we actually have,—nor more than 400,000,000 years ago, or we should not have so much as the least observed underground increment of temperature. That is to say, I conclude that Leibnitz's epoch of 'emergence' of the 'consistentur status' was probably within these dates."*

III. THE GLACIAL PERIOD IN THE SOUTHERN HEMISPHERE.

By Thomas Belt, F.G.S.

THE tablets on which the ice of the Glacial period left its record in the southern hemisphere are probably now mostly covered by the sea, and we cannot trace its progress and extent with the same facility and certainty as in the northern temperate regions. Yet notwithstanding this, and also that the land surfaces of the South that have been glaciated have not been studied to anything like the same extent as in Europe and North America, points of resemblance are apparent, and grounds exist for the belief that both hemispheres have passed through a somewhat similar glacial experience.

In our hemisphere, I have sought to show in former papers, there were two ways in which the ice spread. One was an accumulation on mountain-chains, and a radiation from them over the surrounding country. The other, and I think by far the most important, was the gradual advance of a ridge of ice down the bed of the North Atlantic, and probably also of the North Pacific, which blocked up the drainage of the continents as far as it extended, and caused enormous lakes of fresh or brackish water and immense destruction of life amongst the animals that were caught on the plains by the rising floods. The marks left by the Atlantic ice are seen in Europe, as far as the southern extremity of Ireland, and in America, to the south of New York, and beyond these points, its further progress can be traced by the evidence of the interruption of the drainage of the continents as far as the northern slopes of the Pyrenees on one side of the Atlantic, and to the coasts of

* Trans. Roy. Soc. of Edinburgh, vol. xxiii., p. 161.

Virginia on the other. The real markings on the rocks, however, have not been traced in Europe farther south than 51° N. lat., and in America than 40° N. lat., excepting those of the ice that proceeded from the mountain ranges.

In the other hemisphere, within the distance from the Southern Pole that the ice has been shown by actual markings on the rocks to have reached from the North Pole on the European coasts,—that is, to latitude 51° N.,—there are no large masses of land, excepting the extreme end of South America and the Antarctic continent. And if we take a corresponding circle in the south to the limit the ice has left its marks in America or to lat. 40°, we shall still only embrace Patagonia in South America and the Middle Island in New Zealand. Even if we take the furthest limit of the extension of the Atlantic ice, as shown by its interference with the drainage of the American continent, we only bring South America as far north as the Rio Plata, and New Zealand and Tasmania, with the southern end of Australia, within the area where we could expect to find any similar evidence on the supposition that in the Glacial period the ice extended everywhere as far from the Southern Pole as its extreme limit reached from the Northern.

The conditions are therefore very different in the two hemispheres. In the one, broad continents stretch from within the Arctic circle toward and up to the Equator; in the other, nearly the whole of the temperate zone is covered with water. If, then, there were much less evidence than there is of the glaciation of southern lands, we need not have been surprised; but of late there seems to have arisen an idea amongst some geologists that there is no evidence in the southern hemisphere of the occurrence of a Glacial period, and it may be useful if I bring together what has been described, and show how far the phenomena agree with those of the northern hemisphere.

Commencing in America, immediately south of the Equator, we have first to deal with the remarkable theory of Agassiz, that the great valley of the Amazon was once filled with ice flowing from the distant Andes, which left an enormous terminal moraine on the Atlantic coast. This moraine he supposed blocked up for a time the waters of the great valley, and caused the deposition of various stratified deposits covered by a peculiar drift clay that rarely contains transported boulders. I have examined this deposit from Pernambuco northwards through the provinces of Ceara and Maranham, as far as Para. In some parts it is composed of small angular fragments of rock, cemented together by an

ochraceous clay, and resembling the brecciæ at the base of the Permian rocks in Westmoreland. In others it is a ferruginous clay, containing few stones, but with a layer of quartz pebbles at its base. It is not confined to the valleys, but wraps over the hills like a mantle. Now and then it contains large boulders of granite, but I could never satisfy myself that these might not have been left during the decomposition and denudation of the rocks of the neighbourhood. It differs much from any glacial deposit I have seen, and I am sorry that I can neither suggest any theory to account for its origin nor agree with that of the illustrious Agassiz. To the latter there seems to me insuperable objections. There are no moraines in the valley of the Lower Amazon. The terminal one might have been, as Agassiz suggests, washed away by the waves of the Atlantic, but the great glacier ought to have left others to mark the various stages of its recession. No remnant of these has been found, and we cannot believe that a glacier that left a huge moraine stretching for hundreds of miles across the whole seaward front of the Amazon Valley should have shrunk back for more than 1000 miles without leaving any whatever to mark its retreating course. The Valley of the Amazon abounds with birds and beasts, many of which are found nowhere else. Peculiar species of fishes swarm in the river and its tributaries. If the great valley was filled with ice, where did these find a refuge? To Agassiz this did not present any difficulty, as he believed that the present inhabitants of the world had been created since the Glacial period; but to those who hold the opinion that they are descended from pre-glacial ancestors, and that since the Glacial period there has not been much variation, the peculiar genera and species of the fauna of the Amazon Valley present serious objections to the theory.

Had Agassiz found in the Valley of the Amazon what he considered moraines, I should have had much difficulty in believing that he was mistaken, for no man had more experience of ice-action, present and past. Before him, Charpentier and others had worked out the conclusion that the glaciers of the Alps had in former days stretched far beyond their present limits, but they referred that extension to an elevation of the mountains, and not to a change of climate that affected all the northern parts of the continent. Agassiz accepted the theory, at first, that the upheaval of the Alps must, in some way or other, have been connected with the phenomena, but further study led him to abandon it, and conclude that the climatic conditions could not have

been local, but must have been cosmic. "When," he says, "Switzerland was bridged across from range to range, by a mass of ice stretching southward into Lombardy and Tuscany, northward into France and Burgundy, the rest of Europe could not have remained unaffected by the causes which induced this state of things."* Agassiz was thus the founder of the theory of a "Glacial Period," and in Great Britain, in Scandinavia, and in North America, evidence was soon found, and has been ever since accumulating, attesting the truth of his grand generalisation.

