ON MINING IN NEW ZEALAND. BY JAMES HECTOR, M.D., F.R.S.,
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NEW ZEALAND was not, like many other countries, first colonised on account of the attractions which its mineral wealth offered, and yet it is worthy of remark how early in the history of its occupation we find that mining was practised.

The earliest mine opened in New Zealand was at the Island of Kawau, which now belongs to Sir George Grey, where a vein of manganese ore, and soon afterwards, a copper lode, was opened up in 1842. Coal was also worked in New Zealand, for the first time in 1842, at Motupipi, in the Province of Nelson, so that these two great elements in the manufacturing progress of a country, fuel and metalliferous ores, were brought into notice at the same date, but in localities far apart, within three years of the formation of the colony.

The natives appear to have known nothing of the use of metals, and to have had nothing derived from the mineral kingdom in their possession, which would be deemed useful by the white man. The weapons and implements of the Maoris were made altogether of wood, bone, and stone, and it is a very significant fact for Ethnologists that a race possessing such acute power of observation, should not have made further progress; for had they brought with them to this country any traditional knowledge of the use of metals, they could hardly have failed to have discovered their presence in these islands. They do not, however, deserve the low status accorded to them by Professor Cotta, in a recent lecture, who in describing, in a peculiarly lucid manner, the steps by which man has advanced in the application of natural substances to supply his wants, says:—“On account of the implements prevailing, or at least preponderating in successive periods of time, the history of civilization has been divided into stone, bronze, and iron ages. * * * The stone period was divided afterwards into an older and younger, according as the workmanship was very rude or otherwise. But in some parts of the world, wood, bone, and shell appear to have been used in place of stone. The New Zealanders in the earliest times, and indeed till quite recently, have made their implements and weapons of very hard wood. They have never had a stone period.”†

And again in another passage he remarks:—“Whilst in Europe and many other parts of the Old World, the age of iron had long been introduced, the inhabitants of America continued for centuries to use weapons made of copper, bronze, or stone, and the inhabitants of New Zealand, of hard wood.”‡

As a sufficient answer to these statements, it is only necessary to point to the cases in the Museum, which show every variety of stone weapon and implement used by the Maoris, from the flakes of chert, belonging to a very

* These lectures were chiefly explanatory of geological plans and sections, and having been delivered from notes, and imperfectly reported, are now given in the following condensed form.
† “Geology and History.” By Bernhard von Cotta, pp. 29-30.
‡ Ib., p. 33.
ancient period, up to the highly-finished *Meres Pouanau* which is still used as a weapon in warfars, and as a symbol of independence. Only the other day we heard how Te Kooti, in his progress through the country, thought it of importance to wrest the *Meres* from all chiefs through whose territory he passed, which shows the traditional value attached to them. However, the Maoris appear never to have passed beyond the so-called stone period, although they were sufficiently advanced in intelligence to appropriate at once to their own use the most improved forms of the implements of the iron age, when placed in their hands by the white man.

It is therefore since the settlement of this colony that the metallic ores, already found, have been discovered, of which we have the following:

- Gold—nearly pure, or alloyed with silver or copper.
- Silver—in its native state, as well as sulphide, has been detected, but only in small quantities.
- Mercury—both native, and as sulphuret or cinnabar.
- Copper—in its native state, and as sulphide, silicate, oxide, carbonate.
- Lead—as sulphide.
- Iron—as magnetite, hematite, bi-sulphide, carbonate, and titaniferous iron.

Together with these ores, chromium, zinc, antimony, arsenic, and others in smaller quantities.

These constitute the class of mining products that are excavated from mineral lodes, occupying veins and crevices, or fissures in rocks, but we have also coal and iron ores occurring, interbedded with stratified rocks, and from our superficial deposits of sand and gravel, a rich harvest of gold dust has been obtained. If we include the last group among the mining products, we should not omit building-stones, slates, limestone, cement stone, brick clays and other materials of construction; but although all these form part of the mineral wealth of a country, the term mining is usually restricted to those mining operations that require a command of capital and skilled labour. It is no doubt true that in these colonies "diggers" of alluvial gold are termed miners, and certainly the gigantic works which they sometimes undertake, may fairly entitle them to be considered so; but still I think much inconvenience will arise if a distinction is not made between "diggings" and "mines," the former providing employment for independent individual labour, under temporary tenure, the latter only for an organized system of labour, and the speculative application of capital, the condition requisite for which is security of tenure.

In New Zealand, as in all other parts of the world, accident has frequently led to the first discovery of valuable minerals, and this is not to be wondered at when we consider how many acute observers are found among the first settlers in a new country, where every unfamiliar object excites wonder and curiosity.

A systematic survey, however, with the assistance of the experience embodied in the sciences of geology and mineralogy, greatly increases the chance of finding minerals, by indicating those areas which will reward a more thorough investigation, and limiting the search to profitable fields.

After the actual discovery of a mineral lode, scientific knowledge is also equally useful in order to encourage and direct the operations when the indications are favourable to success, and to repress too sanguine speculation when they are the reverse. This latter duty is a thankless task, but still not the less important and useful in assisting the true progress of a country. It is especially important in all new countries that those mines should be first worked which show the greatest chance of success, as failure is sure to create distrust on the part of capitalists, and what is still worse, to discourage further explorations.
There is one other point on which I must say a few words of caution, respecting the relation of geological science to mining. Geologists are too frequently called on to predict where mineral wealth may or may not exist, but notwithstanding the great advances which have been made in geology, we must admit that the science is still a mere digest of observed phenomena, highly qualified to enable the student to observe and record with accuracy, but not having yet attained to generalizations that warrant prediction on this subject. A positive assertion that minerals exist in "such a district," or "in such a direction," is very easily made and can never be positively disproved. It is therefore quite safe, and likely to catch any credit that may arise from future discoveries, but I am glad to say that it is rarely that true science ventures on such predictions. It is very different in the case of a positive assertion that a mineral does not exist in any particular locality, or, that it cannot exist under certain conditions, which is a statement that should only be ventured from actual observation, as it can, if incorrect, be at once confuted. Geological science will not, therefore, enable us to dispense with diligent and extended search.

Before proceeding with the description of the localities where mines have been opened, it is desirable that I should state briefly the leading features of the geology of New Zealand.

The whole group of islands may be looked on as a narrow mountain ridge, rising from a deep ocean bed and extending in a N.N.E. and S.S.W. direction. The form of the coast is determined by the outstanding bluffs of harder primary formations, or by massive volcanic rocks that belong to the latest Tertiary periods. These hard rocks, and especially those last mentioned, have been the means of preserving patches of upper Secondary and Tertiary formations, which occupy a larger proportional area in the North than in the South island, where the mountains are loftier and occupy a greater breadth of country.

We find, on a closer examination of the structure of the mountain system thus described that it is by no means uniform throughout, but that the rocks composing its southern portion are of much higher antiquity, and show evidence of having been subjected to chemical changes at a greater depth in the earth's crust. This difference is evidently due simply to the southern mountain mass having been elevated to a greater extent as compared with the sea level, than that in the north, and, in consequence, a much thicker layer of the superficial and unaltered rocks has been removed by atmospheric denudation. A few years since it might have seemed absurd to have attributed the present form of mountains, thousands of feet high, traversed by valleys extending even beneath the sea level, to denudation, or to have held that they are the mere core of former mountains of greater magnitude, worn down by the long continued action of ice and running water. But now such a view is in accordance with the best matured opinion.

It is therefore to deficient elevation towards its northern extremity that we must attribute the absence at the surface of many of the rock formations which are prominent in the southern portion of New Zealand, and we must conclude that in the north the same rocks exist at greater depths, and are probably still undergoing chemical changes that have ceased to operate on their southern equivalents.

The sequence of geological formations in New Zealand is abruptly broken about the close of the Lower Mesozoic period.

All the formations prior to this have been, wherever they occur, more or less cleaved and jointed, so as to be hardly distinguishable from the oldest primary slates and sandstones, combined with which they constitute the main part of the rocky framework of the islands, and form some of the highest mountain peaks.
The sub-divisions of the oldest stratified rocks have not been determined, but the fossils already obtained show that they represent groups from the Upper Silurian to the Triassic periods.

The chief mountain range, consisting of these formations, extends from the east coast in the northern part of the Otago province, in a curved line defining the western limit of the Canterbury plains, to Cook's Straits, from where it extends through to the North Island, as a series of intermittent ranges, each trending N.N.E., but as a whole having a direction to the west of north. A second range of the same formation extends from the S.E. of the Otago province, and crosses the island to Jackson's Bay, but is not continued northwards, although outliers are found at some points as far north as Cape Farewell, resting on and altered by the older rocks.

