III.—GEOLOGY.

Art. LVI.—*On the Hawke's Bay Pleistocene Beds and the Glacial Period.*

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Plates XLIII. and XLIV.

Part I.

At the upper end of Sturm's Gully, in the Town of Napier, and about 200ft. above sea-level, is a quarry that was opened several years ago by the contractors who are engaged in the construction of an artificial breakwater for the Port of Napier. The area known as Scinde Island on the maps, and on which the quarry is situated, is composed of limestones about the age of which much difference of opinion has been expressed. The limestones consist of an upper and a lower series, separated by fossiliferous grey and blue marls of varying material and thickness. In places the upper limestone has disappeared; in others it remains as large indurated blocks with a curiously smooth and rounded surface, and pitted here and there with holes which are filled with a brown mud-like material. This rounded and smooth surface is only noticed after the overlying beds of loessic clay and soil have been cleared away, when the smooth and worn appearance of the limestone at once attracts attention. The bed immediately overlying the limestone, and which replaces it over a portion of the island, is a brown mud-clay, with a certain admixture of pumice and scoriaceous material, containing here and there small grits of sandstone. This deposit follows the contour of the hills, and has no sign of stratification. It thickens out very much in places, where it appears to possess more of the characteristics of true clay, and is so used on the south side of the hills, where brick-making is largely carried on. There is no trace of animal life and but little of vegetable life in the bed, a single specimen of raupo (*Typha angustifolia*) being the only plant I have discovered. A careful inspection of the material, however, leads me to the opinion that the mud-clay has been burrowed by worms at a time when the material was perhaps covered with water. In several places the deposit has a kind of scale or slickenside formed over its surface, and when subjected to water-action for any length of time the clay has a tendency to swell and break away suddenly from the surrounding material. Over the Napier hills this brown mud-clay is not associated with any shingle deposits, but this is not the case in most of the other places where this clay is to be found. In the clays exposed between Sturm's Gully and the bluff overlooking the breakwater specimens of grit mixed with loessic mud are to be met with, whilst in the surrounding district extending from Tangoio to Puketapu the loessic clays are associated with shingle deposits in such a way as to suggest that the clays have been mainly derived from the shingle by the percolation of water. I have purposely directed attention to the smooth, worn, and rounded surfaces of the limestones, and to the characteristics of the loessic clays which either replace or overlie them, as they form the text upon which the following remarks are based.

Those who are acquainted with the topography of Hawke's Bay, or have read, with the aid of a reference-map, my description of the shingle deposits in this district, are aware how widely distributed these deposits are. It is a curious circumstance that the shingle deposits, so far as my acquaintance with the North Island is concerned, do not reach in a northerly direction to the 38th parallel of south latitude, and it is certain that the origin of the shingle must not be sought for to the north of that parallel. Shingle deposits are found in abundance farther to the south of that parallel, and they appear to reach their greatest development in the South Island eastward of the Southern Alps, the celebrated plain of Canterbury being made up almost entirely of such deposits. Years ago, when British and other geologists in the Northern Hemisphere were striving to interpret the life-history of the Pleistocene period by supposing the appearance of alternate cold and warm climates within certain limits of the north temperate zone, the ice or glacial theory took strong hold upon the leading geologists of New Zealand, and a number of papers appeared in the Transactions affirming the once large extension of the glaciers in the South Island, and pointing out that the Canterbury Plains are the outcome of a Glacial period, the formation "in their upper portion being morainic and in their middle and lower portion of fluviatile accumulations," the material for the latter being brought from the area within the glaciated districts. The late Sir Julius von Haast, in his "Geology of Canterbury and Westland," estimates that during the Glacial period the snow-line was 1,000ft. lower than it is in New Zealand at the present time. This estimate is a very small one, representing, as it does, only a difference of about 3 degrees of temperature; and this certainly would not be sufficient to bring about a glacial climate in the South Island. Those wishing to read an interesting summary of the views of writers on a supposed Glacial period in the South Island are referred to vols. iv., v., vi., and vii. of the Transactions. In the latter volume Mr. W. Travers reviews the opinions of Sir Julius von Haast on the "Supposed Pleistocene Glaciation of New Zealand," and, whilst believing that a Glacial period has taken place in the country, does not consider there was any more glaciation than ordinary during the Pleistocene period, and believes that the Glacial epoch of New Zealand took place during the Miocene period, soon after the elevation of the present mountains, which at that time stood some 4,000ft. higher than they do now. I cannot find from the Transactions that any paper has been written suggesting that a Glacial period took place in the North Island at the same time as the supposed one did in the South Island, although it might be assumed that any causes which produced, or tended to produce, a colder climate in the South Island beyond what is warranted by a difference in latitude and elevation must have affected, though in a less degree, the climate of the North Island.

Before inquiring as to whether this Island, and, in particular, whether Hawke's Bay, has been subjected to glacial action it may be well to inquire what remains there are in a country which are considered as evidences of a Glacial period. We are sure that this district has been affected time after time by the volcanic outbursts that have taken place in the interior of the Island, by the fact that volcanic products are to be met with over the entire country, and distributed in such a manner as to leave no doubt as to the way those products came to occupy their present position. And the same thing must be done in pursuing the inquiry as to whether a glacial epoch has ever occurred in this district. In England and other countries that are said to have passed through more than one glacial epoch the evidence for such is said to be found,—

1. In the distribution of moraines and drifts—the direct products of glaciers;

2. In the presence of lakes or tarns in mountainous districts;

3. In the finding of erratics or isolated rocks in places where no similar rocks are to be found, such as granites or conglomerates;

4. In the peculiar shapes of the hills or bosses where glaciers have existed;

5. In the scratchings or markings upon the hard rocks in places once covered by glaciers.

Evidence of this kind is considered to be conclusive of the former presence of glaciers in a district or country. The whole of such evidence may not be available, but this would not lessen the value of the facts in cases where it is satisfactorily established that moraines have existed, as moraines are the special products of glaciers.

The greater part of what was formerly the Provincial District of Hawke's Bay is connected with what is essentially an area of shingle deposition. The distribution of shingle and other allied deposits, including sands, pumice, clays, lignite, and a conglomerate, extends to the southward, and is equally diffused on the western slopes of the Ruahine Range. This shingle deposit is to be found even more widely diffused along the eastern side of the South Island, and there are many important reasons for supposing that in the earlier part of the Pleistocene period the area now known as Cook Strait was a land-area. On both sides of the strait the valleys are made up of Pleistocene deposits of shingle, and they almost suggest the possibility of all the valleys along the east side of both Islands having been at some portion of the period connected with an immersed area farther to the eastward of the present coast-line, the entire drainage from the watershed trending to the south-east.

