III.—GEOLOGY.

Art. XXI.—*The Geological History of New Zealand.*

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[*Read before the Otago Institute, 10th October, 1899.*]

If I were to ask you the question, "Why does every civilised Government establish a geological survey?" I expect you would answer, "To develope the mineral resources of the country." This no doubt is true, but I wish to point out that any geological survey which makes the discovery of economic minerals its primary object is sure to be a failure. That is, if its attention is directed to special details, it can never ascertain the true geological structure of the whole country; while it is necessary to know the geological structure and history of a large district before a satisfactory opinion can be given on the mineral capabilities of any particular locality. But the geological history of a large district cannot be learnt without extending the survey through the whole of it, and into parts of the country in which there are no minerals, for one part of the history will be learnt in one place, and another part in another place; so that it is only by an extended and systematic survey that the whole history can be put together. And I repeat that until the geological history of a district is known the opinion of a trained geologist on its economic resources can be of no more value than that of any experienced miner.

It follows, therefore, that the primary and fundamental object of a geological survey is to make a systematic investigation into the structure and palæontology of the whole country in sufficient detail for its geological history to be ascertained with considerable accuracy. The contrary system, of examining local mineral deposits first, is very much like marking out allotments and sections for sale on a map without having previously connected them by triangulation, in which case we all know the result will be confusion. It is the same with a geological survey; and we must remember that of the two parts into which it is divided—the general survey and the subsequent examination of special districts—the first is beyond private enterprise, because no individual has the time, the means, and the inclination to make a systematic investigation of a large country and publish results; while, after the general survey is made, private individuals can easily undertake the local examinations, and may often be paid for doing so. Consequently it is the duty of the Government to take in hand an important work which cannot be done by private enterprise, and this is what most Governments of civilised countries have actually done.

Now, no systematic geological survey has yet been made of New Zealand—that is, there has been no close and continuous examination of the rocks, starting from a few localities and gradually spreading over the whole country. Nevertheless, in the intervals between the examination of mines and mining districts Sir James Hector has managed to get a sketch-map made of the greater part of the country, while some important districts have been examined more in detail. We thus know a good deal about the general geological structure of New Zealand although we do not know it accurately; and, as a consequence, in several cases the evidence appears to be conflicting, so that different opinions may be maintained according to the observer's interpretation of the evidence.

But while something has been done towards unravelling the geological structure of New Zealand, the palæontology has been woefully neglected. Large collections of fossils have been made by the survey, but they remain undescribed—most of them, indeed, as yet unpacked—in the Museum at Wellington, and there appears to be no chance of getting them described. According to the last annual report, there are more than thirty thousand specimens in the exhibition-cases, by far the larger part of which are unnamed and undescribed; while, in addition, there are about five hundred boxes still unpacked, many of which have been stored away for years. A slight attempt was made in 1873 to describe the Tertiary shells and Echinoderms; but the plates which were prepared to accompany the text have never been published. Also, in 1880 a report appeared on the Neozoic corals and Bryozoa, but nothing further has been done by the New Zealand Government. Nearly all we know of the palæontology of New Zealand is either due to the publication by the Government of Austria of the fossils collected by Dr. von Hochstetter in 1859, or is the result of private enterprise. The collections of the survey—made with great labour and at considerable expense—are wasted by the apathy of the Government, which appears not to know how great would be their scientific value if described and figured, and how useless they are as they now exist in the Museum at Wellington. It is a great pity that this should be so, for the geographical position of New Zealand gives to its geology a world-wide interest. It is in New Zealand alone that we have any record of the ancient faunas and floras that successively overspread the South Pacific, and it is here that we must look for the principal evidence of the changes that have taken place in the physical geography and climate of this enormous area. Situated at the antipodes of Europe, any change of climate there brought about by the shifting of position in the axis of the earth, or by a change in the eccentricity of its orbit, or by a change in the obliquity of the ecliptic, or by any cosmical change whatsoever, must find its parallel here, and, consequently, New Zealand is to Europe a base of verification for all such-like hypotheses.

With our present imperfect knowledge it is not surprising that there should be several portions of the geological history of New Zealand on which differences of opinion are held. And I wish at the outset to make it clear that I am about to state my own opinions only, which I do not for a moment suppose are always correct. Geology at its best is an uncertain science, depending largely on the accuracy with which gaps in the series of facts are filled up by theory, and in our knowledge of the geology of New Zealand there are many and wide gaps. A more detailed and more systematic investigation might, no doubt, make me alter several of the opinions I am going to express. Nevertheless, I think that all the geologists who have examined New Zealand are pretty well agreed upon most points of its geological history. It is only on a few questions that we differ, and we may at least claim to have made the path of investigation easier for those who come after us. With this preliminary qualification, I will now proceed with my subject.

GENERAL GEOLOGICAL STRUCTURE.

A chain of mountains runs through the South Island from Otago to Nelson, narrow in Westland—where it is called the Southern Alps—but spreading out both in the north and in the south into several ranges. This mountain-range, or orographic axis, however, does not form the tectonic, or structural, axis of the Island—that is, it is not the central line of elevation of the mountains. This line, which is called the "structural axis," lies at their western base along the line of granites in Westland and Nelson; so that the mountain-range is only the eastern half of a huge geanticlinical arrangement of contorted rocks, the western half having been washed away by the heavy rains which fall upon that side, and which must have fallen for a very long time to have produced so great an effect. As these rains are due to the westerly winds sweeping over a large ocean, we have here a proof that moisture-laden westerly winds have predominated in these latitudes for a very long time.

All the sedimentary rocks up to the Hokanui system (Lower Jurassic) inclusive partake of the flexures in the mountains; while those of the Waipara system (Upper Cretaceous) are also involved to some extent in Otago and Nelson. But the rocks of the Oamaru (Oligocene) and younger series either retain their original plane of deposition or are occasionally distorted locally.

In the North Island the structural axis appears to be continued through the centre of the Island from Wanganui to the Bay of Plenty, and the chief mountain-range lies to the west of it, as in the South Island. This main range is formed by rocks belonging to the Maitai (Permo-carboniferous) and Hokanui systems, smothered on each side by Tertiary beds through which isolated ridges and peaks of the older Maitais and Hokanuis rise at intervals throughout the Auckland Province.

To the south-east of the main range in both Islands volcanic rocks occupy but a small area; but on the north-western side, from the centre of the North Island to Auckland, they cover more than half the country, and appear again in great force further north, between Hokianga and the Bay of Islands.

Wanaka System.

