Rivers. It has also been reported to occur in a dyke across the Kootenay River upon the Granite Poorman Mining Company's property a few miles from Nelson [31]. At Siwash Creek, in the Tulameen district, small flakes of platinum, associated with chromite, often occur in shear zones in granite. Dredging for gold and platinum is being carried on, on the Peace River, North British Columbia.

According to J. B. Hobson the heavy concentrate produced on the Consolidated Caribo hydraulic mine at Quesnel, contains, besides gold and silver, platinum, palladium and osmiridium, one analysis giving a total value of $3,873 per ton. The gold and silver being non-amalgamable are probably included in particles of pyrite and galena, whilst the platinum metals are found as minute grains or are enclosed in particles of chromite and magnetite. A system of "under-currents" is being installed to properly dress this concentrate [32].

In 1917 the recorded output of crude platinum from the placer gravels of the Tulameen district in British Columbia was 57 oz., that for 1918 being 39 oz. For the five years preceding 1892, this district produced on an average over 1,500 oz. per year.

Manitoba.—Samples of gold ore containing platinum have been obtained in the Star Lake district of south-eastern Manitoba [33]. Analyses of the samples from different auriferous reefs were made by the Department of Mines in 1917, and yielded platinum varying in amount from a trace to 0·1 oz. per ton. In addition to gold and platinum, the veins carry small quantities of galena, zinc blende, pyrite, chalcopyrite and arsenopyrite in a gangue consisting mainly of quartz.

Platinum is reported to occur in auriferous quartz veins in several mines and prospects in Le Pas district; a picked sample of ore from the mine of the Northern Manitoba and Development Company, assayed $49 gold and $17 platinum per ton [34]. McCafferty's Prospect, about 5 miles away, contains platiniferous quartz.

Nova Scotia.—According to E. R. Faribault in *Summary Report*, 1918, Part F, of the Canadian Department of Mines, platinum has been found, mostly in traces, in some of the old gold districts of Halifax county and, lately, in the tungsten concentrates of the Moose River mines. So far, all occurrences are in quartz veins in the lower quartzite and slate formation of the gold-bearing series of the Atlantic coast. The platiniferous mineral is supposed to be sperrylite, with which is associated arsenopyrite.

Ontario.—Sudbury is one of the few places where platinum is profitably extracted from deposits *in situ*. The metal, which was first discovered in this region in 1889, is found mostly in combination with arsenic, as sperrylite associated mainly with chalcopyrite in the well-known copper and nickel-bearing deposits of the district.

The origin of the ore-bodies has not yet been settled. They are either marginal deposits in, or off-shoot deposits to, a norite laceolith, which has intruded sedimentary rocks, the ores consisting principally of chalcopyrite, pyrrhotite, and pentlandite. Metallic platinum, gold, silver and palladium occur in the ore, the last also, probably, as an arsenide. The highest platinum content is associated with the highest copper content; the highest palladium with the highest nickel. According to Roberts and Longyear [35] the mean analysis of rocks of from sixteen drill holes gave an average ore content of: copper, 1·11 per cent.; nickel, 1·95 per cent.; silver, 0·223 oz.; gold, 0·022 oz.; and metallic platinum, 0·0068 oz. per ton. The ore is principally worked for its nickel and copper content, and yields a large proportion of the world's supply of nickel. The ore is first smelted at the mines, and a portion of the low-grade matte so produced is then shipped to South Wales for final treatment, the remainder being sent to the recently-constructed refinery of the International Nickel Co., at Port

Colborne, Ontario, and to the United States. It was stated in 1903 that this matte contained on the average 1·25 oz. of the platinum metals per ton of nickel content of the matte, of which about 80 per cent. was extracted [36/p. 10]. The Victoria Mine, owned by the Mond Nickel Co., is stated to carry a high percentage of the precious metals, as is also the Vermilion Mine, although in the latter case the ore body is very small. In 1917 the total output of copper-nickel ore from these deposits amounted to 1,506,828 tons, of which the Canadian Copper Co. raised 1,139,629 tons, the Mond Nickel Co. 361,335 tons, and the Alexo Mining Co. 5,864 tons. The nickel content of the ore of the Canadian Copper Co. was about 2·5 times that of the copper, whilst the ore mined by the other two companies contained the two metals in approximately equal proportions. The matte produced by the Alexo Mining Co. is smelted by the Mond Nickel Co. According to the report of the Royal Ontario Nickel Commission, the matte produced by the Canadian Copper Co. in 1916 was estimated to contain 4,640 oz. platinum and 8,460 oz. palladium, corresponding to 0·10 oz. platinum and 0·15 oz. palladium per ton of matte, the International Nickel Co. recovering in that year 1,093 oz. platinum and 257 oz. allied metals. This company is now reported to have improved its methods of recovery. In 1918 the total matte shipment by the Canadian Copper Co. is stated to have contained, among other precious metals, 8,677 oz. platinum and 13,016 oz. palladium [37].

According to information supplied by the Mond Nickel Co., their nickel residues derived from the refining of the matte are taken over by Johnson, Matthey & Co., Ltd. During the years 1915–18 the residues disposed of were estimated to contain the following amounts of platinum metals:

(In oz. troy.)

	1915.	1916.	1917.	1918.
Platinum	3,078	3,782	4,913	4,465
Palladium	5,474	—	—	—
Iridium and Rhodium	973	—	—	—

Messrs. Johnson, Matthey & Co., Ltd., have kindly supplied the following figures of platinum-extraction from these residues:

	Oz. troy.
1916	3,722
1917	4,719
1918	4,958

The British America Nickel Corporation, who are developing some large deposits in the same district, are also erecting a refinery near Hull on the Ottawa River. It is stated that they will employ the Hybinette process of electrolytic refining, and expect to obtain a high recovery of the precious metals [28/p. 425].

With gradual improvements in the refining process, and with the refining of the whole of the matte produced, instead of a portion only, as at present, it seems probable that the production of platinum metals by the three nickel companies may in time exceed 10,000 oz. per annum.

The 1919 report of the Ontario Bureau of Mines shows that in 1918 the International Nickel Co. treated 62,250 tons of matte for 650 fine oz. of platinum, 787 oz. of palladium, and 473 oz. of metals of the rhodium group. This cannot be used as a basis of calculation, as the proportions are not constant.

On the Quinn claims, near the Crœsus Mine, Munro Township, is auriferous quartz containing platinum. Five assays gave a platinum content of value ranging from $180 to $1,800 per ton (with platinum at from $40 to $50 per oz.) [30]. The Abro Mine in the Timiskaming district in 1915 shipped between 5,000 and 6,000 tons of ore, containing 0·03 oz. of palladium and platinum per ton. The ore consists of pyrrhotite, chalcopyrite and pentlandite, in a gangue of altered peridotite and serpentine [7].

Yukon Territory.—Platinum occurs associated with gold in small quantities in most of the tributaries of the Yukon River, notably at the mouth of the Hootalinqua River, and in the River Lewis [36/p. 12].

Newfoundland

Chromite derived from the serpentinized area in the region of Mount Cormack, situated in the central part of the island, has been found to contain small quantities of platinum [38].

AUSTRALASIA

AUSTRALIA

The most important occurrences of platinum in the Commonwealth are at Fifield and at Platina, in New South Wales.

The outputs of crude platinum in Australia in recent years were all exported to the United Kingdom as under:

Year.	Troy oz.	Year.	Troy oz.
1910	332	1915	56
1911	470	1916	82
1912	610	1917	259
1913	442	1918	607
1914	244		

Note.—These figures do not include the osmiridium produced in Tasmania.

Recent imports of manufactured platinum were as under:

	Oz.		Oz.
1910	320	1914–15	223
1911	504	1915–16	89
1912	318	1917–18	18
1913	301		

The question of the refining of platinum in Australia has been under consideration for some time; so far the crude material has all been sent to England. The outlook for future production of crude platinum in Australia is not promising, with the exception of that of Bald Hill district, Tasmania.