In the central portion of the Province of Otago, included between the two lines as above described, foliated schists are exposed at the surface over an area of 10,000 square miles, comprising micaceous, chlorite, and quartzose schists. This is the district of New Zealand in which the largest quantity of gold has been obtained. On the steep western slope of that portion of the Southern Alps, culminating in Mount Cook, the same schistose rocks are continued as a narrow irregular band for half the length of the island, and then again appear at intervals as far as Cape Farewell. These schistose rocks are only known on the east side of the main line of the New Zealand Alps, in two places, one in the south of the Province of Canterbury, on the Waitaki river, and the other close to Cook's Straits, between the Waian and Wakamarina rivers. In the North Island this formation has not been detected.

The remaining division of the older rocks is best developed in the S.W. corner of Otago where massive mountains of granite, gneiss, and other crystalline rocks occupy a very extensive area.

The chief characteristic of these mountains is their cubical form, due to their being intersected in all directions by profound but narrow valleys, with abrupt precipitous sides to three-fourths of the extreme height of the adjacent mountains. The valleys are partly occupied by arms of the sea, and inland lakes that resemble the Norwegian Fiords, and present most wonderful mountain scenery, that is easily accessible, and yet almost unvisited.

The same granite formation extends to Stewart's Island, and others of the outlying islands of the New Zealand group in a southerly direction. It also occurs at intervals along the west coast northwards to Cape Farewell, but it is frequently difficult to distinguish it from the granite porphyries which will be mentioned in connection with the rocks of the Igneous class. In the North Island no granite has been found corresponding to the old gneiss-granite above described, but dykes of granite-porphyry occur on the Barrier Island.

Let us now turn to the formations that belong to the periods after the break which has been described as occurring in the Mesozoic period, and we find a successive repetition of terrestrial beds with seams of coal and plant remains, with clays, marls, limestone and sandstone, in the manner usual in Secondary and Tertiary formations. The earliest plant remains show many forms that are now extinct, but associated with them are a few that cannot be distinguished from those of the existing Flora. In the newer carbonaceous strata, the resemblance to the existing forms is still greater, some of the peculiar and characteristic trees of the New Zealand forests, such as the Kauri, being well preserved. There is, therefore, very little doubt that since the upper Mesozoic period, dry land has existed continuously, and that some part or other of the New Zealand ridge has always been above water. The succession of marine fossils divides these formations into well marked groups characterised by changes in the species of marine animals on the coast, and showing a gradual
passage from forms allied to the South American types, to those of the Australian seas.

The occurrence of Secondary Cephalopods and Saurian reptiles in the lower groups renders it probable that the strata range from Jurassic formations upwards. But this is a subject pertaining purely to geology.

I will next proceed to describe briefly the Igneous rocks found in these islands, some of which have a more direct relation to the presence or absence of minerals than any of the foregoing.

Among the crystalline rocks we find Syenites, and many varieties of Hornblende and other basic rocks, but they are chiefly to be considered as varieties of metamorphic rocks. In the great Schistose area of Otago, there is a very marked absence of all Igneous rocks, except towards the eastern border, where Dolerites, belonging to the Miocene period, have escaped through the Schists at a few points, but without influencing their mineralogical character.

It is not till the period of the lower Mesozoic rocks, previous to the break in the geological sequence which I have described, that any contemporaneous Igneous formations have been detected. These consist of Diorites, Diabase, and Porphyries, associated with mechanically-formed strata of the same materials (Diorite sandstones and Breccias), containing fossils that indicate the period to which they belong. This formation is associated with a variety of altered rocks, of which Serpentine is the most prominent, and on the whole closely resembles in character the Diorite formation of South America, as described by Darwin and David Forbes. These Diorite rocks are found along a line that extends almost continuously through the South Island, chiefly along the western slope of the mountain axis, but they also appear in one or two localities on the eastern side of the range, though there presenting somewhat different characters. As the best known example of this formation I may instance the Dun Mountain, and mineral belt of Nelson.

What I take to be the same formation occurs in the North Island among the older rocks of the Colville peninsula, Barrier Island, and other mining districts. The relative date of the different Igneous rocks, subsequent to the foregoing, can generally be determined with considerable certainty. They present great variety, and belong chiefly to the upper Tertiary period, but it will be found, as our observations are extended, that volcanic outbursts were taking place in the New Zealand area, at almost every period subsequent to the Mesozoic Diorite series. The influence of the more modern volcanic rocks in producing mineral lodes and veins has been very slight, the only well-established cases being when they have been erupted through the Igneous rocks of the Diorite group, as at Coromandel and the Thames.

Keeping clearly before us these leading characteristics of the geological structure of New Zealand, it is highly interesting to compare them with the structure of the nearest large mass of land in Australia.

Extending along the eastern border of the Australian continent, we have within a short distance of the coast the Australian Cordillera, a main range of Primary rocks, flanked on the east side by a shelf-like remnant of Secondary strata, comprising the various coal fields of New South Wales, while on the west side is an expanse of low-lying country, where only very modern Tertiary formations are found. Towards the South end of the range in Gippsland, we have masses of granite lying to the west of an area of Mica slate and other metamorphic rocks. The marked resemblance of the natural features of this district to the Otago province of New Zealand has been frequently mentioned by diggers, while the analogy of geological structure in the two districts has been the subject of correspondence between Mr. Selwyn, the late Government geologist of Victoria, and myself. Now I find that by covering the Australian Cordillera in a map of Australia, with a tracing of
New Zealand, drawn to the same scale, placing the Otago Mica-schist area directly over that of Gippsland, and making the meridians parallel, that there is a wonderful coincidence between the relative position of the goldfields in the two countries, the chemical character of the gold, and the nature of the associated rocks and minerals.

New Zealand, thus compared, equals in length from Gippsland in Victoria, to Rockhampton in the north of Queensland, a range of territory which is important to the question of relative mineral wealth, when we also observe that New Zealand covers in width the mineral bearing ridge or Cordillera of Eastern Australia, having the ocean on the west instead of the Murray plains, and on the east only small areas of the carboniferous rocks.

By referring to the accompanying map (Plate 21), in which the relative extent and position of the two countries is shown at a glance, it will be found that the chief Victorian diggings, such as Ballarat, Castlemaine, and Bendigo, lie altogether west of the New Zealand boundary, and this is quite in accordance with the absence of any geological formation in New Zealand similar to the highly-cleaved Silurian strata of those gold fields. Then selecting for comparison the chief diggings in both countries, we find that Beechworth, Snowy Creek, and Omeo, correspond exactly in area and position with the richest diggings of Otago. Ophir exactly covers the position of the chief Hokitika diggings; while the Bathurst district has its analogue towards the south of the Teramara. Bingera lies a little to the north of the Nelson gold fields, and the Rocky River diggings cover those of the Waiwera. Continuing northwards there is a long gap without auriferous localities in both countries, till we are struck by finding that Gympie creek, in Queensland, exactly agrees with the Thames diggings. With more perfect maps of Australia than those at my command, and especially one showing the geological formations, it might be interesting to follow the analogy into its minute details, and so far as I am able to judge from the information I possess, it would be fully borne out.

From the description of the New South Wales gold fields, by the Rev. W. B. Clark, I gather that in the southern portion of the Cordillera, the gold, which is of good quality—containing less than 6 per cent. of silver—is chiefly found in that part of the country composed of Hornblende granite and Mica schist; and this, as before stated, corresponds with the general character of the Otago country.

In what he terms the western district, which on our map corresponds with the Nelson district in New Zealand, he describes it as characterised by irregular areas of Hornblende granite, with locally transmuted members of the upper Palaeozoic group, and Serpentine charged with Chromic iron, where the rocks have been altered by dykes of Diorite. This description is quite applicable to the Nelson district, and, moreover, in both districts the gold is found to be alloyed with from 10 to 14 per cent. of silver. At Gympie creek, in Queensland, we learn from reports by the Government geologists, that the gold is obtained from reefs traversing decomposed Diorite rocks, associated with masses of tufaceous Breccia and Conglomerate. Areas of soft felspathic schist also occur, the whole series of formations being intersected by dykes of Diorite. From a collection of the rocks of this district, lately sent to the Museum by Mr. T. Hackett, I select many that cannot be distinguished from Thames specimens: the quality of the gold is also identical, and highly characteristic, as it contains over 35 per cent. of silver, and is found along with small quantities of lead, arsenic, antimony, copper, and other metals. Among the rock specimens it is interesting to find some taken from mines at Gympie Creek, that from their appearance at a first glance, and also from their chemical composition, would be classed as Diorites, yet distinctly containing fossils of the same species that characterise our upper Palaeozoic and Triassic rocks.
Comparative Map of NEW ZEALAND and the AUSTRALIAN CORDILLERA.
To accompany a Paper by Dr Hector.