The oldest rocks in New Zealand are the crystalline schists of Central Otago, which have been called the "Wanaka system."* They are largely developed in the interior of Otago from the Taieri to the great lakes, and from thence they pass north, in a narrow band, at the western foot of the New Zealand Alps, as far as the Spencer Mountains, in the Nelson Provincial District. In Otago they appear to have the enormous thickness of not less than 100,000 ft., or about nineteen miles. The lower part of the system is formed principally of mica-schists, varying from coarsely foliated rocks with thick lenticular plates of quartz to finely foliated, with nearly parallel foliæ. These pass upwards into fine-grained mica-schists, silky phyllites, clay-slates, and quartzites.

Similar schistose rocks appear in Queen Charlotte Sound and the Pelorus; also in Collingwood County, at the mouths of the Aorere and Parapara Rivers. But each of these districts is separated from the main body of schists in Otago and Westland by younger rocks, which cross the Upper Buller from the Spencer Mountains to the Wangapeka River, and which hide the older schists. One of these detached portions —that near the mouth of the Aorere River—is overlain, appa-

* "Report on the Geology and Goldfields of Otago," p. 29; Hutton and Ulrich, Dunedin, 1875.

rently unconformably, by slate rocks containing graptolites of Ordovician age, and this is the only stratigraphical evidence we have as to the age of the schists; but we find in the rocks themselves other evidence of their great age.

In Central and Eastern Otago, away from the main range, these schists are not contorted, but lie at low angles—usually from 15° to 45°—so that the schistose structure cannot have been caused by lateral pressure. Neither can it be due to contact with large masses of igneous rocks, for there is a remarkable absence of those rocks throughout the whole area, the only eruptive rocks as yet described being the chlorite schists near Queenstown. We are therefore driven to the conclusion that the schistose structure is an original one, caused by the interior heat of the earth at a time when it was much greater than at present; and so we are constrained to class the rocks of the Wanaka system as pre-Cambrian.* An additional argument may perhaps be found in the large quantities of graphite and graphite-schist which occur occasionally in some of the older strata, for the occurrence of graphite is characteristic of Laurentian and Huronian rocks. The Wanaka system contains the gold-bearing rocks of Otago.

Takaka System.

The rocks of the next overlying system, called the "Takaka system,"† are found chiefly in the valley of the Aorere River, in Collingwood County; but also in two detached localities—one in the basin of the Baton River (a branch of the Motueka), the other near Reefton. Their united thickness has been estimated by Sir James Hector at between 15,000 ft. and 18,000 ft., but they cover a comparatively small portion of the country.

The lower, or Aorere, series consists chiefly of blue slates with beds of feldspathic and quartzose schist, the former containing graptolites belonging to the genera *Didymograptus*, *Tetragraptus*, *Dichograptus*, and *Phyllograptus*, and is no doubt of Ordovician age. The Baton River and Reefton series consist of slates and sandstones with calcareous beds, sometimes pure limestone. These calcareous rocks contain Trilobites and a number of Brachiopods, as well as a few Mollusca and corals, which appear to be of Siluro-devonian age. In Collingwood County gold reefs are found in rocks belonging to the Aorere series.

Maitai System.

The next rock-system consists of a large mass of sandstones and uncleaved argillites, with occasional beds of lime-

* Trans. N.Z. Inst., vol. xxiv., p. 361.
† Quart. Journ. Geol. Soc. Lond., vol. 41, p. 194 (1885).

stone, which in north-west Nelson and near Reefton lie quite unconformably on the edges of the folded rocks of the Takaka system. It has been called the "Maitai system" from the Maitai River at Nelson, although it is doubtful whether the rocks of the lower part of the Maitai Valley belong to it.* This Maitai system is very largely developed in New Zealand. In Otago, Canterbury, and Marlborough it lies directly on the Wanaka system; and it forms the greater part of the mountain-ranges of New Zealand in both Islands, from the Takitimos in Southland to the eastern side of the Bay of Plenty. It is again found in isolated patches on the north-west of Lake Taupo, and in many other places as far as the North Cape. In the North Island these are the oldest known rocks. The thickness of the system in the South Island is estimated by Sir James Hector at from 7,000 ft. to 10,000 ft.; but it is very difficult to form an opinion, as the rocks are everywhere highly folded and the stratification is often obscure.

Only three species of Brachiopoda have been found, all of which—if they have been correctly named—are also found in the Permo-carboniferous of Tasmania, and one of them—*Productus brachythærus*—seems to be characteristic of that formation in eastern Australia. Straight but slightly tapering tubes up to 2 in. or 3 in. in length and from $\frac{1}{10}$ in. to $\frac{1}{4}$ in. in diameter have also been found in several places in Canterbury as well as near Wellington. They are generally called "annelid tubes," but more probably they are the shells of pelagic Cephalopoda. The so-called annelid-beds, which contain these fossils, appear to belong to the upper part of the Maitai system, and on the western side of Lake Ohau they have been found together with the remains of plants.†

In several localities in both Islands red-jasperoid slates occur, sometimes associated with manganese-oxide, and this, together with the paucity of fossils and the general absence of plant-remains, points perhaps to a deep-sea origin.‡ It seems probable that these beds accumulated in the deeper portions of a sea, the more western and shallower portions of which were at the same time receiving the *débris* from a Permo-carboniferous Australian Continent.

In New Zealand the period closed with an eruption of granite, which is now found at intervals from Stewart Island, through Westland, to near Separation Point in Blind Bay. This granite has penetrated the rocks of the Maitai system, and is found as rolled fragments in the conglomerates of the

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* Quart. Journ. Geol. Soc. Lond., vol. 41, p. 201.

† McKay: "Reports of Geological Explorations," 1881, p. 79.

‡ Red slates are said to overlie rocks containing *Tæniopteris* in the Kaikoura Mountains (McKay: "Geological Reports," 1885, pp. 55–57). Possibly this may be due to inversion.

next system. It is in the rocks of the Maitai system, in the neighbourhood of the granites, that the gold reefs of Preservation Inlet and the Inangahua occur.

Hokanui System.

The next system is better developed in the Hokanui Mountains of Southland than elsewhere, and so it has been called the "Hokanui system." In the southern part of Otago it covers a considerable amount of country, from the Livingstone Mountains to the sea between the mouths of the Mataura and Clutha Rivers, where it is between 20,000 ft. and 25,000 ft. thick. In Canterbury it is known in many places, from Mount Potts and the Malvern Hills to the Upper Wairau and Kaikoura Mountains. It is also developed at Wairoa and Richmond, near Nelson, but it is doubtful whether it exists on the west coast of the South Island.

In the North Island the Hokanui system occurs at Wellington and along the eastern side of the Ruahine Mountains to the Ruakamara Mountains, near the East Cape, always lying on the south-eastern side of the Maitai system. On the west coast of the North Island it is found at Kawhia, Raglan, and Port Waikato, and here it lies on the north-western side of the Maitais. This seems to show that the geanticlinal axis of the South Island runs through the centre of the North Island from Wanganui to the Bay of Plenty, although no Palæozoic rocks are visible, and it is not even a mountain-range, but only a band of volcanic activity.

