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GEOLOGICAL RELATIONS AND DISTRIBUTION OF PLATINUM AND ASSOCIATED METALS.—KEMP

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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE GEOLOGICAL RELATIONS AND DISTRIBUTION

OF

PLATINUM AND ASSOCIATED METALS

BY

JAMES FURMAN KEMP

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 8, 1901.

SIR: I return herewith a report on platinum, by Prof. J. F. Kemp, which I have read and recommend for publication as a bulletin.

Very respectfully,

S. F. EMMONS,
Geologist in Charge of Section of Metalliferous Ores.

Hon. CHARLES D. WALCOTT,
Director of United States Geological Survey.

THE GEOLOGICAL RELATIONS AND DISTRIBUTION OF PLATINUM AND ASSOCIATED METALS.

By J. F. Kemp.

CHEMICAL RELATIONS.

Platinum is one of seven metals which are customarily described as the "gold group." They are separable into three subgroups, based upon their affinities for oxygen.

(1) "Platinum and gold do not combine directly with oxygen under any circumstances.

(2) "Palladium, rhodium, and iridium oxidize when they are heated in the air or oxygen, but their oxides decompose on strong ignition into metal and oxygen.

(3) "Ruthenium and osmium unite with oxygen to form volatile oxides, which do not undergo decomposition even at the highest temperatures."[a]

With the omission of gold it is likewise customary to speak of the remaining six as the "platinum group."

If we fix attention upon the six it is evident that they are separable into two contrasted divisions according to their atomic weights. Thus, ruthenium (101.7), rhodium (103), and palladium (107) are near together, and then after a large interval platinum (194.9), iridium (193.1), and osmium (191) are likewise closely related. With the last named gold (197.2) is to be placed.

When grouped according to the periodic law they fall into the same two divisions of three each, and as they are placed in the same vertical columns with iron, cobalt, and nickel, it is natural to draw parallels between the latter and the former. Iron, ruthenium, and osmium have similar properties; so also have cobalt, rhodium, and iridium, and, finally, nickel, palladium, and platinum. Palladium and platinum exhibit analogies with silver and gold, while ruthenium and osmium are similarly related to molybdenum and tungsten.

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[a] Roscoe and Schorlemmer, Treatise on Chemistry, II, Part II, p. 359.

An appreciation of these relations is important in enabling the reader to gain a correct conception of the several metals, and it may be added that to a certain degree the same association appears in the geological occurrence; but, as will shortly be pointed out, there are other geological facts on which the chemical relations, so far as present knowledge goes, throw no light. Thus, for example, platinum is almost always derived from rocks rich in magnesium and is commonly associated with chromic oxide, yet neither magnesium nor chromium has been mentioned above.

In specific gravity the purified metals range as follows: Osmium, 22.477; iridium, 22.38; platinum, 21.48; ruthenium, 12.261; rhodium, 12.1; palladium, 11.4.

In fusibility the order is as follows: Osmium is the most refractory and has not been melted; ruthenium, iridium, and rhodium follow in order; platinum is next, and its melting point is fixed at 1,779° C.; palladium is the most fusible of all, and melts at about the same temperature as wrought iron.

MINERALS.

The minerals containing the metals of the platinum group are the following. With each a brief outline of its physical and chemical properties is given, for convenient reference and as a guide in identification. The chief source of this information has been the sixth edition of Dana's Treatise on Mineralogy, and Kokscharow's paper on "Gediegenes Platin," in his Materialen zur Mineralogie Russlands, Vol. V, p. 177. Both these have been supplemented by the writer's experience in the field.

Platinum.—The mineral called by this name is an alloy of platinum, iridium, rhodium, palladium, and often osmium, with varying amounts of iron, copper, and gold. Iridosmine is also usually present, but seems to be mechanically involved in the others. The complex nature suggested to Hausmann the name polyxene, meaning many strangers or guests. Full details are given subsequently regarding the chemical composition of the crude platinum of commerce. The crystals are isometric, but extremely rare. The cube is the commonest form. Nuggets, scales, and irregular grains are the usual shapes, and where taken near the mother rock they may be angular. Somewhat uncommonly chromite constitutes a part of the nuggets, and even other minerals, such as serpentine, olivine, pyroxene, and biotite, have been discovered, as noted later.

Cleavage, none; fracture, hackly. Hardness, 4 to 6. Malleable, ductile, sectile. Sp. gr., 14 to 19. Melted platinum is 19.7 and hammered is 21.23. The admixture of iron especially reduces the specific gravity, as iron itself is 7.3 to 7.8. Low specific gravities therefore indicate much iron. The variety rich in iron is called iron-platinum and its specific gravity ranges below 16. Luster, metallic. Color

PLATE I.

PLATE I.

(*A*) Rough, unworn platinum nuggets, Tulameen River, British Columbia. × 35 diam.

(*B*) Thin, worn platinum nuggets, Colorado River, Colombia. × 35 diam.

(*C*) Cubes of sperrylite, prisms of cassiterite, Vermillion mine, Ontario. × 35 diam.

(A)

(B)

(C)

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varies from silvery white to dark gray or almost black. Strong contrasts appear even in the platinum of a single district. The nuggets may be coated with a black, soluble crust, and when dealing with fine dust the observer may experience the greatest difficulty in recognizing the platinum with a lens or a microscope as against chromite or magnetite. The native platinum may be strongly magnetic, even forming natural lodestone, or it may be comparatively inert. It can, however, be readily separated from less magnetic materials in modern magnetic concentrators, such as the Wetherell. When the nuggets and dust are obtained near the mother rock they are angular and rough (Pl. I, *A*), but when they have been transported far they appear as thin scales (Pl. I, *B*).

Platinum is not essentially affected by the ordinary acids, but yields to boiling aqua regia. As a test of pannings, treatment with ordinary acids is not of much value, because chromite, the commonest associate of platinum, is insoluble. Platinum, if not too small, will be found to be malleable, whereas chromite is brittle. From colors of gold it may be separated by quicksilver, because the gold amalgamates and the platinum does not. Among the placer miners platinum is ofted called "white gold."

Platiniridium.—With a great increase in iridium, which in normal platinum does not exceed 5 per cent, this mineral is developed. The iridium may be over 75 per cent. Crystal system, isometric, the cube being the chief form, but as the mineral itself is excessively rare, and when found is usually in scales and grains, crystals are very uncommon. Hardness, 6.7, surpassing platinum. Sp. gr., 22.6 to 23, being thus the heaviest of known minerals. Color, white. Luster, metallic.

Palladium is alloyed in practically all cases with a little platinum and iridium. It is isometric and when crystallized is practically always in octahedrons, but it also occurs in grains and fibrous masses. In any form it is excessively rare. Hardness, 4.5 to 5. Sp. gr., 11.3 to 11.8. Luster, metallic. Color, whitish, steel-gray. Malleable, ductile, sectile.

Allopalladium.—An allotropic form of palladium, hexagonal in crystallization, forming small 6-sided tables. Color, silver-white to pale steel-gray. Excessively rare.

Iridosmine (often called osmiridium).—This is an alloy of iridium and osmium. The other metals of the platinum group are very subordinate, platinum itself being at most under 3 per cent. Ruthenium, however, which fails in platinum, may reach 8 per cent, and is usually present. Hexagonal, but almost always in flattened grains (see Pl. V, *A*). Hardness, 6.7. Sp. gr., 18.8 to 21.12, being thus heavier than platinum, but less heavy than platiniridium. Luster, metallic. Color, tin-white to steel-gray. Iridosmine is a minor associate of platinum, but is harder. Two varieties have been made, based on Siberian occurrences, viz, newjanskite, with over 40 per cent iridium, and sisserskite, under 30 per cent iridium. No provision seems to have been made for percentages between 30 and 40, but none appear in analyses yet recorded. Sisserskite has a slightly higher specific gravity than newjanskite.

All the above minerals are alloys. There are but two definite natural compounds known of any metals of the platinum group with nonmetallic elements—sperrylite and laurite.

Sperrylite.—Arsenide of platinum ($PtAs_2$) with a little antimony and rhodium. Isometric, the octahedron and cube being commonest; the pentagonal dodecahedron, the rhombic dodecahedron, and the diploid are known (see Pl. I, *C*). Hardness, 6 to 7. Sp. gr., 10.6. Luster, metallic. Color, tin-white, streak black. If slowly roasted in the open tube sperrylite gives a sublimate of arsenic trioxide and melts easily. Sperrylite is a very rare mineral and until recently has been known from only two localities—western Ontario and North Carolina. Within the last year, however, investigations of the copper ores of the Rambler mine, Wyoming, by Professors Wells and Penfield, have shown minute crystals of sperrylite in the covellite which forms a considerable part of the oxidized zone of the mine. The platinum which has occasionally been found by assay in other ores may have been present as sperrylite.

Laurite is an extremely rare sulphide of ruthenium with a minor amount of osmium. Isometric, in small cubo-octahedrons. Hardness, above 7. Sp. gr., 6.99. Luster, metallic. Color, dark iron-black; powder, dark gray. Brittle. Known only from the platinum washings of Borneo.

CHEMICAL COMPOSITION OF NATIVE PLATINUM AND IRIDOSMINE.

In the accompanying table have been collected analyses of 42 samples of platinum and 2 of platiniridium. They are arranged in order from those highest in platinum to those lowest. "I-O" stands for iridosmine. In the diagram, fig. 1, a series of curves has been plotted, the percentages of platinum in the above analyses being used as abscissas. The percentages of the other metals are used as ordinates. Inasmuch as no definite chemical relation exists among the members of the alloys, the percentages rather than the molecular proportions have been employed. More or less of iridium and of osmium in some of the analyses is involved in the contained iridosmine. In a few cases, however, the two metals have been determined and the presumption is that they were not combined in this individual mineral. Iridosmine is a very insoluble substance and is sometimes left as a residue during the solution of a nugget. Nearly all the percentages of osmium which are recorded indicate loss rather than actual determinations of the pure metal, although this has formed much the greater part of such reported losses. In summary, it may be said that the analyses have been based upon samples from the following localities:

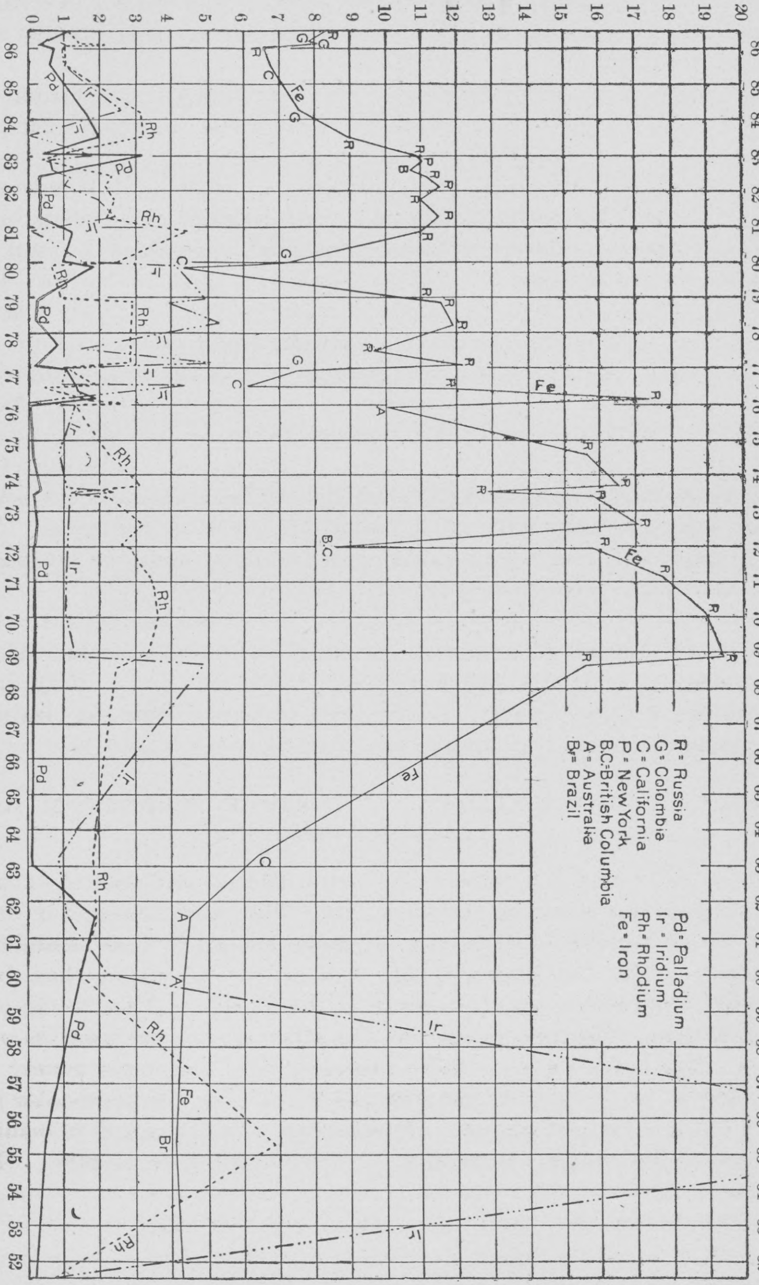


FIG. 1.—Diagram illustrating the chemical composition of native platinum.

Russia, 27; United States of Colombia, 5; California, 4; Australia, 3; New York, 1; British Columbia, 1; Oregon, 1; Brazil, 1.

Table of analyses of platinum nuggets.

	1. Russia.	2. Colombia.	3. Colombia.	4. Russia.	5. California.	6. Colombia.	7. Russia.	8. Russia.	9. New York.	10. Borneo.	11. Russia.
Pt	86.50	86.20	86.16	85.97	85.50	84.34	83.49	83.07	82.81	82.60	82.46
Ir	----	.85	1.09	.98	1.05	2.52	Tr.	1.91	.62	.66	1.21
Rh	1.15	1.40	2.16	.96	1.00	3.13	3.17	.59	.28	----	2.35
Pd	1.10	.50	.35	.75	.60	1.66	1.94	.26	3.10	----	.23
Os	1.08	----	.97	.54	----	.19	----	----	----	----	Tr.
Ru	----	----	----	----	----	----	----	----	----	----	----
I-O	1.40	.95	1.19	2.10	1.10	1.56	----	1.80	----	3.80	----
Au	----	1.00	----	----	.80	----	----	----	----	.20	----
Insol	----	----	----	----	----	----	.93	----	----	----	1.38
Fe	8.32	7.80	8.03	6.54	6.75	7.52	8.98	10.79	11.04	10.67	11.23
Cu	.45	.60	.40	.86	1.40	Tr.	----	1.30	.39	.13	.64
Sand	----	.95	----	----	2.95	----	----	----	----	----	----
Mn	----	----	.10	----	----	.31	----	----	----	----	----
Loss	----	----	----	----	----	----	1.49	----	----	----	.50
Total	100.00	100.25	101.17	98.70	101.15	101.23	100.00	99.72	----	98.36	100.00

	12. Russia.	13. Russia.	14. Russia.	15. Russia.	16. Colombia.	17. California.	18. Russia.	19. Russia.	20. Russia.	21. Russia.	22. Russia.
Pt	82.16	81.72	81.34	80.87	80.00	79.85	78.94	78.92	78.38	77.50	77.14
Ir	1.00	1.81	2.42	.06	1.55	4.20	4.97	3.97	5.32	1.45	5.10
Rh	2.19	2.44	2.14	4.44	2.50	.65	.86	2.87	2.79	2.80	2.74
Pd	.25	.30	.30	1.30	1.00	1.95	.28	.24	.17	.85	.22
Cs	Tr.	Tr.	Tr.	----	----	.05	1.25	Tr.	Tr.	2.30	Tr.
Ru	----	----	----	----	----	----	----	----	----	----	----
I-O	----	----	----	.11	1.40	4.95	1.96	----	----	2.35	----
Au	----	----	----	----	1.50	.55	----	----	----	----	----
Insol	1.89	1.04	.57	----	----	----	----	1.09	.32	----	.98
Fe	11.50	10.94	11.48	10.92	7.20	4.45	11.04	11.52	11.72	9.60	12.13
Cu	.21	.95	1.13	2.30	.65	.75	.70	.25	.28	2.15	.34
Sand	----	----	----	----	4.35	2.60	----	----	----	1.00	----
Mn	----	----	----	----	----	----	----	----	----	----	----
Loss	.80	.80	.62	----	----	----	----	1.44	1.02	----	1.35
Total	100.00	100.00	100.00	100.00	100.15	100.00	100.00	100.00	100.00	100.00	100.00

Table of analyses of platinum nuggets—Continued.

	23. Colombia.	24. California.	25. Russia.	26. Russia.	27. New South Wales.	28. Russia.	29. Russia.	30. Russia.	31. Russia.	32. Russia.	33. British Columbia.
Pt	76.82	76.50	76.40	76.22	75.90	74.67	73.70	73.58	73.42	72.61	72.07
Ir	1.18	.85	4.30	Tr.	1.30	.83	1.15	2.35	1.12	1.14	1.14
Rh	1.22	1.95	.30	2.50	1.30	2.26	3.12	1.15	2.30	3.10	2.57
Pd	1.14	1.30	1.40	1.87	Tr.	.18	.23	.30	.15	.23	.19
Os	-----	1.25	-----	Tr.	-----	Tr.	Tr.	2.14	Tr.	Tr.	-----
Ru	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
I-O	7.98	7.55	.50	-----	9.30	-----	-----	2.30	-----	-----	10.51
Au	1.22	1.20	.40	-----	-----	-----	-----	-----	-----	-----	-----
Insol	-----	-----	-----	.50	-----	2.30	2.56	-----	2.62	3.53	-----
Fe	7.43	6.10	11.70	17.30	10.15	15.54	16.65	12.98	15.88	17.13	8.59
Cu	.88	1.25	4.10	.36	.41	1.98	1.47	5.20	2.01	.32	3.39
Sand	2.41	1.50	1.40	-----	1.22	-----	-----	-----	-----	-----	1.69
Mn	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Loss	-----	-----	-----	1.25	-----	2.24	1.12	-----	2.50	1.94	-----
Total	100.28	99.45	100.50	100.00	99.48	100.00	100.00	100.00	100.00	100.00	100.15

	34. Russia.	35. Russia.	36. Russia.	37. Russia.	38. Russia.	39. California.	40. Australia.	41. Australia.	42. Brazil.	43. Oregon.	44. Russia.
Pt	71.94	71.20	70.15	68.95	68.72	63.30	61.40	59.80	55.44	51.45	19.64
Ir	1.18	1.15	1.03	1.34	4.73	.70	1.10	2.20	27.79	.40	76.80
Rh	2.76	3.46	3.61	3.30	2.48	1.80	1.85	1.50	6.86	.65	-----
Pd	.14	.18	.20	.21	.20	.10	1.80	1.50	.49	.15	.89
Os	Tr.	Tr.	Tr.	Tr.	Tr.	-----	-----	.80	Tr.	-----	-----
Ru	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
I-O	-----	-----	-----	-----	6.36	22 55	26.00	25.00	-----	37.30	-----
Au	-----	-----	-----	-----	-----	.30	1.20	2.40	-----	.85	-----
Insol	2.87	3.85	3.87	3.75	-----	-----	-----	-----	-----	-----	-----
Fe	15.79	17.73	18.90	18.93	15.58	6.40	4.55	4.30	4.14	4.30	-----
Cu	3.72	.50	1.16	1.59	.30	4.25	1 10	1.10	3.30	2.15	1.78
Sand	-----	-----	-----	-----	-----	-----	1.20	1.20	-----	3.00	-----
Mn	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Loss	1.60	1.93	1.08	1.93	1.63	-----	-----	-----	-----	-----	-----
Total	100.00	100.00	100.00	100.00	100.00	99.40	100.20	100.00	98.02	100.25	99.11

NOTES TO TABLE.

1. Russia, Goroblagodat. Berzelius. Köng. Vet. Acad. Handl., Stockholm, 1828, p. 113.
2. Colombia, El Choco. Deville and Debray. Ann. Chem. Phys., III, Vol. LVI, p. 449.
3. Colombia, El Choco. L. F. Svanberg. Handl. Vet. Acad., Stockholm, 1834, 34. Poggendorff's Annalen, Vol. XXXVI, 1835, p. 471.
4. Russia, Kuschwinsk. Goroblagodat. C. Claus, in Rammelsberg's Handbuch der Mineralchemie, 1860, p. 10.
5. California. Deville and Debray. As under 2.
6. Colombia, El Choco. L. F. Svanberg. As under 3.
7. Russia. Goroblagodat. Nonmagnetic. Minchin, in Kokscharow's Beiträge zur Mineralogie Russlands, Vol. V, p. 184.
8. Russia, Nijni Tagilsk. G. Osann. Poggendorff's Annalen, Vol. XIV, 1829, p. 158.
9. New York, Plattsburg. P. Collier. Am. Jour. Sci., Feb. 1881, p. 124.
10. Borneo. M. Bocking. Liebig's Annalen, Vol. XCVI, 1855, p. 243. Two other analyses not in this table will be found under Borneo.

11. Russia. Nijni Tagilsk. Minchin. As under 7.
12. Russia. Idem.
13. Russia. Idem.
14. Russia. Idem.
15. Russia. G. Osann. As under 8.
16. Colombia, El Choco. Deville and Debray. As under 2.
17. California. Deville and Debray. As under 2.
18. Russia, Nijni Tagilsk. Berzelius. As under 1.
19. Russia. Nijni Tagilsk. Minchin. As under 7.
20. Russia. Idem.
21. Russia. Deville and Debray. As under 2.
22. Russia, Nijni Tagilsk. Minchin. As under 7.
23. Colombia, El Choco. Deville and Debray. As under 2.
24. California, Deville and Debray. As under 2.
25. Russia. Idem.
26. Russia. Goroblagodat. Minchin. As under 7.
27. New South Wales, Fifield. J. C. H. Mingaye. Records Geol. Survey, New South Wales, Vol. V, 1896-1898, p. 35.
28. Russia, Nijni Tagilsk. Minchin. As under 7.
29 Russia. Idem.
30. Russia, Nijni Tagilsk. Berzelius. As under 1.
31. Russia, Nijni Tagilsk. Minchin. As under 7.
32. Russia. Idem.
33. British Columbia, Tulameen River, G. C. Hoffman. Geol. Survey of Canada, II, 1886, Rep. I.
34. Russia. Nijni Tagilsk. Minchin. As under 7.
35. Russia. Idem.
36. Russia. Idem.
37. Russia. Idem.
38. Russia. Idem.
39. California. Kromayer. Archiv. Pharmacie, II, Vol. CX, p. 14. Jahresber. Chem. 1862, p. 707.
40. Australia (New South Wales?). Deville and Debray. As under 2.
41. Australia. Idem.
42. Brazil. L. F. Svanberg. As under 3.
43. Oregon. Deville and Debray. As under 2.
44. Russia. Nijni Tagilsk, Platiniridium. L. F. Svanberg. As under 3.

PERCENTAGE OF VARIOUS METALS CONTAINED IN SAMPLES ANALYZED.

When the analyses are studied it is evident that the platinum from certain localities has a characteristic chemical composition.

Platinum.—The platinum varies from 86.50 to 51.45 per cent for platinum proper. One sample of platiniridium has 19.64 and another has 55.44 per cent. Sixteen of the analyses contain 80 per cent platinum and above, twenty are between 70 and 80 per cent, and six are below 70 per cent, exclusive of the platiniridium. In the analyses of samples whose platinum falls below 63 per cent iridosmine is present in such amounts as to be the chief cause of the low percentage.

Iridium.—Iridium varies from a trace to a maximum of 5.32 per cent (No. 20), but of course it rises much higher in platiniridium. In No. 44, which is based on the latter mineral, it reads 76.80 per cent. In those analyses which have recorded percentages of iridosmine the total iridium would be higher if the specimens had been considered commercial samples, but, as has been stated, the iridosmine is probably a mechanical inclusion. The amount of the combined iridium seems to have no definite relation with the platinum.

