Art. XLII.—*The Platinum Gravels of Orepuki.*

By R. A. Farquharson, M.Sc.

[*Read before the Otago Institute, 2nd August, 1910.*]

With the advent upon the world's arena of modern electrical apparatus, accurate methods of chemical analysis, and improved methods of sulphuric-acid manufacture, the demand for platinum, both pure and alloyed, has gone up by leaps and bounds; so much so, indeed, that the supply is falling short of the demand. When we consider this, and also the fact that at the present time one country itself—Russia—supplies over 90 per cent. of the world's annual consumption of the metal, it is at once evident that prices must rapidly increase, and platinum become an article of great commercial value. It has seemed advisable, therefore, not so much from a scientific as from an economic point of view, to investigate the occurrence of the metal in New Zealand. In this investigation attention will, on account of the magnitude of the task, be necessarily limited almost entirely to Otago, though an account will be given as complete as possible of its occurrence in other parts of the Dominion.

As far, then, as recorded observations go, platinum in New Zealand may, generally speaking, be said to occur as follows: (1) In Auckland Province, in two places; (2) in Nelson Province; (3) in Stewart Island; and (4) in Otago, in two places.

In Auckland the more notable of the two occurrences may be described as follows: In 1882, while a shaft in one of the mines of the Thames Goldfield was being deepened from the 540 ft. to the 600 ft. level, a quartz vein was cut which was found to descend nearly vertically. It was also observed that the vein was impregnated with massive pyrites, and, since it is a matter of common knowledge that gold frequently occurs in such sulphide ores, samples of the material were taken and assayed. In the first assay, 200 grains of the crushed and powdered rock were taken, and these yielded bullion to the extent of 0·021 grain. On parting the bullion in nitric acid, it was found to still retain its silvery lustre and appearance, showing that some other metal than gold was present. Several other assays of the stone were then made, from which varying values were obtained, the highest being 0·776 grain from 400 grains of ore. This assay, on parting, was reduced to 0·126 grain, or equal to 10 oz. to the ton. The beads obtained from this succession of assays were then put together and qualitatively analysed. The results showed the presence of silver, gold, platinum, and iridium.

In the continuation of this investigation the metal was found, by assay, in a large reef both at the 540 ft. level and the 600 ft. level, but in very much smaller proportions. Several pockets of tailings from the battery —the result of the crushing of this reef stone—were also washed, and the metal was got in the shape of minute grains accompanying the escaped gold. Viewed under the microscope, the grains were usually rounded, but, curiously enough—and, indeed, quite anomalously—many were found to take the octahedral shape, some being beautifully perfect crystals. Further investigation into this occurrence is going on at the present time, and some interesting facts will no doubt be shortly brought to light.

This occurrence, of course, has a rather important bearing on the history of platinum-deposits. As will be seen in the sequel, the vast majority of occurrences of the metal are in detrital formations, and usually all attempts to trace the metal back to its original habitat have failed. Here, however, we have an actual case, borne out both by assay and by chemical analysis, of the metal found to all appearances *in situ*, and, further, in a quartz vein. The latter point also is remarkable, for there seems to be a general consensus of opinion amongst those who have given most time to the history of the occurrences of the metal that its original habitat is an igneous rock. The rocks may vary from acidic to ultra-basic in composition, but hitherto, despite the fact that Edison in America, and Roscoe and Schorlemmer, have shown that the metal occurs in rocks and reefs more widely than is thought, the occurrence in a vein must be regarded as extraordinary, the only previous occurrences of a similar nature being those at Tilkerode, in the Hartz; at Minas Gerraes, in Brazil; at Santa Rosa, in Columbia; at Beresovsk, in Russia; and at Broken Hill, in New South Wales, though the latter is a peculiar formation, differing from the others in that it consists of the gossany outcrops of veins in a country rock of schists, gneiss, and quartzites.

Of the second occurrence in Auckland very little is known. All that can be found with reference to it is that about the year 1885 J. A. Pond reported to the Auckland Institute the fact that the metal had been found at a place called the Wade, situated about sixteen miles due north of Auckland City. The rock in the immediate vicinity of the discovery consists entirely of a very dark serpentine, probably derived from the decomposition of some basic or ultra-basic igneous rock.

We shall now pass on to the second occurrence—namely, that in Nelson Province. In the north-north-west of Nelson, just inland from Massacre or Golden Bay, there occurs a series of mountain ranges. A brief description of the country from a geological point of view is essential to the proper understanding of the deposits. The following section illustrates the series just mentioned:—

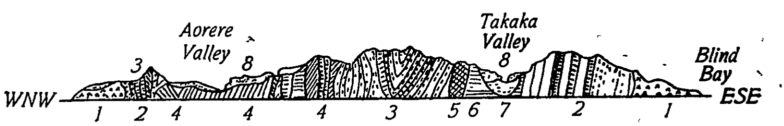

FIG. 1.

1. Granite. 2. Gneiss. 3. Mica-schist. 4. Slates. 5. Hornblende-porphyrite. 6. Serpentine. 7. Tertiary deposits. 8. Diluvium and alluvium.

Applying this section to an ordinary map of the north of Nelson, we see that the western shores of Blind Bay from Separation Point to the mouth of the Motueka River consist of granite flanked by gneiss. Proceeding from the granite, we find on the top of the Pikikirunga Range hornblende-schist intercalated with crystalline limestone. These ranges continue westwards as far as the Takaka Valley, where they are intercepted by hornblende-porphyrite and serpentine. Garnet-bearing mica-schist constitutes the highest peaks of the Anatoki Mountains, while further to the west we have clay-slates or phyllites. The Aorere Valley and the Haupiri Range belong to the clay-slate zone, and the Wakamarama Range also consists of slates. It is the Anatoki and the Haupiri Ranges which contain the matrix of the gold and other metals found in the district.* As Hochstetter† admirably puts it, "The gradual denundation of the mountains, continued throughout countless ages, has produced masses of detritus, which were deposited on the declivities of the mountains in the shape of conglomerates, and in the river-valleys as alluvial gravel and sand. In this process of deposition, carried on under the influence of running waters, nature herself has effected a washing operation, during which the heavier particles of gold contained in the mountain detritus collected themselves at the bottom of the deposits, and close to their source, so that they can now be obtained by digging and washing."

Such, then, is a brief outline of this district. The formations (alluvial) in different parts are geologically almost exactly similar, the only difference being, o. course, in the composition of the alluvium. For convenience, however, it is found advisable to divide the alluvial district into three parts—the Aorere Diggings, the Parapara Diggings, and the Takaka Diggings. Of these, the one we are most intimately concerned with is the latter, the Takaka. Its position is indicated in the foregoing section. A reference to it shows that the diggings occur on the eastern slope of the Haupiri and the Anatoki Ranges, and they comprise principally the three chief branches of the Takaka River. A section through a typical gold-bearing area appears as follows :—

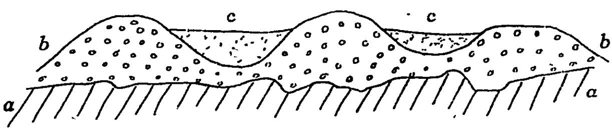

Fig. 2.

a. Clay-slate or bed-rock. *b*. Auriferous conglomerate. *c*. Alluvial sand.

The conglomerate may be cemented by a ferruginous cement, or may be quite uncemented, only loose sand lying between the boulders. The formations, therefore, do not differ at all remarkably from those ordinarily associated with gold-deposits throughout the South Island, and especially in Otago, where the formations are commonly known as the "auriferous drifts." They have, however, one outstanding peculiarity which marks them off from all other gold-deposits except those we have yet to describe, and that is the occurrence in them of osmiridium and platiniridium in small grains of a tin-white colour. These occur with the gold in conjunction with magnetite, numerous garnets, and titaniferous iron-ore (ilmenite).

It is quite remarkable that though, as has been said, these auriferous gravels are geologically similar in the district described in Nelson, and though washing has been carried on, for instance, in the Aorere Valley for a long time, yet no occurrence of platinum or its alloys has up to the present been recorded in any other area in Nelson than the Takaka. This would tend to show that there is probably some peculiarity in the Takaka surroundings that is absent from the other areas examined.

* The above section is taken from Von Hochstetter's "New Zealand," p. 102.

† Von Hochstetter, *loc. cit.*, p. 104.

A discussion of this point, with a probable explanation of the peculiarity, arrived at by comparison of this area with the platinum-bearing areas throughout the world, will be given when we come to investigate the occurrence of the metal near Orepuki, in Otago.

As far as Nelson is concerned, then, it appears that the metal is found in what, as far as the evidence goes, must be regarded as the commonest method of occurrence—viz., in placer or detrital formations.

As will be seen later on, in Russia the metal is got most abundantly from the alluvium at the base of the Ural Mountains, alluvium which has been produced exactly as the Nelson alluvium has been—*i.e.*, through denudation and the sorting-action of water. In Columbia, British Columbia, Brazil, United States, Burmah, France, New Caledonia, and Tasmania the mode of occurrence is exactly the same, so that, in all these countries, to arrive at the original matrix of the mineral we must first trace back the boulders and detritus to the parent rock.

Of a nature almost exactly similar is the occurrence of platinum in Stewart Island. Sir James Hector, in the "Transactions of the New Zealand Institute" (vol. 2, pp. 185, 371), reports that small flat grains of a steel-grey or silver-white colour have been found associated with the gold in alluvial deposits in the island. Nothing further, however, is known about this occurrence.

We come now to the occurrences in Otago, of which there are two. The less important of the two is that reported from the Gorge River, on the west coast, near the celebrated Milford Sound, in Fiordland. This locality is remarkable owing to the presence with the platinum of that peculiar nickel-iron mineral awaruite. In appearance it is not unlike platinum, and was mistaken by the miners for that metal. An analysis of it runs as follows :—

	Per Cent.
Nickel	67·63
Cobalt	0·70
Iron	31·02
Sulphur	0·22
Silica	0·42

Both the metal and the awaruite occur in a district composed almost wholly of serpentine and dunite. The awaruite has actually been found in the serpentine. From this, therefore, it would appear, as Professor J. Kemp points out, that the platinum and awaruite are excessively basic segregations in basic igneous rocks, the dunite specially being ultra-basic.

Occurrences of a similar nature, in which awaruite occurs with the platinum, are reported from California, Oregon, and British Columbia.

There still remains for consideration the second occurrence in Otago; but, as most of our investigation deals with this occurrence, it will be sufficient here to remark that platinum has been known in Otago for some seventeen or eighteen years, but to such a small extent was its value recognized, or so great was the ignorance of the miners who came into contact with it, that it was not until about eight years ago that efforts were made to collect or save it. Up to that time it had been almost contemptuously thrown away.

The first recorded occurrence was about the year 1888, when a miner searching for gold found some ounces of it at the mouth of the Waiau River. The occurrence created very little stir at the time, and the miner even so little valued what he found that he gave most of it away. No further notice was paid to the metal till it began to be saved from the tailings in hydraulic sluicing. The locality from which most of the Otago platinum is obtained is in and around the Township of Round Hill, in Southland, almost due east of Orepuki, though it has also been obtained in small quantities, with gold, along the beach from the mouth of the Waiau to the Orepuki Beach.