He was not likely to be mistaken as to what constituted a moraine, but he found none in the great valley, and he says himself that he had not here the positive evidence that had guided him in his previous glacial investigations.† Not so, however, with regard to his discovery of the marks of glaciation on the mountains of Ceara. Here, only about three degrees south of the Equator, he found undoubted moraines blocking up the valleys, and the evidence of glacial action was to him as clear as in the valleys of Switzerland, of Scotland, and of the Northern States of America.‡ This is the nearest point to the Equator at which glacial moraines have been found. On the other side of the line I found huge moraines in the northern part of Nicaragua, near the boundary between it and Honduras, in lat. 13° 47′ N.‖ This is the farthest south that glacial action has been traced in the northern hemisphere. Prof. W. M. Gabb has informed me that in his geological researches in the mountains of Costa Rica he found no evidence of glaciation. Between the moraines of northern Nicaragua and those of the mountains of Ceara there is an area comprising about 17° of latitude, and including most of Nicaragua, the whole of Costa Rica, of Columbia, of Equador, and of the great valley of the Amazons, in which no certain signs of glaciation have been seen. This wide region includes several large zoological sub-provinces, characterised by highly peculiar tropical genera, and a wealth of species not met with elsewhere on the continents to the north and south. Within this area are large groups of insects the extreme forms of which are linked together by a series of gradations, and every district has its representative forms of types that run through the whole. But as we travel south from the unglaciated districts lying between lat. 14° N. and lat. 3° S. the

* Geological Sketches, Second Series, p. 29.
† *Ibid.*, p. 207.
‡ A Journey in Brazil, by Mrs. Agassiz, p. 456.
‖ Naturalist in Nicaragua, p. 260.

species become more and more separated; the genera comprise species as far removed from each other as before, but these are not connected by the same intermediate forms. These gaps become wider and wider as we get farther south, until at the extreme end of the continent, where the rocks are glaciated from ocean to ocean, isolation, and not affinity, is the characteristic of the fauna, which is made up of waifs and strays that appear rather to have struggled in from the outside, upon a country that had been depopulated, than to have been developed within it.

In the glaciers of Ceara and northern Nicaragua we find the first parallel between the glaciation of the two hemispheres; and it is to be noted here, as it may be elsewhere, that there appears to have been more ice heaped up on the southern half of the world than on the northern, the much nearer approach of the glaciers to the Equator in Brazil than in Central America being the first evidence of it. This was probably due, not to greater cold, but to greater precipitation, proportional to the vast evaporating area of the Southern Ocean.

Travelling southward, we find that Mr. David Forbes noticed in Bolivia great accumulations of *detritus* with grooved stones and deeply-furrowed rocks, resembling those that he was familiar with in Norway.* And on the opposite side of the continent, near Rio Janeiro, Prof. Hartt has described moraines left by glaciers that formerly came down from the mountains of Tijuca.†

Still farther south the evidences of glacial action increase. For the description of the phenomena of La Plata, Patagonia, and Chile we must still turn to the observations of Darwin made more than forty years ago, which, when we consider that the glacial theory was in its infancy, evince the same rare powers of acute observation and philosophical generalisation that have since made his name so famous.

Ascending the River Santa Cruz, Darwin found, at a distance of about 100 miles from the Atlantic and at a height of about 1400 feet above the level of the sea, a great abundance of large angular boulders that had been transported from the Cordillera, the nearest slope of which was still about 60 miles distant. On both sides of the continent from lat. 41° S. to the southern extremity of it, he considers there is the clearest evidence of former glacial action in numerous immense boulders transported far from their parent source.‡

* Darwin, Origin of Species, Sixth Edition, p. 335.
† Geology and Physical Geography of Brazil, p. 26.
‡ Origin of Species, Sixth Edition, p. 335.

He describes Terra del Fuego as largely covered with till and boulder clay perfectly unstratified, and in which he looked in vain for marine remains.

On the western coast the ice from the Chilian Cordillera appears to have flowed across the Straits to the island of Chiloe, as Darwin found it covered with large boulders of granite and syenite that had come from the mainland. On one of the Chonos Islands he found a quantity of comminuted marine shells in the drift, and in Chiloe two or three fragments of a *Cytherea*.* We may compare these facts with those in the northern hemisphere, where the drift in the southern shores of the Baltic, brought by land ice from Scandinavia, is found—as in the vicinity of Bromberg—to contain broken and worn sea-shells that have probably been picked up in the passage of the ice across the ocean-bed.

Bearing just the same relation to the Glacial period in South America as the loess of the Rhine and the Danube does in Europe, and still more resembling the diluvial clay of the South of Russia, the Pampean mud is spread out in Rio Plata, Banda Oriental, and Entre Rios. It covers an immense tract of country. Darwin passed continuously over it from the Rio Colorado to St. Fé Bajada, a distance of 500 geographical miles, whilst M. d'Orbigny traced it for 250 miles farther north. From east to west, in the latitude of the Plata, it extends for at least 300 miles.

It is a reddish, slightly indurated, argillaceous earth, sometimes more than 100 feet thick, with lines of calcareous concretions, and occasionally changing into a compact marly rock. Marine shells are found scattered over the surface of this deposit at some places; but Darwin notices, as a remarkable fact, their absence throughout the deposit, excepting in the uppermost layers near Buenos Ayres. Even microscopical organisms appear to be very rare, and only found in the lower part of the deposit. Thus, in some of the red mud scraped from the tooth of a Mastodon found at the bottom of the Pampean mud at Gorodona, Prof. Ehrenberg found seven species of *Polygastrica* and thirteen species of *Phytolitharia*. Of these nearly all are of fresh-water origin, only three being marine. At Monte Hermoso, in Bahia Blanca, the lower part of the Pampean mud contains a similar assemblage of microscopical organisms. Prof. Ehrenberg considers that they must have lived in brackish water.

The most remarkable facts respecting the Pampean

* Trans. Geol. Soc., vol. vi., p. 426.

formation are its vast extent and the great number of the remains of large extinct mammals imbedded in it. Mr. Darwin says that he is firmly convinced that it would be impossible to cut a deep trench in any line across the Pampas without meeting with the remains of some quadruped. Wherever sections are exposed skeletons or detached bones are found, so that "the whole area of the Pampas is one wide sepulchre of these extinct gigantic quadrupeds."* At Punta Alta, within an area of about 200 yards square, were found the remains of no less than nine species of gigantic extinct mammals, including three Megatheriums, a Megalonyx, a Mylodon, and an extinct horse. Some of the skeletons were nearly perfect, besides which there were many detached bones. On the banks of the Parana two entire skeletons of the Mastodon were found near the base of the Pampean mud.

The Pampas extend southwards to the Rio Colorado. There, beds of gravel begin to take the place of the Pampean mud. These are at first thin, and composed of small pebbles. Farther south the gravel-beds are composed of coarser pebbles, with sometimes large boulders. This deposit of shingle extends for 800 miles up to the Straits of Magellan. In some parts the plains of gravel rise in step-formed terraces to a height of 1200 feet above the sea. Marine shells are scattered over the surface of the plains, but are not found in the beds of gravel, which, like the Pampean mud, contain in some parts numerous remains of the great extinct quadrupeds.

Darwin mentions that the Mammalian remains have not anywhere been found in existing marshes or peat-beds: all are entombed in the body of the deposit of which the plains are composed.

In the Pampas, in the caves of Brazil, and in deposits of similar age in other parts of South America, more than one hundred extinct species of quadrupeds, many of great size, have been found. There are representatives of the sloths and armadillos as large as existing elephants. There are also representatives of genera that do not now exist in South America, but still live in other parts of the world—such as leopards and antelopes. The remains of the horse are abundant, though when the Spaniards discovered America it was extinct there.