Rhodium.—Rhodium is not recorded in the sample from Borneo (No. 10), but it does appear in all the others. Its minimum percentage is 0.28 in No. 9, the sample coming from New York. Its maximum is 4.44 in No. 15, a Russian specimen. In the sample of platiniridium (No. 42) it reads 6.86. When the curve of the rhodium is plotted it exhibits some points of similarity with that of iridium, but there are so many other marked contrasts that one can not trace a definite relation between them.

Palladium.—Palladium is not recorded from Borneo, but it is invariably mentioned in all the other analyses. It ranges from a trace as a minimum to 1.95 per cent in No. 17, a California specimen, as a maximum.

Osmium.—Osmium is not often specifically determined. As already stated, most of the figures cited as osmium mean simply loss. We can only say that it is usually present, but that, aside from inclusions of iridosmine, it is in small quantity.

Ruthenium.—Ruthenium is not recorded in any analysis of platinum or platiniridium, but it does appear in iridosmine, as is shown by the second table of analyses.

Iridosmine.—Iridosmine mechanically involved may be present in large amounts. Almost all the analyses show some, and the amount ranges from 0.11 as a minimum to 37.30 as a maximum. In platinum from North America and Australia it is more abundant than in the samples from Russia. The maximum of 37.30 was found in a sample from Oregon. It will be of interest to insert at this point a series of analyses of iridosmine itself, because they throw light upon the composition of this mineral as included in native platinum.

Analyses of iridosmine.

	1. Russia.	2. Colombia.	3. Russia.	4. Russia.	5. Borneo.	6. Australia.	7. Colombia.	8. Russia.	9. California.	10. Russia.	11. Russia.	12. Russia.
Ir	77.20	70.40	70.36	64.50	58.27	58.13	57.80	55.24	53.50	46.77	43.94	43.28
Os	21	17.20	23.01	29.90	38.94	33.46	35.10	27.32	43.40	49.34	48.85	40.11
Pt	1.10	.10	.41	2.80	.15	------	------	10.06	------	------	.14	.62
Rh	.50	12.30	4.72	7.50	2.64	3.04	.63	1.50	2.60	3.15	1.65	5.73
Pd	------	------	------	------	------	------	------	Tr.	------	------	------	------
Ru	.20	------	------	------	------	5.22	6.37	------	.50	------	4.68	8.49
Au	------	------	------	------	------	------	------	------	------	------	------	------
Fe	------	------	1.29	1.40	------	------	.10	Tr.	------	.74	.63	.99
Cu	Tr.	------	.21	.90	------	.15	.06	Tr.	------	------	.11	.78
Total	100	100	100	100	100	100	100.06	100	100	100	100	100

NOTES TO TABLE.

1. Russia. Deville and Debray. Annales Chem. et Phys., III, Vol. LVI, p. 449.
2. Colombia, El Choco. Idem.
3. Russia. Idem. Sp. gr. 20.5.
4. Russia. Idem. Sp. gr. 18.8.
5. Borneo. Idem.
6. Australia, undoubtedly New South Wales and from the Richmond or Clarence rivers. Idem.
7. Colombia, El Choco. Idem.
8. Russia. Nijni Tagilsk. Claus. Beiträge zur Chemie der Platinmetalle. Dorpat, 1854. Jahresber. Chemie, 1855, pp. 423, 444, 814, 905.
9. California. Deville and Debray. As under 1.
10. Russia. Berzelius, Poggendorff's Annalen, Vol. XXXII, 1833, p. 232. Sp. gr. 19.386–19.471, Ir.Os.
11. Russia. Deville and Debray. As under 1. Sp. gr. 20.4.
12. Russia. Idem. Sp. gr. 18.9.

The table of analyses brings out very clearly the fact that platinum is extremely subordinate in iridosmine, and may entirely fail. It varies from nothing through a general amount of less than 1 to 10.08 in No. 8, a Russian sample, as a maximum. The iridium varies from 43.28 as a minimum to 77.20 as a maximum. The osmium ranges from 49.34 as a maximum to 17.20 as a minimum. These extreme values do not correspond exactly to the minimum and maximum values of iridium, but it may be stated that in general the low values of osmium accompany high values of iridium, and vice versa. Rhodium is present without exception, and reaches in No. 2, from Colombia, 12.30, as a maximum. These values are pretty well distributed between this amount and 0.50 as a minimum. Palladium, which is universally present in platinum, practically fails in iridosmine, while ruthenium, which fails in platinum, may be present in considerable amounts in iridosmine. No. 12, from Russia, contains 8.49 per cent. Gold fails entirely, and iron and copper are either entirely lacking or insignificant.

Gold.—Gold is frequent in samples from California and Colombia, but in almost all cases it seems to fail in Russian material. When present, it varies from a minimum of 0.20, in No. 10, from Borneo, to 1.50, in No. 16, from Colombia. Presumably, the gold cited in the analyses appears as an alloy, but gold is also known mechanically included with, or plated or welded upon the platinum, as will be more fully described under the minerals which are associated with the nuggets.

Iron.—Iron is mentioned in all the analyses except No. 44, of a Russian sample of platiniridium. In platinum proper its minimum is 4.30, in No. 43, from Oregon. This low percentage is accompanied by a high percentage of iridosmine—37.30. Another sample, No. 41, from Australia, likewise contains but 4.30 of iron; and it has 25 per cent iridosmine. The maximum values in iron are present in the samples with moderate percentages of platinum—69 to 76. The highest figure recorded is 18.93, No. 37, from Russia. As the amount of platinum increases, the iron tends to decrease, but the statements are based chiefly upon Russian material. The curve of iron in the diagram (fig. 1) is very significant. We need, however, for its true estimation, to bear in mind the geographical localities. If one fixes attention upon the Russian samples, whose points are marked with an R, it is evident that the iron increases quite regularly and uniformly from the richest nugget, with 86.50 platinum, to the one with 68.95. Nearly all the points which have been plotted below this curve are based upon analyses from other localities. The iron in the specimens from Colombia is quite uniform, standing in nearly all cases between 7 and 8 per cent. The California samples likewise have comparatively small amounts.

Copper.—Copper was absent or undetermined in No. 7, from Russia,

PLATE II.

PLATE II.

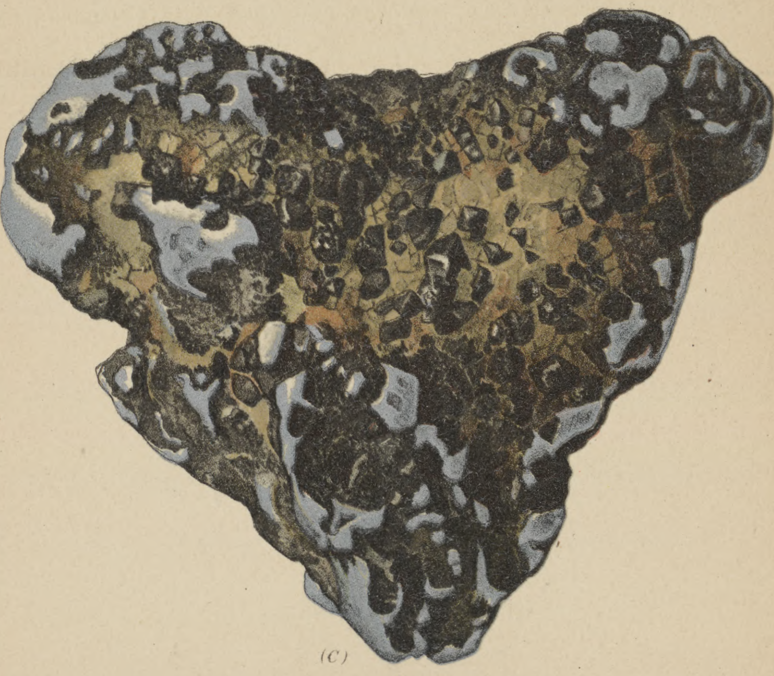
(*A*) Nugget of platinum, gold, and chromite, Colombia. × 20 diam.

(*B*) Nugget of platinum, gold, and dolomite or magnesite, Colombia. × 20 diam.

(*C*) Platinum nugget with olivine and octahedral chromite, Tulameen district, British Columbia. × 9 diam.

(A)

(B)



(C)

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but it is otherwise invariably present. It ranges from a trace in No. 6, from Colombia, to a maximum of 5.20 in No. 30, from Russia. It is usually less than 1 per cent, although, in looking through the table, a considerable number of analyses will be found above this figure.

Other metals.—Manganese has been recorded in two cases, Nos. 3 and 6, both from Colombia. The amounts, however, are small—0.10 and 0.31, respectively. It probably appears in much the same relation as iron. Lead has been recorded in one from Fifield, New South Wales, but only traces are mentioned. This is No. 27, although the lead is not given in the table. In No. 24, from California, 0.55 per cent lead is mentioned in the original citation with a query. Quicksilver has been recorded in one from California. It is No. 39, and 0.60 per cent is given in the original. Nickel has been reported in platinum from Nijni Tagilsk, by Terreil. In a sample containing 8.18 Fe, 0.75 Ni was determined.[a]

MINERALS ASSOCIATED WITH THE NUGGETS.

It is necessary to discriminate between the minerals which actually form a part of the nuggets and those which are merely associated with them as components of the gravels. Under the former head chromite, olivine, serpentine, pyroxene, mica, and gold have now been discovered.

Chromite.—Chromite is much the commonest of all the foreign minerals which are found attached to the nuggets. Its general relations with the platinum are illustrated by Pl. II, *A*, *B*, and *C*, and Pl. III, *A* and *B*. The nuggets from which the drawings of Pl. III were made came from British Columbia. Those from which Pl. II was prepared are from Russia, Colombia, and British Columbia. The platinum is intermingled with the chromite in such a way that sometimes one mineral and sometimes the other is the host, and there seems to be no question that the two minerals have crystallized together. Sometimes the chromite appears as little octahedrons perched upon the platinum. These are illustrated in Pl. II, *C*, a specimen from British Columbia. The British Columbia nuggets which contain platinum sometimes have a crumbly aspect, suggesting that the grains of chromite are held together by the platinum and have not traveled far. Nuggets with chromite have been observed in Colombia, Russia, British Columbia, and at Plattsburg, N. Y. Nevertheless, nuggets with attached chromite are not particularly common and appear as a small minority in the commercial samples. The chromite is always suggestive of a basic igneous rock as the source from which the nuggets have been derived.

Olivine.—Olivine has been discovered upon a few nuggets from British Columbia. The illustration, Pl. III, *B*, has been drawn from one of a number of thin sections which have been prepared by the writer.

[a] Comptes rendus, Vol. LXXXII, 1876, p. 1116.

The olivine seems quite abundant upon the fresh nuggets, but when the thin sections are cut it is discovered that the core is platinum and that merely an outside shell of olivine grains adheres to it. The latter grind off with the greatest facility, so that it is very difficult to preserve them for microscopic examination. These attached olivines suggest in the strongest manner a peridotite as the source of the nuggets. Serpentine, quite certainly derived from olivine, has been observed upon a number of Russian specimens and is likewise suggestive of basic igneous rocks as the source of the metal.

Pyroxene.—Upon one thin section of a nugget from British Columbia adhering crystals of pyroxene have been discovered by the writer. They are illustrated by Pl. III, *C*. The pyroxene appears to be common augite. It possesses the usual high extinction angle and the other normal optical properties. Pyroxenites occur near the place of discovery of the nugget, and have probably been the mother rock.

Mica.—Kokscharow has recorded one instance in the Urals in which a platinum scale was found embedded in a mica crystal.[a]

Gold.—Gold has been mentioned in connection with the analysis of platinum, and the remark was there made that the yellow metal was probably alloyed with the platinum in the cases cited. It does, however, occur either mechanically involved with the platinum or plated or welded to it, and in searching over a number of nuggets several have been found in which the gold formed an auxiliary mineral. They have been obtained chiefly from Colombian samples, and two small ones have been selected for illustration, as shown by Pl. II, *A* and *B*. Pl. II, *B*, is of special interest, as it shows gold, platinum, and dolomite or magnesite on the same piece. The white mineral effervesces feebly with warm nitric acid. A number of others, which are small, have, however, likewise been studied. Some were obtained in British Columbia and some in Russia.

So far as known to the writer, no other minerals have been actually found forming a part of the nuggets except iridosmine. It is possible that magnetite may at times have been taken for chromite. The rusty crust on some nuggets may be a mineral not mentioned above.

Associated minerals in the gravels.—Minerals associated with the platinum nuggets are the familiar ones which have been so frequently studied in connection with the much more abundant gold-bearing placers. The commonest ones are gold, silver, copper, iridosmine, and other members of the platinum group, chromite, magnetite, menaccanite, garnet, zircon, rutile, small diamonds, topaz, quartz, cassiterite, pyrite, and epidote. Almost any mineral of high specific gravity which is commonly met in rocks may be expected to appear in the pannings. Purchasers of platinum dust also occasionally meet bits of lead, which appear to be shot that have been fired from a gun. It is possible that they have gotten into the gravels after having been used by some hunter. It is at least charitable to attribute this source to the lead.

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[a] Materialen zur Mineralogie Russlands, Vol. V, p. 371.

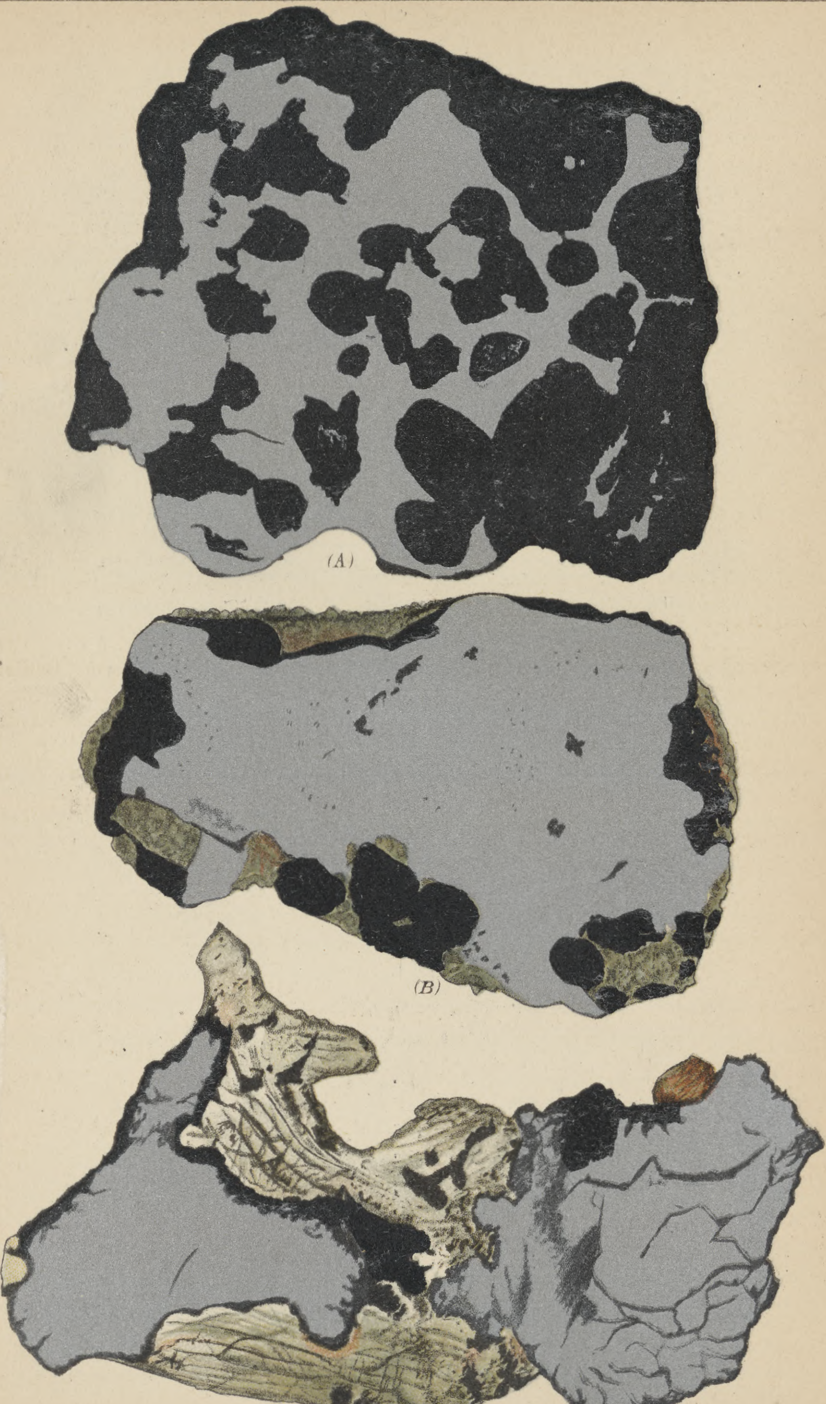
PLATE III.

PLATE III.

(*A*) Polished nugget of platinum and chromite, Tulameen River, British Columbia. × 10 diam.

(*B*) Thin section of nugget of platinum, chromite, and olivine, Tulameen River. × 14 diam.

(*C*) Thin section of nugget of platinum and pyroxene, Tulameen River. × 15 diam.



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PLATINUM IN COUNTRY ROCK.

The greatest interest has been felt by all familiar with the subject in the discovery of platinum in the mother rock, and a number of observers have endeavored to trace the nuggets back to their sources. In four or five cases this has been accomplished.

Urals.—The first person to succeed, or to believe that he succeeded, was Dr. Moritz von Engelhardt, who was professor of mineralogy in the University of Dorpat. In the early part of the preceding century it seems to have been a not infrequent custom among several of the European governments to commission a scientific man to travel with a view to investigating the mineralogical resources of some particular region. Gustav Rose's famous trip through the Urals and the Altai Mountains may be cited as an example. In a somewhat similar way Professor von Engelhardt was sent in 1826 by his university to trace, if possible, the gold and platinum of the Urals to their sources. His results were published in a small pamphlet of 44 pages, in Riga, in 1828.[a] Professor von Engelhardt studied the gold and platinum at Nijni Tagilsk and at Nijni Turinsk. On his return from Nijni Turinsk to Nijni Tagilsk he discovered, near the village of Laja and upon the bank of a neighboring brook, weathered porphyritic rocks which furnished superficial deposits very similar to those in the platinum mines at Nijni Turinsk. Although they were deeply weathered, he was able finally to secure some specimens of fresh material. In his description he states that they exhibited a part that resembled greenstone and a part like syenite, consisting of hornblende and reddish white feldspar, with some imperfect crystals and rounded nests of individual feldspar. The outer surfaces of the bowlders and of the cracks were coated with brown ocher and black oxide of manganese, but toward the center the feldspar crystals became white and kaolinized. The larger nests of feldspar seemed like spheroids of feldspar-porphyry. The remaining finely crystalline base was a mixture of hornblende and feldspar and was brown and stained with iron. The binding material of the bowlders was feeble. It resembled brown jasper, or brown clay ironstone, and appeared in rounded grains and angular bits.

In places the rock was entirely black and full of fine pores. The outer portion could be knocked off in curving shells, so that the observer might imagine that he had a slag before him if it were not that the core made it possible for him to recognize the porphyry. By a careful examination of these specimens Professor von Engelhardt was enabled with a lens to discover in the fresh porphyry shining metallic points resembling the platinum which was washed from the sands at Nijni Turinsk. These were submitted to a very careful

[a] This little work is not easily accessible in America, but a copy is now in the possession of the writer.

chemical investigation by his colleague, Professor Osann, who separated a pair of the little grains and identified them as platinum. The granules obtained from the "syenitic greenstone porphyry" were rounded, with little elevations and depressions. The depressions were largely stained black, while the elevations were tin white and strongly metallic. A few little grains, which were a mixture of gold and platinum, possessed a grayish yellow color. Each platinum grain was inclosed in limonite or brown ocher, which also coated the small pores even of the fresh rock. Dr. Engelhardt states that probably the numerous, larger pores of the weathered porphyry had likewise contained grains of platinum, which were freed when the rock fell to pieces.[a] This discovery is extremely interesting, because it indicates the presence of platinum in a feldspathic rock and not in a peridotite or serpentine, or in an especially basic type. In this connection a comparison with the results obtained by the writer in British Columbia will be of interest.

A few years after Professor von Engelhardt made his discovery, Gustav Rose visited Dorpat in connection with his famous trip through the Urals. Rose records his great desire to discover platinum in the country rock and the interest which he felt in Dr. Engelhardt's investigations. He visited the locality and had no difficulty in collecting similar samples of rock, and, on his return through Dorpat he procured additional material from the same lot upon which Dr. Engelhardt had made his determinations. Rose was, however, unable to verify Engelhardt's discoveries and found no platinum in any specimen of the rock.[b] These results would indicate that the platinum is sparsely and irregularly distributed, an experience which has been met by others. Professor von Engelhardt's observations are so well fortified by chemical tests on the part of his colleague, Professor Osann, that one would hesitate to question them.

Interest has been felt by geologists everywhere in the announcement that platinum had been again discovered within the last few years in the country rock of the Urals, but as the published descriptions have been in Russian they are not easily accessible to English-speaking people. In the sketch of platinum in Russia which is subsequently given, a translation of the most important paper will be found. In this place it will be merely remarked that in a paper by Prof. A. Inostranzeff, read before the St. Petersburg Society of Naturalists in 1892, and entitled Primary Deposits of Platinum in the Urals, a description is given of the most recent discovery. Daubrée had identified platinum by assay in bowlders of peridotite from the vicinity of Nijni Tagilsk in 1876. In the summer of 1892 Professor Inostranzeff visited this district and recognized the fact that

[a] Die Lagerstätte des Goldes und Platin im Ural-Gebirge, by Moritz von Engelhardt, Riga, 1828, pp. 30-31.

[b] Reise nach dem Ural, etc., by Gustav Rose, Vol. I, p. 340.

the gravels containing the platinum had been derived from Soloviev Mountain, which was known to consist chiefly of serpentine and peridotites. About that time the story spread that a laborer had been seen mining by himself. When he was finally located it was found that he had blasted into the rock of the mountain and had followed up a pocket some 35 cm. in diameter. The rock which had been mined appears to be an altered olivine rock which has passed even beyond the stage of serpentine. It consists of chromic iron, serpentine, and dolomite, and seems to be somewhat shattered, because its pieces are cemented together by opaline silica. When this shattered and more or less decomposed rock was crushed and panned it yielded colors of platinum of an exceedingly fine character, but they were distinctly recognized. On assay of 500 grams of the crushed rock, taken in several samples, platinum was found to be present to an amount of 0.0107 per cent, or about 3 ounces to the ton. This platinum contained no iridium.

There is record of the presence of platinum in the gold-bearing quartz veins at Beresovsk, Russia.[a]

Colombia.—As early as 1826 Boussingault announced in a letter to Humboldt that he had obtained scales of platinum upon panning the ferruginous outcrop of a vein which occurred at Santa Rosa, near Medellin, province of Antioquia, Colombia. Further details are given in the subsequent description of platinum in Colombia. By a misunderstanding of the records this locality is sometimes mentioned as being in Brazil, as, for example, in Dana's Mineralogy.

Mexico.—In 1875 Sandberger announced that he had detected platinum in some pseudomorphs of limonite after pyrite from an unrecorded locality in Mexico.[b]

Brazil.—In various papers on platinum the statement has been recorded that the metal has been discovered in place in Brazil. C. F. Hartt states, on page 448 of his Geology and Physical Geography of Brazil, that platinum is found in quartz veins which cut syenitic gneiss. The veins are called the Boa-Esperança. Hartt also states, on page 542, that the gold of Gongo Seco, in the province of Minas Geraes, contains palladium, and in a footnote he states further that the gold of Brazil is always alloyed with silver and occasionally with platinum, and that it may contain iron. Iridium and iridosmine are found in the gold washings of Minas.

NOTE.—Since this bulletin was written, the writer, with the cooperation of Dr. David T. Day and Mr. A. W. Johnston, has accumulated proof of the presence of platinum in pyrite and in quartz veins from several American localities. The notes are in preparation for publication.

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[a] Phillips's Ore Deposits, 2d edition, pp. 545-546.
[b] Neues Jahrbuch, 1875, p. 625.