[New Zealand Goldfields marked 0]
1. Tuapeka.
2. Wakatipu.
3. Hokitika.
4. Buller.
5. Collingwood.
6. Wakamarina.
7. Thames.

[Australian Gold-fields marked +]

Outline of New Zealand dotted

Australia Lat. 25° to 38° S average Mer. 150° E.
New Zealand Lat. 34° to 47° S. average Mer. 172° 30′ E.
These general coincidences between the distribution of the minerals in the two countries, I believe to be more than accidental; and I only venture to advance them in this imperfect manner to show that in both the Australian and New Zealand mountain systems we have the same mineral fields represented on parallel lines, which lie at the same angle to the meridian in each case; and further that the peculiar features of each is repeated at equal intervals, distinguished especially by the deterioration in the value of the gold, as we pass northwards in both countries; the only material difference being that New Zealand is situated geographically nine degrees further south, than that portion of Australia.

GOLD MINES.

Gold was discovered within less than three years of the foundation of the colony, in 1840, but it was not practically worked until 1852, when the mines at Coromandel first attracted attention to the same district that at the present time forms the chief seat of mining operations in New Zealand; but the yield from those mines has, up to the present time been small, when compared with the quantity of alluvial gold obtained in the South Island, subsequent to 1861, at which date the gold fields of Otago became prominently known. I have already alluded to the peculiarities of the manner in which gold is distributed in New Zealand, and taking these as a guide we naturally divide the gold fields into the following districts for convenience of description:—

1. The Northen gold field.
2. Nelson and Westland, or Western gold field.
3. Otago, or Southern gold field.

The Northern gold field is situated chiefly on the west side of the Cape Colville peninsula, but gold has also been obtained in small quantities on the eastern side. The peninsula is a bold mountain ridge, having a mean altitude of 2000 feet above the sea level, composed of slate rocks interbedded with the eruptive rocks belonging to the Diorite series of the lower Secondary period. These rocks form at least three well-defined belts crossing the peninsula obliquely in a north-east direction, the depressions which separate them being occupied by tufaceous deposits of volcanic ash, intermixed with ejected fragments of rocks of various ages. These Tufas which envelope the older rocks to an altitude of at least 1400 feet above the sea level, were deposited in the Tertiary epoch, and form part of a formation that occupies a very extensive area in the Auckland province.

The district as yet tested by the miners is a very insignificant portion of the whole area of the country, and the auriferous reefs which have been discovered, are confined to a few isolated localities, in which the tufa presents a very marked difference from its prevailing character, being a fine-grained rock containing a large quantity of auriferous pyrites (Bisulphide of Iron) dispersed through its substance in minute grains and imperfect crystals. This rock, which from its proneness to chemical change decomposes freely, and frequently contains Gypsum (Sulphate of Lime), is the characteristic bed-rock of the auriferous lodes at the Thames and Coromandel. In all the auriferous areas Diorite dykes intersect the tufaceous rock, and it is not yet satisfactorily determined whether the auriferous tufas should be considered to form part of the Tertiary volcanic series, or a distinct formation intermediate in age between them and the slate rocks of the district. The auriferous reefs are rarely well defined, and consist chiefly of sub-crystalline quartz in which the gold is found distributed through the compact portions as minute specks, or entangled in a crystalline or dendritic form, where the quartz is open in its texture. On the whole, the reefs appear to be richest in the decomposed rock near the outcrop, which has frequently led to over-sanguine anticipations regarding some of the
mines; but it is well established that the quartz continues to be auriferous after it is traced into the harder undecomposed rock.

The gold contains the proportion of silver which is characteristic of the compound of gold and silver known as Electrum, and is associated with native Arsenic, Sulphides of Copper, Lead, Zinc, Antimony, and other metals, but only in small quantities.

At Coromandel, where mines were first worked in this formation, the lodes have been “proved” to a depth of over 300 feet from the surface, but the best mines at the Thames have, as yet, principally been confined to the decomposed, and comparatively superficial rock. Veins have been discovered and gold obtained at all levels on the ranges, from the sea level to an altitude of 2000 feet. The quantity of gold that has been obtained from some of these quartz reefs is very great, and for considerable distances the quartz has yielded, pretty uniformly, at the rate of 600 oz. per ton. Such reefs are, however, very exceptional. The quartz reefs are not altogether confined to the fine-grained tufa rock, but when in other formations they are not so auriferous. Those in the underlying slate rocks however contain decidedly more gold than the reefs in the overlying Tertiary tufa, which seldom yield appreciable quantities.*

The amount obtained up to the present time (Dec., 1869) is 213,489 oz., only a few hundred ounces of which have probably been obtained as alluvial gold, the remainder having been extracted from the rock matrix by true mining processes.

The development of this mining district must be looked on as hardly commenced, though unless new districts be discovered, the large yield in proportion to the labour employed, which has hitherto characterised the early days of the mines, cannot be expected to continue.

Before proceeding to describe the second group of gold fields I may mention shortly the character of the rock formation near Wellington, which is the only other locality in the North Island where gold has been obtained in appreciable quantities, though not as yet sufficient to entitle it to rank as a gold field.

The locality where the gold has been obtained is about twelve miles west of the City of Wellington, near Cape Terawiti, where the country is composed of abrupt ridges of Primary slates, shales, and sandstones; with intervening valleys, some of which are occupied by marine tertiary strata. The older rocks belong to two distinct periods, and though both are found generally in a vertical position, the line of junction between them is well marked. The district has been traversed by a series of dislocations, which cross the lines of stratification in oblique lines. The consequent displacement appears to have indurated the sandstones, and altered the shales, when in contact with them, into friable cherty slates of a deep blue colour, traversed by thread-like veins of quartz. The altered sandstone is slightly micaceous, and has been so infiltrated with silica, that hand specimens have been mistaken for granite.

Near these altered patches of rock, a small quantity of fine-grained but rough unworn gold is generally found, the total quantity obtained having been about eighty ounces. Well-defined reefs of quartz also occur in the district, especially in the sandstones, but none of these have yet proved auriferous, on being tested, and the evidence seems to indicate the veins in the blue cherty slate, as the probable source of the gold.

Nelson and Westland, or Western Gold Fields.

In this district, which extends along the west coast of the South Island, for the northern half of its extent, the gold fields are situated on the western

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* For full particulars respecting these mines, see Report by Captain Hutton, "Geological Survey of New Zealand," 1869.
slope of the main range of the Island. The alluvial diggings at Collingwood were first discovered in this district in 1858, and in 1864 the great gold fields near Hokitika, attracted the majority of the mining population of New Zealand. Since then the field has been gradually but thoroughly explored, and more or less gold obtained in almost every part of it. The mode of occurrence of the gold admits of very simple classification dependent on the physical features of the country.

The Southern Alps which are near to the West Coast, in the latitude of Mount Cook, are continued northwards through Nelson province to Cook's Straits, by the Spencer Mountains, forming a well-marked range, that defines the head waters of the streams flowing to the east, and is characterised by the line of eruption of the Mesozoic Diorites. The towns of Nelson and Hokitika are, according to this view, equally situated on the west side of the mountains; and between Blind Bay, at Nelson, and the west coast at Hokitika, a well-marked depression extends in a S.W. direction for one hundred and forty miles, separating the central range from a triangular area of mountain country, that has its northern termination at Cape Farewell, and its southern one at the Grey river. This latter district is extremely rugged, and displays a greater variety in its geological structure, than any other part of New Zealand.