We have seen that it has been stated by the late Sir Julius von Haast that the Canterbury Plains "have been formed in their upper portion by morainic and in their middle and lower by fluviatile accumulations." Whether the same thing has taken place in connection with the shingle deposits of this district is a question which is yet unsettled. Before proceeding to discuss the merits of the evidence available in favour of a Glacial period in the North Island it may be well to give a brief survey of the distribution of shingle and cognate deposits in the district more immediately connected with the water system of Hawke's Bay. This is the more necessary because at the present time there are two separate and distinct shingle-areas in the district, the one being the areas known as the Ahuriri and Ruataniwha Plains, the other certain areas which will be now described. The former areas are situated between the latter, and, in fact, they overlie some of the latter deposits which remained after a period of submergence that took place between the close of the one formation and the opening of the more recent one. The coast-line of Hawke's Bay, extending from Cape Kidnappers in the south to Te Mahia in the north, consists mainly of high cliffs, rising in places more than 400ft. above the sea. The only low coast is that which bounds the Ahuriri Plain, and extends from Tangoio to near the Kidnappers. At the mouth of the Wairoa River the cliffs are somewhat lower than to the immediate north or south; and near the south entrance there is a large exposure of shingle conglomerate, which has hitherto withstood the force of the heavy breakers that constantly roll in from the open ocean.

These conglomerates are found topping the hills to the right of the road between Wairoa and Te Kapu, and they strike across in the direction of the cemetery on the hills at the back of the Wairoa Township. I have seen no shingle between this p ace and Mohaka, but at the mouth of the latter river heavy conglomerates rest immediately on Miocene beds, at a height varying from 80ft. to 150ft. above sea-level. Traces of these conglomerates are to be found along the coast for several miles to the south, in the direction of the Waikare River, always topping the Miocene beds, and being situated in what appears to be an old valley leading to Lake Tutira, where, on the highest hills to the north of this lake, I lately saw shingle conglomerates and sands *corresponding to* the Pohui series. Large loose boulders were also seen, similar to those topping the Miocene beds on the sea-cliffs between Mohaka and Waikare. Isolated deposits of shingle are met with on the hills in the vicinity of Tangoio, and at Maraetara near Petane, at Redcliffe near Taradale, and on all the islands between Tangoio and Napier shingle deposits, with clays, &c., are exposed. Finally, all the hills extending from Havelock to the Black Reef, inside the Kidnappers, are made up of shingle sands and cognate deposits. I have already explained that the Pohui conglomerates are met with to the north of Lake Tutira. This, I believe, is the most northerly point reached by these beds. With respect to the shingle deposits that are exposed to the south of Tangoio, they are connected directly with more extensive deposits farther to the westward by means of the rivers draining into Hawke's Bay in the south: for example, the Esk or Petane River passes wholly through shingle and conglomerate deposits which are connected directly with the great conglomerate series in the Pohui district.

And the same remark applies equally well in the case of the Tutaekuri, Ngaruroro, and Tukituki Rivers in their upper and middle course. The area forming the Ahuriri Plain, across which these rivers pass in their lower course, is not connected with the deposits under notice. The former is much younger than the latter, and is the result of subsidence and refilling from some of the material of the older deposits mixed with new material from the upper waters of the rivers above named. All the shingle deposits through which the Esk, Tutaekuri, Ngaruroro, and Tukituki flow are at a much higher level than the rivers themselves, and they are often mixed with clays, sands, lignites, and other materials, as if they had once occupied lake- or swamp-areas. It is important to observe that the shingle and cognate deposits do not pass from one river-basin to another: that is, the area which really constitutes the water-parting between any two river-basins shows no traces of shingle deposition. In other words, there is no evidence that the shingle, which is well exposed in many places through the course of each river, merged in the several river-basins and covered the country from the westward to the place where the rivers emptied themselves into the sea or inland lake, as the case might be. Though no merging of the shingle deposits took place, either in the middle or lower course of the rivers named, it is found that these deposits are all connected with an extensive area of country flanking the Mangahararu, Titiokura, Kaweka, and Ruahine Ranges. This area is made up of grits, shingle, conglomerate clay, and lignite, and it extends in one continuous line, from north-east to south-west, for a distance of more than 120 miles. The whole of the country extending from Pohui, on the Taupo Road, through the Ruataniwha Plain to Woodville, is composed mainly of those beds. Traces of limestone are to be seen here and there, but generally the limestone has been displaced by the conglomerate and cognate beds in the whole of this area. In the shingle deposits no boulders of any large size are found, nor are there traces of erratics of a material different from the general characteristics of the rocks composing the conglomerates and shingle. Along the slopes of the ranges between Kereru and Pohui there are a few traces of larger and coarser material than is usually associated with the conglomerates, and farther to the south these deposits become most marked, as they form long transverse ridges, running almost at right angles to the direction of the Ruahine mountain-chain. The boulders composing these ridges are subangular, and are mixed with a friable clay, and are seen to overlie the older conglomerates, and, indeed, are unconformable to them. The greater portion of the Ruataniwha Plain appears to be made up of these beds, which, though younger than the conglomerates, are older than the present river-deposits, being evidently connected with the rivers when they flowed at a higher level and in much larger volume. These transition beds are Ruahine products, and they may be traced as offshoots from the mountains throughout their whole extent, but more particularly between Hampden and Woodville. The underlying conglomerates flank the mountains and dip at a high and uneven angle wherever exposed. On the western side of the mountains similar beds are met with, and they dip at an angle which suggests great changes since the time of deposition.

I have now given the distribution of the conglomerates, and what may, perhaps, be classed as drift deposits in this district. It will have been noticed that their main distribution is in a north-east and south-west direction, in what was apparently an immense valley which communicated with the sea on the east by several transverse valleys, which subsequently became the valleys through which the rivers from the western watershed pursue their course to the ocean.

The question next arises as to what occupied the area previous to the deposition of the conglomerates. I have already explained that generally where the shingle and conglomerates are absent limestone is present—limestone belonging to the same geological period as the Napier limestone. Where there are no clays in Napier the limestones are present, but where the clays are well developed the limestones are either absent, or their rounded surfaces and bouldery appearance testify to great denudation. Now, this rule holds good over the whole of the district, except that the shingle and conglomerates occupy the place of the loessic-clays. Previous to the deposition of the conglomerates the whole of the area between the east coast and the present volcanic belt of which Tongariro is the centre was covered with young Tertiary limestone belonging to the Pliocene period. This is proved by the fact that on the top of the Ruahine Mountains outliers of this limestone are found opposite the Kereru, and the range immediately to the east of the Kaweka Mountains is also made up of limestone, whilst similar limestone is to be seen farther to the west at a height of 4,500ft. above sea-level on the south end of the Kaimanawa Mountains.