Platinum was observed and reported to be a constituent of copper ores very early in the nineteenth century. In the series of samples of tetrahedrite, or some mineral resembling it, which was sent from Guadalcanal, Spain, to Paris in 1806, the French chemist Vauquelin discovered platinum in amounts varying from a trace to as much as 10 per cent. The ore came from veins, and the platinum no doubt was found in place. Additional details are given regarding the local geology in the notes upon platinum in Spain.[a]

France.—Berthier and Becquerel have detected it in limonite from the departments of Charente and Deux Sevres, France.[b]

A very interesting case of the occurrence of platinum in tetrahedrite and in bournonite in certain limestones of the western Alps has been described by E. Gueymard,[c] a French mining engineer, long a resident of the region. The platinum varied from nothing to amounts that could be weighed. The majority of the samples, however, failed to afford it. (Details are subsequently given under "France," p. 65.) The occurrence is of great interest, and, taken together with the results of Vauquelin and the known presence of platinum in the nickel-copper ores of Sudbury, makes it desirable to scrutinize this type of ore with great care. It is quite possible that in the past small amounts of platinum have been overlooked, which, with modern electrolytic methods of separation, could be profitably obtained, and there is reason to believe that occurrences of this sort are more promising for economic treatment than are those of native platinum sparsely distributed in otherwise barren rock. The failure of platinum to amalgamate makes its metallurgical recovery much more difficult than that of gold, and its extraction through the medium of copper furnishes one of the most promising lines of attack.[d]

Germany.—In this connection it is interesting to note its detection by Maximilian, Duke of Leuchtenberg, in 1847, in the black sand which remained at the anode when copper sulphate was electrolytically treated.[e] Platinum has been discovered in amounts that admitted of separation in old silver coins which circulated in Germany and which had derived their silver from silver-copper ores.[f]

H. Rössler has described the methods of separating the platinum from the silver which was obtained from the mines at Commern and Mechernich. These famous ore bodies consist of beds of Lower Triassic sandstone, which are impregnated with nodules of galena or

[a] Vauquelin, Annales de Chemie, Vol. LX, 1806, p. 317. Journal für die Chemie, Physik und Mineralogie, Vol. II, 4, 1806, p. 694. Leonhard's Jahrbuch, Vol. II, p. 311.

[b] Poggendorff's Annalen, Vol. XXXI, 1834, p. 590.

[c] Comptes rendus, Vol. XXIX, 1847, p. 814.

[d] It is interesting to observe that eight months after this paragraph was written platinum, in the form of included sperrylite, was announced in the ore of the Rambler Copper Mine, Wyoming (W. C. Knight, Eng. and Min. Jour., Dec. 28, 1901, p. 845; Wells and Penfield, Am. Jour. Sci., Feb., 1902, p. 95).

[e] Bull. Acad. Sci. St. Petersburg, Vol. VI, 1848, p. 129. Dingler's Polytech. Journal, Vol. XXXV, 1847, p. 106.

[f] M. Pettenkoffer, Poggendorff's Annalen, Vol. LXXIV, 1848, p. 316.

cerussite, and more rarely of copper carbonate. While the silver was probably derived from the galena, and while the platinum may have come from the same source, yet the subordinate presence of copper casts a little uncertainty over the original association of the platinum as between it and the lead.[a]

Platinum in association or combination with galena has been reported several times. Details of such an occurrence in France that could not be verified will be found under "France," p. 65. Another from Algiers has been reported, but further corroboration is desirable.[b] (See p. 82.)

Pennsylvania.—In 1852 Dr. F. A. Genth announced that he had detected platinum in the assay of a clay slate containing pyrite, chalcopyrite, and galena in Lancaster County, Pa. He likewise discovered traces of platinum and silver in ilmenite from a mica-schist in the same place.[c] In later years platinum has been detected by A. W. Johnston in variable but sometimes considerable amounts, of which the details are given later, not far from Boyertown, along the border of Berks and Montgomery counties, Pa. The mother rock is a black Triassic shale. A black dioritic gneiss from eastern Pennsylvania has afforded appreciable assays.

Arizona.—Shales have been brought from Arizona, from some place in the vicinity of the Grand Canyon of the Colorado, which on assay have yielded weighable amounts of platinum. (See under "Arizona," p. 51.)

Ontario.—In 1888 F. L. Sperry noted small, shining, metallic crystals in the concentrates obtained from the Vermillion gold mine, a few miles west of Sudbury, Ontario, which was based upon a quartz vein cutting rusty diorite. When these crystals were investigated by Messrs. Wells and Penfield, of New Haven, they were found to be arsenide of platinum ($PtAs_2$), the first compound of platinum with a nonmetallic substance which has been recognized. They named the mineral "sperrylite," and it has since been discovered in many of the nickel mines of Sudbury. It seems to favor the chalcopyrite rather than the pyrrhotite, but Clarke and Catlett have shown that the sulphide of iron and nickel, polydymite, likewise contains considerable proportions of platinum. These discoveries, therefore, revealed the presence of platinum in place and in association with ores which are usually regarded as of igneous origin, and which are known to occur in basic igneous rocks.[d] Full descriptions, with citations of the literature bearing on the subject, will be found subsequently under "Canada," p. 38.

[a] H. Rössler, Liebig's Annalen, Vol. CLXXX, 1876, p. 240.

[b] Comptes rendus, Vol. VII, 1838, p. 246.

[c] F. A. Genth, Pharm. Centralblatt, 1852, p. 72.

[d] Microscopic investigations now being made by one of the writer's students, Mr. C. W. Dickson, upon Sudbury ores, cast much doubt upon the igneous origin of the sulphides, and indicate a replacement of ferromagnesian silicates.

Wyoming.—Platinum has been recently reported by W. C. Knight as a constituent of the copper ores, and more particularly of the covellite, of the Rambler copper mines, about 60 miles south of Laramie. Wells and Penfield have detected sperrylite in the covellite.[a]

New South Wales.—In 1889 attention was directed to certain ferruginous materials resembling gossan which outcropped in the vicinity of Broken Hill, in the extreme western portion of New South Wales, Australia. When this ferruginous cap was assayed it was found to contain platinum, even up to several ounces per ton. The cappings are quite widely distributed in the region, and rest upon more or less altered metamorphic rocks, embracing gneisses, quartzites, and schists of Lower Silurian age. Shafts have been sunk to shallow depths, and have revealed the fact that iron greatly diminishes, and clays and kaolin come in, until unaltered rock is encountered. The clays also gave assays for platinum. It is thought by J. B. Jaquet that the iron caps are due to uprising springs, which have likewise introduced the platinum.

North Carolina.—In 1898 it was announced that sperrylite had been discovered in North Carolina as early as 1894 by W. E. Hidden. Later on Messrs. Hidden and Pratt followed up the sperrylite and associated minerals, until they definitely located them in a ledge of rock upon the top of Mason Mountain, Macon County. The rock consists of garnet of the variety rhodolite, and of biotite, together with considerable iron sulphides. Pannings of the surface soil yielded sperrylite.

British Columbia.—In the summer of 1900 A. W. Johnston and the writer succeeded in demonstrating the presence of platinum in the peridotite of the Tulameen River, British Columbia, and in a neighboring granite. In the former the platinum favors asbestiform streaks, which appear to be present along lines of faulting in the peridotite. In the granite the platinum was discovered along a crushed belt which was richly stained with chlorite. More details are subsequently given under "British Columbia" (p. 38).

Résumé.—From this review of the discoveries which have been hitherto made it is evident that platinum is not exclusively limited to the olivine rocks, nor indeed to the igneous rocks and the placers, but that it does appear sometimes in veins with other metals, especially copper. It would follow that the platinum migrates in solution. It or its arsenide probably is soluble in some form of solutions which involves copper. Commercially speaking, however, the amount which has thus far been detected is small.

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[a] W. C. Knight, Eng. and Min. Jour., Dec. 28, 1901; Wells and Penfield, Am. Jour. Sci., Feb., 1902, p. 95.

PLATINUM IN AUSTRALIAN COAL.

A most extraordinary case has been recorded of the presence of the metals of the platinum group in the ash of certain Australian coals (exact locality not mentioned), along with vanadium.[a] The coal, as analyzed by Messrs. Thirkell & Co., of London, yielded the following:

Carbon	65.2	Water at 100° C	0.7
Hydrogen	4.6	Ash	1.7
Oxygen	21.8		
Nitrogen	1.9	Total	99.7
Sulphur	3.8		

The ash yielded the results under No. 1. No. 2 is a second sample.

	No. 1.	No. 2.
Vanadium	25.1	2.90
Platinum metals	3.6	.23
Oxygen with above	44.0	5.10
Sandy and earthy matters	27.3	91.77
Total	100.0	100.00

This means in the original coal a little over 144 troy ounces of vanadium and $20\frac{2}{3}$ ounces of the platinum metals per long ton of coal, and makes the coal the richest crude platinum ore yet assayed.[b] No. 2 is an analysis of the ash of the coal in bulk. It implies only an eighth as much vanadium and a fifteenth as much of the platinum metals per ton of coal, if the ash were the same percentage of the coal as before; but its percentage is not given in the citation. The amounts of vanadium and platinum which are given in the citation are over 146 ounces of vanadium and more than 11 ounces of the platinum metals per ton of coal, which, if correct, would imply a high-ash coal.

Coals whose ash is rich in vanadium are known in Argentina and in Peru, but no mention of platinum has been made in connection with them.

PLATINUM IN METEORITES.

In January, 1899, John M. Davidson, of Rochester, N. Y., announced that he had identified platinum in two meteorites. Of the Coahuila meteorite, 608.6 grams were tested and yielded 0.014 gram of platinum. Of this, 0.0015 gram was insoluble and gave indications of iridium. Of the Toluca meteorite, 464 grams afforded a little platinum, with indications of iridium.[c] Palladium was earlier announced in an Italian meteorite.[d]

[a] Seventeenth Ann. Rept. U. S. Geol. Survey, Part III, p. 282.
[b] This would be 124 ounces of vanadium and $17\frac{4}{5}$ ounces of the platinum metals per short ton.
[c] Platinum and iridium in meteoric iron, by John M. Davidson: Am. Jour. Sci., Jan., 1899, p. 4.
[d] G. Troltarelli, Jour. Chemical Society, Vol. LX, 1891, p. 533.

PLATINUM IN THE SUN.

Platinum has been detected by the spectroscope in the sun.[a]

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BULLMAN, Charles. The platinum group of metals: The Mineral Industry, Vol. I, 1893, p. 373.

BREITHAUPT. On the varieties of native platinum: Poggendorff's Annalen, Vol. VIII, 1826, p. 500.

DAUBRÉE, A. Experiences sur l'imitation artificielle du platine natif magnetipolaire: Comptes rendus, Vol. LXXX, 1875, p. 526.

DEVILLE and DEBRAY. On the chemistry and metallurgy of the platinum group: Annales Chim. Phys., 3d series, Vol. LVI, p. 449.

FRÉMY, E. Nouvelles recherches sur les métaux qui accompagnent le platine dans sa mine: Comptes rendus, Vol. XXXVIII, p. 1008. Erdmann's Jour. f. prakt. Chem., Vol. LXII, p. 340.

HOWE, James Lewis. Bibliography of the metals of the platinum group: Smithsonian Miscellaneous Collections, No. 1084. Washington, 1897. This is the most complete work of reference on the platinum group of metals.

MILLER, E. H. The assay of platinum: School of Mines Quarterly, Vol. XVII, 1895, p. 26.

VOGT, J. H. L. On the processes of crystallization in eruptive rocks: Zeitsch. f. prakt. Geologie, July, 1893, pp. 267-268; October, 1894, p. 397.

REVIEW OF LOCALITIES WHERE METALS OF THE PLATINUM GROUP HAVE BEEN DISCOVERED.

NORTH AMERICA.

CANADA.

QUEBEC.

About the middle of the last century there was considerable interest in the gold-bearing placers which had been discovered along the south bank of the St. Lawrence River in what is known as the Eastern Townships of Quebec. A few minute scales and grains of platinum and iridosmine were noted by T. S. Hunt in the gold of the Rivière du Loup. It is also stated that these minerals are likewise found with the gold of the Rivière des Plantes.[b]

The source of this platinum has not been discovered, but it is well known to geologists that serpentine occurs along the border between Quebec and Vermont and New Hampshire. It is possible, however, that it may lie too far to the west to have furnished the nuggets. The glacial drift, moreover, casts some uncertainty over the exact source. Here reference may be made to the nugget which was found at Plattsburg, N. Y., regarding which a note is subsequently made under New York (p. 57).

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[a] J. N. Lockyer, Proc. Roy. Soc. Lond., Vol. XXVII, 1878, p. 279; Hutchins and Holden, Proc. Am. Acad. Sci., Vol. XXIII, 1887, p. 14; Am. Jour. Sci., Vol. XXXIV, 1887, p. 451.

[b] T. S. Hunt, Geol. Survey Canada, 1851-52, p. 120.

ONTARIO.

In 1889 the announcement was made by Messrs. Wells and Penfield that they had identified the arsenide of platinum ($PtAs_2$) as a natural mineral. It had been collected by Mr. F. L. Sperry from the heavy concentrates of a gold ore taken from the Vermillion mine, which is situated a few miles west of Sudbury, in the western part of Ontario. At this mine there is a quartz vein carrying gold, which cuts across a belt of dioritic rock containing chalcopyrite and nickel-bearing pyrrhotite.

Professor Wells named the new mineral sperrylite, after its discoverer. The greatest interest was felt by all scientific people in this discovery, because sperrylite is the first and only natural compound of platinum with a nonmetallic substance which has been found. Since the first announcement it has been recognized that sperrylite or some other form of platinum is generally present in the nickel-copper ores of the Sudbury region. Small traces of the platinum metals have been detected in the mattes and in the nickel oxide furnished by these mines. Clarke and Catlett have likewise shown by assay that platinum is present in polydymite, a nickel-iron sulphide which occurs in the mines. The observations, however, of T. S. Walker have indicated that the home of the sperrylite is in the chalcopyrite rather than in the pyrrhotite, because when the surface decomposition products of the Vermillion ore body were panned by him he obtained in the heavy residues sperrylite, chalcopyrite, pyrrhotite, and other iron-nickel sulphides. On careful examination sperrylite was observed embedded in the chalcopyrite, but not in the pyrrhotite. Mr. Walker also states that, while traces of the platinum metals occur in all the Sudbury mines, the richest assays are obtained from those whose yield is high in copper, and that very little appears in those which are poor in this metal. It is a curious fact that the analyses of the sperrylite do not indicate the presence of iridium, although this metal is found in the assays of the ores. It must therefore be present in them in some other form than sperrylite.

In the nickel-copper mattes which are exported there is about 1 troy ounce of platinum to each 1,000 pounds avoirdupois of nickel. Palladium is also present to an amount of about 2 ounces palladium to each 3 ounces of platinum.[a]

It is well known to all who are familiar with the literature of ore deposits that the nickel-copper ores of Sudbury occur along the outer edges of igneous intrusions which seem to have been originally norites. Where associated with the ores, however, the rocks are now diorites, the pyroxene having been changed to hornblende.

Nearly all observers who have visited the mines have reached the conclusion that the ores are of igneous origin and that they were

[a] The Mineral Industry, Vol. VII, 1898, p. 569.

brought into their present position with the igneous rock in which they occur. As regards the platinum, these views coincide with the belief that in its original home this metal most frequently occurs in association with olivine as a true igneous mineral in the peridotites, even though no olivine has ever been found in the Sudbury norite-diorite. But it is only fair to state that some authorities, notably F. Pošepny and S. F. Emmons, have felt that there were objections to the view that the Sudbury ores were of igneous origin. In the citations below a list of papers bearing upon the platinum is given, and besides these a few others upon the general geology of the nickel-copper ores.[a] For the general geology of the Sudbury district, see the Geological Survey of Canada, New Series, Vol. V, Part I, Report F.

Attention may at this point be directed to the occurrence of sperrylite in North Carolina, which is subsequently described (p. 59).

In connection with a careful chemical and geological investigation of certain magnetic iron ores from eastern Ontario, F. J. Pope made some careful assays for platinum. As certain of these ores were igneous in their origin and were derived from basic rocks, some hope was entertained that traces of platinum might be discovered in them. None, however, were found.[b]

BRITISH COLUMBIA.

Platinum has been obtained in commercial quantities in connection with the gold washings of southwestern British Columbia, and this source has proved to be the most productive of all thus far developed upon the North American Continent. When the California washings began to fall off, the gold seekers penetrated the mountains of the northwest, and much interest was felt in British Columbia as early as 1861. Some prospecting was done on the Similkameen River. The Similkameen forks into two branches at the town of Princeton, which lies about 30 or 40 miles north of the international boundary on the east side of the Cascade Mountains. In the early days these two branches were called the South and North forks, but later the North Fork received the name Tulameen. The gold washings in 1861 and subsequent years were not extensively developed, although from time to time parties of Chinese worked them. Almost from the start it was recognized that platinum occurred with the gold, but not

[a] Clarke, F. W., and Catlett, Charles. A platiniferous nickel ore from Canada: Bull. U. S. Geol. Survey No. 64, p. 21. Am. Jour. Sci., 3d series, Vol. XXXVII, p. 372.

Emmens, S. H. The Mineral Industry, Vol. I, 1892, p. 377.

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Garnier, J. Mines du nickel, cuivre, et platine du district de Sudbury: Mémoires de la Société des Ingenieurs Civile, Paris, March, 1891.

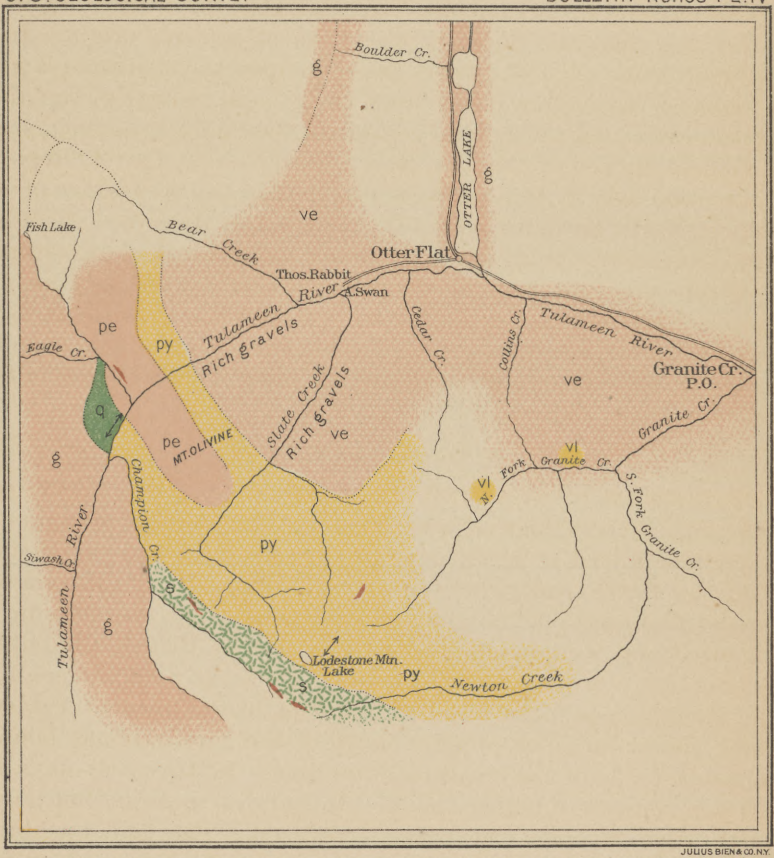
Merritt, W. H. Trans. Am. Inst. Min. Eng., Vol. XXIV., p. 755.

Penfield, S. L. Crystalline form of sperrylite: Am. Jour. Sci., 1889, p. 71.

Walker, T. L. Notes on sperrylite: Am. Jour. Sci., Feb., 1896, p. 110.

Wells, H. L. Sperrylite, a new mineral: Am. Jour. Sci., Jan., 1889, p. 67.

[b] Investigation of magnetic iron ores from eastern Ontario, by F. J. Pope: Trans. Am. Inst. Min. Eng., Vol. XXIX, p. 402.



GEOLOGICAL MAP OF THE TULAMEEN PLATINUM REGION, BRITISH COLUMBIA

BY

J. F. KEMP

Scale

2 1 0 2 4 MILES

LEGEND

Volcanics

vl	Later Miocene Rhyolite and basalt
ve	Earlier Miocene
(red line)	Dikes Rhyolite and diabase
s	Green schist
q	Quartzite and schists
pe	Peridotite
py	Pyroxenite-syenite
g	Granite

.... Boundaries approximately accurate

↗ Glacial striae

until fifteen or sixteen years later was it saved. The accompanying map, Pl. IV, will serve to give the reader the geographical location of the district, and the later geological description will make clear the relations of the platinum.[a] In 1885 gold was observed in the gravels of Granite Creek, a tributary of the Tulameen, some 12 miles above its junction with the Similkameen.

Prospectors rushed into the district and washed the gravels not only of this creek but of the old bars on the Tulameen which had received attention as early as 1862. For several years the activity was considerable, and as much as $383,000 worth of gold is accredited to Granite Creek from 1885 to 1888. It had been recognized in 1862 that the gravels of the Tulameen yielded pay as far as Eagle Creek, which enters the Tulameen from the north, about 12 miles above Granite Creek, and during the later gold washing the richest platinum ground was found to begin at Eagle Creek and to extend downstream. Platinum also bore a high proportion to gold in Slate Creek, a tributary which enters the Tulameen from the south, about 8 miles above Granite Creek. The platinum in instances attained a ratio of 1:3 as compared with the gold. From these upper waters of the Tulameen, beginning at Eagle Creek and passing downstream, the relative amount of platinum gradually decreases, and while it is found in Granite Creek and in all the other placers of the drainage system of the Tulameen and Similkameen rivers, it nevertheless decreases in amount with the distance from Eagle Creek and the headwaters of the Slate. Printed descriptions of the geology of this district are few. Dr. George M. Dawson visited it in 1887, and as a result of his trip gave some valuable notes upon the mineral resources as well as the local geology in the report of the Canadian Geological Survey for 1887–88, Part R. Much light is also cast upon the local geology by the very valuable work of Dr. George M. Dawson upon the Kamloops map sheet, which lies about 50 miles to the north.[b] Some further notes upon the resources of the district will be found in a recent paper by W. J. Waterman.[c] A scale map with an outline geological section is given. During the summer of 1900 the writer spent nearly three months in the district investigating the geology of platinum along the Tulameen, and through the courtesy of the S. S. White Dental Manufacturing Company is permitted to contribute the following results:

As regards platinum, the area of chief interest is in the valley of Slate Creek and along the Tulameen River, below Eagle Creek. As

[a] Reference to the early discoveries on the Similkameen will be found in the reports of the Canadian Geological Survey, 1862, p. 127; 1877–78, pp. 63B and 156B.

[b] Report on the geology of the Kamloops map sheet, by George M. Dawson: Geol. Survey of Canada, Vol. VII, Part B. The present writer is much indebted to the late Dr. Dawson for personal advice.