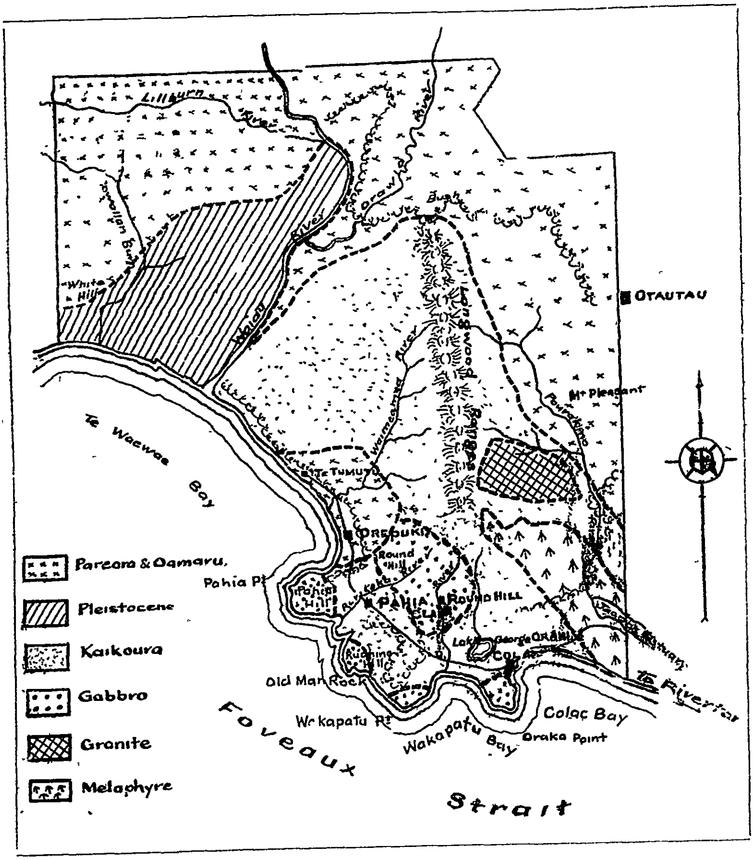

Fig. 3.—Geological Map of the Round Hill Gold and Platinum District.
(Scale, eight miles to an inch.)

The above, in conjunction with the occurrence on which this paper is based, is a fairly complete account of all recorded occurrences of the metal in New Zealand up to the present time.

I shall now proceed to an investigation of the occurrence at Round Hill and Orepuki. In this investigation it is my intention to treat the subject from the point of view of (1) the physiography, (2) the geology and the petrography, of the country; and, further, to endeavour to trace the metal to its original source.

The accompanying map illustrates the district as a whole, geologically and topographically.

GENERAL GEOLOGY.

Having got a general outline of the geographical characteristics of the country, we are now in a position to devote some little attention to its general geology. As will be seen from the accompanying geological map, the geological masses we have found represented are six in number—viz., (1) Kaikoura formation, (2) Oamaru formation, (3) Pleistocene, (4) basalt, (5) granite, (6) melaphyre.

As is usually done, we shall begin with the oldest, the Kaikoura formation.

Captain Hutton, when Provincial Geologist of Otago, in 1872, gave in his paper on the geology of Otago a description, on general lines, of the structure of the west of Otago, which we think it will be highly advisable to make use of here. "The whole of the District of Southland," he says, "is included in an inclined trough of Palaeozoic and Secondary rocks, the major axis of which lies in a south-east and north-west direction, rising to the north-west where the rocks are thrown up and close the upper end of the trough. The lower end, towards the Mataura River, is open. The belt of Palaeozoic rocks that forms the rim of this trough runs from the Umbrella Mountains on the north-east, round by the Takitimu Mountains and Longwood Range on the west, and passes into the Bluff Hill on the south-west. In its folds are enclosed large masses of Secondary rocks. The south-west edge of this trough has been broken down in several places, and Tertiary rocks have been deposited indifferently on both the inside and the outside and overlapping its edge. These have in their turn been largely removed by denudation, and replaced by immense deposits of gravel and silt."

From this it will be seen that a section across the major axis of the trough taken in the district with which we are at present concerned may, as it actually does, appear as follows :—

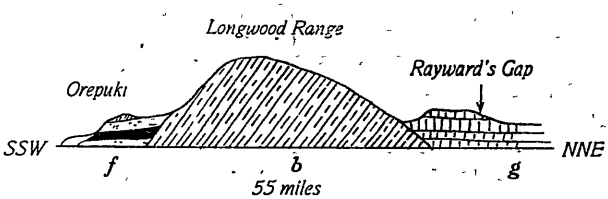

FIG. 4.

At *f* and *g* we have the trough, inside at *f* and outside at *g*. *b*, Slates, *g* and *f*. Tertiary rocks.

The Kaikoura formation of Hutton is a part of the Upper Palaeozoic period, and is also a part of the Te Anau series of Hector, classed in the Upper Palaeozoic also. It is represented in the district by the Longwood Range and its outskirts (see map). Roughly speaking, then, it comprises all that part of Southland extending from near the eastern bank of the Waiau to near the Pourakino River, and from the head of the range to the sea-coast.

The rocks consist principally of clay-slates and grey sandstones or quartzites. According to Sir James Hector, who reported on the district in 1864, and whose paper appeared in the "Quarterly Journal of the Geological Society" in 1864, these rocks consist of indurated shales with calcareous sandstones ; but an examination of them leads us rather to support

Captain Hutton. The quartzites are grey in colour, and consist of rolled quartz grains of fair size, with only very subordinate feldspar, united by a clear cement, which is of the nature of a crystalline outgrowth from the grains. Moreover, the indurated shales of Hector are probably little more than the clay-slates of Hutton. The general strike of the beds is south-east and north-west. No fossils have been found.

Associated with these rocks are rather numerous intrusions of igneous rocks. These have been recorded by several observers. Hutton, in the paper above referred to, says that associated with the Kaikoura sandstones are dykes of diorite. Hector, in his geological map of Otago (in 1864), has diorite rocks shown at such places as Oraka Point, Pahia Hill, and Wakapatu Point. Further, in the *New Zealand Mines Record*, vol. 3, appears the statement that the Longwood and Takitimu Mountains consist partly of a massive development of diorite and syenite in mountain masses and in strong intrusions among sedimentary formations.

An examination of the district confirms these statements to a certain extent. Three distinct types of rock have been identified by me. These occur as giant intrusions, for the term "dyke," usually associated with minor intrusions, very incompletely describes these. The outcrops of diorite at Oraka Point, Pahia Point, and Wakapatu Point, mentioned by Hector, but not mentioned by Hutton, were confirmed; and, further. another distinct outcrop was noticed on the edge of the beach near Orepuki Township. Further, the whole district extending from Orepuki inwards and from Round Hill along the base of the Longwood as far as Colac Bay was also found to consist of this same rock. Whether the outcrops at the points before mentioned are just branches of this one great intrusion or not, it is hard to say, for the outcrops cannot be followed up on account of the bush; but it seems extremely likely.

As this diorite rock forms the whole rock-mass of the Round Hill district, we shall defer any further consideration of it till we come to describe the minute geology of the Round Hill Claim.

In addition to the diorite outcrop, two intrusions have been observed by us. It is a remarkable fact also in this connection, that, though both Sir James Hector and Captain Hutton have separately examined the country under review, neither of them has observed either of the two intrusions mentioned below.

A reference to the map will show that both outcrops occur on the eastern flank of the Longwood Range, and consist of (*a*) melaphyre and (*b*) granite. It is to be noted, however, that Hutton in several places speaks of rocks which he calls "argillites." Also, these he says occur in the Kaikoura formation in various places, and he defines the term "argillite" as a name given to a rock formed from thick beds of clay that have undergone a sufficient amount of metamorphism to obliterate the lamination, while it has not been sufficient to induce any signs of foliation.

Further, argillite, he says, is much jointed in several directions so as to break into irregular rhombohedra. Now, this melaphyre is a rock bluish-green in colour, and with none of the appearance usually associated with igneous rocks; no minerals can be identified in hand-specimens, and no cleavage-surfaces are anywhere evident. Also, a rough jointing is sometimes seen in it, probably a relic from the days when it was an undecomposed basalt. It is just possible, therefore, that what Hutton calls an argillite may be here, at any rate, a melaphyre. Whatever may be the case, however, no mention heretofore has been made of a granite. We shall therefore describe each in detail.

The melaphyre has the appearance in hand-specimens above outlined. It occurs very prominently round the coast towards Colac Bay from Riverton, and extends back into the Longwood Range for some distance, until it appears to thin or pinch out, as in the map. The actual boundaries of the mass, or the junction of it with the main rock of the range, have not been made out with any accuracy, owing to the great difficulty of following the rock through the interminable bush. From what could be gathered from miners, however, as well as from a consideration of the rough direction at Riverton, it is thought that the position in the map is fairly accurate.

The rock is very tough, and splinters with more than usual difficulty, much like some close-grained phonolites. It does not seem to be acted on by denuding agencies with any great rapidity, and is fairly hard.

In section, the most noticeable feature on looking at the slide is the large amount of decomposed material. In this decomposition not only is it the feldspars that take part, but the olivine too is almost all serpentinized. The minerals seen in the section are—

Plagioclase.—This forms several phenocrysts in the section examined, and, judging from the extinction-angle on—*i.e.*, at right angles to—the brachypinacoid, which varies between 25° and 30°, the mineral is mostly a basic variety of labradorite gradually passing into bytownite. The crystals show the albite lamellar twinning very well, for some of the phenocrysts are not so decomposed as others. Combined with the albite the pericline and Karlsbad twinning occurs, but rather rarely. Besides the phenocrysts is an abundance of very fine lath-shaped feldspars forming a great portion of the groundmass. These are all semi-decomposed, forming, like the phenocrysts themselves, patches of calcite.

Olivine.—Very few patches of this mineral have been identified with certainty. Its place is almost always taken by yellowish-green masses of serpentine and other products due to the weathering of the mineral. In those which have been identified the mineral is quite without crystal outline, exhibits the usual cracks, and is usually surrounded with the serpentine border due to decomposition. The form appears to have been rounded, or in some cases oval, and the mineral is usually quite colourless. Here and there occur patches of what appears to have been olivine, but nothing now is left except a mass of material like calcite, showing peculiar radial extinction.

Augite.—This is remarkable as being the only essential mineral which has resisted the weathering-agents. In hardly a single case does the augite—at any rate, in phenocrysts—appear at all decomposed. It occurs in roughly rectangular forms, is usually pale in colour, and here and there shows a lamellar twinning. The forms represented are the orthopinacoid, the base, and rarely a dome. The extinction-angle is high, being usually over 30° in the prismatic zone. Where decomposition has set in the products are mostly chlorite, yellowish-green in colour. The mineral occurs as it does in most basalts, in two generations. The groundmass appears to have been studded with small grains of the mineral having the characters of the phenocrysts, but in a more advanced stage of decay.

Besides these essential minerals there occur small grains of magnetite and rather numerous crystals of apatite in long acicular crystals. Their further characters cannot, however, be made out.

With regard to its structure, the rock belongs to the holocrystalline class of basalts, for, while there is a fair amount of isotropic material present, this is due to alteration and not to the presence of glassy matter. Further, the order of crystallization of the various constituents is not well marked, the mutual relations between the augite and feldspar with regard to priority varying considerably. No ophitic structure has been observed.

Turning now to the *granite*, we see that, in hand-specimens, it is of a white colour, rather fine-grained, with pronounced orthoclase differing very little from white in colour, and pronounced quartz crystals. The ferro-magnesian mineral is biotite, but is unusually rare in occurrence; the rock, therefore, resembles in appearance some specimens of ditroite without the blue colour of the sodalite.

In section, the rock is seen to be made up mainly of quartz, orthoclase, and biotite. The *quartz* occurs in large plates without crystal outline, enclosing in some cases fluid pores, which are arranged in lines. Occasionally the quartz occurs fixed into the interstices between feldspar crystals, showing probably that the mineral crystallized after the feldspar.

The *orthoclase* also occurs in large plates, but, unlike the quartz, is usually semi-decomposed to form kaolin. Karlsbad twinning is usually to be seen. In addition to the orthoclase, several crystals of microcline and oligoclase are to be seen. The microcline shows the peculiar cross-hatched appearance under crossed nicols, and the oligoclase, of which a considerable amount occurs in the rock, shows both Karlsbad and albite twinning lamellation. A very well-marked zonary banding has also been noticed in the orthoclase.

