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IX.—*The Origin of the Fauna and Flora of New Zealand.* By Capt. F. W. Hutton, F.G.S.*

II. The Antarctic and North-Temperate Elements†.

In my address last year I pointed out that the immigrant part of our fauna and flora could be divided into five elements, viz.:—(1) Australian, (2) Polynesian, (3) South American, (4) Antarctic, and (5) North-Temperate. I explained that of these elements the first three had invaded New Zealand together from the north at three different epochs. The first invasion was in the Lower Cretaceous, when New Zealand formed part of a large South-Pacific continent ‡, extending from New Guinea to Chili. The second was in the Eocene period, the third in the Pliocene, during both of which times New Zealand was an island, although considerably larger

* From advance sheets communicated by the Author from the 'New Zealand Journal of Science,' vol. ii. p. 249.

† Annual Address to the Philosophical Institute of Canterbury, delivered 6th November, 1884. For Part I. see Ann. & Mag. Nat. Hist. ser. 5, vol. xiii. p. 425.

‡ M. A. Milne-Edwards appears to have advocated in 1874 the hypothesis that New Zealand had formerly been joined to some islands of Polynesia, while it remained separated from Australia. I have not seen his paper. (See N. Z. Journ. Sc. i. p. 258, footnote.)

than at present; but I had to postpone the proof of the Pliocene upheaval. We now come to the consideration of the two remaining elements—the antarctic and the north-temperate—and we have to inquire at what time they came.

The antarctic element, as we shall presently see, must have invaded New Zealand from the south. It consists of plants, sea-birds, freshwater fishes, marine fishes, marine Crustacea, and marine shells. There are also a few insects, such as the beetles *Heterodactylus* and *Pristancylus* of the Auckland Islands, but no land birds or land Mollusca. A very large portion of the north-temperate element no doubt came with the antarctic forms; for, as we saw in my last address, the percentage of endemic species of plants belonging to each element is almost identical. These probably travelled to the southern hemisphere by the chain of the Andes, and then spread with the Fuegian plants. But several of our plants, insects, and arachnids are allied to northern forms, and have no near relations in South America. These probably migrated to us direct by the mountains of the Indian archipelago at the same time that we were invaded by the Australian and Polynesian floras. This latter portion I shall leave out of consideration, and shall confine my attention solely to the invasion from the south by both the antarctic and north-temperate elements.

Now in dealing with this part of our fauna and flora we have to take into consideration two means of dispersal, at present going on, which are not found, or only to a very limited extent, in the tropical parts of the ocean. In the first place the almost constant westerly winds travelling round the globe in high southern latitudes cause an easterly current which must necessarily drift to great distances the detached masses of kelp which are commonly seen floating in these seas, and the kelp might easily convey marine Crustacea and Mollusca with it. In the second place the larger petrels range widely over the southern ocean, and might sometimes carry seeds in their plumage. I leave icebergs out of consideration, for they would not assist marine animals in migrating, and I do not see how any of our insects or freshwater fishes or the seeds of any of our flowering plants could get upon them. Capt. Cook thus describes the vegetation of South Georgia, between lats. 54° and 55° S.:—"Not a tree was to be seen, not a shrub even big enough to make a toothpick. The only vegetation we met with was a coarse strong-bladed grass, growing in tufts, wild burnet, and a plant like moss, which sprang from the rocks" *. No flowering plant

* 'Voyage round the World, 1772–75,' vol. ii. p. 213.

has been found south of 62° S. The most southerly land on which vegetation occurs is Cockburn Island, one of the South Shetlands, in lat. 64° 12′ S., and here there are but a few mosses and lichens. Sir J. Hooker landed on Possession Island, in 71° 56′ S., and on Franklin Island, in 76° 8′ S., and did not find a fragment of vegetation on either *.

But if marine currents, petrels, and the wind have been the only, or, indeed, the chief means of transport, we ought to find that the diffusion of plants and animals bears some relation to the distances of the land-masses from each other. Now the distance of South Africa from Tasmania is about the same as that of New Zealand from South America, and between Africa and Tasmania there are several possible halting-places; so that we should expect that the connexion of New Zealand with South Africa, brought about by these means, would at any rate be nearly as great as that between New Zealand and Patagonia. This is really the case in our marine fishes and marine Mollusca, in each of which about the same number of species belong to South Africa as to South America; while about six times as many are found in Tasmania, which is about one fifth of the distance of Patagonia and one sixth of the distance of the Cape of Good Hope. But such is by no means the case in the marine Crustacea, for here as many of our species are found in South America as in Australia, while only one third of the number occur in South Africa. The species of flowering plants common to New Zealand and antarctic South America are three times as many as those common to New Zealand and South Africa. The species of antarctic flowering plants (excluding the grasses) common to New Zealand and Australia (including Tasmania) are only twice as many as those common to New Zealand and South America, while the grasses are only three times as many. Even the sea-weeds do not agree in distribution with the marine fishes, for while the number of species common to New Zealand and South America is rather larger than the number common to New Zealand and South Africa, the species common to New Zealand and Australia are only about twice as numerous as those common to New Zealand and South America. The freshwater fishes show the same thing; five are common to New Zealand and Australia and two to New Zealand and South America. Evidently then the

* Icebergs are said to be formed in the Gulf of Penas, in Chili (lat. 47° S.); but such an isolated occurrence need not be taken into account in the dispersal of plants, for these icebergs could not drift far without melting.

communication between New Zealand and Patagonia has been easier for marine Crustacea, freshwater fishes, and plants at some former period than it is now; and this could only have been caused by some intermediate land having formerly existed.

This is quite in accordance with the opinion of Sir J. Hooker, who thinks that possibly the "plants of the Southern Ocean are the remains of a flora that had once spread over a larger and more continuous tract of land than now exists in that ocean, and that the peculiar antarctic genera and species may be the vestiges of a flora characterized by the predominance of plants which are now scattered throughout the southern islands" *. And again, "The supposition that more land formerly existed along the parallels between Fuegia and Kerguelen's Land, possibly in the form of islands, remains the forlorn hope of the botanical geographer" †. Mr. Moseley also considers more land to be necessary to account for the almost identical floras of Kerguelen's Land, the Crozets, and Marion Islands ‡; and Mr. Wallace comes to the same conclusion in his 'Island Life.'

As some doubt may still remain as to the necessity of supposing a greater extension of land in former times, it will be as well to compare the floras and faunas of New Zealand and Tasmania. We know that the high lands of both these places have never been submerged during the whole of the Tertiary era, and that, although at present separated by about 900 miles of ocean, they have probably approached to about 600 miles. A comparison therefore of their floras and faunas will furnish a very instructive example of the powers of dispersion of plants and animals across the sea.

Baron von Müller enumerates 948 species of Tasmanian flowering plants, while the South Island of New Zealand has 688 species, and of these 103 are common to both, *i. e.* about 6¾ per cent. of the whole. According to Dr. Buller's 'Manual' (1880) 97 land birds have been recorded from New Zealand. Of these 53 are perching birds and 44 are waders or rails. In Tasmania, according to Mr. E. P. Ramsay (1877), there are 107 land birds, viz. 78 perchers and 29 waders or rails. Of these only 6 perching birds § and 15 waders are common to both places. There have also been found in New Zealand 1 Australian perching bird (*Eurystomus pacificus*) and 7 waders,

* Flora Nov. Zeal., Intr. p. xxi (1853).

† Phil. Trans. vol. clxviii. p. 13 (1879).

‡ Linn. Journ. xv. p. 485.

§ *Circus Gouldii*, *Hylochelidon nigricans*, *Graucalus parvirostris*, *Zosterops cærulescens*, *Anthochæra carunculata*, and *Chalcites plagosus*.

none of which are known in Tasmania. Of these perching birds, *Z. cœrulescens* first appeared in New Zealand about thirty years ago; *H. nigricans*, *A. carunculata*, *E. pacificus*, and *G. parvirostris* are occasional stragglers, not naturalized; while *C. plagosus* migrates annually to and from Australia. There are also two freshwater fishes, both of which go to the sea to breed, common to Tasmania and New Zealand. No freshwater shells and no land-shells, with one doubtful exception *, are known to inhabit both places; no sphinx moths and but very few insects of any kind, some of which may have been introduced. If we were to include allied species, the list of plants would be increased, but not very much. On the other hand, some of the plants, birds, and insects may have migrated into both Tasmania and New Zealand from the north, and may never have crossed the intervening ocean; while some of the birds and insects may have been helped across by ships, and are not therefore fair examples of natural dispersal. On the whole we may well be astonished that, notwithstanding the strong westerly cyclones and the special facilities afforded by petrels, no animals except a few birds and insects and but few flowering plants have been able to cross this very ancient barrier of from 600 to 900 miles of ocean. This is the more remarkable when we remember that the floras of Kerguelen's Land, the Crozets, and Marion Islands are almost identical, although the islands are more widely separated than New Zealand is from Tasmania, and they are of much smaller dimensions. The conclusion is that this antarctic group of islands must either have been connected or else separated by channels much less than 600 miles across at some former period.