New South Wales.—Platinum is obtained at Platina, in the Fifield division, in the east central part of the State, from a buried gravel channel, in which it occurs in association with gold and osmiridium. The rocks in the vicinity of the "leads" consist chiefly of slates, but the source of the platinum is not known [2/p. 557]. These deposits were first exploited in 1894, and from that year to 1918 inclusive, the total output of platinum from New South Wales was 14,680 oz. [39]. The gravels have yielded amounts of 6 dwt. platinum and 2 dwt.

gold per ton, but according to Government reports the richer deposits are nearly worked out ; mining operations are carried on with great difficulty, as there is a great scarcity of water and a deep overburden, varying from 20 to 80 ft. in depth. It is estimated that there are 200 acres of platinum-country available, sufficiently rich to pay, were it worked on a large scale with an abundant supply of water [40].

A new occurrence has recently been discovered about 1 mile distant from the old Platina deep " lead," the platinum being associated with small quantities of gold. The " lead " has so far been proved to extend over an area about 1 mile in length, and from 60 to 150 ft. in width, the wash varying in depth from a few feet to up to about 80 ft. The pay gravels, which rest on shales and sandstones of Silurian and Devonian age, intruded by dioritic dykes, are stated to be from 1 to 3 ft. thick. The following analysis is representative of the crude platinum produced :

	Per cent.		Per cent.
Platinum	75·90	Osmiridium	9·30
Iridium	1·30	Iron	10·15
Rhodium	1·30	Silica	1·12
Palladium	trace		

[41/p. 14.]

Platinum is frequently found in beach sand deposits on the coastal border between Queensland and New South Wales, notably at Ballina, close to the mouth of the Richmond River ; at Evans Head, further south ; and at Currumbin, near the mouth of the Tweed River. In this locality black sands containing platinum, associated with gold, cassiterite, monazite and osmiridium, accumulate on the beaches during stormy weather. At Ballina and Evans Head, the platinum predominates over the gold, but at Currumbin, further south, the gold is in the greater quantity [2/p. 557]. The minerals are present in a very finely divided state, and separation of the valuable metals is a matter of considerable difficulty. The problem does not appear to have been satisfactorily solved up to the present time, although promising experiments have recently been carried out with screening and magnetic treatment. The deposits are, unfortunately, very low grade.

The sources of the metals are uncertain. The platinum and osmiridium appear to have been derived from the western edge of the Clarence coal measures, which now exist only as fragmentary outcrops. The gold, tin and monazite may have their origin in granite and other rocks of the New England tableland. Chromite is present in some of the Currumbin sands, which suggests serpentine as the probable source of platinum [2/p. 557]. Other associations are zircon, garnet, tourmaline, ilmenite, magnetite and sapphire.

In the Broken Hill district, principally at Little Darling and Mulga Springs Creek, platinum has been proved to extend over a considerable area in a copper-nickel gossan, closely associated with gabbro, decomposed gneisses and schists. In addition to platinum, the amounts of which vary from a trace to 16 dwt. per ton, gold, silver, iridium and palladium are also present [42]. The deposits bear some resemblance to the nickel deposits of Sudbury, Ontario, and it is thought that here, too, the platinum occurs combined with arsenic, as sperrylite.

Queensland.—In addition to the beach deposits between Southport and Currumbin, described above, platinum has been found in Coopooroo and Wairamba Creeks on the Russell Goldfield, near Innisfail; also in the Lucknow and Alma "reefs" of the Gympie Goldfield, where it is present in quartz lodes with native gold, and arsenopyrite, the accompanying rocks consisting of slates, alternating with volcanic tuffs and conglomerates; the metal also exists in the neighbouring gold-bearing alluvial deposits of Brickfield Gully.

Another occurrence of alluvial platinum is known at the head of the Don River in Central Queensland [2/p. 556].

Victoria.—Platinum occurs in the Walhalla Copper Mine, where it is associated in a hornblende-diorite lode-formation with copper pyrites, gold and silver. The ore is stated to contain from 2 to 7 dwt. platinum per ton. In the Thompson River Copper Mine platinum is found in a hornblendic rock rich in chalcopyrite.

Tasmania.—Iridosmine has been produced from the Bald Hill district near Waratah, in the north-western part of the state, since 1900, the metal being obtained from placer deposits in Nineteen Mile Creek and its tributaries, Linger-and-Die,

McGinty's and Barren Creeks, and from Savage River. It has been located *in situ* in the rocks of Bald Hill, principally in serpentine, but also with chalcedony and opaline silica in lode-formations. In the former case, it is associated with magnetite, pyrite, pyrrhotite, nickel and gold. The iridosmine in the placer deposits is sometimes coated with iron oxide, and is also at times found enclosed in chromite. The following analysis in percentages, made at the Imperial Institute, is typical: osmium, 57·09; iridium, 33·80; platinum, 0·37; ruthenium, 8·19; palladium, 0·21; gold, 0·04; iron, 0·30; copper, trace.

Other localities in Tasmania at which osmiridium has been located are Heazlewood River, Whyte River, Castray River, Huskisson River, Wilson River and Boyes River; also the Badger gold diggings, west of Savage River, and the Salisbury goldfield near Beaconsfield.

The following table gives the recent annual output of osmiridium in Tasmania:

Year.	oz. (troy).	Value in £.	Year.	oz. (troy).	Value in £.
1910 . .	120	530	1915 . .	247	1,581
1911 . .	272·9	1,188	1916 . .	222·2	1,899
1912 . .	778·8	5,742	1917 . .	332·1	4,898
1913 . .	1,261·6	12,016	1918 . .	1,607	—
1914 . .	1,018·8	10,076	1919 . .	1,669·7	39,614

South Australia.—In the north-east part of the State traces of platinum have been recognized by analysis as occurring in the outcrop of a lode near Boolcoomatta. Further information on this occurrence is not available.

Papua.—Osmiridium, associated with small amounts of gold only, is known to occur as alluvial in the neighbourhoods of various serpentine areas; in the Lakekamu district, in flaky form; in the Yodda Valley, in appearance similar to native bismuth; and in other places in shot-like granules [88].

New Zealand

Platinum is only obtained commercially in New Zealand from the Orepuki district of Southland, where it is produced

by the Round Hill Gold Mining Company as a by-product in the washing of auriferous gravels. According to information recently supplied by the Mines Department, the annual output of crude platinum for the last ten years has averaged 30 oz., but in view of the recent falling-off of the gold production in this locality, the prospects of any increase in the output of platinum seem small.

In South Island the presence of platinum has been reported on the Thames River in quartz lodes, in a region of serpentine and diorite, and in a pyritic lode near the Taramakau River in the district of Westland, in close proximity to sheets of altered magnesian eruptive rocks [2/p. 557]. The platinum in the latter case occurs in association with silver, in the proportions of about 7 parts of the latter to 1 of the former, together with pyrite and limonite. Samples taken from the lode have been stated to have an average content of 3 dwt. 8 gr. platinum per ton [43].

Other localities in South Island where platinum has been located are the Taraka and George Rivers, which flow into Awarua Bay; the east coast of Otago, in beach sands and river gravels; the Clutha River; and the Nelson gold district.

Concentrates containing up to 2·5 per oz. per ton are reported to have been obtained from the Parapara sub-division. Platinum in New Zealand is often associated with gold, and the deposits are in many cases similar to those of the Urals.

CHAPTER III

SOURCES OF SUPPLY OF PLATINUM METALS

(*b*) FOREIGN COUNTRIES

EUROPE

France

Platinum metals are not produced in France, but platinum is known to occur at several places. In the Department of Charaste and Deux Sevres it occurs associated with pyrite and limonite; in the Valle du Drae, Hautes Alpes, above Chatalard, platinum occurs in tetrahedrite in metamorphic limestone; at St. Arey, near La Mure (Isere), it occurs in bournonite, in dolomite and altered limestone. Platinum is found in argentiferous tetrahedrite and malachite near Presles, in Savoy [30].

As mentioned below, under Russia (p. 36), France controlled the production of platinum in Russia before the war through the Compagnie Internationale du Platine, due to its extensive ownership of platinum deposits and its contracts with Russian companies.

The accompanying table gives a summary of recent imports, with countries of origin, as far as can be obtained.