The *biotite* occurs in small plates with ragged outlines and no distinct terminations. It exhibits strong pleochroism from light yellow to deep brown, and has almost straight extinction, and is very susceptible of alteration. The latter produces a green coloration, and in places a green chloritic pseudomorph with pieces of magnetite. Its inclusions are rare, and consist mainly of magnetite and pieces of apatite. No accessory minerals have been seen.

The structure is that characteristic of all plutonic rocks—*i.e.*, hypidiomorphic—only a minor proportion of the constituents developing their external forms freely. The normal order of the crystallization has also been obeyed: the biotite and magnetite have first crystallized, then the feldspar, and lastly the quartz with microcline, though the oligoclase has probably preceded the quartz.

The next geological formation we must discuss belongs to the Miocene period in New Zealand, and, more particularly, to the series called by Captain Hutton the Oamaru and Pareora series. The strata belonging to this series Hutton, in the report on this district above referred to, has seen fit to subdivide as follows: (*a*) Brown-coal formation; (*b*) Oamaru formation proper. We shall deal with these separately.

(*a*.) *Brown-coal Formation.*—The main body of this occurs skirting round the Wairaki Hills, but another small patch is also found on the south-west side of the Longwood Range at Orepuki, and for a short distance on both sides of the Waimeamea River. As Hutton remarks, it never rises to great altitudes, but occupies portions of old valleys scooped out of Secondary and Palaeozoic rocks. The Orepuki occurrence has roughly the shape of a triangle, with an area of about one and a half square miles. The seam is exposed only in water-races, in which some difficulty was experienced in measuring the thickness. According to some of the miners who have worked on the races, the thickness is about 15 ft. The formation is at a height of 200 ft. above sea-level, covered by dark, tough shales, with a floor of brownish-coloured shales, and with a covering of soft green sandstone. These shales contain leaves of dicotyledonous plants, which have not yet been identified with any degree of certainty. As the formation nears the beach the coal has been washed away, and its place has been taken by a thick deposit of sands and gravels of Pleistocene age. Associated with these Pleistocene gravels are also beds of lignite, some of which can be distinctly seen on the sea-cliffs. This lignite is muddy and very poor, and has nothing whatever to do with the brown-coal formation. A section through this Orepuki occurrence appears as follows:—

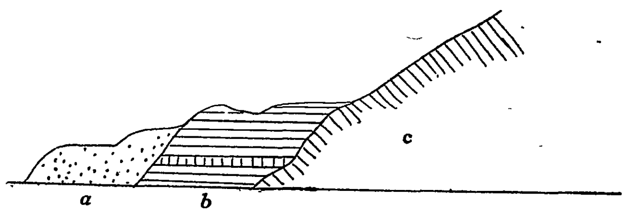

FIG. 5.

a. Soft sandstone, with lignite. *b.* Brown-coal formation (Oamaru).
c. Slates (Kaikoura).

(*b.*) *Oamaru Formation.*—A reference to the map shows that in the district this formation has a comparatively large development. Leaving out of account the Orepuki portion, we may describe it thus: Beginning in the south-west corner, to the north of the Pleistocene deposits, it stretches to the northern boundary; then away to the east; crosses the Waiau River about the neighbourhood of Clifden, whence a narrowing tongue extends nearly to the mouth of the river; extends to the eastern boundary after skirting the outlying northern spurs of the Longwood Range; and finally pinches out just above the Jacob's Estuary, on the border of which Riverton is built. The basaltic formation of Mount Pleasant stands surrounded by it.

Viewed on a large scale, the strata seem to be nearly horizontal, but rising slightly to the north. The rocks are almost wholly composed of shelly limestone or calcareous sandstones. The limestone is in places very fossiliferous. The following fossils have with certainty been recognized: *Hemipatagus formosus, Waldheimia lenticularis, Terebratula gualteri, Pecten hochstetteri, Pecten polymorphoides.* Others have been found, but their identification is not yet complete. It will be seen that several of these fossils are identical with those found in the limestone formation of Oamaru, in Otago, and at the Weka Pass, in Canterbury. These fossils characterize the oldest Tertiary and marine beds in New Zealand.

The limestone, which at places forms cliffs 30 ft. high on the banks of the Waiau, is not pure, averaging usually between 60 and 70 per cent. of CaO.

Sir James Hector, in a map of this district prepared in 1864, considers this formation as belonging to the Pliocene period, and describes it as a Pliocene marine tertiary. Undoubtedly it is marine, but the occurrence of the fossils just mentioned would assign it rather to the Miocene than to the Pliocene.

Finally we shall consider the Pleistocene deposits. These are almost entirely gravel deposits, the only exception being the fairly large formation occurring to the west of the Waiau River and bordering Te Waewae Bay. The formations are composed of beds of sand, clay, and shingle, with occasional seams of lignite in the lower portions. These lignites are usually poor; occasionally well-preserved trunks of trees are found in them, and a well-marked vegetable structure is often seen; sometimes they contain resin, like the coal in places at Nightcaps.

The low land on the west of the Waiau is also composed largely of gravel, and consists of a fairly flat plain, interrupted here and there by small hillocks, which give to it an appearance very like that presented by a peneplain. The valley of the Waiau River, too, in its upper portion is said to be strewn with fragments of gneiss and greenstone, along with other eruptive rocks.

The gravels all along the coast from the Waiau to Jacob's Estuary are all referable to this period. They are usually, however, covered over by silt and surface soil. Their origin is probably due to the spreading-out by the sea of the detritus brought down by the rivers.

Such, then, is the general geology of this district. The following sections, together with the one previously given showing the relation of the Longwood to the geological structure of the south-west of Otago, will serve to illustrate the main features just outlined:—

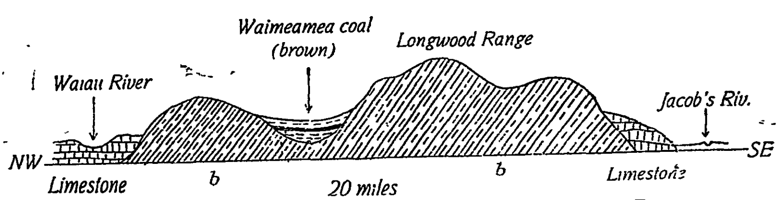

Fig. 6.—Section from Jacob's Estuary to the Waiau River.

b. Palaeozoic slates, &c.

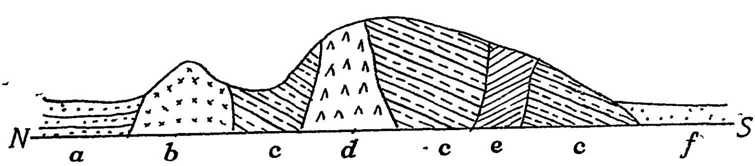

Fig. 7.—From North of Mount Pleasant to the Sea-coast.

a. Oamaru formation. *b*. Basalt. *c*. Palaeozoic slates. *d*. Granite. *e*. Melaphyre. *f*. Gravel plain.

It will be interesting, before concluding, to compare the district with that of the Coromandel Peninsula, in Auckland. One cannot but be struck with the similarity on broad lines between the two. We have seen that the Longwood district consists of a main central ridge running north and south, with spurs given off on all sides, and the whole densely wooded. The main axis, or what might be called the base, consists of Palaeozoic slates. These are pierced, as we have seen, by dykes consisting of diorite, melaphyre, and granite. On each side of the axis come younger rocks of Tertiary age.

Look now at the Coromandel district. It also consists mainly of a mountain-ridge running nearly north and south, with numerous spurs, and all densely wooded. The base or bottom of the structure consists of Palaeozoic slates, which are also pierced by dykes. The latter are composed of trachyte, and what was originally called by Captain Hutton a diorite, and what has since proved to be in some cases a dolerite and in others a melaphyre. Further, the older formation forms the centre, and younger formations of Tertiary age form the outskirts. Brown coal also occurs in the peninsula in places, resting unconformably, as in the Longwood, on the older slates.

In addition, it may be remarked that quartz veins occur in the Coromandel, and they also occur on the south-eastern slopes of the Longwood. Gold, too, is found in both localities.

A similarity is also to be noticed with the structure of Great Barrier Island, north of Cape Colville Peninsula. This, as Captain Hutton points out (New Zealand Geology Reports, 1868), consists of a base of dark-blue siliceous slates, penetrated here and there by dykes of quartz-porphyry and what he calls a diorite, but which may be of similar character to the diorite of the Coromandel dykes—*i.e.*, either dolerite or melaphyre.

There is, however, a marked difference in the associated volcanic rocks in the two districts. In the Longwood district the only volcanic rock is the basalt already described, but in the Coromandel district hypersthene-andesites were first erupted, and these were followed by large outpourings of rhyolites characterized by the presence of tridymite. The andesites are everywhere older than the rhyolites.

Round Hill District and Claim.

General Appearance.

It will be seen that the country to the north consists of Round Hill and two chief ridges. Round Hill has a barometric height of 1,120 ft., and the ridges of approximately 700 ft. and 800 ft. respectively. Between the Hill and the first ridge there is a gully, down which the Rurikaka Stream flows. Between the first ridge and the second occurs a steep-sided gully, down which flows in a rapid stream the main branch of the Ourawera River. Between the second and the third ridge occurs another similar gully, down which the other branch flows. A rather similar succession goes on all round the lower spurs of the Longwood Range.

In a southerly direction from the Rurikaka a rather peculiar knob is found, bordered on the far side from Round Hill by the Ouki Stream, the bed of which is flatter than that of the other streams above it. From this stream, both on the east and on the west side of the district, a more or less gradually rising slope occurs, extending on the west towards Pahia and on the east towards Riverton.

It will thus be seen that the Ourawera River flows in a kind of obtuse V-shaped hollow, rising rather abruptly to the north, and sloping gradually from the base of the ridges to the sea. On each side the land rises fairly rapidly, but more so on the east than on the west, and the slope increases as we go towards either the north-west or north-east. Thus the greatest height of the land on the west side (with the exception of the knob previously mentioned) is about 500 ft., while on the east side it may rise to 700 ft.

The Township of Round Hill is between 250 ft. and 300 ft. above sea-level, the claim itself, occurring as it does along the eastern bank of the river, being about 200 ft. to 230 ft. above sea-level.

From the bottom end of the claim the land is almost quite flat on all sides, and it is on this flat plain at the base of the spurs that Lake George is situated.

The whole district is densely wooded; even Round Hill, though a trig. station, is covered with trees of unusual height. In the course of our investigation, realizing the importance of Round Hill as an observatory, we made an excursion to the top.

The Ourawera, we could see, has now reached its base-level of corrosion in that portion which extends from the base of the ridges to the coast. Its action now is one of erosion—*i.e.*, that gradual eating-away of its banks to form ultimately a more or less flat plain. The deposits, therefore, now being formed from the river are those got from the denundation of the rocks and soil in the neighbourhood.

The bank on the west side is gradually sloping at once from the bed of the river, but on the east side there is a rather steep cliff from the bed, about 20 ft. to 30 ft. high, and extending almost the whole length of the claim. This has been formed probably from the sluicing, which has been going on for a considerable number of years.

Of the coast-line, all that need be said is that it has characters exactly similar to the bed of the river from the east side. The land ends in a cliff of about 10 ft. to 30 ft. high, and is flat from there inland. The beach is very flat.

General Physiography of the Neighbourhood of Orepuki.

