Haast

PVM

R. V. WALDHEIM, WIEN.

GEOLOGY

OF THE

PROVINCES OF CANTERBURY AND WESTLAND,

NEW ZEALAND.

A REPORT COMPRISING THE RESULTS OF OFFICIAL EXPLORATIONS.

BY JULIUS VON HAAST, PH.D., F.R.S.,

DIRECTOR OF THE CANTERBURY MUSEUM, PROFESSOR OF GEOLOGY IN CANTERBURY COLLEGE (NEW ZEALAND UNIVERSITY),

AND

LATE GOVERNMENT GEOLOGIST TO THE PROVINCE OF CANTERBURY, NEW ZEALAND.

Christchurch:

PRINTED AT THE "TIMES" OFFICE, GLOUCESTER STREET AND CATHEDRAL SQUARE.

1879.

PREFACE.

When, shortly before the abolition of the Provinces, in 1876, the Government of the Province of Canterbury intrusted me with the preparation of a final report on the Physical Geography and Geology of this Province, I was well aware that I had accepted an arduous task, as I felt that my duties as Director of the Canterbury Museum would generally claim my whole attention. As the work proceeded, I found that I could devote only at intervals the necessary time to its preparation, and on different occasions the manuscript had to be laid aside for several months at a time. In fact, when the mind has to be devoted to the consideration of such important questions as those treated in this work, it ought to be free from the ever-recurring daily anxieties of a responsible official position. And, on this score, I may be allowed to claim the indulgence of the reader for many shortcomings in this report, and for the delay in issuing it from the press, more than two years after its publication was undertaken by me.

As the Province of Westland, (up to 1866 a portion of the Canterbury Province), had before its separation repeatedly been visited by me, I was induced on that account to include its description in this publication. Moreover, it would be extremely difficult to offer a satisfactory account of the Physical Geography and Geology of the Southern Alps without treating also of the character of their western slopes. It has been my endeavour to give in this publication not only the substance of all my previous official reports in a more condensed form, but also to add a great deal of new unpublished matter, all of which has been accumulating for years past. I have endeavoured to avoid, as much as possible, entering into controversies, and have only done so in order to answer objections made in other scientific publications against my views or theories published in former reports.

A descriptive account of my explorations, with numerous extracts from my journals, has been given in the first three chapters, as I believe that in that manner I can offer a great deal of information in a more popular form to the reader on the Physical Geography, Geology, Zoology, and Botany of the Country, than purely scientific reports can generally convey to him. I have endeavoured to make him acquainted with the peculiarly grand features of the Southern Alps, to make him participate in the difficulties, dangers, and joys of an explorer's life, and, at the same time, to show him that the work of the Geologist in an unknown country, in which, moreover, he has to seek his way, construct his own map, and carry often a heavy load on his back, is not an easy one, and that it cannot be accomplished without considerable loss of time. The series of lithographs attached to this report, representing faithfully some of the finest scenery in Canterbury and Westland, will, at the same time, assist in bringing the countries traversed more vividly before the reader than mere word-painting could do. It was once my intention to add several chapters on the Zoology and Botany of both Provinces, together with meteorological and statistical tables; but they would have increased the bulk of this report, already exceeding its intended size, by more than 140 pages.

The pleasant duty now devolves upon me to thank most heartily all those inhabitants of Canterbury and Westland whose hospitality I have enjoyed, or who have facilitated in many ways my progress through the country. It would be impossible to name them all, because, without exception, every one of them has always cheerfully offered me what assistance he could. To my friends, Professor Dr. F. Ritter von Hochstetter, in Vienna, for superintending the printing of chromo-lithographed maps and sections; the Rev. J. W. Stack, and Messrs R. Mainwaring and W. M. Maskell, for reading the proof sheets for me, my warmest thanks are also due.

JULIUS VON HAAST.

Christchurch, Canterbury, N.Z.,
December, 1878.

C

CONTENTS.

PART I.

Historical Notes on the Progress of the Geological Survey.

PART II.

Physical Geography.

PART III.

Geology.

ILLUSTRATIONS.

PART I.

HISTORICAL NOTES

ON THE

PROGRESS OF THE GEOLOGICAL SURVEY

OF

CANTERBURY, NEW ZEALAND.

CHAPTER I.

FROM THE BEGINNING OF THE GEOLOGICAL SURVEY TO THE DISCOVERY OF THE WEST COAST GOLDFIELDS.

BEFORE entering on the principal object of this Report, which is to present in a condensed form the main results of the topographical and geological surveys conducted by me since the latter part of the year 1860, in the Province of Canterbury, it may not be deemed superfluous if I offer a short narrative of my explorations, giving a somewhat detailed description of some of the journeys which were undertaken into those portions of the province, never before trodden by the foot of man. Such an account may be the more acceptable, as my other occupations will prevent me, at least for some time to come, from publishing as I had intended, a book in a more popular form on this subject. In this narrative I have very often quoted largely from former reports and other publications, thinking that I could not improve upon the descriptions and accounts which gave the first vivid impressions of the grand and sublime scenery with which the Southern Alps abound in every direction.

It was towards the end of 1860, when residing in Nelson, and occupied in preparing the results of the journey in the south-western portion of the Province of Nelson, undertaken on behalf of the Provincial Government for publication, that I received a letter from his Honor W. S. Moorhouse, Esq., Superintendent of Canterbury, requesting me to proceed as soon as convenient to that province, as he was anxious that I should make some geological detail examinations of the Mountain range which separates Port Lyttelton from the Canterbury plains. Through this range the tunnel for the Christchurch and Lyttelton railway, a truly gigantic undertaking, considering the growth of the settlement, had been projected, and after having been begun by some English contractors (Messrs. Smith and Knight), the contract after a few months was thrown up by that firm, principally owing to the fact that they had met with some specially hard basaltic rocks on the Lyttelton end of the projected tunnel.

Geological Survey of Mount Pleasant, Banks Peninsula, 1860.

My examinations of Mount Pleasant, the mountain in question, began on December the 1st, of that year, and occupied me for about a fortnight. On December the 19th I presented my Report,* together with 34 geological specimens, in illustration, to his Honor the Superintendent, with which that gentleman proceeded to Melbourne to obtain if possible a new contractor for that important work. Mr Moorhouse made a preliminary arrangement with Messrs. Holmes and Co. of that city, and after these gentlemen had satisfied themselves from a personal inspection of the ground that the deposits to be pierced by the tunnel were not of such difficult nature as the former contractors had imagined, and that the main results of my survey might be relied upon, the new contract for the continuation of the work was finally settled. This important undertaking to which Canterbury owes a great deal of its remarkable progress was brought to a successful termination on May 25, 1866, when both adits met near the centre, the tunnel being open for railway traffic on December 9, 1867.† A careful geological examination of the range between Lyttelton and the Canterbury plains, which has an average altitude of 1300 feet, and a more general survey of the mountains forming Lyttelton Harbour showed that Banks Peninsula consists of

* Report of a Geological Survey of Mount Pleasant, presented to his Honor the Superintendent, and laid before the Provincial Council, Dec. 20, 1860.

† The tunnel was laid out and its execution solely superintended by Mr Edward Dobson, C.E., Provincial Engineer.

several extinct craters, mostly submarine, that the ridge or caldron wall to be pierced by the railway tunnel was built up by a great number of basaltic lava streams, beds of tufas and agglomerates of varying thickness, dipping at an average angle of nine degrees to the north, and that the deposits were traversed by vertical dykes of trachyte, filling fissures passing through them, and having been injected from below. As this was the first instance of an ancient crater wall of large dimensions being passed through by a tunnel, from which valuable geological data could be obtained, I followed the work as it proceeded, with a considerable degree of interest, and in the geological description of Banks Peninsula I shall be able to give some details of no mean scientific interest, which these important engineering works disclosed.

During my stay in Canterbury the Provincial Governmeut did me the honour to offer me the appointment of Provincial Geologist, which I accepted; and, after going back to Nelson for a few weeks, I returned to Canterbury towards the middle of February to begin my labours.

Explorations of the Rivers Rangitata and Ashburton, 1861.

In order to obtain a general insight into the geology of the country I selected the River Rangitata to its sources as my base of operations. And after the necessary preparations were made, I started on the 20th February, 1861, for that river, accompanied by my friend the late Dr. A. Sinclair, who went with the intention of assisting me in the botanical researches to be made in the mountain ranges. Until June of the same year I examined this river as well as the Southern Ashburton and their different main branches to their very sources, fixing on the unsurveyed ground all the principal topographical features. This journey brought us into Alpine regions of imposing beauty and grandeur, only surpassed by the still more sublime scenery which further explorations of the central Alps round Mount Cook revealed during the course of the next year.