I have already said that the greater part of the north-temperate plants spread over the southern hemisphere with the antarctic plants; and there can be no doubt that they migrated from the north to the south along the great meridional chains of mountains in a "continuous current of vegetation," as first shown by Sir J. Hooker, and subsequently advocated by Sir C. Lyell, Darwin, and Wallace. But I think that too much stress has been laid on the necessity for a series of alternating glacial epochs in each hemisphere to enable the plants to pass over the equatorial regions. Mr.

* *Paryphanta Milligani.*—A large species with a wide aperture, living in damp woods, and not at all likely to stand a voyage. New Zealand and Tasmanian specimens have not been compared, and the dentition of both is unknown. In New Zealand the species has been found in one locality only.

Wallace, who is the latest exponent of this view, says that the "causes [which produced the continuous current of vegetation from north to south] were the repeated changes of climate, which, during all geological time, appear to have occurred in both hemispheres, culminating at rare intervals in glacial epochs, and which have been shown to depend upon changes of eccentricity of the earth's orbit and the occurrence of summer or winter in aphelion, in conjunction with the slower and more irregular changes of geographical conditions; these combined causes acting chiefly through the agency of heat-bearing oceanic currents and of snow-and-ice-collecting highlands" *.

An inhabitant of the southern hemisphere may well ask in surprise, "Where is the evidence for this comprehensive statement?" And Mr. Wallace himself, in the ninth chapter of his book, argues lucidly in favour of there having been no changes of any importance in the climate of the northern hemisphere between the Triassic and Pleistocene periods. All the information we obtain from Mr. Wallace is the following:—"That there was such a greater accumulation of ice [in the southern hemisphere] is shown by the traces of ancient glaciers in the Southern Andes and in New Zealand, and also, according to several writers, in South Africa, and the indications in all these localities point to a period so recent that it must almost certainly have been contemporaneous with the glacial period of the northern hemisphere" †. And further on he says, "We may further assume that what we know took place within the Arctic circle also took place in the Antarctic—that is, that there have been alternations of climate during which some portion of what are now ice-clad lands became able to support a considerable amount of vegetation" ‡. This is all I can find in Mr. Wallace's book, and it must be allowed that it is very unsatisfactory. Let us therefore try to estimate fairly what the evidence really is.

The only evidences in the south of former temperatures higher than at present are:—(1) The Miocene fauna which I discussed in my former address, and (2) The fossil trees of Kerguelen's Land and the Crozet Islands, which must once have formed part of a luxuriant forest. But at the present time Fuegia, which is considerably south of Kerguelen's Land, supports luxuriant forests §, and so also might the Crozet

* 'Island Life,' p. 484. † *Loc. cit.* p. 157.
‡ *Loc. cit.* p. 490.
§ Dr. Coppinger says that in the museum of Santiago there is a section

Islands and Kerguelen's Land if they were of larger extent. The influence of land in mitigating the effect of the icy ocean is well shown by a comparison of New Zealand with St. Paul's Island, in lat. 38° 10′ S., on which the largest tree is only a few inches in diameter. The Kerguelen trees therefore do not imply a higher temperature than at present, but only a greater extension of land, which we have already seen must at one time have existed. We now turn to the evidence of cold periods in the southern hemisphere, and we will take New Zealand first.

It was Dr. von Haast who first pointed out that the New-Zealand glaciers had been far more extensive at some former period than they are now *; and the evidence he brought forward has been admitted by all. For example, there is no doubt that at one time, not geologically remote, the glaciers of the Waimakariri and of the Rakaia reached the Canterbury Plains, and that a branch from the Upper Rakaia passed through Lake Heron and joined the glacier coming down the Rangitata. This former great extension of our glaciers has been aptly called by Dr. von Haast our "*Glacier* Epoch," to distinguish it from the "*Glacial* Epoch" of Europe, with which probably it had no connexion. But we have evidence of another and much earlier glacier epoch than the one just mentioned. At Lawrence, in Otago, there is a small rock-basin filled up with a conglomerate, the stones of which have come from the west, and some of them are distinctly marked by glacial striæ. This conglomerate can be traced in a south-east direction to the Tokomairiro Plains, proving that a glacier at one time descended a valley running from the Tapanui Mountains to Kaitangata, quite across the present drainage of the country. The lower part of this valley has been filled up with rocks of Oligocene age, and we have here, therefore, the proof of an Eocene glacier epoch †. At Wharekauri, or Big Gully Creek, in the valley of the Waitaki, there is also another rock-basin filled with Oligocene rocks; and at Castle Hill, on the road from Christchurch to Hokitika, there is evidence of a third and still earlier glacier epoch in a rock-basin, some eight miles long, which has been

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of a beech tree from Magellan which is more than 7 feet in diameter ('Cruise of the Alert,' p. 91).

* "Notes on the Geology of the Province of Canterbury," Cant. Proc. Gov. Gazette, 24th Oct. 1862.

† 'Geology of Otago,' p. 93, and Cox, Geol. Reports, 1878-9, p. 47.

partly filled by marine Upper Cretaceous rocks, upon which lie Oligocene and Miocene strata.

What now has been the cause of these three glacier epochs in New Zealand? Are we to attribute each of them to a general lowering of the temperature of the southern hemisphere—that is, to a true glacial epoch? Or are we to refer them to some other cause? According to Mr. Wallace our last glacier epoch was due to a general lowering of the temperature, brought about by changes in the eccentricity of the earth's orbit, in combination with geographical changes, as explained by Dr. Croll. It will therefore be necessary to say a word on this subject.

It is well known that, owing to the varying attractions of the planets, the mean annual velocity of the earth in its orbit is not the same year by year; and as the earth has to complete its annual revolution round the sun in a fixed time, the distance it travels in each year varies. When the mean velocity increases the orbit increases, and *vice versâ*. But as the length of the major axis of the orbit must remain constant, a greater or less length of orbit is obtained by an increase or decrease of the minor axis. So that when the average speed of the earth is great the orbit becomes more nearly circular, and when the average speed is small the orbit becomes more oval. But the sun must always occupy one of the foci of the orbit. Therefore as the orbit gets flatter the position of the sun continually recedes from the centre; or, in other words, the orbit gets more and more eccentric. As the annual amount of heat received by the earth from the sun varies inversely as the length of the minor axis, it follows that the greater the eccentricity the greater is the total amount of heat received from the sun. But when the eccentricity is great the earth is much nearer the sun in perihelion and further away from it in aphelion than when the eccentricity is small. Consequently that hemisphere of the earth which has its winter in aphelion and its summer in perihelion during a time of great eccentricity will have its seasons exaggerated, a long and very cold winter being followed by a short but very hot summer; while the other hemisphere will have a short warm winter followed by a long and cool summer. Owing, however, to the combined action of precession of the equinoxes and revolution of the apsides, the hemisphere which has its winter in aphelion is changed every 10,500 years, and as a period of great eccentricity will last longer than this, these alternations of climate will recur perhaps three or four times before the eccentricity is greatly diminished.

These facts, which have been well known for many years, were first brought prominently before geologists by Sir J. Herschel in his address to the Geological Society of London in 1832. From them we know that the earth's orbit has varied in past time, and we infer that these variations must have caused considerable changes in climate. But what these changes were and to what extent they were carried are speculative deductions from the laws of physics, and are difficult to verify. The well-known hypothesis of Dr. Croll was the first of these speculations. It is very ingenious and worked out with great skill; but it must of course be subject to all the complexities and uncertainties in which all meteorological phenomena are involved.