If we look at a detail map of the Province of Otago, and especially of the southern portion of it, we cannot but be struck with the almost uninterrupted growth of bush which prevails as we go westwards from Invercargill to Orepuki. Almost from Invercargill itself to the water's edge on the west coast there extends a continuous stretch of forest of the very densest description. Not only does this occur near the coast, but for miles and miles inland until the Waiau River is reached, and if a clearing is met one finds it due only to the indefatigable labours of some prospectors on the look-out for gold.

It is at once seen, therefore, that any examination of such a district is fraught with more than ordinary difficulty. Even at the present time, in spite of the fact that the railway-line to Te Tumutu has been open for more than twenty years, in spite of the fact that there is still a large inducement in the Dominion for the extension of the sawmilling industry, and in spite of the fact that the district has proved to be more than ordinarily auriferous, the means of locomotion are restricted to bridle-tracks, bush-tracks, water-races, and sawmill tram-lines. Decent roads are quite unknown in the district until we get as far north almost as Nightcaps. One cannot wonder, then, that the information in regard to this district is very meagre; nor can one wonder that what information there is, geological or otherwise, is more or less of a contradictory character Even in my own case, though I had the advantage of tracks, water-races, and tram-lines, not to speak of a guide or two possessing a fair knowledge of the country, my path was far from easy. When I consider, therefore, that Dr. Hector and Captain Hutton made a survey of the country, the former in 1864 and the latter only a little later, I can easily see how very difficult it must then have been for them.

While the above remarks are applicable to the whole of the western and south-western part of the Southland County (except, of course, the alluvial plains of the Waiau), they are especially applicable to the district which we have under investigation. This is bounded on the west side by the meridian of 167° 30′, on the south by Foveaux Strait and Te Waewae Bay, on the east by the meridian of 168°, and on the north by the parallel of latitude 45°.

The physiographical features can be classified conveniently as follows: (1) The mountains, (2) the plains, (3) a lake, and (4) the rivers.

The mountains of the district are represented by (*a*) the Longwood Range and its offshoots, and (*b*) various isolated peaks.

The Longwood Range consists of the main ridge running almost due north and south, and tapering at the northern extremity to a single peak called Bald Hill. The average height of the ridge is about 3,000 ft., and its breadth at the widest part is about four miles. From both sides of the range extend about five or six parallel spurs, which slope gradually down to the plains at the bottom. At the lower extremity of the range there are also several diverging spurs, and to the most westerly of these the name of Round Hill has been given. The whole range, including the spurs and the valleys, is very densely wooded, and, except for some water-races and a sawmill track or two, is practically virgin forest, with trees on an average about 50 ft. high. In contradistinction to most of the ranges of Otago, the mountains of this one are not rugged. Their summits are rounded, and they altogether present an appearance more like hummocks than mountain-peaks.

It is hardly necessary to state that the range constitutes the chief watershed of the district, the main river-system having its origin entirely in the valleys which everywhere occur on the flanks of the ridge.

Various isolated peaks occur on the extreme north-west of the district, but these do not attain any size, the highest being only about 1,000 ft. high, and composed entirely of a Pleistocene gravel formation.

Other isolated peaks occur, jutting out into the sea south of Orepuki and along the coast as far as Riverton. They also nowhere attain any considerable size, and are always completely covered with bush; but they give the country a rather peculiar appearance, and, in conjunction with the plains which are always associated with them, they are strongly suggestive of the idea that the district has been submerged comparatively recently. More will, however, be said with regard to this later on.

Let us now turn to the plains. Generally speaking, the whole district between the Longwood Range and the sea-coast all around consists of one densely wooded plain. In fact, it is quite remarkable that the whole of the south-east coast of Otago from the mouth of the Mataura River to ten miles west of Waiau, Preservation Inlet, on the south-west coast, is extremely flat; nor does it begin to rise until a distance of more than thirty miles from the coast is reached (the only exception to this being in the case of the district between the Longwood and the coast, where the range is distant only about five or six miles from the sea-beach). Further, too, a consideration of the soundings round this part of the coast shows that the slope continues gradual for some considerable distance under the sea-level. This plain consists, as far as can be made out, of a gravel formation, the pebbles being such as would be brought down by the river—*i.e.*, more or less rounded, smooth, and only in rather rare cases flat. This plain looks, therefore, much like one of fluviatile deposition, such as occurs in Otago, in the Waikato district of Auckland, and, according to some authorities, in Canterbury. Further evidence and opinions as to its origin will appear later on.

A continuation of this plain is found east of the Longwood, intersected here and there by streams flowing from the range. The most pronounced in character, however, of all the plains is that formed by the Waiau River. This river during nearly all the latter half of its course flows between banks composed partly of pebbles and partly of limestone or calcareous sandstone. For a distance of two miles in some places, in others three, on either side of the river flat alluvial land extends, passing gradually into a series of hilly spurs, and from there to the mountains. It is this flat that constitutes the Waiau Plain. It is very wide at the mouth (about a mile), and gradually tapers backwards, but it extends for many miles up the river, and south of Lake Manapouri the land is so flat that marshes have been formed. Evidently it is a plain of fluviatile deposition, the uniformity of surface being produced by the deposition of gravel and silt as the fall of the river has diminished. Pronounced terraces have been seen in places on the banks, and, since the flow of water is so great that these could hardly have been formed by changes in the course of the river, it is legitimate to assume they are due to a small elevation of the surrounding district, especially as the depth of the river is very considerable.

No other plains worthy of mention occur.

The rivers must now be considered. These are: (*a.*) The Pourakino, which rises amongst the easterly spurs of the Longwood, flows generally in a southerly direction, and after a rather tortuous course empties itself into Jacob's Estuary near Riverton. It is chiefly interesting on account of the gold-washing that goes on near its source and as far as the point where the river enters the plains. (*b.*) The Ourawera, which, rising in the southerly spurs of the Longwood, flows due south, and, with a tributary from Lake George, enters Wakapatu Bay. It is along the course of this river that the gold and platinum grains are found which form the basis of this paper. (*c.*) The Rurikaka River, which has its source near the base of Round Hill, and, flowing in a south-westerly direction close past Pahia Township, enters Foveaux Strait. (*d.*) The Waimeamea, which, having its source on the western slopes of the range, with a tributary system very like that of the Pourakino, flows in a south-westerly direction across the plain, and after a remarkably tortuous course across the flat country enters Te Waewae Bay. (*e.*) The Orawia, a tributary of the Waiau, may also be taken as a separate stream. It takes its rise in the comparatively hilly country to the north of our northern boundary, flows also towards the south-west, and after a tortuous course joins the Waiau opposite Bald Hill.

In the case of the last three rivers—viz., the Rurikaka, the Waimeamea, and the Orawia—and to some extent the Waiau, which we shall describe next, it will be noticed that they fall very conveniently into the classification (adopted by Professor J. C. Russell in his "River Development") of streams which have their source in mountain-ranges and flow across broad plains to the sea. Such streams may be divided, he says, into three divisions—the mountain tract, where the streams flow impetuously in narrow depressions; the valley tract, where the stream widens and is bordered by flood-plains; and the plains tract, where the grade is still more gentle, and the stream meanders in broad curves through alluvial lands of its own manufacture.

With the three streams above we have the mountain tract pronounced, followed by a more or less pronounced valley tract. The plains tract is very evident, being shown by the complicated meanders of their courses. A similar course is followed by some rivers in the North Island, especially the Wanganui. This river, coming from the plateau of the centre of the mainland, flows in its lower portion through flat plains which quite recently (in the Pliocene) were beneath the sea-level. Complicated meanders are thus produced, and in this case, as in others, lakes are in process of forming by the erosive action of the waters on the banks. This action is especially to be seen in the case of the Orawia and Waimeamea.

It is usually understood that rivers acquire complicated meanders in their courses comparatively late in their period of existence. The work which a river unceasingly carries on is the bringing of its bed to its base-level of corrosion, after which the slow erosion of its banks begins. But, while this is true in most cases, it is not always true. As Professor Russell points out, a similar phenomenon may be witnessed with even young rivers when the land through which they flow has recently been raised from beneath the sea, and, as will be shown afterwards, it is probable that such has been the fate of at least some of the coastal part of the district.

Finally, the Waiau River has to be considered. Easily the largest of the Southland rivers, this notable river has a discharge of about 1,130,000 cubic feet of water per minute, or two-thirds the amount of the Clutha River. Though broad and deep, it is, even when flowing across the plains, unfortunately too rapid for navigation. Unlike most rivers, it starts away as a large river from, not a hillside, but from the southern extremity of Lake Te Anau, the largest lake of the South Island of New Zealand. After rushing swiftly over eight or nine miles of large boulders between high banks it enters Manapouri Lake. From this it emerges at the south-east corner, to be joined almost at once by the Mararoa, itself a good-sized river. Some fifteen miles further on it receives the water from the Monowai Lake and the Hunter Mountains, and thenceforth, with a rather tortuous course, it flows in a southerly direction to empty its waters by several mouths into Te Waewae Bay.

In addition to these features, a lake occurs in the district midway between Wakapatu and Colac Bay. Lake George, as it is called, is only about 100 chains long and 60 broad. The depth is in no case more than 15 ft., and this fact, together with the marshy nature of the surrounding land, gives the impression that it is either a relic of a former depression or is due to depression actually in process. It is supplied by a small unnamed spring from the lowest spurs of the range.

Of the beaches which occur along the coast all that need be said is that they are unusually flat. At Orepuki the beach at low tide extends for fully 50 yards along the sand to the margin of the water.

GEOLOGY OF THE CLAIM.

It has already been remarked that the whole district extending for about two miles from Orepuki Township into the Longwood and along the base of the range about Round Hill to the edge of the coastal plain consists of a mass of diorite, possibly as an intrusion. This rock forms the base or bed-rock of the claim, and therefore calls for close attention.

An examination of the rock confirms Captain Hutton's description of it. It consists, in hand-specimens, of whitish feldspar and crystals of black or dark-green hornblende showing prismatic cleavages rather prominently. Occasionally, as is common in all igneous masses, parts of the rock are finer grained than others, and the rock then has a slightly lighter green colour. On exposure to the weather the feldspar is very soon acted upon, disappears to a great extent, and leaves the rock with more or less rounded crystals of hornblende projecting from it, and with an external appearance not unlike the nephrite coating seen, but very rarely, on a troctolite.* The rock is exceedingly tough, and very prone to decomposition, so much so that when a fresh surface has been exposed for about a year a more or less thick scale of decomposed material can be taken off. A fresh surface shows very fine cleavage surfaces of hornblende, and when the feldspar is not so prominent as usual the rock has almost the appearance of a pure hornblende rock. The feldspar usually has a faint greenish tinge, probably due to the proximity of the green ferro-magnesian mineral. After weathering has acted on it for a considerable time, as with the rock under the alluvial deposits of the claim, the hornblende becomes almost pea-green in colour, studded with white specks of decomposed feldspar. Ultimately a clay, bluish-green in colour, and of the consistency of putty, results.

Examined under the microscope in section, the rock may be said to exist in two varieties—(*a*) one in which hornblende is plentiful to the exclusion of augite, (*b*) one in which much augite is present.

The (*a*) variety consists of plagioclase and hornblende almost wholly. The plagioclase is usually quite fresh, and shows very pronounced polysynthetic twinning after both the albite and pericline laws. Karlsbad twinning was also seen in one or two sections. From the extraordinary number of lamellae and their marked development we should infer that the feldspar was very basic. A determination of the feldspar proved this conclusively. In the determination, as usual, a section was selected cut nearly perpendicular to the lamellae. This was to be recognized by the fact that the illumination of the two sets of lamellae was almost equal when the twin-line was parallel to a cross-wire. Several measurements of the extinction-angles were taken, with the result that the angle was found to be about 35° (or 55°). The feldspar, then, is an almost pure anorthite. That this is the case was also proved by an analysis of the rock, in which it was found that, while the amount of lime was very high, the amount of potash was exceedingly low (see later). The rock, therefore, is rather exceptional, for the general rule is for the feldspar to vary between oligoclase and labradorite. Inclusions are in some cases numerous, consisting of fluid pores and other kinds whose exact nature it was impossible to determine. A striking peculiarity with regard to these feldspars is the presence in some sections of a decided bending of the lamellae. This bending, too, is not altogether restricted to the plagioclase, for a section has been seen in which the augite (or diallage) seems to have been bent. This bending, we know, is a result of dynamic metamorphism, and it is probably here due to pressure subsequent to the solidification of the rock-mass after intrusion.