Mr. Wallace, in his great work on the distribution of

* Darwin, Naturalist's Voyage, p. 155. The whole of my information respecting the Pampas is derived from this work and from The Geological Observations on South America by the same author.

animals, has given an excellent summary of the facts known respecting these lost animals, and has placed the question of their extinction before us with clear-cut distinctness.* He shows that in very recent geological times a great change has taken place in the fauna not only of South America, but of North America and Europe, and that this change is unprecedented in older geological periods. We now live, he says, "in a zoologically impoverished world, from which all the hugest and fiercest and strangest forms have disappeared." He urges, with luminous force, that there must have been some physical cause for this great change, which must have acted at the same time over large portions of the earth's surface. Such a cause he considers is to be found in that great era, the glacial period.

There is much to be said in favour of Mr. Wallace's conclusion. The Pampean mud occupies the same relation to recent deposits as other clays whose glacial age has been satisfactorily determined. Both it and the gravel-beds of Patagonia, in many places, lie directly above marine deposits of undoubted late Pliocene age, as they contain shells of *Ostrea Patagonica*. They hold, therefore, the same position between the tertiary and recent deposits that glacial beds occupy in other countries. The Patagonian deposits also contain large boulders that have been transported from the Cordillera.

The Pampean mud has been compared with the loess of the Rhine—a similar fine slightly-indurated clay, which contains the bones of the extinct mammoth and woolly rhinoceros. It appears to be still more like the beds of diluvial clay that form the wide-spread steppes of Southern Russia. This clay is of undoubted Glacial age, and when traced northward contains large blocks of stone derived from rocks hundreds of miles to the north, just as the Pampean mud when traced southward is replaced by gravel-beds with boulders from the Cordillera. In the January number of this Journal I have advocated the theory that the diluvial clays of Northern Europe and the loess of the Rhine and the Danube were spread out in a great lake, when the bed of the Atlantic was occupied by ice that stopped the drainage of Europe as far as it extended. In eastern North America there is evidence of a similar interruption to the drainage of the continent to at least as far as North Virginia.

It is a remarkable fact that to about as far from the South Pole in South America as from the North Pole in North

* Geographical Distribution of Animals, vol. i., p. 143.

America there is the same evidence of the land having been covered with water which was not that of the sea; as the deposits left by it do not contain marine remains. If we may suppose that a similar mass of ice accumulated around, and spread from the Antarctic as from the Arctic regions, and that ultimately a prolongation or arm of that icy mass reached the eastern coast of South America, so as to dam back the streams as far as the Rio Plata, we shall have, I believe, a complete explanation of the deposition of the Pampean mud and the Patagonian gravels, and of the destruction of the great mammals and the entombment of their remains.

The present physical geography of the world and the existing distribution of its inhabitants were immediately preceded by a wide-spread entombment of land animals, unparalleled elsewhere in the geological record. In lake basins and estuaries of Eocene and Miocene age there have been preserved abundant remains of land animals, more especially in connection with the movements of elevation of certain mountain chains and the volcanic phenomena that accompanied them; but, compared with that which we are discussing, these entombments are insignificant and partial. The destruction of life that took place in the Glacial period was continental, if not world-wide, in its extent. The deposits in which the remains are found were not formed in old lake basins; they fringe, and in some cases nearly overspread, the continents, or run in great arms up the larger valleys. Here and there in America, Europe, and Asia, there are isolated deposits containing the remains of tertiary mammals, but the bones of the glacial mammals are spread over all the northern parts of the northern continents, and in South America are of equal extent.

The blockage of the coasts by ice flowing down the ocean beds seems just such an event as would bring about the destruction of life and the entombment of the remains of which we have so much evidence. I shall have to return to the consideration of the possibility of such a mass of ice having advanced northwards from the Antarctic circle when we have examined the evidences of glaciation in New Zealand; but let us assume now for a moment that such an accumulation did take place, and that it flowed down the eastern coast of South America; then, as it blocked up the drainage of each great valley, progressively from the south, northward, the waters pounded back would rise and overwhelm the animals living on the plains. The nature of the deposits favours this supposition. The lowest parts, or

those first formed, contain some evidence of brackish water conditions such as might have been produced by the embracement of the salt water of bays within the area blocked up by the ice; but the upper parts contain nothing but the remains of land animals, whilst the proof of the presence of water is complete in the rounded and stratified shingle forming the Patagonian plains.

Mr. Wallace has shown that the cave fauna in Brazil differs from that of the Pampas in containing a larger proportion of existing genera, and is inclined to believe that this may imply that the Pampean mud is a little older than the cave deposits.* It may, however, be due, I think, to the destruction of life having been more complete in Buenos Ayres and Patagonia than in Brazil, and that, in pre-glacial times, as now, the former countries formed a part of a distinct zoological sub-region. That the destruction of life in Brazil should have been less complete than farther south is likely—not only because we have no proof that the great flood extended so far north, but because there was a large extent of country, neither covered with ice nor overwhelmed with water, where many of the species might be preserved. In Patagonia and Buenos Ayres the lower country was covered with water, the upper mostly with glaciers descending from the mountains, so that the retreat of the animals from the flood was in a great measure cut off. The peculiar species that have been preserved in the Chilian sub-region, which includes Patagonia and Buenos Ayres, are principally alpine forms, such as the Chinchillas, the Alpacas, and the Viscachas, which we may suppose found a refuge during the great flood in some high lands not covered with glacier ice. Others may have retreated northward up the western side of the Andes, and returned southward after the greatest severity of the Glacial period had passed away. The remains of an extinct llama are found on the high plains of Mexico, so that the genus had undoubtedly a former greater extension northwards. The principal extirpation of life appears to have been amongst the bulky species, on whom the changes of environment would press most heavily, and which were confined to low-lying districts. Thus the Mastodon, whose remains are found at great heights in the Andes, appears to have escaped the complete destruction that befel its bulky companions at the time of the greatest extension of the ice, as I saw remains of it in Mexico that from their fresh appearance were probably as recent as those

* Geographical Distribution of Animals, vol. i., p. 146.

of the species that is found in post-glacial deposits in the Northern States.

Whilst the eastern coasts of Patagonia are fringed with plains of gravel, the western are indented with deep fiords like those of Norway, and, as Dana and Ramsay have shown, these fiords are evidence of great glaciation, and have probably been excavated by ice-action.