Frequent changes in the formation are common in this area, from Hornblende rocks to Schist and Clay slates, while the summits of the mountains are frequently capped with outliers of the upper Secondary coal formation and marine limestones; while in the majority of the streams that radiate from it, gold is found under such circumstances as to indicate that auriferous lodes occur in rocks throughout the district. A few quartz reefs have already been discovered, such as at Moonlight Creek on the Grey river, and Waimangaroa near the Buller, and at Wangapeka and Collingwood, in the north; but as a mining field it is still practically undeveloped. The alluvial gold, on the other hand, been very extensively worked, the yield up to the present time amounting to 2,235,591 oz. The alluvial gold occurs in well-defined "leads," of which there are three distinct kinds, without including the local "sluicing" diggings in the valleys of the mountain torrents, already alluded to, as generally distributed throughout the area. Unlike the gold drifts of Otago, which rest on the denuded surface of their parent rocks, the auriferous gravels in the western district, as a general rule, rest on the surface of recent Tertiary rocks, of marine origin, having, in fact, been carried out of the mountains by the rivers, and deposited along a gradually changing coast line. They thus have a general distribution parallel to whatever was the western shore of the island at the time of their deposit.

The earliest formed, and most elevated of these "leads," extend in a N.E. direction, from near Ross, where they are cut off obliquely by the sea coast, into the Nelson province, running parallel with the main range, and have already been traced as far as the high terraces near the source of the Little Grey river. They have here their greatest altitude, though still resting on the marine strata, and slope steadily to the south, till at Ross the main lead is actually beneath the present sea level, and worked by true "deep sinking." These leads have been intersected by the more modern streams, and a second class of leads thereby formed; while the third class of alluvial workings is formed by the ancient and modern sea beaches, along which the gold has been drifted by the action of the waves and surf. These workings extend for more than two hundred miles along the coast, and as they are undergoing constant renewal they will afford a permanent source of employment.

The peculiarity of the Westland alluvial diggings that requires to be most impressed on the mind, is that, in the majority of cases, the streams have cut
their channels much below the surface of the country, leaving the richest leads in positions very inaccessible to the water supply required for mining, without adopting a thoroughly organized system of irrigation, so that notwithstanding the reputation of the West Coast as having almost the largest rainfall in temperate regions, the gold fields there are actually languishing for want of the supply of water so essential for gold washing.

**Otago, or Southern Gold Fields.**

The most extensive alluvial diggings in New Zealand are in this district, and they possess peculiarities that distinguish them from most other gold fields. Notwithstanding the large quantities of alluvial gold that has been obtained in Otago, amounting to 2,548,999 oz., the actual mining operations for the extraction of gold from the matrix, have, up to the present time, been comparatively insignificant.

The gold fields may be divided into two districts. In the eastern district of the province the surface is undulating, and without being mountainous, has a general elevation ranging from 1000 to 4000 feet. The prevailing rock in this district is a very soft mica and chlorite schist cut by vertical joints, and traversed by horizontal laminae of quartz. The undulations of the surface, as a rule, lie in a direction parallel with the east coast, and each ridge appears to consist of a mass of the schist formation that has been tilted along its western boundary, after the deposit of the Brown coal series (Miocene). A succession of trough-shaped valleys are thus passed over in travelling from the east coast into the interior, along the western side of each of which the Brown coal is generally found to dip under very heavy deposits of alluvial gravels.

The leading features of a section through this part of the province are roughly shown in the accompanying diagram. A B C D are the successive valleys, with the intervening ridges, the most easterly of which shows the Brown coal formation, capped with Dolerite d, as at Saddle hill, and the others represent Maungatua, Roughridge, and the Dunstan ranges, respectively; a Schistose rocks; b Brown coal formation; c Auriferous alluvium.

Besides the quartz in a laminated form, veins of auriferous quartz exist, and, as a rule, are situated along the lines that mark the lines of uplift of the ranges, or in the positions marked by 1 2 and 3 in the above section, and therefore on the west side of each of the ranges. These are not however to be considered as quartz veins, in the sense in which the term is commonly used in Victoria, and cannot be looked on as the only source from which most of the gold in the Otago drifts has been derived.

One of these reefs has been mined at Waipori and yielded an average of one ounce per ton. Other reefs have been recently opened in the western slope of the Dunstan ranges (3 in section), the results already obtained from which promise much higher returns.

No granite or Diorite dykes are known to exist in this eastern district.

In the western, or Wakatipu Lake district, we find a much greater variety of rock formation. The mountains are lofty and abrupt, and are cut into sharp
ridges and peaks, due partly to the unequal manner in which the different kinds of rocks have resisted denudation, but we must also take into account the effect of great dislocations which appear to have affected this district at a late geological period, for we find at considerable altitudes masses of Tertiary Limestone that are unknown at the same elevation in the eastern district. The schist rocks in this western district are less uniformly foliated than we find them in the east. They also afford a much greater variety of minerals, and even become truly crystalline, in some instances, where dyke rocks intersect them, so that the district may be compared to the north-west district of Nelson.

Several quartz reefs have been mined in this district, on the Shotover and Arrow rivers, and much expensive machinery carried into very inaccessible positions, but these adventures have not proved so successful as was anticipated. However they were commenced at the time the great exodus of diggers took place to the western gold fields, which may account for the reefing capabilities of the country not being better explored. Judging from its geological structure the north-western district of Otago is the most likely part of the province for the occurrence of mineral lodes.

Before leaving the subject of our gold fields, the general mode of the distribution of the alluvial deposits in New Zealand deserves a further description. This subject is important, as most of the mineral wealth, hitherto obtained, has been from this class of deposits, which is generally associated with iron-ore dust or sand, the black sand of the miners, so that these minerals may be considered together. The source of these, like all other sands, is from the disintegration of a parent rock, and together with the other elements of the rock, they constitute what is known as "drift." Gold drift consists of sand and gravel containing gold, and is formed by the action of running water in streams, or water in motion, as along a sea or lake beach. The same action causes the re-assortment of the materials, so that the heavier particles become separated from the lighter, and it must be borne in mind that no other agent than water in motion can exercise this sorting influence. It is therefore not merely the existence of auriferous rocks at the surface in a district which determines the extent and richness of the alluvial diggings, but we must also take into account the amount of disintegration of these rocks, and also the degree of concentration to which the detritus has been subjected. As might be expected, alluvial gold is found to vary in composition according to the nature of the rock which formed the original matrix; thus in Otago the gold is pure or only alloyed with a little copper; at Whakamarina, silver appears in the proportion of 7 per cent., while on this side of the Strait it contains double that proportion; and in the north, at Auckland, though the alluvial gold does not contain the same proportion of alloy, as that obtained from the reefs, which is a circumstance that has been remarked on all gold fields, still it is less pure, as a general rule, than the gold from the above-mentioned localities.

In the South, the gold is associated on the other hand with platinum, zircons and garnets, and in the Nelson province with the rare mineral, Osmiridium. In like manner the iron sand varies in composition. In the neighbourhood of basaltic rocks, as at Dunedin, it contains 75 per cent. of titanite of iron, which is a refractory compound of the oxides of titanium and iron, while in some parts of the interior of Otago the sands consist either of magnetite or lodestone, or of haematite, both of which are pure oxides of iron and more valuable as ores. On the West Coast the sand has also the latter character, and it is worthy of remark that, notwithstanding its proximity to volcanic rocks. The well-known Taeanaki iron sand, from its containing only 8 per cent. of titanite iron, apparently belongs to the sands derived from the older rocks principally syenites and altered greenstone slates.
The distribution of these sands, according to the size of their particles, is very instructive, the deposits being of two kinds—beach formed and river formed. The former are principally on the West Coast, both gold and iron sand being of very fine grain. The greatest altitude at which any beach gold has been found is about 125 feet above the sea, at Watchman’s terrace, north of the Grey river. It is found everywhere from Cape Farewell to Jackson’s Bay, the richest deposit being at Okaara, about the centre of the great Westland Bight. The coast line south of this does not favour the deposit of fine gold, having bold rocky shores and headlands. On the sandy beaches of the south and east coasts of Otago auriferous sand again appears, and has been found as far north on the East Coast as the commencement of the shingle formation of the Canterbury Plains.

In the North Island the great iron sand deposits have their maximum at Taranaki, but extend north and south of that place, rarely being found at a greater altitude than ninety to one hundred feet above the present sea level, though small quantities can be found in nearly every stream, except where flowing wholly within marine tertiary rocks. No gold has as yet been found with any of these deposits in the North Island. The river-formed deposits of gold of the interior of the South Island are divided into three groups, according to their position and the manner they are worked. The oldest drifts are deposits at high levels, out of reach of the present drainage system of the country, so that they can only be worked by bringing water to bear upon them by a system of “fluming.” In Otago such terraces have formed the source of the bulk of the alluvial gold obtained from rich diggings of the second class, which are marginal deposits of rivers and streams, or shallow alluvial flats. Gabriel’s Gully is one instance of this, as at the Blue Spur, between Gabriel’s and Monro’s gullies we find a patch of the high level older drift that has been tapped and sluiced down the bed of a modern stream which concentrated the gold. The remaining form of alluvial gold is that liberated by streams which are excavating rocky beds, but the amount is very insignificant compared to that obtained in Victoria with this form of mining. The quantity of gold got by shallow sinking on false bottoms in Otago, has naturally led miners to expect that deep leads will be found to rest on the true rock bottom. This subject requires a rigid enquiry into the causes which have operated in producing the surface features of the country.