[c] Economic geology in the Similkameen district, by W. J. Waterman: British Columbia Mining Record, Vancouver, November, 1900, p. 411. A few notes at an earlier date are given by J. T Donald in Engineering and Mining Journal, March 19, 1892, p. 327.

will be seen by the accompanying map, which is roughly accurate for this region, a great dike of peridotite crosses the Tulameen at its junction with Eagle Creek, and extends in a general direction a little west of north as a huge mountain ridge. It runs to the south, reaching into the headwaters of Slate Creek, and constituting the highest summit of this divide. For convenience of reference the writer has called this summit Mount Olivine. Although the exposures are nearly all concealed by heavy sands and gravels in the upper waters of Slate Creek, the peridotite does not seem to extend farther in this direction, but it is cut off by a rock called pyroxenite on the map (Pl. IV). It is a curious fact that the pyroxenite also borders the peridotite on the east and likewise on the west, south of the Tulameen. To the southeast, however, the pyroxenite shades into syenitic varieties, which contain very considerable proportions of unstriated feldspar. Just above Eagle Creek, and on the northwest bank of the Tulameen, a small area of schists and quartzites more or less penetrated by dikes of porphyries is met. The relations of these rocks are obscure. Still farther to the west the whole country for a long distance consists of granite, and the granite has been again observed at the headwaters of Boulder Creek on the north. It presumably swings around from Fish Lake to Boulder Creek, and constitutes the intervening country at the headwaters of Bear Creek. The same granite appears along both shores of Otter Lake, and is therefore a very important member of the local geology on the northern and western side of the Tulameen. The pyroxenite is succeeded on the east by enormous masses of volcanic rocks of a general andesitic character, which appear to be the same as Dawson's Earlier Miocene volcanics, as described in the report on the Kamloops sheet. These volcanics are the most extensive formation in this central a.ea, and they serve to conceal the older rocks. They have been somewhat compressed and sheared, and have evidently passed through fairly severe metamorphism. In the upper waters of the north fork of Granite Creek basalts and what appeared to be rhyolite were observed, which lack this metamorphism and which seem to correspond to Dawson's Later Miocene volcanics. At some point on the headwaters of Cedar Creek coals have recently been located, which are probably of Miocene age, corresponding to the Tranquille beds of Dawson. They have, however, been so altered as to possess coking properties. The writer observed Miocene float to the south of this region, but did not visit the coal exposures. On the southwestern border of the pyroxenite, at the headwaters of Slate Creek, a belt of green schists appears, which extends for several miles along the headwaters of Champion Creek. The actual contact of the pyroxenite and the schist is visible in the mountain region just to the west of the source of Slate Creek, but the two are so mashed together that it was impossible to determine which is the older. No contact metamorphism could be observed in the schist, and the writer

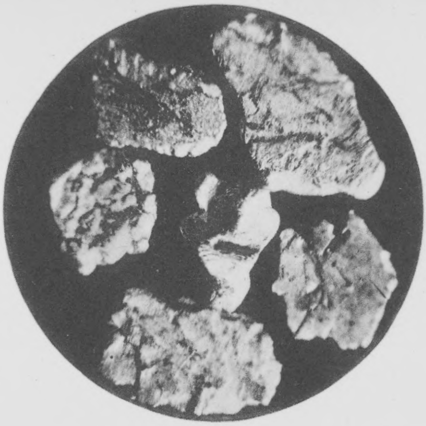
PLATE V.

PLATE V.

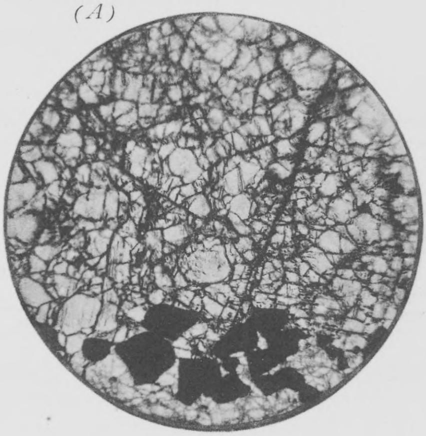
(*A*) Iridosmine, Slatousk, Urals. × 35 diam.

(*B*) Peridotite containing olivine and chromite, Tulameen River, British Columbia. × 70 diam.

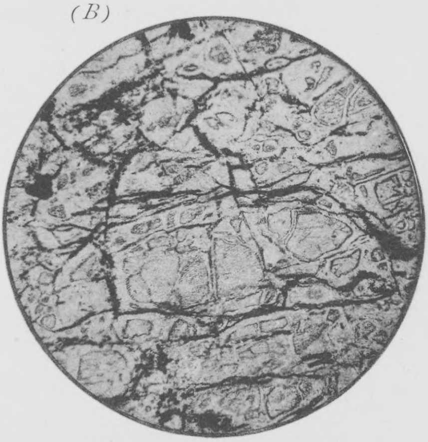
(*C*) Serpentinized peridotite, Tulameen River. × 70 diam.



(*A*)



(*B*)



(*C*)

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was unable to decide whether it is later or earlier than the pyroxenite. Several dikes of later eruptive rocks have penetrated all these older forms, and, as they show but slight traces of metamorphism, they are probably later than the Earlier Miocene volcanics. They are chiefly rhyolites or quartz-porphyries, but to the northeast of Lodestone Mountain and near the old Brigade trail a large dike of diabase was observed. This whole region has been extensively glaciated. Striæ were noted in two cases, one of which was along the Tulameen just above Eagle Creek, where the direction of the valley is somewhat east of north. The striations follow the trend of the valley and may have been influenced by it. A number of others were observed upon the summit of Lodestone Mountain, where the topography must have had less influence. They were closely parallel, however, to the previous ones.

An extensive and complex series of terraces may be also observed along the streams, and it is evident that the region has undergone a number of elevations and depressions in Pleistocene time. Along the Tulameen there is an almost continuous bench, of which now only stumps remain, and at Granite Creek post-office a number can be recognized up to 200 or 300 feet above the river. Opposite the mouth of Slate Creek a bench, which is washed in the hydraulic works of Alexander Swan, reaches an altitude by aneroid above the Tulameen of 330 feet. It causes Slate Creek to turn to the west and to enter the Tulameen in a direction against the current of the latter. The terrace evidently buries an old outlet of Slate Creek, which has been partially exposed by the hydraulic operations. A similar high bench of gravels has turned Champion Creek westward. It is possible that the presence of ice in the valley of the Tulameen is responsible for the deposition of these bars. Similar phenomena are not found on the north side. It may be added that the valley of the Tulameen and its branch creeks is a very narrow and steep one, and the topography gives every evidence of recent development. In its general character this entire country, as has been well set forth by Dr. George M. Dawson, is a plateau which has been deeply dissected by the present streams. The drainage has not been so long in operation as to smooth off the divides. The banks are yet so steep as to make zigzag trails a necessity.

The rocks which are of chief interest in connection with the platinum are the peridotite, the pyroxenite, and the granite. All petrographic details will be particularly limited to these.

MINERALOGY OF THE NUGGETS.

A careful search through large quantities of Tulameen platinum has revealed a considerable number of nuggets which contain chromite. A few have particles of olivine still adhering to them, and before the examination in the field was taken up it was expected that olivine rocks would be found in the region, although in Dr. Dawson's reconnaissance none were found, and the statement was made in his report that apparently none existed. It may be added that since the writer's return a nugget has likewise been discovered with adhering pyroxene, as has been stated on page 26. This association, as well as that with chromite and with olivine, is illustrated on Pl. III. When, however, the country was carefully observed along the upper waters of Slate Creek it was at once discovered that the great dike of peridotite, with its flanking pyroxenite, was present.

Peridotite.—The peridotite is an extremely interesting rock. It is of the variety dunite, and contains, so far as the writer's observations have gone, no other minerals than olivine and chromite. Some secondary serpentine and some amianthus can be found, and occasionally a little pyrite; but in its fresh condition the rock appears to be practically pure olivine, with occasionally a little chromite. Pl. V, *A* and *B*, will serve to illustrate it, and the following analysis, made in the laboratory of the United States Geological Survey by W. F. Hillebrand, indicates its composition:

Analysis of peridotite (variety dunite) from Eagle Creek, British Columbia.

SiO_2	38.40	$H_2O+110°$	4.11
Al_2O_3	.29	CO_2	1.10
Fe_2O_3	3.42	P_2O_5	Tr.
FeO	6.69	S	.06
MgO	45.23	$C\ _2O_3$	.07
CaO	.35	NiO	.10
Na_2O,K_2O	.08	MnO	.24
$H_2O-110°$	.24	Total	100.38

If we neglect the Al_2O_3, Na_2O, K_2O, $H_2O-110°$, S, Cr_2O_3, NiO, and MnO, and assume that the 4.11 H_2O is in serpentine, this analysis yields the following percentages of minerals:

Magnetite	4.90
Serpentine	31.49
Olivine	61.22
Calcite	0.63
Magnesite	1.58
Total	99.82

This result is undoubtedly very close to the truth.

The mass of the peridotite is occasionally traversed by veins of fibrous serpentine or amianthus, which appear to have been produced from the peridotite itself along lines of minor dislocation. The fibers of the serpentine run perpendicularly to the walls, as is the common case in such bodies of rock, and through the mass of the fibers grains of chromite are at times distributed in recognizable lines. These veins of serpentine become rusty on exposure and yield a bright red or brown decomposition product, which at once attracts the eye of a trav-

PLATE VI.

PLATE VI.

(*A*) Pyroxenite, Tulameen River. British Columbia. × 70 diam.

(*B*) Augite-syenite: augite. orthoclase, and magnetite, Tulameen River. × 70 diam.

(*C*) Serpentinized peridotite, Mount Soloviev, Urals. × 70 diam.

(A)

(B)

(C)

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eler or prospector. Occasionally the peridotite becomes a dense black serpentine, especially in the vicinity of the dislocations. Shining specks of chromite appear through the dark-green mass. Every endeavor was made by the writer to discover in the midst of the peridotite a mass of chromite of large extent, but except for bunches the size of the fist or at times still larger, and for certain minor streaks and veinlets, the search was unsuccessful. Great masses of the rock appeared with no chromite at all except in microscopic form.

Pyroxenite; augite-syenite.—The pyroxenite is a black, rather coarsely crystalline rock, which, in typical cases when examined with the microscope and as shown in Pl. VI, *A*, contains practically nothing else than common green augite. It has sometimes been subject to geological deformation, and has then developed secondary hornblende, and in a few cases a little original brown hornblende has been observed. Magnetite is not infrequent, and at Lodestone Mountain it becomes a prominent feature in the rock. It occurs, however, richly distributed through the pyroxenite and not in large, pure segregations. In the upper waters of Slate Creek and in the headwaters of the North Fork of Granite Creek and of Newton Creek much feldspar enters the pyroxenite, changing it to an augite-syenite (Pl. VI, *B*). When examined microscopically all the samples of this rock which were obtained indicated unstriated feldspar, and therefore orthoclase, as the prevailing component. This was a matter of surprise, because in the field it was thought that the rock would certainly prove to be a gabbro or a diorite. On the contrary, it is a very basic syenite, and it therefore furnishes some interesting parallels with the rocks in the platinum region of the Urals. The discovery of pyroxene upon one of the platinum nuggets, and, so far as known, the entire absence of pyroxene in the peridotite, as well as the absence of olivine in the pyroxenite, make it probable that the platinum has been derived from both of these rocks. The pyroxenite is clearly a later rock than the peridotite, because on Mount Olivine (which name, as earlier stated, has been given to the high peak where the peridotite reaches its maximum elevation just south of the mouth of Eagle Creek) tongues and dikes of pyroxenite were found penetrating the peridotite, and on the slope of Mount Olivine toward the Tulameen dikes of pyroxenite in peridotite can likewise be observed. It is possible that the syenite is a separate intrusion from the pyroxenite, but no evidence of this was met, and it seemed more probable, from such relations as could be discovered, that they shade into each other.

MOTHER ROCK OF THE PLATINUM.

In the endeavor to trace the platinum back to its original location in the mother rocks, it was evident after a brief survey of the ground that to be of economic importance it must occur in some special form of the peridotite or pyroxenite. Mountainous masses of these rocks could not, in the nature of the case, be systematically sampled and assayed. The abundance of chromite in the nuggets would lead one to search first of all for masses of chromite, and secondly one would wish to test every other peculiar type of rock. These latter were practically the veins of serpentine and the dikes of pyroxenite in the peridotite. Incidentally, too, a number of assays were made of the typical country rocks, of the basic dikes, such as diabase, and of the varieties rich in magnetite from Lodestone Mountain. As has been already stated, no deposits of chromite of large size could be found. Assays of the serpentine veins have yielded in a number of cases platinum in amounts varying from a trace to nearly 2 ounces to the ton, but more extended sampling did not indicate a sufficiently even distribution of the platinum to justify exploitation. Assays of the older pyroxenite from lines of dislocation and from Lodestone Mountain, where the contained magnetite is abundant, failed to give other than very small traces or nothing whatever. A most careful search was made over the talus slopes and the exposed ledges in the endeavor to discover platinum in place, and hundreds of hand specimens in which chromite was especially abundant have been examined with the lens. In no case could a nugget be found. But it is fair to state that, when in small bits, chromite yields a shining fracture that is very difficult to distinguish from platinum itself, and while the writer was in no case able to assure himself, even by microscopic examination, that platinum was present, it is possible that very small scales of it were overlooked. Masses of rock rich in chromite were cobbed in several cases and were crushed and panned, but even in the concentrates it was not certain that platinum was present. Assays, however, did indicate it. The conclusion is therefore inevitable that the platinum, as a rule, is in excessively fine scales and that the large nuggets are rare. It requires the concentration, in the processes of weathering, of an enormous mass of rock in order to yield the gravels. The drainage system in British Columbia is comparatively young, and no such amount of rock has been exposed to concentration as has been the case in the old and long eroded region of the Urals. Probably from this cause the amount of the gravels as well as of the available platinum is less in British Columbia than in Russia.

Rumors are current along the Tulameen that platinum had been discovered in former years near the mouth of Siwash Creek, which enters the Tulameen about 3 miles above Eagle Creek. Accordingly, a trip was made to this locality with a view of testing the report. The trail crosses Siwash Creek half a mile or more above its junction with the Tulameen and at an elevation of 200 or 300 feet above the latter. Below the ford Siwash Creek flows in a deep and narrow gorge, with numerous cascades, all due to the sheeting of the granite. In several places not far below the trail lines of dislocation are evident. One crosses the Siwash at right angles to its line of flow and has changed the granite to a more or less decomposed mass over a width of 15 to 20 feet. The granite is stained green by chlorite. Assays of this material indicated a trace of platinum. At the first high cascade, a short distance below, the creek flows in a gutter caused by a belt of schistose rock, the schistosity appearing to be the result of excessive shearing in the granite. Samples of this material yielded good qualitative tests for platinum, although not enough to weigh. The identification of platinum in a rock of this character is extremely interesting, because it is a highly acidic eruptive and in strong contrast with the olivine and pyroxene rocks with which platinum is especially identified. The granite at Siwash Creek consists of quartz, orthoclase, plagioclase, biotite, and a little epidote. It is a typical granite, and except for the manifest effects of crushing does not deserve detailed description. Whether the platinum has been introduced in solution along lines of dislocation or whether it was an original mineral in the igneous rock can not be stated. No assays have been made of the unaltered material, and, so far as is known to the writer, its presence is limited to the lines of dislocation. The granite along Siwash Creek is also penetrated by a number of narrow dikes of diabase, but so far as known these are barren of platinum.

The following table gives the results of about 35 assays. Where trace is given it means a coloration test.

Tabulation of assays of platinum-bearing rocks from the Tulameen district, British Columbia.

Kind of rock.	Ounces per ton.	Remarks.
Banded zone of fibrous serpentine in peridotite.	.25	Rusty; poor in chromite.
Do	Tr.	0.2 per cent chromite, by panning.
Do	None.	0.5 per cent chromite, by panning.
Do	.25	
Do	None.	
Do	None.	
Do	None.	
Do	None.	
Do	.125	Some gold—not all platinum.
Chromite or rock rich in chromite	.5	Selected chromite.
Do	None.	Rock rich in chromite.
Do	None.	Do.
Do	None.	Do.
Do		8 per cent chromite on panning.
Do	Faint tr.	Peridotite, 4.5 per cent chromite.
Olivine-diabase	None.	Typical olivine-diabase.
Do	None.	Bowlder.
Pyroxenite dike	.25	In peridotite.
Do	.125	Pyroxenite rich in magnetite, dike in peridotite.
Pyritous talcose rock	Faint tr.	Pyritous streak in peridotite next a quartz-porphyry dike.
Crushed pyroxenite	Faint tr.	Serpentinized pyroxenite along a line of displacement.

Tabulation of assays of platinum-bearing rocks from the Tulameen district, British Columbia—Continued.

Kind of rock.	Ounces per ton.	Remarks.
Peridotite	Faint tr.	Fresh peridotite.
Serpentinized peridotite	Faint tr.	
Do	Faint tr.	
Serpentine	Faint tr.	
Dark serpentine	Faint tr.	
Fresh peridotite	Strong tr.	
Sheared pyroxenite	None.	
Do	None.	
Serpentinized peridotite	None.	From crushed zone.
Do	Faint tr.	11 per cent chromite.
Sheared granite	Faint tr.	Sample from 20 feet of face.
Altered granite	.125	Much chlorite.
Granite	Faint tr.	Next trap dike.
Schistose streak	.125	Probably a sheared granite.
Pyroxenite	Faint tr.	Dike in peridotite.
Old volcanics		Slight trace of iridio-platinum.
Do	None.	

The early placer washings and the two or three later hydraulic plants were all operated upon the gravels above the levels of the main creeks or in the shallow waters where bed rock was not deeply buried. Some later projected enterprises are based on dredging the Tulameen, but they have not yet assumed visible shape.

An analysis of the Tulameen platinum was made by Dr. G. Chr. Hoffmann, chemist of the Geological Survey of Canada.[a] The sample weighed originally 18.266 grams. Of this, 17.894 was platinum and the rest rock matter—magnetite, a little pyrite, and a few flakes of gold. Sp. gr. of platinum, 16.686. The platinum was separated into a magnetic part, 37.88 per cent, and a nonmagnetic part, 62.12 per cent. These were analyzed separately, and then the total analysis was computed, as follows:

Analysis of platinum from the Tulameen River, British Columbia.

	Magnetic.	Nonmagnetic.	Total.
Pt	78.43	68.19	72.07
Pd	0.09	0.26	0.19
Rh	1.70	3.10	2.57
Ir	1.04	1.21	1.14
Cu	3.89	3.09	3.39
Fe	9.78	7.87	8.59
Iridosmine	3.77	14.62	10.51
Embedded chromite	1.27	1.95	1.69
	99.97	100.29	100.15

Nonmagnetic, sp. gr. 17.017; magnetic, sp. gr. 16.095.

[a] Report of the Survey, Vol. II, 1886, Part T. Trans. Roy. Soc. Canada, Vol. V, 1887, p. 17.

In each case some of the grains contained chromite. It is evident that iridosmine is relatively high in the nonmagnetic portion and that iron is the same in the magnetic portion. Dr. Hoffmann has announced the occurrence of platinum in the black sand of Rock Creek, a tributary of the Kettle River, Osoyoos division, Yale district.[a] Platinum has also been met in small quantities at Lilooet and elsewhere in the drainage of the Fraser River.

ALBERTA.

Dr. Hoffmann has detected platinum in sands from near Edmonton, on the North Saskatchewan River.[b]

NORTHWEST TERRITORY.

Platinum has been reported in the black sands which have been obtained from the Yukon off the mouth of the Teslin and the Lewes rivers. The amounts are stated to be considerable. Forty cubic feet of sand are said to have yielded 12 pounds of concentrates, which contained platinum at the rate of 96 ounces to the ton. This means about two-fifths of an ounce to a yard of gravel.[c]

UNITED STATES.

ARIZONA.

Specimens of a shaly rock have been sent to the East from some locality near Williams, Arizona, which have yielded assays for platinum. The clays in Cataract Canyon, a branch of the Grand Canyon, are also said to contain platinum.

CALIFORNIA AND OREGON.

As soon as the gold washings were developed in California, in 1849, scientific interest was attracted to the small accessory minerals which occurred with the colors. The presence of platiniridium was early announced by R. M. Patterson, of the Philadelphia mint,[d] and subsequently platinum itself was discovered in a great many places. The most productive deposits are in Trinity County, along the Trinity River, 3 to 4 miles below Junction City, but the annual product amounts to only a few ounces. Platinum and iridosmine have also been found in the beach gravels at Port Orford, which is in Oregon, some distance north of the California line. Some interest has been felt in saving these minerals, but they are excessively fine and the quantity

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[a] Report Geol. Survey Canada, Vol. VI, Part R, p. 9.

[b] Idem, Vol. V, Part R.

[c] U. S. Consular Reports, Vol. LIX, 1899, p. 567. The Teslin River is here called the Hootalinqua. The Mineral Industry, Vol. VII, p. 569.

[d] The earliest announcement of platinum from California known to the writer is by R. M. Patterson, Ueber die Beschaffenheit und das Vorkommen des Goldes, Platins, und der Diamanten in den Vereinigten Staaten: Zeitschr. Deutsch. geol. gesell., Berlin, Vol. II, 1850, p. 61. The paper is a translation of a portion of a letter which was addressed to the American Secretary of State by Mr. Patterson, of the Philadelphia mint.

is not great. They occur along the coast at other localities near this point. Further details will be found in the subsequent citations. The platinum resources of California have been very carefully investigated by D. T. Day, who has published a paper[a] summarizing and tabulating the results of many tests. Dr. Day's results are herewith quoted in full.

As early as 1852 Prof. W. P. Blake[b] called attention to the existence of platinum at Port Orford, on the Oregon coast, and noted that the platinum equaled from 10 to 30 per cent of the gold. This article seems to be the original source of the statement that the proportion of platinum to gold increases northward. B. Silliman,[c] in his mineralogic notes on California, etc., extended our knowledge to the occurrence of platinum in the older deep placers, worked by the hydraulic process in Butte County. He also notes the occurrence of iridosmine with the platinum. Meanwhile T. Sterry Hunt had found platinum and iridosmine on the Rivière du Loup, Quebec, Canada, in 1851.

The various notes concerning the finding of platinum on the Pacific coast have been well summarized in the publications of the California State mineralogist, and show that platinum has been found at many places on the Pacific beach from as far south as San Bernardino County northward to the mouth of the Columbia. Indefinite reports have been made of its occurrence farther north, on the Washington beach, but its amount is certainly not great. The principal beaches where platinum has been reported, beginning at the south, are: Santa Barbara, Lompoc, the beaches of San Luis Obispo County, Santa Cruz, and occasionally between Santa Cruz and the Golden Gate. In accordance with Blake's statement, the richest beaches are farther north, in Humboldt and Del Norte counties. The beach mines of Gold Bluff, north of Arcata, Big Lagoon, Stone Lagoon, Little River, Crescent City, California, and Gold Beach and Port Orford, in Coos County, Oregon, have all yielded platinum in commercially appreciable quantities. Still farther north platinum is found at Yaquina Beach, Oregon, but the sands there are poor. Port Orford has proved, perhaps, the richest beach.

Sharpless and Winchell have made an unusually careful examination of the sands at Bandon, on the Oregon beach. They almost invariably found platinum, but the proportion was not so encouraging as less careful workers had estimated. All this beach platinum is discouragingly fine and difficult to save.

Most of the platinum product has come from inland diggings, where the grains are comparatively coarse. It has become well known in the placers of the American River, and in Plumas, Shasta, Trinity, and Siskiyou counties, California. The Bee Gum district in Shasta County, the Hay Fork district in Trinity County, and the deposits along the Trinity from Chapman's mine, south of Junction City, northward to beyond North Fork, are most promising.

Conditions of occurrence.—Though platinum metals are so frequently found in many of the gold placers of the region including Trinity, Shasta, and Siskiyou counties, their occurrence in this region is by no means universal. There seems, for example, to be no platinum in the Weaverville placers on the Trinity. The platinum-bearing placers confirm the accepted idea that the platinum originates in the serpentine rock in which this region abounds; for the platinum-bearing gravels are sure to be closely associated with some prominent serpentine ridge. Nevertheless, no platinum has yet been found in place within the area named.

A hurried trip through this region enabled the writer to learn, by the analytical aid of Dr. Waldron Shapleigh, that in the Bee Gum district of Shasta County, at

[a] Trans. Am. Inst. Min. Eng., February, 1900, Vol. XXX, p. 702.
[b] Am. Jour. Sci., 2d series, Vol. XVIII, p. 156, and Vol. XXII, p. 8.
[c] Am. Jour. Sci., 3d series, Vol. VI, p. 132.

Hay Fork, and at Chapman's mine, on the Trinity, osmiridium makes up perhaps the greater part of the mixture of platinum metals. At Chapman's mine Colonel Barrows obtained 30 ounces of small nuggets averaging one-third inch in diameter, apparently altogether too hard for platinum, and yet considerably coarser than is usual for osmiridium, which has the habit of occurring in very small scales. Dr. Shapleigh has shown that these nuggets yield a small amount of platinum on treatment with aqua regia, and then fall apart into the ordinary scales of osmiridium. He has found, also, that the Pacific beach platinum often contains more than 90 per cent of osmiridium. This explains the fact that little effort has been made to mine the platinum, for until recently the osmiridium has had practically no value.