Leaving South America and passing to the continent of Africa, we find but little evidence of the Glacial period, as its southern extremity only reaches to about lat. 35° S. Mr. G. W. Stow has, however, shown that the southern ranges of mountains undoubtedly bore glaciers. Thus the Katberg range is in many parts rounded and smoothed, as if by the passage of ice, and on its northern slopes there are great mounds and ridges of unstratified clay packed with angular boulders of every size, from small gravel and pieces of a few pounds weight to masses of several tons.* The slopes of the Stormberg are similarly glaciated, and there are immense accumulations of morainic matter in all the valleys. Both lateral and terminal moraines have been observed in these mountains. In British Kaffraria, near Greytown, the ice would appear to have reached nearly to the present sea-level. Mr. Stow comes to the conclusion that the rounding-off of the hills in the interior, the numerous dome-shaped rocks, the enormous erratic boulders in positions where water could not have carried them, the frequency of unstratified clays, clays with imbedded angular boulders, drift and lofty mounds of boulders, and the large tracts of country thickly spread over with unstratified clays and superimposed fragments of rock,—all indicate the conditions that in other countries characterise the Glacial period.†

The Rev. W. B. Clarke has informed Mr. Darwin of facts from which it appears that there are traces of former glacial action on the mountains of the south-eastern corner of Australia, but I do not know the particulars.‡ I have not seen any notice of glacial phenomena in Tasmania, but it is extremely probable that they will be found. In New Zealand the evidences of former glaciation are clear and unmistakable, and they have been described by many able observers. The large glaciers that still exist in the mountains of the South Island bear about the same relation to the

* Quart. Journ. Geol. Soc., vol. xxvii., p. 539.
† *Ibid.*, p. 544.
‡ Darwin, Origin of Species, Sixth Edition, p. 335.

ancient ones as those of the European Alps do to the much larger ones of the Glacial period. The western sea-board is penetrated by long sounds or fiords, many of which are more than 1000 feet deep. On the eastern side of the range the fiords are replaced by arms of large and deep fresh-water lakes; and so far do the marine fiords on one side, and the arms of the fresh-water lakes on the other, cut into the mountain chain that in many places they reach to within 10 miles of each other.* The New Zealand geologists appear to be unanimous in ascribing the formation of the sounds and deep lakes to the action of ice. The former great extension of the glaciers is marked by immense morainic accumulations and transported boulders. These deposits have been ably described by Dr. Haast. For more than 90 miles south of the River Mikonuhi, on the western coast, all the lower country is covered by mounds and sheets composed of unstratified clays packed with boulders from the mountain chain. The moraines form low hills bounding the sea, the waves of which have cut them into cliffs. Along the whole of this shore glaciers must have descended from the New Zealand Alps down to, and probably beyond the present sea-level. Some of the imbedded blocks exposed in the sections on the sea-coast are of immense size, often larger than the celebrated Pierre-a-bot, in the Jura. These blocks have principally been brought from the very centre of the chain, and the distribution of the different rock formations in the drift and alluvial beds has led Dr. Haast to the conclusion that the configuration of the mountain chain was similar to what it is now at the time of the great extension of the glaciers.†

On the eastern side of the range the old glaciers did not reach to so low a level as on the western side, but terminated many miles from the sea-coast, which is bounded by great plains of stratified drift. In the northern part of the South Island Mr. Locke Travers has shown that many of the lakes are enclosed by huge moraines,‡ and in the North Island there is also evidence of intense glacial action.

The southern and eastern coasts of the South Island are bordered by great plains, composed of gravel and rounded boulders, which sometimes overlie beds of silt containing bones of the extinct moas. In the south part of the island the Southland Plains extend for nearly 40 miles along the

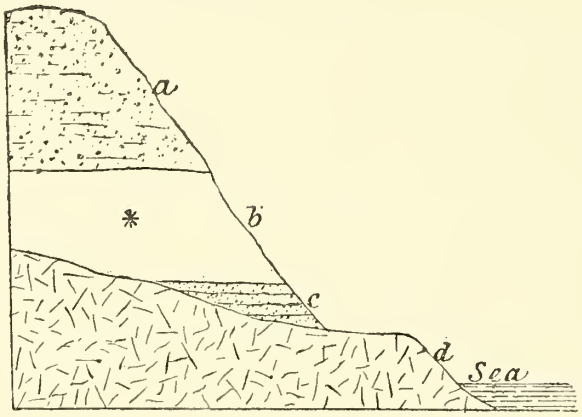
* Hutton and Ulrich, Report on the Geology and Gold-Fields of Otago. 1875.

† Quart. Journ. Geol. Soc., vol. xxiii., p. 350.

‡ *Ibid.*, vol. xxii., p. 254.

coast, and back from it for about 26 miles, besides sending arms up the valleys of the Mataura, Oreti, and Jacob Rivers. This plain is composed of shingle, sand, and clay, with some seams of lignite near the base of the deposits. It wraps around the Moonlight Range and Hokonui Hills, which stand up like islands out of it. The beds of which it is composed contain the bones of the great extinct apterous birds. Marine remains are not found, but Captain Hutton ascribes its formation to the action of the sea when the land stood at a lower level, as he finds it impossible to believe "that the alluvia of the Mataura, the Oreti, and the Jacob Rivers should all join one another with gradual slopes behind the seaward range of hills without the intervention of some uniform widely-acting cause, such as the sea."*

Section N. Side of Oamaru (Captain Hutton).



a. Gravels of the Plains.
b. Silt with Moa Bones at *.
c. Gravels with twenty-two species of Marine Shells, all but two still living on the New Zealand coasts.
d. Basalt.

These plains rise gradually from the sea-coast until they attain a height of about 600 feet next the mountains. On the coast they overlie marine deposits of late Pliocene age. The above section, from the work already quoted, shows the relation of the beds on the north side of Oamaru Cape.

The silt formation extends inland for a considerable distance, and is extensively developed at Hampden. Captain Hutton notes the great analogy it presents to the Pampean formation of South America. The remains of the extinct birds are distributed, like those of the extinct beasts at Buenos Ayres, throughout the deposit. The above section might indeed be almost exactly paralleled from South America, more especially in Patagonia, where the gravel-beds

* Geology and Gold-Fields of Otago, p. 79.

containing bones of extinct mammals overlie marine strata of late Pliocene age.

On the east coast, great plains, separated by rocky promontories, border the sea. The well-known Canterbury Plains are the greatest of these outspreads of gravel: they have been well described by Dr. Haast, and the question of their origin has been a fruitful source of controversy; they are 112 miles in length, and run back from the coast to the base of the mountains in the interior; gradually rising until they attain an elevation of about 1500 feet above the sea, according to Dr. Hochstetter.* These plains are composed of boulders, gravels, sand, and clay, and in some parts the deposits are upwards of 200 feet thick. Throughout the whole formation no marine remains have been found. At Banks's Peninsula the gravel-beds are replaced by deposits of silt that cover the volcanic hills to a height of about 800 feet above the sea. This fine loam must, from its description, closely resemble the loess of the Rhine and Danube, and it contains the bones of the great wingless birds and land-shells, but nowhere has the least trace of marine life been found in it.†

We have thus in New Zealand a repetition of the phenomena observed in Patagonia—great plains of gravel and silt on the eastern, and deep sounds or fiords on the western, coasts. In both countries the deposits of the plains entomb the remains of large extinct animals, and their geological age is fixed by both overlying marine beds of late Pliocene age. They are the representatives in position of the glacial beds of the northern hemisphere. Considering the very different distribution of land and water in the two hemispheres the resemblance of their glacial phenomena is most remarkable. Yet still more remarkable is it that most of the able naturalists of New Zealand not only deny that there is proof of a Glacial epoch in their country, but even are inclined to refuse us one elsewhere on the evidence they find there. I do not gather very clearly Dr. Haast's opinion on this question, and as a few years ago he was certainly in favour of New Zealand having been covered with an ice-sheet like Greenland, he may perhaps be excepted; but the remainder of the geologists, headed by Dr. Hector and Capt. Hutton, contend that the glaciation of New Zealand had no connection with a general glacial period, and that the great accumulation of ice was owing to the mountains

* New Zealand, English Edition, p. 508.