He maintains that the large quantity of snow that would fall in the winter of each year on that hemisphere whose winter was in aphelion would not be all melted during the hot but short summer that followed, and consequently it would accumulate year by year and bring on a glacial epoch. His reasons for thinking that the whole snowfall would not be melted in summer are :—(1) that, as snow can never rise in temperature above 32° F., the direct radiation from land covered with snow and ice would cool the air and lower the temperature of all surrounding bodies; (2) that the rays of the sun falling on the snow and ice would to a large extent be reflected back again into space; and (3) that thick fogs and cloudy skies would effectually prevent the rays of the sun from reaching the earth. If a reduction of the summer temperature by these means is allowed, he then urges that great changes would take place in the oceanic currents, which would tend still further to lower the temperature of that hemisphere on which snow was accumulating.

I need not allude to the objections that have been urged against this hypothesis. It is sufficient for my purpose to point out that, according to Dr. Croll himself, all depends upon the snow falling on land, for without land there will be no snow to radiate, to reflect, or to form fogs and clouds. Now in the antarctic regions there is no great extent of land that is not already covered with snow. During the long cold winter of a high eccentricity the snow would fall into the sea, would be melted, and work its way towards the equator. Consequently there would be no accumulation, and a high eccentricity would not bring on a glacial epoch in the southern hemisphere. On the contrary, greater cold would probably precipitate the moisture more to the north, and so lessen the snowfall in high antarctic latitudes where alone there is land.

Possibly therefore the ice would be reduced in quantity. Both Mr. Wallace and Dr. Croll * allow that high eccentricity alone would not bring on a glacial epoch unless the geographical conditions were favourable; and so they would no doubt allow on reconsideration that no severe glacial epoch could occur in the southern hemisphere under the present conditions. In New Zealand more snow might fall in winter, but probably it would be all melted again by the greater heat of summer; and, as the mean annual temperature would be higher with greater eccentricity, it is not likely that our glaciers would be much larger at that time than now. Under the present geographical conditions greater eccentricity might produce a greater precipitation of moisture in the form of snow or rain in winter and greater floods in summer, and therefore a diluvial epoch, but not a glacial epoch.

Now there is no reason to suppose that any very important geographical changes occurred in the southern hemisphere during the Pleistocene period; on the contrary, as will appear presently, the insular floras prove long isolation; but there are several reasons for thinking that a diluvial epoch has occurred in New Zealand at a comparatively late date—that is, during the depression which, as we shall presently see, followed our last great glacier epoch. These reasons I have lately given in a paper sent to the Geological Society†, and I need not reproduce them here; but the evidence is not confined to New Zealand alone.

The Pampæan formation of South America, so ably described by Darwin, which contains the remains of an enormous number of huge terrestrial mammals, is much like the so-called "loess formation" of Banks peninsula and Oamaru, and in both cases violent and often-recurring floods sweeping down to the sea torrents of mud and the bodies of drowned animals seem necessary to account for the phenomena. Also in a letter to me (dated June 1884) Prof. R. Tate says that strong evidence is afforded by the distribution of *Diprotodon* that Australia has passed through a pluvial period. So that there is evidence in New Zealand, in Australia, and in South America to show that the last high eccentricity of the earth's orbit may have produced in the southern hemisphere a diluvial epoch; but we shall see directly that there is no evidence at all of its having produced a glacial epoch ‡.

* Phil. Mag., Feb. 1883, p. 81.

† "Sketch of the Geology of New Zealand."

‡ For evidence of a diluvial epoch in South Africa see Stow, Quart. Journ. Geol. Soc. xxvii. p. 543.

Although there is no reason to suppose that any very important geographical changes occurred in the southern hemisphere during the Pleistocene period, it is almost certain that during earlier Tertiary times there was a greater extension of the antarctic continent between South America, South Africa, and New Zealand. What effect this had on climate is doubtful. According to Mr. Wallace it produced a long persistent more or less glaciated condition *; while Dr. Martin Duncan invokes the same antarctic continent as the cause of a warm Miocene sea.

Other hypotheses depending on cosmical causes, and therefore affecting the whole world—such as a change of obliquity in the ecliptic or a decrease in the heat derived from the sun—have been put forward to account for the European glacial epoch; but as these hypotheses have very few adherents, they need not be discussed here, especially as I believe it to be possible to bring forward sufficient evidence to prove that our great glacier epoch was not due to a general reduction of temperature in the southern hemisphere, and therefore was not due to any cosmical cause affecting the whole earth.

In the first place there is no palæontological evidence of any great change of climate in the southern hemisphere during the Pliocene and Pleistocene periods. In South America, according to Mr. Darwin, the raised beaches contain the same species of Mollusca as at present live in the neighbourhood. The same is the case in New Zealand both with the Pleistocene and Pliocene deposits; and no one has ever proved that any difference is to be found in South Africa. So the evidence of migration from polar regions towards the equator, which forms such a cogent part of the proof of a European glacial epoch, is altogether wanting in the southern hemisphere.

In the second place, our glaciers were always confined to valleys, and there is no proof that they ever reached the sea. There are no tills or boulder-clays and no stratified moraines. There are no true erratics, *i. e.* blocks brought from some other drainage-system, and no marine shells have ever been found in any of the glacier deposits, even in those which are now at the sea-level. Dr. von Haast certainly adduces the fact that marine shingle or sandspits are found *between* some of the moraines on the west coast of the South Island as a proof that those glaciers entered the sea †; but this might well be due to the subsidence after the glacier epoch, of which, as I shall presently point out, we have many independent

* 'Island Life,' p. 193.

† Geol. of Canterbury and Westland, p. 378.

proofs. If these glaciers had reached the sea, their moraines would show traces of having been deposited in water quite as much as the shingle spits between the moraines.

In the third place, the cold that would be necessary to bring back our glaciers to their former dimensions would be sufficient to exterminate throughout New Zealand all but the more cold-loving species of plants and animals *. But we find, as I showed in my last address, that the principal part of our subtropical fauna and flora was introduced before the Miocene period, and has flourished ever since. It has, however, been lately suggested that the survival of our terrestrial fauna and flora through a cold glacial epoch may have been due to the sea standing at that time at a lower level than at present, and so affording room for the plants and animals to retire to †. No doubt Sir W. Thomson has calculated that the ice-cap covering northern Europe and America during the glacial epoch might have caused, by its attraction, a rise of the ocean of some 380 feet at the north pole and a lowering to the same extent at the south pole ‡, and that the amount of water taken from the ocean to form the ice might have lowered the level 120 feet all over the world, thus reducing the rise at the north pole to perhaps 260 feet and increasing the fall at the south pole to 500 feet at most; that is, a fall of about 300 feet in the latitude of New Zealand. But this fall would occur when the ice-cap was on the northern hemisphere. If the ice-cap shifted to the south the ocean would stand about 70 feet *higher* instead of lower round our islands, and consequently there would be no low-lying land for the plants and animals to retreat to. It is no doubt true, as mentioned by Dr. A. Geikie, that the Pleistocene raised beaches and shore deposits of New Zealand indicate a greater elevation of the southern than of the northern parts of the country §; but our knowledge on this subject is not yet sufficiently exact to enable us to draw any conclusions. At present it appears as if these deposits indicated an elevation of 10 feet near Auckland,

* Trans. N. Z. Institute, viii. p. 385.

† Dr. v. Haast, Geol. of Canterbury and Westland, p. 381.

‡ Archdeacon Pratt and the Rev. O. Fisher make it more, but only on the supposition that the interior of the earth is fluid. Mr. Belt's calculations on this subject are of no value, as the enormous simultaneous ice-caps supposed by him to have occurred are quite incredible.

§ 'Text-book of Geology,' p. 280. Dr. von Haast, however, who is the authority quoted by Dr. Geikie, is of the opposite opinion. He says, "One fact, however, is certain—namely, that the land in Post-pliocene times in the northern part of the province [of Canterbury] along the east coast stood at a *lower* level than at the central and southern portions" (Geol. Cant. p. 366).

rising to 800 in Canterbury and Otago; and if this be true, the Pleistocene submergence could hardly be due to displacement of the sea caused by the attraction of an ice-cap on the south pole, for the rise is too great and too rapid.

That the former extension of our glaciers was not caused by a cold period is, I believe, acknowledged by all New-Zealand geologists, and also by the late Dr. von Hochstetter*. Instead of a glacial epoch four other hypotheses have been put forward to account for the phenomena:—(1) The first is the elevation of the land, in combination with a more plateau-like form of the mountains, which would thus collect more snow †. (2) The second is elevation, in combination with the subsidence below the sea of Central Australia ‡. (3) The third is the plateau hypothesis alone, the land being at the same level as now. It is supposed that these plateaux have been reduced to sharp ridges by the erosion of the glaciers, and thus the retreat of the glaciers is accounted for §. (4) The fourth is elevation alone, the retreat of the glaciers being caused by subsequent depression ||.