At the time of my visit platinum was noticed also in the placers near Grants Pass, Oregon, and by examining numerous samples of black sands traces of platinum were found in the Snake River from Bakersville to Lewiston, and in a sand reported to come from Miles City, Montana.[a]

In examining the well-known platinum localities on Granite Creek, near its junction with Tulameen Fork, in British Columbia, it was estimated that the placers contained about one-fifth as much platinum as gold. I could get no test for osmium, but Dr. Hoffmann, of the Canadian geological survey, has found samples of platinum yielding as high as 25 per cent, and on the average about 10 per cent, of osmiridium.

In further search for the platinum metals, the writer collected heavy sands from placer mines in California, Oregon, Washington, Idaho, Montana, and Alaska. These samples averaged 4 pounds in weight. The sand was first separated by ordinary assay sieves into about nine sizes: Coarser than 20-mesh; through 20, 40, 60, 80, 100, 120, 160, and then 200 mesh. Each size was then in good condition for easy separation of the highly magnetic portion by a rude form of separator. By limiting the magnetic separation to the highly magnetic particles, very little gold or platinum was removed with the magnetic portions, as the panning of these portions proved.

By panning each size and then counting (or weighing, where the amount was considerable) the flakes of gold and platinum a fair idea of the proportion of platinum to gold could be gained. As the sieving was carried to such uniform sizes, it was possible, by counting weighed amounts, to estimate the unit weights of flakes of the different sizes, and thus to approximate, roughly, the total weight of gold and platinum obtained.

The results are shown in Table I.

In addition to the sands mentioned above, about 25 ounces of Klondike gold dust was examined, and only a grain or two, probably of platinum, was found.

A number of concentrates collected by Mr. A. H. Brooks, of the United States Geological Survey, from the Tanana River district, in Alaska, and also the beach sands brought from Cape Nome by Mr. Brooks and Mr. Schrader, showed no platinum.

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[a] Dr. F. W. Traphagen confirms this find of platinum at Miles City, Montana. The concentrated sand examined by him contained 10 per cent of platinum.

TABLE I.—*Pan tests of platinum-bearing gold sands.*

Post-office and State.	Weight of sample, in ounces.	Value of platinum metals per ton.	Percentage of platinum to gold.
CALIFORNIA.			
Crescent City, Del Norte County	80	$0.04	17
Smith River, Del Norte County	23	0.54	6.8
Crescent City, Del Norte County (South Fork Smith River)	62	681.31	2.230
Trinity Center, Trinity County	35	0.28	79
Burnt Ranch, Trinity County	45	13.09	104
Weaverville, Trinity County	20	0	0
Big Bar, Trinity County	40	3.75	11
Junction City, Trinity County	49	1934.18	----------
Hawkins Bar, Trinity County	63	4.05	34
Randsburg, Kern County	50	0	0
Wilson Creek, Humboldt County	45	0.02	8
Big Lagoon, Humboldt County	60	0	0
China Flat, Humboldt County	25	177.08	138
Orleans, Humboldt County	36½	6.87	50
Hamburg, Siskiyou County	20	0	0
Do	55	.86	280
Sawyers Bar, Siskiyou County	79	2.39	31
Oak Bar, Siskiyou County	123	0.54	12
Fort Jones, Siskiyou County	51	0.07	.1
Sawyers Bar, Siskiyou County	45	0.07	3
Klamath River, Siskiyou County	63	2.40	51
Rock Ranch, Siskiyou County	29	0.51	26
Callahan, Siskiyou County	58	7.02	134
Hornbrook, Siskiyou County	19	0.18	06
Callahan, Siskiyou County	25	0	0
Scott River, Siskiyou County	9	1.83	.6
Happy Camp, Siskiyou County	48	50.97	148
Cecilville, Siskiyou County	20	2.01	14
Do	14½	0.15	8
Walker, Siskiyou County	37	0	0
Shasta River, Siskiyou County	30	0	0
Klamath River, Siskiyou County	30	0	0
Gottville, Siskiyou County	20	0	0
Camptonville, Yuba County	37	.32	4
Do	50	0	0
Quincy, Plumas County	40	0	0
Laporte, Plumas County	50	0	0
Butte Valley, Plumas County	35	0	0
Do	30	0	0
Slate Creek, Sierra County	40	0	0
Gibsonville, Sierra County	50	0	0
Do	20	0	0
Chico, Butte County	40	5.46	8.4
Magalia, Butte County	60	0.30	1.2
Inskip, Butte County	20	0	0
Brownsville, Butte County	30	0	0
Michigan Bluff, Placer County	56	.34	1
Do	59	0.19	.1
Grizzly Flats, Eldorado County	40	0	0
Smith Flat, Eldorado County	40	0	0
Railroad Flat, Calaveras County	50	0	0

TABLE I.—*Pan tests of platinum-bearing gold sands*—Continued.

Post-office and State.	Weight of sample, in ounces.	Value of platinum metals per ton.	Percentage of platinum to gold.
CALIFORNIA—continued.			
Mokelumne Hill, Calaveras County	84	$0.02	.2
Genesee, Plumas County	63½	0.06	.008
OREGON.			
Denmark, Curry County	25	1.08	300
Denmark, Curry County:			
No. 1	49½	.06	20
No. 2	44½	0	0
No. 3	50½	.15	18
No. 4	48½	.24	10
No. 5	47½	.25	60
No. 6	45	.32	121
No. 7	50	0	20
No. 8	57½	.21	50
No. 9	53	.03	3.6
No. 10	50	0	0
No. 11	52	.01	12
2 miles north of Pistol River, on Oregon Beach	118	.06	8
2 miles south of Pistol River, on Oregon Beach	60	0	0
IDAHO.			
Rocky Bar, Elmore County	50	0	0
Princeton, Latah County	60	0	0
MONTANA.			
Forest, Missoula County	50	0	0
ALASKA.			
Sand from beach north of Lituya Bay	100	0	0

The total results above reported show that if all the sands examined were considered together, there would be about half as much of the platinum metals as of gold.

With regard to the percentage of platinum in the sands from various parts of the Pacific coast, Dr. Shapleigh has furnished the following table:

TABLE II.—*Percentage of platinum in sands from Pacific coast.*

Locality.	Metals.	Highest per cent.	Lowest per cent.
Bee Gum district, Shasta County, Cal	Platinum	20	13.5
	The other platinum metals	84	79
Hay Fork district, Trinity County, Cal	Platinum	73	30
	The other platinum metals	58	18
Trinity River district, California	Platinum	27	15
	The other platinum metals	80	72
Crescent City, Del Norte County, Cal	Platinum	11	8
	The other platinum metals	83	46
Port Orford, Oreg	Platinum	47	15
	The other platinum metals	83	23

The "other platinum metals" include iridium, osmium, ruthenium, rhodium, and palladium.

The platinum from California is characteristically low in iron and at times quite high in copper and iridium. It may also contain much iridosmine mechanically involved in the nuggets. In some of these respects it presents a contrast with the metal from Russia.

The following analyses have been collected from various sources:

Analyses of platinum from the Pacific Coast.

	1	2	3	4	5	6	7
Pt	85.50	79.85	76.50	63.30		57.45	57.75
Ir	1.05	4.20	.85	.70	53.50	.40	3.10
Rh	1	.65	1.95	1.80	2.60	.65	2.45
Pd	.60	.95	1.30	.10		.15	.25
Os		.05	1.25		43.40		.81
Ru					.50		
Au	.80	.55	1.20	.30		.85	
Fe	6.75	4.45	6.10	6.40		4.30	6.79
Cu	1.40	.75	1.25	4.25		2.15	.20
Iridosmine	1.10	4.95	7.55	22.55		37.30	27.65
Sand	2.95	2.60	1.50			3	
Pb			.55?				
Hg				.60			
Total	101.15	100	100	100	100	100.25	99

NOTES TO TABLE.

Nos. 1, 2, 3, 5, and 6 are taken from the valuable paper by Deville and Debray in the Annales de Chimie et de Physique, Vol. LVI, 1859, pp. 449-481.

No. 4 is from Kromayer, Archiv Pharmacie, ii, Vol. CX, 14. Jahresberichte, 1862, p. 707.

No. 7 is by F. Weil, and was originally published in Armengand's Genie Industrielle, May, 1859, p. 262. See also Dingler's Polyt. Jahrbuch, Vol. CLIII, p. 41; Neues Jahrb., 1860, p. 354.

PAPERS REFERRING TO PLATINUM IN CALIFORNIA AND OREGON.

The following references to the occurrence of platinum in California will be found of interest:

CALIFORNIA, Annual Reports of the State Mineralogist, as follows: Vol. IV, 1884, pp. 309, 311 (on iridium, see p. 231); Vol. VIII, p. 217, for Humboldt County; p. 584, for Siskiyou County; Vol. IX, p. 717, for Trinity County; Vol. XII, p. 408, for Trinity County.

DAY, D. T., Notes on the occurrence of platinum in North America: Transactions American Institute Mining Engineers, Vol. XXX, p. 702, February, 1900.

GENTH, F. A., On a probably new element with iridosmine and platinum from California: Proceedings Academy Natural Sciences, Philadelphia, December, 1852, p. 209. American Journal of Science, March, 1853, p. 246. Dr. Genth does not mention the exact locality from which he obtained the sample. He notes the presence of sisserskite, $IrOs_4$, in six-sided scales, and some platin-iridium and native platinum. On analysis the platinum yielded Pt. and Pd. 90.24, Ir. and Rh. 2.42, Fe. 6.66, and sisserskite 0.68.

SILLIMAN, B., American Journal of Science, 3d series, Vol. VI, p. 132.

On platinum in Oregon the following will be of interest:

BLAKE, W. P., American Journal of Science, 2d series, Vol. XVIII, p. 156. Professor Blake states that in the placer gold of Port Orford, on Cape Blanco, there is as much as 10 to 30 per cent of platinum which in earlier years was discarded.

COLORADO.

A number of reports have been current of discoveries of platinum in Colorado, and the writer has seen several samples and the results of assays, but in no case were exact localities recorded. One sample resembles a black hornfels and probably came from a contact zone of eruptives on shale or slate. It was permeated by films of pyrrhotite. It resembled closely a similar rock which was said to have come from the Lake Superior region and which was circulated among geologists and consumers of platinum ten to fifteen years ago.[a]

GEORGIA.

Platinum has b en reported from Lumpkin County, Ga., but the writer has been unable to obtain details of its geological relations.[b]

IDAHO.

Platinum has been discovered in the gold-bearing sands of the Snake River from Bakersville to Lewiston, along the western border of the State.[c]

MONTANA.

Platinum has been reported from the vicinity of Miles City.[d]

NEW YORK.

A remarkable nugget of platinum was found about 1880 in the glacial drift near Plattsburg, N. Y. In course of time it came into the possession of Prof. Peter Collier, who submitted it to a careful mineralogical and chemical examination. The nugget consisted of metallic platinum and chromite in the proportions of 46 per cent of the former and 54 per cent of the latter. It measured 4 by 3 by 2¼ cm. It weighed 104.4 grams. Its specific gravity was 10.446. The specific gravity of the separated platinum was 17.34. The nugget was slightly magnetic. After the chromite had been mechanically separated from this metallic portion, the latter was soluble all but 0.74 per cent. An analysis of the platinum yielded the following result:

Analysis of platinum from nugget found in glacial drift near Plattsburg, N. Y.

Pt	82.814
Ir	.627
Rh	.286
Pd	3.105
Fe	11.040
Cu	.397
Al_2O_3	1.953
CaO	.069
MgO	.030
Total	100.321

[a] Compare note on the Rambler mine, Wyoming, p. 34.
[b] Charles Bullman, The Mineral Industry, Vol. I, p. 375.
[c] D. T. Day, Trans. Am. Inst. Min. Eng., Vol. XXX, p. 705, February, 1900.
[d] D. T. Day, idem, p. 705.

Some osmium was also present, but was not determined on account of the difficulty of the analysis. The gangue was mostly chromite and on analysis yielded the following:

Analysis of gangue of same platinum nugget.

Cr_2O_3	54.944
FeO	31.567
Al^2O_3	5.690
SiO^2	3.731
CaO	3.405
MgO	.941
Total	100.278

It is evident from these results that chromite is the chief component and it is possible that in it a little alumina may have replaced some of the chromic oxide. There remains uncombined, therefore, silica, lime, some alumina, and probably a little magnesia, although it is also possible that some, or even all, of the magnesia may have replaced a portion of the ferrous oxide of the chromite. Pyroxene would be the most natural mineral which would embrace the remaining uncombined elements.[a]

As this nugget was found in the glacial drift it has clearly been brought in from the north. The glacial striations near Plattsburg have been reported by H. P. Cushing to run from S. 15° E. to S. 15° W. and to be influenced by the local topography. Farther south the writer has noted them in the valley of the lake, as well as back in the mountains, to be S. 60° W. as a rule. A southwesterly movement of the ice sheet would have brought glacial material to Plattsburg from the great areas of serpentine which occur in Quebec north of Vermont and which are commercially productive of chromite. There seems little reason, therefore, to doubt that the nugget has been derived from this source, but as yet no platinum has been announced in the serpentine region.

NORTH CAROLINA.

In 1847 C. U. Shepard announced the discovery of platinum in a small sample of concentrates, which had been saved by Mr. T. J. Clingman, of Asheville, N. C., from gold washings in the northern part of Rutherford County. The platinum nugget weighed 2.541 grains, and had a specific gravity of 18. This, if authentic, was the earliest discovery of platinum in the United States, but the metal must be extremely rare in the region, because no further records of its occurrence in the metallic state have been made. North Carolina is rich in areas of serpentine and basic igneous rocks.[b] Prof. F. P.

[a] A remarkable nugget of platinum, by Peter Collier: Am. Jour. Sci., 3d series, Vol. III, p. 123.

[b] Native platinum in North Carolina, by C. U. Shepard: Am. Jour. Sci., 2d series, Vol. IV. p. 280. See also Minerals and mineral localities of North Carolina, by F. A. Genth: Vol. II of Geol. of N. C., p. 12. Two other localities are given, and palladium is also reported.

Venable, however, after a careful examination of the evidence has decided that the discovery was probably not authentic.[a]

After the discovery of sperrylite in the Sudbury region of Ontario, great interest was felt by all geologists in locating it in other places. In 1894 Mr. W. E. Hidden observed it in the pannings of gravels taken from the Ned Wilson branch, Coler Fork of Cowee Creek, Macon County, N. C. The quantity was small, and the announcement was not published until 1898, when more was found in connection with the mining of rhodolite, a variety of garnet of gem grade. Messrs. Hidden and Pratt subsequently traced the rhodolites to their parent rock, which proved to be a ledge on the top of Mason Mountain. The rock consists of rhodolite, biotite, and considerable iron sulphides. In pannings of some of the loose decomposition products taken from the surface of the ledge, crystals of sperrylite were discovered. This rare arsenide of platinum has therefore been found in place in North Carolina.[b]

PENNSYLVANIA.

In 1852 Dr. F. A. Genth detected platinum in a clay slate from Lancaster County, Pa. The slate contained chalcopyrite and galena, and when 300 grams were fused with oxide of lead and black flux they yielded a button which, on being cupelled, was found to contain from 0.0005 to 0.0014 per cent silver, gold, and platinum. Some iridium was likewise identified in a qualitative way. Ilmenite from the same general locality afforded tests for silver and platinum.[c]

Platinum has also been detected by assay in a black shale which occurs east of Boyertown and near the little village of Sassamansville. The locality is not far from the line between Montgomery and Berks counties. Although some tests afforded amounts sufficient to weigh, the distribution is too irregular and variable to warrant mining.[d] A vein from this vicinity containing quartz, pyrites, and oxidized lead minerals yielded one-half ounce per ton of platinum and either gold or palladium.

A pyritous dioritic gneiss from the Archean areas of Pennsylvania, locality not definitely known, has given assays from one-half ounce to over 2 ounces to the ton.

MEXICO.

Platinum has been reported from the Las Yedras mine, Sinaloa, but the writer has been unable to discover further particulars on record.[e] In a brief note on an interesting series of specimens from a

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[a] Jour. Elisha Mitchell Sci. Soc., Vol. VIII, pt. 2, 1892. See also W. E. Hidden, Am. Jour. Sci., Vol. XXII, 1881, p. 25.

[b] Occurrence of sperrylite in North Carolina, by W. E. Hidden: Am. Jour. Sci., November, 1898, p. 381. See also same for April, 1898, p. 294, and for December, 1898, p. 467.

[c] F. A. Genth, Pharm. Centralblatt, 1852, p. 72.

[d] Information kindly furnished by A. W. Johnston.

[e] Charles Bullmann, The Mineral Industry, Vol. I, p. 375.

quicksilver mine whose locality is not given, F. Sandberger has stated that with the ores he found some pseudomorphs of limonite after pyrites, which on assay yielded weighable amounts of platinum.[a]

CENTRAL AMERICA.

HONDURAS.

Platinum has been reported from Choloteca and Gracias, but further particulars are not available.[b]

WEST INDIES.

SANTO DOMINGO.

Very early in the history of platinum grains were brought from Santo Domingo, probably in connection with the endeavors of the French to acquire possession of the island. The grains were obtained from the gold washings of the Yaqui River (or, as it is also spelled in foreign articles, Jacky, or Jacki, or Iacki). The Yaqui rises in the central part of the Republic and flows northwest into the sea near the boundary with Haiti. The French chemist, Vauquelin, submitted some of the grains to chemical examination in 1810. He first dissolved off a ferruginous crust, which gave a yellow solution with hydrochloric acid. In this way 0.3 gram was lost in a total of 36.7. On solution in aqua regia a residue of 0.8 gram was obtained, consisting of little black needles, with some quartz and a black sand. The needles were considered iridium and the black grains chromite. Qualitative examination yielded tests for copper, iron, chromium, osmium, iridium, rhodium, and palladium. M. Vauquelin believed that titanium was also present, but he obtained no test for gold.[c]

SOUTH AMERICA.

BRAZIL.

Platinum was observed at a very early date in the gold washings of Brazil. In the valuable description of this great country by C. F. Hartt it is specifically recorded as being found in several places in the province of Minas Geraes. The localities are chiefly in the basin of the Rio das Velhas, in the southern central part of this State. The country rock is described by Hartt as a syenitic gneiss which is cut by quartz veins. In the Bõa Esperança veins platinum is said to be present, and at Gongo Seco, 20 miles east of Morro Velho, the gold is said to contain palladium. Hartt remarks in general that the gold of Brazil is always alloyed with silver and occasionally with platinum.

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[a] Neues Jahrbuch für Mineral., 1875, p. 625.

[b] Charles Bullmann, The Mineral Industry, Vol. I, p. 375.

[c] L. N. Vauquelin, Analyse du platine trouvé à Saint-Domingue: Annales du Museum d'Histoire Naturelle, Vol. XV, 1810, p. 317. Compare also Guyton de Morveau, Annales de Chemie, Vol. LXXIII, 1810, p. 334. A. Vogel, Platinerz von San Domingo: Jour. Chem. Soc. London, Vol. XXVII, 1874, p. 196.

It may likewise contain iron. Iridium and iridosmine occur in the gold washings of Minas. This reported occurrence of platinum in veins is an exceedingly interesting and important one, and corroborates in a general way the statements already made for several other places. Additional citations by Hartt are reproduced below, but the original sources have not been accessible to the writer. A peculiar variety of gold, known as "ouro preto," is obtained in this region. It was formerly collected in considerable quantity, but now only the poorest laborers pay attention to it. A sample obtained from O. A. Derby was analyzed in 1882 by W. H. Seamon, who gives the composition as follows:

Analysis of ouro preto from Brazil.

Gold	91.06
Palladium	8.21
Silver	Trace.
Iron	Trace.
Total	99.27

Specific gravity, 15.73.

The iron was regarded as a mechanical adherent. When calculated the formula is $PdAu_6$. Berzelius, in 1835, published a similar analysis from Porpez. This variety was called porpezite.

Analysis of porpezite from Brazil.

Gold	85.98
Palladium	9.85
Silver	4.17
Total	100.00

The geological relations of the peculiar gold-palladium alloy have been described by Johnson and Lampadius, as follows: The alloy occurs in beds of a rock, called by the natives zacotinga (or jacotinga), which is an aggregate of specular hematite, mica, quartz, and pyrolusite. This is the itabirite of the European writers. The rock is crushed and washed.[a]

[a] Berzelius, Neues Jahrbuch für Mineral., 1835, p. 184. J. Cloud, Palladium in Brazilian gold: Poggendorf's Annalen, Vol. XXXVI, 1810, p. 310. C. F. Hartt, Geology and physical geography of Brazil, pp. 448, 542. Johnson and Lampadius, Journal für prakt. Chemie, Vol. X, 1837, p. 501. See, also, on the rock, Heusser and Claraz, Zeit. Deutsch. geol. Gesell., Vol. XI, 1859, p. 448. Lampadius and Plattner, Ueber das gemeinschaftliche Vorkommen des Platinerzes und des gediegen Silbergoldes in einem Gangfossile aus Brazilien: Jour. technische Chemie, Vol. XVIII, 1833, p. 453. (Not accessible to J. F. K.) W. H. Seamon, Analysis of native palladium gold from Taguaril, near Subara, Minas Geraes, Brazil: Chemical News, Vol. XLVI, 1882, p. 216. Williamson, Geology of the Parahyba Gold Region: Trans. Geol. Soc. Manchester, England, Vol. VI, 1866, p. 113. W. H. Wollaston, On platina and native palladium from Brazil: Philos. Trans. Royal Soc. London, Vol. XCIX, 1809, p. 189.

The following authorities are likewise cited by Hartt: Burton, The Highlands of Brazil; Castelnau, Expedition dans l'Amérique de Sud; von Eschwege, Geognostisches Gemaelde von Brasilien. No mention of platinum could be found by the writer in v. Eschwege's Pluto Braziliensis.

FRENCH GUIANA.

An announcement was made to the French Academy, in 1861, by Damour, that a very curious nugget had reached him from Aïcoupaï, on Hamelin Creek, in the basin of Appronaguel. It weighed 0.85 gram. Its specific gravity was 13.65. It was malleable, silvery white, and less fusible than gold. On analysis it yielded:

Analysis of nugget from basin of Appronaguel.

Platinum	41.96
Gold	18.18
Silver	18.39
Copper	20.56
Total	99.09

It dissolved so easily in nitric acid that it was believed to be clearly a mechanical mixture, and not an alloy—that is, the copper and silver were easily removed, and a brown sponge of gold with white scales of platinum remained.[a]

COLOMBIA.