Following the valley of the Northern Ashburton, we reached on the 26th February the remarkable broad opening in the ranges by which the valleys of the Rangitata, Ashburton, and Rakaia are united, and of which a considerable portion is filled by morainic accumulations, between which a number of small picturesque lakes are situated.

We followed this opening to the Rangitata, having the snow-covered peaks of the central range before us; and after descending several hundred feet into the bed of the River Potts where it joins the Rangitata, we crossed that river and reached Mesopotamia, then the sheep station of Mr. Samuel Butler, where I established my head-quarters. Here the valley of the Rangitata is several miles broad, and a number of terraces rise to a considerable altitude one above the other to nearly 3500 feet above the level of the sea, or 1900 feet above the river-bed. Here and there rounded hills, often in the form of sugar loaves, true *roches moutonnées*, appear amongst them, showing at a glance that this country had once been subjected to the action of ice for a considerable time. During the next week, in order to become acquainted with the geological structure of the country, we explored Butler's and Forest Creeks to their sources, both wild mountain torrents flowing in their upper portion through deep rocky gorges. We also ascended several peaks, of which Mount Sinclair, 7022 feet high, at the head of Forest Creek and the southern termination of Two-thumb Range offered an extensive and magnificent view. The valleys of the Rangitata and Ashburton, with a portion of the Canterbury plains, and all the ranges to the east, were not only lying as a map before us, but the Southern Alps appeared also in all their sublime grandeur on the opposite side, the noble form of Mount Cook standing prominently above them all. From west to north the whole range was visible, reaching from Mount Cook to Mount Tyndall at the head waters of the Godley River; peak above peak, in bold majestic outlines, all glistening in snow and ice, a sight never to be forgotten. The course of the Godley was also visible, but a long spur concealed Lake Tekapo and the Mackenzie Country from our view. On the 12th of March, after having finished our preparations, we left Mesopotamia to ascend the Rangitata to its sources. Although the river-bed in these middle Rangitata plains is in most places nearly a mile wide, and the water flows in numerous branches, it is only at very low water that the river can be crossed on foot, and even when the water is not very high, horses find it difficult to bear up against the current. After ten miles travelling over level ground amongst dense scrub, mostly consisting of *Discaria toumatoo*, the Wild Irishman of the settlers, the junction of the two main branches was reached. I first ascended the southern branch, naming it the Havelock. From this point the river-bed continues for several miles to be more than a mile broad, and only gradually becomes narrower. The scenery rapidly increases in grandeur, peak above peak, pinnacle above pinnacle appear covered with snow, wherever it finds a resting place. The mountains on the southern banks of the river, although very broken, being only the outrunning spurs of the Forbes Range, are not so picturesque, being intersected by deep valleys, whilst on the northern banks rise the precipitous flanks of Cloudy Peak, their base washed by the main stream. Towering to the blue heaven two gigantic pyramids here stand, the one in front of the other, the wild majesty of which defies description. Between them glaciers of the second order descend, their white masses shining like molten silver, but only visible where deep rents seem to have cloven the mountain asunder. Several small but beautiful waterfalls are seen, often many hundred feet high, but generally not in a continuous fall, the breaks between them as they jump from ledge to ledge adding however not a little to the splendour of the scenery. In some spots the waters wind amongst the rocks like streaks of silver, little promontories or forest vegetation alternately concealing them for a time, until they appear again clinging to the mountain sides. In another place, high above the river-bed, a streamlet falls over an overhanging rock, but instead of reaching the bottom, the wind takes possession of it, blowing it into an almost imperceptible mist, over which the sun threw, when we passed, a magnificent rainbow. Five miles from the junction of the Havelock with the Clyde the beech forest (*Fagus Solandri*) which still now and then grew upon the steep mountain sides, disappeared, and a new and strange vegetation took its place. Crossing and re-crossing the river where it seemed best fordable, we halted ten miles above the junction, where another important stream joined the Havelock from the west-south-west. A magnificent peak rose to a great altitude at the end of the valley, covered with perpetual snow, from which the ice streams descended towards the valley, the terminal faces of which we could discern at its head. Another reason why I selected this spot as a camping place was, that here behind an outjutting spur a little flat occurred, covered with coarse grass, so that we had some feed for the horses. The river-bed, still a mile broad, consisted of boulders in its whole extent, amongst which numerous water-courses meandered, shifting however with every fresh.

On the early morning of March the 14th we started towards the first source branch, and after crossing the different streams into which the Havelock is here divided, and of which the last one gave us considerable trouble, owing to the very large boulders in its channel, we arrived at last on the left bank of the tributary, which I named the Forbes. The ground here became so rough that we were obliged to leave the horses behind, and climbing over the huge boulders and masses of debris, brought down no doubt by avalanches, through and over which the foaming water was roaring, we soon reached the first tributary of this stream, descending at an inclination of 20 degrees from a glacier of the second order, hanging some 2500 feet above, on the side of the huge mountain, down which its icy outlet rushed with such fury that we had difficulty in crossing it. Signs of avalanches became now very numerous, *couloir* succeeding *couloir* and the mountain sides were everywhere covered with debris and blocks of rock, and although these signs of destruction were great, the power of nature was still greater. Everywhere amongst these blocks, where the least stability could be obtained, plants, often in great luxuriance, had driven their roots. The clear atmosphere of New Zealand, which is deceptive when judging of distances, was still more so here. The snowy giants seemed quite close before us, and it was only by walking continually towards them that their distance became apparent.

After three miles walking the valley became narrower, the river rushed over enormous blocks of rock, which impeded its progress so that it wandered from one side to the other, compelling us constantly to climb over the huge blocks or along the rocky walls of the jutting spurs. A large green parrot, quite unknown to me, flew screaming over the valley, wondering at the intruders on his domain, whilst a few Paradise and blue ducks on the edges of the river uttered their well-known notes. After two hours' climbing, having passed in the mean time over several other outlets from glaciers of the second order, we reached a large stream, pouring down the steep mountain side with a thundering roar. The feeder of this torrent hung like a huge frozen tear from the slope of the mountain. We had great difficulty in crossing it, the water rushing against our legs like a mill-stream against the paddles of a water-wheel. Climbing another small ridge before us, squeezed between two precipitous promontories, the first true glacier came in sight. It was about 600 feet broad, 100 feet high, consisting of well stratified ice, the layers of a thickness of from three to five feet, concave and apparently adopting the form of the valley. The ice itself was very dirty at the terminal face, and the whole surface was deeply covered with fragments of rocks, some of enormous size, so as to conceal it entirely. From a vault at least 30 feet high and broad, the stream rushed turbid with suspended matter, leaping over and sometimes confined between enormous blocks, often the size of small houses, which the glacier continually throws in its way. I climbed down to the cave the ice of which at the extremity of the glacier was so much decomposed that by a single blow of the hammer huge blocks were shivered to a thousand pieces. But I was not allowed to stand there very long. Seeing that a part of the vault was giving way, I retreated, and being warned by the call of my companions, I had to stoop behind a huge block, whilst a large fragment of rock several tons in weight fell down, leaping over my place of shelter, and falling into the river with a tremendous crash.

By joint observations with two aneroid barometers and the boiling water apparatus, I found the altitude of the terminal face of the glacier to be 3837 feet above the sea level. As it was impossible, owing to the falling blocks, to ascend the glacier itself, I followed the lateral moraine, but soon came to the straits through which it squeezes itself. The walls on both sides for about a thousand feet were nearly vertical, and were scratched and polished. As it was not possible to pass these straits, I ascended the hill a few hundred feet, but found that the upper surface of the glacier continued charged with morainic accumulations as far as I could see. Behind the straits the valley enlarged to a basin, bounded in a straight direction by nearly perpendicular walls, at which the almost vertical stratification was visible. This magnificent wall, many thousand feet high, was perfectly bare of vegetation, and only in a few deep holes patches of snow appeared which otherwise would not have found any resting place. It was really a scene of wild grandeur. Main tributaries descended from both sides of the chain skirting this huge wall, and forming in the basin the trunk glacier. This glacier having an east-south-east direction is the most important feeder of the Forbes stream. Another stream, but of smaller dimensions, joins it in a straight line with its general course, east-north-east, a few yards beyond where the principal stream leaves its icy vault. Not being able to find a ford I could only make observations from the point of junction. This second glacier, inferior in size, consisted of white ice, perfectly clear, no moraines of any kind reposing upon it. Only a few solitary blocks appeared scattered upon its pure surface. Vast snow slopes clothed the side of the range, stretching to the bases of the pyramidical peaks, rising above them in savage beauty with only occasional deep snow holes in their steep sides. The gentle lines of this *nevé*, by which this second glacier was fed were, notwithstanding, clearly defined. It formed a concave saddle between the towering giants at both sides, only pierced through by a few sharp needles, and showing that the smaller joints of this comb were only concealed by the soft snow garment thrown over them.