There is, no doubt, a stratigraphical break between the Hokanui and Maitai systems, but in no place is the former seen to rest on rocks older than the Maitais, and the boundary between the two systems is very difficult to draw.

Near the junction of the Hokanuis with the Maitais thick beds of greenstone-ash (known as the "Te Anau series") are found, often accompanied by intrusive basic rocks, and it is sometimes uncertain to which system they should be referred. Indeed, they may belong to more than one geological horizon. They are probably connected with the outbursts of basic and ultra-basic eruptive rocks which are found from Bluff Hill in Southland to Nelson. These rocks in the West Coast Sounds are chiefly gabbros and diorites which have acquired a foliated structure through pressure subsequent to their eruption; and the same kinds of rocks are found in the Upper Buller and in the Riwaka Mountains, west of Blind Bay. Hurunui Peak, in North Canterbury, is another dioritic volcano belonging to the lower part of the Hokanui system. Ultra-basic rocks (peridotites and serpentines) are found at intervals from Milford Sound to D'Urville Island, and these also appear to belong to the same period as the diorites.

The sedimentary rocks are blue mud-stones, with greenish or brown sandstones and occasional beds of conglomerate. Granitic conglomerates are commonly found in Southland in the Upper, or Mataura, series; and Mr. S. H. Cox says that he has found them at the base of the Lower, or Wairoa, series, in conjunction with beds of greenstone-ash and breccias, thus showing that the granites are older than some of the basic rocks.

Remains of plants are found all through the system, and in the upper part thin seams of coal often occur. The most characteristic plants are *Pterophyllum, Podozamites, Thinnfeldia, Tæniopteris,* and *Polypodium.* Fossil animals are also tolerably abundant, and include *Ammonites, Belemnites, Trigonia, Edmondia, Monotis, Trigonotreta, Spirifirina,* and *Athyris.* Also a single vertebral centrum, belonging probably to *Ichthyosaurus,* has been described by Sir James Hector; and teeth, apparently belonging to a Labyrinthodont, have been found near the Nuggets, in Otago, and also in the Wairoa district, near Nelson. These fossils are sufficient to prove that the rocks are of Lower Mesozoic age, and probably they are the equivalents of the Trias-jura formation of eastern Australia.

Inferences from the Facts.

We now come to a great break in the geological history of New Zealand, and this enables me to pause in my narration of facts and see what we have already learnt before going on to the second part of the history. Our oldest rocks—those of the Wanaka system—are undoubtedly the products of the denudation of a land-surface, but where that land lay we cannot tell. We are also quite as ignorant of what was taking place in our part of the world during the older Palæozoic era, further than that the fossils of the Siluro-devonian rocks seem to imply a shallower sea than that which prevailed in the Ordovician period.

The next fact we have is that, after the deposition of the Siluro-devonian rocks, a synclinal trough was formed in north-west Nelson and Westland, to the west of the present main axis. Denudation followed, by means of which the Takaka rocks were completely removed, except those preserved by the syncline. This implies the existence of a land-surface in our area during the late Devonian or early Carboniferous. It is possible that these movements took place in the middle of the Devonian period in connection with similar ones which at that time occurred in Australia; and, if such is the case, land probably existed in the Upper Devonian in both the Australian and New Zealand areas, so that they may have been connected and formed part of a continent. But we have in New

Zealand no land plants or animals of the period by which we could test the truth of this hypothesis.

The land then sank and the Maitai system was deposited. Towards the end of the Carboniferous period the New Zealand area appears to have been under a deep ocean, but with shallower water to the west and north-west, for in Tasmania and Australia we find that the rocks, which were probably contemporaneous with our Maitai system, contain shallow-water beds with plant remains; while in New Zealand there is an absence of conglomerates and of fossils generally. Perhaps, also, we have direct evidence of deep-water conditions in our deposits of manganese-ore and red-jasperoid slates.

Probably it was early in the Permian period when elevation, with folding of the rocks, again took place; and this was accompanied by the intrusion of granite in the South Island along the axis of the present New Zealand Alps. After a long interval the granite was followed by a series of basic volcanic eruptions, and the land began slowly to sink, and this was continued during the Triassic and the first half of the Jurassic periods. During the whole of this long-continued subsidence—while the rocks of the Hokanui system were being laid down—land must have been in the close neighbourhood, for in the rocks we find bands of conglomerates and abundant vegetable remains.

The sedimentary rocks of the Hokanui system have much the same lithological characters throughout New Zealand, and appear to have been chiefly the products of large rivers which drained a continent, and not the products of small island streams; so that probably New Zealand was then placed near the coast-line of a large continent stretching away to the north and west. Whether this land reached to Tasmania and Australia we cannot say until the New Zealand fossils have been compared with those of Australia; but if it be true that a Labyrinthodont lived on the banks of these rivers a land-connection between Australia and New Zealand must have existed. Certainly there is no evidence that the Permo-triassic land was a mountainous region near New Zealand, for there are no signs of any deep local excavations having taken place, such as would have been produced by mountain streams, and no evidence has as yet been found of the presence of Permo-triassic glaciers.

About the middle of the Jurassic period folding of the rocks again occurred along the same north-east and south-west axis; the Alps were formed, and the present land of New Zealand may be said to have been born, for since then it has never been submerged. Up to the present we know of no igneous outbursts which accompanied this third folding. But some of the granites along the West Coast—such as that between Waimangaroa and Denniston, near Westport—may ultimately prove to be of Jurassic age, for this granite differs from the others in the significant fact that the quartz shows no pressure granulation, while most of the other granites have been altered into gneissoid rocks by the pressure exerted when the sedimentary rocks were being folded.

In the period that followed the upheaval of the New Zealand Alps great denudation took place on the north-western side—the evidence for which will be given presently—and this must have been due to moist westerly winds producing heavy rains, as at present. We must therefore assume that the Tasman Sea was then in existence, and we have reason for supposing that it has been in existence ever since. The evidence for this is the absence of terrestrial mammalia and snakes from our present fauna, and the remarkable distinctness of our Cretaceous and Tertiary fossils from those of other countries. But New Zealand was not at first so small as it is now. Not only did it spread more to the west, but it seems to have extended north to New Caledonia; and, very probably, it was attached to New Guinea, from whence it drew the more ancient elements of its present flora and fauna.

Waipara System.

Resuming now our history, we come next to rocks of Cretaceous—probably Upper Cretaceous—age, called the "Waipara system."* This is found on the eastern side of New Zealand, at the Shag Point coal-mines in Otago, and from the Malvern Hills in Canterbury to Cape Campbell. Crossing Cook Strait we find it again on the east coast of Wellington and in Hawke's Bay; and again, perhaps, from Poverty Bay to the East Cape. On the west coast of the South Island we have the coal measures of Greymouth and Westport, and also those of Pakawau, near Collingwood.† But on the west coast of the North Island Cretaceous rocks are known only in the valley of the Wairoa River, north of the Kaipara, and perhaps at Kawhia. However, we must remember that, as the fossils of the North Island have not yet been carefully compared with those from the South, it is impossible to feel certain about their age.