Platinum was first discovered in connection with gold washings in Colombia. The original sample was obtained at Cartagena and was brought to Europe in 1735. The sample was reputed to have been obtained in the river Pinto, a stream which the writer has been unable to locate on the modern maps. Colombia is now a producer of commercial platinum second in rank to the Urals. The deposits are all in the form of placers and are situated upon the western watershed, near the divide which separates the waters of the northerly flowing Atrato from those of the southerly flowing San Juan. The general district is called El Choco. It embraces two provinces—a northerly one, named Atrato, whose capital is Quibdó, and a southerly one, San Juan, whose capital is Novita. The greater part of the platinum is obtained in San Juan. It occurs with gold along the main stream and its tributaries from its junction with the Sipi to the headwaters. Charles Bullman states that below the Tamana the proportion is ten to one in favor of gold, while above it is two to one. The only outcropping rocks in the basin of the San Juan appear to be of very recent origin. They are described by Bullman as indurated clays and conglomerates, probably of Tertiary age. As Bullman was unable to discover evidences of marine life, he considers them to be freshwater deposits. The sediments are at present much tilted, and are supposed to have been upheaved at the close of the Tertiary. There is evidence also of glacial action, according to Bullman, the ice having moved from northeast to southwest, and having transported bowlders, clay, sand, and the precious metals. These later deposits, in part at

[a] Damour, Comptes rendus, Vol. LII, 1861, p. 688.

least of glacial origin, are locally called caliche. Bullman defines the word as follows: "By caliche is meant sand, pebbles, and bowlders bound or held together by clay, or it may be called a weathered, disintegrated, cement gravel." As shown in the accompanying section (fig. 3), the caliche rests upon clays and conglomerates. The present drainage has cut deeply into both the latter formations, and has concentrated in the river gravels the precious metals which were contained in the formations now constituting the banks. It is believed

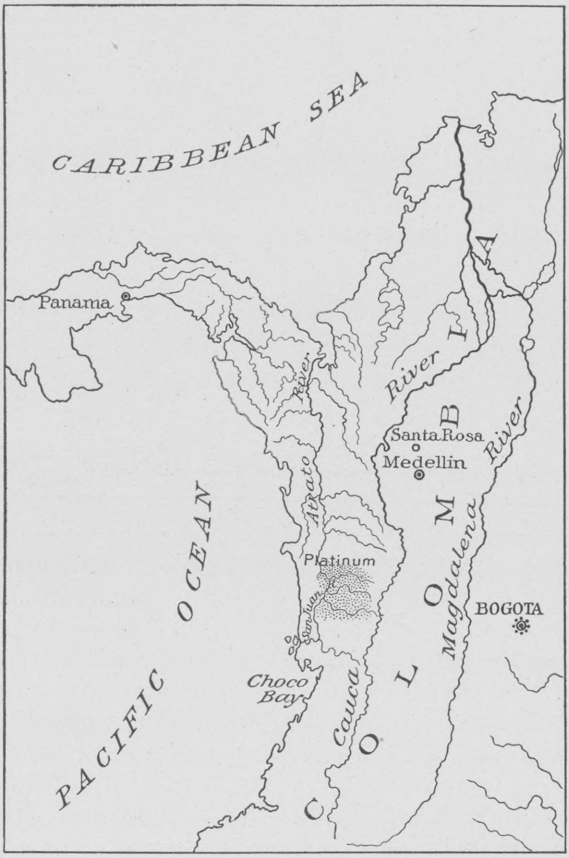

FIG. 2.—Sketch map of Colombia, showing the location of the platinum placers.

that the gold and platinum have come from the granitic, syenitic, and metamorphic rocks of the Andes. Mr. Bullman concludes that very little has been derived from fissure veins, although more or less quartz containing gold is obtained in the gravels.

In mining, attention is paid both to the bars in the running streams and to the caliche. In working the former the miner builds up a little barricade of larger bowlders, in the lee of which the sands are dug up and washed in a batea. Women are more especially engaged in this work. The mining is carried on in a desultory manner, the natives working at low water and being content with such returns as supply the necessaries for their simple life in this region.

When sufficient water can be readily obtained it is used to sluice the caliche, which is broken down by bars, raked over somewhat with a crooked tool, and tumbled into the sluices. At periodic intervals the clean-up takes place. Some more ambitious attempts have been made to dredge the rivers, but without much success, the gravels being of low grade.

The nuggets of platinum occasionally carry chromite, but, although a considerable quantity has been examined by the writer, through the courtesy of Mr. A. W. Johnston, of the S. S. White Dental Manufacturing Company, other minerals aside from gold have not been observed. Other observers have recorded the characteristic presence of zircons. The nuggets occasionally reach rather large size. One in the museum of the geological department of Columbia University weighs 52.597 grams and has a specific gravity of 13.584. Assuming a specific gravity for platinum of 17.6 and for chromite of 4.5, this would imply 16.124 grams of chromite and 36.473 of platinum.

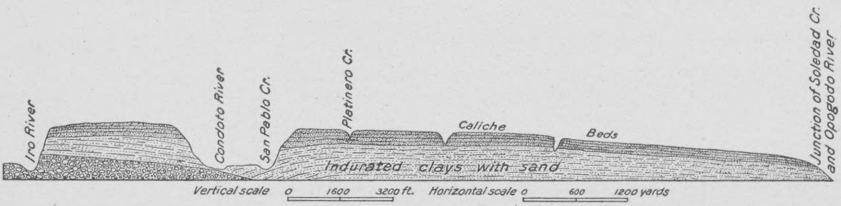

FIG. 3.—Geological cross section of the caliche beds from the Iro to the Opogodo. (After Charles Bullman.)

It was obtained by Mr. Bullman. A still larger one is owned by Baker & Co., of Newark, N. J. Its weight is stated to be about 2 pounds.

Gold has also been observed involved in the nuggets of platinum, and it seems at times to occur with the latter mineral in the mother rock. The platinum has not been definitely traced back from these washings to the mother rock, but some observations were made, as far back as 1826, by Boussingault, a French traveler, who communicated them to Humboldt, by whom they were laid before the French Academy. Humboldt presented them with an introduction of his own, which has given the impression that the observations were made in Brazil, and has occasioned the erroneous citations of platinum from the province of Antioquia, Brazil, which appear in Dana's Mineralogy and elsewhere. M. Boussingault's observations were made at Santa Rosa, province of Antioquia, Colombia, about 10 leagues northeast of Medellin. The locality is situated 2,775 meters above the sea. The country rock is described as a syenite or syenitic gneiss of the same general quality as that which prevails at Medellin, and it is cut by many veins of quartz. The surface is covered by alluvium, which has been concentrated by the streams. Together with the gold, occasional lumps of limonite are met and are saved by the gold washers. They are afterwards pounded up and panned down, because they contain considerable gold. Other lumps of limonite are gathered directly from the outcrops of the veins and appear to be portions of the gossan. In the pannings of one of these lumps derived from the outcrop of a vein, Boussingault obtained grains of platinum which were the same in appearance as those washed from the gravels of El Choco. While the specimen was not found absolutely in place, there seems reason to believe that Boussingault has correctly referred it to its original situation, and has therefore recorded a very important and interesting case of the occurrence of platinum with other metallic minerals in a vein whose filling was largely quartz. Boussingault states that the syenite, together with porphyritic greenstones, extends from Santa Rosa over into the Choco district.[a]

EUROPE.

AUSTRIA-HUNGARY.

A few scales of platinum have been discovered as a very rare mineral in the gold-bearing sands of Ollálipian, Siebenbürgen.[b]

FRANCE.

Scales of platinum in very small amounts have been discovered in one or two places in France in connection with gold. Thus at Morbihan, in Brittany, it is occasionally seen with gold in tin-bearing sands which occur along the coast. It is likewise known at Gard, in Cevennes.[c]

The announcement was made in 1833 that platinum had been detected in galena in western France, but subsequent assays failed to corroborate the statement. Investigation, however, proved the presence of platinum in limonite in several localities in the Departments of Charente and Deux-Sèvres.[d]

In 1847 E. Gueymard, a French mining engineer, discovered the

[a] The above notes upon platinum in Colombia have been drawn chiefly from a report which was made by Charles Bullman in 1890 for New York parties and which was privately printed. For the courtesy of its use the writer is indebted to Mr. A. W. Johnston, to whom acknowledgments are here made. In a modified form the general results of Mr. Bullman's examination also appear in the very valuable paper upon the Platinum Metals which he contributed to the Mineral Industry, Vol. I, p. 373. A description of the methods of gold washing will be found in the Engineering and Mining Journal, April 2, 1892, p. 347. Boussingault's paper appears in the Annales Chem. et Phys., Vol. XXXII, 1826, p. 204, and in Poggendorff's Annalen, Vol. VII, 1826, p. 515; Vol. X, 1827, p. 490.

[b] v. Zepharovitch, Mineralogisches Lexikon für Oesterreich, Vol. I, p. 318. See also Jahresber. Chem., 1847-48, pp. 1022 and 1152.

[c] A. Lacroix, Mineralogie de France Vol. II, p. 390.

[d] Dingler's Polytech. Journal, Vol XLIX, 1833, p. 232; Poggendorff's Annalen, Vol. XXXI, 1834, pp. 16 and 590; Phil. Mag., 1834, p. 158.

presence of platinum in tetrahedrite, which he found in metamorphic limestones on the mountain called Chapeau, above Chatelard, in the commune Champoleon, in the Vallée du Drac, Hautes Alpes. The limestone occurs in beds between protogine and a rock that appears to be related to spilite. The gray copper contains silver up to 12 per cent, and in addition antimony, lead, zinc, iron, sulphur, and a little arsenic. The gangue is dolomite, quartz, and barite, being very similar to the veins at Guadalcanal, Spain. M. Gueymard made a hundred analyses; 80 afforded no platinum, and in the remaining 20 the amount was not always large enough to weigh. His experiments were, however, subsequently verified in Paris, and of their reliable nature there seems to be no doubt. He extended his researches to St. Arey, near La Mure (Isère), and in the bournonite of the dolomites and of the altered limestones he identified platinum. Sometimes he could detect it in samples of 5 grams, and again he could not in samples of 20 grams, but it proved to be more commonly present than at Chapeau. A third locality was discovered in the Plan des Cavales, on the mountain of Rousses, Oisans, Isère. The country rock consists of protogine, gneiss, talc-schist, and some beds of Liassic limestone, now changed to dolomite and magnesian limestone. Here are situated old mines from which was obtained a foliated green carbonate of copper which carried 50 per cent Cu. This mineral yielded in two cases weighable amounts of platinum. Again, he discovered indications of platinum in slightly argentiferous gray copper and copper carbonate near Presles, on the right bank of the Bens, in Savoy.

When M. Gueymard's samples were tested in Paris traces of rhodium and iridium were likewise identified. The amounts of the platinum metals are not, however, sufficient to justify mining.[a]

GERMANY.

A very interesting occurrence of allopalladium was early noted in the mines at Tilkerode, in the Hartz. It was at first thought that the mineral contained selenium, but the selenium was afterwards shown to be a mechanical mixture. The mineral was called eugenesite by Zinken. It contains palladium, silver, and gold.[b] The allopalladium occurs as microscopic six-sided scales on the gold of the Eskeborner shaft, together with quartz, selenide of lead, selenide of mercury, dolomite, and calcite. The mines at Tilkerode are based upon irregular lodes in diabase, or between it and neighboring slates.

Platinum has also been reported from the Siebengebirge[c] and from Freiberg.[d]

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[a] Mémoire historique sur la découverte du platine dans les Alpes, by E. Gueymard: Comptes rendus, Vol. XXIX, 1849, p. 814; Vol. XXXVIII, 1854, p. 941.

[b] Luedecke, Minerale des Harzes, p. 6.

[c] Berg- und Hüttenm. Zeitung, Vol. XIII, 1854, p. 232.

[d] Idem, Vol. VII, 1848, p. 628.

GREAT BRITAIN.

A few grains of platinum have been observed in the gold-bearing sands of Wicklow, in Ireland.[a] Some few scales have also been noted on the island of Jersey and in the sands at the mouth of the river Urr, Kirkcudbrightshire.[b]

RUSSIA.

It is a curious fact that platinum was not discovered in the Urals until nearly a hundred years after it had been brought to Europe

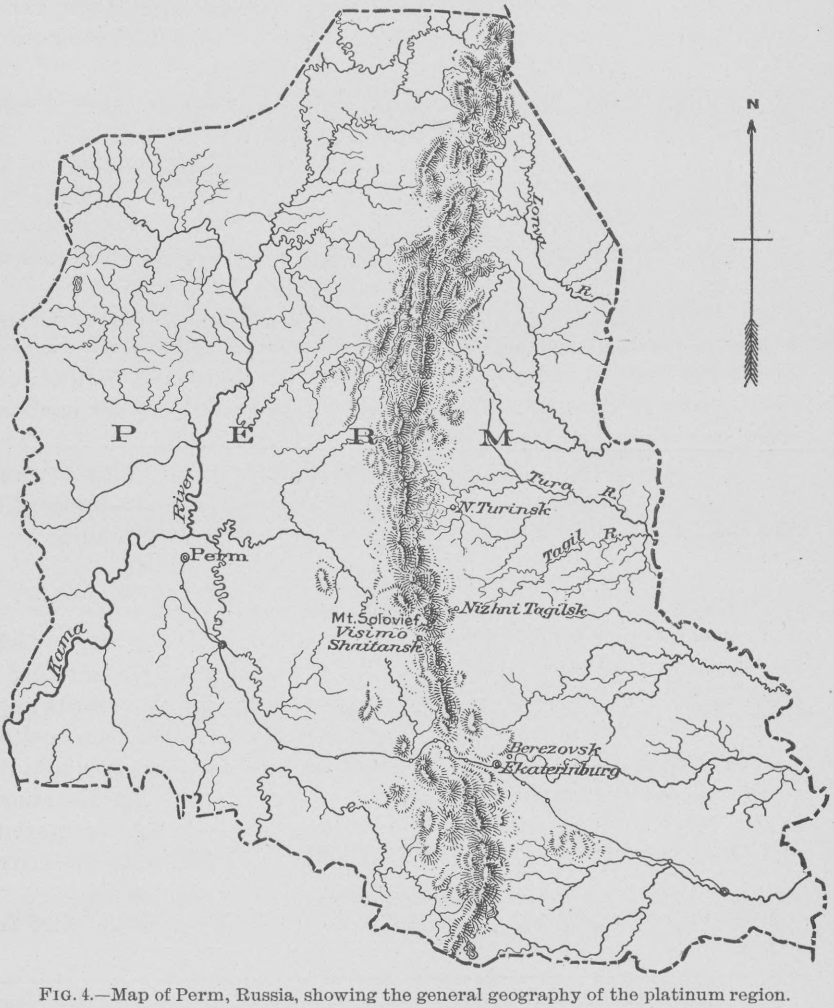

FIG. 4.—Map of Perm, Russia, showing the general geography of the platinum region.

from South America. It was, in fact, known to occur both in Colombia, Brazil, and in Santo Domingo before it was detected in the Rus-

[a] W. Mallet, Philos. Mag., 3d series, Vol. XXXVII, p. 393.
[b] Greg and Lettsom, Mineralogy of Great Britain, 1858, p. 245.

sian gravels in 1819. It is possible that it was known at even a much earlier period in some of the gold washings of Bohemia, because certain old records are of such a character as to leave little doubt that the writers referred to platinum, and in Colombia in all probability it was known to the Spaniards in the first half of the sixteenth century.

The Russian sources of supply furnish nearly all the commercial platinum. Although the metal is known over a wide area, the really productive districts are comparatively limited. They lie along the eastern watershed of the Urals, in the eastern portion of the kingdom of Perm, and on the western watershed farther south. The boundary between European Russia and Siberia leaves the summits of the Urals north of the platinum district and runs off to the southeast, so that a large area of the eastern drainage is embraced in European Russia. A few years ago the greater part of the platinum came from the district of Nijni-Tagilsk, but at present the largest supply is obtained in the Goroblagodat and Bisersk districts, which are about 130 miles north.

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GOROBLAGODAT AND BISERSK DISTRICTS.

These two districts are situated northeast of the town of Nijni-Turinsk. From the watershed of the Urals two small rivers or creeks, called the Iss and the Veeya, flow eastward and enter the Tura River. They rise about 10 miles apart and preserve this general distance to their mouths. They are each about 30 to 40 miles long. The Tura, which is the main stream of the region, rises to the south near the Perm-Ekaterinburg Railroad. The Tura crosses the railroad near the village of Kooshva and pursues a northerly course of 35 miles until it meets the Iss. It then bears away 65 miles eastward to the town of Verkotoor, after which it swings around to the southeast and, crossing the boundary of the kingdom of Perm, flows past the well-known city of Tiumen and soon joins the Tobol River. The Tobol discharges into the Irtish, which empties into the Obi. The waters finally reach the Gulf of Obi and the Arctic Sea. The course of the Tura is in many respects similar to those of the Tulameen and Similkameen rivers of British Columbia, since all three flow north, northeast, and finally southeast. The productive platinum ground is found all along the Iss and the Veeya and on the Tura from its junction with these two streams as far as Verkotoor. The linear distance, therefore, is approximately 100 miles, and the general area is estimated at about 2,000 square miles.

Physiography.—In physiographic character the region is an old land area which has suffered protracted surface weathering and degradation. The drainage has reached a stage approximating a base-level or graded slope, and consequently the concentration of heavy minerals of all sorts, originally in a state of sparse dissemination in the country rock, has been extreme. This fact must be borne in mind in any comparison for economic purposes between the Urals and any other platinum region, such as, for example, British Columbia or the United States of Colombia. The rivers of the Urals appear to have been formerly larger than now, and the valleys are often choked and silted. The rivers meander, with many oxbows and cut-offs, across the level stretches.

Distribution of the platinum-bearing gravels.—Platinum is found in commercial quantity most richly along the Iss. The gravels are less

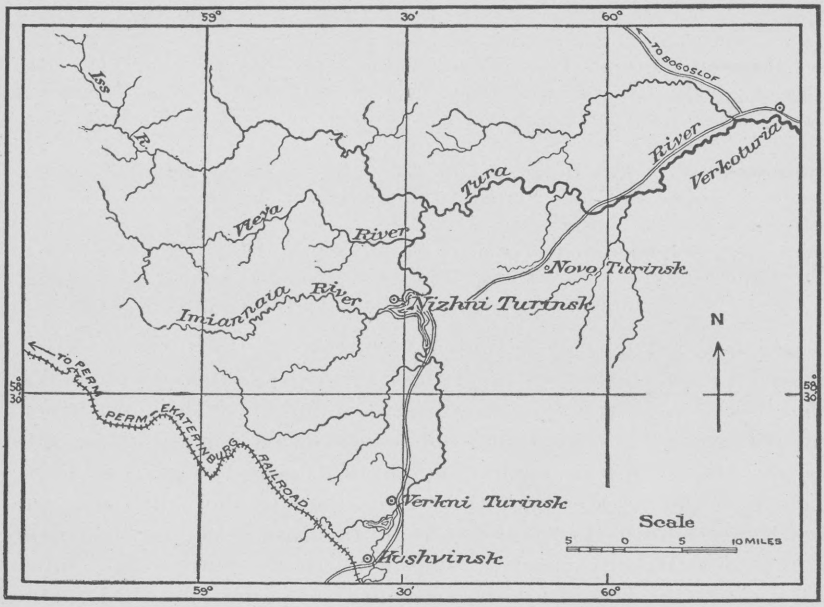

FIG. 5.—Sketch map of the platinum-bearing streams in the Goroblagodat and Bisersk districts, Russia. (After C. W. Purington.)

rich along the Veeya and on the Tura. The two tributaries are undoubtedly responsible for the platinum in the Tura. The platinum is afforded by placers of the usual type, but on account of the former larger development of the drainage there are productive gravels away from the present streams and in abandoned channels which are more or less similar to those with which the gold seekers of our Western States are familiar. The productive ground extends, as a rule, to distances varying from 200 to 800 feet on each side of the present rivers. Along the broader parts of the Tura, Purington states that the total width of the productive ground may be half a mile, and that generally throughout the region he has obtained colors by panning, from the grass roots downward, but of course the richest streak lies nearest to the bed rock.

Hard geology.—The rock formations along the Iss and the Veeya are very suggestive of those in British Columbia, and the accompanying geological map (fig. 6), which is reduced from the valuable report of Prof. A. M. Saytzeff, will be useful for comparison with that earlier given for the Tulameen district. Near the headwaters of each stream are extensive outcrops of peridotite, which are associated with equally large areas of syenitic gneiss. There are smaller exposures of diorite, gabbro-diorite, and gabbro, all of which are represented by the same conventional sign on the map. Still farther downstream each creek passes into an area of porphyrites, within the limits of which are two associated exposures of Lower Devonian limestone. Beyond the

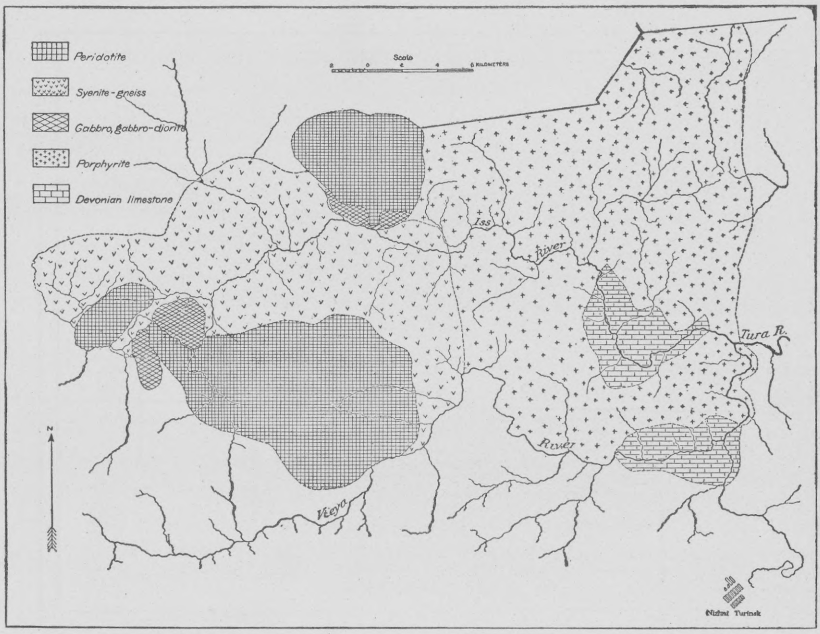

FIG. 6.—Geological map of the headwaters of the Iss and the Veeya rivers. (After a colored map by A. M. Saytzeff.)

junction of the Veeya and the Iss with the Tura the geology has not been colored on the map which accompanies Professor Saytzeff's report upon the platinum deposits, but the rock formations along the Tura seem to have no special connection with platinum, because the river derives all of its metal from its two tributaries. The fullest statement of geological details will be found in the paper by Professor Saytzeff, entitled Geological Investigations in the Nicholay-Pavdinsk district, which is subsequently cited in the bibliography. A brief outline, however, is here given regarding the several formations.

The syenite-gneiss is, as a rule, coarsely crystalline and well foliated, but it sometimes exhibits a finely granular structure and may pass to massive types. In the coarse varieties the reddish feldspar and the dark-green hornblende can be readily identified. The rock is greenish gray in color and contains veins and nests of quartz.

Under the general name of peridotite a considerable variety of rocks is included, viz, peridotite, olivine-gabbro, olivine-diallage rock and rock composed chiefly of diallage, and serpentine. All of these are closely related and pass one into the other by transition. Similar ones occur likewise in the district of Nijni-Tagilsk.

The diorites, gabbro-diorites, and gabbros are all closely related to one another by transitions. Gabbro seems to have been the original from which the others have been derived by the metamorphism of the pyroxene to amphibole. The rocks also exhibit gnessoid structure at times.

The porphyrites are chiefly diabasic and uralitic.

In addition to the rocks mentioned, talc-schist has been discovered in the soil of one or two of the mines. The Lower Devonian limestone is a dark or light-gray variety, and in some places has a purple-red color. It is fine grained and has many veins of calcite, some of which contain cinnabar. Pebbles of cinnabar from the veins are found in the gravels together with the platinum where the limestone forms the bed rock. The dip of the limestone is steep, and the riffles and pockets formed by its passage across the creeks furnish some of the richest deposits. The limestone is penetrated by igneous dikes, which are thought by some observers to have a connection with the introduction of the cinnabar.

Mother rock of the platinum.—Professor Saytzeff has carried out some investigations in order to trace back the platinum to its mother rock. He concludes, from its association with chromite and with serpentine, that the peridotite is the chief source, but that the metal is present in the syenites and the gabbros. As regards the latter rocks the conclusions are based chiefly upon the association of the nuggets in some places exclusively with bowlders of these types. Platinum seems actually to have been found only in the bowlders of peridotite or its derived serpentine. Mr. Purington pounded up a sample of serpentine taken from the gravels and weighing about 20 pounds. He succeeded in panning scales of platinum worth about 2 cents from it. This would be equivalent to about $2, or from a seventh to an eighth of an ounce, per ton.