All the same phenomena could be observed which invest the formation of glaciers with such a lively interest. The unbroken surface of the glacier was lower down rent and crevassed, a greater inclination had to be passed over, an ice cascade was formed, the towers and minarets of which stood in utter confusion during their descent, and contrasted greatly with the unbroken ice above. But soon the scattered masses were again brought near each other, they were welded together into a continuous sheet, and only now and then broad pinnacles of rock pushed their bold heads between the slowly descending ice streams, which uniting, formed at last the trunk glacier. Where the ice cascade occurred the colours of the ice were most lovely, azure blue being predominant; but also mixed tints between blue and green, and even changes into a deep green were met with. This second glacier had its terminus about 200 feet higher than the first one described, but it seemed that sometimes it descended a considerable distance lower. A sharply defined line on the side of the mountains running parallel with the glacier, and some 20 or 30 feet above, proved its greater dimensions and descent in some seasons. The mountain sides above that line were covered with grass and flowers, below it only shingle occurred; this line did not cease above the terminal face of the glacier, but continued for a few hundred feet lower, when it curved towards the river. It was evident to me that it owed its existence to the glacier, which in winter was not only higher in point of altitude, but also advanced further into the valley. The limit of descent of the glaciers was, as I observed by further examination, very much determined by the circumstance whether they were covered with moraines or not, the first ones being more sheltered from the sun's rays were always larger when reaching their termini, and invariably travelled farther down the valley than those of which the ice was unprotected.

It was not without a certain feeling of awe that I stood thus in the lonely wilderness, gazing in admiration at one of the most beautiful phenomena of nature, and this feeling was still heightened by remembering that never before had a human foot stood upon this spot. The weather was most lovely, no clouds in the deep blue heaven; but in the afternoon, the wind, coming from the south-west, brought well-shaped cumulus clouds, which appearing on the mountain summits, up which they seemed to have crept, instead of continuing their course, rapidly fell down the nearly vertical and ribboned walls, soon disappearing entirely from our sight, being condensed when they reached the *nevé*. We returned to our camp, and had a heavy thunderstorm during the night, the loud peals of thunder awakening a thousand echoes in the mountains, the wind was so high that we thought every moment our tent would break down. The river near our camp roared every moment louder and louder, and we could distinctly hear the boulders roll along its bed, borne on by the furious waters. Towards morning the storm subsided, blue sky was visible between the rapidly flying clouds, which followed each other in apparently endless succession. It being impossible to continue my researches up the swollen river I examined during the day the mountain side above our camp and the descending streamlets. Their waters were already clear again, whilst the Havelock for many days continued to be not only very high, but also yellow and thick from suspended matter.

Having a long day's work before us, we started next morning before daybreak; the stars of smaller magnitude had already disappeared, and the first light very soon began to illumine the sky. The huge mountains round me stood in all their stern majesty, having a cold, steely, and frozen appearance, but now the sun smote their highest summits with his golden beams, throwing a deep rosy hue over their vast snowfields. A wonderful change took place in their appearance, filling the soul with admiration and delight. Soon on our way, following up the main stream, we had a troublesome walk over boulders of very large size, nearly filling the valley, here a mile wide from side to side. The rise in the ground became now more visible, and the river, still high, dividing and uniting every moment, roared loudly. With every footstep new views were obtained. High upon the mountains considerable snowfields were visible, with glaciers of the second order descending to the steep sides, from which fine waterfalls hung like silver threads upon the mountain walls. The ranges grew gradually more gigantic, and the river which still had a general south-easterly by south course, here turned south-south-east, flowing along the main chain. At this turn it is joined by two other tributaries, coming also from large glaciers.

The valley from the turn became much narrower, and we had to climb every moment over rocks and ridges jutting into the foaming water. For several miles the mountains on both sides were so very steep that no true glacier could be formed, and the same magnificent cascades continued therefore to descend into the valley. We had to wade some of these streams, which, notwithstanding they reached only to our hips, required all our strength to bear up against their enormous pressure. But now a new and more serious impediment presented itself in the shape of a large overhanging rock, along which the river rushed in great fury; we tried to round it, but the water was too deep, so that we were compelled to climb it. Looking down into the river below us we observed at another place a natural bridge over the river, formed by the remains of a huge avalanche, into which the water had excavated a cavern, and through which it was then flowing. Although the summer was already declining, it had hitherto resisted the sun's rays, which, it is true, could reach it only for a few hours during the day. It being impossible to descend, we had to climb up the face of the rocks higher and higher, till we were at last some 1000 feet above the river, when a magnificent scene was presented to us. Before us lay a broad valley running nearly north, on its western side the gigantic peaks of the central chain, on its eastern side, running parallel with it, another high range, both uniting six miles from our place of observation. Here a stern pyramid rose, towering with its pointed peak above all its neighbours. From both sides considerable glaciers descended, pouring their ice streams into the valley; those on the western side coming from a very large *nevé* lying at the base of this rocky giant. On both sides some fine waterfalls were formed by the outlets of several glaciers of the second order, of which one appearing to fall from a height of about one thousand feet, dissolved in mist before it reached the valley. Scarcely any sign of vegetation was here visible on the sides of the mountains, all seemed ruin, desolation, and destruction. Descending to the terminal face of the glacier I found it nearly 1500 feet broad, and 100 to 150 feet high, the glacier having for the first few miles only a slight inclination. The altitude of the outlet I ascertained from barometrical measurement to be 3909 feet above the level of the sea.

The high pyramidical peak from which the lateral chain between the Havelock and Clyde runs off in a south-east direction I named Mount Tyndall. It was nearly evening before my necessary bearings and observations were completed, and climbing back from the summit of the ridge, a last view was obtained; after which we descended to our camp. For several days I was occupied with surveying and geological researches, and remained camped in the same spot; every change in the weather, sunshine and clouds, morning and evening, giving us new opportunities of admiring the astonishing scenery around us.

On March 18th we returned to Mesopotamia to give our horses rest and food, they disliking the snow grasses, having when camped near the head of the valley principally fed on the leaves of the *Celmisia coriacea*, the cotton plant of the settlers. After laying in a new supply of provisions we started again on March 22nd, selecting this time the eastern main tributary of the Clyde, which I had named the Lawrence. The bed of this river for several miles offered fair travelling ground over shingle reaches, after which, either large morainic accumulations or enormous shingle cones obstructed the course of the river to such an extent, that the water was confined to a narrow channel, through which we found it impossible to advance with the horses. We therefore camped about seven miles from the head of the valley, and started on the 25th of March in the early morning towards the glacier, the terminal face of which, after considerable difficulties, was reached about noon. Owing to the fact that the river had now assumed the character of a wild mountain torrent, often running between perpendicular rocky banks, or foaming over and between enormous blocks of rocks, we were often obliged to seek our road through the sub-alpine vegetation on the mountain sides. The growth of the scrub was in many places so dense, that it was necessary to walk literally on the top of it, the natural consequence being that we broke occasionally through, and then could only release ourselves with the greatest trouble and exertion. This denseness of vegetation occurs principally in those localities where the north-west winds have bent the branches in one direction, giving them the appearance of clipped hedge-rows.

Returning on the next day to the Clyde, I remained camped near the junction of the Lawrence with that river, in order to make a collection of fossils in the Mount Potts Range which I had discovered in my way up; whilst Dr. Sinclair with my servant returned with our horses to Mr Butler's station for provisions. It was when crossing one of the main streams of the Rangitata, which was rising rapidly, that my deeply lamented friend lost his life, trusting too much to his own strength. My servant returning to me with the sad intelligence that he had seen Dr. Sinclair enter one of the branches, but not observed that he reached the other bank, we started immediately to see if it were not too late to give any assistance, but finding that the river was now quite impassable near the spot where the accident had happened, we kept down on the left bank of the river towards Mr. Butler's station. Not being able to extricate ourselves in the dark amongst the swampy terrain above the junction of the Potts, we only reached it next morning. Before arriving at the station we met Messrs. John King and Frederick Shrimpton, of Timaru, who were on a visit at Mesopotamia, and who had started before daylight up the river to look for the rider of one of my horses, which had arrived late in the evening at the station with Dr. Sinclair's blankets fastened to the saddle. After a hasty meal we started again together up the river, when we found the body some 300 yards below the spot where Dr. Sinclair had entered the river.