Hornblende.—This is uniformly green in colour in small plates, with usually no distinct terminations. Pleochroism is marked, from green to yellow. The extinction-angle varies between 13° and 15°; the plates are

* It is seen very conspicuously in ore from the west coast of Otago.

usually elongated in the direction of the pinacoid faces. No twinning has been seen. The hornblende is often much altered. The more usual alteration consists in the development round the borders of the plate of a secondary outgrowth of the mineral, causing an apparent extension of the plate. Another type not uncommon in the sections examined consists in a large development of chlorite, which is distinctly pleochroic, green in colour, and very ragged in outline. Now and again calcite and magnetite are formed in small quantities.

The (*b*) variety consists of plagioclase, augite, and hornblende. The plagioclase has characters exactly similar to those in the (*a*) type; the hornblende also much the same as before. The augite is rather peculiar. In some cases it seems to take the form of diallage, and with those cases in which it occurs to a large extent it would lead one to call the rock not a diorite, but either an augite-diorite or a gabbro. The diallage occurs in large plates with a more or less well-marked schiller structure formed by rows of inclusions, an extinction-angle of nearly 40°, strong orthopinacoidal cleavage, and with no pleochroism. The plates are also usually colourless, and the inclusions are often very numerous. Augite as distinguished from diallage also occurs. This is without regular outlines, with an extinction-angle of 35° (approximately), and quite colourless in section. Alteration, as with the hornblende, is sometimes pronounced. The usual type of alteration is the development of uralite. This begins at the border of the plate, gradually extending inwards, and frequently a ragged scrap of augite is enclosed almost entirely by uralite. The latter has only a very faint pleochroism. In another type of alteration chlorite is formed, and even calcite, just as in the case of the (*a*) type of rock.

The structure of the rocks presents characters strongly suggestive of dynamic action. On first looking at a section with crossed nicols one cannot help being struck with the "crushed" appearance of the rock. The whole section seems to be composed of a mosaic of small plates of feldspar and ferro-magnesian mineral placed in a curiously disorganized manner. The appearance is exactly the same as the granulitization seen sometimes in granitic masses, and is probably due to the same cause—*i.e.*, crushing of the rock-mass after consolidation.

Sometimes there is an appearance very like the groundmass seen in quartz-porphyries that are holocrystalline—namely, a very small mosaic—in this case consisting of altered hornblende or augite and little plagioclase plates.

An analysis of the rock runs as follows:—

	Per Cent.
SiO_2	47·40
FeO	6·60
Al_2O_3	18·17
CaO	12·23
MgO	7·17
K_2O	0·20
Na_2O	2·75
H_2O	0·75
Fe_2O_3	5·42
MnO_2	Trace.
TiO_2	Trace.

Note.—In this analysis the CaO was determined volumetrically with $KMnO_4$ standard solution. This was the method followed by the analysts of the coral limestone at Funafuti, and it certainly seems neater and just as accurate as the other way. On fusion of the powder with the fluxes a greenish tinge was noticed, due, of course, to MnO_2, but the quantity present was too small to be worth tabulating. The TiO_2 was determined by the colorimetric method, but the quantity present was very minute, being also not worthy of tabulation.

W. C. Brögger, in his "Das Ganggefolge des Laurdalits," has given several diagrams of rocks based on their chemical composition, or, rather, what Professor Washington, in his "Quantitative Classification of Igneous Rocks," calls "molecular proportions." A consideration of the above analysis will show—(*a*) a percentage of silica which is exceptionally low—even too low for a diorite, but quite usual for a gabbro: (*b*) a very large percentage of CaO and Al_2O_3, and at the same time an exceptionally low one of potash; this shows, as has been previously shown from the extinction-angle, that the feldspar in the rock is almost wholly a nearly pure anorthite: (*c*) a rather high percentage of total iron and a truly high percentage of Fe_2O_3. It may be remarked that a more than ordinary amount of black magnetite grains were found in powdering the rock, and an examination of a section shows that magnetite sometimes occurs to a considerable extent.

Professor Washington, in his "Chemical Analysis of Igneous Rocks," gives (p. 286) the analysis of a hornblende-gabbro which runs as follows:—

	Per Cent.
SiO_2	49·80
Al_2O_3	19·96
Fe_2O_3	6·32
FeO	0·49
MgO	7·05
CaO	11·33
Na_2O	2·22
K_2O	0·61
H_2O	1·71

Note.—The analysis is marked A2II, so the results can be relied on.

Comparing this with the analysis of the rock in the claim, we see that, except for the low percentage of FeO in the former, these analyses agree very well. The claim, therefore, placed as nearly accurately as possible, will have the following position in Professor Washington's scheme of classification: "Class II. Dosalane. Rang 4. Docalcic. Hessase."

It will be noted from the foregoing that the rock will be more accurately classed as a hornblende-gabbro or simple gabbro than as a diorite, though the latter name was given to it by Captain Hutton and Sir James Hector.

Considering now this rock only as far as regards the claim, we find above a series of strata of which a typical exposure is illustrated in the following section:—

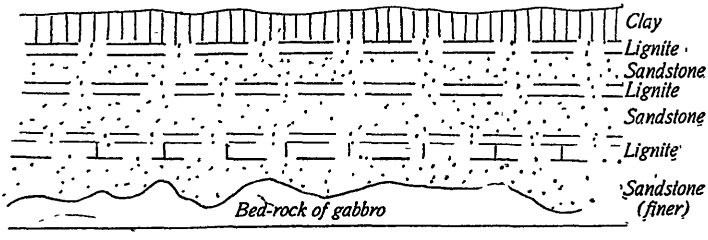

Fig. 8.

In this we see that, resting on the eroded surfaces of the bed-rock, there is first a layer of sandstone and silt about 5 ft. thick, followed by a stratum of lignite of about the same thickness; after this comes another stratum of sandstone, then a layer of lignite, and so on. Three distinct seams of lignite separated by beds of sandstone are to be seen. Above all is the clay, or in places the artificial tailings. The geology, therefore, of the claim is very simple. The sandstone on the bottom is usually fine, interspersed here and there with small pebbles. Sometimes fairly large pebbles of gabbro are found.

The lignite above is poorer in some places than in others, but generally speaking its value does not amount to much. That this lignite has drifted into its present position is shown unmistakably by the following: (*a.*) It is usually muddy, the woody tissue being interspersed with pockets of fine silt, or sometimes very similar in appearance to a brownish-black clay. (*b.*) Rounded pebbles of varying size, and consisting of gabbro, are found in it, more often than not in the bottom of the layer. (*c.*) Prone tree trunks and branches, consisting of miro, pine, and rimu, have been seen in it. (*d.*) An instance has been noticed where a tree-trunk has a vertical position in it, and the lignite has its layers bent up and around the trunk. Whether the trunk actually grew as it has been found is not known, but the probability is that it was simply sticking out of an underlayer, and a fresh deposit was formed round it. (*e.*) The bands are not continuous, but occur in some places and not in others, and often dovetail into the silt and sand. This would tend to show the existence of current bedding. The sandstone above the bottom layer of lignite is much the same as that below it, but does not contain, as far as can be seen, any pebbles. The thickness of the sandstone layers varies between 5 ft. and 20 ft. The beds are of only local extent, occurring only in the hollow between the two sides of sloping ground. The lignite (to a very small extent) and the sandstone are auriferous, a fact which can be shown in the case of the sandstone by a simple prospect with a shovel. No fossils of any kind have been seen.

What, then, is the origin of these formations? To answer this question, let us first suppose we have a coastal area like the Round Hill district undergoing submergence, while, of course, the land further in remains more or less stationary.* The first effect of this is to increase the corrosive action of the streams. Since, however, the land is mostly bush-covered, the corrosion will not be very great, but the amount of vegetation brought down will be proportionately increased. Again, as submergence goes on, the sea will invade the river-valleys, forming ultimately a bay or estuary, and it may extend even to some distance up the sides of the mountain-range. The water of the streams, charged with detritus and vegetation, on meeting the comparatively calm water of the bay will be unable longer to retain the material in suspension, and it will be precipitated. The result is that at first a bar will be formed, but later on the bar will be flattened out. The strata in the bar will be composed partly of silt and partly of woody material, according as the stream has brought more *débris* than vegetation, or *vice versa*. There will, therefore, be a tendency towards the formation of a flat plain, as the sea-action will round off all irregularities, and the slope will increase gradually inland. A succession of periods of flood will thus cause the formation of bands of silt, or vegetable matter mixed with silt,

* If depression all round took place, the corrosive action would, of course, be diminished.

or even in some cases nearly pure woody tissue, especially when the streams come from heavily bushed country. Again, as the land becomes more submerged, any ridges which may exist will be converted into headlands or capes, and in later stages even islands may be formed. Beach-pebbles will occur, of course, but these do not necessarily occur at the margin of the water; indeed, in the case of a bay it is probable that the pebbles will be deposited further out into the sea than in the case of open coast.

Next suppose this area, once submerged, is gradually elevated. The headlands and capes and islands will increase in size, the detrital deposits will appear, and finally a flattish plain will make its appearance, extending between the ridges and right up to the flanks of the range. The corrosive action of the rivers will be lessened, and deposition will occur further up the rivers, tending to increase the extent of the plain.

Let us now apply these principles to the district we are concerned with. Its physiography is exactly similar to that in the case we have supposed. In the sea beyond the mouth of the Ourawera occur small islands, and there are isolated peaks extending at intervals from Orepuki to Riverton. Between these is a succession of flat plains, with a gently rising slope from the coast. At the locality of the claim there are the detrital deposits before mentioned, and the whole range is densely bush-covered. We can therefore suppose that at an earlier period in the earth's history the coast hereabouts was depressed owing to continental oscillation or other causes; that the hollow or rounded surface of the bed-rock of the claim formed an old river-bed down which a stream from the mountains carried at intervals silt and vegetable growth, or both together; that a bay formerly existed where now the Ourawera discharges its waters into the sea, and that a long arm of comparatively calm and shallow water extended from the bay up into the river-valley. The stream then, on meeting the sea-water, would be compelled to precipitate the material it brought down, and the deposits of the claim would then be formed under the water.

The flattish coastal plain would also be formed about the same time. Later on an elevation of the land took place. The Ourawera, bringing down its *débris,* would have its grade lessened,* and consequently would deposit the material higher up, and would enlarge the plain, besides covering its upper part with river-pebbles. The strata formed under the sea-water would now appear close to the base of the range. Bush would grow over all the plain, and the appearance it now presents would be formed. On this theory, the elevation cannot at present be completed, or there was a former much greater elevation of the land, which extended further out than it does at the present day, for, as we have previously remarked, islands occur out in the sea just beyond the mouth of the Ourawera, and these are distinctly not volcanic. Further, the river must have been much larger than it now is, otherwise it could not have deposited such large masses of lignite as do actually occur—such as seams 5 ft. thick after compression. It is possible, however, that it was assisted to some extent in this respect by wood washed along the former shore and banked up in the quiet bay.

It has been assumed that a submergence followed by an elevation occurred, or, rather, as the river-bed shows, first a greater elevation than now, then a submergence, followed by a smaller elevation than before, which latter may still be going on.

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* With reference to the coastal district only; as before, the inner portion remaining steady, or nearly so.