† Dr. Haast, Trans. New Zeal. Inst., vol. vi., p. 423.

having then been higher. Dr. Hector, who first suggested this explanation, candidly admits that the shore deposits do not support it, and considers that there must have been unequal movements of elevation, and that the former greater weight of the mountains was due to their greater bulk, which has since been reduced by denudation.

Dr. Hector, so far as I can make out from his writings, only seems to offer this as an alternative to accepting the occurrence of a general Glacial epoch, and we must turn to the works of Captain Hutton for the reasons that have weighed with the New Zealand geologists in rejecting the theory of a Glacial period, which, since Agassiz first propounded it for the northern hemisphere, has been adopted by nearly all our leading geologists. In the first place Captain Hutton thinks that the date of the last great glacier period of New Zealand, must be placed much further back than that of the northern hemisphere, because, since it occurred, some of the old lake basins have been filled up with deposits brought down by the streams; the surfaces of the rocks that were formerly covered with ice have been weathered to a depth of ten or twelve feet; old river courses have been filled with gravels, and the streams have cut new channels to great depths, so that in many places the drainage system of the country has been altered.* But in reality these facts should rather have been advanced as evidence of the analogy of the glacial phenomena of the two hemispheres instead of as a distinction between them. We have but to appeal to the erosion of the deep gorge of the Niagara, for at least a distance of three miles since the glaciation of Canada, to the reversal of the drainage of the great lakes from the Mississippi into the St. Lawrence, to the buried old river channels of the north of England and of Scotland, and to the numerous filled-up lake basins of Europe and America, to show that it is the resemblances and not the differences that strike us with greatest force.

Captain Hutton has not, however, restricted his argument to the physical side of the question, but has sought to strengthen it by appealing to the evidence of the organic remains. It is admitted that the Glacial deposits contain no marine organism, but, as we have already seen, they overlie beds of gravel and sand, with sea shells of late Pliocene age, as shown in the Oamaru section. These late Pliocene deposits are largely developed at Wanganui in Cook's Strait, and it is from a study of the present and past range of the species of the marine mollusks in these and similar beds,

* Geology and Gold Fields of Otago, p. 94.

that Captain Hutton's ingenious argument is founded. He has given a list of a great number of mollusks found in these beds that do not now live so far south, whilst only a few occur that do not now live so far north.* This, he thinks, proves that there was no reduction in the general temperature in times immediately preceding the glaciation of the country. We do not know, however, the age of these preglacial deposits, and they may be as far back in time as our coralline crag, and the value of the evidence has been much lessened by some facts described by Mr. C. W. Purnell. He states that at Wanganui there are three distinct fossiliferous strata, separated by thick beds of volcanic mud, and that the shells of these different horizons are mixed together in Captain Hutton's lists.† If this is so, it may yet appear, when the fauna of each zone is more critically studied, that the same evidence of a gradual refrigeration of the climate in the Pliocene epoch exists in New Zealand as in Europe.

Captain Hutton further argues that as many of the shells that extend back to the Miocene epoch, and still exist on the coast of New Zealand, are littoral species, and are not found elsewhere, we should have to suppose, if the extension of the glaciers was due to the change in the climate, that during the cold period they crossed the deep sea to Australia or Polynesia, and that, on the return of a warmer climate, they all came back again to New Zealand without leaving any behind on the coasts they had retired to during the Glacial period. He concludes, therefore, that since the Miocene period there can have been no reduction of temperature sufficient to account for the former extension of the glaciers, and that we must necessarily look to elevation of the land as the main cause. He admits, however, that it is possible that the two may have been combined, but considers that at present the evidence seems to be in favour of there never having been a Glacial epoch in New Zealand, and consequently none in the southern hemisphere.‡

Now, if the theories I have advocated respecting the Glacial period are correct, the two conditions of the glaciation of the land, and at the same time its relatively greater elevation above the level of the ocean, must have existed together. For such an amount of ice as is necessary could not be piled up around and outside the Arctic and Antarctic circles at the same time without abstracting so much water

* Trans. New Zeal. Inst., vol. viii., p. 383. Captain Hutton has also published an abstract of his views in the Geological Magazine, 1875, p. 580.

† Trans. New Zeal. Inst., vol. vii., p. 453.

‡ Ibid., vol. viii., p. 387.

from the ocean as to lower its level to the extent, I believe, of about 2000 feet; and this lowering of the ocean would give a coast line along which the littoral mollusks might retreat northwards during the Glacial period. In the line of soundings made between Australia and New Zealand by the officers of the *Challenger*, it was found that from the Australian shore the water deepened gradually until a depth was attained of 2600 fathoms, at about one-third the distance sccross. Nearer New Zealand the water shoaled suddenly, and at a distance of about 280 miles from its shore, a depth of only 275 fathoms, or 1650 feet, was found with a rocky bottom. These soundings were taken in one line only, and there can be scarcely a doubt that a lowering of the sea level 2000 feet would add more than 300 miles to the extension of New Zealand northward, and afford the necessary refuge for its fauna and flora during the Glacial period.

To prove the necessity of lands to the northward, now submerged, having then been above the sea, it was not necessary to appeal to the evidence of the marine shells, which is so far doubtful, as it is known that many shallow water species, under other circumstances, live at a great depth; as that of the inhabitants of the land was equally available and more certain. For the bones of the great extinct birds are not confined to the drift beds, but are found in old kitchen middens, ovens, encampments, and other places on the surface of the glacial beds, proving, that after the cold period had passed away, they returned again. It is certain that they must have been expelled from the existing area of the South Island, when glaciers came down beyond the present coast lines on the west side, and the great plains of drift were being formed under water on the east. The marine mollusks might have passed across some channels of the sea, but the apterous birds required a continuous land passage during their retreat, and the withdrawal of the waters of the ocean would have afforded this, not only to the North Island, but to the great plateau now submerged, whose existence has been indicated by the few soundings of the *Challenger* expedition.

We may agree with the New Zealand geologists that their country stood at a higher level above the ocean than it now does when it was glaciated; but instead of looking upon this as evidence in favour of local causes having led to the accumulation of the ice, it is only another link in the evidence to prove that the level of the ocean was lowered, and that the glaciation of the southern hemisphere took place at

the same time as that of the northern, as it occurred when the land stood relatively to the sea higher than it now does. There is the same objection to its being movements of the land that effected this, as there is to the theory of similar land movements in Great Britain, for the New Zealand geologists would send their country 3000 feet up into the air to allow the glaciers to descend to the present sea-level, and lower it 2000 feet to permit the gravels of the plains to be spread out, making a total movement of more than 5000 feet; yet after these enormous imaginary oscillations, we find everywhere, as we do in England, the pre-glacial shell beds with their littoral species only within a a few feet of the present shore line.