We brought the body of my lamented friend to Mesopotamia, and buried him on March 29th. Near the banks of the river, just where it emerges from the Alps, with their perpetual snowfields glistening in the sun, amidst *Veronicas* and *Senecios*, and covered with *Celmisias* and *Gentians*, there lies his lonely grave. With almost juvenile alacrity he had climbed and searched the mountain sides, showing that, notwithstanding his advanced age, his love for his cherished science had supplied him with strength for its pursuits, until at last, overrating his powers, and not sufficiently aware of the treacherous nature of alpine torrents, he fell a victim to his zeal. Great and deep was my sorrow, and with a saddened heart I had to continue alone the work upon which we had set out together.

Having to wait for the return of my servant whom I had sent to Christchurch with the necessary documents concerning this sad accident, I was only able to start again on April 9th to examine the head waters of the Clyde, the remaining third main branch of the Rangitata. For the first eight miles this branch has a broad shingle bed, over which we could proceed without any trouble, after which the valley narrowed considerably, the river sometimes flowing close to perpendicular rocks compelled us frequently to cross its channel; and although the water was very low, it gave us the greatest trouble, not alone owing to the rapid flow of the water, but also to the enormous boulders in the bed of the river affording only very treacherous footing to the horses. We camped at the junction of the McCoy, another important source branch from the north, finding here a little grassy spot. The view up this stream was most magnificent, it seemed as if the mountains on both sides, consisting of the same sandstones and slates as before described, had been rent asunder, so that the river flowed through an immense fissure. The McCoy is five miles long, and besides several streams coming from glaciers of the second order, it is formed by the junction of three glacier streams, of which the central and largest issues from a glacier of considerable size, covered entirely with moraines, and passes between two huge promontories. The two others, descending from north-east and north-west, are without any moraines, they both descend from a large *nevé* lying at the eastern and western base of the central pyramidical peaks, from the southern recesses of which the main glacier descends. Their extremities lie again 400 to 500 feet higher than the former, owing to the circumstance that they are not sheltered by a thick deposit of debris like the central one. Also here, where the *nevé* ends, the ice is very much broken and crevassed, having most splendid bluish tints. It would be easy to ascend the north-western *nevé*, which seems to have an easy gradient, and would lead over a col into the Lyell glacier at the head of the western branch of the Rakaia. At one spot the snow exhibited the deep red colour, owing to the presence of *Protococcus nivalis.*

Another day was devoted to following the main stream to its sources It would be possible to ride to this glacier on horseback, of course only in autumn, and after a period of dry weather, although the boulders are often of enormous size, but by crossing and re-crossing it could be accomplished by an able horseman. I preferred leaving the poor horses behind, as they could find so little suitable food, to save them another day's heavy journey. Climbing along the precipitous sides of the mountains, and wading through smaller branches, we arrived after three miles of laborious walking, at the main glacier, filling up the whole valley, and presenting a very fine sight. The extremity of this glacier, the largest which I visited in this journey, presents a straight wall of an altitude of 150 feet, showing the usual bedding; the ice is very dirty, and many large boulders are imbedded in the body of the glacier itself. In the centre is a wide ice vault from which the stream rushes over huge boulders. The glacier is covered deeply with a moraine, consisting of blocks, often of a gigantic size, which fall when they reach its termination with a tremendous crash from the edge. During my stay, a block of at least 10 tons, just above the ice cavern, fell down into the water, dashing it high in all directions. In the perpendicular face of the glacier was a round hole 30 feet below its moraine roof, through which a little streamlet fell like water from the gutter of a house.

On both sides of the cave, lying closely to the ice, moraines were formed along which the explorer could climb.

The direction of the glacier is for the first mile from its extremity, north; its terminal face stretches obliquely across the valley, which is no doubt occasioned by the junction of another large glacier stream coming from the west, and here washing its base. The glacier from which this stream is derived lies in a deep gorge with nearly vertical walls, terminating about 150 feet above the Clyde glacier. Its extensive *nevé* lies at the eastern slopes of Mount Tyndall, opposite another *nevé* from which one of the branches of the Havelock glacier descends. A col with an unbroken snowfield would bring the Alpine traveller to the *nevé* of the latter. The breadth of the Clyde glacier is 1300 feet, but a line at a right angle with the valley would reduce it to 1000. I climbed the mountain side near the junction of the two glacial streams to have a better view of it, and could not cease to admire the exquisite wild beauty of the splendid scenery around me. It would be very difficult to give any idea of the varied shape of the mountains around. Needles are seldom seen, but huge pyramidical peaks frequently rise above the general line of the chain. Some of them are so precipitous that for several thousand feet no snow can cling to their walls, which stand above the dazzling garment at their feet in stern grandeur. Cumulus clouds at a great altitude came from the north-west, and the change from sunshine to shade gave an additional charm to their forms. I made the terminal face of the Clyde glacier 3762 feet above the sea, the mean of barometrical observations and of the boiling water apparatus, both agreeing within 23 feet. The water coming from the cave was of a deep semi-opaque blue colour, and had not the milky hue which such waters generally exhibit, the long continuation of fine weather having brought about this change. It was near sunset when I had finished my observations, and we therefore hurried back to our camp, but found that the river since the morning had risen a little; the difference in temperature between the cold night and the warm sunny day causing a greater waste of ice.

Having thus accomplished my work at the head waters of the Rangitata, I returned to Mesopotamia, where I was occupied for some days in packing my collections, which had been stored there, and sending them with a dray to Christchurch. On April the 26th I said good-bye to my kind host, and left this interesting locality, which offers to the physical geographer an endless supply of valuable facts, and proceeding along the right bank of the Rangitata I arrived on the 28th at the Peel Forest station. On the way I examined the porphyritic zone in the McLeod range, and the tertiary outlier with seams of brown coal in Coal Creek, passing over the low saddle by which, in the great glacier period, one of the branches of the Rangitata glacier reached the Canterbury plains. For some days I was occupied with a geological exploration of Mount Peel, and a survey of the morainic accumulations in the banks of the Rangitata, after which I descended the river to the upper ferry, as owing to a heavy freshet it was impossible to cross it on horseback. I proceeded next across the plains to the Southern Hinds, which I ascended to its source, and after paying a visit to the Gawler downs, the geological structure of which proved of considerable geological importance, I crossed the Northern Hinds and Southern Ashburton, and reached the Mount Somers station on the evening of May 9th. On the outlying spur of the small terraced hill between the two last-mentioned rivers, I found that some large rocky projections, the so-called Two Brothers, consisted of palagonite tufa, a very interesting volcanic deposit, which was hitherto known only to exist in a few other localities in the Northern Hemisphere. Having devoted some days to an examination of the extensive porphyritic zone of Mount Somers, and the tertiary beds at its base with the picturesque limestone caves washed out in them, I again ascended the Southern Ashburton on May 11th, to the junction of the River Stour. Following this tributary to the saddle by which the Upper Ashburton plains are reached, we had from this spot a most beautiful view. Immediately in front of us a small nearly circular lake lying between the moraines, which here cross the valley from side to side, enlivened by numerous waterfowl, formed a charming foreground, the middle portion consisted of the Ashburton plains with its lakes and water-courses, above which the wild serrated Arrowsmith range, covered with perpetual snow, rose majestically into the glorious evening sky, illuminated brilliantly by the last rays of the sun. On the 13th of May I crossed with my pack-horses the Ribbon-wood range, which is here over 5000 feet high, in order to reach the valley of the Ashburton near its sources. Owing to the great steepness of that range on its western side, where the horses had to be led down amongst rocky precipices and moving shingle reaches, we had the greatest difficulty in reaching the bottom of the valley, and it was quite dark before a suitable spot was found where the tent could be pitched. Next evening we camped at the highest spot in the valley, where there was some grass for the horses, and proceeded the following day to the glacier at the head of the valley, the outlet of which forms the principal source of the Ashburton. We had to climb for some distance amongst large blocks of rock before the glacier was reached, the terminal face of which I found to be 4832 feet above the level of the sea. This glacier, although smaller than those at the head of the principal branches of the Rangitata, is exceedingly beautiful. The ice is quite pure, and is broken half a mile above its termination into numberless fine seracs, forming one of the most splendid ice cascades I ever saw. On both sides the mountain slopes are very precipitous, consisting often of nearly perpendicular walls of rocks several thousand feet high, which offered an instructive insight into the geological structure of that stupendous mountain chain. The weather was exceedingly favourable, fine cloudless days, rendering travelling quite an enjoyment; but the nights were here so very cold that the water was frozen every morning in the pools near our tent.

To reach again the Upper Ashburton, I followed the river to the point at which it enters these plains. We had some very deep and rocky gorges to cross, but found the scenery very picturesque. Another week was devoted to an examination of the Clent hills, where I made a rich harvest of impressions of fossil ferns; I also descended Trinity valley to its junction with the Rangitata, where small coal seams in the palæozoic rocks, like those of the Clent hills, raised my hopes that large and workable seams might be discovered if I persevered in my search; and finally I visited Lake Heron, with its remarkable sugarloaf hill, a fine *roche moutonnée*, and its neighbourhood. The winter, with mist, rain, and snow, had now fairly set in, and I was therefore obliged to retreat to lower regions, leaving with great regret the magnificent alpine scenery which for several months past had afforded me so much instructive enjoyment. On June 1st I started on my return journey, and reached Christchurch on June 5th.