These hypotheses resolve themselves into three, viz. subsidence of Central Australia, broad plateaux, and elevation—taken either singly or in combination. We will examine each of them.

The subsidence hypothesis is thus explained by its author:—"One cause of the greater extent of the New-Zealand glaciers . . . . . is that the elevation of the New-Zealand mountains was probably coincident with the submergence of the low land in the interior of Australia, which is covered with a Post-pliocene marine formation. The equatorial north-west winds would thus impinge on the New-Zealand Alps without, as at present, being deprived of a large amount of their aqueous vapour by passing over the arid plains of Australia, and the

* 'New Zealand' (1867), p. 505.

† Hector, "Geological Expedition to the West Coast of Otago," 'Otago Provincial Gazette,' 5th Nov. 1863, and Trans. N. Z. Inst. vi. p. 374 (1873).

‡ Hector, in a letter to Sir J. Hooker, dated 15th July, 1864, in Lyell's 'Principles of Geology,' 12th ed. vol. i. p. 243; and Trans. N. Z. Institute, vi. p. 385 (1873).

§ Haast, Q. J. G. S. xxi. p. 135 (1864), and 'Geology of Canterbury and Westland,' pp. 372–4 (1879). In his 'Geology of Canterbury' (p. 376) Dr. v. Haast says that I was the former chief exponent of the theory that the extension of our glaciers occurred during a partial submergence of the land. I do not know to what Dr. v. Haast alludes. The submergence that I have always advocated was in the Pleistocene, after the glacier epoch was over.

|| Dobson, Trans. N. Z. Inst. iv. p. 340, and vi. p. 294; Travers, Trans. N. Z. Inst. vi. p. 299.

condensation of snow by the mountains would be therefore very much in excess, and consequently the glaciers much larger than at present" *. This hypothesis is similar to one long ago proposed to account for the former extension of the Swiss glaciers by the submergence of the Sahara. But in our case it has been shown that the hot north-west winds, as well as the cold south-west winds, are parts of westerly cyclones †, and that they are saturated with moisture when they reach New Zealand. That our north-west winds owe their heat and dryness to local causes and not to the arid plains of Australia has been explained by Dr. Knight ‡ and by Mr. Barkas §. The subsidence of Central Australia might possibly decrease their temperature and therefore *decrease* the amount of aqueous vapour held by them; but this could not possibly increase the amount of snow on the mountains.

The plateau hypothesis was proposed many years ago by Rendu to account for the former extension of the glaciers of Switzerland; but it never obtained many adherents. It was shown that the effect of plateaux is to diminish, not to increase, the size of glaciers; and Prof. J. D. Forbes cites in proof the fact that, while the snowfall in both places is about the same, "the largest glacier in Norway (Lodal) may be rudely estimated to have only *one seventh* of the surface of the Aletsch glacier of Switzerland, tributaries in both cases being excluded; but the snow-field connected with it may cover 400 English square miles at least, which probably exceeds in extent anything in the Alps. The perpetual snows of the Fondalen are much larger, and those of Sulitelma not inferior" ‖. The size of glaciers therefore is not proportional to the size of their snow-fields, as supposed by the advocates of the plateau hypothesis. Neither is the denuding power of the snow so great as supposed. Of course the snow-fields themselves *preserve* the rocks that lie below them; it is only when the snow gets pressed into ice and begins to descend the valleys that any erosion can take place; but even this erosion has, I think, been greatly over-estimated by the advocates of the plateau hypothesis. On this point I gladly avail myself of the opinion of Sir A. Ramsay, whom no one will accuse of underrating the amount of glacier erosion. In a discussion at a meeting of the Geological Society of London

* Trans. N. Z. Inst. vi. p. 385.

† "On the Principles of New Zealand Weather Forecast," by Commander Edwin, R.N., Trans. N. Z. Inst. xii. p. 40.

‡ Trans. N. Z. Inst. vii. p. 470.

§ N. Z. Journ. of Science, i. p. 576.

‖ 'Norway and its Glaciers,' p. 232.

in 1875 he said that "he thought that the effects of glacial action had been immensely exaggerated, and believed that all the great features of the country existed before the glacial period;" * and in the following year, in his paper on the history of the river Dee, he says that "by far the greater part of the valley-excavating work was performed between Permian and Pre-glacial times, and that the work of the glaciers of the latter period somewhat deepened, widened, smoothed, and striated the outlines of the mountains and valleys, and excavated many rock-bound lake-basins, but on a grand scale did not effect any great changes in the pre-existing larger contours of the country" †.

In our own case we must remember that, even if glacier erosion is as great as claimed by the advocates of the plateau hypothesis, there have been in New Zealand, in the Lower Cretaceous and Eocene periods, two earlier and probably quite as extensive glacier epochs, which must have reduced to ridges the supposed plateau, if it ever existed. We must also remember that the New-Zealand Alps have been undergoing subaerial denudation without interruption from the Jurassic period to the present day; and we have conclusive proofs that most of the valleys had been hollowed out nearly as deeply as now in the Eocene period, because we find all the large river-basins partly filled with Oligocene, or, in some cases, even with Upper-Cretaceous rocks. I will limit myself to one example in illustration. In the middle Rakaia, on the right bank of the river opposite the south end of Lake Coleridge, there is an outlier of Oligocene Limestone, called Red Cliff. It is lying in its original plane of deposition, and is no doubt a fiagment of a set of beds which once filled all this part of the valley. At present it is restricted to a patch occupying a sheltered side valley on the south side of the river; but it again appears at the river-bed as an apparently detached fragment separated from the main mass in the valley by river-gravels. This isolated portion is known as Castle Rock. Now the first thing to be noticed is that this Oligocene limestone descends to below the present level of the river, proving conclusively that the Rakaia is now running at a higher level than it did in the Eocene period before the limestone was deposited. The second thing to be noticed is that the junction up the side valley between the limestone and the Palæozoic rocks on which it rests must mark the limit of the

* Quart. Journ. Geol. Soc. xxxii. p. 204.

† Quart. Journ. Geol. Soc. xxxii. p. 227. See also Dr. Knight, in Trans. N. Z. Inst. vii. p. 479.

Rakaia valley at the time when the limestone was deposited. If therefore any great lateral denudation had taken place since that time, the line of junction ought to stand out as a prominence. But, on the contrary, it is in a valley, apparently much in the same position with regard to the other parts of the valley as when the limestone was formed. Consequently no great plateau on the south of the Rakaia can have been removed.

Many other instances could be cited, but this one must suffice, for it alone is sufficient proof that the denudation which has taken place during the comparatively short time that has elapsed since the commencement of our last great glacier epoch cannot have affected the shape of the mountains to such an extent as to make it worth while to take this cause into consideration, even if it acted in the direction supposed. That the large river-valleys were more or less filled to a height of 3000 or 4000 feet above the present sea-level by Tertiary rocks, most of which have been since removed, is no doubt true; but as this is below the line of perpetual snow, which is estimated by Dr. von Haast and Mr. M'Kerrow to be between 7000 and 8000 feet, this filling up of the valleys, if it affected the level of the snow-line at all, would raise it by radiation in the same way that the plateau of Thibet raises the height of the snow-line on the northern slopes of the Himalaya.

As therefore both the subsidence- and the plateau-hypotheses are quite untenable, we must fall back on elevation of the land as the main if not the only cause of the former extension of our glaciers; and it is strongly confirmatory of this hypothesis that the two earlier glacier epochs each occurred at a time when we have independent proof that the land stood at a far greater height than at present. With regard to the last glacier epoch, it has been estimated that an elevation of between 3000 and 4000 feet would be quite sufficient to bring back the glaciers to their former dimensions *.

But if our last glacier epoch was caused by elevation of the land, it is easy to prove that it must be of an older date than the glacial epoch of Europe, because while our islands are separated by a strait only 500 feet deep, the difference between their floras and faunas is far greater than the difference between the floras and faunas of England and Europe, which were separated in the Pleistocene period immediately after the glacial epoch. In the South Island we have six different kinds of birds represented by different species in the North

* Trans. N. Z. Inst. xiii. p. 385.