Now, all the Pliocene deposits with which I am acquainted in this district are of marine origin, and it must be evident that great changes have taken place in the surface of the country since these deposits were formed. Either there must have been elevation to the extent of 4,000ft. or more, or there has been a lowering of the ocean to this extent. In any case the fact remains that to-day there is a difference in elevation of similar deposits in this district of more than 4,000ft., and, as they are all marine deposits, it may be supposed there has been elevation to this extent since the close of the Pliocene period. At the close of this period there were no mountains like the Ruahine and Kaweka Ranges, for the whole country to the south and east of Ruapehu appears to have been covered with limestone, and for some time after the elevation of the Pliocene beds had begun it would seem that the drainage from the volcanic centre was mainly to the north, east, and south.

At the present time the watershed of Hawke's Bay may be said to be limited by the Ruahine and Kaweka Ranges; but it is certain from the products such as are exposed for 300ft. or more at the Kidnappers that the watershed when these deposits took place was in the direction of the volcanic centre. Even before the mountains began to take definite shape it would seem that a large portion of the limestones had been denuded, and their place occupied by deposits made up sometimes of pumice and shingle, and sometimes, with pumice, shingle and lignites or clays. All these beds are largely developed in the vicinity of the Ruahine and Kaweka Mountains, and they are found covering the country, at an elevation of 2,000ft. or more, down to sea-level. The elevation of the Ruahine and other associated ranges produced important changes in the physical features of this district. From the appearance of the Pleistocene deposits, which certainly had been completed before the elevation of these mountains, it would appear that the places where the deposition took place were large trough-like areas, which acted as catchments for the material brought down from the volcanic district. At that time the whole of what is now sea, extending from the Kidnappers to Te Mahia, was partly covered with limestone and partly with shingle and pumice-beds of the Kidnappers type.

This large area which had been elevated during the Pliocene period, and had been partly denuded and covered by newer deposits, was again submerged during the elevation of the Ruahine Ranges. At the same time, what is now the Ruataniwha Plain was depressed several hundreds of feet, the elevation of the one area being in a measure balanced by the depressions within the areas named. It is not possible to say whether the Ruahine, Kaweka, and associated mountains were raised to a much greater height than they now are. Judging by the material distributed over this district, and which has come from these ranges, it would seem that the height has not been much greater than at present. Denudation has undoubtedly been very great in those mountains, as the filling-up of the Ruataniwha and other areas amply testifies; but there is little evidence on the mountains themselves to show that they have been subjected to ice-action, or that glaciers have had possession for any length of time.

I have already quoted Sir Julius von Haast on the probable lowering of the snow-line by 1,000ft. by some cause not readily apparent. But, if we assume that the Ruahine and Kaweka Mountains were under similar conditions, and that the snow-line was lowered for this Island by 1,000ft., it would then be impossible under present physical conditions for glaciers to exist on those mountains. In the latitude of Napier the snow-line is about 8,000ft. above sea-level, this being the height of the snow-line on Ruapehu. The highest peaks of the Ruahine reach a little above 6,000ft., and there is one peak on the Kaweka within a few feet of 6,000ft.; so that if we assume the same conditions to have existed in the North Island as in the South during the latter part of the Pleistocene period there was no portion of the mountains covered with perpetual snow. It may have been that the physical conditions, as regards climate and winds, were unlike what they now are, and that in the latitude of 39° or 40° S. glaciers existed at a much lower elevation. We know that in the Southern Alps the Franz-Josef Glacier, on the west side of Mount Cook, comes to within 700ft. of sea-level; whilst the Tasman Glacier, from the same mountain but on the eastern side, has its terminal face at an elevation of 2,350ft. above the sea. These glaciers are situated in a latitude corresponding to the south of France and north of Italy, in Europe; and, if physical conditions can exist in a warm temperate area like New Zealand so that important glaciers can descend to within a few hundred feet of sea-level, and be surrounded at the same time by arborescent ferns and a luxuriant vegetation such as are reported to exist in the vicinity of the Franz-Josef Glacier, it may have been quite possible for glaciers to have existed on the Ruahine and Kaweka Mountains, whilst at the same time a warm temperate flora such as now prevails flourished on the mountain-side and in the warmer valleys below.

On the top of the Kaweka Range there is a mountain-tarn, and many large boulders are lying about. Farther to the south there are peculiar terrace-like walls, and there are also traces of what I suppose are moraines, made up of subangular stones lying in parallel bands, and arranged in as regular a way as if put down by human hands. On the Ruahine also there are several large areas covered with blocks of sandstone, and there are tarns and deposits similar to those on the Kaweka. Assuming that these regularly-arranged rocks are terminal moraines, they only serve to show that small accumulations of ice have existed on the mountains, but that the ice did not descend lower than 4,500ft. from sea-level. But a difficulty presents itself on the supposition that no glaciers other than small and unimportant ones have existed in the western mountains. I have referred to deposits coming from the Ruahine and overlying the older Pleistocene deposits on the western side of the Ruataniwha Plain, and, in fact, extending from Hampden to Woodville. These deposits consist of long ridges of rough semiangular shingle and boulders, mixed with clay and loose soils, running almost at right angles to the mountains, and terminating on the plains in high faces or bluffs from 20ft. to 50ft. in height, with a somewhat steep and even overhanging slope. These ridges run for miles back towards the mountains, widening as they go, and all of them subsequently merge where the slope is suddenly terminated by a deep longitudinal valley which intervenes between the ridges and the foot of the mountains. Two years ago in August I stood on the margin of this valley, which was then white with snow, and the question came to my mind how this deep valley had been scooped out, as the scooping had evidently taken place since the formation of the ridges. Was it by means of water or ice, or was the valley simply a great rift that had been made by the elevation of the mountains? The evidence in favour of ice- and water-action seemed to me the more probable, and this opinion has been strengthened lately by reading the account given by Wright, in "Man and the Glacial Period," page 30, on the formation of what are known as "kames," or ridges. He says, "I have witnessed the formation of a long ridge of gravel by the gradual falling-in of the roof of a tunnel which had been occupied by a subglacial stream, and over which there was deposited a great amount of morainic matter. As the roof gave way this was constantly falling to the bottom, where, being exempt from further erosive agencies, it must remain as a gravel-ridge or kame."