Exploration of the Malvern Hills and Mount Torlesse, 1861.

The Provincial Government being very anxious that I should undertake an examination of the Malvern Hills as soon as possible, I started again, in the middle of June (1861), for that district, where I was occupied for six weeks in surveying that important region, principally in reference to the coalfields and lodes of copper, said to exist there;

until heavy falls of snow at the end of July, which made geological investigations impossible, drove me back to Christchurch. During that journey I opened up a seam of coal, in the valley of the Kowai, three feet and a-half thick. It consisted of a fine excellent black (altered) coal, the discovery of which was considered of such importance, that the late Mr. James Burnett, of Nelson, a competent mining surveyor, and who had been my assistant in my Nelson explorations, was entrusted with the necessary preliminary work to open up the seam and look for others. This gentleman began the work on October 4th, but could not finish it, as he had to return to Nelson; I, therefore, continued it at the beginning of November employing several miners, and driving an adit through the whole beds until the older rocks were reached. This investigation proved that we had been opening up the outcropping end or edge of a series of coal seams, where the seams are not of such regularity as we may expect to find them toward the middle portion. I therefore recommended that borings should be undertaken towards the centre of the valley, which stretches between the Mount Torlesse range and Russell's hills. After this work was completed, and I had reported its principal results to the Provincial Government, I proceeded with a geological examination of the mountain ranges in the neighbourhood, including Mount Torlesse and the Thirteen Mile Bush range; during which I also surveyed the small outlier with Brown coal seams, situated at the head of the MacFarlane stream, one of the source branches of the Kowai. The result of this survey of the district proved that these ranges, as well as all the higher portion of the Malvern Hills, are built up by the same old sedimentary rocks, which I had first met in this Island between the Awatere and Waiau rivers in the Province of Marlborough, and of which also all the ranges to near the summit of the Southern Alps along the course and up to the source of the Rangitata and Ashburton rivers, previously examined, consist. During careful detail examinations I made of these deposits of enormous thickness, I followed some of the large flexures into which they were bent, and found that in some spots they had actually been inverted, so that the lower beds appeared to be the upper ones. Generally the dip of the great anticlinal and synclinal curves is very steep, if not vertical, which gives to the high rocky ranges quite a ribboned appearance. On the summit of these ranges and on the moving debris slopes on their sides, I made a very rich harvest of particularly interesting plants, and when I mention that on Mount Torlesse alone I collected over two hundred flowering plants, of which over thirty were new to science, it will be easily understood how great my delight was at being able to make such a remarkable addition to the alpine and sub-alpine flora of New Zealand. Similar large collections were made by me during my journey to the sources of the Rangitata and Ashburton, first together with my lamented friend Dr. A. Sinclair, and after his death alone.

Exploration of the Head Waters of the Waitaki, 1862.

After having written a progress report on the work undertaken in the Kowai and on the ranges in the neighbourhood, I started again, end of January, 1862, this time for the Mount Cook District, with a view to ascertain if any auriferous deposits occurred in that region, and to continue the regular work of the geological survey of the province. The rich goldfields in the Province of Otago having in the meantime been discovered, it was of course of vital importance to ascertain if formations of similar nature could not be traced over the boundary line into this province. During a period of over four months, I accomplished with the active and hearty co-operation of Mr. Arthur D. Dobson, my assistant in the topographical work, and now District Engineer at Westport, the survey of the extensive river system, situated at the head of Lakes Tekapo, Pukaki, and Ohau, the outlets of which form the River Waitaki. During this journey, about 130 miles were chained, and numerous points were fixed from the base lines thus obtained. This brought me into the very centre of the Southern Alps of New Zealand, which in grandeur and beauty are worthy rivals of their European namesakes. Passing through Burke's Pass, the remarkable Mackenzie plains were reached, once the bed of an enormous glacier, and after its retreat filled by morainic accumulations and alluvial deposits, with here and there a small range or isolated hill rising above them, showing by their peculiar forms that they have been rounded and ground down by the action of the huge ice stream which once passed over them. Proceeding towards Lake Tekapo, the most northerly of the three lakes, the outlets of which unite in the Mackenzie plains, we soon reached the huge morainic accumulations, several miles in breadth, by which Lake Tekapo is surrounded, and which clearly show the origin of this fine sheet of water. These moraines, at the termination and along both sides of the lake, have a concentrical arrangement one within another, proving that the huge glacier had retired repeatedly for a distance, then become stationary for some period, so as to have time to pile up its debris load all around. Several old river-beds, one more than a hundred feet above the lake, showed how its waters had gradually diminished, abandoning one course for another. Some large blocks of rock with sharp edges were lying here and there on the surface, and so conspicuous at a considerable distance that at first sight we mistook some of them for houses.

It struck me at once as most remarkable that the water of this lake was of a milky white colour, even when its surface was quite unruffled by any breeze, and which could only be accounted for by assuming that large torrents, coming from still huge glaciers, brought down so much finely triturated matter that it could not all settle down on the bottom. Although I found from barometrical observations that the lake is only 2437 feet above the sea level, the forest vegetation had already entirely disappeared, sub-alpine shrubs taking its place. The view from the shores of the lake is grand in the extreme. It is bounded by lofty mountains on both sides, which gradually rise higher and higher, and form a magnificent background at its upper end where the River Godley enters it. From here to the sources of that river the mountains assume a truly alpine character, covered with perpetual snow, and culminating in Mount Tyndall and other high peaks of at least 11,000 feet altitude, and of bold majestic forms, towering high above the landscape in front. Passing along the western shores of the lake, which are formed by immense morainic accumulations nearly 1500 feet high, we soon left the last sheep station behind us and reached the head of the lake, from which is obtained a beautiful view of the Godley river, terminated by two large glaciers, filling the whole valley. At the head of the lake the delta of the river consists of a huge swamp, through which its waters flow slowly in many channels. It is to this point that the surveys of my friend Mr. Edward Jollie extended, and which were now continued to the head of all the principal branches. Thousands and thousands of water-fowl were here congregated, amongst which the spotless plumage of the White crane was very conspicuous, giving some animation to the sternness of the grand scenery around us. It was with some difficulty that we crossed here a portion of the main valley, on Feb. 22nd, in order to reach the outrunning spur between the main river and the Macaulay river. Ascending the Godley we were obliged to cross and re-cross the river, which, in a valley of more than two miles width, covered with river shingle, meanders in numerous channels from side to side. The more we advanced, the grander became the scenery. Snowfields with glaciers of the second order descending from them now covered the flanks of the wild serrated peaks on both sides, from which, in every direction, high and picturesque waterfalls issued, often hanging on the rocky precipices like so many ribbons of floating silver, before they plunge into their dark gorges, or fall into the river-bed with one great bound. The beautiful sub-alpine vegetation growing in all luxuriance in such localities with its various forms and the rich tints of the foliage, added another charm to the grand landscape around us.

On February 24th, we camped a few miles below the terminal face of the two great glaciers by which the valley is closed. This was the last spot where any grass for our horses could be found. For ten days we remained here, occupied with topographical and geological work, during which some extensive excursions over both glaciers were undertaken. Next day I started towards the great northern glacier, which I named the Godley after the founder of the Canterbury Province, and the terminal face of which is separated from the other large glacier, coming from the west by a space of a few chains only, where a small rocky ridge stands between them. Proceeding about three miles over river shingle, which gradually became larger and more angular, we reached the outlet of the glacier, rushing wildly in a broad channel and washing on one side the terminal face of the glacier one and a quarter miles wide; and on the other side the slopes of the high rocky mountain on the eastern side of the valley, and which rose here with an almost perpendicular wall for several hundred feet above the foaming waters. We were obliged to climb the mountain side and to force our way through a dense sub-alpine vegetation growing here most luxuriantly. The glacier itself formed a vertical or even overhanging wall, two to three hundred feet high, from which at intervals, huge blocks of ice fell with a tremendous crash into the foaming river beneath, and by which the water was thrown up to a great height all around. Some of these blocks of ice are sometimes during heavy freshets taken down by the river as far as ten miles below the terminal face of the glacier, stranding in shallow waters, as I had an opportunity to observe when returning to Lake Tekapo. The river issues from a low ice vault on the eastern side quite close to the mountain slope. Another mountain torrent coming from a glacier on the south-western declivities of Mount Forbes, and flowing in a westerly direction, joins here the outlet of the Godley glacier, shortly after its leaving the ice vault.