The strata are usually much disturbed, except in North Canterbury, and sometimes form mountains 5,000 ft. or 6,000 ft. in height. Also, they lie quite unconformably on the older rocks. In Canterbury and Marlborough they rest indifferently on the Hokanuis or on the Maitais, and at

* Under this name I include the Lower Greensand formation of Sir James Hector, as well as the lower part of his Cretaceo-tertiary formation.

† Trans. N.Z. Inst., vol. xxii., p. 377.

Pakawau they lie directly on the Takaka system. This shows that great denudation of the land had taken place between the time of the upheaval of the Hokanui and the deposition of the Waipara system.

During the formation of the older rocks of this system extensive eruptions of rhyolite took place along the western margin of the Canterbury Plains, and these were followed by dolerite and basalt. In Banks Peninsula we also find the oldest volcanic rocks to be rhyolite; and it is possible that the andesitic calderas of Lyttelton, Little River, and Akaroa may also belong to the Cretaceous period, although it is more probable that they are Tertiary. Many of the andesites of Banks Peninsula are peculiar from containing olivine, while the dykes cutting them are augite-trachytes.

At the Waipara River and at Amuri Bluff the sedimentary rocks contain *Trigonia, Inoceramus, Conchothyra*—a genus allied to *Pugnellus*—as well as *Belemnites* and *Ammonites;* also marine saurians belonging to the genera *Cimoliosaurus, Polycotylus*, and *Leiodon*, which are more nearly allied to the contemporaneous reptiles of North America than to those of Europe. *Ammonites* and *Scaphites* have also been found at Waipawa, near Napier; but none of these Cretaceous fossils are known from the west coast of the South Island. Of the plants, *Araucaria, Flabellaria*, and *Cinnamomum* may perhaps be taken as characteristic; but, according to Baron von Ettingshausen, there are also several genera which still live in New Zealand. These are *Panax, Loranthus, Hedycarya, Santalum, Fagus, Dammara, Podocarpus*, and *Dacrydium*, to which, on the authority of Mr. Buchanan, we may add *Aciphylla*. These probably formed part of the foundation of our present flora; and, if this be the case, land must have existed continuously in New Zealand from the Upper Cretaceous period to the present day. And, as the land stood higher in the Cretaceo-jurassic times, we may safely infer that since the middle of the Jurassic period New Zealand has never been altogether submerged beneath the sea.

Oligocene Period.

*Oamaru Series.**—The oldest Tertiary rocks in New Zealand are the coal measures of Kaitangata, Waikato, Whangarei, and other places. These were formed on land which, in the Oligocene period, sank below the sea, when they were

* I here include the Ototara and Mawhera series of Sir James Hector's Cretaceo-tertiary formation, as well as his Upper Eocene formation, except the Mount Brown beds. My reasons for doing so will be found in the "Quarterly Journal of the Geological Society of London" (vol. 41, pp. 266 and 547); also in the "Transactions of the New Zealand Institute" (vol. xx., p. 261.)

covered by marine rocks, which culminated in a limestone, well known as a building-stone, in many parts of New Zealand. This stone, under various names, is found in patches all round the coasts of New Zealand, from Winton in the south to the Bay of Islands in the north, as well as in many of the inland valleys. It belongs to that variety called polyzoal limestone, because it is made up principally of small fragments of calcareous Polyzoa, &c.; and it is, no doubt, the remains of a reef which in the Oligocene period encircled New Zealand. These Tertiary rocks lie unconformably on those of the Waipara system at the Weka Pass, Mount Somers, and a few other places; but elsewhere they lie upon older rocks, belonging to the Hokanui and other systems. At the time of the formation of the Oamaru limestone there were living in our seas a Zeuglodont whale (*Kekenodon onamata*), as well as true cetaceans (*Squalodon serratus*), a penguin (*Palæeudyptes antarcticus*), the huge shark (*Carcharodon angustidens*), rays (*Trygon* and *Myliobates*), and a sparoid fish (*Sargus laticonus*), as well as the nautilus called *Aturia australis*. But with them are found some Cretaceous-looking Echinoderms belonging to the genus *Holaster*. These last were no doubt survivors from Mesozoic times, and I agree with Dr. Stache and Sir F. McCoy in thinking that the rocks in which they occur belong to the Oligocene period.* A species of *Unio* has been described from the coal-beds in Otago.

In the neighbourhood of Oamaru basic volcanic rocks underlie the marine beds, and in other places of Otago and Canterbury volcanic rocks are interbedded with the sedimentaries which belong to the earlier part of the Oamaru series. The most remarkable of these is a hydrated tachylyte, which is found in several places between Lookout Bluff, near Hampden, and Castle Hill, in the valley of the Waimakariri, a distance of a hundred and fifty miles.† The volcanic system of Dunedin probably belongs to the close of this period, as also do the volcanic rocks in the neighbourhood of Palmerston South, and those on the northern side of the Hurunui Plains at Culverden and Pahau, as well also as a large part of the volcanic rocks of Banks Peninsula. The older rocks in the Dunedin Peninsula are andesites, followed by olivine

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* Mr. G. F. Harris is also of opinion that they are younger than the Eocene of London, Paris, &c. (see "Catalogue Australasian Tertiary Mollusca in the British Museum," p. 15; 1897). In the Geological Magazine for 1891, vol. 7, page 491, Dr. T. W. Gregory quotes me as having once been of opinion that the Echinoderms belonged to Dr. Hector's Cretaceo-tertiary. This is a curious mistake, for my paper on the correlations of the Curiosity-shop beds was written to show that there was no Cretaceo-tertiary formation in New Zealand.

† Journ. Roy. Soc. of N.S.W., vol. xxiii, p. 152.

tephrites,* a rock not known from any other part of New Zealand.

Before going any further I should like to point out that each of our geological systems, from the Hokanui to the Oamaru, seems to have been ushered in by volcanic outbursts, which were followed by depression and subsequent elevation.

Miocene Period.

Pareora Series.†—Marine rocks of Miocene age, with from 20 to 65 per cent. of the fossil molluscs belonging to still living species, and with the teeth of the shark *Carcharodon megalodon*, are found in many parts of the New Zealand coasts; while in the interior they go up to a height of 3,000 ft. above the sea in the South Island, and to not less than 4,000 ft. in Hawke's Bay. In a few places—such as Pomahaka, Waihao, and Mokau River—they are underlain by beds of coal.