Island*, and this cannot be due to difference of climate, because some parts of the South Island are further north than parts of the North Island. Of the plants I am not competent to speak, but a comparison of the floras on each side of Cook's Strait would be of great interest †. Consequently the two islands of New Zealand must have been separated during, at least, the whole of the Pleistocene period. But an elevation of 500 feet would join them, and an elevation of 1100 feet would lay bare the whole of Cook's Strait, so that we are driven to the conclusion that this amount of elevation has not occurred during the Pleistocene period, and consequently our glacier epoch must have been earlier than the European glacial epoch. On the other hand, the similarity of the land-shells, insects, plants, birds, &c. forbids our placing the last separation before the Pliocene. That is to say, New Zealand must have stood more than 500 feet higher than at present during some part of the Pliocene period; for, if not, the plants and animals on the two islands would have been more differentiated than they are.

But there is other and independent evidence that our glacier epoch is older than the glacial epoch of Europe and North America. First, there are the glacier phenomena themselves. Several of the older lakes, such as those of the Rakaia and of the central parts of Otago, have been completely filled up; while others, such as the lake in the Upper Dillon, Lake Heron, Lake Tekapo, and Lake Pukaki, are approaching their end. Glacier striæ are generally absent, although the rocks still retain their rounded form; and in the district of Central Otago masses of rock 10 or 12 feet in thickness have been removed from the mountains by ordinary atmospheric weathering since the ice passed over them ‡. In the second place, the drainage-system has been much altered since the glacier epoch; the gorges of the Kawarau, Dunstan, Mataura, and Upper Taieri in Otago §, and that of the South Ashburton in Canterbury, having been entirely cut since then.

* South Island.		North Island.
Myiomoira macrocephala	represented by	*M. toitoi.*
Myioscopus albifrons	,,	*M. longipes.*
Turnagra crassirostris	,,	*T. Hectori.*
Glaucopis cinerea	,,	*G. Wilsoni.*
Ocydromus australis	,,	*O. Earli.*
Apteryx australis	,,	*A. Mantelli.*

† In the Trans. N. Z. Inst. xvi. p. 466, Mr. W. T. L. Travers gives an interesting table showing the distribution between the islands of sixteen genera of plants; but as no attempt is made to distinguish the differences due to different station and climate from those due to isolation, it is not available for my present purpose.

‡ 'Geology of Otago,' p. 91. § *Ibid.* p. 94.

Let us now see what palæontological evidence there is to fix the date of this upheaval. Marine strata belonging to the Pareora system, and containing, so far as we know at present, from 20 to 45 per cent. of living species of Mollusca, are found throughout New Zealand from Southland to Auckland. These may be considered as of Miocene age. The next series, in ascending order, shows a very different assemblage of fossils. It is called the Wanganui system, and is widely spread over the North Island. The marine beds contain a number of shells, of which from 70 to 90 per cent. are still living. This system must therefore be referred to the newer Pliocene. No fossiliferous marine rocks of this system are known as yet in the South Island, but it is represented by thick masses of unfossiliferous gravels. Marine deposits with shells of still living species, and therefore of Pleistocene age, are found at various places in both islands, from Auckland to Oamaru and Dunedin*, and, in addition, there are many unfossiliferous shore-deposits and other indications that a gradual elevation was going on during the whole of the Pleistocene period all round the coasts south of Auckland. While therefore we have ample evidence in fossiliferous rocks that the land stood at a lower level than at present during the Miocene, Newer Pliocene, and Pleistocene periods, there is a break in our geological record in the Older Pliocene of which we have no trace in marine strata. This can only be accounted for by one of two suppositions: either (1) that all the beds of that age have been covered up or have been removed by denudation; or (2) that during this period New Zealand stood at a higher level than at present, in which case the marine beds would be deposited at a level which is now below the sea, and consequently inaccessible to us. As we have both Miocene and Newer Pliocene beds in abundance, there is no reason for thinking that the first supposition is correct; while we have good reasons, in the distribution of our fauna and in our old glacier marks, for believing that New Zealand was considerably elevated in the Pliocene period. The conclusion therefore is, that our last great glacier epoch was caused by an elevation of the land that took place during the Older Pliocene; or, more precisely, in the interval between the marine beds of the Pareora and Wanganui systems. Possibly this elevation may have continued in the South Island during the whole of the Pliocene, but it was certainly over before the advent of the Pleistocene. In my address

* See Trans. N. Z. Inst. v. p. 387; 'Geology of Otago,' pp. 70, 78; M'Kay, Geol. Reports, 1878-79, p. 84; Von Haast, 'Geology of Canterbury,' p. 366; Percy Smith, Trans. N. Z. Inst. xiii. p. 398.

last year I mentioned this elevation as necessary to explain the flora of the Kermadec Islands, but I had to postpone the proofs of it until now.

It appears therefore that, so far as New Zealand is concerned, Mr. Wallace is incorrect in his statement already quoted, that the traces of ancient glaciers "point to a period so recent that it must almost certainly have been contemporaneous with the glacial epoch of the northern hemisphere."

Let us now turn to Australia. In Tasmania there appear to be several glacier lakes, but I have seen no description of any moraines. Lake Omeo, in the Australian Alps, may also have had the same origin; but it must not be forgotten that in a dry climate like Australia the wind may excavate rock-basins. A glacial epoch, however, is not required to account for rock-basins among mountains. Whether Australia has undergone the rigours of a glacial epoch is a moot question with Australian geologists. Mr. Tenison-Woods* and Mr. Howitt† can find no traces of it; while Prof. R. Tate is of the contrary opinion, and instances striated rock-surfaces and small granite erratics *on the beach* at Black Point, Holdfast Bay, near Adelaide‡, but he considers all these to be of Pliocene age. This is in lat. 35° S., only one degree south of Sydney. Prof. Tate also describes parallel grooves and scratches running east and west in the rocks in the bed of the Inman, Cape Jarvis; and on these grooves Mr. Selwyn had previously remarked that they strongly reminded him of similar grooves he had so frequently seen in the mountains of North Wales. Mr. G. S. Griffiths has also lately read a paper to the Royal Society of Victoria, "On the Evidences of a Glacier Epoch in Victoria during Post-Miocene Times." Mr. Griffiths allows that the evidence is not altogether satisfactory, consisting as it chiefly does of the wide distribution of clays with gravels and boulders, for the most part well water-worn; but he considers that a *Pliocene* glaciation offers the best explanation of the facts. If the glacial theory is rejected, he says, "we shall have to believe that since the Pliocene era commenced Victoria has been elevated and depressed to a considerable extent at least five or six times" (p. 26). It seems to me, however, that one subsidence, varied with several slight upward oscillations, is all that is required; and as in Victoria marine Pliocene rocks occur up to 1720 feet above the sea §,

* Proc. Linn. Soc. of N. S. Wales, vii. p. 382.

† Quart. Journ. Geol. Soc. xxxv. p. 35.

‡ Trans. Roy. Soc. S. Australia, 1878–79, Anniversary Address.

§ Lock's 'Gold,' p. 931, quoted by Mr. Griffiths, p. 22.

I think that this last hypothesis presents far fewer difficulties than the former, especially when we remember that there are no true glacial phenomena in New Zealand. It is indeed hard to believe that these supposed glacial marks are due to a general cold period in the southern hemisphere; for if such had been the case the South Island of New Zealand must have been covered with snow and ice, and almost all life would have been destroyed, a supposition which Mr. W. T. L. Travers has shown it is impossible for us to allow*.