Let us now turn to the consideration of the question of the origin of the great plains of drift and silt that border the eastern and southern coasts. Dr. Haast, in his able essay on the structure and origin of the Canterbury Plains, considered that the gravels were the exuviæ from the great glaciers of the interior that had been spread out by the floods produced whilst it was melting. Some serious objections have been urged against this view. The sheets of gravel wrap around the hills, and are spread right across the water-sheds between different river systems. They are nearly level for scores, or even hundreds of miles. Ranges of hills are isolated so that they rise up from the plains like islands out of the sea. The waters, necessary to overflow such an extent of country, would be raging torrents, which, instead of depositing sediments, would sweep everything before them into the ocean; and would be rather agents of destruction and denudation than of deposition above the sea-level. There are beds of silt up to 800 feet above the sea-level at Banks's Peninsula, and for the deposition of these beds we require the presence of tranquil waters, and not torrential floods. It may also be remarked that it is not probable that, even on the hottest day, sufficient ice could be melted to produce the quantity of water required to submerge the country next the sea shore beneath a flood several hundred feet deep. The very statement of the enormous quantity of water required seems to condemn the theory when we remember that every day the water produced would be carried off, if near the sea there was nothing to stop its outflow and dam it back.

These considerations have led the generality of New Zealand geologists to adopt the theory that the great seaward plains are of marine formation, and that the gravels, sands, and loams were spread out when the land stood much

lower than now. The theory is the same as has been proposed to account for the similar outspreads of sheets of gravel and drift in other parts of the world in the Glacial period, and the same objection is to be made to it—the absence of marine remains. In the case of New Zealand, the drift has not been found to contain even the broken and worn sea shells that in Europe occur in some cases where ice had advanced on the land from the sea, bringing some of the productions of the latter with it.

If the theory is correct, the land must have sunk nearly 2000 feet, to allow of the formation of the Canterbury Plains. As it was slowly sinking and rising again, every portion of the area submerged would become a sea beach, and pass through the different stages of shallow and deep water; that at the present sea-level to a depth of about 2000 feet. As the land emerged, these stages would again be passed through. Along these successive coast-lines there would be bays and promontories, estuaries and sand banks, rocky cliffs and pebbly beaches. We have evidence, as Captain Hutton has shown to us, that the mollusks never left the shores. What then has become of their remains? We may grant that there must have been much destruction of the old sea beds during the rise of the land, but there ought to be some exceptions from that devastation, and not total and supreme annihilation. The beds themselves have not been destroyed; there are sheets of gravels, sands, and clays, lying as they are supposed to have been spread out during the submergence, but they contain no marine organism. Contrast these with the pre-glacial beds in the same districts, as, for instance, the clays and sands on the coast at Wanganui and Oamaru. These teem with sea shells, yet the unconsolidated sands and gravels of which they consist have passed through all the vicissitudes of the Glacial period. In Europe it is the same; the pre-glacial marine beds at Cromer and elsewhere, often of loose sand, are full of marine shells. We have also in Europe the post-glacial raised beaches, as in Scotland, up to 50 feet, and in Norway up to 600 feet above the sea-level, and these are often so crowded with marine shells, that in Norway they have been worked for many years for burning into lime.

We cannot believe that no life existed in these seas, for we know that it abounds both in the Arctic and Antarctic regions up to the foot of the great ice-sheet. Dr. Hooker states that along the shores of the Victoria Barrier the soundings were invariably charged with diatomaceous remains, that the water and the ice of the South

Polar ocean abound with them, and that they occur in such myriads that where washed on the bergs or pack-ice by the sea they stain it a pale ochreous colour. These remains were detected along every ice-bound shore, and in the depths of the adjoining ocean between 80 and 400 fathoms.* Nor is life in the polar regions restricted to these minute organisms, for recent Arctic explorations have proved that mollusks and crustaceans swarm at the very foot of the Greenland glaciers, and even to the north of Siberia where the water is freshened by the great floods, poured into the Arctic Ocean by the Obi and the Yenisei.

In New Zealand, Mr. Crawfurd has recognised the significance of the absence of marine life in the deposits forming the plains, and has suggested that they have been spread out in great fresh-water lakes. To account for the origin of these lakes he supposes that there was formerly a barrier of land running down the south-eastern coast, which has since entirely disappeared.† Agreeing as I do with Mr. Crawfurd, that the facts he has brought forward show that these deposits are not marine, it is difficult to believe in the possibility of a ridge of land having been elevated, since Pliocene times, along the whole coast of New Zealand, to a height of 2000 feet, and utterly destroyed since, so that not a vestige of it remains.

It will have been premised that I attribute the origin of these deposits, as I have those of similar ones in South America, to the advance of the Antarctic ice upon the coast so as to block up the drainage of the land. The great feature of the Glacial period is, of course, the enormous development and accretion of ice, and to call in its aid appears less hazardous than to invoke oscillations of the earth's crust, which, in our present ignorance of the condition of the interior, may be impossible. I do not hide from myself the vast quantity of ice that is required on this supposition; nor the difficulty of accounting for its formation, and I have only been driven very gradually and unwillingly to the conclusions I now hold respecting its extent. In my last paper in this Journal I endeavoured to show that in the North Atlantic area the ice would accumulate most at the northern end of that great evaporating basin; that when it was heaped up on Greenland to such a height as to intercept all the moisture of the currents of air travelling northwards, the precipitation would take place on its southern slope only; and

* Flora Antarctica, vol. ii., p. 503.
† Trans. New Zeal. Inst., vol. viii., p. 369.

that the latter would advance southward, not only by flowing glacier-like, but by the area of precipitation itself being moved southward. A similar accumulation and extension must, I think, have taken place in the Antarctic regions. We have learnt that there is a great precipitation of snow around the edge of the ice-sheet with which the Antarctic continent, so far as we know, is covered; but an equilibrium has been attained between the forces concerned in its formation on the one hand, and its liquefaction on the other, so that it does not now advance further.

In the Glacial period that equilibrium must have been disturbed in favour of the accumulation of the ice, not necessarily by greater cold, which would tend to lessen the precipitation, but from some cause favouring a larger amount of moisture reaching the polar regions, and falling there in the form of snow. If this did occur, I believe that the ice might obtain powers of accumulation and growth, where it was fed by large evaporating areas, that might enable the ice-sheets now nearly confined within the Arctic and Antarctic circles to advance upon and invade the temperate regions; especially down the ocean depressions. I indicated some of the causes of accretion in my last paper. The currents of air travelling from the tropical and temperate zones towards the Poles, such as the counter trade winds, are charged with moisture which is precipitated when they reach colder regions or encounter mountain-chains. Confining ourselves to the southern hemisphere we find that much of the moisture falls as rain in low latitudes, yet that a certain proportion of it reaches the Arctic circle, and there falls as snow, and recuperates the ever-melting ice-sheet. Let us suppose that some change took place by which much more of this moisture would reach the southern ice-sheet, such, for instance, as would probably be effected if the obliquity of the ecliptic was increased. This, by raising the temperature of the temperate zone, would cause much more moisture to reach the southern ice-cap, and be precipitated there so as to add to its extent and height. As the edge of the ice-cap moved northward, it would gather to itself not only the moisture that would have reached it in its old position, but that which belonged to the area it now occupied.