About 235 species of Mollusca have been described from the Pareora series, and eighty-four from the Oamaru series, and fifty-one of these species are common to both; so that both series are closely connected palæontologically. Nevertheless, the Pareora series very often lies unconformably on the Oamaru series, the latter having undergone considerable denudation before the former was deposited. Examples of this may be seen at Palmerston South, Oamaru, Elephant Hill, Kakahu, Greymouth, and Komiti Point, in the Kaipara; while at other places—*e.g.*, Southland, Waiau (in Amuri County), Hawke's Bay, and Kawau—the Pareora series rests upon Mesozoic or Palæozoic rocks. From this we infer that at the end of the Oligocene period the land was slightly elevated for a short time and then subsided to a lower level than before, New Zealand in the Miocene period being reduced to a group of islands.

The marine rocks are chiefly soft sandstones and clays, but limestones are largely developed on the east coast of the North Island from Wellington to Hawke's Bay.

The fossils are remarkable for the large size of the shells belonging to the genera *Ostrea, Pecten, Lima, Cucullæa, Crassatella, Cardium, Cytherea, Dentalium, Pleurotomaria, Turbo, Scalaria, Turritella,* and *Natica*, which give the fauna quite a tropical appearance. And this evidence is much strengthened by the fact that the fruit of palm-trees has been found not only at Mongonui in the north, but also when making the Livingstone Tunnel near Oamaru. Several of our

* Ulrich, Report Aust. Assoc. Adv. Science; Christchurch, 1891, p. 127.

† I include here the Waitemata series of Sir James Hector's Cretaceo-tertiary and the Mount Brown series of his Upper Eocene, as well as his Upper and Lower Miocene formations.

Miocene and Pliocene genera of Mollusca appeared first in Australia, and afterwards in New Zealand, showing that part of our Tertiary fauna reached us from Australia, and not from an antarctic continent. Nevertheless, out of the 268 species of Mollusca known from the Oamaru and Pareora series, only thirty-one, or 11½ per cent., are found in Australia, which is a less percentage than exists at the present time. So that our fauna was, even in the Miocene, very different from that of Australia. What is perhaps still more noticeable is that no less than thirteen species of our Miocene Mollusca are also found fossil in the Tertiary rocks of Patagonia, and of these only two are known in Australia. This shows some connection with Patagonia in which Australia did not share.

Another important fact connected with the Miocene period is the great outburst of volcanic energy in the North Island. In the South Island the only eruptive rocks we know to be of this age are the dolerites of Moeraki and Mount Charles in Otago, and those of Timaru and Mount Cookson near Waiau; to which may perhaps be added Mount Herbert in Banks Peninsula. These were the last expiring efforts of vulcanism in the South, and its energy now shifted to the North. The andesites of the Thames Goldfields,* as well as those of Whangarei Heads, Kaipara, and the Great Barrier Island, as also the trachytes of Hicks Bay,† date from the early part of this period. And as pumice is found in rocks of Miocene age at Hawke's Bay‡ it seems probable that part of the rhyolites and andesites which form the plateau extending from the southern side of Lake Taupo through Patatere to Te Aroha are of Lower Miocene age. At a slightly later date came the rhyolites forming the cliffs round Lake Taupo, which are remarkable for containing small crystals of hypersthene, by the presence of which the pumice of Taupo can be distinguished from that found elsewhere.

Pliocene Period.

The Wanganui series contains a number of marine fossils, of which from 75 to 93 per cent. of the shells and about 76 per cent of the Polyzoa belong to still living species, so that we can safely consider it to be newer Pliocene. It lies unconformably on Miocene rocks at Napier, and it is doubtful whether we have in New Zealand any marine beds belonging to the older Pliocene. The Wanganui series is known only in the southern half of the North Island, from Patea and Wanganui on Cook Strait to the northern part of

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* Report Aust. Assoc. Adv. Science, vol. i., p. 253; Sydney, 1887
† Cox, Reports Geol. Explor for 1876–77, p. 112
‡ Hill, Trans. N.Z. Inst., vol. xx., p. 304.

Hawke's Bay.* However, it probably occurs also at Taranaki, Poverty Bay, and several other places in the North Island.

In the South Island the marine rocks of the north appear to be represented by thick beds of unfossiliferous gravels deposited by mountain torrents, some of which may date back to the close of the Miocene.

Of volcanic rocks we may probably assign the rhyolites of Tarawera, Rotorua, and the Thames Peninsula† to the Pliocene period, as well as the hornblende and augite-andesites which form the bases of Ruapehu and Mount Egmont. But very little is known about the sequence of the volcanic rocks of the North Island.

The Great Glacier Epoch.

We now come to one of the most interesting phases in the geological history of New Zealand—I refer to the great glacier epoch. Ancient glacier-marks, principally in the form of terminal moraines, are numerous in the South Island, and they are no doubt of various ages. But it remains uncertain whether they form a single continuous and diminishing series from the earliest records to the present day, or whether there have been two or more periods of marked extension of the glaciers. The most northerly glacier-marks are found round Mount Olympus and the Arthur Range, in Nelson. None have been recorded from the Kaikoura Ranges, although at the present day they are capped with perpetual snow, and none are known in the North Island. The St. Arnaud and Spencer Mountains gave origin to many glaciers. The principal ones on the northern side of these ranges filled the valleys now occupied by Lakes Rotoiti and Rotorua (of the Nelson Provincial District), while to the south and east large glaciers went down the Clarence and the Waiau-ua, the latter being no less than fourteen miles in length. The ancient glacier of the Waimakariri was thought by Sir Julius von Haast to have extended for a length of fifty-four miles, reaching out on the Canterbury Plains as far as Sheffield. This view is open to several objections, but it seems to be certain that the Rakaia Glacier, at the time of its greatest extension, debouched on to the Canterbury Plains, and stretched nearly as far as Woolshed Hill, which would give it a length of about fifty-five miles. Less is known about the ancient glaciers of the Rangitata and Waitaki; but in Otago that of the Clutha certainly came as far as the Lindis, and perhaps to Cromwell, which would give it a length of about

* Trans. N.Z. Inst., vol. xviii., p. 336.
† James Park, Quart. Journ. Geol. Soc. London, vol. 55, p. 451.

sixty miles. The glacier which filled Lake Wakatipu did not drain into the Clutha, but went due south by Athol to the Oreti River. The united glaciers of Lakes Te Anau and Manapouri extended to Blackmount, on the River Waiau, a distance of sixty-five miles, thus being the largest of the New Zealand glaciers. There is also in Otago the remarkable isolated moraine in the Lower Taieri, which forms low hills—some 400 ft. or 500 ft. in height—between Lake Waihola and the sea. This moraine may perhaps be older than any of the others. A few marine fossils have been found in the sandy clays underlying it, which seem to indicate a Miocene age for those beds, so that the moraine itself may belong to the older Pliocene.*

In Nelson the terminal moraines of the largest of the ancient glaciers are about 2,000 ft. above the present sea-level In South Canterbury they go to 1,000 ft., and in South Otago to 600 ft.; but in Westland and in the West Coast Sounds the glaciers advanced to below the present sea-level. There are, however, no stratified till-deposits, and nowhere do we find the moraines enclosing marine shells, so that there is no evidence that these glaciers descended into the sea. Another remarkable feature is that no boulder-clay has as yet been detected in New Zealand—nothing but the ordinary moraines of valley glaciers. Neither are there any true erratics—that is, large blocks of rock which have been transferred from one drainage system into another. All our erratics have come down the valley in which we now find them.