We come now to South Africa. Mr. Wallace says that, "according to several writers," there are traces of ancient glaciers in the Transvaal. But so far as I know only two writers (Mr. Stow and Capt. Aylward) have expressed this opinion from a personal knowledge of the country; and Mr. Wallace has forgotten to mention that, at the meeting of the Geological Society at which Mr. Stow's paper was read, Mr. Griesbach, who had examined the district, "disputed the possibility of any of the gravels (of the Vaal) being of glacial origin"†. Again, Mr. Wallace says that "we have here *all* the chief surface phenomena characteristic of a glaciated country"‡. But this is not quite correct. The only phenomena mentioned are striations, rounded hills, and unstratified gravels and clays, with boulders, called by Mr. Wallace morainic matter. There are no perched blocks, no terminal moraines, no glacier lakes. Now rounded hills occur in many places where no ice has ever been, various marks have often been mistaken for glacial striæ, and tumultuous accumulations of gravel with boulders occur in all mountainous countries liable to floods. The only unmistakable evidences of ancient glacier action—viz. terminal moraines and lakes—are absent. It is true that Dr. Shaw mentions abundant lacustrine deposits along the Vaal River§, and these may occupy old glacier lakes. But if so, these deposits clearly do not "point to a period so recent that it must almost certainly have been contemporaneous with the glacial period of the northern hemisphere." On the contrary, they point to a time older, perhaps, than the glacier epoch of New Zealand. There is also another and quite distinct line of argument, which leads to exactly the same conclusion. The mountain-system of the Transvaal, in lat. 25° S. to 27° S., may be compared to the New-Zealand Alps, between the latitudes 44° S. and 45° S. The South-African mountains are certainly not higher,

* Trans. N. Z. Inst. vii. p. 409.
† Quart. Journ. Geol. Soc. xxviii. p. 27.
‡ 'Island Life,' p. 158, footnote.
§ Quart. Journ. Geol. Soc. xxviii. p. 26.

and the rainfall on them is certainly not greater. But this portion of the New-Zealand Alps has no glaciers at all comparable to the large ones supposed to have formerly existed in the Transvaal, although it is 18° further south, and is much nearer to the sea, so that a reduction of temperature sufficient to bring glaciers to the Transvaal would be equivalent to moving it *at least* 20° further south. Now Kerguelen Land, situated in 48° S., would also be virtually removed 20° further south —that is to a latitude where, as I have already mentioned, no vegetation, except perhaps a few mosses and lichens, could exist. If this has been so, the whole of its present phanerogamic flora must have been introduced since this glacial epoch. But as out of its twenty-one species of flowering plants there are two genera and eleven species found only there or in the neighbouring islands, we cannot suppose that its flora dates from the Pleistocene. Consequently this glacial epoch, if it ever took place, must have been long anterior to the glacial epoch of Europe.

Proofs of a former extension of glaciers undoubtedly occur in South America as far north as 42° S., which is about the northerly limit of glacier-marks in New Zealand. But in South America there is no evidence as to their date. This is, however, unnecessary, for we have already seen that the ancient glaciers of New Zealand, of Australia, and of South Africa (if any) belong to periods very different from the glacial epoch of Europe. Mr. Wallace therefore was hardly justified in assuming, without making a personal examination, that "the close similarity in the state of preservation of the ice-marks and the known activity of denudation as a destroying agent, forbid the idea that they belong to widely separated epochs"*; and consequently his argument that "if we reject the influence of high eccentricity as the cause of this almost universal glaciation, we must postulate a general elevation of *all* these mountains about the same time"†, falls to the ground.

I believe that almost all New-Zealand geologists are now agreed that our last great glacier epoch was in the Pliocene period ‡; and it seems that an elevation of the land in Pliocene times affords the only satisfactory explanation of the phenomena. The question now arises, Did the Pliocene extension of land-area include the outlying islands? This is a

* 'Island Life,' p. 504. † *Loc. cit.* p. 504.

‡ Travers, Trans. N. Z. Inst. vi. p. 302; Dr. von Haast, Geol. of Canterbury, p. 372; Dr. Hector, Geol. Reports, 1883, p. xiii; S. H. Cox, Geol. Reports, 1883, p. 9. Mr. Dobson alone would put it later, Trans. N. Z. Inst. vii. p. 440.

question which has been lately much discussed in France. M. Blanchard maintains that all were included; M. Alph. Milne-Edwards thinks that the Chatham Islands only were connected with New Zealand; and Dr. H. Filhol, while allowing a former land extending down to the Auckland Islands, doubts whether Campbell Island ever formed part of it *, his reasons being partly geological considerations which compel him to think that this island only appeared above the sea at the close of the Pliocene, and partly the absence of all land-birds and lizards. Mr. Wallace says, " Whether this early land extended eastward to the Chathams and southward to the Macquaries we have no means of ascertaining; but as the intervening sea appears to be not more than about 1500 fathoms deep, it is quite possible that such an amount of subsidence may have occurred "†. To try to form an opinion of our own we must examine the faunas and floras of these islands.

Chatham Islands.—Distant 400 miles from New Zealand, the fundamental rock of the main island is a micaceous slate ‡, upon which lie Miocene limestone and volcanic rocks. Pitt's Island is composed of volcanic rocks and limestone, with some lignite and shale. It is more than 600 feet high, while the main island does not attain to that altitude. There appear to be no raised beaches or other signs of recent elevation §. There are twenty-one species of land-birds, of which six are endemic, and of these four are representatives of New-Zealand species ‖. The gold cuckoo is identical with that of New Zealand and Australia. It migrates annually to and from the islands, and Mr. Potts informs me that it has been seen on the beach at the north-west point of the island, quite exhausted and wet with sea-spray. This was in October, the month in which the bird always arrives. There is, I believe, no proof that *Apteryx*, *Stringops*, or *Ocydromus* ever lived on these islands, and no moa-bones have been found there. But on Pitt's Island there is a flightless rail (*Cabalus modestus*)

* See N. Z. Journ. of Sci. i. pp. 251, 259.
† 'Island Life,' p. 455.
‡ Haast, Trans. N. Z. Inst. i. p. 180.
§ Travers, Trans. N. Z. Inst. iv. p. 63.

‖

CHATHAM ISLANDS.		NEW ZEALAND.
Anthornis melanocephala	represents	*A. melanura.*
Sphenœacus rufescens	"	*S. punctatus.*
Gerygone albofrontata	"	*G. igata.*
Myioscopus Traversi	"	*M. albifrons.*
Rallus Dieffenbachii.		
Cabalus modestus.		

allied to *Ocydromus*. There is one species of lizard on Pitt's Island, identical, I believe, with the common *Mocoa zelandica*. Also a slug (*Janella bitentaculata*) and a land-shell (*Thalassia neozelanica*), both of which are common in New Zealand. The flora has been tabulated by Mr. Buchanan in Trans. N. Z. Inst. vol. vii. From this list I find that sixty-seven species of flowering plants are known, of which twelve, or 18 per cent., are endemic. There is also one endemic genus.

Now, when we remember that no lizards or land-shells have passed between Tasmania and New Zealand, and that very few plants are common to the two, although the distance is not much more than twice that of the Chatham Islands, it becomes evident that our connexion with these islands must at one time have been much closer than it is now; and the presence of the flightless rail and the slug point strongly to an absolute connexion between the two lands. This is again confirmed by the occurrence of the migratory cuckoo; for, as Mr. Darwin has pointed out, there are no migratory birds on true oceanic islands, that is on islands which have never formed part of the main land *.

The Antipodes Islands.—Distant from New Zealand 450 miles. They appear to be entirely volcanic, and attain an elevation of 700 feet. The only land-bird known is a paroquet, and the only plant known is *Phormium tenax*.

Auckland Islands.—Distant from New Zealand 240 miles. According to Dr. Hector these islands are composed of granite, with Tertiary sandstones, lignite, and volcanic rocks †. They rise to 2000 feet above the sea. The land-birds are *Harpa novæ zealandiæ*, *Anthornis melanura*, *Myiomoira macrocephala*, *Myioscopus albifrons*, *Anthus novæ zealandiæ*, *Platycercus novæ zealandiæ*, var. *aucklandicus*, *P. auriceps*, and a rail said to be identical with *R. brachipus* of Tasmania. There is also a flightless duck (*Nesonetta aucklandica*), belonging to an endemic genus, and a species of *Mergus*. There is a slug (*Janella bitentaculata*), and three species of land-shells (*Patula unguiculus*, *Amphidoxa zebra*, and *Thalassia neozelanica*, var. *antipoda* and var. *aucklandica*). All but the last variety occur in New Zealand.

Campbell Island.—Distant from New Zealand 420 miles. According to Dr. Hector, the rocks are blue slate and sandstone, like our Lower Mesozoic beds, as well as chalk with flints, and volcanic rocks‡. Dr. H. Filhol, however, does not mention any sedimentary rocks except limestone. Its highest

* Appendix to Mr. Romanes's 'Mental Evolution in Animals,' p. 359, footnote.

† Trans. N. Z. Inst. ii. p. 179.

‡ *Ibid.* p. 176.

point is 1600 feet above the sea. According to Mr. H. Armstrong, a ground-lark and a small bird like a wren (probably *Zosterops*) are found here, but Dr. Filhol saw no land-birds. It has one endemic land-shell (*Helix campbellica*), and two endemic flowering plants.