The extreme length of the ridges to the west of the Ruataniwha makes it improbable that they were formed solely by the action of ice; but the products and the arrangement of the material are such as to suggest drift accumulations where water has played an important part. For years I have endeavoured to find out how such striking landmarks as those to be seen near Hampden and Te Ongaonga, on the Ruataniwha Plain, could be formed, and during the flood in this district in December last year I noticed on the beach at Waitangi, near Farndon, that ridges had been made by the waves of the sea washing over the beach and carrying shingle into a backwater area connected with the Ngaruroro River. These ridges had faces and an outline corresponding in every way with those described as facing the Ruataniwha Plain on its western margin. Geikie, in his Geology, page 892, mentions kames, but is doubtful as to the way they are formed. There is one other place near the mountains that requires notice. Between the Kaweka Range and a lower line of hills farther to the east, and known as Blowhard, there is a deep and somewhat wide valley of sterile country composed of a kind of brown tufaceous clay containing here and there peculiar patches of subangular pumice pebbles. Interbedded with this deposit are very large boulders and rough stones of all sizes and shapes. The valley is parallel with the Kaweka Range, but does not now receive the drainage from it. The country is much broken, and the limestones which top the hills at Blowhard, both when *in situ* and when lying about in large blocks, contain flutings and ridges, the origin of which it is hard to interpret. There are several lakes within the area named, and the coarse accumulations of shingle, &c., in the vicinity may represent the products of glaciers. But glaciers can only exist in temperate climes under special conditions as to elevation, moisture, protection from warm winds, and a suitable basin of accumulation of *névé* or *firn* to provide a supply for the glacier, and these conditions are certainly not possible at the present time either on the Kaweka or the Ruahine Mountains.

Nor do the immense deposits which represent the Pleistocene older period, such as are scattered over the district outside the area just described, supply satisfactory evidence in favour of an extended glacial cap on the mountains and reaching to the plains below. The pumice deposits in many places are more than 100ft. in thickness, and the shingle, though not composed of material derived from lava or other volcanic products, contains many specimens of trachyte; and, judging by what was thrown from the several craters during the eruption at Tarawera in 1886, it is quite possible that all or most of the shingle which is interbedded with the pumice was thrown from a volcanic orifice. Whether this was the case or not, we are forced to recognize that the time when the deposits took place was one of great volcanic activity, and when most of the country was covered with volcanic ejectamenta. The blue clays, with many pumice pebbles scattered through them, and containing an abundance of marine shells, show that differential earth-movements were in progress whilst the Lower Pleistocene beds were being deposited. These blue clays are succeeded by pumiceous sands and lignites at the Kidnappers, and by fine pumiceous mud-clay at Poverty Bay, which are crowded with leaves of every variety and size. In the Patangata beds, the *Unio* and other fresh-water shells are found in abundance in the lignite beds; and at Ormond and Gisborne, in the Poverty Bay district, specimens of a small fish like the inanga, so common in the underground streams flowing from Tongariro into Lake Rotoaira, are common, as also a *Unio* and other shell-fish. In the same beds feather impressions have also been obtained. These beds, in which so many traces of animal and vegetable life are found, show that the land was probably rising at the time of their deposition, and they further show that the country, in part at least, was covered with a varied vegetation, possessing all the characteristics of the present flora.

I do not profess to be able to distinguish the different kinds of trees which characterized the Lower Pleistocene period simply from the leaf-impressions in my possession, but there can be no doubt they illustrate the flora not of a locality, but of a large district in both vertical and horizontal space. And this leads me to one of those aspects in connection with so-called glacial phenomena that have always appeared to me to receive too scant attention at the hands of the glacialists. Because plants indicating a cold climate are found associated with those of a warmer climate it has been generally assumed that a colder climate prevailed, whilst the contrary must have been the case. Every basin of accumulation must be considered in its flora and fauna as representing a horizontal and a vertical area. Take, for example, the deposits now going on in Hawke's Bay from the Rivers Ngaruroro and Tukituki. These rivers carry down to the sea the material from the whole of their drainage-basins. Leaves from the slopes of the Ruahine and Kaweka Ranges will be mixed with plants from the warmer hill-slopes bounding the Heretaunga Plain, just as the shingle and finer rock-material from the one area will be mixed with the coarser material from a different area at the spot where deposition is most favourable. Now, when the deposits underneath the Bay come to be raised, as they very probably will, the leaves which have left their impressions on the finer sediment will illustrate first a warm temperate climate, and second a climate no less than 20 degrees lower than what we now enjoy in Napier. But the verdict of the glacialists as read by their interpretation of fossil life to-day would be that cold summers and mild winters formerly prevailed in this district. Thus Professor James Geikie, in his "Fragments of Earth-lore," p. 265, says that "during one period of Pleistocene clement winters and cool summers permitted the wide diffusion and intimate association of plants which have now a very different range. Temperate and northern species, like the ash, the poplar, the sycamore, the fig-tree, the judas-tree, &c., over-spread all the low grounds of France as far north at least as Paris."

But surely this is not dealing with the subject of the geographical distribution of plants on lines which the study of physical geography points out as necessary if we are to arrive at a proper estimate of the work done by rivers in the matter of erosion and reconstruction. My illustration might be carried to an inland sea—the Mediterranean, where rivers such as the Rhone and the Po from glacial areas and the Nile from a tropical area pour their burdened waters into the same basin of accumulation. By means of currents and gravity the material from the different rivers will tend in the direction of the deepest portion of the basin, and the floral representatives from Europe and Africa will eventually merge or form parts of the same continuous area of deposition. Thus the same statement might be made with respect to the plant-impressions from these areas as is now made with regard to the Pleistocene period—that clement winters and cool summers permitted the growth of tropical, temperate, and arctic plants within the same area. Surely the fossil leaves and plants, specimens of which are open for the inspection of members, from the Pleistocene deposits of this district do not tell us anything more as to the kind of climate which prevailed at the time of their deposition further than to limit the bounds of temperature within the basin of accumulation both in vertical and horizontal space. And there can be little doubt, it seems to me, judging by the character of the leaf-impressions so widely scattered among the deposits of the district, that a fairly warm climate prevailed in the lowlands during the Pleistocene period not unlike that now experienced along the east coast of this Island, whilst in the uplands the contrasts of heat and cold were no wider than they now are between Napier and the volcanic zone.

But, assuming that the Pleistocene deposits described by me as being so widely diffused over this district afford evidence of glacial action, I do not see that even then the climate that prevailed was necessarily cooler than what it now is in the lowlands. It has already been pointed out that glaciers reach within 700ft. of sea-level in the South Island under special conditions. This represents an elevation of about 1,600ft. for Hawke's Bay; but climate depends upon many modifying influences other than latitude and elevation, and, if these are present, as in the case of the Franz-Josef Glacier, there appears no reason why glaciers could not exist in the Ruahine and Kaweka Mountains, even though the climate of the district is represented by a warm temperate flora.