It was thus evident that the surface of the Godley glacier could only be reached from this western side with great difficulty and considerable loss of time, so instead of crossing, we followed up the smaller branch for some distance, and returned late in the evening to camp, bringing with us a large collection of geological and botanical specimens, the latter containing several interesting novelties.

Next day I crossed the Godley river opposite our camp, where the river flows with great velocity in numerous branches—I counted twenty-one of them—and reached soon the western glacier, which I named the Classen glacier. From the fact that several older moraines, densely clothed with sub-alpine vegetation were already half buried in the present terminal moraine of the glacier, it was clear to me that the glacier after a period of retreat is now again advancing. The terminal face of this glacier about a mile broad is with the exception of an ice wall, about eighty yards broad, a quarter of a mile from its southern end, and of a low ice vault the same distance from the northern end, entirely covered with morainic accumulations, on which, but not without danger from the rolling blocks of rock it is easy to ascend. The height of the glacier is here 180 feet above the valley. Travelling over the glacier for several miles I found that with very few exceptions it was covered everywhere with a debris load of great thickness, which as it very often consisted of very large blocks of sandstone and slate, made travelling rather laborious. I measured one of them, a block of fine grained greenish sandstone, and which was by no means the largest, and found it to be 20 feet high, 16 feet broad, and 27 feet long. Another huge block of chocolate coloured slate measured 24 feet, with a thickness of 11 feet, and a breadth of 19 feet. The view from this glacier was most grand and varied. On both sides rose high mountains, of which the Hector range on the northern side, covered with large snow fields from which a great number of branch glaciers descended to join the main ice stream, was conspicuous by its wild serrated outlines and majestic forms. The greater portion of the Godley glacier, bounded by lofty snow-covered peaks, was also visible. To the south the horizon was bounded by the blue mirror of Lake Tekapo, lying at the termination of the broad valley of the Godley, through which the river was seen meandering in countless channels. Continuing our ascent of the glacier we found that it turned gradually to the south, and that the morainic accumulations, hitherto covering the whole ice from side to side, now broke up into a number of ridges, which the eye could follow to the bold rocky projections and buttresses, which rose with sharply defined outlines from the vast snowfields in front of us. The upper portion of the glacier, consisting of clean ice only slightly crevassed, offered favourable travelling ground; it formed a vast amphitheatre surrounded by a number of high peaks, of which Mount Darwin and the Hochstetter dome—which appeared again at the head of the great Tasman glacier—were the most prominent. The panorama around us was really magnificent, and as I never expected that alpine scenery on such a gigantic scale could be found in New Zealand, the grandeur of the landscape astounded me still more. The stillness of nature was only interrupted by small rills of water running over the ice, and disappearing soon in small round holes which descend abruptly below the surface, and by the plaintive notes of a pair of Keas which were soaring high above us. A few avalanches fell during the day, the thunder of which was repeated over and over again by the echoes in the rocky walls around us. Towards the middle of the day we were startled by the fall of an enormous mass of overhanging ice, which was pushed over a vertical precipice about a thousand feet high, and came down with such a loud peculiar jingling crash that I cannot find words to describe it. The day was cloudless and very fine, and when towards evening we crossed the river to regain our camp, the water had risen so considerably that it was not only much higher than in the morning, but we had a still larger number of branches to pass.

Some days were now devoted to an ascent of several mountains in the neighbourhood, where besides the results obtained in the pursuit of the topographical and geological work, a rich harvest in zoological and botanical specimens was secured. The observations made during these ascents on both sides of the river proved clearly, that an enormous power had been at work as high as 3000 feet above the present level of the valley. During the great glacier period, broad terraces had been carved into the mountain sides by the moving ice, the angle of which, however small, could be measured. We were camped at an altitude of about 3300 feet above the level of the sea, and although we were still in summer and had generally fine weather, on March 3rd we were visited by a strong south-east wind accompanied by a heavy snowfall, so that the mountains to their base, and even the valley were covered with snow for nearly two days. The thermometer stood three degrees below freezing point (29 degrees Fahrenheit), and some water-holes near the camp were frozen over. It was a remarkable sight to see the whole landscape covered thus with a uniform white garment. However, as soon as the wind changed, the snow disappeared, and the temperature rose again to about 60 degrees Fahrenheit in the shade.

On March 5th we started before daybreak for an exploration of the Great Godley glacier. As it was impossible to cross the river near the glacier itself we had to do so several miles below the junction of the outlet of the Classen glacier, intending afterwards to wade through the outlet of the latter near the glacier vault. When in the middle of the river-bed, the first rays of the sun began to light up the summits of the highest peaks with a deep roseate hue, while all below was still in deep shade ; the sky was without clouds, and all promised a fine day. Travelling along the huge moraine accumulations in front of the Classen glacier we reached the outlet ; but after several attempts to wade across it we found it too deep and rapid, so we were obliged to climb up the terminal face, which owing to the continual falls of stones was not without danger, and to find our way afterwards down again on the other side of the glacier vault, which caused us a considerable loss of time. Before reaching the foot of the Godley glacier we had to ford a small stream which issues from the eastern side of that glacier and which although very rapid was not deep. The ascent of the terminal face was easily accomplished the ice being here covered with an enormous load of debris, sloping with an easy angle into the river-bed. Keeping towards the centre of the glacier and after a laborious walk of nearly two miles we at last reached the ice, which for a short distance was level and unbroken and offered us good travelling ground, but soon it began to be so much crevassed that it became dangerous to advance without the necessary protection, we therefore attached ourselves to a rope brought for the purpose and advanced in a line, of which I as usual took the lead. I had now to cut steps with an ice axe up and down the crevasses, gradually getting broader and deeper, which made our advance very slow work. However, observing that on our right hand the eastern and principal portion of the glacier formed a wall about sixty feet above that portion on which we travelled, we managed with some trouble to ascend to it, when we found ourselves again on a large moraine. A most extensive and magnificent view now opened before us. That portion of the glacier on which we had been travelling came from a large valley opening to the north, and its surface stood at a much lower level than the main glacier, which by pressing against the former had crevassed it near the junction to so considerable an extent that passing over it was of the utmost difficulty. The united glacier itself at the junction of the two main valleys was over three miles broad, forming here a magnificent *mer de glace*, and surpassing in beauty and size any of the glaciers of the Swiss Alps. The mountains on both sides have outlines of remarkable grandeur which become still more striking by being divided by two low saddles, of which Sealy's Pass, * between Mount Petermann and the Keith Johnstone range, and leading into the head waters of the Whataroa, a large West Coast river, is the most conspicuous. On the north-eastern side of the second saddle the colossal pyramid of Mount Tyndall rises in stern solemnity above the vast snow fields from which the great Godley glacier takes its rise. Observing that the extreme western side of the united glacier offered a better travelling ground than the huge moraine on which we were, the ice appearing there level and without large crevasses, we descended again to its lower portion, and after some trouble caused by the number of small crevasses crossing our path, we at last reached the western edge of the glacier where travelling was easy and progress much more rapid. At the termination of the outrunning spur, between the two main glaciers, I established my principal topographical station, and as the ice was here for a considerable distance comparatively smooth and level, we measured a base line, on the two extreme points of which we fixed all the principal features of the mountains around us, connecting them at the same time with some important stations lower down the valley, which we had previously fixed. It is impossible to convey in words a description of the sublime panorama around us, where everything is on a gigantic scale; and as one specimen of the weird grandeur of the scenery, I may only mention, that a mountain chain on the western side of the Grey glacier is so perpendicular that not a patch of snow will adhere to it, presenting a nearly vertical wall of an altitude of 6000 feet, along which the striped appearance of the alternating layers of the light coloured sandstones and dark clay slates can be easily discerned; whilst on the opposite side, where it slopes down to the Classen glacier, it is covered with vast snowfields, from which a number of branch glaciers descend to the main glacier. It was late in the afternoon before we were able to proceed on our return journey. Keeping now along the western side of the glacier, where the ice was comparatively smooth and unbroken, we had only a short scramble over the huge blocks of the morainic accumulations near the

* Mr. Edward P. Sealy who visited this glacier in 1871 taking a number of beautiful photographs, ascended this *nevé* saddle, which he ascertained to be about 6000 feet high. He describes the scenery as very grand and wild.

terminal face, and reached just before dark, the outlet of the Classen glacier. Searching once more for a ford, we at last found one, and although the water was so very rapid that we could only with the greatest exertion bear against it, we all waded safely across, and in another hour reached our camp, after a long day's journey.