Now comes the question, What was the cause of this great accumulation of ice in our mountains? We cannot account for it by a colder climate, for there is not the least palæontological or biological evidence to show that our climate has ever been colder than it is now. On the contrary, all the evidence goes to show that it was formerly warmer. Thus in the south we find local outliers of warmth-loving plants and animals which flourish much better in the North Island. Such are the nikau palm (*Areca sapida*) on Banks Peninsula and at Westport, where also *Lomaria frazeri* occurs, a fern which is not found elsewhere south of Auckland. These are survivals of a more genial age in the South Island. Indeed, the greater part of our present flora is of subtropical origin, as also was that of Europe before the cold of the glacial epoch killed it off and largely replaced it by a northern flora. Nothing of that kind has happened in New Zealand. Again, several northern marine shells still live in Foveaux Strait, such as *Triton spengleri*, *Scalaria zelebori*, and *Cookia sulcata*. If New Zealand had lately passed through a cold phase all these plants and

* Report Aust. Assoc. Adv. Science, vol. v., p. 232; Adelaide, 1893.

animals would have been killed off in their southern localities, for there is no place near New Zealand to which, in Pleistocene times, the subtropical flora could have temporarily retreated and then returned after the cold was over.

The same may be said of almost the entire faunas and floras of the islands lying to the south of New Zealand. Yet we find in the Auckland Islands a peculiar genus of duck (*Nesonetta*) which cannot fly, and in Antipodes Island a peculiar parroquet (*Cyanorhamphus unicolor*) which has almost lost its powers of flight. These birds must have been developed on the islands where we now find them, and the process must have been a slow one; yet during the whole of that time the islands could not have been covered with ice. We may extend this argument to other islands in the Antarctic Ocean, such as Kerguelen Land and the Crozets. These possess several peculiar plants and animals, and it is certain that the islands could not have been covered with ice since the first appearance of their present floras. A general reduction of the temperature of the whole Southern Hemisphere being therefore out of the question, we must look for other and local causes for the extension of the glaciers. Two theories have been advanced—one is that our mountains during the great glacier epoch were flat-topped, forming plateaux on which large masses of snow collected; the other is that the mountains stood at a greater altitude than at present, due to a general elevation of the whole Island.

Now, passing over the question whether large snow-covered plateaux necessarily imply large glaciers—they do not do so in Norway—we are met with the fact that most of our river-valleys had been cut down to their present level before the Oligocene period, for rocks of that age fill several of them nearly or quite to the bottom. For example, it is certain that in the Eocene period the Rakaia River ran at a lower level than it does at present. As this is an important point I will give the proofs of my statement.

In the valley of the Rakaia, opposite the east end of Lake Coleridge, there is an outlier of Oligocene limestone called Redcliff. It is lying almost horizontal in its original plane of deposition in a lateral valley on the south side of the river, and is, no doubt, a fragment of a set of beds which once filled all that part of the valley. Now, as this limestone passes under the gravels and descends below the present level of the river, it is evident that when the Rakaia scoured out the valley in the Eocene period it must have been running at a lower level than at present, for it now runs on the top of alluvial gravels which partly fill up the whole valley. Also the junction of the limestone with the Palæozoic rocks must mark the limit of the valley of the Rakaia at that place when the limestone was formed. If, therefore, any great lateral denudation had taken place since that time, the line of junction between the two rocks ought to stand out as part of a prominence. But it does not do so; consequently, the lower portion of the Rakaia Valley cannot have been greatly enlarged since the Eocene period. This is confirmed by the fact that on the southern slopes of Mount Algidus, in the Upper Rakaia, there is another outlier of Tertiary *marine* rocks, showing that there also the valley was very deep long before the Pliocene period.

It is therefore very unlikely that a great plateau in the upper part of the Rakaia Valley has been lately removed; and we may say, generally, that as the rivers of the South Island had cut such deep valleys before the Oligocene period it seems impossible, from what we know about river erosion, to believe that any large plateaux could at that time have been in existence—that is, none to which we could attach any great importance.* If also, as we have seen, the New Zealand Alps were formed in the middle of the Jurassic period, and have been exposed to the action of the weather ever since, plateaux of any size could not have existed from the Jurassic to the Pliocene and then have rapidly disappeared, especially at a time when, by the hypothesis, they were protected by a covering of perpetual snow.

This plateau hypothesis failing, we are left with that of elevation to account for the phenomena; and it has been calculated that an elevation of between 3,000 ft. and 4,000 ft. would, at the present day, be sufficient to expand our glaciers to their former dimensions.† That the New Zealand Alps did formerly stand higher than they do now we have direct evidence in the deep fiords of south-west Otago and Marlborough, which must have been excavated when the land was considerably elevated. The greatest depth recorded in the West Coast Sounds is 1,728 ft., in Breaksea Sound; but in many places no bottom was reached with the line used, and we may safely assume that when the valleys were scooped out they stood more than 2,000 ft. higher than they do now. And this agrees fairly well with the quite independent estimate that an elevation of 3,000 ft. or 4,000 ft. would be sufficient to reproduce all the phenomena. In Canterbury also we find evidence of a former elevation, for in sinking a well in Christchurch a quantity of solid timber was found at a depth of more than 400 ft., which must either have grown on the spot or have been brought there by a river. How deep the shingle-beds of the Canterbury Plains go we do not know.

* See Ann. Mag. Nat. Hist., series 5, vol. 15, p. 91.

† Trans. N.Z. Inst., vol. viii., p. 385.

Lastly comes the question, When did this elevation take place? I will take the biological evidence first. The great similarity between the faunas and floras of the two Islands of New Zealand shows undoubtedly that they were once united; and an elevation of 500 ft. at Cook Strait would connect them again. Nevertheless, we find six different kinds of birds represented by different species in each Island; and this is not due to differences in climate or in the physical features of the two Islands, but to changes in the animals which have taken place since the Islands were separated. It is the same with the extinct moas. Nearly all—perhaps all—of the known species were confined to one or other of the Islands, and certainly none were abundant in both. But this implies that the Islands have been separated by Cook Strait for a long time, during which, of course, there could have been no general elevation.