Imports

Recent imports in kilograms (42·87 troy oz.) into France of crude, manufactured and scrap platinum, were as under:

From Year.	United Kingdom.	Russia.	Germany.	Serbia.	Switzerland.	Austria-Hungary.	Other countries.	Total.
1910	480	5,878	1,104	204	85	—	44	7,795
1911	575	6,895	822	782	127	—	192	9,393
1912	—	5,454	283	144	—	271	84	6,235
1913	78	4,500	220	—	2	171	97	5,067
1914	63	2,595	161	—	—	—	102	2,921
1915								188
1916								578
1917			No	details	avail	able		578
1918								41

GERMANY

Platinum has recently been discovered in Westphalia, deposits having been found in Freudenberg, Siegen, Meschede, in Siegerland, Sauerland and Westerwald. It occurs in a series of fragmental deposits, including principally slates and graywackes, the latter composed of quartz and slate, with an argillaceous cement; it is also occasionally found in the recemented fragments which are presumably derived from the basal granite formation, underlying the platinum series [44/p. 606]. The beds are believed to be of marine origin, and are probably of Silurian and Devonian age. The platinum, which is present in a very finely-desseminated state, is associated with chromium, nickel, arsenic, antimony, iron, copper, lead, zinc, silver and gold, some of which appear to have been introduced by solutions at a stage subsequent to sedimentation. Krusch investigated these deposits in 1914, and is of opinion, in view of the similarity of the chemical associations with those of the Ural and British Columbian formations, that the original source of the platinum was peridotite, or other form of basic igneous rock. A number of samples, analysed by Krusch, yielded values ranging from a trace to 33·5 gm. (1 oz. troy) platinum per ton [45]. At the outbreak of war the capital necessary for exploitation had not been raised, but in 1918 it was stated that treatment works had been erected at Wenden [3].

As mentioned above, about 25 per cent. of the Russian output of platinum before the war was refined in Germany,

and it is known that German capital was helping to finance the pre-war platinum operations of that country [3].

Imports

The following is a summary of imports into Germany of crude, manufactured and scrap platinum in kilograms (42·87 troy oz.) for the years 1910–13 :

From Year.	United Kingdom.	France.	Austria-Hungary.	Russia.	United States.	Other countries.	Total.
1910	419	846	265	278	127	216	2,151
1911	292	895	451	190	255	239	2,322
1912	458	642	554	272	48	307	2,281
1913	191	683	233	451	236	230	2,024

Russia

Up to the year 1914, Russia produced about 93 per cent. of the total world's supply of platinum, the metal being derived from extensive deposits of alluvial sands in the Ural Mountains. The platiniferous area extends approximately 80 miles along the central part of the chain of mountains in the Government of Perm, and along the eastern slope, the principal centre of the placers being at Goroblagodat, and on the western side at Nizhni Tagilsk.

Platinum was first discovered in the Urals in 1823, and exploitation commenced in the following year. In 1828 the Russian Government instituted platinum coinage, which consisted of 3-rouble, 6-rouble and 12-rouble pieces, the coins containing about 2 per cent. iridium. A 3-rouble piece weighed 10·31 gm., and the price paid by the Government to the producers was 16*s.* 10*d.* per oz. ; but owing to the subsequent rise in value of platinum, the coinage was discontinued in 1845 [46/p. 606].

The platinum industry began to develop in 1869, the price at that time being under £5 per lb. [47], but from that year onwards the value, although subject to considerable fluctuations, has steadily increased. It has been estimated that since the beginning of the industry in Russia, about 6,000,000

oz. of platinum have been recovered from 30,000,000 to 40,000,000 c. yd. of gravel.

As was explained in Chapter I, the official statistics of the Russian output of crude platinum are considered to be low. In the following table, the estimated and official figures of production are given for the years 1910–17:

In oz. troy

Year.	Estimated output.	Official output.
1910	300,000	176,334
1911	280,000	187,008
1912	300,000	177,596
1913	275,000	157,735
1914	240,000	157,182
1915	124,000	119,789
1916	90,000	78,682
1917	50,000	—

In the official statistics the Ural mining district is divided into five principal areas. The following table shows the annual outputs by districts in recent years:

In oz. troy

District.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
South Verkhotur	111,070	121,314	118,048	102,552	106,528	80,985	52,353
Perm	46,068	46,885	38,709	36,878	38,050	22,996	14,818
North Verkhotur	11,862	11,362	13,166	11,376	7,426	12,288	9,968
Tcherdynsk	6,359	5,016	6,162	6,109	4,753	3,518	1,542
South Ekaterinburg	972	1,040	1,382	816	421	2	—
Total	176,331	185,617	177,467	157,731	157,178	119,789	78,681

Exports of crude platinum from Russia for the years 1911–15 were as follow [15/p. 923]:

To.	1911.	1912.	1913.	1914.	1915.
Great Britain	1,053	2,107	1,580	—	66,884
France	168,527	169,580	140,615	64,778	7,900
Germany	51,612	50,558	58,458	17,906	—
United States	—	—	—	—	5,266
Total	221,192	222,245	200,653	82,684	80,050

The platinum industry in Russia has always been mainly in the hands of a few large firms of foreign countries. For a long time Johnson, Matthey & Co., Ltd., controlled the greater part of the trade. In 1898 the Société Anonyme de l'Industrie du Platine was established in Paris, and, by purchasing a large number of mines, and leasing others, was able to secure a large share in the control of the industry.

The refining of the crude platinum has been, and still is, almost entirely in foreign hands, all but approximately 2 per cent. of the entire output being refined abroad. In 1915 it was reported that the construction of a refinery at Ekaterinburg was completed, which was to be placed under Government control. The principal platinum-refining works were formerly those of Johnson, Matthey & Co., Ltd., of England, but early in the eighties this firm was, to a certain extent, superseded by Heraeus & Co.. of Hanau, Germany. They, in turn, in 1909, were compelled to give first place to the Société Anonyme de l'Industrie du Platine, of Paris, which became the chief centre of the platinum-refining industry, a position which it held until the outbreak of war. France at that time had a monopoly of 90 per cent. of the Russian production. This foreign control had an unfavourable effect on the industry, and in 1913 the Russian Government passed a law forbidding the exportation of crude platinum. In July 1915, exportation was again permitted, subject to a 30 per cent. *ad valorem* export tax, and at about the same time an order was issued forbidding the exportation of raw platinum in quantities valued above 500 roubles (£53), the price of the metal to be fixed by the State [15/p. 923]. In February 1917 the Government further enacted an order prohibiting the importation of drawn and spun platinum. It was hoped by these means to encourage the establishment of domestic refineries. In 1916 the Government fixed the price at £16 10s. per oz. In March 1917 it was reported that the miners were not satisfied, and later sales were reported up to £22 per oz. of crude metal, 83 per cent. fine [48/p. 17].

According to N. Vissotzki [49], the platiniferous belt of the Urals, geologically speaking, consists of four parallel bands striking, roughly, north and south; the westernmost

of these, made up of crystalline schists, forms the watershed between Europe and Asia. The next band to the east comprises olivine- and mica-gabbros, diallage-peridotites, diorites and altered syenites—all of which have been erupted from a great depth. The third band is made up of Lower Devonian sedimentary rocks, shattered and buried in places by diabasic eruptive rocks. The eastern portion of this band is formed of eruptive rocks of deep-seated origin which may be gneissose granites. The fourth, or most easterly band, is composed of ancient rocks, which have been eroded by the advancing sea of Lower Tertiary age.

The area emerged from the waves as early as the Carboniferous period; consequently the accumulation of platinum, and in some localities of gold, in the surface-deposits, were not swept away. They were concentrated later on in the alluvia—perhaps at the time of the most intense glaciation, probably in the Pleistocene.

Throughout the Urals, the primary source of the platinum is associated with the eruptive basic rocks, among which the platiniferous and auriferous dunite forms three great masses. The principal outcrops of platiniferous dunite and platinum-bearing alluvia are connected with the second of the four parallel bands mentioned above. Towards the south, the band becomes discontinuous, and finally dies out altogether. Here a few outcrops of platiniferous olivine-rock contain a small percentage of platinum, with osmiridium and other members of the group associated with it.

The two principal platinum-producing districts are in the central Urals, and are: (1) The Shuvaloff Estates, Isov district, on the River Iss, near Goroblagodat. (2) The Demidoff Estates, Nizhni-Tagilsk district, on the Martjan River in the South Verkhotur district. Prior to 1879 the latter field furnished the larger part of the platinum, but since then the former has been the most productive, and now supplies about 80 per cent. of the total output. The whole of the platinum is derived from gravel deposits, which are usually auriferous, and associated with dunite.