As I remarked in my last paper on the Atlantic Glacier, but reversing the direction of its progress, it would be a ridge of ice slowly advancing northward, and appropriating the precipitation of the regions it invaded to aid in its further progress. Its advance would be due to two causes,

the flow of the ice itself, and the area of frozen precipitation being moved northward by the accretion on the northern slope of the ice-sheet; for when it had attained a certain height above the sea-level it would intercept the whole of the moisture of currents of air travelling over it, and cause its precipitation on its northern slope, so that, as it advanced further from the Pole, there would be more and more precipitation, and its progress would only be ultimately checked by it reaching a warm enough latitude to greatly increase the liquefaction of the ice. The height of the ridge would increase as it reached more temperate regions, as it would primarily depend upon the altitude to which the moisture was carried before it was precipitated, and this would be greater the lower the latitude the ridge of ice attained to.

I do not suppose that this ridge of ice, or the zone of greatest frozen precipitation, ever reached to New Zealand or to the Rio Plata, but only that the ice flowing from it did so. The zone of greatest precipitation may have been hundreds of miles farther south, and if anyone then could have stood on the edge of the great ice-sheet he would have seen to the south probably what appeared a level plain of ice reaching to the horizon, so gradual would have been its rise in that direction. M. Favre, in his elaborate account of the old glaciers of the northern rivers of the Alps, has proved that at their greatest extent the slope of the upper surface of the ice was very small, and for great distances nearly horizontal.* And Mr. Helland, describing the great ice-sheet that covers North Greenland, states that it resembles a great sea, but seems to rise slowly inland. Where the glaciers are largest on the coast the rainfall is not considerable, and Mr. Helland concludes from this that the source of the ice must be far in the interior.† In consequence of this property of flowing with a small slope the ice has been conveyed to the coast for more than a hundred miles, at least, from where it was accumulated, and the whole of the lower part of its course is far below the limits of perpetual snow. The coast of Greenland does not, therefore, owe its icy mantle to the climate there, but to the outflow from the snow-gathering grounds of the far interior. And in the Glacial period the neighbourhood of Lyons was glaciated by ice that had flowed from the far distant Alps, and which in a great part of its course was nearly horizontal on its upper surface.

* Archives des Sciences de la Bibliothèque Universelle, 1876, t. lvii.

† Quart. Journ. Geol. Soc., vol. xxxiii., p. 146.

Judging from what we know of the slope of the upper surfaces of the present ice-sheets of Greenland and Spitzbergen, and from the marks left by the old Alpine glaciers, we shall not, I think, be justified in allowing the still larger circumpolar ice-sheets a greater surface slope than 1 in 200; and supposing that the ice was 2000 feet higher than the present level of the sea, when it reached New Zealand, we should have to go back in the direction from which it flowed more than 200 miles before we reached a height of 8000 feet above the present sea-level, which may have been the zone of greatest precipitation.

Prof. Tyndall, in his well-known and often-quoted observations on the Glacial period, has so forcibly and clearly defined some of the necessary conditions to allow of a great accumulation of ice, that I may be allowed again to refer to them. He shows that the ancient glaciers required for their formation that water should be evaporated by heat, and that by lessening the force of the sun's rays we should not increase the glaciers, but cut them off at their source; and he illustrates this by referring to a distilling apparatus, and reminding us that if we wished to increase the quantity distilled we should certainly not attain our object by reducing the fire under our boiler. "It is quite manifest," he says, "that the thing most needed to produce the glaciers is an improved condenser; we cannot afford to lose an iota of solar action; we need, if anything, more vapour, but we need a condenser so powerful that this vapour, instead of falling in liquid showers to the earth, shall be so far reduced in temperature as to descend in snow."* If the theory I am advocating is correct the great condenser that exists within the Antarctic circle moved northward, and as it so moved the vapour to be condensed increased in quantity, for the reasons I have already given. It was prevented from falling in liquid showers, though it did not reach the earth as snow, but as ice flowing from the icy ridge that was fed and capped with snow.

Air, as it rises, expands, and much of its heat becomes latent, so that it is cooled according to a definite and well-ascertained law. To speak popularly, there is an inexhaustible store of cold up above, available for glaciation, if it could only be brought down.† The vapour in the air is chilled when it rises to a great height through the abstraction of its heat by the expanding air. The vapour is thus condensed, and at high altitudes frozen, so that it falls as snow.

* Heat as a Mode of Motion, p. 188.

† I am indebted to Prof. Joseph Henry, of Washington, for this suggestion.

Most of this snow is again liquefied before it reaches the earth by the higher temperature of the lower portions of the atmosphere it has to pass through. But if it be intercepted above, on a mountain range, it may accumulate there and feed glaciers that descend for thousands of feet below the snow-line. In its descent, in this form, only its upper surface is exposed to the warm air, and the lower portions of the mass are preserved as in an ice-house. Thus, glaciers may be said to bring down the cold of the upper regions of the atmosphere, and the advance of a ridge of ice from the north and south into the temperate zones, in the Glacial period, would give us the machinery for doing this on a scale commensurate with the extent of the glaciation of the two hemispheres.

According to this theory, the ice that reached the coasts of New Zealand and South America was not due to a great lowering of the mean temperature of these countries, but flowed down upon them, bringing with it the cold of regions thousands of feet above the sea-level and hundreds of miles to the southward. The theories of local glaciation require a much greater change of climate than this does, just as in the valley of Chamoinix a very considerable lowering of the present mean temperature would be necessary to cause ice to accumulate there, instead of flowing down to it from Mont Blanc. In all the treatises on the Glacial period that I have seen, the question sought to be answered is—"What causes would bring about changes of climate to allow perennial snow to accumulate on lands in temperate regions. Instead of this, I think the problem to be solved is—What are the conditions that would cause ice to be piled up around the Arctic and Antarctic circles, and gradually invade the temperate zones, bringing down the cold of the upper regions of the atmosphere as it progressed? I shall not now attempt to answer this question, but occupy what space I have left in showing how such an advance of ice explains the facts we have been considering in the southern hemisphere and some others in this part of the world.