Macquarie Island.—Distant from New Zealand 600 miles. The rocks are said to be greenstone, sometimes veined with quartz, occasionally amygdaloidal, and containing mesotype and analcime*. The land-birds are *Platycercus novæ zealandiæ*, var. *erythrotis*, an endemic rail (*Rallus* (?) *macquariensis*), and a species of *Ocydromus* (probably *O. brachypterus*).

The floras of the southern group of islands—Auckland, Campbell, and Macquarie—are so closely connected that they must be taken together. They have between them 111 species of flowering plants, of which 25—*i. e.* 22 per cent.—are endemic. There is also one endemic genus and seven antarctic species, which are not known from New Zealand. We may therefore conclude that the evidence given by the birds and land-mollusca is decidedly in favour of the Auckland Islands and Macquarie Island having been connected with New Zealand. Whether Campbell Island formed part of this land, or whether it dates from a still later time, may remain for the present an open question. But the possession of an apparently endemic species of land-shell and two endemic species of flowering plants is in favour of the former supposition. It is remarkable that the floras of the Chatham Islands and of the southern group of islands have each become differentiated by about the same amount, and we must infer from this fact that their isolation from New Zealand was pretty nearly contemporaneous. I mentioned in my last address that the flora of the Kermadec Islands, judging from the very scanty collections that have been made there, contains only 14 per cent. of endemic species, and its isolation may therefore date from about the same time. It appears probable that all were connected, or nearly connected, with New Zealand during the Pliocene period; and, if this be correct, it follows that the differentiation of the flora since then has been about 20 per cent., which is not very different from the rate of change in the marine mollusca.

We now come to the question, By what route did the antarctic plants reach New Zealand? As the Auckland Islands, Campbell Island, and Macquarie Island all contain antarctic species which do not occur in New Zealand, it is evident that their floras are not altogether derived from New Zealand, but that the antarctic plants came through them and

* Prof. Scott, Trans. N. Z. Inst. xv. p. 487.

spread northward. It is true that there are also antarctic species in New Zealand which are not found in the southern islands; but this is only what we should expect, when we consider the relative size of the places, and reflect that these islands are merely the remains of a more extensive land. But granting that these plants came to New Zealand from the south, did they spread from South America to the east or to the west? Mr. Wallace says that the route by which the Fuegian plants may have reached New Zealand is "easily marked off." It is by South Shetland Islands, Graham's Island, the Antarctic Continent to Victoria Land, thence to Adelie Island, Young Island, and Macquarie Island *—thus passing from Graham's Land in a westerly direction at the high latitude of more than 70° S. to Victoria Land, along a coast where no vegetation now exists. He gives, however, no reasons for adopting this route, and it does not seem to be quite consistent with his previously expressed opinion of a "long-persistent more or less glaciated condition" of the southern hemisphere. On the other hand, Sir J. Hooker points out that there are five groups of islands between Fuegia and Kerguelen Land, then none to Macquarie and Campbell Islands, and none across the whole Pacific Ocean from Campbell Island to Fuegia. He says that "Tierra del Fuego and the neighbouring southern extremity of the American continent appear to be the region of whose botanical peculiarities all the other antarctic islands, except those in the vicinity of New Zealand, more or less evidently partake. It presents a flora characterizing isolated groups of islands extending 5000 miles to the eastward of its own position. Some of these detached spots are much closer to the African and Australian continents, whose vegetation they do not assume, than to the American, and they are all situated in latitudes and under circumstances eminently unfavourable to the migration of species, save that their position relatively to Fuegia is in the same direction as that of the violent and prevailing westerly winds"†. But in a footnote he says that too much stress has been laid upon winds in spreading plants, pointing out that both in the Pacific and in the North Atlantic plants have spread against the prevailing wind.

Of the form of the basin of the Southern Ocean we know very little; but it appears to be shallow, getting deeper towards the north. The 2000-fathom line passes close to Cape

* 'Island Life,' p. 489.
† 'Flora Antarctica,' ii. p. 211.

Horn, but keeps some distance to the south of the Cape of Good Hope. Tristan d'Acunha and Kerguelen Land stand upon submarine plateaux which extend nearly to lat. 30° S., but it is uncertain whether either of them is connected with the antarctic plateau which surrounds the pole. The New-Zealand plateau is said by Mr. Wallace to be connected with the antarctic plateau; but other geographers make a deep channel between Campbell Island and Macquarie Island, and another south of Macquarie Island. From what is known of the geology of the antarctic islands it appears that all are volcanic, except South Georgia, which is part of an old slate-mountain range, and Kerguelen Land.

If we examine the faunas and floras of the islands along this track we find that Tristan d'Acunha, although three times as far from Fuegia as it is from the Cape of Good Hope, has its flora much more nearly allied to that of Fuegia than to that of Africa. Kerguelen Land also has its flora much more related to that of Fuegia than to that of the Auckland Islands, although the distance is half as far again. This island has also fifty-eight species of marine mollusca, of which thirteen are found in South America, six or seven in New Zealand, and only four at the Cape of Good Hope; and it has one endemic land-shell—*Helix Hookeri.* Its fauna and flora must therefore have come from the west and passed on by the east to New Zealand. We have already seen, in the early part of this address, that more land communication than at present exists is necessary to explain the migration of the antarctic fauna and flora; and we have therefore in the antarctic plateau, stretching from near South America in an easterly direction to Victoria Land, and either connected with, or but slightly separated from, land that extended to 30° S. in the South Atlantic and Indian Oceans, the probable position of the continent along which the migration took place, but which was always separated from New Zealand by a broad and deep channel south of Macquarie Island.

There remains now only the question, What was the date of this migration into New Zealand? It is evident that it could not have taken place, as a whole, in the Pliocene or later, because we have already seen that the floras of the outlying islands have only differentiated some 20 per cent. in species since the Pliocene; while the New-Zealand antarctic flora, as I mentioned in my last address, has differentiated by about 65 per cent. in the species. Also it must, as a whole, have been before the Eocene, as since then the differentiation of species has been at least 90 per cent. The main immigration must therefore have taken place either in the Miocene, when New Zealand was reduced to a number of islands*, or else part must have arrived in the Pliocene and part in the Eocene, at both of which times New Zealand extended much further to the south. Let us try to see which of the two is the more probable.

It would be a great mistake to suppose that our alpine flora is almost exclusively composed of plants of antarctic or north-temperate origin. Of 189 species of alpine plants belonging to 64 genera, I find that 48 per cent. are of antarctic (including north-temperate) origin, 37 per cent. are subtropical, and 15 per cent. belong to endemic genera. As about 44 per cent. of the total flora is antarctic, 48 per cent. subtropical, and 18 per cent. endemic, it would appear that the special adaptation of antarctic plants to cold regions has not availed them very much. For, composing 44 per cent. of the whole vegetation, they have only attained to 48 per cent. of the alpine flora. Some of our alpine species belong to quite subtropical genera, as *Myrsine*, *Cyathodes*, *Dacrydium*, and *Phyllocladus* ; but there is no large genus in New Zealand that is not represented by alpine forms. On the other hand, only about 35 per cent. of the antarctic species are alpines, the other 65 per cent. living on the lowlands ; and out of 56 antarctic genera, about one half have no alpine species at all. Again, out of 189 New-Zealand alpine species only 13 are found elsewhere (9 in Australia or Tasmania, and 4 in Fuegia) so that 93 per cent. are endemic. Out of 64 alpine genera only 17 are confined to the Alps, and 7 of these are endemic. These facts show that our alpine flora has, on the whole, grown out of the lowland flora, and that the arrival of alpines, as alpines, has been quite exceptional. The ancestral forms have arrived on the lowlands and their descendants have gradually worked their way up the mountains. Mr. Wallace has remarked that alpine plants are particularly well placed for dispersal, on account of the high winds so common in mountains. This is quite true, and explains their migration from mountain-top to mountain-top along a chain ; but it will not apply to the spread of plants to distant islands, because, although more seeds of alpine than of lowland plants would be blown away, all would arrive on the island at or near sea-level, and thus the alpines would not find their accustomed station, while the fewer seeds blown or carried by birds from lower levels would have a better chance of living

* There is evidence that an elevation occurred between the deposition of the Oamaru and Pareora systems ; but this elevation was slight, and New Zealand was probably of no greater extent at that time than it is now.

in their new home. Alpine plants might succeed if they were blown into higher latitudes, but they would have less chance than lowland plants in a migration towards the equator. So that in the case of a migration between New Zealand and an antarctic continent, alpine plants of the former would more readily pass to the latter than the antarctic plants to New Zealand.