In England, Europe, and America the Glacial period is recognized to have taken place during the same period as characterizes our pumice, shingle, and conglomerate deposits. It is supposed, however, that during the Pleistocene period a succession of warm and cold epochs took place in such a way that a warm epoch was succeeded by a cold one, and that this alternation from warm to cold continued until the close of the period. Geikie, in "Fragments of Earth-lore," page 319, enumerates five such glacial and five interglacial epochs as having occurred in Europe. The conclusion is based upon the fossil flora and fauna that have been found in the deposits which are referred to this period, and he says that the "cold conditions that culminated in the Glacial period began to manifest themselves in Pliocene times"; whilst Heer, in his "Primeval World of Switzerland," remarks that "from the Miocene to the beginning of the Quaternary period, during a comparatively short time, a complete alteration took place, and the temperature of the Glacial period sank below the present level." It is fully recognized that, so far as Europe and North America are concerned, the Pleistocene deposits are such as to show great alternations of level in the surface of the land, with corresponding changes in the fauna and flora, and that the climatic contrasts during the period were very marked.

It is necessary, however, to guard against too hasty conclusions on this important question of climate, for in the "Quarterly Journal of the Geological Society," No. 198, and published in May last, Mr. E. J. Newton, F.R.S., in an important paper which he communicates to the society, says: "Much interest attaches to a correct knowledge of the climate prevalent during the Pleistocene period, indications of which are to be found in the arctic fresh-water bed of Norfolk, the boulder-clay, and the animals which are found in the various deposits. The probability of alternations of warm and colder periods during Pleistocene times has long been advocated; but it has been thought possible by some that, with a more continental climate than at present prevails in Britain, the alternation of summer and winter might be sufficient to account for the seeming mixture of species. Whatever may be the cause, the Pleistocene fauna as found in the brick-earth, gravel, and cave deposits seems to be of a mixed nature, the species finding their nearest allies at the present day living under widely diverse climatic conditions. Some of the Pleistocene species thus indicate extreme cold, others point to distinctly steppe conditions, while a third seems just as strongly to prove the prevalence of a warm climate. These difficulties will doubtless eventually be removed, but in the meantime too much stress must not be placed upon the range of Recent animals as an indication of the past, seeing that there are many circumstances besides climate which help to determine the distribution of species."

This quotation shows that the inferences drawn from finding an intermixture of animals representing warm, temperate, and cold regions of the earth must be accepted with caution until we are better acquainted with the climatic conditions that prevailed during the Pleistocene times. But the many changes and the contrasts which characterized the Pleistocene period of Europe and America do not appear to have taken place in New Zealand during the period recognized as Pleistocene. As remarked by Professor Hutton in vol. viii. of the Transactions, p. 386, "The evidence is against the idea that a colder climate formerly obtained in New Zealand." This statement is founded on the character of the fossil shells found in certain Pleistocene beds examined by him, and he arrives at the conclusion that "since the Miocene period there can have been no reduction of temperature sufficient to account for the former extension of our glaciers." This conclusion supports my own, which is based upon evidence derived from entirely different sources. As pointed out above, the fossil leaves which are scattered through the lignite and pumice beds of the Lower Pleistocene period do not support the view that the climate differed in any material point from what we have at the present time, as represented by plain and mountain. It may perhaps be urged against this that the deposits containing the fossil leaves represent an interglacial period, and that the shingle and conglomerates above and below the leaf-beds represent two or more Glacial periods. But this is impossible, for the reason that all the beds belonging to the Lower Pleistocene deposits are strictly conformable to one another, and it would be manifestly impossible for such to be the case had the beds been laid down in different epochs. To me it is quite evident that the shingle was carried down in a manner similar to the pumice, and probably from the same source, but in what way the deposition took place—whether into a lake or estuary, or into a series of depressions which afterwards became part of a river-bed—I cannot say. During the deposition of the lower beds of the Pleistocene period—that is, during the time which followed the elevation of the Pliocene limestones until the elevation of the Ruahine and Kaweka Ranges—the climatic conditions prevailing in the North Island seem to have undergone little or no change. The conformity of the beds shows this to be so, and the fossil flora and fauna testify to the fact. If glaciers of any size ever existed on these mountains the products are to be found on the Ruataniwha Plain, in the valley between Blowhard and the Kaweka Range, and in the kames, which have been described as forming such a characteristic feature along the western margin of the Ruataniwha. The evidence here is much stronger than on the mountains themselves of the former existence of glaciers, and it is also stronger than that supplied by the distribution of the so-called loessic clays, the high-level shingle deposits, or the rounded and worn limestones on the Napier and adjacent hills. There, if anywhere in the district, is evidence forthcoming of morainic accumulations of drifts and of glacial products generally. But unless the elevation of the mountains was much greater than at present, which seems very unlikely, some other cause must be found to account for their existence should it be found that glaciers have occupied the mountains and valleys along the western part of this district.

In any case it appears that the reason urged for the existence of a Glacial period in the South Island by Haast, Hutton, and Travers — namely, a great elevation of the land — can hardly apply to this Island, as there is nothing whatever to show that the mountains were ever higher than they now are. Evidence of elevation and depression since the close of the Pliocene period is to be met with everywhere, but the elevation has been insufficient without the operation of other causes to bring about an ice period, nor have the depressions had any apparent effect upon the flora and fauna. In Europe we are told the depression of the land "preceded and accompanied the appearance of the ice-sheets," and, what is stranger still, "the submergence had a remarkable relation to the extent of glaciation." It will be noticed how unlike the periods known as Pleistocene were in the Northern and Southern Hemispheres, as judged by the facts at present collected. In the north the period was one mainly of depression; in the south we are told it was one of elevation. In the north the surface-changes are said to have been frequent, depression and re-elevation following at regular intervals; whilst in the south few changes took place, and the physical conditions remained almost constant. It is difficult to account for such diverse interpretations of a period which has so many things in common in both hemispheres, and it may be that the time will come when a more perfect knowledge of the physical conditions that prevailed on the earth during the Pleistocene period will enable glacialists to harmonize what now presents so many contradictions, and to simplify phenomena which are too often interpreted so as to fit in with some theory or other that has received the approval of geologists simply as a working theory and nothing more.

Part II.

In striving to harmonize what appears so contradictory as to the sequence of events connected with the Pleistocene period in the Northern and Southern Hemispheres, it may be well to refer to certain recognized facts connected with the sun and the earth in relation to the other portions of the solar system. From the sun the earth receives its heat, which reaches the surface through the medium of the atmosphere. Of every 100 units of heat that comes within reach of the aerial ocean Alexander Woeikof says that only about 60 per cent. reaches the earth's surface at the equator, 55 per cent. at 20° north and south, 41 per cent. at 40°, 24 per cent. at 60°, and only about 10 per cent. at the poles. Hence much more than half of the amount of heat which comes within the limits of the earth's envelope passes back into space without doing any effective work whatever on the surface of the earth. Now, there is nothing that we know of in nature which can give off any portion of heat for an indefinite length of time without lowering or diminishing its own effectiveness. A ton of coals has so much available energy and no more: and so with respect to the energy of the sun. He cannot go on for ever sending his heat and light to our own and other worlds without loss of energy, for the sun, like everything else of which we are cognisant, must have had a beginning, and he will also have an end. If such is the case, it follows that the supply of heat which the sun has given and is giving off is a varying quantity, diminishing slowly and surely as periods roll on. It may be assumed, therefore, that much more heat was given off from the sun during the Pleistocene period than is given off now; hence more heat must have reached the earth in each zone than is the case at the present time. It follows also that, so far as the heat from the sun affects the earth, the latter was, on the average, warmer in Pleistocene times than in Recent.