Placers.—The placers are of two varieties—those which are in the beds of the running streams and those which are now above water. The former seem to be chiefly dug by hand dredges, and, so far as the descriptions lead one to infer, wing dams, sluices, and the familiar contrivances of our Western States seem not to have been yet introduced. The gravels which occur above the rivers are worked throughout the district. On the land there is a general surface layer of peat or vegetable material called turf. Below this is a variable thickness of poor gravel, and then the pay streak is met. The overburden varies from

5 to 20 feet, and the pay streak is 4 feet and less. The overlying material is stripped off, and then the productive gravel is carted to the washers. Less frequently the productive gravel seems to be a saprolite, or crust of decomposed peridotite, as described by Professor Saytzeff. Gold accompanies the platinum in a very subordinate capacity. As is usual in our Western placers, clayey streaks give the best returns. Opposite the mouths of tributary brooks the platinum is often particularly rich. The valley of the Iss narrows and widens, and the best placers are found in the wider reaches, where the velocity of the stream becomes checked. Where there are hollows in the bed rock, more especially in the limestone, the concentration is often marked.

Fairly large bowlders are sometimes present along the Tura, but on the Iss they do not exceed 18 inches. Only the local rocks are represented by them, and, as a rule, they are but slightly rounded. The region has never been glaciated.

Mr. Purington gives some estimates of value which are based on statistics obtained from local authorities and from his own pannings. From the grass roots down, the gravels over the whole region will not yield over 40 cents to the cubic yard. Along the Upper Iss 63 cents is the estimated contents, and on the Lower Iss 65 cents, for an average of $10\frac{1}{2}$ feet of gravel. Along the Tura the gravels, which are dredged in 7 feet of water, are estimated at 52 cents to the yard. These values would seem to be amply sufficient to afford a large margin of profit if, in other respects, the region is at all adapted to the methods of hydraulicking or dredging that have been developed in western North America.

In Professor Saytzeff's descriptions of the workings, many detailed cross sections of the gravels are given, together with pictures of the carts and washers. A description of the methods of working will also be found in Mr. Purington's recent paper, and those of the Nijni-Tagilsk region have been described and illustrated by Mr. G. F. Kunz and Prof. Henry Louis in papers to which reference will be subsequently made in the bibliography.

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NIJNI-TAGILSK DISTRICT.

The productive ground in this district is found about 22 kilometers, or about 18 miles, south-southwest of Nijni-Tagilsk. Platinum occurs

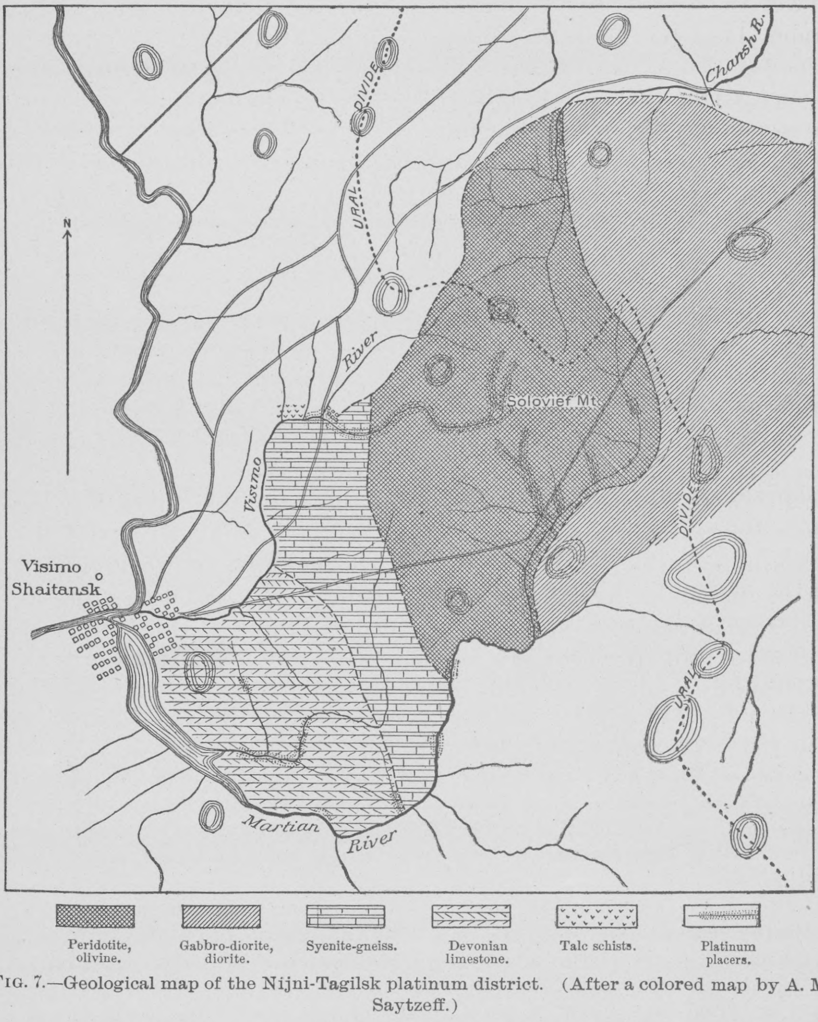

FIG. 7.—Geological map of the Nijni-Tagilsk platinum district. (After a colored map by A. M. Saytzeff.)

on both the eastern and the western watershed, but it is obtained more especially on the western. The streams head in Mount Soloviev. The Vissim, the Martian, and the Chansh (or Schaitansk) flow westward, while some of the headwaters of the Tagil, a tributary of the Tura, flow eastward. Mount Soloviev consists chiefly of peridotites, but it has associated with them the same gabbros, diorites, syenitic gneisses, and Devonian limestones which have already been mentioned under the northern district. The accompanying geological map, taken from Professor Saytzeff's paper, will give an idea of the geological relations. In their petrographic characters the rocks seem to be much the same as in the northern districts. The peridotite has, however, been somewhat fully described by Inostranzeff in connection with his investigations of the mother rock. A full translation of Professor Inostranzeff's paper is given on subsequent pages, and in it an outline of the peridotites will be found. The accompanying photomicrograph (Pl. VI, *C*) has been prepared from a specimen which was gathered in the region by Dr. G. P. Merrill in 1897, and which has been very kindly placed in the hands of the writer.

In connection with an investigation of the bowlders which had been observed to contain platinum, Daubrée has given an analysis of a specimen of the peridotite, as follows:

Analysis of peridotite from Mount Soloviev.

SiO_2	47.60
Al_2O_3	3
Fe_2O_3 and FeO	7.60
MgO	26
CaO	11.30
Loss on ignition	4.30
Total	99.80

Under the microscope it consisted of diallage, olivine, veins of serpentine, and chromite. Some small scales of platinum were noted in the rock.[a] It is interesting to compare this analysis with the analysis of the mother rock from British Columbia, p. 44.

In addition to the pocket of platinum-bearing rock which is described by Professor Inostranzeff, Prof. Henry Louis has mentioned a streak of serpentinized rock which was 6 feet wide and which was actually mined to a depth of 35 feet. It was crushed and washed, and yielded 15 dwt. per ton. Below 35 feet the values gave out.[b]

Placers.—As already stated, the placers lie mostly on the western watershed and are found over an area of about 80 square miles. They are similar in character to those described in the region farther north. The gravels are often from 30 to 40 or even 60 feet deep, and the pay streak lies upon the bed rock, and is 6 to 10 inches thick. Sometimes, however, another pay streak will be found part way down. The richest layers are somewhat irregular in shape and distribution. When next the bed rock they are usually attacked by shafts, from which the miners burrow out and through which they bring the gravels

[a] Comptes rendus, Vol. LXXX, 1875, p. 707.
[b] The Mineral Industry, Vol. VI, p. 542.

to the shaft and finally to the surface. The mining is done in the winter and the washing in the summer. The gravels are broken up by puddling machines and washed by being passed through sluices with riffles. A brief account of the methods of mining will be found in the paper by Mr. G. F. Kunz in the report on Mineral Industry of the Eleventh Census, page 341. The largest nuggets are obtained in this region, but the platinum is less pure than that gathered along the Iss. It is angular and of darker color and contains more iron, whereas along the Iss it is light colored, and is more apt to be in scales, especially when it is obtained at some distance from the mother rock. Many analyses of Russian platinum are given on pages 18–19.

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PRIMARY DEPOSITS OF PLATINUM IN THE URALS

By A. INOSTRANZEFF.[a]

Originally discovered in South America, platinum was brought to Europe in 1735,[b] and was recognized by Shaeffer as an element in 1752. Notwithstanding the fact that it was discovered so long ago, it has been extracted up to the present only from placers, and its original place of formation has been unknown. It is true that, as a mineral disseminated in hard serpentine rocks, platinum has been found

[a] Reported at the meeting of the department of geology and mineralogy of the St. Petersburg Society of Naturalists, November 7, 1892. (Translated from the Russian.)

Table of Russian weights.

1 poud = 40 funts = 36 pounds avoirdupois.
1 funt = 96 zolotniks = 0.9 pound avoirdupois.
1 zolotnik = 96 dolei = 0.0094 pound avoirdupois.

[b] Dana, Mineralogy.

in the mountains of Brazil and in the Cordilleras of North America,[a] but in such minute quantities that these discoveries could hardly be regarded as proving the original place of growth of the nuggets.

In Russia platinum was first found in the gold mines of Dakovlev in 1819,[b] later in the sands of Neviansk, Bilimbayevsk (1822), and Kuvshinsk factories (1824); and finally, in 1825, the richest Ural sands of the Sucho-Vissimsk works in the district of Nijni-Tagilsk were discovered.

According to Gustav Rose,[c] platinum occurs in the central and southern parts of the Urals, as well as in the northern, eastern, and western slopes. In the majority of places it is met in small quantities, associated with native gold. Only in the sands of the Nijni-Tagilsk works is platinum found in considerable quantity, and it is usually not associated with gold.

A study of Russian platinum has been made by many scientists, and a concise statement, enlarged by personal observations, may be found in an article by H. T. Koksharov,[d] in which he makes the following remarks: "The original place of deposition of platinum in the Urals has not been found as yet, but judging from the samples of native (virgin) platinum, in which can be seen adhering chromic iron, and sometimes, although seldom, serpentine, it should be sought for in the latter, as mentioned by Rose, because in serpentine chromic iron occurs in masses.

Daubrée,[e] in his experiments with the samples of the country rocks furnished him by Jaunez de Sponville from the mines of Tagilsk, found in them platinum associated with olivine, serpentine, and chromic iron. A close relation between the platinum of the sands and that of the rocks which contain olivine was determined by the same scientist in New Zealand, where the mines form a part of the Dun Mountains. This mountain is composed of a rock in which olivine predominates, and which was called "dunite" by Hochstetter. Daubrée observed a like relation of platinum sands to serpentine in the island of Borneo.

This summer I had occasion to travel in the Urals and to visit several places well known to geologists, among which were the mountainous district of Tagilsk, containing most interesting platinum mines. They are situated southwest of the Nijni-Tagilsk factory, along the rivers Vissim, Martian, and Chansh, on the western slope of the Urals. As has been known for a long time, the soil of the Tagilsk platinum mines, as well as a considerable part of the fragments found there, consists of serpentine and olivine rocks. There are also metamorphic schists and a peculiar conglomerate, which is developed in the neighborhood, consisting of fragments of serpentine and olivine rock and chromic iron, held together by a lime cement.

The platinum occurs in the sands in grains, and frequently in nuggets. [The largest found weighs 23.5 funts—21.15 pounds.] On washing the slimes, gold, iridium, and osmium are found.

The Tagilsk platinum mines are located along the rivers Vissim, Martian, and Chansh, which rise in the mountain Soloviev. The distribution of the platinum around about the Soloviev Mountain suggested long ago the advisability of searching in the mountain for its original source, but all prospecting has remained fruitless. At the time of my visit to the Tagilsk mines I had the opportunity of witnessing the discovery of the original place of deposition of platinum in the Urals. This discovery, like many others, was due to a laborer who had no license to perform any work there, but did it on his own account. Such persons are known in Siberia as plunderers or pillagers.

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[a] Mining Journal, 1891, Book III, p. 324.

[b] Minchin, Chemical analysis of the different kinds of Uralitic platinum: Trans. Min. Soc., Part II, 1842, p. 101.

[c] Reise nach dem Ural, dem Altai und dem Kaspischen Meere, Vol. II, 1837.

[d] Materials for the Mineralogy of Russia.

[e] Daubrée, Association de platine natif à des roches à base de peridot, Paris, 1876.

The manager of the platinum mines, Mr. Costenetzky, learned that in the northern part of the Soloviev Mountain such a plunderer was excavating the rock, and that this rock was being crushed and washed in a neighboring river. The plunderer noticed that he was being watched and ran away. It was therefore impossible to know whether he actually obtained platinum or anything else. This circumstance, however, led the manager to begin a reconnaissance of the locality. Through the kindness of the Tagilsk administration and Mr. I. A. Hamilton, some of the rock where the laborer had conducted his work was blasted with dynamite, and on the freshly formed surface could be seen the following: The massive rock in its fresh fracture appeared blackish green, with polyhedral jointings. The portions along the crevices were of a whitish-yellow color, and surrounded the cleavage planes like a band, giving the appearance of an altered mass of rock. In the place where the laborer conducted his work there was discovered a pocket, 35 cm. in diameter, which extended deep into the rock.

As compared with the native rock, this rock appeared, when fresh, to be of a less compact nature, and could be quite easily split to pieces with a chisel; but if left in the air it would harden. In some places this rock was very close to the altered surface of the native rock, while in others it was directly in contact with the fresh, unaltered country rock. Besides, between the pockets there could be seen separate small pieces of the native country rock. The rock containing the pockets consists principally of chromic iron, serpentine, and dolomite, the last named of which is in small quantities in the form of cement, and a still lesser quantity of opaline silica, which appears sometimes as a spheroidal mass.

In connection with the distribution of the serpentine and the chromic iron it may be noticed that they are frequently in layers parallel to the plane of contact with the neighboring country rock.

This method of distribution reminds one of the distribution of serpentine in some of the ophicalcites.

The country rock is of a finely granular texture, and in thin sections one may observe with a microscope transparent greenish grains of olivine, which largely make up the mass of the rock. The bands consist of rock partly unaltered and partly altered through the process of superficial change to the yellowish serpentine.

Under the microscope the wall rock exhibits crystallized grains of colorless olivine of varying size and with a characteristic shagreen surface. The grains were grouped so that, with the binding mass, they represented a hexagonal contour, and their outline resembled the section of a crystal of olivine. The mass that binds these grains together is a light-green serpentine, distributed in colored veins which have a foliated structure. Through the serpentine is disseminated a little chromic iron, which appears by reflected light to have a dull luster. It is more in evidence in places where some of the material crumbled out in preparing the sample for examination. The olivine predominates over the serpentine. In polarized light the olivine exhibits strong interference colors. Serpentine under the same conditions reveals a granular structure. But in some places one may detect with polarized light sporadic inclusions of grains of dolomite. In treating the substance with H_2SO_4 the acid dissolves a considerable quantity of iron and attacks the olivine, removing it and separating out an amorphous silica. In this reaction the serpentine loses its original color and is darkened, but the grains of dolomite are completely dissolved. Being guided by the principal component parts of the country rock of the Soloviev Mountain—that is, olivine and chromic iron—and considering serpentine as a product of the change undergone by olivine, one sees clearly that the serpentine has been derived from that variety of peridotite which is called dunite.

Comparing this rock with the real dunites of other countries, we see a material difference, viz, that the latter consist almost entirely of olivine, while in the former there is some serpentine, which has undoubtedly been produced from olivine by metamorphic processes, as is shown by the hexagonal section occupied by separate fragments of olivine all bound together by serpentine.

Such a rock might be called paleodunite; but we must not overlook the fact that in the olivine rocks several are connected by transition, and the decrease of one of the component parts in one rock may lead to its transition into the other. Thus the presence of enstatite makes a special variety, but it may decrease in amount almost to disappearance. Such a rock was described by Wadsworth[a] under the name saxonite, but Rosenbusch[b] did not accept the name, and renamed it harzburgite.

Nevertheless, the description of saxonite, furnished by Wadsworth and illustrated in Pl. IV, fig. 4, of his work, reminds us of the rock of the Soloviev Mountain, with only the difference that in the latter no enstatite was disclosed and there is considerably more olivine than in saxonite (harzburgite).

Under the microscope the rock with pockets appears to consist of many irregular angular grains of chromic iron, and to be fractured and have many cavities. The cementing material between the grains of chromite is chiefly serpentine, and in lesser quantity dolomite and opal, the last named sometimes in beautiful spheroidal masses. The last two minerals penetrate the crevices and cavities of the chromic iron.[c] In reflected light the chromic iron exhibits a weak, black, shining metallic luster; but no other minerals with a metallic luster can be seen. A few pieces of the rock (with pockets) could be observed, by means of a strong magnifier, to contain exceedingly fine grains or leaves of native platinum disseminated in the chromic iron. This search for it, by the way, was very difficult on account of the presence of the hollows in the seams of the chromic iron, which in a certain position before the light gave an exceedingly strong luster.

To determine the presence of platinum in the rocks (with pockets) in which the platinum could not be seen by means of a microscope, about 14 funts (5,733 grams) of it was taken from the place of blasting, crushed, and carefully washed. On obtaining the slime in the iron pan used in the washing, under the water there was observed a thin silvery band of native platinum, which was difficult to separate from the chromic iron by continuous washing on account of the danger of losing the fine microscopic leaves.

On examining the slime, even with a strong magnifying glass, no platinum was found. The examination was interfered with largely by the mass of angular grains of chromic iron, which possesses a strong, metallic, glassy luster, and by the size of the platinum, which was microscopically minute. The quantity of concentrates obtained in this experiment was 25 grams, and in order to find the chemically pure platinum, the following method was adopted. The concentrates were treated with aqua regia, the solution each time being evaporated to dryne s on a water bath; the residue was then treated with sulphuric acid twice and again evaporated to dryness on a water bath. The residue was then treated with absolute alcohol, filtered, and to the clear solution was added solid ammonium chloride in excess. The solution was then slightly warmed and ammonium chloroplatinate precipitated. The precipitate was then filtered out and dried in the filter, ignited, and weighed in a porcelain crucible.[d] The platinum obtained was then treated with aqua regia, in which it dissolved completely, thus proving the absence of iridium. The solution was evaporated to dryness in a water bath, the residue treated twice with sulphuric acid, and again evaporated to dryness. After washing the residue, a few qualitative tests were made. A part of the solution was reduced by zinc, and chemically pure platinum was obtained. This was tested

[a] M. E. Wadsworth, Lithological Studies, 1884, p. 125.

[b] Rosenbusch, Mikroskopische Physiographie, 2d edition, 1887, p. 269.

[c] H. J. Joss, who came at the time of my return from the platinum mines in Tagilsk, brought several samples of native rock to St. Petersburg. These samples were shown at the meetings of several scientific societies of the city.

[d] In all my experiments with platinum, no platinum apparatus of any kind was used. All solutions, ignitions, and weighing were made in porcelain apparatus.

with platinum iodide, for the characteristic platinum reaction, and afforded a rose-crimson color.[a] In all, 0.0644 gram of chemically pure platinum was obtained from the slime, or considering the weight of the whole quantity of rock employed in this experiment (5,733 grams), it produced 0.00112 per cent of platinum.

Bearing in mind the fact that the platinum is found here in exceedingly fine particles, we might justly suppose that in the rough washing which was performed a part of the platinum was carried away by the water, and that the given figure is probably below the correct one. In order to obtain an accurate result, 500 grams of the rock was crushed and carefully mixed, and from this was taken 100 grams, which was treated twice with aqua regia. This solution was carefully evaporated to dryness on a water bath and the residue treated with sulphuric acid twice, with repeated evaporation. Then the residue of silicic acid was filtered out. The filtrate was again evaporated to dryness on a water bath and the residue dissolved in alcohol. Slightly warming this solution with chloride of ammonium, just as in the previous experiment, a precipitate of ammonium chloroplatinate appeared. This was collected on a filter, rinsed, dried, and by ignition converted into chemically pure platinum, amounting to 0.0103 gram, or 0.0103 per cent of the rock. This platiuum was treated qualitatively in the same way as that obtained from the concentrates.

From the same 500 grams of the crushed rock another 100 grams was taken and treated with aqua regia six times. In this operation 35 grams of the rock went into solution. The filtrate was separated first with an excess of sulphuric acid, then with water to dryness on a water bath. The solution in water, with the addition of a little sulphuric acid, was filtered from the precipitate. The platinum was reduced by zinc, collected on the filter, washed, and dried. The filter was then burned and the platinum weighed, amounting to 0.0111 gram, a quantity nearly the same as that obtained with ammonium chloroplatinate (0.0103 gram). Therefore the average amount of chemically pure platinum contained in the rocks may be taken as 0.0107 per cent.

Comparing the results of the last experiment with the determination of platinum in the concentrates, it is evident that in washing the crushed rock there was a loss of platinum, first because the water carried some away; and, secondly, for the reason that in 14 funts of the material used it was difficult to pick out only the rock with pockets. Some of the native olivine rock was present and thus reduced the percentage of the metal.

Rock containing platinum is found in the pockets, with dunite, although the metal occurs in an exceedingly fine state. Platinum is usually associated with other precious metals, such as gold, silver, iridium, osmium, etc., and the deposits in these mountain rocks are no exception to the general mode of occurrence. The amount of platinum is somewhat sporadically distributed, at one time enriching the accompanying rock and at another decreasing to complete disappearance. Of course we have a right to suppose that platinum is sporadically disseminated in its native rock, and it is possible that the laborer had already worked out that part of the pocket in which the platinum was not of microscopic size nor in sparsely distributed condition. This fact also points to the finding of platinum in the sand, in which it can be seen with the naked eye, disseminated in chromic iron. Of course the continuation of the investigation in the Soloviev Mountain must disclose such pockets, and it is not improbable that veins will be discovered in considerable number. It may be that in this rock (with pockets) will be found microscopic particles of platinum which can be extracted by washing, although now it can be extracted only by chemical means.

The place of discovery, at all events, contains a considerable quantity of the metal, and, expressing it in the ordinary way, it is 41 zolotniks to every 100 poods of rock. At the present time in the Tagilsk platinum mines rock is being worked which contains 2½–12 zolotniks per 100 poods.

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[a] Annales de Chemie et de Physique, 1832.

From further investigation we may expect some additional information to that reported by myself. But, in all events, 150 years had elapsed before the original place of deposition of platinum was discovered. Speculations, as expressed by different investigators, concerning this mountain rock which contains the precious metal, are now out of place. There is no doubt that the original source of platinum is peridotite, to which future investigations in the different parts of the Urals, one of the most interesting regions in the world, should be confined.

PLATINUM ELSEWHERE IN RUSSIA.

Platinum has been reported in a number of other places in the Russian Empire. Federov has mentioned its occurrence, together with gold, in the extreme north of the kingdom of Perm, along the Loswe River and its tributaries. Syenitic gneiss seems to be the prevailing country rock.[a] Platinum is said to occur along the Ivalo River in Lapland, associated with diamonds and probably derived from a peridotite.[b]

Platinum is said to have been found in traces in the province of Baikal and Yenisei, Siberia.[c]

Palladium has been reported by T. W. Wilm in the gold-bearing sands on the south coast of the Black Sea. It is stated that it constitutes 8 to 10 per cent of the concentrates.[d]

Platinum is said by J. A. Phillips[e] to occur in small quantities in the auriferous quartz of the Beresovsk gold mines. Beresovsk lies a few miles northeast of Nijni-Tagilsk.

SPAIN.

One of the most interesting discoveries in connection with platinum was made early in the last century by the French chemist Vauquelin. He received a suite of ores from a silver mine at Guadalcanal, a few miles northeast of the Rio Tinto district, Seville. The ore resembled tetrahedrite closely, and on analysis was found to contain copper, lead, antimony, iron, sulphur, silver, and sometimes arsenic. It was associated with a gangue of calcite, barite, and quartz. The platinum proved to be variable, reaching at times 10 per cent and again being present only in traces. The same was true of the silver.[f] The silver mines of Guadalcanal are situated north of the city of Seville. The country rock is mica-shist, and the mines were formerly very productive, but are now of little importance.[g]

This discovery of platinum in a mineral containing copper, together with antimony and sometimes arsenic, and in an undoubted vein, is

[a] Mineralogisches aus dem nördlichen Ural, by E. V. Federov: Tschermaks mineral. Mittheil. Vol. XIV, 1894, pp. 85, 143.