We see, as previously stated, that in the West Coast district, a stratum of auriferous alluvium is found to slope to the south from the Nelson province, until at Ross it forms a true deep lead, being worked by underground mines that are below the sea level, and are kept dry only by pumping. But the basins in Otago are very different in character, being deep depressions in the rock which have no outlet at the present time, except through rocky gorges. These basins have been, to some extent, moulded in their form by a previous extension of the glaciers, during the great Pleistocene elevation of the New Zealand area; but the depressions being partly occupied by Brown coal and other Tertiary strata, proves that they are of much higher antiquity than that period, and that the original inequalities are due to dislocations. But, at the same time, there is no question that the glaciers have been the most active agents in breaking up the surface rocks, and filling the depressions with the auriferous alluvium. This is especially evident in the western district, where the glaciers are still at work, and where the valleys which they occupied during their previous greater extension have not been filled up, but are now occupied by lakes. We have, in these cases, an opportunity of examining the configuration of the valleys by means of the soundings line, and Plate 19, which is a map and a diagramatic section of the N.W. district of Otago, between the Wakatipu lake and the West Coast, will assist in making clear the nature of
these lake basins, and the relation of the interior lakes to the Sounds on the
West Coast.

The section, the general position of which is shown on the map by the
dotted line A to B, has been carried over a higher range of mountains than
actually occurs in this line, for the purpose of showing the manner in which
the glaciers have excavated the valleys, and rather represents a former than
the present condition of that particular part of the range. The dark patches
on the map represent a few only of the moraines that are shown on the original
map which is in the Otago Museum, and which gives the full details of the Pleis-
tocene geology of this interesting district.

The Wakatipu lake, which is fifty-two miles in length and two to three
miles in width, lies, in its upper part, between the Schistose rocks on the east,
and the upper Paleozoic rocks on the west, so that it marks the junction of two
formations. Its surface is 1070 feet above the sea level, which is exceeded by
its depth, for it has been found by soundings to vary from 1170 to 1296 feet,
the bottom of the lake being nearly level from side to side, and from end to
end. The waters of the lake, at the present time, escape over a rocky fall at
Frankton, which is almost the middle of its eastern side, but from the lower
end of the lake, at Kingston, a broad valley can be traced to the south, joining
that of the Mataura river, which, at first sight, appears to have been the
former outlet. The lake is fringed by terraces showing the gradual shrinking
of its area, as the level of its outfall has been lowered. The only apparent
barriers, in the direction of the Mataura valley, is a great moraine accumula-
tion at Kingston, elevated 270 feet above the level of the lake; but on
following down the Mataura river it is found to run over a rocky channel, and
to cut its way through a gorge at an altitude of 700 feet above the sea, so that
even were the Kingston barrier removed, the lake would not be completely
drained in that direction. The lake is therefore contained in a rock basin, and
not formed by the simple damming up of a valley.

On the western side of the range, within a distance of thirty to forty miles,
we have, on the other hand, a series of arms of the sea occupying exactly similar
excavations, frequently 1800 feet beneath the sea level. McKerrow lake is an
example of one of these, the exit of which has been barred by coast drift
covering a moraine like that barring the lower end of the Wakatipu lake,
at Kingston. The outlet of McKerrow lake is by the Kaduku river,
which is a tidal river, so that the surface of the lake is at the sea level; yet
its waters, which are quite fresh, have a depth of at least 470 feet. Milford
Sound, which is also shown on the map, twelve miles further south, has a
depth, at its upper part, of 1270 feet, but across its entrance the depth is only
130 feet, while the mountains surrounding it rise to 6000 and 9000 feet.

All the valleys on both slopes of the range are occupied by glacier
moraines, and although it is only in the higher cluster of mountains that we
now find glaciers to exist, there is no want of evidence of their former greater
extension.

The section will explain the operation of glaciers in excavating valleys:
\( a \) represents an area of the mountain top, which is above the altitude of per-
petual congelation, and from which therefore the snow deposited can only
escape by assuming the form of ice, descending by its weight as a glacier \( b \)
through the valleys to the point at which it melts, owing to the increased
temperature counterbalancing the supply of ice. At this point it deposits its
moraine or rubbish heaps \( c \), and moraines found further down the valleys are
sure indications of the glacier having had formerly a greater extent. At the
point where the ice descends from the plateau \( a \) to the glacier \( b \), it is generally
an abrupt fall, known as the "ice cascade," and it is at this point that the
chief amount of erosion takes place, by which the valleys are eaten back into,
the plateau in the lines of least resistance, so that the plateau is at last cut up into sharp ridges and peaks, on which snow can no longer rest in quantity to maintain the glaciers, which consequently disappear, leaving only the moraines to mark the successive steps of the process. This is however quite insufficient to explain the origin of the deep excavations in the hard rock, as above described, and the difference in the amount of the excavation on the opposite sides of the axis, irrespective of the character of the rock excavated, (which is in fact the most resisting in its character on that side where the excavation has been apparently the deepest) points to an unequal subsidence as the origin of these basins. This subsidence has been most rapid in the central and western part of the range, so that in the case of a long valley, like that occupied by the Wakatipu lake, the slope became gradually reversed, and what was at first the higher part of a glacier-excavated valley, has become a depression without an outlet. Gradually this depression is being filled up, by the material brought down by the streams, and carried from the moraines higher up the valleys, as represented by d in the section; but this material cannot, especially where resting on the rocky floor of the valley, have been subjected to the action of running water after it has been deposited in the still waters of the lake, and therefore fails in one of the essential processes for the formation of auriferous leads, namely, the concentration of the gold from the lighter particles of the detritus.

From these considerations it is evident that it is only round the margins of rock basins, or in positions above the level of the notch in the margin over which the water escapes, that we can expect to find auriferous leads.

High on the eastern slopes of the mountains, in the position marked e on the section, are found patches of gravels belonging to the newer system which drained the mountain range previous to this unequal subsidence, and before the excavation of the deep gorges by the extended glaciers of the Pleistocene period; and the gold in most of the alluvial workings in Otago, can be traced to such patches of older drift.

I will now describe briefly the mines which have been worked in New Zealand for the less precious metals, and mention the localities where "lodes" have been discovered.

The Island of Kawau, where the earliest opened mine is situated, was first purchased by the North British Investment Company, about 1841, as a cattle run. It lies four miles from the main land, thirty-seven miles north of Auckland, is about three and a half, by three and a quarter miles in extent, and, from the Admiralty survey, appears to have an extent of about 5200 acres. The island consists of slate rocks which form two principal masses of high land, separated by an E. and W. depression, partly occupied by Bon Accord harbour, and continued eastward by several valleys with wide alluvial bottoms. In each of these masses hills rise from 500 feet to 600 feet altitude, the summits marking the outcrop of mineral veins in most cases. The strike of the older rocks is very varied in direction, but ranges between N.E. and N.W. The dip has a prevailing westerly direction, generally at a high angle. All these rocks are, however, cut by cleavage veins and faults, that give them a false trend to N. 320° E. In this line lie the mineral lodes, and "belts" of mineralized rock, four of which are known.

The first discovery was made at Manganese Point, where the lode shows as follows:

a. Soft decomposing slate.
b. Red jaspiloid slate, encircled with iron and manganese.
c. Soft red rock containing the same ores.
d. Hornstone.
e. Blue slates.
From the beds b. and c. a quantity of ore was excavated and shipped to London, where it was sold for £7 per ton.

Within a few months a copper lode was accidentally found cropping out, a large sample of which, taken at random, realized £15 to £20 per ton. This led to regular mining operations, and in 1846 a well-defined lode of copper ore was opened up, twelve feet in width, running N.E. and S.W., with a dip or underlay, of three feet to the fathom. The ore consisted of blue and yellow sulphurets, containing an average of twelve per cent. of copper. Several shipments of the ore were made, in the raw state, but had to be abandoned on account of the danger of fire, from the heat generated by the decomposition which the ore underwent in the holds of the vessels.

Works were then erected for the reduction of the crude ore to the state of regulus, by roasting, in which condition it was a safe article for shipment.