The Isov district.—Platinum is concentrated in the channels of the Rivers Iss, Veeya and Tura. In the north of this region

it is obtained from the Sosnovki, Kytlymi, and Mala Kosva Rivers; further north again, platinum occurs with gold in the Vagran River, and in the system comprising the Rivers Lobva, Niasma, Lialia, Aktai, Emerlo and Talits, the gold here being predominant. Other sources of supply of platinum and gold in this district are on the Ivdevl River. In the south of the area, platinum deposits are worked on the tributaries of the Tagil, Salda, Imiaun and Tura Rivers [15/p. 921].

The Nizhni-Tagilsk district.—The richest placers occur in the valleys of the Visim, Martian, Sisim, Chaush and Cherna Rivers. Further south, platinum is found with gold in the gravels of the Nevian, Verkhne-Iset, Bilenibaev, Alapaev, Sysert, Kyshtym and Mias areas, and also in the Tanalyk, Sakmar and Urtazym Rivers.

Other localities of smaller importance are the Nikolae Pavdinsk and Rastes districts in the northern Urals, and the Systersk mining district.

The placers are derived from country rock, made up of serpentine gabbro, diallage and olivenite, the principal associated minerals being quartz, zircon, ilmenite, chromite, magnetite, spinel, native gold and palladium. Gold is present in the concentrate in very variable quantities, and sometimes contains silver, but the latter generally occurs in combination with palladium. The crude platinum usually includes some iridium, rhodium, ruthenium and iron.

The basic igneous rocks, from which the platinum is derived, are exposed in the form of discontinuous elliptical outcrops near the summits of the Urals, particularly on the western side of the mountains. These outcrops attain larger dimensions in the northern and central Urals than further south. The process of concentration of platinum in the gravels has clearly extended over a very long period of time, and it is probable that the richer gravels have been reconcentrated, perhaps several times [50/p. 299]. Platinum nuggets are rarely found, but three of large size were discovered in the Nizhni-Tagilsk district, their weights respectively being 25½ lb., 21 lb., and 11½ lb.

Duparc, in a brief description of the geology of the deposits, states that they are essentially of magmatic origin. The

structure of the rock is in the nature of concentric bandings; the felspathic rocks at the outer edge gradually grade into the intermediate stage of pyroxenes, until the central dunite is reached, composed of olivine and chromite. The richness of the gravels is in proportion to the size of the dunite deposits, and to the extent of erosion of these rocks. According to Duparc, platinum ore derived from a pyroxenite source usually contains high percentages of platinum and palladium, but low percentages of osmium and iron. The same writer estimated in 1916 that the reserves were sufficient for about twelve years, provided that the same methods of working and rate of extraction were employed during that period [51].

The amount of the platinum in the wash is very variable. The average yield was formerly over ½ oz. per c. yd., but latterly, owing to the gradual exhaustion of the richer deposits, the average returns have not exceeded from 2 to 3 dwt. per c. yd. The crude metal assays about 83 per cent. platinum, from 5 to 7 per cent. osmium and iridium, with small amounts of ruthenium, palladium, and gold, and about 10 per cent. impurities, mostly iron and copper [52]. The thickness of the pay gravels varies from 3 to 6 ft., and about 4 ft. may be taken as the average width, the overburden running from a few to over 60 ft. The extent of the productive area is about 170 sq. miles, and from 15,000 to 20,000 miners were employed before the war [2/p. 558]. It has been noticed that the platinum deposits are characterized by their uniformity, of course not being so sinuous in direction as gold deposits.

In former times mining was entirely carried on by primitive methods with hand labour, but the utilization of dredges has steadily increased, since their introduction in 1900. In 1909, 13 per cent. of the total production was obtained by dredging, and in 1914 this percentage rose to one-third of the total output. The season during which dredges may be employed extends on the average from the middle of April to the middle of October. In the South Verkhotur and Perm areas dredges have been used in the large enterprises; but at the small mines the working is very primitive, and carried on largely with the help of *starateli*, or tributers. In 1914 a

modern 7½ c. ft. dredge was installed on the Nikolaie-Pavdinsk Estate.

In mines where dredging is not in use, the gravels are mined by open cuts, or, if the overburden is thick, shafts are employed. The former method is much preferred, both on account of its relative cheapness, and also because it is possible to obtain a better clean-up of the bed-rock.

The usual types of stationary plant in use include the *botchka*, or conical revolving screen ; the *tchaska*, or puddling machine, with a bottom of perforated iron plates ; and the *boronka*, or conical screen, on which the stones and clay are turned over by a double rake [53]. The gold is removed by amalgamation with mercury in wood, iron or porcelain bowls. Special methods are in use in certain parts of Russia for working the deposits during the winter. The workings are allowed to freeze, and the frozen ground is mined after being partially thawed by means of wood fires. The method is simple, but care must be taken to ensure that the thawing does not proceed too far, otherwise the ground collapses, and the workings become flooded. The method is suitable for depths to 30 ft., and in localities where the snowfall is comparatively slight.

Latest reports from Russia indicate that no dredges are now working there, the platinum being produced by hand methods only.

Some interesting experiments were recently carried out by V. N. Chorzhevski in the Nizhni-Tagilsk district, with a view to testing the commercial possibility of mining platinum *in situ*. The metal here occurs, in association with chrome iron ore, in dunite rock, which in this region extends over an area of 11½ sq. miles. The platinum appears to be present in quantities directly proportional to the amount of chromite in the rock. The dunite is first ground under runners ; the chromite slack is separated from it ; and after this has undergone a second grinding, the metal is separated by washing [54]. An experimental test, carried out in March 1917, is stated to have produced over 200 oz. platinum from 9,720 lb. chromite slack. Another experiment with 3,600 lb. of grey slack, "or fines," consisting chiefly of undecomposed dunite obtained from the dredges, is reported to have yielded ⅓ oz. of platinum.

Lapland.—Platinum occurs associated with chromite and diamonds, in alluvial deposits on the Ivalo River. It is believed to be derived from serpentine rock, of which the neighbouring country is largely composed [2/p. 556].

Finland.—Platinum has been found in the south in a lode-formation containing quartz, siderite, calcite and dolomite. Gold and carbonate of copper are also present in small quantities. [2/p. 557.]

Platinum Currency

In a dispatch to the Great Powers on February 26, 1920, the Soviet Government promised to withdraw the decree annulling Russia's foreign debt, to pay arrears of interest, and giving as a guarantee to an Anglo-American syndicate certain important platinum and silver-mining concessions, in return for which the abandonment of intervention in Russia's internal affairs was demanded. To be used in payment of foreign purchases, the Government was about to issue "platinum" credit notes of 50, 100, 500, and 5,000 roubles, the issue to be limited to 65,000,000 roubles, and backed by platinum reserves of 37,500,000 roubles. The Government would be ready to convert the platinum reserves into coin if required [55].

Spain

Promising deposits of platinum have recently been reported at Ronda, in the province of Malaga. Domingo de Orueta, a Government geologist, having noticed the similarity of the geology of this district to that of the platiniferous deposits of the Urals, proceeded, a few years ago, to explore the area systematically, and was soon rewarded, in the discovery of the metal. The deposits, which are alluvial, extend along the Verde and Guadaiza rivers, and are derived from serpentine and peridotite rocks, the latter composed principally of rhombic pyroxene, with some spinel and some dunite. Chromite occurs in association with the platinum. The pay gravels contain about 8 gr. platinum per ton, and are stated to have an average thickness of 5 ft., the depth of overburden in the Guadaiza area, where apparently the richer gravels are found, being about 33 ft., as compared with 49 ft. in the Verde locality

[10/p. 547]. The Spanish Government have taken over the exploitation of these deposits, and no public prospecting, without Government permission, is allowed.

Platinum is known to exist in a number of other localities in Spain, especially in the northern districts; but so far as is known, it occurs in very small quantities of no commercial importance. The metal has been recognized in the following rivers: Minho, Luna, Sil, Orbigo, Gallego, Cinca Darro and Lower Jenil, where it occurs in the concentrate sands, accompanied by magnetite, ilmenite, zircon and, frequently, gold [56].

ASIA

Armenia

Platinum, in association with gold, is reported to occur in the district of Batum and Sasun, on the Charokh River [44/p. 610].