The next few days were devoted to ascending several of the tributaries of the main river, all having glacier sources, and to study their geological structure and physical features, and on March 6th we broke camp and descended the river, in which, on the banks, or upon some of the islets, groves of large specimens of *Discaria toumatoo*, the Wild Irishman of the settlers, were growing. Some of them which I measured were 16 to 18 feet high and over two feet in diameter at the base. They formed with the gigantic *Aciphylla Colensoi*, the Spaniard or Bayonet grass, an often impenetrable thicket which, when they had to be passed, most severely punished man and horse. Arriving at the junction of the eastern branch of the Godley, I ascended that river, which I named the Macaulay, to its glacier sources. The valley of this picturesque stream is crossed several times by huge morainic accumulations, through which the river has cut itself narrow gorges, and which we had sometimes considerable trouble to pass. The sources of the Macaulay come from several small but interesting glaciers, lying at the southern flanks of Mount Forbes, and some beautiful and high waterfalls offer a peculiar attraction to this valley. Also here several high mountains were ascended, of which Observation Peak between both rivers offered a glorious panoramic view.

On March 12th I returned to Lake Tekapo, where I devoted a few days to an examination of its shores, which generally consist of thick beds of glacier silt. I also visited the islands in the centre, true *roches moutonnées*, and consisting of very hard blue semi-crystalline sandstones. It is evident from the appearance of the deltas, which advance often very far into the lake, that it is filling up rapidly, even without taking into consideration that the bottom must be raised not inconsiderably in course of time by the enormous amount of glacier silt brought in continually by the large torrents which feed it. Close to the principal lake several smaller lakes and numerous lagoons are lying amongst the ice-worn rocks and the morainic accumulations. Amongst the former, Lake Alexandrina, the physical features of which I found full of interest, is the most considerable. After having shod the horses and replenished our stores, we started again on March 19th for an exploration of the river which joins Lake Tekapo on its western shore, and which I named the Cass, in honour of the then Chief Surveyor of the Province. It is a good sized stream, which before joining the lake has cut for several miles through the broad moraine accumulations, here of great thickness, and by which instructive sections were laid open. The main sources of the Cass issue from two glaciers which descend from the high Alpine range bordering the upper valley of the Godley river on one side, the Murchison glacier on the other. The channel of the river where it passes through the morainic accumulations is sometimes so very narrow and deep that we were obliged to take to the terraces above it, which would have offered favourable travelling ground, but for the existence of a number of very boggy creeks, which were so dangerous, that in one of them we nearly lost one of the pack-horses. However, as soon as we reached the spot where the river flows between the ranges, the valley becomes broader, and for more than ten miles upwards a shingle bed of a quarter of a mile in breadth afforded us anew the means of a more rapid advance. The view up the valley upon the snow-clad mountains with several glaciers descending from them, and of which one forms a splendid ice cascade, is very striking. Several fine waterfalls gave still more animation to the scenery. We camped late in the evening near the junction of the two main branches with one of the glaciers in front of us. This glacier, which I visited next day, and named the Faraday glacier, descends to 4723 feet above the sea level; it is easy of access, as a broad shingle bed leads up to its terminal face. A very rich alpine flora was growing here, and offered me an opportunity to enrich my collection with a number of new or extremely rare plants.

Another day was devoted to the exploration of the eastern glacier, which I designated the Hüxley glacier. Its position is much higher than the former, the terminal face being 5242 feet above the sea level. It is reached by a gorge of wild beauty with high serrated rocky ranges on both sides, from which several fine large water-courses throw themselves down in picturesque cascades. The glacier itself, which has a large frontal moraine, has a steep inclination, and is broken a little above its terminal face into a magnificent icefall. Observing a saddle near the the eastern side of the glacier, some 800 feet above the ice-vault, we climbed along the large lateral moraine, skirting here the glacier till we reached that depression. I found that it leads to a small glacier which forms one of the western branches of the upper Godley, and which I had previously explored. We ascended afterwards a fine mountain peak on the eastern side of that pass, surrounded by a number of frowning precipices, between which we had to climb along steep rocky ridges before we could reach the summit. From this point, 7400 feet high, we had an extensive view, both over the valleys of the Godley and Cass rivers, and of the glacier system at their head, radiating from the snowfields of the Southern Alps, the grand pyramid of Mount Tyndall towering grimly above all the other peaks visible from here.

Having finished the work here, we returned to Mr. Beswick's station, and started again on March 26th, in order to reach the river which flows into Lake Pukaki, and which would doubtless bring us to Mount Cook. Passing by the northern end of Lake Alexandrina, its deep blue waters, scarcely ruffled by a breeze, formed a striking contrast to the milky white surface of Lake Tekapo, covered with foam-crested waves, on the other side of the range on which we were travelling. We soon crossed the Fork river, and keeping along the foot of the high ranges on our right, we ascended again to glacier deposits, which continued for another mile. We then reached alluvial beds with numerous small boggy creeks between them, and camped in the afternoon in the bed of Irishman Creek where it issues from the ranges. Continuing our journey next morning, we ascended, after two hours march, a ridge near the sources of the Maryburn, from which we obtained a most extensive view. The large Mackenzie Country with its fine rounded hills and its numerous rivers and water-courses, and bounded on the south and east by apparently low ranges, was spread out before us. To the south lay Lake Pukaki with its ice-worn island, looking not unlike the back of a gigantic whale; whilst on the east, the southern end of Lake Tekapo was just visible. Towards the west the wild serrated snow-covered ranges on the western bank of the Tasman river, gradually rising higher and higher towards the north, were visible from the shores of Lake Pukaki to the magnificent Sefton peak in the Moorhouse range, after which the spurs in front of us concealed from us the still higher alpine peaks to the north. I consider this one of the finest panoramas in our Alps, from the extension and striking contrast of the country surrounding the explorer. Soon we came upon morainic accumulations on a truly gigantic scale, which now belonged to the Tasman system, and were situate about 1500 feet above the valley of that river. The view towards the Central Southern Alps became more extensive with every step, and soon Mount Cook, rising with its sharp tent-like ridge high above all the surrounding peaks appeared before us, and was hailed with great delight.

For several miles we travelled over these huge moraines, often deeply cut into by small mountain torrents, and then reached the banks of the River Jollie near its junction with the Tasman, as I named this broad and rapid river. The descent into the bed of the former river was not accomplished without considerable difficulty, as we had to take the heavily packed horses down very steep and high banks where one false step would have endangered their lives. On some *roches moutonnées* standing here above the morainic accumulations we obtained the first full view of the upper valley of the Tasman. It was towards evening when this grand sight first burst upon us. The majestic forms of Mount Cook, Mount Haidinger, of the Moorhouse range, and many other wild craggy peaks covered with snow and ice, rose in indescribable grandeur before us, and whilst their summits were gilded by the last rays of the sun, the broad valley of the Tasman river with its numerous meandering channels was already enveloped in deep purple shade. It was a moment of extreme delight never to be forgotten. Crossing the Jollie we camped on the other side on a fine grass flat, on which groves of gigantic "Wild Irishman" trees were growing, and prepared ourselves for a passage over the river. In order to carry as many provisions as possible, every horse had been packed, we were therefore obliged to attempt the crossing of the swift river on foot, the rushing dirty waters of which were divided here into a great many channels, over a river-bed more than a mile wide.

Hitherto the upper portion of the valley itself had been concealed from us by a bold ice-grooved mountain spur, which advanced into the river-bed on the left bank, but after crossing a small branch near it we rounded this promontory, and a panorama of stupendous dimensions was lying before us. The valley, more than two miles broad, continued its straight course for about twenty-five miles, but ten miles above our position the terminal face of a gigantic glacier filled it from side to side. For more than fifteen miles the eye could follow the course of this enormous ice stream up to the vast snowfields, in which the noble mountains at the head of the valley were almost entirely enveloped. Alpine peaks appeared everywhere glistening with snow and ice, frowning rocky precipices furrowing their sides, and, above them all, the bold and majestic form of Mount Cook stood out conspicuously. This was still more striking as this glorious mountain rises abruptly in the foreground for more than 10,000 feet above the broad valley, and on its western flanks it is also separated from its southern continuation by a low snow saddle. After this low saddle the Moorhouse range rises again to a great altitude, the sharp contours of this glistening ice-clad mountain mass, standing out boldly against the azure sky of a bright summer day, whilst deep below it two large glaciers, one, the Hooker glacier, coming from the southern flanks of Mount Cook, and another, the Mueller glacier, bringing down the ice masses from the Moorhouse range, filled the broad lateral valleys. Nothing I had previously seen can be compared with the sublimity of the scenery, which certainly has not its equal in the European Alps.