Now, the question of temperature is one of great importance in connection with all aqueous and aerial movements. If the sun is the source of a varying supply of heat, it is certain that the earth, if the nebular theory is assumed, is also parting with a varying quantity of heat. This earth cannot possibly remain at the same temperature for an indefinite period of time, for, without considering the amount of heat supplied by the sun, it follows from the law of exchanges that this earth is parting with some of its own heat into outer space. It is true the amount is small, being only $\frac{1}{36}$th of a degree per annum, but continued for a long period of time the quantity becomes of high importance. From the equator, as we proceed either in vertical or horizontal space, the cold increases at a progressive rate, so that on the equator at an elevation of 15,000ft., or in round numbers, say, three miles, a place is reached which is always below the temperature of frozen water; and the same may be said with respect to temperature beyond the arctic and antarctic circles, in the direction of the poles. This condition of things could not always have been so: in fact, the temperature of the earth at one period of its history was such that unless the mountains were much higher than they now are no snow could have remained upon them, even towards the poles, and frost and hail must have been unknown. At that time the temperature of the atmosphere must have been such that much more aqueous vapour was held in suspension than is now possible, as the quantity of vapour is limited by the temperature of the air. Thus at the present time a cubic foot of dry air weighs about 1¼oz.; and this at a temperature of 60° Fahr. will absorb about 5½gr. of vapour, and no more. At a temperature of 80° Fahr. the same quantity of air will absorb about 11gr. of vapour, and so on according to the degree of temperature of the atmosphere, it being found that in order to saturate a given space like a cubic foot the vapour required increases as the temperature increases. If, as is now recognized by most geologists, the earth has reached its present condition by a slow process of cooling, it follows that the temperature of the earth itself, irrespective of the heat received from the sun, was greater than it now is, and with the additional solar heat it is certain that greater contrasts of heat and cold must have prevailed on the earth's surface and its attendant atmospheric envelope.

But if we assume that during the Pleistocene period the earth was warmer, that evaporation was possibly greater, and the movements of the atmosphere and the waters of the ocean were more pronounced than they now are, it is of the highest importance to understand the effect of increased evaporation as a diffuser of heat over the earth's surface. For example, a pound of water at boiling-point absorbs during its evaporation as much heat as would raise 5½lb. of water from freezing-point to boiling-point, and this without increasing the temperature of the vapour. If we consider the vast quantity of evaporation that takes place in the warmer zonal regions of the earth, it must be evident that an enormous amount of energy is expended in this constant conversion of water into vapour, and that large quantities of heat are transferred in this way from the warm to the colder zonal regions. As pointed out by Balfour Stewart, "Our own earth is . . . an engine having the equatorial regions as its boiler and the polar regions as its condensers, for at the equator the air is heated by the direct rays of the sun, and we have there an ascending current of air, up a chimney as it were, the place of which is supplied by an indraught of colder air along the ground or floor of the world from the poles on both sides. . . . Very often, too, aqueous vapour as well as air is carried up by means of the sun's heat to the upper and colder regions, and there deposited, in the shape of rain or hail or snow, which ultimately finds its way back again to the earth, often displaying in its passage immense mechanical energy." But what becomes of the heat—the latent heat which was absorbed when the water was passing into vapour? That it does not return to the earth is evident, for the rain or snow or hail, as the case may be, is much below the temperature of the vapour from which it was derived by condensation.

In this process of carriage and condensation a large quantity of heat becomes dissipated, and is finally lost by passing away into outer space. Thus, although great stores of heat are carried from the warmer to colder regions of the earth by atmospheric agencies, in the performance of this work much extra heat is demanded, and it is by the expenditure or partial loss of this heat that the work of condensation is carried on. The nearer the product of condensation is to the freezing-point the greater the quantity of heat left behind, and subsequently diffused in space. Thence it follows that the wider the temperature contrasts between any two zonal regions the greater must be the quantity of heat which passes between them. But although the earth was warmer and the sun gave out more heat to the earth in Pleistocene times, it does not necessarily follow that the climate of Europe, America, and Australasia was warmer than now. Climate is the average state of the weather in any district or country based on a long period of observations, but the causes which regulate the weather are by no means well understood, as the people of Hawke's Bay have been made fully aware during the past twelve months. The great modifiers of climate are latitude and elevation; but there are other modifiers, which, though second to those named, have yet an important influence on the climate of a country. At the present time Europe maintains but few glaciers except in the Alps and northern Scandinavia, and none are met with in any portion of the British Isles. During the Glacial period nearly the whole of western Europe is said to have been covered with ice, and, as already pointed out, the period is said to have been one mainly of submergence. None of the Alpine glaciers now descend below the level of 4,000ft.; there are no glaciers in North America of large size or descending below the 4,000ft. level; so that it may be supposed the climate of Europe in Pleistocene times was from 10° to 15° below the average temperature of that continent at the present time.

Considering the latitude of the area in which glaciation is said to have taken place, it seems that some causes which do not now exist must have operated to produce such unusual climatic contrasts as are said to have characterized the Pleistocene period of Europe and America. The difficulty which presents itself here is not so much in the wide extension of the glaciers as in the vast amount of condensation that must have taken place beyond the snow-line, in order to provide a *névé* or *firn* for the supply of the glaciers. For a glacier is simply an ice river below snow-line with its source above snow-line, and the very fact that glaciers exist is evidence in itself that below the snow-line the temperature is more than sufficient to melt the ice were the supply from the *névé* not so great. The movement of the Franz-Josef Glacier in New Zealand to within 700ft. of the sea-level, and far below the limit of perpetual snow, shows that such a thing is possible. But a glacier of this kind is clearly dependent on some special cause. It is not possible to conceive of a glacier unless on the assumption of a source of supply in a region where water is never found other than in one of its crystallized forms. The "snow-line" implies that everywhere above that line the temperature of the air is such that condensation produces either snow or hail. Cut off the supply or *névé* from the Franz-

Josef and Tasman Glaciers and they will disappear in a definite time, as estimated by the average annual temperature of the area they now occupy; and the same thing must have held good in Pleistocene times if we assume that the same physical conditions existed then as now. But Geikie says that the Pleistocene period was one of depression in Europe, although, so far as Switzerland is concerned, Heer appears to think that the Alps were somewhat higher than at present. In any case, if glaciers covered the areas they are said to have covered in Europe, America, and elsewhere, there must have been special areas for the accumulation of snow to supply those glaciers. Nor can we conceive of such areas being below the "snow-line," as it is at present understood. But was the snow-line higher or lower during Pleistocene times? This question is a difficult one to answer, because, if the temperature of the earth was warmer—which has been assumed—it follows that the "snow-line" would be, on the average, higher.