Borneo

Platinum was discovered in south-eastern Borneo in 1831, in the gravels of Gunung Lawack, but for a long time the natives were ignorant of its value. In recent years it has been obtained on a small scale as a by-product in the process of gold-washing, carried on in the province of Tanah-Laut, in the south-eastern extremity of the island [57]. The deposits occur in streams, which rise in the Bobaris Mountains, where the country rocks are composed of schists and gneisses, intruded by serpentine gabbro and diorite dykes [50/p. 298]. Platinum has, however, not yet been located *in situ*. In addition to gold, the platinum is associated with osmiridium in the gravels, the two former being frequently found intimately intergrown. The platinum content of the native metal has been found by a number of analyses to vary from about 57 to 83 per cent., and that of osmiridium from 0·18 to 10·07 per cent. [58].

The rare mineral *laurite*, a sulphide of ruthenium and osmium, was discovered in these deposits.

According to L. Hundeshagen [59], the platinum occurring in the diamond placers of western and south-eastern Borneo

is in the form of thin scales, ranging from 0·1 to 1·0 mm. in length. These platinum scales contain from 3·8 to 4·5 per cent. of copper, evidently as an alloy.

China

In the Uryanchai district of Mongolia, situated on the Russian border, deposits of auriferous gravels have been worked on a fairly extensive scale for some time past. It was announced a few years ago that platinum and iridium had been found in appreciable quantities, associated with the gold, some large platinum nuggets being obtained from this region in 1911. Although no attempt at commercial development has yet been made, the prospects of profitable extraction appear to be hopeful. Extensive outcrops of olivine rocks have been noticed in the vicinity, and the nature of the occurrence is stated to bear some resemblance to that of the platiniferous fields of the southern Urals [8/p. 107].

Japan

Platinum occurs in the Yubari-garva, Pechau and other rivers in the province of Hokkaido. It is also found in Nishi-Mikawa, province of Sado. In the former locality gold and iridosmine are associated with the platinum, and in the latter gold and iron sands are present [60]. In no case has the metal been traced to its parent source. In the Hokkaido deposits the average quantity of platinum present is only 2 or 3 per cent. of the iridosmine content. It is possible that further exploration in these areas will reveal occurrences of greater importance [9/p. 597].

Sumatra

Platinum is obtained at Sipongi, where it occurs with wollastonite and grossularite in limestones and schists, near intrusions of granodiorite and augite diorite. Gold is also present.

L. Hundeshagen [59] is of opinion that the present ore deposit was originally a layer, or a big lens, of limestone imbedded

in the old schists, which has, by apophyses of granite, been altered into garnet and wollastonite, being at the same time, or very soon afterwards, mineralized by hot solutions carrying copper, gold, platinum, etc. A sample of slightly decomposed wollastonite with no copper, or only minute traces of that metal, proved to be richest in platinum, the assay showing 6 gm. of platinum per 1,000 kg., while samples with 2 to 10 per cent. of bornite and malachite contained only traces of platinum; and none could be detected in auriferous garnet, poor in wollastonite. About 10 to 25 metres from the outcrop the concentrated river sand shows small particles of whitish crystalline gold and rounded grains of white platinum, the latter varying from 0·1 to 0·3 mm. in size.

AFRICA

Congo Free State

In the Katanga district, platinum and palladium have been reported to occur in certain alluvial gravels, accompanied by gold and silver. One sample from this locality is stated to have yielded the following amounts per metric ton: 3·4 gr. platinum, 12·3 gr. gold, 8·3 gr. silver. It has also been located *in situ* in sandstones containing gold.

Madagascar

Platinum is produced on a small scale as a by-product in alluvial gold mining on the Vatana River, near the village of Ambia, in the Vatomandry district. Traces of the metal have also been found in auriferous gravels in the regions of Fenerive, Marolambo, and Vandrozo, over an area extending along the eastern side of the island for a length of about 450 miles. The platinum is apparently derived from the decomposition of pegmatite. It is rarely found pure, being usually coated with iron oxide, and strongly magnetic, a property which is utilized in the process of separation from the gold [61].

NORTH AMERICA

Mexico

Platinum has been shown to exist in the states of Guerrero and Hidalgo in deposits of ferrous clays, which are of undoubted sedimentary origin, and are apparently laterites. The metal exists in a very finely disseminated state, invisible to the naked eye [62].

United States

At the beginning of the war there was a considerable shortage of platinum in the country, caused partly by the falling-off of the imports, and in part owing to the increased demand in connexion with munition manufacture.

California is the principal producer of crude platinum, and in 1917 this State supplied 460 oz. out of the total output of 605 oz.; with the exception of a few ounces from the State of Washington, Alaska and Oregon provided the balance.

A considerable quantity of foreign crude and manufactured platinum is imported annually, as shown in the following tables:

Imports of Manufactured Platinum into the United States

(In troy oz.)

	1912.	1913.	1914.	1915.	1916.	1917.	1918.
From British countries:							
Canada	777	582	55	139	511	332	253
United Kingdom	19,169	16,595	6,476	7,692	9,513	3,195	357
Other British countries	4	—	—	—	5	—	25
Total, British countries	19,950	17,177	6,531	7,831	9,569	3,527	635
From foreign countries:							
France	25,725	24,519	16,570	3,480	3,395	2,507	814
Germany	22,673	29,075	30,015	2,350	10	—	—
Netherlands	—	—	—	—	159	—	—
Norway	—	—	258	—	—	120	—
Russia (European)	—	—	815	—	—	—	—
Colombia	—	—	—	480	—	207	1,665
Other foreign countries	—	—	—	63	512	57	3
Total, foreign countries	48,396	53,594	47,658	6,373	4,076	2,891	2,482
Grand total, oz.	68,346	70,771	54,189	14,204	13,645	6,418	3,117

Imports of Crude Platinum into United States

(In troy oz.)

	1911*.	1912.	1913.	1914.	1915.	1916.	1917.	1918.
From British countries :								
Canada	554	45	314	535	139	91	25	76
United Kingdom	28,153	19,951	8,368	7,084	6,805	36,703	1,561	1,073
Other British possessions	—	7	—	—	5	—	—	—
Total, British countries	28,707	20,003	8,682	7,619	6,949	36,794	1,586	1,149
From foreign countries :								
France	44,964	10,178	7,284	4,921	3,507	13,014	52	166
Germany	37,041	15,335	23,345	15,105	2,366	—	—	—
Norway	—	—	200	442	285	302	—	—
Panama	—	—	—	160	105	92	12	372
Brazil	—	—	—	—	—	118	103	27
Chile	—	9	—	—	—	—	766	3
Colombia	5,503	6,627	10,461	12,387	13,121	25,588	21,071	25,365
Other foreign countries	17	13	—	—	1	103	99	21,663
Total, foreign countries	87,525	32,162	41,290	33,015	19,385	39,217	22,103	47,596
Grand total, oz.	116,232	52,165	49,972	40,634	26,334	76,011	23,689	48,745

* Including manufactured platinum.

In 1917, 38,831 oz. of refined platinum metals, of which 7,384 oz. is believed to have been of domestic origin, were recovered from alloy with other metals, and 72,186 oz. were obtained from the refining of scrap metal, and sweepings. The shortage was also to some extent relieved by the receipt from Russia early in 1918 of a special consignment of 20,922 oz. of crude platinum, which had been collected in 1917 by the Russian-English Bank, and which was taken out of Russia by F. W. Draper and delivered to the United States Government. It yielded 17,640 oz. platinum, 64·75 oz. palladium, 182·11 oz. iridium and 48·56 oz. of rhodium, a total of 85·725 per cent. of platinum metals, slightly above the usual 83 per cent. [63].

Alaska.—The first production of platinum in Alaska was in 1916, in which year about 12 oz. were shipped to the United States. In 1917 the output rose to 81 oz., of which 66 oz. were obtained from the Seward Peninsula and 15 oz. from the Copper River country.

In 1918 an increased output of 135 oz. was partly obtained from alluvial deposits and partly as a by-product in the treatment of copper ore of the Salt Chuck mine, Ketchikan [65].