Proofs that the land was formerly much higher, especially in the south, are given by the following: (*a.*) The outlying islands have a fauna and flora very similar to that of New Zealand, and must have been connected to the mainland in late Tertiary times. (*b.*) The absence of older Pliocene marine formations in both Islands, and the absence of nearly all Pliocene formations in the South Island: what Pliocene formations do occur are wholly gravels, which would naturally be formed in the denudation of a mountain-range. (*c.*) Further, the submerged valleys on the west coast of Otago, in the Sounds region, show that formerly the land was much higher, for if, as is most probable, the actual shape of the bottoms as shown by soundings has been caused by glacial erosion, it is evident that a great elevation must have once taken place.

That a former subsidence of level in the South Island has taken place, probably in the Pleistocene, is shown by several writers. On the west coast of the South Island, according to Dr. Hector in the Geological Survey Reports, 1866–67, comparatively recent sea-beaches or beach-terraces extend to more than 220 ft. above the sea. Mr. Dobson, another observer, has estimated these terraces at 400 ft. (Trans. N.Z. Inst., vol. 7, p. 444). At Amuri Bluff, on the east coast of Canterbury, there are three distinct terraces, and Mr. McKay obtained Recent marine shells from the highest, which he estimates to be 500 ft. above the sea. These three terraces also appear further south. Further, a deposit of fine silt occurs along the east coast of Canterbury and Otago from Banks Peninsula to Moeraki. Its lower portions are stratified, but its upper ones are not. At Oamaru the gravels at its base contain large numbers of Recent marine shells, and the upper parts have yielded moa-bones. This silt goes to a height of 800 ft. at Banks Peninsula, and to 500 ft. or 600 ft. at Oamaru. Further, the entrance to the West Coast Sounds has been terraced to a height of 800 ft. above sea-level. Finally, the remarkable river-terraces found throughout the South Island all furnish collateral proof of a once lower level. It is to be noticed that these instances also show a subsequent elevation of the land, and it is quite possible that this elevation is still going on.

The topmost height of the actual detrital deposits amounts to between 400 ft. and 500 ft. It is quite possible, therefore, that the depression or submergence of which instances have just been given lowered the level of this part of the country also by 500 ft. The claim deposits would then easily be accounted for.

HISTORY OF THE CLAIM AND PLATINUM.

It is in a district having the characteristics just described that the company at present called the Round Hill Hydraulic Sluicing Company has its working-area. The main facts about the claim and the discovery of platinum are as follows: Somewhere about the year 1880 some prospectors working in the neighbourhood came upon what they believed to be good alluvial gold. As usual, though the district was in a dense bush and without even the crudest means of outside communication, claims were soon pegged off in great numbers, and in a very short time a considerable number of men (about four hundred), mostly Chinese, were engaged on the field. For a short time the yield was decidedly good, but at last, despite great exertions on the part of the European part of the population (for the Chinese soon made off), barely enough gold could be got to pay expenses. Recourse was then made to hydraulic sluicing, by which, of course, the quantity of material "washed" would be enormously increased. A company was formed, with a head office in Liverpool; the water-races formerly held by the individual miners were all bought over; three elevators were soon put in working-order, and in 1891 sluicing on a fairly large scale began, and has continued up to the present time. Some idea of the extent of the field may be got when we consider that up to 1898 the amount of ground worked by the company was 33 acres, representing 2,100,000 cubic yards of material. The yield of gold for the same time has been 7,751 oz. 16 dwt., equal to a recovery of 1¾ grains per yard, or in value to 3½d. per yard. The total length of all the races amounts to seventy miles, and the total carrying-capacity amounts to thirty-six Government heads of water. The elevators are capable of lifting to a height of 50 ft., and they elevate about 70 tons of material per hour.

After sluicing had been going on for some considerable time, the manager, who is of a decidedly curious turn of mind, began to notice that after washing up he got, in addition to the gold, a small quantity of a silvery-white mineral in fine thin scales. Though somewhat struck with the discovery, he took no further notice of it until, having at length sent some to the Bank of New Zealand at Riverton, he was informed that it was platinum, and well worth saving. The bank agreed to give him £2 an ounce for it at first. After every subsequent wash-up, therefore, the platinum was separated from the gold by amalgamation and was sold, but it was not until about 1897 that any was saved at all. All record of the amount got from the field before this date is thus hopelessly lost.

It has been estimated that the average annual yield of gold from the claim is now about 2,000 oz. The yield of platinum to date could not be got accurately, but we have been informed that an average figure representing the amount got from this locality alone is 150 oz. per year. This would make the total quantity saved to date about 1,200 oz., an amount which is probably in excess of that actually sold.

It must not be supposed that this is the only place in the neighbourhood where the metal is found. We have already mentioned the fact that it was found as far back as 1878 at the mouth of the Waiau, and it has long been known that it occurs on all the beaches from that river as far as the Orepuki Beach. The quantity, of course, is small, and the scales minute and thin, but it evidently pays to collect it. After every severe storm it is not an unusual thing to hear of miners prospecting the beaches for gold, and returning not only with gold but with a fair quantity of platinum.

An examination of the gravel-deposits and the sand shows that the minerals most commonly associated with the metal are chiefly garnets and small grains of non-magnetic or but slightly magnetic iron-oxide. In the claim ordinary strongly magnetic magnetite also occurs.

It will thus be seen that the second occurrence of platinum in Otago is in the alluvial plain of the Round Hill district, and to a smaller extent along the beaches from the Waiau to Orepuki. No records have been made of any occurrence on any other beach to the east, though it is quite possible that traces of it may be discovered, for the beaches as far as Riverton are more or less covered with ripples of ironsand, and this is especially prevalent with the platinum at Orepuki.

Seeing that the platinum from the beaches is essentially the same as that from the claim, one description will do for both occurrences. The metal almost invariably occurs in the form of round or oval thin plates or leaves. Rarely we find small rounded grains, and it has been stated that crystals also occur. W. S. Hamilton, in a paper on the discovery of these so-called crystals read before the Southland Institute in 1886 (see Trans. N.Z. Inst., vol. 18, p. 402), says that he obtained from the Orepuki sands several crystals which, to use his own words, were minute but tolerably perfect. The form was a square tablet, perfect on three sides, but irregular on the fourth. With regard to this, we may say that, though we have examined a considerable number of scales and samples, no such form has been discovered, or, indeed, any approaching to it, and, as it has never been mentioned since, the probability is it is a mere peculiarity arising from sea, river, or pebble action. The scales are slightly magnetic, often of fair size, some having a surface as large as that of a large pin-head. Usually the surface is covered with several intersecting series of striae.

Search has been made in Dr. Reinhard Brauns's "Das Mineralreich," but nothing of any great importance was found, as far as the present paper is concerned, on the subject of platinum. Following however, his example and that of several other investigators, amongst whom we may mention Professor J. F. Kemp, we took a typical scale, and, after carefully polishing it, subjected it to an etching process. In this the solution used was a mixture of nitric and hydrochloric acids, and the strength of the etching-solution was systematically varied. The scale was first of all immersed in a solution of one part of aqua regia to eight of water, and treated carefully for a quarter of an hour. It was then washed and examined in reflected light. No alteration was, however, found. The strength of the solution was then increased gradually from one part in eight of water to one part in two of water. With this solution, after heating gently for half an hour, etching was noticed, but to a small extent. Lastly, a solution of one part in one of water was used; the surface then became decidedly etched, but no definite pattern was formed, so that it was not considered worth while to photograph it. This result shows that there can be no mechanically included gold in the scale, for the gold would disappear with comparatively weak acid. It is also proved conclusively that the opinion expressed by W. S. Hamilton in the paper above referred to—that the striae are caused by the scale being built up of a number of smaller crystals—is without foundation. For if crystalline structure were present the etching would be sure to give evidence of it in the formation of a definite pattern.

ANALYSIS OF THE METAL.

In all investigations into the occurrence of platinum in different localities an analysis is of importance from both an economic and a purely scientific point of view. The composition of nuggets, grains, or scales has been found to be very different in different countries, and several general rules can be founded on a comparison of the different results. It will be interesting and instructive, therefore, to compare our results with those already obtained by different investigators. The method adopted was a slight modification of the one devised by Deville and Debray.

The results obtained from the analysis of the platinum-alloy were as follow:—

	Per Cent.
Platinum	74·61
Iridium	1·30
Palladium	1·36
Rhodium	3·52
Gold	0·39
Iron	5·08
Copper	0·15
Iridosmine (osmiridium)	14·32
Osmium	Trace.

Let us now compare these results with those obtained by Professor J. F. Kemp, as tabulated in his pamphlet on the "Geological Relations of Platinum" (see Bulletin of U.S. Geological Survey, No. 193). Professor Kemp has here collected the results of forty-two analyses of platinum by various chemists, and has arranged them in a series of curves in which percentages of platinum form the abscissae and those of other metals the ordinates. On examining the table and analyses it will be seen that, generally speaking, there seems to be a kind of rule with regard to the amount of osmiridium present and that of the pure metal present, the one increasing as the other decreases, and *vice versa.* The same relation seems to hold in the case of the iron present. It will be noticed that on no occasion when the percentage of platinum in the alloy amounts to 70 does the amount of osmiridium exceed 10·5 per cent., and that percentage occurs only in one specimen. Further, where the amount of osmiridium is relatively small the amount of iron is fairly large, but where the osmiridium is in large quantity the iron falls very low. Thus with a percentage of IrOs (iridosmine) of 6·36 the amount of iron is 15·58, but with 25 per cent. of IrOs the iron falls to 4·30 per cent.

In looking now at our analysis some remarkable peculiarities are at once evident. In the first place, there is platinum amounting to 75 per cent., yet the amount of osmiridium is very high—14 per cent. This is a direct contrast to the results of Professor Kemp's conclusion; indeed, only one analysis at all similar to it has been found. It is given in Dana's "System of Mineralogy," the sample being from British Columbia, and having the following proportions:—

	Per Cent.
Platinum	68·19
Iron	7·87
Palladium	0·26
Rhodium	3·10
Iridium	1·21
Copper	3·09
Iridosmine	14·62

There is another from the same locality having IrOs equal to 10·51 per cent., with platinum 72 per cent.

Further, in all the analyses where platinum amounts to between 72 and 76 per cent. the iron amounts to not less than 10 per cent., whereas in the Orepuki metal it reaches only to 5 per cent. The amount of rhodium present is also high. It will also be seen that a fair amount of gold was shown to be present; but it must be remembered that this was identified only by loss on treatment with acid, and, as the estimation by loss is not quite reliable with very small quantities, it is probable that the amount is not quite so much. The other constituents are, however, in very fair accordance with the results got for them by other writers.

An analysis was also attempted of the osmiridium residue. By Claus's method the percentage of iridium was found to be 59·63. Further separation was not effected.

Origin of the Platinum.

Owing to the interest quite recently awakened with regard to the geological relations of the platinum discoveries, a large number of places —with a more or less technical description of them—where the metal has been found have been recorded. It will be advantageous in our investigation to first briefly review the records hitherto noted of the principal occurrences.

Nearly all discoveries can be grouped roughly in three large classes—(1) veins, (2) placers, (3) eruptive rocks.

In veins the discoveries are few, and rather remarkable. The chief one is that noted by Professor W. C. Knight, from the Rambler Mine, in Wyoming. The district has a country rock of gneiss-granite, penetrated in several places by large dykes of dark basic rocks. The dykes are composed mostly of a typical diorite, and it is in the outcrop of one of the dioritic intrusions that the mine is worked. It is also to be noted that, so far as is known, the metal or ore does not occur at all beyond the region of the intrusion.

The second noteworthy occurrence is reported by C. F. Hartt, from Brazil, in South America. The country rock here is described as a syenitic gneiss cut by quartz veins. Nothing further is known about it.