The situation of the smelting works, which were most expensively constructed, was in Bon Accord harbour, where there is deep water close to the wharves.

The first four years workings realized upwards of £60,000, but the pumping machinery was deficient, so that the mine had to be abandoned for eighteen months, till a large Cornish engine was obtained. This effectually kept the water down, and the mine was extended to a vertical depth of 35 fathoms, with a horizontal extent of 150 fathoms, on a lode averaging 6 feet in width, and consisting of a massive gangue that contained thirty per cent. of copper ore, and the same of iron ore, intermixed with dark green chloritic clay. The lode lies between green slates, containing grains of metallic copper, and stained with salts of copper, and a hanging wall of indurated chert.

The mine appears never to have been worked out, but was abandoned, partly owing to complications respecting the proprietorship, but mainly owing to the superior attractions of the Californian and Australian gold fields at that time. The particular lode that was worked is on a headland on the south side of the island. It was lost in tracing it inland, to the north, but there is good reason to believe that this headland is only a dislocated mass, formed more in the manner of a landslip than a structural fault, and that there may have been a displacement of the lode. *

The Great Barrier Island, on which have been the most extensive copper mining works in New Zealand, is about twenty-four miles long. A central chain runs through the island, throwing off spurs on either side, rising to an extreme elevation of 2330 feet, and maintaining an average height of about a thousand feet throughout its length.

The greater part of the island is composed of volcanic (Trachytic) rocks, resting on sub-metamorphic slates and sandstones, of the same kind as at Kauau. These slaty rocks are, in several places, but especially at Mine Bay, cut by intrusive dykes of quartz porphyry, consisting of a felspathic paste containing grains of fine quartz. Felstone, which may be considered as the same rock devoid of quartz, Diorite, which is a mixture of Felspar and the fusible mineral Hornblende, and, lastly, a true dyke granite, containing quartz, Mica and Felspar. In these rocks we have representations of the crystalline metamorphic formations, which are so abundant in the South Island, brought to the surface as dykes.

Captain Hutton thus describes the position of the mines [Geological Reports, 1869, p. 4] :

copper pyrites, peacock copper, blue and green carbonates of copper, black oxide of copper, native copper, galena, Dufrénoysite and iron pyrites, but not in large quantities.

“The lode which has been worked for copper for some time at Mine Bay, and which now goes by the name of the ‘Otea Company’s Copper Mine,’ is an old fissure in the slate rocks, filled up with angular debris of slate and diorite of all sizes, from that of a walnut or less, to blocks weighing more than a ton. These blocks are cemented together by a matrix that is sometimes siliceous, and at others felspathic, and it is in this cement or matrix that the copper ore occurs. No lead is found in this lode.

“The fissure runs in a nearly north and south direction across the neck of the small peninsula called Miner’s Head. This neck is about 200 yards across. The lode is about 25 feet in breadth at the adit level, which is only a few feet above the sea, and expands to about 40 feet at 14 fathoms above adit, and this breadth it keeps pretty regularly until it reaches the top of the hill in which it is situated, and which I estimate to be about 200 feet above adit. I was informed by one of the miners who helped to sink the shaft, that at 12 fathoms below adit the lode was only 9 feet through; it is therefore probable that the fissure dies out altogether at about 20 fathoms below adit. It is, of course, possible that this fissure may be continued downwards indefinitely; but there is no evidence of a fault or slide having taken place, and the facts of its original gaping character, and its constantly decreasing breadth as it gets deeper, incline me to the opinion that it is merely a superficial crack. The fact of the lode containing blocks of diorite shows that the dykes were in existence before the fissure was formed, and that therefore they are not the cause of the lode being charged with copper.”

The mine was first worked in 1845, by Messrs. Abercrombie and Sydney; the ore being a bright yellow sulphide, containing fifteen to sixteen per cent. of metallic copper. The first proprietors worked it for several years, and were then succeeded by Messrs. Whittaker and Heale; then by Messrs. Ninnis and Rowe; and lastly by the Great Barrier Company. The works were then suspended, in 1861, but in 1867 they were again reopened by the Otea Copper Mining Company.

The total quantity of ore mined has been 2,323 tons, the aggregate sales realizing upwards of £30,000. In order to get this ore, Captain Hutton estimates that about 3200 cubic fathoms of vein-stuff have been excavated, which would give a yield of nearly three-quarters of a ton of ore to the cubic fathom; and that about 3800 cubic fathoms remain to be got above the present adit, which will probably yield 2900 tons of ore dressed to fifteen per cent. If my opinion as to the lode dying out about twenty fathoms below adit be correct, it will follow that not more than 4000 cubic fathoms can be got in this direction, which would yield about 3000 tons of ore, making a total of about 5900 tons of ore still remaining in the mine.

Copper ore was also discovered at Whangapara, in a more northerly locality of the same island, but no regular mine was opened there.

Nine miles north of Mongonui, in the promontory that forms the northern boundary of Doubtless Bay, copper was discovered, and partly worked, by Mr. Brodie, about the year 1849.

The peninsula consists, in great part, of porphyritic Trachyte, and Diorite slates. At the copper mine the cliffs are 300 feet high, and the few confined bays at their base are almost inaccessible.

Here a mass of Breccia Conglomerate abuts against a dyke of hard black Diorite. The Breccia consists of a chloritic matrix, with carbonite of lime, and contains large blocks of Trachyte, and quartz Porphyry. Interspersed are masses of sulphide of iron and copper, and also pure metallic copper. “Cop-
per-green,” from the decomposition of these, forms a broad green mark on the cliffs, which first attracted attention from the sea.

The next copper mining adventure to be mentioned is that of the Dun Mountain Mining Company, and for the collection of some of the information concerning it I am indebted to my late assistant, Mr. T. R. Hacket, who came to New Zealand, originally, as Mining Manager to that Company.

Along the east side of Blind Bay, extending S.W. from D’Urville Island, is a line of bare brown hills, which are characterised by low scrubby vegetation, that contrasts with the surrounding green of the forests. These mark what is known as the “Mineral belt,” and their singular barren appearance is due to the large proportion of Magnesia which is mixed with the soil that is derived from the rocks which compose them.

The section of the hills between Nelson and the Mineral range, shows that these magnesian rocks occur in the upper part of the Triassic formation,—the lower part consisting of slates, limestones, and indurated sandstones, containing Triassic fossils, passing, in an ascending series, to Diabase rock and Breccia, associated with Diorite and other dykes. In this part of the formation, metallic ores of copper and chrome occur, not as distinct lodes, but as lenticular masses and nests. Dun Mountain, which is the best known locality, is composed of a peculiar mineral, named Dunite by Professor Hochstetter, which has the same composition as Olivine, a mineral generally found in basaltic lavas. This rock appears at the surface as a large mass, several miles in extent. It is speckled with chromic iron, very much in the same manner as garnets occur in schistose rocks; but the principal deposit of ore is in a band of Serpentine, lying to the east of the Dunite, and between it and a band of limestones. The Serpentine is traversed by dykes of Felstone and Diallage, and a great variety of other minerals—the district being certainly the most interesting locality in New Zealand to a mineralogist.

Copper, associated with Specular iron, was first discovered in 1853, and occurs in the metallic form, and also a red, gray, and blue oxide, but in small quantities, about thirty tons only having been excavated.

The chrome ore forms wedge-shaped masses in the Serpentine, which vary in thickness, from a few inches to as much as twelve feet. The ore is crystalline in its texture, generally pure, but occasionally traversed by thin streaks of Serpentine. The veins are generally discovered cropping out at the surface for a few fathoms in parallel lines, but never form continuous lodes.

Chromic iron which is chiefly used for making dye stuffs, contains about forty-five per cent. of chromium, and was worth, before the discovery of the Aniline dyes, £10 10s. per ton. 5000 tons have been raised, and the veins already opened expose an estimated quantity of 10,000 tons. The mines, which are at an altitude of 2500 feet above the sea, have been connected with the Port of Nelson by a line of railway 12½ miles in length, and having a gradient in a great part of its course, of one in eighteen. The shipments of the ore amount to 4500 tons, which are delivered in London at a cost of £3 13s. per ton.

On the same belt of mineral ground as the Dun Mountain, several other mines have been opened, in a line extending for fifteen miles, but ore has only been shipped from three of these mines, which possess the same general character as the Dun Mountain mine, without however, the occurrence of the Dunite or some of the other minerals, which might otherwise have been supposed to be necessary accompaniments of the metallic ores. I may mention that the only other place in New Zealand where Dunite has been discovered, besides the Dun Mountain, is at Milford Sound, where it also contains chromic iron, and passes into jade or Maori greenstone.