Still, as I said before, it is evident that the two Islands were once united. Indeed, we may go further and say that in all probability the Chatham Islands, the Auckland Islands, and perhaps Campbell and Macquarie Islands were at one time united to New Zealand by land, for their faunas and floras are closely allied to those of New Zealand, and are quite unlike those of Tasmania.

As no lizards nor land-shells have passed between Tasmania and New Zealand, and as very few birds, insects, and plants are common to both countries, although the distance between them is not much more than twice that between New Zealand and the Chatham Islands, it is evident that our connection with these and with the Auckland Islands must formerly have been much closer than it is now. And the presence of a slug common to all three suggests that there was a land-communication between them.

Now, these outlying islands contain many endemic species of plants and animals, and, in the case of the Chatham Islands, we cannot explain the existence of these distinct species by differences of climate. Out of twenty-one land-birds on the Chathams, seven—that is, one-third of the whole—are endemic. And of the plants about 15 per cent. are endemic. This implies that the Chatham Islands have been isolated for a very long time, and we can say with some confidence that this isolation must have lasted ever since the close of the Pliocene period. But when New Zealand extended so far as to include the Chatham Islands it probably stood at a much higher elevation than at present; and the Pliocene period, therefore, is the time we should expect that the greatest extension of our glaciers took place.

We will now take the geological evidence. In the first place, it is significant that there are no marine Pliocene beds in the South Island, but only huge deposits of shingle and sand which may well have been derived from glaciers in the mountains. Among the older of these are the Moutere Hills, in the Nelson District, the Mount Grey downs in Canterbury, and the shingle-beds under lava-streams at Timaru.

Secondly, since the culmination of the glacier period several important changes have taken place in the physical geography of the country. The gorges of the Kawarau and Dunstan, as well as those of the Mataura and Upper Taieri, in Otago,* have all been cut, as have also those of the South Ashburton and the Waimakariri, in Canterbury. Also several of the older lakes have been completely filled up, as, for example, those of the Rakaia and the Waiau-ua; while others —such as Lake Heron, Lake Tekapo, and Lake Pukaki—are approaching their end; all of which implies a long time. We thus see that both kinds of evidence place the great glacier epoch in the Pliocene period; and if it should turn out to be true that no older Pliocene marine beds exist in New Zealand, then we may confidently place the greatest extension of our glaciers in the older Pliocene, when both Islands stood higher than they do now. If, however, it should be found that older Pliocene marine beds connect the Miocene with the newer Pliocene in the North Island, then we should have to assume that the South Island alone was elevated in the Pliocene, and that the great glacier epoch may have lasted through the whole of it. However, I think the first supposition to be the more probable.

Pleistocene Period.

During the Pleistocene period the great volcanoes of Tongariro, Ruapehu, and Mount Egmont emitted andesite lavas, while basalts were erupted in the neighbourhood of Auckland and near the Bay of Islands.

The old swamps, or lakes, in which such a large quantity of moa-bones have been found, also belong to this period, and as they have attracted much attention a word or two in explanation may be interesting. At the time when these large deposits of bones were being formed the climate of New Zealand seems to have been different from what it is now. This was probably due to a greater eccentricity of the earth's orbit; for then, when our winter happened in aphelion, long cold winters would be followed by short but hot summers. The heavy snows which fell during the winter would be rapidly thawed in the spring, with the result of producing heavy floods. This was our diluvial epoch, which followed the great glacier epoch.

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* "Report on the Geology of Otago," Dunedin, 1875, p. 94.

Now, it seems likely that during this time the early winter snows would kill many moas, as well as other birds, on the hills, and that their bodies would be washed down on to the lower grounds by the spring floods, so that in time immense quantities might accumulate in the hollows. This speculation is much strengthened by the fact that no large deposit of moa-bones has ever been found in any of the swamps on the plains away from the hills, either in Southland or in Canterbury, or in the Waikato and Piako districts. However, we should also remember that some parts of these plains may have been below the sea at that time, for we have evidence that after the culmination of the glacier epoch a great depression of the land took place until it stood lower than it does now.

Raised beaches with recent species of marine shells have been found at Tauranga at an elevation of 25 ft. above the sea; at Taranaki, 150 ft.; at Amuri Bluff, 500 ft.; and at Motunau, 150 ft. above sea-level. Also old marine terraces, but without shells, exist on Mahia Peninsula at 200 ft. to 300 ft. of elevation, as well as near Wellington; and all along the west coast of the South Island as far as Green Islet, south of Preservation Inlet. We may therefore safely infer that the South Island and the southern part of the North Island sank in the Pleistocene to a considerably lower level than they now attain, and that they are once more rising.

The evidence given by the alluvial deposits of our rivers is also quite in accord with that of the sea-terraces. When the land was sinking the rivers filled up their valleys and formed the broad alluvial plains so common from Southland to the Waikato. When the land began to rise again the remarkable series of river-terraces which catch the eye in most of our valleys were formed out of these alluvial deposits.

The origin of the silt deposit—sometimes called loëss—which is found on the eastern side of the South Island is a difficult problem to solve. It is found chiefly from Invercargill to the Mataura River, and from Oamaru to Timaru and Banks Peninsula, lying on the low hills and on the river gravels. It evidently forms the latest deposit in every locality in which it is found, and it is equally evident that it is not being formed now. Two theories have been advanced to account for it. One is that it is a wind-formed deposit analogous to the sand-dunes of a desert. The other is that it is a marine deposit, but formed very rapidly by the floods of our diluvial epoch washing away the fine mud left by the retreat of the glaciers.* Many objections can be made to both of these theories, but it would detain me too long to discuss them.

* Trans. N.Z. Inst., vol. xv., p. 411.

Changes in Physical Geography.

New Zealand also offers for solution many problems in physical geography, due to the changes which have taken place since the Cretaceous period, which are very interesting to those who know the ground. But time warns me that I can only glance at a few of them.

Lake Wakatipu and the Arrow River formerly drained into the Oreti River by Kingston and the Dome Pass. Subsequently, the Kawarau and Dunstan Gorges were cut, which allowed the lake to flow into the Clutha. This change seems to have been due to the moraine at Kingston blocking the former channel, and causing a lateral overflow at the Arrow Bluff. To the same cause—*i.e.*, to morainic deposits—we must attribute the change in the drainage of Lake Heron from the Rangitata into the Rakaia River. The Shag River at one time drained the Maniototo Plains, until the gorge of the Upper Taieri was cut. In early Cretaceous times the Hurunui and the Waiau-ua united, and entered the sea at Kaikoura. At a later time they turned down the Weka Pass, and it was not until the Pliocene period that each cut its own valley to the sea. The Upper Manawatu flowed into the Wairarapa, and in the older Pliocene a river ran from near the Manawatu Gorge to Napier. The courses of all these rivers were changed by the deposition of marine rocks in the valleys, which blocked them; and this, on the subsequent rise of the land, caused the rivers to overflow to one or the other side, according to the position of the lowest opening.