Another interesting discovery is noted from near Seville, in Spain, by the French chemist Vanquelin. The metal was found in a mineral containing copper together with antimony in an undoubted vein, which was actually being worked for silver. The country rock is a mica-schist.

Again, a remarkable occurrence, which we have already mentioned, is reported from New South Wales. The metal was found near Broken Hill, the seat of the great silver-mines of Australia. The localities where the metal has been found are described as consisting of schists, gneisses, and quartzites, all of which are highly altered sediments. Intruded into these in various places are dykes and bosses of granite and very basic diorite. Some serpentine occurs within a distance of seven miles. The actual lode has already been described. The platinum occurs here in very minute specks, incapable of being distinguished by the eye. It has been suggested that the metal owes its presence to hot springs which formerly issued from the lode, the metal being absorbed by the clays and kaolin round the vein.

Lastly, attention must be directed to the New Zealand lode in the Auckland Province, at the Thames goldfields. A reference to the parallel drawn between the Longwood and the Coromandel Peninsula shows that the lodes in this instance are also in a district penetrated by dykes of diorite or dolerite, though the actual veins are of quartz.

With regard to the third class—*i.e.*, in eruptive rocks—since all placer deposits are derived more or less from igneous rocks or mountainous sedimentary formations, it will be sufficient to describe the most common placer deposits, referring them where possible to their original mother rock (igneous or otherwise).

Platinum has been obtained in commercial quantities in connection with the gold-washings of south-western British Columbia. As far as the metal is concerned, the area which is of special importance is in a valley of a small creek along the Tulameen River. In the neighbourhood of the creek a large dyke of peridotite crosses the country, but does not extend to any great distance beyond. It is cut short by a rock of pyroxenite type, which in its turn is replaced by a large mass of andesite. Evidently, then, the gravels are formed from either the peridotite or the pyroxenite. A careful examination of some nuggets which occurred amongst the scales of platinum revealed the presence of chromite, and, in a few cases, of pieces of olivine. Later on a nugget was got with pieces of pyroxene adhering.

This strongly suggested the fact that the metal came from both rocks. Assays made of the rocks distinctly show traces of platinum, though no grains were large enough to be visible to the naked eye. It appears from this that here the mother rock of the metal has been distinctly identified, and it is well to note the character of the two rocks.

A very similar placer occurrence is reported in connection with the gold-washings of Columbia. The district, which is near Bogota, is formed of the detritus of two rivers flowing from a ridge which is itself an offshoot from the Andes. As far as can be gathered, the country rock is a syenite or syenitic gneiss, with a little granite and much metamorphic rock.

The most notable formation of this kind is, however, the Ural region of Russia. The actual deposits are found on the eastern slopes of the range, and are limited to two localities—the valley of the Iss River and the vicinity of the Town of Nizhni Tagilsk. Both regions are old land-areas which have suffered protracted surface weathering and degradation. The drainage has reached a base-level, and consequently the concentration of heavy minerals has been extreme. The rock-formations along the Iss are almost exactly similar to those along the Tulameen, in British Columbia. Near the head of each stream are extensive outcrops of peridotite associated with equally large areas of syenitic gneiss. Smaller exposures of diorite, gabbro, and gabbro-diorite also occur. The other formations further down are of no practical importance, since the river into which the Iss flows derives nearly all its water from its tributary. To trace this platinum to its mother rock Professor Saytzeff carried out some investigations. The result of his tests shows that the peridotite is the chief source, but the metal also occurs to a small extent in the gabbros.

The Tagilsk region is exactly similar to the above, with peridotites, gabbros, and diorites.

Again, it was noted in 1870 by a Russian observer that the metal occurred in Lapland, and the consensus of opinion seems to be that it was in this case also derived from a peridotite.

Borneo can also be cited in this connection. Platinum was found here in gravels from a series of mountains which consisted of serpentine, diorite, and gabbro.

Just lately, too, it has been mentioned in the "Transactions of the Institute of Mining Engineers," or more particularly in a paper by E. Glasser on the "Mineral Wealth of New Caledonia," that platinum occurs in placers on the Fly River, and these placers are, according to Glasser, derived from the denudation of the great serpentine "massifs" which occur in the neighbourhood.

Besides these occurrences, there are several exceptional ones reported from different countries.

Beach-sands have been found on the Oregon coast to yield very high percentages of the alloy as compared with gold.

In Brittany, in France, the metal has been got with tin-bearing sands along the coast; and in the latest issue of the Geological Survey Proceedings of Queensland mention is made and assays given of beach-sands along the coast which contain quite an appreciable amount of the metal.

Finally, an extraordinary case has been recorded of the presence of metals of the platinum group in the ash of some Australian coals. Such an occurrence has been recorded from no other district, and an assay shows that the ash is quite the richest ore yet assayed for platinum.

What, now, can we gather from these discoveries? If we look back for a little at the geology of the claim we shall see that the characteristics of it are—(*a*) beds of lignite, (*b*) a base of gabbro rock which is an intrusion into a clay-slate formation, (*c*) a gravel placer or beach formation. From the review just given it will be evident that any one of these masses could be not only a repository, but, in the case of the gabbro at any rate, an original habitat of the metal. It was therefore necessary to examine and test both the lignite and the rock in a very thorough manner.

A mass of the lignite was burned completely to an ash, and when a sufficient quantity of ash remained a charge was made up as follows (crucible fusion) :—

	Grains.
Ash	100
Soda..	125
Borax	20
PbO	60
Argol	5

After cupellation an examination of the cupel showed the merest speck of gold, so small as to be unweighable.

It was not thought worth while to follow up this line any further, because, since the lignite is a detrital formation, and as it was brought down by waters which also brought down masses of the neighbouring rock, and since it was probable that more platinum would be evidenced in the rock than in the lignite—for these reasons it seemed better to devote attention to the rock.

A microscopic examination of several sections failed to show the faintest trace, either in reflected or polarized light, of any isotropic mineral other than magnetite. Recourse was then had to assays.

A portion of the rock was taken clean and crushed in a piece of clean cloth. When fine enough, two charges were made of it, as follows :—

A.

	Grains.
Rock-powder	1,000
Soda	1,250
Borax	500
PbO	500
Argol	50

B.

Rock-powder	1,000
Soda	1,250
Borax	600
PbO	600
Argol	45

After crucible fusion, scorification, and cupellation, the weights of the beads were found to be—A, 0·003 grain; B, 0·003 grain. Since, however, some decomposed material adhered to the rock, fresh assays were run with exactly the same charges. The bead of A weighed then 0·001 grain, and that of B 0·0012 grain. Both beads were then put together, inquarted and parted in nitric acid, dried, and the combined weight got. It amounted to 0·002 grain.

From this it will be seen that the whole was practically pure gold, with only a trace of silver, and that probably due to the lead-oxide used.

An amount equal to 0·002 grain in 2,000 grains of powder works out at nearly 16 grains per ton. Taking the price of pure gold at £4 per ounce, this means that the rock is worth 3s. per ton, so that it is decidedly auriferous, and might even pay to crush. When we consider, then, that the *débris* of the claim has been the accumulation of perhaps hundreds of years, when we consider that the sandstone of the claim is auriferous, that the washdirt of the miners consists of a mixture of decomposed rock material and sand with pieces of lignite, and so on, and when we consider that more gold is found where the rock is most decomposed, it would appear that much of the gold of the company comes from this gabbro rock. This is further suggested by the fact that the value of the gold fluctuates between £4 2s. 6d. and £3 16s. 6d. per ounce, for it is well known that gold from igneous rocks is usually very pure. The impurities, or the gold of lesser value mixed with it, may have come along the beach, for it is also well known that the gold which does occur on the beach at Orepuki and at the mouth of the Waiau is inferior in value, amounting rarely to more than £3 10s. per ounce. The appearance of the gold in the claim also strongly suggests a different origin from ordinary reef gold. The grains are very small, and there is no record of a nugget of any size ever having been found near the claim. An examination in reflected light shows that many of the grains are irregular, rounded sometimes but at others almost rectangular, and with ragged edges. It would thus seem that they had to some extent been washed along by a running stream, while others had been freed just where they are. It was appearances like these which led McKay, in his "Gold-deposits of New Zealand," to say, "On the Orepuki and Longwood Range field no payable quartz lodes have been found, and the alluvial gold had a source distant from where it is now found. In this case the alluvial gold does not indicate the existence of reefs in the neighbourhood." As it is to be hoped we have shown, it is quite possible for the gold of the claim to have come from the rocks (gabbro) in the neighbourhood, washed down and concentrated from the hills near at hand when a larger stream was flowing.

In connection with the gold which we consider to have been, to some extent, washed along the beach, it is just as well here to consider the opinion expressed by W. S. Hamilton in the paper previously referred to on the renewal of gold on the beaches of the south of Otago. He says, "Just as wood is often silicified into stone in large quantities, or carbonized into coal, so it would appear that it may be metallized into the ironsand of our goldfields, auriferous, cupriferous, or platiniferous, from either some obscure conditions of process or inherent quality of the original substance. The ironsand of our goldfields appears to be derived from the breaking-down of pyritized wood by mechanical or chemical means. This pyritized wood occurs along the sands, and, by the replacement of the sulphur by oxygen, magnetite may easily be formed from timber." He then goes on to say, "The renewal of gold in our beaches seems to be an example of this slow change of the ironsand. Miners observe the same renewal in the washings of the Orepuki Goldfield." This theory of renewal is, of course, mere nonsense, for it is a well-known fact that in all beach-workings the world over more precious metal occurs after heavy storms than was present before. The reason is that the gold, being very heavy, requires a great force to move it away, and this force is provided by the fury of the waters, while the lighter material on top is easily carried off, leaving the gold uncovered.

Several distinct assays were then run of the rock-powder; the beads were put together, so that a total weight of 0·02 grain was obtained; the whole was inquarted and parted in nitric acid as before, care being taken to use only a minimum of silver to prevent any loss of other metals which might be present. After parting and drying, the bead was again weighed. Its weight amounted to 0·0195 grain. This strongly suggests that no metal except gold was present in the rock, for, although a small difference in weight (0·0005) was obtained, this could never be regarded as conclusive.

To remove, however, all element of doubt with regard to the presence or otherwise of platinum in the rock, recourse was had to the following method: A large mass of perfectly fresh rock weighing over 4,000 grammes (nearly 10 lb.) was taken and carefully powdered. The pestle and mortar used was first rendered perfectly clean, and the preliminary crushing of the rock was done in new cloth, so that all danger of introduction of any foreign materials whatever was done away with. After crushing had been gone on with until the powder was fine enough to go through a 60-mesh sieve it was panned off. By this means all the lighter portion of the powder was gradually carried off, and ultimately there was left a mass of black material about 30 grammes in weight. This was carefully examined by means of a microscope for any trace of the silvery metal, but none was found. Since, however, the result of most observations on the occurrence of the metal in igneous rocks tends to show that it is present in them in exceedingly fine division, the concentrates were subjected to a process as follows: A quantity of aqua regia was added to the porcelain vessel containing the residue, and the liquid was evaporated to dryness on a water-bath. This process was carried out two or three times, to insure the solution of any metal present. The residue (from the evaporated solution, not the original residue) was then twice treated with sulphuric acid, and again evaporated to dryness on a water-bath. This residue was taken up with absolute alcohol and water, filtered, more alcohol was added, and to the clear solution was added ammonium-chloride crystals in excess. The solution was slightly warmed to dissolve the crystals, and put aside for twenty-four hours. On examination at the end of that time no trace of a precipitate was visible, and, though the liquid was again filtered, absolutely no trace of the yellow chloroplatinate was found. Care, of course, had been taken not to have too much liquid when the ammonium-chloride was put in, for in that case a small quantity of platinic chloride, even if present, might not be precipitated.