From these considerations it appears evident that antarctic plants would have but a slight chance of establishing themselves in New Zealand if it were of smaller dimensions than at present, and especially if the surrounding seas were warmer, as appears to have been the case in the Oligocene and Miocene periods. These plants must therefore have come either during cold periods, of which there is no evidence, or else they must have come during those periods of elevation in which New Zealand stretched more to the south. This last supposition is certainly the more reasonable, and it agrees well with the proportion of endemic species found in the antarctic and north-temperate elements. There must therefore have been a greater continuity of land between Fuegia, Kerguelen Land, and New Zealand in both the Eocene and the Pliocene than there is now. Whether this land was always a series of islands, as it must have been in its earlier and its later stages, or whether it once was nearly continuous, is a matter of speculation. Of the twenty-one species of flowering plants of Kerguelen Land, three (or 14 per cent.) are found there only; while eleven (or 50 per cent.) are confined to Kerguelen, the Crozets, Marion Island, and Heard Island. I should therefore judge, from what we know of the flora of New Zealand, that this group of islands separated from Fuegia in the Miocene, and that the islands themselves were not separated from each other until late in the Pliocene. The distribution of the petrels also points to the ancient date of the present oceanic conditions of the southern hemisphere. It is the only group of birds which has originated in the south and spread to the north. The albatross, fulmar, and shearwater of the north are all representatives of southern species, while the south has several genera not represented at all in the north—e. g. *Ossifraga*, *Pterodroma*, *Daption*, *Prion*, *Pelecanoides*. The only genus better developed in the north than in the south is that of the shearwaters (*Puffinus*), which is hardly ever seen out of sight of land. All the truly oceanic petrels are of southern origin*. From this it seems probable that an antarctic continent south of Africa, and including Tristan d'Acunha and Kerguelen Land, may have existed

* Hutton, 'Ibis,' 1865.

from the Eocene to the Pliocene period, that it was submerged before the Pleistocene, and that we now see remnants of it in Graham's Land, Enderby Land, and Victoria Land. During the time this land existed it is possible that colder and warmer periods may have occurred when the eccentricity of the earth's orbit was great; but this I consider a mere speculation unsupported by any evidence, for changes of climate are not required to account for any of the phenomena.

It is evident from what has been said, that the north-temperate plants came to New Zealand before the Pleistocene period, and consequently they could not have migrated along the Andes during the glacial epoch of Europe. Either there have been many other glacial epochs, or else glacial epochs are not necessary for this meridional migration. I believe the latter to be the more correct view, because there is no evidence of glacial epochs in the southern hemisphere, and because the physical changes necessary to elevate or depress a chain of mountains for a few thousand feet are far less than those which are now acknowledged by nearly all geologists to be necessary for bringing about profound alterations in climate over immense districts of the globe. No one has as yet been sufficiently bold to advocate a glacial climate in New Guinea and Borneo, and yet the evidence of plant migration from Asia into Australia is as strong as that for a migration along the Andes ; and, as it is very unlikely that an elevation of the Indian archipelago coincided in time with the glacial epoch of Europe, so it is very unlikely that glacial epochs are necessary for the meridional migration of plants. It follows that if plants have travelled from the northern hemisphere to Australia and New Zealand, some must have passed through the tropics and into temperate climates again without undergoing any change of generic importance. In the same way the subtropical and temperate plants of New Zealand have invaded the snow-clad regions of the South Island, and have become alpines, without undergoing any generic change. And just as the occurrence of alpine species of subtropical genera does not prove that the tops of our mountains are warm, so the occurrence of species of tropical genera in the European Miocene does not necessarily prove it to have been tropical in temperature. As these plants migrated towards the equator they would gradually accustom themselves to altered conditions without losing the marks of their affinities.

I will now summarize in as few words as possible the results we have arrived at in both addresses. New Zealand, which formerly existed as the southern part of a continent extending through Australia to India*, was isolated from Australia towards the close of the Jurassic period†, but was attached to a South-Pacific continent and received a stream of immigrants from the north. None arrived from the south, because Fuegia was not then in existence. In the Upper Cretaceous the land shrank to a size considerably smaller than at present. In the Eocene, elevation took place and New Zealand extended outwards in all directions, but remained isolated from other lands. Plants and animals came in both from the north and from the south. In the Oligocene and Miocene periods New Zealand was, except for a short interval, a cluster of islands, but was upraised once more, and obtained more immigrants from north and south during the Pliocene; after which subsidence occurred, and the land throughout the South Island and southern half of the North Island sank considerably below its present level, to be again elevated during the Pleistocene period.

It has been objected that we have no right to infer that because elevation or subsidence can be proved to have occurred in one particular district of the earth's surface therefore this elevation or subsidence extended over neighbouring areas. But the more the geology and palæontology of large geographical regions, like North America or Europe, are studied, the more clearly we see that subterranean movements have affected large regions simultaneously, or nearly simultaneously, and that the local deviations from uniformity are comparatively small. So it comes about that we have in each large geographical area a series of rock systems which are nearly synchronous over the whole area, although not synchronous with those in other and distant areas. I think that our knowledge of the palæontology of Australasia is already sufficient to show that we have here also another of those large geographical areas which, when viewed on a large scale, has been moved uniformly; and therefore that the rock-systems of New Zealand can be correlated with those of Australia, and perhaps, in the earlier periods, with those of the peninsula of India.

Of course it is not denied that a scattered immigration may have been going on ever since the Cretaceous period; but it is asserted that this immigration has been small and almost inappreciable in comparison with the rushes that took place from the north in the Lower Cretaceous, and from both north and south in the Eocene and Pliocene periods. The emigra-

* This is the Indo-oceanic continent of Mr. H. F. Blanford (Quart. Journ. Geol. Soc. xxxi. p. 535).

† I need hardly say that I use these terms with very wide margins.

tion from New Zealand has, I think, been small. Probably no land existed in the Antarctic Pacific to convey plants and animals from New Zealand to South America, and a northern migration of New-Zealand plants is almost out of the question. A few stragglers may have been carried by birds to Tasmania or to temperate Australia, bnt that perhaps is all that can be allowed. Our fauna and flora is indeed a standing protest against the views of those naturalists who would make the winds scatter abroad insects and seeds of plants over hundreds of miles, and who imagine land-shells and lizards to float about on logs for days and weeks together without being killed.

Notes to Part I.

1. Mr. Etheridge, as mentioned in the text, was the first to suggest that the Desert Sandstone of Australia was a lacustrine deposit; but it was a mere suggestion. Prof. Ralph Tate arrived at the same conclusion quite independently, and brought forward facts to support it. (See Anniversary Address, Roy. Soc. of South Australia, for 1878–79, p. lx.)

2. At the meeting of the Linnean Society of New South Wales, held on 30th July, 1884, Mr. Ratte exhibited fossils of the genera *Rostellaria*, *Fusus*, *Pleurotomaria* (?), *Belemnites*, *Venus*, and *Nautilus*, from the interior of New Caledonia, together with a fragment of bone. He observed that these fossils were characteristic of the Upper Cretaceous period, and were likely to identify these New-Caledonia beds with some already known in New Zealand. He also exhibited an *Inoceramus* from the Neocomian of Noumea.

3. Before this Address was delivered, Mr. A. Agassiz had come to the conclusion that the specialization of the Atlantic and Indo-Pacific faunas began soon after the end of the Cretaceous period. (Report on the 'Blake' Echini, part i. p. 83, September 1883.)

4. Since this Address was in type I have come across an article in the 'Geological Magazine' for 1882, by Mr. J. S. Gardner, in which several of the views maintained in my two Addresses are enunciated.

X.—*Descriptions of Sponges from the Neighbourhood of Port Phillip Heads, South Australia.* By H. J. Carter, F.R.S. &c.

[Plate IV.]

Having through the kindness of Mr. J. Bracebridge Wilson, M.A., F.L.S., of the Church of England Grammar School, Geelong, Col. Victoria, received a great number of spirit-preserved and dry specimens of Sponges which have been forwarded simply in the hope that they might afford material for the advancement of our knowledge of this branch of Natural History, I propose in return to carry out his views in this respect to the best of my ability, and thus shall commence with the following descriptions.