This mine is a palladium-copper mine containing mainly bornite with a little chalcopyrite, and the alteration products covellite and chalcocite, the metals present being, besides copper and palladium, gold, silver and platinum. The ratio of palladium to platinum averages 50 to 1. The concentrates produced, representing about 3½ per cent. of the weight of the ore, contain: copper, 40 per cent.; gold, 1·2 oz.; silver, 5·3 oz.; and platinum metals, 3·15 oz. per ton [89].

In the Seward Peninsula the larger portion is derived from placer deposits in Dyme Creek, Koyuk district, where the gravels are primarily worked for gold, 1 oz. platinum being obtained for every $5,000 worth of gold. In 1918, 56 oz. were recovered. Bear Creek and Sweepstake Creek have also supplied small quantities of platinum, and a little is derived from placers on Boob Creek, in the Tolstoi district [48/p. 19].

A possible source of platinum appears to lie in the neighbourhood of the Red Mountain, on the Kenai Peninsula. The mountain is composed of fine-grained dunite, in which abun-

dant chromite occurs. Up to 1917 no placer mining had been attempted in this locality [66].

In the Goodro Mine, at the head of Kasaan Bay, Prince of Wales Island, were found in 1918 both platinum and palladium, the latter in greater amount, and carried in bornite and chalcopyrite; some chalcocite and covellite are present also in the ore. The copper minerals are disseminated through pyroxenite, and the country rock consists of limestones, slates and other sedimentaries. The platinum content is small, but regular, whilst the amount of palladium present is proportional to the amount of copper, there being about 1 oz. of palladium to every 8 to 12 per cent. (units) of copper [67].

A Bill has been introduced into Congress providing for the incorporation of the United States Platinum Corporation, with capital stock of $30,000,000, the object of which is to secure a concession from the Government of land areas in Alaska containing platinum sands, and to pay for such privilege, as a royalty or subsidy, one-eighth of the net profits obtained from the working of the concession [68].

California and Oregon.—Platinum has been proved to exist over a wide area in placer deposits associated with gold, but the proportion of the platinum metals to the gold is usually small. Platinum is obtained from sands in streams rising in the belt of serpentine rocks in central California, and from the serpentine areas in the Siskiyou and Trinity counties in the north-west of the State, which continue north-east into Curry, Josephine and Jackson counties in south-western Oregon [50/p. 300]. The sources of the platinum obtained along the foot-hills of the Sierra Nevada were old stream channels on the western slopes of the mountains, which are now buried beneath lava several hundred feet deep. These "deep leads" are also mined by drifting for their gold and platinum contents, and in a few cases a fair amount of the metals is extracted from them. Some platinum is obtained by hydraulic mining, but this is carried on with difficulty, owing to the prevailing scarcity of water [48/p. 18].

Platinum occurs in black sands found on the Pacific coast in the counties of Coos, Curry and Josephine, Oregon and Del Norte, California. Formerly these beach deposits were rich

in platinum, but at the present small quantities only are obtainable after stormy weather. This area has recently been examined by the United States Bureau of Mines, but the results were disappointing.

In California most of the output of platinum is produced by dredging for gold in the Butte, Calaveras and Stanislaus counties [48/p. 19]. In Trinity county mining is in progress on the Trinity River, about 4 miles below Junction City, by the Valdos Dredging Co. The output from this source for sixteen months in 1916–17 was stated to be 1,950 gm. Platinum, with gold and osmiridium, is also obtained on the Yuba River, about 12 miles east of Marysville in Yuba county, by the Yuba Consolidated Goldfields [10/p. 540]. Some alluvial platinum has been recovered at the Bean Hill Gold Mine, situated 12 miles south-east of Placerville, and this locality is at present under investigation [69]. Californian metal contains from 25 to 45 per cent. iridium. Its origin is believed to be the serpentine- and olivine-bearing rocks of the Sierra Nevada and other ranges.

In Oregon, in addition to the platinum obtained from the beach deposits near Bullards and Marshfield [48/p. 20], it occurs in placer deposits, rich in chromite, in south-west Oregon, the principal output being derived from the Waldo district.

Platinum also exists in small quantities in streams in the neighbourhood of the Blue Mountains, eastern Oregon, where the Powder River Gold Dredging Co., in Sumpter district, produces on a small scale. Other platiniferous localities in eastern Oregon are the Granite and Canyon districts, and Spanish Gulch in Wheeler county [10/p. 541].

Colorado.—Platinum is known to exist in the black sands from Clear Creek. Its presence has also been reported in the gold gravels of the Iron Hill placer at Como, where it occurs mechanically combined with magnetite. Another occurrence recently discovered is in a vein worked by the Rollcall Mining Co., near Villa Grove. An assay of material from this vein, taken at a depth of 1,500 ft., showed the following values: gold, 3·2 oz.; platinum, 5·09 oz.; silver, 3·05 oz.; and copper, 3·5 per cent. [9/p. 592].

Nevada.—In 1909 the occurrence of platinum in Clark county was noticed by the United States Geological Survey to be in association with copper, nickel and cobalt ores from the Key West and Great Eastern Mines, near Bunkerville. The ore bodies are contained in pegmatites and basic intrusions, which carry pyrrhotite and chalcopyrite, the platinum content in the ore averaging about 0·2 oz. per ton [70].

In 1914 platinum, with palladium, was discovered at the Boss Gold Mine, situated 10 miles west of Goodsprings, in Clark county. The mine was originally worked for copper, and later for its copper and gold contents. The country rock consists of limestone of middle Carboniferous age, intruded by sills of quartz monzonite porphyry, the ore bodies occurring in a fault zone in the limestone. The copper ores comprise mainly chrysocolla and malachite, and contain traces only of platinum. The gold ore occurs in a fine-grained siliceous matrix, containing a bismuth-bearing variety of *plumbo-jarosite* (a hydrous sulphate of iron and lead). The rare metals are present in the free state, being apparently alloys of gold, platinum and palladium [71].

In 1919 the Boss Mine shipped $22,365 worth of platinum-bearing ore [72]. A plant of 300 tons monthly capacity has recently been erected at Los Angeles, California, for the treatment of its complex ores, which average 7 per cent. of copper, 4 per cent. bismuth, and 1·0 oz. of platinum and palladium, 0·75 oz. of gold, and 3 oz. of silver per ton. The pulp from ore pulverized to 80 mesh is agitated with sulphuric acid (2 per cent.). The acid solution contains the copper and about 20 per cent. of the platinum. The copper is precipitated as cement copper, together with the platinum, by means of scrap-iron. The remainder of the platinum, together with the gold and silver, is first leached with, and then precipitated from, a neutral solution of calcium chloride. The inventors of the process claim that approximately 92 per cent. of the copper, 96 per cent. of the platinum metals, gold and silver, and over 90 per cent. of the bismuth are recovered by this process [73].

Metals of the platinum group have recently been shown to exist in small quantities in the ore of the Oro Amigo Mine,

situated between 1 and 2 miles north-east of the Boss Mine. This ore differs from that of the Boss Mine, in that bismuth and plumbo-jarosite are absent. According to H. K. Riddell, the platinum metals content averages from a trace to 0·1 oz. per ton of ore.

North Carolina.—At Mason Mountain, in Mason county, platinum occurs associated with rhodonite, garnet, biotite and iron sulphides in metamorphic deposits.

New York.—It was reported a few years ago that platinum existed in large quantities in alluvial sands of the Adirondack region. J. M. Clarke, the New York State Geologist, examined the occurrence in 1917, and found that platinum was present in traces only, the deposits being of no economic importance [10/p. 541].

Pennsylvania.—At Lancaster county platinum is associated with pyrite, chalcopyrite and galena in mica-schist, and also at Boyertown in black Triassic shale.

Washington.—The production of platinum on a small scale has been reported from beach deposits at the mouth of the south fork of the Lewis River near Yacolt, and also on beaches southward from the Straits of Juan de Fuca [10/p. 542]. The metal has also been located at various places in the Cascade Mountains in the central part of the State.

Wyoming.—Palladium and platinum, in the proportion of 3 to 1, are obtained at the Rambler Mine, in Albany county, the metals occurring as sperrylite in copper ore, contained in the kaolinized portion of a dunite dyke, intrusive into granite gneiss. The ore consists of covellite, chalcocite, chalcopyrite and tetrahedrite, with nickel and gold [74]. It is stated that the platinum and palladium contents vary directly with the percentage of copper present, a typical assay giving the following values: copper, 5 per cent.; gold, 0·02 oz.; silver, 1 oz.; palladium, 0·4 oz.; and platinum, 0·6 oz. per ton [75].