From results got from assays, and from qualitative tests for the metal, we are forced to the conclusion that it does not occur naturally in the gabbro. There is, of course, the very remote possibility that the metal occurs so sparsely distributed in the rock that the actual piece taken really contained none. The assays, however, were all done on pieces of rock broken from different places, and if there had been any present we should have expected a small, yet distinct, indication. It is unlikely, too, that a piece of rock 10 lb. in weight from the heart of the claim should contain no trace of metal if it were really present in the rock.

Where, then, does it come from? The clay-slate formations of the range can be dismissed as far as the claim is concerned, for the present stream does not flow through them, nor could it have been possible for even a large stream to have done so. The cause of the stream being larger was not a greater length, of course, than it now has, but an elevation of the land causing a greater rainfall and thus increasing the water-supply without lengthening the course to any extent. The stream everywhere flows through gabbro rocks until reaching the plains.

There seems to us only one other possible explanation—*i.e.*, that the platinum was formerly present as a beach deposit which was subsequently covered up by the detritus from the land brought down by the rivers. Such beach deposits are by no means unusual, as we have just previously shown in our review of the methods of occurrence, instances having been reported from Oregon, Queensland, New South Wales, and so on.

The origin of the beach-sands is conceived to be as follows: At the period when the level in the south of Otago was much lower the erosive action of the rivers in the neighbourhood would be greatly increased, seeing that a larger fall would be provided for their waters. The interior would, of course, have to be comparatively stationary, and observations in nearly all areas in which elevation and depression of coastal beaches have been observed tend to show that the interior does remain more or less stationary. The Waiau River would be affected in this way. We have already seen that it is a very large river, with an output equal to two-thirds that of the Clutha. If we examine its course from the time it leaves Lake Manapouri we shall see that it receives tributaries from the Hunter Mountains, from Lake Monowai, and from the Takitimu Mountains. During a period of depression, therefore, the erosion of these areas would be greatly increased, and, since the rate of flow of the river would be greater, its carrying-capacity would also be much greater. Consequently, at the mouth, which would be further inland than it now is, much of the gravel would be deposited, the remainder being deposited all along the banks. The material at the mouth, by the action of the waves, would gradually be distributed along the coast, so that everywhere along the borders of the land a bed of gravel and silt would be formed. This would include minerals derived from the rocks, the heaviest of which would first be dropped, and the others in the descending order of their specific gravity. The probable existence of a beach at Round Hill has been dwelt on already. On to this beach the finer of these minerals would be carried. It is conceived that the platinum has been brought in this way down the Waiau, and distributed along the beaches.

Let us now examine the evidence in support of this supposition. In the first place, the rocks from which the River Waiau flows would have to be platinum-bearing. If we examine the geology of the west coast of Otago we see that almost the whole of the left bank of the Waiau consists of the Manapouri formation of Hutton and the Kaikoura formation of Hutton. Hutton, in his "Geology of Otago," in describing the former, says that it is found only on the west coast of Otago from Milford Sound to Preservation Inlet, extending inland to Lakes Te Anau and Manapouri and to the upper part of the Waiau. The rocks, he says, are composed of syenitic gneiss, granulites, hornblende-schists, serpentine-schists, and limestone (marmolite). Dr. Hector, in describing the same, says that they are hornblende-schists, felstone dykes, and serpentines. The latter, he says, wrap round the formation, and in places are found on its surface. Again, Hutton, in his "Geological History of New Zealand" (1899), refers to these rocks as eruptives. He calls them chiefly diorites and gabbros that have acquired a schistose structure by pressure. He says they are coincident with the peridotites and serpentines occurring at intervals between Milford Sound and D'Urville Island. The Takitimus, from which also tributaries come to the Waiau, are placed by Hutton in his Kaikoura formation, which has been described by Dr. Hector and Mr. S. H. Cox as filled with dykes of diorite and serpentine. It is thus evident that the river comes from a district in which serpentines and highly basic rocks are not uncommon. These serpentines have been connected by Hutton with the serpentines in Nelson, and indirectly with those of Milford Sound. It will be noted that platinum has been found in the serpentine district of Nelson, and it has been found actually in the peridotite rock north of Milford Sound. It is therefore quite conceivable that it may originate from this serpentine or diorite rock near Manapouri, for results go to prove that the metal is most often found in districts which are characterized by the presence of these rocks. In New Zealand alone we have already seen that there are three distinct occurrences, all associated with either a serpentine or a peridotite which alters into a serpentine. It was for this reason that attention was called to the occurrence in the Takaka Valley, in Nelson.

In the second place, the theory presupposes the existence of a more or less powerful current in Foveaux Strait, which would aid in the dispersion of the gravel along the shores. A reference to the accompanying

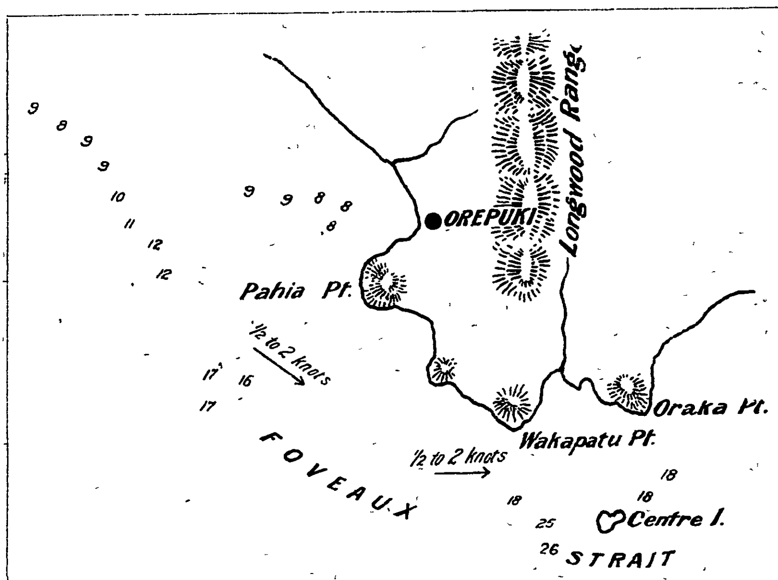

FIG. 9.

sketch, which has been directly copied from the Admiralty chart, affords ample evidence of the existence of such a current. From the sketch it will be seen that a current sets in from west to east, and flows with an average speed of from a half to two knots per hour. This would be sufficient to produce the easterly distribution of the pebbles observed on the beaches from the Waiau to Orepuki. The sketch is on a reduced scale, and soundings have been introduced, which show the gradual slope continuing well into the sea.

Further, the shape of the coast-line in the upper part is exactly what would be produced by gravel-deposition — a long low flat pebbly plain densely covered with bush. In its lower part it suggests to some extent the former existence, or even the present existence, of great denundation by heavy sea-action. All the projections, such as Pahia Point, Oraka Point, Wakapatu Point, are denuded on their western sides, and the sea takes a bend round their eastern sides, forming a comparatively quiet bay. All the beaches down to Wakapatu are strewn with pebbles, and an examination of these pebbles shows that they consist of pegmatite, granite, diorite, and a white mica-schist. These rocks all occur on the western bank of the Waiau, and are not found anywhere on the intervening country.

The fact that hardly any platinum has lately been found on the coasts past Orepuki also strongly supports the theory, for owing to its high specific gravity the metal would be amongst the very first to be deposited, and so would, in ordinary circumstances, not be carried far. Further, the metal has been found at the mouth of the Waiau not only in finer scales, but in nuggets weighing 2 oz. or 3 oz. These would naturally be dropped as soon as the velocity of the stream, from any cause, began to slacken; or, rather, as soon as the fall of stream began to be not so great these would ceased to be rolled along the bed.

It must be remembered, too, that in the Orepuki district the metal occurs chiefly in the form of scales. These are especially capable of being transported by water owing to the flatness of their surfaces, and the large amount of surface therefore exposed to any propelling agency.

Lastly, the theory affords an easy explanation of the fact that the platinum in the claim is found invariably on or very near to the decomposed outer zone of the gabbro bed-rock. Owing to its weight it would be deposited first of all on the beach-sands, nor would it be as liable to subsequent removal by water-action as the sand above it. Of course, even if it had come from the gabbro rock, and had been at first located in, say, the sandstone, it would ultimately reach the bottom in accordance with the principle observed in almost all alluvial areas—*i.e.*, the (so to speak) burrowing-action of the precious metals by which they work their way down from the highest level until they are stopped by impenetrable material.

It may here be stated that W. S. Hamilton considers the origin of the platinum as identical with that of the gold—viz., the "metallization" of wood into a platiniferous substance, from which the metal is derived by some oxidation or replacement. This, of course, would presuppose the existence of platinic solutions, or salts of platinum capable of being volatilized, quite near to the locality. With regard to this, Professor Meunier has stated that by introducing volatilized chlorides of iron, nickel, platinum, &c., 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. He therefore concludes that the native platinum has been brought in presumably a similar manner, and has been deposited so as to yield either nuggets or grains (see "Comptes Rendus de la VII Session Congrès Géologique International," p. 157).

It certainly is rather interesting to know that metals or alloys can be deposited in this way; yet crystallization from fusion seems not only to be as competent to bring about the observed results, but also to have much greater claims to probability and to general confidence.

With Hamilton's theory, too, the question why twigs alone have been chosen as the basis for "metallization" requires an answer.

To sum up: We have seen that this, the chief occurrence of the metal in the South Island, is in an alluvial district near the sea-coast, with a gentle slope towards the sea-beach, and situated at the base of the most outlying spurs of a mountain-range. We have seen that, contrary to what was to be expected, the platinum does not originate from the gabbro rock directly above which it is found, and which occurs all over the neighbourhood. We have given reasons for believing that it may originate in the serpentine region near the head of the Waiau, a region from which most of the tributaries of the river derive their water; and we have endeavoured to show that if such be the case it would be quite possible for the metal in the form of fine scales to be swept or worked along the beaches, and ultimately find itself in the position it now occupies. If the theory is true it will be quite in accordance with observations made in platiniferous regions the world over, though it must be admitted that the fact that the metal actually occurs as a constituent of beach-sands derived from a source far distant, and does not originate in the basic rocks which occur all round it, is quite peculiar, and one might almost say unique.

From the economic standpoint, if the case is as we suppose, the value of the discovery cannot be very great as far as the mother rock is concerned, for ages of denudation and concentration will be necessary to make even alluvial deposits payable, and it is almost impossible to think that it would pay to crush a mother rock which furnishes, even after a tremendous length of time, detritus giving such comparatively small returns. The theory, however, enhances the probability of further discoveries of heavy particles of the metal towards the mouth of the Waiau.

LITERATURE.

It only remains now to give a synopsis of the literature to which we have had access, and in this connection especial mention must be made of the paper on the platinum group of metals by Professor J. F. Kemp (see below). The references are divided into two groups—(*a*) those relating more to the geology of the country; (*b*) those relating more particularly to platinum.

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(*b.*) *Platinum.*

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Art. XLIII.—*Petrological Notes on Rock Specimens collected in South Victoria Land.*

By Richard Hansford Worth, Assoc.M.Inst.C.E., F.G.S.

Comunicated by T. V. Hodgson, F.L.S.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

This paper embodies the results obtained from an examination of material collected in South Victoria Land by Mr. T. V. Hodgson, biologist to the British National Antarctic Expedition (1901–1903). It is merely intended as a supplement to the official report, and is confined to description of individual specimens, without any attempt to generalize or arrive at large conclusions as to the structure of the district. From a much greater mass of material the affinities of the various rocks have been worked out by Dr. Prior, and it is only where the specimens have not been described in the official report that any detail is entered upon, except that in some instances slight variances have been met to which attention has been given.