[b] A. E. Nordenskjöld, Poggendorffs Annalen, Vol. CXL, 1870, p. 336.

[c] Notice explicative sur la carte minéralogique de la Siberie (prepared for the Paris Exposition, 1900), p. 10.

[d] T. W. Wilm, Russ. Phys. Chem. Gesell., St. Petersburg, March, 1893.

[e] Treatise on Ore Deposits, 2d edition, pp. 545–546.

[f] Notice sur l'existence du platine dans les mines d'argent de Guadalcanal en Estramadura: Annales de Chemie, Vol. LX, 1806, p. 317.

[g] Ore Deposits, by J. A. Phillips, 1896, p. 493.

extremely interesting and important. Reference may be here made to the additional occurrence of platinum with tetrahedrite in the Alps and the neighboring parts of France, as is described under "France," p. 65. The similar occurrence of platinum in the form of sperrylite in the Sudbury region of Ontario may be likewise mentioned in this connection, and the ore at the Rambler mine, Wyoming.

AFRICA.

ALGIERS.

The only mention of platinum in Africa that has been met by the writer is a brief note by G. Aimé upon an occurrence of galena at a place called La Bouzaria, a few miles from the city of Algiers. The communication was made to the French Academy and the sample was handed to MM. Berthier and Becquerel for verification of the reported presence of platinum, but the results of their assay have not been found.[a]

ASIA AND THE EAST INDIES.

BORNEO.

Platinum was discovered in 1831 in the gold washings of Goenoeng Lawack, southeastern Borneo. The gravels occur in a hilly country. Their bowlders are diorite, syenite, copper, and fragments of quartz, which are mingled with a sand of quartz and magnetite. They range from several feet to several fathoms in thickness, and toward the coast are buried beneath marshes. Cinnabar is said to accompany the grains. When analyzed, samples afforded the following results:

Analyses of platinum nuggets from southeastern Borneo.

	1	2	3
Pt	70.21	71.870	82.60
Ir	6.13	7.920	.66
Rh	.50	1.286 (Rh and Pd)	--------
Pd	1.44		
Os	1.15	.480	.30
Au	3.97	--------	.20
Fe	5.80	5.866	10.67
Cu	.34	.430	.13
Iridosmine	8.83	8.430	3.80
Hg	--------	.658	--------
Fe_2O_3	1.13	.420	--------
Cu	.50	--------	--------
Insol	--------	2.240	--------
Loss	--------	.400	--------
Total	100.00	100.000	98.36

NOTES TO TABLE.

1 and 2. Bleekrode, Platinerz von Borneo: Poggendoff's Annalen, Vol. CIII, p. 656. Platinerz von Goenoeng Lawack auf Borneo: Idem, Vol. CVII, p. 189.

3. M. Bocking, Liebig's Annalen, Vol. XCVI, 1855, p. 243.

[a] Mineral de plomb sulfuré d'Alger, by G. Aimé: Comptes rendus, Vol. VII, 1838, p. 246.

The Fe_2O_3 and Cu mentioned at the end of the analysis were insoluble in HCl.

The following microscopic minerals occur with the platinum grains: Topaz, zircon, ruby(?), diamond, quartz, and feldspar, but no ilmenite.

According to L. Horner the gravels occur in the drainage area of the Banjermassing River, which rises in the Ratoos Mountains. The mountains consist of serpentine, diorite, and gabbro. A red clay lies at their bases and contains the gravels which hold the gold and platinum. The platinum is to the gold as 1 to 10, but at the time of Horner's observations it was thrown away. He estimates that 10,000 ounces were being lost yearly (1842).[a]

BURMA.

Platinum has long been known as an associate of gold in the placers that are washed near Ava, in Upper Burma. The locality does not, however, appear to be commercially productive.[b]

JAPAN.

In a catalogue of the minerals of Japan in the collection of Mr. T. Tsunashiro for the Paris Exposition platinum and iridosmine are reported as occurring in grains in the sands of the river Yubari, Ishikari.

AUSTRALIA AND OCEANIA.

NEW CALEDONIA.

Scales of platinum have been observed in the gold-bearing sands of Andam Creek, below Boudé.[c]

NEW SOUTH WALES.

Platinum has been discovered in several localities in New South Wales. The one which first attracted attention is in the northeastern corner of the province, on the seacoast, between the mouths of the Richmond and Clarence rivers. For many years the sands have been washed for gold. More or less platinum occurs as well, and from time to time a few ounces have been saved. It is, however, of no great economic importance.

In 1889 platinum was discovered in some peculiar deposits near Broken Hill, the famous lead-silver camp, in the extreme western part of the province. In the course of a few years the matter was carefully investigated, more particularly by Mr. J. B. Jaquet. In the platinum-bearing localities the country rock consists of schists,

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[a] L. Horner, Poggendorff's Annalen, Vol. LV, 1842, p. 526. In Beck's Erzlagerstätten there is cited a paper by T. H. Posewitz, Das Diamanten-Vorkommen in Borneo: Jahrbuch K. Ungar. Landesanstalt, Vol. VII. It is not accessible to the writer.

[b] J. Prinsep, Poggendorff's Annalen, Vol. XXXIV, 1835, p. 380; A. Faber, Pharmac. Centralblatt, 1848, p. 569.

[c] Pelatan, Les mines de la Nouvelle Calédonie, Paris, 1892, p. 53. This citation is quoted from A. Lacroix, Mineralogie de France, Vol. II, p. 390.

gneisses, and quartzites, all of which are highly altered sediments of Lower Silurian age. They have been penetrated by dikes and bosses of granite and very basic diorite. Some serpentine likewise occurs within 6 or 7 miles. The platinum has been detected in a very peculiar ferruginous deposit, which is similar to the gossan of the normal vein. These gossany outcrops are irregular and never extensive. They cap the altered sediments and eruptive rocks alike, and no definite law of distribution can be detected, but at times they certainly are situated at the junction of a compact and a more loosely textured rock. As they are followed down, the ferruginous character diminishes, and the deposit passes into ferruginous clays, and these

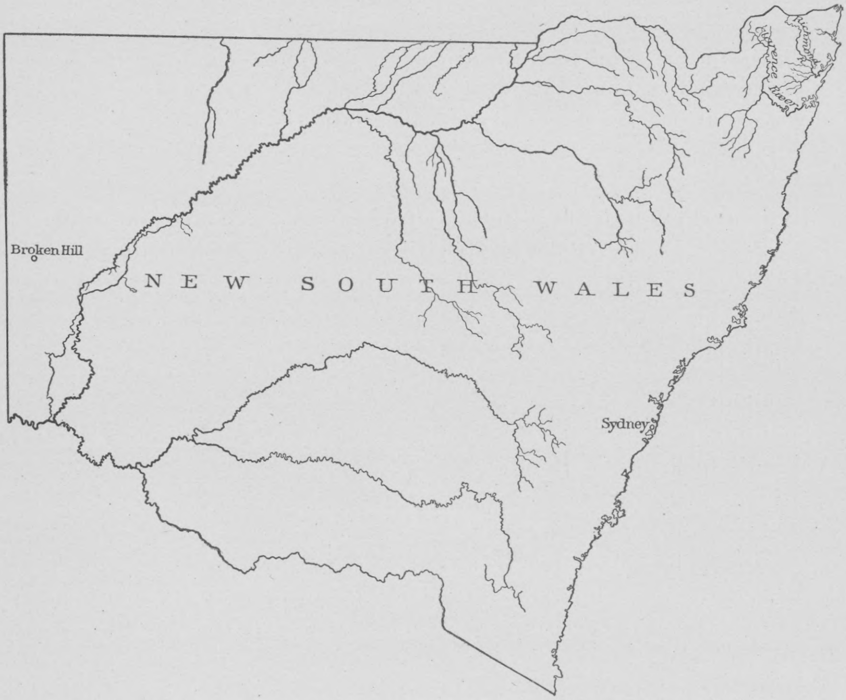

FIG. 8.—Sketch map of New South Wales, showing the distribution of platinum.

into granules of silica cemented with kaolin, or into kaolin itself. Decomposed feldspathic rock ensues, which may represent either gneiss or a portion of a granite dike. There are no defined walls. The platinum-bearing rock passes gradually into the others. The platinum occurs distributed through the decomposed material, but more abundantly in the clays and kaolins than in the iron cap. Shafts have been sunk to a depth of 20 feet, and many assays have been made. The yield is extremely variable, but it may be said to range from an ounce and a half down to a quarter of an ounce or less per ton. Copper has been met in some of the outcrops, but no traces of copper pyrites or other iron or copper sulphide ores have been found.

No platinum has been detected by the eye. It is so extremely fine that it is known only by assay. Mr. Jaquet states that there is no analogy between these deposits and well-defined lodes. He concludes that they have been produced by springs, which issued at one time where the deposits are now found. Iron, copper, and platinum were thus probably carried to the surface. The iron and copper were precipitated by the oxidizing action of the atmosphere, but the platinum was absorbed by the clays and kaolin. Platinum is not known, however, beyond a few feet in depth.

This occurrence is a most extraordinary and interesting one, and proves beyond question that platinum is not limited to placers, nor, indeed, to basic igneous rocks. If Mr. Jaquet's conclusions are cor-

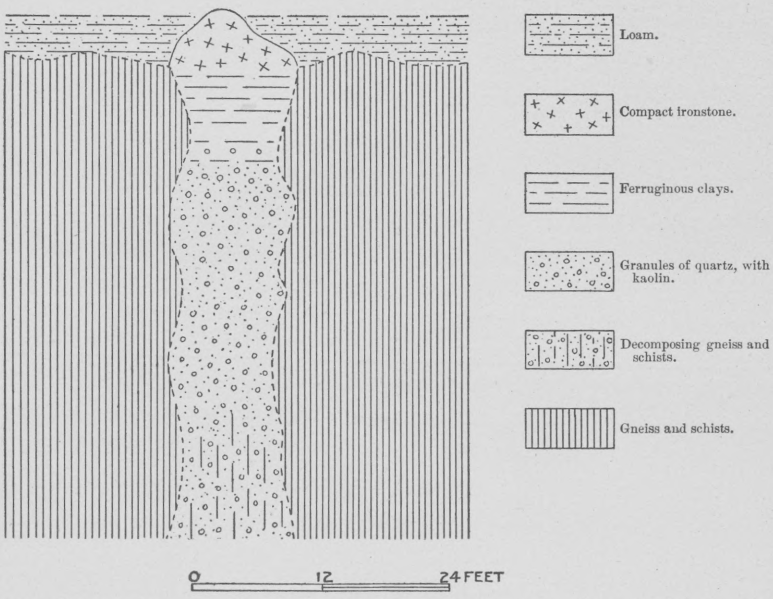

FIG. 9.—Geological section of the platinum deposit near Broken Hill, New South Wales. (After J. M. Jaquet.)

rect it would certainly seem to be demonstrated that platinum circulates in solution. Some years after the above discovery platinum was found in commercial quantity in the deep placers of Fifield. The country rocks at Fifield are Silurian and Devonian. Silurian slates have been penetrated by diorite, which consists of hornblende, plagioclase, and accessory sphene and quartz. One gold-bearing reef has been located in the diorite. The gold and platinum bearing gravels form a lead from 60 to 150 feet wide, which extends for a little over a mile. They are covered by 60 to 70 feet of loam, with occasional bands of barren quartz conglomerates. The platinum and gold occur as small waterworn grains in crevices in the bed rock and in the few inches of sand just above it. The nuggets range up to 5 dwt. It is thought by Mr. Jaquet that the platinum and gold have been concentrated from the neighboring conglomerates, which are supposed to be Tertiary.

Platinum has also been discovered as a rare mineral in a few additional gold washings in the colony.

For a general list of papers bearing upon the economic resources of New South Wales, see the bibliography prepared by W. S. Dun, which has been published in the Records of the Geological Survey of New South Wales, Vol. VI, Part IV, pp. 183–357. For platinum, see more especially pp. 312–314. In this place only the more important papers will be mentioned:

On the beach sands, see the Records of the Geological Survey of New South Wales, Vol. IV, Part I, page 25; also Proceedings of the Royal Society of New South Wales, Vol. XXVI, p. 368. Brief notices appear in the Annual Reports of the Department of Mines and Agriculture.

On the deposit near Broken Hill, see J. B. Jaquet, Report of the Department of Mines and Agriculture for 1892, p. 143, and the Records of the Geological Survey of New South Wales, Vol. V, 1896, p. 33. An abstract appears in Zeitschr. für prak. Geologie, 1893, p. 322.

On the Fifield deposits, see G. W. Card, Records of the Geological Survey of New South Wales, Vol. IV, p. 130; also J. B. Jaquet, Report of the Department of Mines and Agriculture, 1895, p. 181, and Records of the Geological Survey of New South Wales, Vol. V, p. 34.

Attention should be directed at this point to the remarkable occurrence of platinum in Australian coals which is described earlier in this paper (p. 35). It is not known to the writer from which one of the colonies the coal was obtained.

NEW ZEALAND.

Platinum has been found over a considerable area in New Zealand almost entirely in connection with the gold washings. It occurs in the eastern part of Middle Island, on the Cluthe River, and in a few gold districts of the Nelson region in the northern part of Middle Island. Iridosmine is frequent in the latter. It was noticed in this district by von Hochstetter. Some small scales of iridosmine were brought back by him from the Takaka diggings. The occurrence of the metal in this district is of extreme interest when taken in connection with the country rocks of the Urals and of British Columbia. As is well known, Baron von Hochstetter discovered in the Dun Mountains, near Nelson, the very peculiar rock, consisting of olivine and chromite, which he named dunite. It is almost exactly the same in mineralogical composition and texture as the chief mother rock which has been found in the other two platinum districts just cited.

One other interesting feature of the New Zealand gravels is the occurrence of bits of nickel-irons in association with the platinum. Like it they appear to be excessively basic segregations in igneous rocks. In the Zeitschrift für praktische Geologie for June, 1898, p.

222, a stray paragraph appears in which it is stated that in the Nelson district of New Zealand platinum has been found in an eruptive rock near the Takaka River. The eruptive breaks through limestone and the quantity is not commercial, but further particulars of the original source of the statement are not given.

COX, S. H., Notes on Mineralogy of New Zealand; Trans. New Zealand Institute, September to November, 1881.

HAMILTON, W. S. On platinum crystals in the iron sands of the Orepuki gold field: Trans. New Zealand Institute, Vol. XVIII, p. 402.

HOCHSTETTER, F. M. Geologie von Neu-Seeland, Vol. I, 1864, p. 212.

TASMANIA.

Within the last few years the iridosmine which has been discovered in the gold placers of western Tasmania has assumed commercial importance. The need of osmium for certain forms of incandescent burners had brought these placers into notice. Montgomery states that a good deal of platiniridium and iridium is obtained along the Savage River, having probably been derived from the serpentine which is known upstream. Platinum itself is reported from the Wilson River, and osmiridium, containing, however, very little osmium, from parts of the King River gold field and the Salisbury field, near Beaconsfield. The original matrix has not been discovered.[a]

CONCLUSION.

A careful review of the facts set forth in the preceding pages makes it possible to establish the following types of ore deposits and mineralogical associations for the platinum group of metals.

I. Placers.—The platinum has been mostly derived from peridotites, but also in less degree from pyroxenites, gabbros, metamorphosed gabbros (now dioritic rocks), and syenites, often gneissoid.

Geologists have long appreciated the importance of the peridotites, but have not generally realized that, in a minor degree, the syenites are also of wide distribution and that they likewise deserve emphasis. Thus, for example, they are recorded in the Urals, in Colombia, Brazil, and British Columbia.

II. Veins.—Platinum or palladium has been observed in veins in connection with gold at Tilkerode in the Hartz; in Minas Geraes in Brazil; at Santa Rosa in Colombia; and at Beresovsk, Russia. Whether the platinum or palladium is or is not associated in these localities with other metallic sulphides, such as are mentioned below, does not appear from the incomplete records.

The peculiar deposit at Broken Hill, New South Wales, may be mentioned in this connection, although it differs from the type.

[a] A. Montgomery, The Useful Minerals of Tasmania. (The statements are taken from a reprint kindly sent the writer by the author; but although evidently from some scientific society, it bears neither date nor reference.)

Platinum as a subordinate component in complex antimonial sulphides of copper and other metals (i e., tetrathedrite and bournonite) occurs in veins at Guadalcanal, Spain, and probably also in veins in the Val du Drac and elsewhere in eastern France. While this association is as yet only of mineralogical interest, it nevertheless shows that platinum *can* occur in this way, and makes it desirable that similar ores be tested where found.

Sperrylite occurs with covellite at the Rambler mine, Wyoming.

III. Platinum disseminated in eruptive rocks.—The platinum occurs in two forms. The first is the arsenide, sperrylite, which is associated with copper-nickel ores in uralitized norites, at Sudbury, Canada. The mother rock of the North Carolina sperrylite has not yet been fully described and interpreted. Platinum in polydymite may be mentioned as a corollary to the Sudbury occurrence.

In the second form the platinum in the native state is contained in basic eruptives, more especially peridotites. The platinum is frequently involved in a very intimate way with chromite. In the most natural interpretation of the phenomena the two minerals are regarded as having crystallized in the normal passage of the fused magma to the solidified condition. It should be clearly stated, however, that two views have long prevailed regarding chromite. Its deposits which are large enough to mine are so uniformly in serpentine, and are so often of such great extent, that the chromite has been believed by some to be a product of metamorphism. Its masses are supposed to be segregations which have resulted from the change of anhydrous chromium-bearing silicates to the hydrated form, with attendant separation of chromic oxide.[a]

On the other hand, chromite has been looked upon as a true igneous mineral; it has been discovered in basic eruptives, not in the least changed to serpentine; and it has therefore been believed to be, even when in serpentine, an unaltered survivor from a previous anhydrous magnesian eruptive.

In the one or two cases in which platinum has been discovered in quantity in the country rock (on Mount Soloviev, Nijni-Tagilsk district) it has certainly been associated with an altered and serpentinized or even carbonated form of peridotite. It is fair to raise the question whether the presence of the platinum is in any way connected with this excessive alteration, or whether the change happened to take place where the platinum was previously abundant. In the Tulameen district A. W. Johnston and the writer have found platinum in serpentinized belts along dislocations, but many belts have also been tested which gave no platinum. In these occurrences the platinum is so excessively fine that evidence is not easily attainable as to its relations to the mother rock. In the present state of our knowl-

[a] A brief review and discussion of this difference of opinion, together with citation of authorities, will be found in the writer's Ore Deposits of the United States and Canada, 1900, p. 413.

edge it might be possible to develop an argument not easy to refute, that the platinum in these surroundings had entered in solution or had been deposited in connection with the secondary changes, and yet from a study of many nuggets and from very careful and detailed observation of the peridotite on the Tulameen, it is the writer's belief that the platinum is, in far the greater part, a true igneous mineral. This belief rests upon the following grounds:

1. Some nuggets contain the platinum associated with perfectly fresh olivine, and the relations are precisely those of two minerals which have crystallized from fusion and of which the platinum is the older. Had there been any secondary introduction of platinum, so sensitive a mineral as olivine would have shown some signs of change.

2. The platinum and chromite can be satisfactorily explained, as regards their relations, on the basis that the chromite is a slightly older mineral, which has become involved in and with the platinum, and that the latter has crystallized a little later. That the period of the much more abundant chromite has lasted into that of the rarer platinum, or even longer than it, is quite possible, because of the influence of the principle of solution. Chromite is somewhat more infusible than native platinum,[a] as has been shown experimentally by the writer's friend, A. W. Johnston. Nuggets of associated chromite and platinum have been placed before the oxyhydrogen blowpipe, and the platinum has been fused to globules and beads upon the still unaffected chromite, which, however, finally slagged over. No mineral in a fused magma can crystallize out at a temperature above its fusing point, although its elements or ions may be held in the molten mass, because of phenomena of solution, at a temperature considerably below its fusing point under the conditions of pressure prevailing at the time. It is therefore quite reasonable that chromite should have first begun to crystallize, and that around centers thus set up platinum should have later separated out, and should even have entirely inclosed chromite or have been itself inclosed by the continued growth of the chromite. In this way the structures shown in the drawings of nuggets given on a previous page can be satisfactorily explained. That, however, the platinum and chromite which, perhaps in a very finely divided state, have thus once formed may have later passed into solution and have become segregated and concentrated is not to be denied, but, so far as the writer can learn, our knowledge of the chemical relations of the two elements is so limited that the nature of such solution and precipitation can not be outlined.

Iridosmine is invariably involved in a mechanical way with the platinum, and it also occurs as a separate mineral. Iridosmine is

[a] It must be remembered that the so-called native platinum is not the pure metal, but an alloy of predominant platinum with other metals of the group and with never-failing and important iron, minor copper, and frequent gold, all of which affect the fusibility.

excessively infusible, and because of this character it probably crystallized before the platinum and then became mechanically involved in the latter. When now found free it probably formed amid surroundings where little or no platinum was present.

When platinum is observed associated with olivine and free from chromite, it is probable that in this portion of the magma there chanced to be little or no chromic oxide, just as, vice versa, we repeatedly find chromite and no platinum.

J. H. L. Vogt, in one of his valuable and suggestive papers, has outlined a course for the crystallization and separation of the platinum somewhat different from the one here given.[a] Vogt had his attention specially focussed on the iron in the platinum and iridosmine, and endeavored to place the latter two in line with the terrestrial and meteoric irons of various kinds. In the present discussion attention is fixed upon the phenomena of the chromite, platinum, and iridosmine as presented in their actual occurrences. Vogt, consequently, considers the iridosmine as the culminating stage in the separation of the platinum group, whereas the writer regards it as the first development and the forerunner.

Stanislas Meunier has taken a quite different view regarding the origin of the platinum as well as of terrestial irons, of magnetite, chromite, and even of other metallic minerals. A. Inostranzeff has remarked the irregular shape of some of the Russian platinum and its lack of crystal form as observed in the mother rock. Professor Meunier lays great emphasis upon this character, and draws analogies between it and the relations of certain magnetites, chromites, and terrestial and meteoric irons to their associated silicates. The metallic minerals are described as ramifying throughout the other silicates and as even penetrating their cleavage cracks in such a way as to support the inference that they are of later origin than the silicates. Professor Meunier then states that by introducing volatilized chlorides of iron, nickel, platinum, etc., together with hydrogen, into a porcelain tube heated to redness and containing fragments of pyroxene, olivine, or rock, he is able to deposit the metals or alloys of several metals in the interstices in such a way as to imitate closely the natural occurrences. By varying the gases he can make magnetite, chromite, and even silicates. He therefore concludes that the native platinum has been brought in, presumably in a similar manner, and has been deposited so as to yield the nuggets.[b]

While it is of great interest to know that the single metals, their alloys, and even the silicates can be deposited in this way, yet crystallization from fusion appeals to the writer as equally competent to bring about the observed results and as having much greater claims to probability and therefore to general confidence.

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[a] Compare Zeitschr. für prak. Geologie, July, 1893, pp. 267-268.

[b] A summary of much previous work by Professor Meunier is given in the Comptes rendus de la VII Session, Congrès Géologique International, p. 157.

One or two final conclusions of practical value may be drawn in closing this paper.

1. Experience thus far gained leads to the conclusion that platinum is very sparsely distributed in its mother rock and that the chances of finding it in quantities sufficient to mine are small. There is, nevertheless, a chance. If found, the recovery of the platinum by any means other than stamping and washing remains to be solved, and as the metal may be in a very finely desseminated state, this problem is a serious feature of the situation.

2. Large and permanent placers are to be looked for only in very old land areas which have been subjected to protracted degradation and concentration.

3. In the assay of antimonial, arsenical, and other copper ores, but especially of tetrahedrite (gray copper or fahlerz), it is worth while to look for small percentages of platinum.

4. Deposits of chromite deserve similar testing.

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