The question of climate, however, is one of much difficulty, as the distribution of the land, the height of mountains, the direction of winds, of currents, and of mountain-chains, all tend to modify and influence the temperature of a country. The Gulf Stream that washes the western shores of Europe causes countries like the British Isles, Denmark, and Norway to enjoy a temperature much higher than what is enjoyed by the people along the eastern shores of North America in similar latitudes, and whose shores are washed by the arctic return-current. It is estimated that not less than half the heat received from the sun within the torrid zone is carried by ocean-currents to the north and south, for diffusion among the colder waters of the ocean. But it is quite possible, and, indeed, very probable, that the land- and water-areas were differently arranged during Pleistocene times from what they now are. A cold current passing along western Europe would so modify the climate that glaciers would certainly increase in size, and the conditions of the countries named above would become greatly modified. Assuming that the glaciers have existed in Europe, America, and elsewhere during Pleistocene times, and assuming also that the facts as to elevation, depression, and temperature are such as have been stated, it seems hardly possible to harmonize the differences except on the supposition that some cause outside the earth itself was operating to bring about the conditions named.

Many theories have been offered to account for the incoming of a cold period and the return to a normal period of temperature over an important portion of the earth's surface. Heer says, in his "Primeval World," that "from the Carboniferous to the Cretaceous period no climatal changes can be proved to have taken place; whilst from the Miocene to the Pleistocene (Quaternary) period, during a comparatively short time, a complete alteration took place, and the temperature of the Glacial period sank below the present level." Such a statement, coming from so high an authority, should be received with due respect; but, if we accept the statement as covering the actual facts, it seems to me we shall be led into mazes which go rather to show that the earth in all its developments is rather the product of chance than of a definite law of progress. Was there no change during the thousand centuries that intervened from the Carboniferous to the Cretaceous period? Denudation proceeded, new life began and ceased to be, and yet we are told that there was no climatal change! It is not possible to prove by actual experiment that climatal change is constant and ever-active, but the law of change operates, and, as far as we know, has always operated, through everything in nature, and, if it is recognized that heat is passing, and has passed, from the sun and this earth since the time when the latter was a gaseous mass, it needs no proof to show that climatic changes, however small, must have gone on from the Carboniferous to the Cretaceous period, just as they have gone on since the Cretaceous till now. Had there been no climatic change, whence would have come the differentiations in the animal and vegetable kingdoms? With a warm earth, and a warmer sun than now, the earth contrasts in the early periods of life were less marked than now. Every moment since the earth began to be habitable for the support and maintenance of life, life contrasts have been increasing in the exact proportion to the increase in the differentiations and adaptations in the animal and vegetable worlds. As the heat diminished there were more places adapted to the existence of life, or, in other words, the activities for the maintenance of life increased and extended. This extension brought about adaptation, and so it has been that time, multiplied by climatic change, has produced what we have to-day as the total product of all geological change.

But do those changes proceed at a more rapid rate to-day than they did in the earlier periods of geological history? I think so. Movements are greater or more rapid between particles of the same substance in exact proportion to their contrasts in the matter of temperature. The mixture of two pints of water, one at 90° of temperature and the other at 92°, would be much slower than the mixture of the same quantity of water at 45° and 100° respectively. The law of exchange comes in here, and the movement in the latter would be more active because the contrasts are greater.

The same applies in the case of air, strong winds being the result of wide contrasts of temperature combined with the tendency which is found everywhere to make everything of the same mean or average heat. In the earlier periods of the earth there was a greater closeness of temperature in the waters of the ocean than there now is, just as there was in the temperature of the air. There could be no sea or ocean until the temperature had fallen below that of boiling water, and when condensation began the water contrasts were small, and whatever animal and vegetable life existed was limited by the closeness of its contrasts. This was at the beginning of life in this earth of ours. Since then contrasts have increased as each new geological period has come into existence. Loss of heat in the earth, followed by contraction, has brought about increasing contrasts, and these have been followed by the rapid multiplication of differentiation adapted to the new conditions. Now, are we to suppose that this condition of things has not been continuous, and that climatic changes, with their attendant modifications of animal and vegetable life, had reached their maximum of differentiation, to be followed by a throw-back period, which accords with the sequence in the order of animal and plant life such as existed at the time when the Glacial period is said to have begun?

This Glacial period has been generally recognized by all the geologists of Europe and America, and the facts are such that it is evident glaciers or aqueous movements must have existed to a far greater extent than they do to-day over certain areas of the earth's surface. But, whilst granting this, is it necessary that causes should be sought for outside the ordinary physical phenomena which regulate the surface-changes such as are now going on? Is it possible to suppose that at some period of the earth's history a fresh-water lake could be sustained from the surplus drainage of an area equal in extent to that which is said to have been glaciated? For, if so, there appears to be no greater difficulty in supposing that with a slightly higher elevation the same amount of condensation could take place, and under special physical conditions like those now existing for the production of the Tasman and Franz-Josef Glaciers in New Zealand a so-called glaciated area could be produced equal in extent to what is said once to have existed in Europe or America. Let the fact be remembered that a Glacier is a secondary product, representing the surplus condensation beyond the snow-limit. As soon as the *névé* or *firn* exists there is a tendency in the plastic mass to move; but the movement is only possible below the snow-line so long as the supply is in excess of the melting-capacity of the sun's rays acting on the mass. The glaciated area of Europe represents the excess of cold in the annual balance between the heat of the sun above and below the snow-line; but the heat below the snow-line may be equal to the maintenance of a warm, temperate flora, and yet be insufficient to melt the large accumulation of glacial ice from an area beyond the snow-line favourable to deposition and accumulation such as must have existed in order to produce glaciers like those which are supposed to have covered north-western Europe and a large portion of America, north of the parallel of 50° N.