Utah.—Platinum and gold in very fine particles occur in the Green River, east of Vernal; also in the Colorado River, near Hite, below the mouth of the Green River. Attempts to mine these deposits have so far proved unsuccessful, due largely to the inaccessibility of the region, as well as the finely-divided condition of the platinum [41/p. 11].

SOUTH AMERICA

Brazil

José Vieira do Couto, in 1801, first pointed out that platinum occurs in the sands of the Lages River, near Conceiçao, Minas Geraes. According to E. Hussak [76], platinum in that region occurs only in the alluvium of rivers having their rise on the eastern slope of the Serra do Espinhaço. The platinum is accompanied by black pebbles of quartz-tourmaline rocks, magnetite, hematite, rutile, octahedrite, xenotime, monazite, senaite, pseudomorphs of rutile after octahedrite (*captivos*), zircon and gold, which is sometimes of a copper-red colour (palladium-gold). Palladic gold was formerly called *ouro branco* (white gold), by the miners.

At Condado, further north on the eastern slope of the same Serra, platinum also occurs with very similar associations. The platinum from both localities occurs in bunchy, mammillated and globular forms, concave within, with thin walls, having a radiated fibrous structure under the microscope. It is frequently in thin foliated crusts, having the characteristic structure of hematite. It was accurately described by Wollaston in 1805 and 1809. Hussak thinks the primary formation was an olivine rock, or gabbro, while the platinum is secondary, having been most probably re-deposited from solutions resulting from the decomposition of platiniferous pyrites or of sperrylite ($PtAs_2$), minerals derived, possibly, from the neighbouring schistose quartzite, or from the overlying conglomeratic quartzite.

The platinum of Condado, although comparable, as regards density, to the Russian platinum, is very rich in palladium, is non-magnetic and contains practically no iron. An analysis by G. Florence gave the following percentages: insoluble residue, 0·92; platinum, 73·99; iridium, 0·08; palladium, 21·77; iron, 0·10 (= 96·86), undetermined (rhodium and osmium), 3·14.

In the Rio Abaeté, Minas Geraes, platinum—very different in appearance and chemical composition from that of the Serra do Espinhaço—occurs in placer deposits, associated with gold, diamonds and the following minerals: rolled pieces of a

hydro-phosphate of barium and aluminium (*gorceixite* = "marumbé" of miners), garnet, almandite, pyrope, ashy-blue oxide of titanium (*bagageira*—regarded as a good indicator for diamonds), magnetite, chromite and calcium-titanate (*perovskite*). Pyroxene-olivine rock, a typical picrite-porphyry, rich in perovskite, and granular magnetite rocks, rich in titanium, have been observed by Oliveira in the vicinity. Hence it is highly probable that the platinum, as in the Urals, came from olivine rocks. The platinum occurs in thin laminæ, strongly rolled, and, rarely, in cubical crystals with the edges visibly rounded. It is strongly magnetic and contains no palladium. Minute crystals of osmiridium may occur with those of platinum, and in the platinum particles are found regular inclusions of osmiridium, as at Nizhne Turinsk, in the Urals, the platinum of which locality it resembles in chemical composition, magnetic properties and crystalline structure. The following analysis shows the percentage and composition of a general sample: insoluble residue, 7·57; iron, 9·62; palladium, trace; copper, trace; platinum metals, 82·81.

The auriferous alluvial of the Cuyabá and Coxim rivers in the southern part of the State of Matto-Grosso, also contain some platinum. According to Luiz Castano Ferraz [77], platinum occurs in the River Coxipó-Mirim, where gold-dredging is carried on, combined with palladium, iron, osmium and iridium in small spherical grains, flattened on one side, of a brilliant white colour and strongly magnetic. It is found in alluvial deposits, associated with various kinds of quartz and oxides of iron, marcasite, arsenopyrite, rutile, anatase, almandine, garnet, black tourmaline, monazite, staurolite, white topaz, sphene, cassiterite, wolfram, graphite, galena and native silver.

In the State of Bahia, platinum has been found in Ituassú, Feira de S. Anna and Serra do Assuruá, and it is said to occur at Sâo Bartholomeu, and in the Serras do Pitango and Macahubes [78].

Platinum also occurs in Brazil as rare disseminations in the gold-bearing *jacutinga*, intercalated in the itabirites (e.g. at Gongo Socco Mine, long since abandoned). The jacutinga occurs as narrow bands and nuclei in the itabirites, containing

a high percentage of gold, with much talc, clay and pulverulent pyrolusite. As accessory minerals zircon, rutile, cassiterite and tourmaline occur. Hussak thinks that the gold-bearing jacutinga has been derived from altered pegmatite veins.

From analyses made by Johnson (1833–41) on the Gongo Socco bullion, it would appear that the percentages of silver and platinum decreased while those of copper and palladium increased with depth (Henwood). The percentages of palladium varied from 3·89 to 4·80, and that of platinum from 0·04 to 0·12.

At Candonga, gold occurs in an eruptive rock rich in magnetite enclosed in itabirite, and is probably of contact-metamorphic origin. The gold occurs in grains of high standard, and with it are found fine indented scales of palladic gold, of a bright copper-red colour.

At Itabira do Matto Dentro gold occurs in jacutinga, lying between a micaceous iron schist, rich in quartz, and an enormous solid bed of itabirite. The palladium-gold may be copper-red, dark-brown or silver-white in colour. Native platinum also occurs with the gold.

Grains of platinum have also been found in the most northerly of the auriferous lenticular masses, which occur near the Bruscus River, near Pernambuco, in Cambrian crystalline schists. The matrix is a coarse white quartz containing small quantities of the arsenides and sulphides of iron, and the sulphides of copper, lead and zinc.

Platinum, although widely distributed in Brazil, occurs in such small quantities that so far there has been no production; but in the near future richer and more extensive deposits may be discovered, or it may be found practicable to win the metal from those already known, as an important by-product.

Palladium-gold, or *porpezite*, is a natural alloy of palladium and gold, and may contain up to 10 per cent. of the former metal. It is found in Brazil, in gold-washings, and also in the gold-bearing jacutinga reefs at Gongo Socco, Candonga and Itabira do Matto Dentro. In 1870 Henwood showed that the palladic gold from Gongo Socco contained, to a moderate depth from surface, from 0·04 to 0·12 per cent. of platinum. (Palladium-gold has also been reported from gold-

washings in the Caucasus, near Batoum.) Ruer concludes, from an examination of the freezing-point curves of artificial alloys of gold and palladium, that these alloys form a continuous series of mixed crystals, and that there is no indication of chemical combinations [79].

COLOMBIA

This republic is the second largest producer of platinum in the world, and in pre-war years supplied about 5 per cent. of the world's total output. Owing to the decline of the Russian supply, and the increased demand for the metal, the industry has in recent years received a considerable stimulus, and in 1916 Colombia's production rose to approximately one-third of the Russian output.

Platinum was first introduced into Europe from Colombia in 1735, although the metal was known in America for some time previously [46/p. 608]. In 1810 the value of platinum stood at $5 to $6 (U.S.) per oz., and in 1823 the price had further dropped to from $3 to $4 per oz. As a result, platinum was rejected as waste in the operation of refining gold by the "dry-blowing" system. Later, when platinum became valuable, much of this dumped metal was recovered, notably in Quibdo, the capital of the Chocó district, where much gold-refining was carried on.

The following table gives the outputs of crude platinum from Colombia, in recent years, principally produced in the Chocó district:

Year.	Oz. (troy).	Year.	Oz. (troy).
1911	12,000	1915	18,000
1912	12,000	1916	25,000
1913	15,000	1917	32,000
1914	17,500	1918	35,000 (estimated)

The larger portion of the production is shipped to the United States, the exports to that country for the years 1910–18 being as follows:

Year.	Oz. (troy).	Year.	Oz. (troy).
1910	1,600	1915	13,121
1911	5,503	1916	25,588
1912	6,627	1917	21,278
1913	10,461	1918	27,030
1914	12,387		

The crude platinum is estimated at 84 to 85 per cent. fine. The price in 1917 fluctuated from £16 to £20 10s. per oz., the average for the year being nearer the latter amount.