The advance of the ice from the Antarctic regions would not be directly southward. The moist winds that fed it blew from the north-west, and its progress would be to the south-east towards its source of supply. And as the quantity of moisture in the air would be greater in some regions than in others, owing to the irregular distribution of land and water to the northward, the progress of the ice would not be equal all around the Antarctic, but some parts would

be greatly in advance of others. In both New Zealand and Patagonia there are wide plains to the east and a coast indented with deep fiords to the west. It is certainly a curious circumstance that we have similar facts of glaciation in two countries so far removed, unless they were due to general and not to local causes. The advance of an ice-sheet from the south-east accounts for the phenomena; the drainage of the eastern coasts would be obstructed, whilst local glaciers would form, or be greatly increased where they now exist, by the precipitation of frozen moisture from the south-west winds when the mountains were raised by the lowering of the ocean-level, 2000 feet higher above the sea than they now stand.

Excepting the formation of the plains, I do not know of any evidence in South America of the advance of the ice upon the eastern coast; but in New Zealand Capt. Hutton has described an immense accumulation of clay containing angular blocks of mica-schist, many of large size, on the eastern or coast side of the Taieri Plain, and extending from the Taieri River nearly to Otakaia, a distance of about 3 miles. This deposit is many miles to the eastward of any known extension of the inland glaciers, and Capt. Hutton ascribes its origin to an earlier glacier period than the last. He says that there is a similar mica-schist on the sea-coast at Brighton, but rejects the supposition that they could have come from thence, because "many of the blocks are considerably above the highest level of the mica-schists there, and there is no conceivable agency by which they could have been brought from there."* The formation of this morainic deposit, and the transport of blocks of mica-schist inland, so difficult to account for by the extension of local glaciers, is just what we might expect on the theory of the advance of the ice from the south-east. No broken shells have been found in this deposit, such as mark, in other parts of the world, the drift left by glaciers that had crossed ocean-beds; but perhaps further examination may detect them.

It may be said, in regard to the formation of great lakes of fresh water by the advance of such enormous masses of ice upon the coasts, that the cold would be sufficient to freeze the lakes themselves and change them to masses of solid ice. But a minute's consideration will remove this objection. The temperature of the ice when it reached the coasts of New Zealand and South America would be little, if anything, below the freezing-point, and it

* Geology and Gold-Fields of Otago, p. 62.

would be melting itself instead of freezing the water it came in contact with. There is no more reason for the lakes it caused being frozen than that the Manjalen Sea—which is formed in a similar way—should be so.

The advance of the circumpolar ice-sheets in the form of low ridges, rising very gradually from their outer edges and culminating at a height of perhaps not more than 8000 or 10,000 feet above the present level of the sea, and then decreasing in height towards the Poles again, in consequence of the moisture being precipitated on the outer slopes, is, I think, more in accordance with our experience than the usual form of the theory of ice-caps, which would make them highest at the Poles. The latter supposition, it has been shown, is opposed to the facts that the ice flowed northward from the northern end of Scandinavia; that the high peaks of the Lofoden Isles are not glaciated; and especially that at the present time the northern end of Greenland is much more free from ice than the southern extremity. Whilst every inlet of South Greenland is occupied by ice flowing from the interior, and breaking off into great bergs when it arrives at sufficiently deep water, in the extreme north the glaciers do not reach the level of the sea. And in the Glacial period, instead of there being more ice than now within the Arctic and Antarctic circles, there was probably much less. Within the ridge of ice that then, I think, irregularly encircled the southern hemisphere, and, in the northern, bridged across the northern ends of the Pacific and Atlantic Oceans, both plants and animals that could hybernate through the severe and long winters might have existed in greater abundance than now. Even now, in the Antarctic, behind the ridge of ice that surrounds the South Polar continent, it is possible that there may be large areas of land free from ice in summer, and supporting a flora and fauna, which, if they could be studied, might throw much light on the distribution of animal and vegetable life in the South Temperate zone. And were that barrier of ice once passed a journey to the South Pole might be found to be less impracticable than one to the northern extremity of the globe.

Whilst the physical phenomena of the Glacial period in New Zealand and South America are so similar, there are differences in its effect on the pre-glacial fauna that must be noticed. Although there was great destruction of life amongst the individuals of the great apterous birds of New Zealand, there was not the same extirpation of species as

in America, nor even so much as in Europe amongst the great mammals. Numerous bones of the moas are found in the stratified deposits of the plains, but the same species reappear in the post-glacial surface-beds. Their complete destruction did not take place at the same time as the megatherium and its associates in America, or the mammoth and the woolly rhinoceros in Europe, but must rather be correlated with that of the Irish elk and the American mastodon. The preservation of the large birds through the great vicissitudes of the Glacial period may have been owing to the following causes:—Long before the ice from the Antarctic reached the coasts of New Zealand, a great stretch of land to the north would be laid dry by the lowering of the sea-level, so that there was possibly more space suitable for their occupation during the greatest extension of the ice than now. The same lowering of the sea-level took place all over the world, and in South America a similar extension of land surface must have ensued; but there the new land, to the north of the districts glaciated or submerged beneath the waters of the great glacial lake, would be occupied by northern animals who would resist the immigration of those fleeing the catastrophes of the south. In New Zealand, also, there was not the same competition with smaller animals, which appears to have led to the extirpation of many of the bulky species of the continents during the changing conditions of the Glacial period. Had, for instance, New Zealand at that time become connected with Australia, the great extension of area thus obtained, instead of tending to the preservation of the moas, would have probably led to their extermination by bringing them into competition with the marsupials of the continent. But a channel, 2600 fathoms deep, separates the two countries; and that there was then no land connection between them is evidenced by the absence of the gum-trees and acacias of Australia from the flora of New Zealand, and of the marsupials, the cockatoos, the grass parroquets, and the pigeons of the former from its fauna.

Although the large apterous birds of New Zealand were not exterminated during the great glaciation of the country, there are other signs of the impoverishment of its fauna. About 200 species of beetles had been described in 1872, and these belonged to no less than 110 genera, giving an average of less than two species to each genus. Many of the species live also in Australia, or have nearly allied forms there. The great paucity of insects, the isolation of the species, and their affinity with those of Tasmania and

Australia, is probably due to a great destruction of the native species during the Glacial period, and the arrival since of several from the countries to the north-west. I do not know how else some of the facts can be explained, such as that of there being only eight butterflies, and amongst these some of wide distribution; and that of the Heteroptera there are thirteen known species belonging to thirteen different genera and nine distinct families.* Such gaps as these in the fauna of a country are as significant as the grooved and polished surfaces of its rocks, and the naturalist may as surely point to the evidences of the Glacial period as the geologist.

Mr. Wallace has also drawn attention to the large destruction of species of insects in the Chilian sub-region, evidenced by the great number of peculiar genera of beetles of extremely isolated forms, and I might multiply instances from the faunas and floras of southern lands, all tending to the conclusion that the southern hemisphere has been glaciated as much as, or more than, the northern; but I could not do justice to this phase of the question within the limits of this article, and I have only glanced at some of its most salient points with the object of indicating that the physical evidence of glaciation does not stand alone, but is strengthened by that of the present distribution of animal and vegetable life.

* Capt. Hutton, Trans. New Zeal. Inst., vol. v., p. 227.