The River Waikato at first flowed through the Waiotapu Valley into the Bay of Plenty. Its direction was disturbed by volcanic action in the Rotorua district, and its course was then deflected into the Hauraki Gulf. There it remained until the gorge at Taupiri was cut. What caused this last movement has not yet been clearly made out; but probably it was due to changes in level during the last upheaval of the land when the dome was formed on which Tongariro and Ruapehu now stand.*

Summary.

I will conclude with a short summary of the results at which we have arrived.

Of what took place on this part of the earth's surface during the early Palæozoic era we know next to nothing; but towards the close of the Devonian period land certainly existed, although its outlines are quite uncertain. This land must have sunk, for in the Carboniferous period a deep sea rolled where New Zealand now is, while far away to the

* Cussen, Trans. N.Z. Inst., vol. xxvi., p. 398.

north-west there was the Continent of Australia, with vast mountain-ranges covered with snow, and with glaciers glittering in every valley.

This state of things lasted into the Permian period, by which time the bed of the ocean had been gradually raised, so that the sea became shallow, and the New Zealand area lay near the shore-line of a continent stretching away towards Tasmania and Australia, to which, perhaps, it was joined. This land was covered with ferns and Cycads, and probably there were a number of active volcanoes ejecting rhyolitic lavas. But what animals lived on the land we do not, as yet, know.

In the middle of the Jurassic period came a violent upheaval. The rocks were crumpled up, the coast-line was changed into a mountain-range, and the land between it and Australia sank, forming the Tasman Sea. The new land, which we may now call New Zealand, for it has never since been entirely covered by the sea, extended in a westerly direction to at least twice its present breadth, and to the north it joined New Caledonia and New Guinea, which at that time probably formed part of a South Pacific continent. Plants and animals—including snails, worms, and insects, but no birds—came trooping down from the north to form the basis of our flora and fauna.

A long period followed, in which the western side of the mountains of the South Island were constantly being worn away by the heavy rains brought by cyclones sweeping over the Tasman Sea; but this did not take place to so great an extent in the north, for in those latitudes westerly winds are not so prevalent.

In the Upper Cretaceous the land subsided, and New Zealand was reduced to comparatively small limits. This land, however, supported many angiospermous trees, as well as gymnosperms, whose descendants are still living; while in our seas were marine reptiles and shells which have long since become extinct.

A little before the commencement of the Tertiary era the rocks were folded once more, the land rose again, and again it stretched far away to the north, but was not again united to New Guinea nor to northern Australia. A second invasion from the north followed, and quantities of plants of all descriptions, accompanied by animals—among which were many land-birds—migrated into New Zealand, and it is the descendants of this Eocene invasion which form the greater part of our present flora and fauna.

This was the last folding of rocks in New Zealand on an extensive scale, for all the younger rocks usually lie in the same position in which they were originally deposited, and circle round the bases of hills formed by older rocks. Not only was the last touch given in the Eocene period to the internal structure of the mountains, but the chief valleys were also deeply scoured out, so that when the land sank again in the Oligocene period these valleys were filled up with marine limestones and other rocks.

The Oligocene and Miocene were periods of depression, separated by a slight upheaval which lasted only for a short time. During most of the Middle Tertiary era New Zealand must have formed a narrow ridge of land, very irregular in shape, running north-east and south-west, with some detached islands on each side, three or four on the south-east side, and a dozen or more to the north-west, none of them being very high above the sea.

In the older Pliocene came the last great upheaval. All the islands were joined together, and the land stretched away to the east and south so as to include the Chatham and Auckland Islands, as well, perhaps, as Campbell and Macquarie Islands; while to the north it certainly extended to the Kermadecs, and perhaps much further. On the mountains of the South Island large glaciers were formed; and the torrential rivers running from them tore into disconnected fragments the Miocene marine rocks which obstructed their valleys. Probably at this time more land than at present existed in the Antarctic Ocean, for New Zealand added to its flora and fauna many antarctic plants and marine animals. But this land could not have connected New Zealand with either Patagonia or South Africa, for if it had done so we should certainly have had many more immigrants, including land birds, and, probably, mammals.

It is possible that this large extension of land to the eastward may have produced desert or steppe-like conditions in a portion of New Zealand, evidence of which some botanists think they find in our flora; also, in the old lake at Kapua, near Waimate, there is some slight evidence of a dry epoch having, at that place, succeeded the diluvial epoch during which the moas were buried.* But this may have been due to quite local causes.

Subsidence seems to have commenced first in the southern portion of the North Island, for in the newer Pliocene large portions of what are now dry land were under the sea, and Cook Strait had been formed. But at a later date sinking began in the South Island also, so that in the Pleistocene period the sea at Amuri Bluff stood at least 500 ft. higher than it does now. This sinking has again been followed by an elevation of all parts of New Zealand, the centre of the

* Trans. N.Z. Inst., vol. xxviii., p. 629.

North Island rising as a low flat dome, on the summit of which stand Ruapehu and Tongariro; while the South Island has also been elevated several hundred feet. And this elevation appears to be still going on.

This short sketch will, I hope, show you that New Zealand has had an eventful history, and we need not be surprised if we still occasionally feel it to be somewhat unsteady.

Table of the Geological Formations of New Zealand.

Name of Formation	Probable Age.
Cainozoic System—	
Wanganui series	Newer Pliocene.
Glacier epoch	Older Pliocene.
Pareora series	Miocene.
Oamaru series	Oligocene.
Waipara System	Upper Cretaceous.
Hokanui System—	
Mataura series	Lower Jurassic.
Wairoa series	Triassic.
Maitai System	Permo-carboniferous.
Takaka System—	
Baton River series	Siluro-devonian.
Aorere series	Ordovician.
Wanaka System	Pre-cambrian.

Art. XXII.—*On the Geology of the District between Napier and Puketitiri.*

By H. Hill, F.G.S.

[*Read before the Hawke's Bay Philosophical Institute, 14th August, 1899.*]

A trip to the Kawekas by way of Puketitiri is a pleasure not easily forgotten by any one fond of nature. These mountains lie to the north-west of Napier, at a distance, speaking generally, of fifty miles. The range is isolated, being separated from the Ruahine Ranges in the south by a long low saddle, through which the River Ngauroro passes, and from the Te Waihiti and Raukumara Ranges to the north and north-east by a wide area of broken country, through which traverse the head-waters of the Mohaka River.

The Kaweka Mountains and offshoots may be said to form the watershed of the Rivers Ngauroro, Tutaekuri, and Mohaka, the two first rising within a very short distance of each other. Between Napier and the mountains the general strike of the rocks is north-east and south-west, so that in traversing the country from north-west to south-east the strike of the beds is crossed, and