The warm temperate flora of our own country in the midst of glaciers which descend to within 703ft. of sea-level shows that under favourable conditions glaciers can exist in close proximity to a rich and varied flora, capable of maintaining not merely an abundance but also a variety of animal life. But the seasonal contrasts such as prevailed in glaciated districts may have been even wider than those now prevailing within a given vertical and horizontal area, if we suppose, as is very probable, that the water- and land-areas were very different from what they now are. The surface of Europe shows that great earth-movements must have taken place during the later Tertiary period, and these movements were necessarily accompanied by the disappearance of some and the appearance of other river-basins. This fact, it appears to me, is too much over-looked at the present time by geologists. It is too often forgotten that denudations, aerial, aqueous, and æolian, are constantly modifying and destroying river-basins and bringing into being new ones; so that at the close of a period the differentiations may be supposed to have reached their maximum, there being numerous river-basins of small size separated from one another by low elevations; whilst the commencement of a period sees few rivers, of mighty size, the drainage of a single river embracing what is now understood as a "river system." This latter condition is, no doubt, what existed at the beginning of the period known as the Pleistocene, when the physical changes were such as to produce wide contrasts within the same area of vertical and horizontal space.

And that these contrasts existed seems to me assured if we consider what great varieties of aerial pressure are possible on the earth's surface at the present time in consequence of the inequalities of surface. First, let it be assumed that the land-area covering the earth is one-fourth that of the water-area. The average height of this surface above sea-level is 2,660ft. At sea-level the pressure of the atmosphere is on the average 15lb. to the square inch, which represents 31in. of barometric pressure. At 2,660ft. the pressure of the barometer is 28in., which corresponds to 13·5lb. to the square inch. By the graphic method this would give an average pressure for the whole earth's surface at sea-level of 14·625lb. to the square inch. Fig. 1:—

Pressure of Atmosphere.				
Water. 15lb.	Water. 15lb.	Water. 15lb.	Land (2,660ft.). 13·5lb.	Total for Earth. *Av.* 14·625lb.

Second, let it be supposed that the same area of land existed at the beginning of the Pleistocene period as at present, but that the contrasts were wider, and that the average height of the land was 10,200ft. The barometric pressure, assuming that the same aerial envelope surrounded the earth, would then have been 21in., which is equal to 10lb. to the square inch. This would give for the remaining three-fourths represented by the water-surface a pressure of 16·6lb. to the square inch, the height of the barometer over the same area being 33·33in. Fig. 2 illustrates this by the graphic method:—

Pressure of Atmosphere.				Height of Barometer in Water.
Water. 16·16lb.	Water. 16·16lb.	Water. 16·16lb.	Land (10,200ft.). 10lb.	33·33in.

As a third example, let it be assumed that half the earth's surface was occupied by the land at the opening of the Pleistocene period, the average height being 5,620ft. The barometric pressure over the land would average 25in., corresponding to 12·1lb. to the square inch. This would give a surface pressure over the other portion of the earth amounting to 17·15lb. to the square inch, the barometer showing a height of 35·43in. Fig. 3 illustrates this by the graphic method:—

Pressure of Atmosphere.	
Water, 17·15lb. bar. pressure to square inch.	Land, 12·1lb. bar. pressure to square inch.

We know the physical conditions resulting from the atmospheric pressure as shown in fig. 1, as these conditions exist now; but what would probably be the characteristics of the animal and vegetable life assuming that the earth presented either of the conditions illustrated by figs. 2 and 3? Under fig. 1 the temperature contrasts may be assumed to vary directly as the pressure; consequently the land and water contrasts at the present time are, on the average, comparatively small. But those contrasts widen under the conditions described in fig. 3, and they increase still more under the conditions assumed to exist in fig. 2. Now, it seems to me that either of the conditions illustrated in figs. 2 and 3 would be sufficient to bring about results such as the flora and fauna of the Pleistocene period show to have existed before, during, and after what is said to have been the glacial era. A pressure of 16·16lb. to the square inch under No. 2 condition, or of 17·15lb. under No. 3 condition, would have produced strong contrasts in the animal and vegetable world, for on the one hand the temperature in the area approaching the sea-level of the earth's surface must have been high, whilst in close proximity the high lands would undergo all the rapid changes of temperature such as one meets with in the higher regions of the atmosphere, where the air is so rare that it is unable to hold much moisture, and, as a result, radiation takes place at a very rapid rate.

Here, then, I think we may look for light in explaining the phenomena of the Glacial period, with its antecedent and subsequent changes. In his "Fragments of Earth-lore," page 270, Geikie says that "the Glacial, Pleistocene, and Post-glacial periods are not sharply defined, but merge," and he would like "one general term to include both. They form together a tolerably well-defined cycle of time, characterized by its remarkable climatic conditions, which were most strongly contrasted in the earlier stages of the period. Also, it appears that various oscillations of surface appear to have taken place again and again in the earlier and later stages of the cycle." The contrasts in temperature which must have taken place on the earth's surface during the progress of the physical changes such as I have shown to be possible without the help of external causes would produce all those characteristics which the glacialists say existed during the period claimed by them as glacial; but it further helps to explain why traces of that period are not to be found over the entire land-area known to geologists as the Pleistocene. The surface of the earth does not undergo depression and elevation synchronously. In one place areas may subside, in others they may be elevated, and representing the same geological period, and it may be that in one Pleistocene area the fossil life — both the fauna and flora — may show wide climatic variations, whilst in another there may be hardly a trace of such. In any case there seems to be no need to seek for external causes to bring about the cold period which marks the fossil fauna and flora of the later Pleistocene times. Earth-movements in combination with atmospheric pressure are sufficient to bring about all the physical changes necessary, and the conditions I have offered in explanation are capable of producing all those phenomena which are characteristic of the period preceding, during, and following what is generally known as the Glacial period.

Art. LVII.—*On the Occurrence of Moa-footprints in the Bed of the Manawatu River, near Palmerston North.*

By H. Hill, F.G.S.

[*Read before the Hawke's Bay Philosophical Institute, 9th July, 1894.*]

Plate XLVII.

During a brief stay at Palmerston North, in February last, my attention was directed by Mr. H. J. Gilberd, one of our members, to some footprints of a bird he had lately discovered in the bed of the Manawatu River, not far from his place of residence. Being well acquainted with the character of the area in which similar footprints are found at the mouth of the Turanganui River, and having several of the footprints in my possession, I was curious to see whether the footprints and the deposits bore any resemblance to one another in the two localities. The place where the footprints under notice were found is situated towards the right bank of the Manawatu River, and about 6ft. above water-mark at the time of my visit. The place, however, must be covered with water, or nearly so, during the winter season. The top of the river-bank would be about 18ft. above the deposit containing the footprints. A recent flood in the river had washed away a portion of the river-bank, and a number of large-sized logs had become exposed, all of them lying parallel to the present flow of the river, and suggesting a different direction or flow at the time of their deposition. The deposit in which the trees are found is an alluvium running into a bluish sandy clay, which, however, does not appear to be of any large extent, as a shingle conglomerate is seen to underlie the alluvium in several places both above and below where the blue sandy clays rest on the conglomerates. The area where the footprints were was possibly a swamp or depression, which was filled by flood-waters heavily charged with clay and pumice-sands, and which became exposed as soon as the river assumed its normal flow. The deep impressions show