At Anniseed Valley mine, a few miles south of the Dun Mountain, which
was discovered in 1861, the chrome ore is in serpentinous schists, between a mass of Elvenite with copper, on the west, and a band of limestone on the east; while Black Reef, and Ben Nevis mine, still further south, occur in tough green serpentine. All the mines would yield a large supply of the chrome ore, if there was any demand for it, but they are very difficult of access.

At the northern termination of the mineral belt, a few small copper veins have been discovered, at Croixelles Harbour, and D'Urville Island, the ore, as at Dun Mountain, occurring in small nests in Serpentine and Hornblende schist.

There are two more copper lodes to be noticed, but neither of which have yet been worked. They are both in the Province of Otago, and the ore is Sulphide of Copper, occurring in the metamorphic schists. This first is at Moke Creek, near the Wakatipu Lake, where the lode is about four feet in width. Limestone and wood are found in the neighbourhood, and by reducing the ore to a regulus, containing sixty per cent. of the metal instead of twenty, which is the average of the crude ore, it might be worked with advantage if the land carriage were improved, notwithstanding its distance from the coast.

The second lode, at Waipori, near Tuapeka, has only been imperfectly explored, but it appears to be similar to that at Moke Creek. I will only enumerate a few of the indications which have been observed elsewhere of the occurrence of other ores, as no other mineral lodes have been explored besides those I have mentioned. Thus we have silver lead ore in the Wangapeco river in Nelson; red copper ore in Bligh Sound, on the West Coast, and Magnetic iron ore of Otago; and lastly, I must not omit to mention the Manganese veins which have been worked in the island of Pakihi, near Auckland, an account of the geology of which is given by Captain Hutton in the first volume of our Transactions; nor the rich lode of the same ore which is found at Tikiiria at the Bay of Islands.

**COAL FIELDS.**

The classification of the coal deposits of New Zealand is founded partly on geological age, but chiefly on the chemical composition of the coal. Besides the tertiary lignites, there are two coal formations, both of which, as I have already mentioned, belong to a period which is equivalent to the Upper Secondary and Older Tertiary strata of Europe. All the thickest seams of coal yet found, are in the upper formation. The coal is of two varieties, the one containing a large quantity of water in its composition being inferior; while the other is a dry coal, and of value equal to the best that is ever imported from Australia.

Coal mines have been opened in every Province of the Colony, but the space at my disposal only permits of my mentioning a few of the chief localities where coal is being actually worked. I commence with the Kawa kawa mine, at the Bay of Islands, from which coal is at the present time being excavated at the rate of about 1500 tons per month, chiefly for the supply of the Thames Gold Fields. This valuable seam was originally discovered in 1863, by Maoris, when digging for Kauri gum, but it was not systematically worked for several years after that date. The seam is from ten to sixteen feet thick, and occurs at the base of a Green sand formation, that crops out not only at Kawa kawa, but so far south as Wanganui, and at intermediate localities, so that its extent is very considerable. The coal is now excavated by a drive into the side of the hill where it was first found, but for a long time it was worked by a shaft sunk on the outcrop of the seam. A tramway has been made for three and a half miles, to convey the coal to a point on the river where it can be
placed in barges which take it down to deep water. Notwithstanding the extra expense arising from repeated handling of the coal, it is delivered alongside the colliers at 14s. per ton. The coal, when carefully selected, has very powerful heating qualities, and burns with a rich gaseous flame. It has been repeatedly tested, and favourably reported on, by steam vessels, and its only drawback is that it is friable, and is frequently shipped without the impurities containing sulphur having been removed by screening. At Wanganui small colliers can ascend to the point above where the tramway terminates, so that coal is put on board for 13s. per ton. The coal is however very different in its quality from that at Kawakawa, notwithstanding that it appears to be either the same or an equivalent seam in the same geological formation, having a larger proportion of ash and water, and a corresponding deficiency of gaseous matters.

Twenty miles south of Auckland, coal mines have been worked for many years near Drury, where there is an extensive coal field. According to Professor Hochstetter there is only one seam, having an average thickness of six feet. The quality of the coal is that of common Brown coal with over 20 per cent. of combined water, but from its containing large quantities of fossil resin, it proves a very valuable fuel.

On the Waikato river there is a still larger extent of the same coal formation, containing one principal coal seam which is eight to twelve feet thick. Captain Hutton is of opinion, as the result of careful survey, that in this field there is about 140,000,000 tons of coal available, without pumping or mechanical appliances for raising the coal. This coal is extensively mined for supplying the steamers that ply on the Waikato river, and answers well for that purpose.

There are no other coal mines in the North Island except those above mentioned, but in the district between the Mokau and the Wanganui rivers, there are extensive coal seams, and also from near the East Cape, on the opposite side of the Island, samples of coal of very superior quality have been obtained.

On the west coast of the Province of Nelson, there are several distinct coal fields, the most northerly of which, termed the Pakawau field, is about thirty square miles in extent. The coal occurs as several seams, none yet found exceeding four feet in thickness, at the base of a sandstone and shale formation 1500 feet thick. Mines have been opened at Pakawau, and Collingwood in Golden Bay, and in the beautiful little harbour of West Wanganui, on the West Coast. The coal varies in quality, but is, on the whole, more valuable than that found in the northern fields. The quantity of coal raised from this district has not been great, as the best seams are in rather inaccessible positions, but if they are opened up with caution and proper economy, there is no reason why they should not prove remunerative.

In connection with this coal field, I should mention the deposit of Plumbago or Black Lead, which has been mined to a small extent near Collingwood, as it is probably derived from an altered portion of a coal seam. The Plumbago is, however, of good marketable quality, seven tons exported in the manufactured form, having an approximate value of £1400.

The Buller coal field occupies a narrow strip along the coast north of the Buller river, forty miles in length and seven in width, and is peculiar from the great elevation at which it occurs. The formation consists of quartzose grits, 200 to 300 feet thick, with a single seam of very pure coal, ten feet thick, near


† For comparative value of this Plumbago, see "Juror's Rept. N. Z. Exhibition, 1865," p. 417.
the base of the formation, which rests on the top of a range of mountains from two thousand to three thousand feet above the sea level.

The only obstacle to the working of this coal is the expensive character of the works required for conveying it to the shipping place; but the Buller river is so much superior as a port, to any other place on the N.W. coast of the Island, that with such coal seams in its neighbourhood, it is certain in time to become one of the chief places from which coal will be exported. The coal is the best in quality of any yet found in New Zealand, and judged of both by chemical analysis and by practical test, compares favourably with the best British Bituminous Coal.

The two fields last mentioned have more a prospective than an immediate value in the present state of the West Coast District; but the development of the Mount Davy coal field will have a practical influence on the resources of the country at the present time.

The area occupied by the coal formation in this instance is not so great as that of either the Pakawau or Mount Rochfort fields; but the value and accessibility of the coal seam gives it a superior importance. The best coal appears to be in one main seam, associated with micaceous sandstone and grits containing plant impressions, and small carbonaceous layers, as seen at the Brunner Mine, in which the coal has been followed on the level for 1100 feet, and likewise explored to the outcrop; the total length of the galleries and chambers being nearly 4000 feet.

The thickness of the seam varies from fifteen to twenty-three feet, and is contained between a roof and floor of solid grit, which enables it to be worked with facility, timbers being required for the support of the roof only in a few places where it had a tendency to flake.

The coal formation rises, at an angle of 12°, in an easterly direction from the water level to an altitude of at least 2000 feet in the Mount Davy Mountains, and extends to the north for a distance of seven miles, intersecting the coast about twelve miles north of the Grey river. (See Map and Section, Plate 14.) Any coal within this area can, of course, be worked "level free," as in the case of the present mine, which system involves the least possible working expense, all excavations being in marketable coal, and no outlay being required for hauling the coal or draining the mine.

Westward from the mine the coal dips under 1500 feet of strata of sandstone and septaria clays, which are again overlaid by indurated chalk marls, with fossils characteristic of the upper secondary period, principally Echinodermata (Sea-urchins), ten species of which have already been distinguished and figured, and a large Inoceramus. Under a considerable portion of this area, coal will hereafter be worked by shafts; but the coal above the water level will be the first to deserve attention.

To the eastward, we find the coal formation cut off suddenly by a great break or fault, as shown in the section.