During 1918 the United States Government fixed the price at $105 per oz., which stimulated production.

The deposits are alluvial, and consist of re-concentrates of older gravels. The principal source of supply is at the head of the San Juan River, which enters the Pacific Ocean north of Buenaventura, the richest deposits occurring in the Condoto, Opagado and Tamanal Rivers, tributaries of the San Juan [80]. Platinum is also obtained in the Upper Atrato River, which flows northward to the Caribbean Sea. It is nearly always found associated with gold. In the gravels of the San Juan River the two metals are present in about equal proportions, and in those of the Atrato the ratio is approximately 85 of gold to 15 of platinum.

The area including the watersheds of the San Juan and Upper Atrato Rivers is known as the Chocó district. T. Ospina, Director of the Colombian School of Mines [81], estimates that in the area are 5,000 sq. miles of gold and platinum deposits, the Mira River forming the southern boundary of the area. In 1916 he estimated that there were in it 68,000,000 c. yd. of actually profitable gravel, with a reserve of 336,000,000 yd. of possibly profitable ground. Platinum has also been recovered in much smaller amounts on the Micay River in the Barbacoas district, near the frontier of Ecuador. The stream beds in which platinum occurs are those in which Tertiary conglomerates have become eroded; the river gravels about the areas underlain by that formation are barren. The conglomerates are composed of rounded boulders of basic rocks, such as diabase, melaphyre, peridotite and dunite [46/p. 620].

At Novita Vieja, in the centre of the Chocó district, a bed of conglomerate 6 to 12 ft. thick has been laid bare, over an area 2½ miles long and ½ mile wide, through the sluicing away of the overlying sands. It contains 0·5 oz. of gold, and 0·5 oz. of platinum, per ton [82]. According to Castillo, the parent rock is a typical gabbro, pyroxene predominating over the felspar [83/p. 826].

Platinum has been found in the Chocó district in serpentine rock. Granite also occurs in the same district, traversed by quartz lodes containing palladium, iridium, osmium and rhodium.

Colombian crude platinum contains from 80 to 85 per cent. platinum, the remaining 15 to 20 per cent. consisting chiefly of iridium and osmium. The sands in which it occurs are described as brown in colour, and carrying, besides platinum and gold, the heavy minerals chromite, magnetite and ilmenite [83/p. 384].

In the past, mining operations have been very irregularly carried on, by primitive methods of working, but dredges are now being employed in increasing numbers. In 1915 a dredge was operated on the Condoto River, in the province of Chocó, by the Anglo-Colombian Development Company, and showed good results. Native methods of working are very simple. The alluvial gravels derived from dried-up beds of ancient rivers are hand-washed with the use of the *batea* or dish. Where the metal occurs in the bed of a river it is obtained by diving girls, who work down to the platiniferous gravels, removing the gravel in small dishes, the men being employed in washing the gravels on the river banks [84]. About 90 per cent. of the total output is recovered by these primitive methods.

A large portion of the industry is in the hands of two companies, one of which is the South American Gold and Platinum Company, of New York, a Lewisohn company, which has absorbed the interests of the above-mentioned Anglo-Colombian Development Company, Ltd., the Gold Fields American Development Company, Ltd., and Johnson, Matthey & Co., Ltd., of London. The second company—the British Platinum and Gold Corporation, Ltd.—has recently amalgamated with the Paris (Transvaal) Gold Mines, Ltd., taking in the latter's interests on the Opogodo and other places.

The question of transporting platinum concentrate to the coast is not a matter of much difficulty, as the Atrato River is navigable as far as Quibdo, and the San Juan can be ascended by vessels of moderate draught for over 140 miles inland.

An estimate of average working costs appears to be 6*d*. per

c. yd. for dredging, and 3*d*. for hydraulicing [85]. In 1917 new platiniferous deposits were discovered in the Caceres district, between the Cauca and Nechi Rivers, in the department of Antioquia. The mineralized area extends along the Caceri River, a distance of 14¼ miles, the width at the north end being 1¼ miles, and 300 ft. at the southern extremity [10/p. 545].

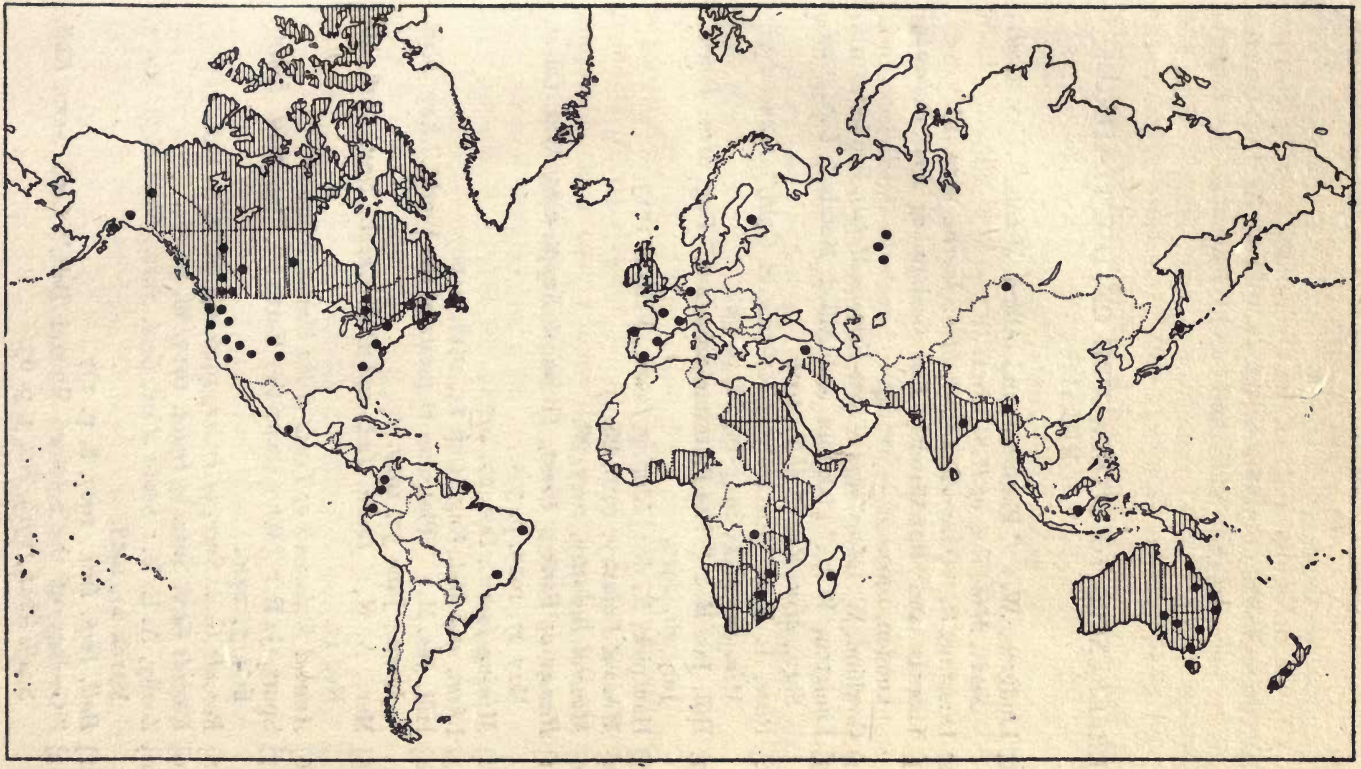
Ecuador

Platinum occurs, in association with the gold obtained from steam gravels, in the area covered by the Rivers Bogota, Cachabi, Uimbi, Santiago and Cayapas, but it has not so far been found in sufficient quantities to be of economic importance.

Dredging has been employed in mining these deposits, but does not appear to have been a success, and operations are now largely confined to native washings [86].

French Guiana

Platiniferous gold-bearing sands are found in the Aporuague River, the metal, according to an analysis by A. Danmer, having the following composition in percentages: platinum, 41·96; gold, 18·18; silver, 18·39; copper, 20·56 [87].



MAP SHOWING THE PLATINUM-BEARING DISTRICTS REFERRED TO IN THE TEXT.
(British Empire and Protectorates shaded.)

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