The facilities for working the coal on the south, or Canterbury side, are not so great as those at the present mine, but the southern extension of the field in that province is not yet ascertained, and it is probable that even a larger area will prove available for working by shafts on the south than on the north side of the river.

The supply of the coal is not equal to the present demand at the port, being controlled by the defective system of transport from the mine by barges. In the ordinary state of the river, the barges can only take a very small quantity of coal, rarely delivering more than forty or fifty tons a day, and involving a very large expenditure of labour. A survey has been made for a railway from the port to the mine, a distance of seven miles; and, from the favourable nature of the country, this line should not cost more than £20,000
REFERENCE.

a. Alluvial Drifts.
b. Upper Tertiary Limestones.
c. Chalk and Limestones.
d. Clay Marls.
e. Conglomerate Sandstones.
f. Miocene Sandstones with Coal (g).
h. Slates.

GEOL O GICAL MAP AND SECTION
of
GREY COAL FIELD
To accompany Paper by D' Hector.
which is a very small outlay, considering that it is the only heavy expenditure required to secure the regular supply of coal.

Provided that no fault occurs in the strata, I see no reason for doubting that on the most moderate computation the portion of the field already leased should yield 5,000,000 tons of coal.

The expenses of working the mine are so small that the coal should be delivered at Greymouth at a very moderate price, if the working were carried on more extensively, and a steady market for the coal established.

The seam of coal is pure and homogeneous, and possesses the property of caking with such facility that the whole quantity excavated can be utilized, so that no labour is unproductive, as is the case in mines where stone bands, shales, and other worthless matter have to be excavated along with the coal.

In the south-west of Otago coal seams occur at the base of a chalk marl and sandstone formation, at Preservation Inlet, which formation appears to be of the same age as that which extends through Southland, and runs out on the coast in the south-east district of Otago, but there the marls are replaced by sandstones and shales, in the same manner as in the Pakawau field. The value of the coal varies in quality in different localities, but is, on the whole, good fuel. An attempt has been made to open a mine at Preservation Inlet, but not much progress has yet been made. At Morley Creek, Waikawa, and other places, the coal is mined, but chiefly for local use.

In the interior of Otago province, lignite is found almost everywhere, except in the Wakatipu Lake district, and mined for the supply of the diggers, who could not carry on their mining operations in the treeless uplands of the Otago gold fields, were it not for mineral fuel being thus widely distributed. On the East Coast several very extensive areas of Brown coal formation occur, from which Dunedin is largely supplied. The largest of these is at Coal Point, near the Clutha river, where the seams have an aggregate thickness of fifty-six feet, and the formation extends over about thirty square miles.

Forty miles north of Dunedin the Upper Secondary coal formation again commences, and, running north, skirts the eastern slope of the mountains in broken patches, being found at several points in the Province of Canterbury, and re-emerging on the coast at Motana in the Amuri country.

At the Malvern hills coal seams of different qualities, including Anthracite, Bituminous coal, and common Brown coal, have been worked, and the whole series of the Upper Secondary and Tertiary coal formation appear, from the fossils, to be represented. The most extensive mine is in the Brown coal, of which there are several thin seams, that yield about 800 tons a year. The proximity of this coal field to Christchurch, and the fact of coal of very superior quality being found in different parts of it, gives it considerable importance.

Newer basins containing inferior coal also occur along the Canterbury and Nelson mountains as in Otago.

From the foregoing brief outline I think that New Zealand must be considered as, on the whole, well supplied with mineral fuel. Certainly, coal of the most valuable description is confined to limited and not very accessible areas, but still there is nothing to prevent its being profitably worked for the supply of our steam service; but the great point for congratulation is, that throughout almost every part of these Islands, coal of a practically useful description is to be found within a short distance.*

Before concluding this review of the mines of the Colony, I will make a few remarks on the building materials. The number of kinds of stone already

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worked in New Zealand is very large. They are generally divided into granites, limestones, and sandstones. Of the former, the only quarry is at Adele Island in Blind Bay; but this valuable stone exists in unbounded quantities on the West Coast of Otago, under the most favourable circumstances for excavation and shipment. The variety in colour and grain is also very great. It is not necessary to say anything regarding the quality of granite as a building stone, as it is well-known, and no large erection, especially of a marine character, should be undertaken without employing it. Although not properly belonging to this group, but still allied to it in the manner of quarrying, we have syenites from the Bluff, and Nelson Boulder bank; dolerites and basalts from Port Chalmers, Dunedin, and Lyttelton, and lavas from Auckland.

Of Sandstones—pure siliceous varieties occur with the coal formations. Flagstones are largely used in Nelson, being obtained from the Dun Mountain; they are very applicable to construction in earthquake countries, but the particular kind found at Nelson is defective from its steatitic character preventing the proper adhesion of mortar.

Freestones—abound in the tertiary formation of New Zealand, including sandstone, clay sandstones, and argillaceous sandy limestones and pure limestone. The finest is the now famous Oamaru stone, which possesses characters that excel most ordinary building stones used in other parts of the world, on account of its durability and facility of working, as it is moulded and cut by machinery with even greater ease than wood. The same formation is very extensive, and beds of equal quality will no doubt be found in other localities. It is very easily excavated by making openings in the low round hills near Oamaru. The absence of a good shipping port limits the extensive use of this stone, which would without any doubt become a valuable export. There are no roofing slate mines in New Zealand, but from hand specimens obtained in various parts of the upper Palaeozoic rocks, there is no reason to doubt that they exist in several localities, especially in the neighbourhood of Queen Charlotte Sound, and the Wakatipu Lake.

Limestones abound in the tertiary rocks, having sufficient purity and compactness to fit them for burning, and in the older slate rocks there are a few developments of what in a quarryman's sense may be described as mountain limestone, blue compact, sub-crystalline or flaggy. The most accessible places where this limestone occurs is on the north side of Shag valley in Otago, and near the Dun Mountain in Nelson; while at Collingwood massive marbles occur, that might be used for ornamental purposes; cement stones abound in the middle tertiary clays underlying the limestone, and also in more recent clays concretions are found in definite layers which contain almost sufficient lime in their composition to enable them to rank as cements. The Moeraki boulders,—the wonderful size and spherical form of which has attracted the attention of all travellers along the Otago coast—are examples of such concretions which have been formed round a nucleus of organic matter.

Having thus in a very condensed form explained the different mining operations which have been commenced in this country, with the object of showing the extent to which they have been successful, I would remark that all mining involves a certain amount of speculation; and if, so far, the adventures in this colony have not been invariably successful, yet when we consider how very limited and fitful the attempts have been, and the few localities that have been tested, it must be admitted that there is good evidence that New Zealand is endowed with a fair share of mineral wealth. At the same time we should not forget that unless we have a thriving population, minerals will not increase the real progress of the country. Many of the richest mineral producing countries in the world occupy a very inferior position
among nations, and it is only when the development of mineral wealth comes as an accessory to other productive industries, that it is a real advantage to the country, by affording employment for labour and manufacturing ingenuity.

I append two Tables, compiled from official returns; the first showing the amount of Coal which has been imported into the colony, chiefly from New South Wales. This return shows that there is a very large annual expenditure for this item, part of which, at least, might be directed to the development of our own coal fields, if the difficulties of access to the coal seams could be surmounted; and also if the very unfounded prejudice which prevails against the use of the better kinds of Brown coal, for domestic purposes, was overcome.

On the important utility of these coals I will quote the opinion of Professor Hochstetter, who says:—"That those Brown coals,—being as they are, of a nature and quality, far different from English coals,—should, in many instances, be deemed, in New Zealand, far inferior to what they are, is easily accounted for; and years will pass away before the prejudices will be overcome with a people that hitherto have only known and used the excellent coal of their mother country. Time and experience, however, will show, that the Brown coal in New Zealand can be used for the same purposes, for which just the same coal, and sometimes of a far inferior quality, is used on a most extensive scale in various parts of Germany and especially in Austria, in whole provinces of which (Styria, Krain and Northern Bohemia) it constitutes the almost exclusive fuel for manufacturing and railroad, as well as for domestic purposes."—"New Zealand," by Dr. F. von Hochstetter, p. 90.

The second Table shows the quantity of the different metallic ores which has been exported from the colony during each year. This return is necessarily imperfect, especially for the years prior to 1853, at which date the regular publication of the statistics of the colony was commenced. They are however approximately correct, and show the total value of exported minerals, during the past twenty-five years to be £19,652,201.

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TABLE II - EXPORTS FROM 1869 TO 1889, INCLUSIVE.