The passage of the river, although divided into so many channels, gave us a great deal of trouble, as we attempted it on foot; however, we managed after some delay in searching for fords, to get across, when we found good travelling ground on grassy banks, till we reached the broad valley of the Hooker, which washes the southern foot of the Mount Cook range. Having crossed this torrent-like river we proceeded for about a mile along the eastern base of that range, and camped in the evening not far from the terminal face of the great glacier, situated 2456 feet above the sea level, and to which I gave the name of the Tasman glacier, in honour of the discoverer of New Zealand. We began our work here on the 31st March, and attempted first to reach the glacier by following the valley on its western side along the mountain slopes. After crossing a small stream, which for a mile flows between them and the western lateral moraine of the Tasman glacier, we arrived at such an impenetrable thicket of "Wild Irishmen" and "Spaniards," that after more than an hour's battling with the terrific vegetation to gain access to the glacier, we had at last to give up the attempt with our clothes torn and hands and faces covered with blood. In descending the valley again for a quarter of a mile, we came upon more open ground, and then reached the terminal face without further delay. The ascent to the summit of the glacier is here very gentle, as several gullies—or I might style them water-courses—run up amongst the morainic accumulations, which are here of enormous thickness. No ice was visible except in one single spot, where a vertical wall of nearly twenty feet, showing very dirty water-worn ice, stood amongst the large blocks of rock, thrown one across the other. The altitude of the summit above the valley is about 200 feet; when once on the surface of the glacier itself the truly gigantic proportions of the huge ice stream become only then quite manifest. The whole was covered for several miles upwards from side to side with an enormous mass of debris, which with few exceptions concealed the ice everywhere. In many spots a number of alpine flowering plants, grasses and cryptogams were growing luxuriantly amongst the morainic accumulations, proving the comparatively slow progress of the ice, whilst several channels, of which one in the centre was the most conspicuous, were running along it in the direction of its advance. The debris in these channels had lost its sharp angles, and exhibited the sub-angular form, so characteristic of river shingle. It was thus clear that during and after heavy rains quite large torrents were here flowing on the ice. Gradually the ice became more conspicuous, standing as vertical steps, but mostly parallel to the flow of the glacier amongst the moraines. In other spots deep ponds descended 150 to 250 feet below the surface, being surrounded by walls of ice and filled with water of a dirty white or pale bluish colour. The vegetation also diminished step by step, and only here and here a few stunted grasses still occurred amongst the thick stone covering, which also in the channels retained now its angular character. These moraines are thickest on both sides, and towards the centre enormous blocks occur amongst them, and the character of the rocks is generally similar in the same ridges. Crevasses also begin to appear on the western side and in the centre, mostly running with the direction of the glacier, thus giving proof of the enormous pressure from above. On the eastern side they run north-west and south-east.

After two miles travelling in the central portion we followed a north-east direction towards a large open valley, in which also a fine glacier, which I named the Murchison, a few miles above the valley of the Tasman glacier, reaches with its terminal face from side to side. We had to cross a number of crevasses which became now wider and deeper, and gave us considerable trouble before we reached this lateral valley about a mile broad. The Tasman glacier expands here considerably, advancing a few hundred yards into this valley, below which it narrows again to its former breadth, being washed by the large outlet of the Murchison glacier, which now flows along its eastern side to its termination, producing the same effects as I observed along the terminal face of the Godley glacier. Some five miles higher up the glacier became now on a large portion of its surface clear of morainic accumulations, which broke up into a number of lateral and central ridges. The travelling on the ice appeared to us now quite easy, and was real enjoyment after the heavy work of climbing continually over huge blocks or jumping from boulder to boulder, which very often were lying in an unsteady position. From an erratic block of immense size lying here above all others, we obtained a magnificent panoramic view all round. It is impossible for

ɪd by M. Jaffé, Vienna.

me to describe in adequate words the majestic scenery by which we were surrounded; the weird mountain chains with their crowning peaks in stately forms, and numerous tributary glaciers on their flanks, often broken into innumerable seracs, of which the glorious ice cascade of the Hochstetter glacier was the most conspicuous, and the wide ice stream itself carrying slowly its enormous load of debris to its terminal face, crevassed and with deep ponds all around us—all this impressed our minds with deep admiration. But the magnificent pyramid of Mount Cook, or Ao-rangi, stood high above all, towering into the sky. As far as the eye could reach everywhere snow and ice and rock appeared around us, and in such gigantic proportions that I sometimes thought I was dreaming, and instead of being in New Zealand I found myself in the Arctic or Antarctic mountain regions. In returning to our camp, keeping to the western side of the glacier we discovered lying amongst the western lateral moraine deep below us, three very pretty lagoons, their water of an intense blue colour, unruffled by any breeze, and enlivened by numerous Paradise ducks, forming a pleasing contrast to the wild and desolate scenery around us.

The next day was devoted to an examination of the terminal face of the great glacier, along which we intended to measure a base line. Following along the base of the morainic accumulations for about a mile no ice was visible; we then came to a depression on the surface of the glacier, the terminal face retreating here for about fifty yards, and now exhibiting a vertical wall of ice about 50 feet high and one hundred yards broad. However, although a little water was trickling down, there was no outlet, but a deep and wide channel in the shingle deposits in front proved that in heavy rain a large stream must rush down here in a cascade which received its principal supply from the broad channel on the top of the glacier. After this short space of visible ice the morainic accumulations concealed it again till we reached the eastern termination of the glacier, when the united outlets of the Murchison and Tasman glaciers hurried along their muddy waters in a broad and deep torrent. The glacier vault, situated about one hundred and fifty yards above the terminal face of the Tasman glacier, was rather low and insignificant, considering the considerable amount of water issuing from it. We had taken two horses with us, so that in case we were obliged to cross any outlet we could do so, and it may be easily imagined that we were not a little astonished to ride thus all along the terminal face of one of the most gigantic glaciers in the Temperate Zone for more than one mile and a half without meeting with any water or any other serious obstacle, of course there were a few small rills, trickling here and there, but they disappeared very soon below the enormous shingle and boulder accumulations filling the whole valley.

For a few day afterwards we had bad weather, first from the north-west, which turned on the afternoon of the same day to south-east with sleet and snow, by which in a few hours the mountain sides became covered uniformly with a white garment, and it became so cold although still at the end of March, that the water near our tent was frozen over. However, snow and ice disappeared soon in the lower regions, after the first bright day. On the 4th of April, the weather had improved so much that we could continue our explorations. Early in the morning of that day we crossed the Hooker river near the rocks forming here its northern banks, sloping into the river from the southern spur of the Mount Cook range, and procceded then to the Mueller glacier, by which the lateral valley was closed a few miles higher up. Before us we had the remarkable Moorhouse range, crowned by the bold summit of the Sefton peak, which with its large snowfields and numerous tributary glaciers descending into the valley, forms, without doubt, one of the most striking vistas in the Southern Alps. We reached the glacier, which is advancing in an easterly direction to the south-eastern foot of the Mount Cook range, after an hour's ride. It has here two lateral moraines, of which the outer one, standing more than a hundred feet above the glacier itself, is densely covered with sub-alpine vegetation. Asccnding the latter, one of the most glorious views which I ever beheld opened out before us. Across the wide Mueller glacier to our feet which trended to the west, appeared a broad valley to the north, which half-a-mile higher up was closed by the terminal face of a large glacier. This glacier for more than ten miles filled the deep valley between the snow-covered ranges on both sides. At its termination the magnificent pyramid of Mount Cook rose in all its stern grandeur, forming with Mount Stokes on the south-western side of the low snow saddle separating it from the former, a large basin, filled by the ice-streams descending from three sides. My whole party stood riveted to that remarkable spot.

After crossing the Mueller glacier, also covered with a thick morainic load, scarcely showing any ice exposed, I examined the slopes of the Moorhouse range, which offered a good insight into the geological structure of the district. Retracing our steps over the glacier, we proceeded to its terminal face, which presents some beautiful and peculiar features. This glacier abuts, as before mentioned, against the

ıted by M. Jaffé, Vienna.

glacier.

Printed by M. Jaffé, Vienna.

south-western spur of the Mount Cook range, and I now thought that the outlet of the Hooker glacier would have sufficient power to destroy its terminal face so effectually, that it would not reach the rocky mountain side. However, I observed that that outlet kept more towards the centre of the valley, finding its way some 150 yards from the foot of the range below the Mueller glacier, and issuing with the outlet of the latter from a magnificent ice vault. For more than a hundred yards below it, the ice forms perpendicular walls on both sides about a hundred feet high, often washed out into bold forms, resembling turrets, minarets, or gigantic statues, and sometimes crowned with enormous erratic blocks. Whilst travelling on the glacier listening to the strange gurgling sounds of the water, flowing under our feet between the ice, several large avalanches fell with a thundering noise, whilst another glacier of the second order, hanging high above the trunk glacier, threw an enormous mass of ice upon it with a loud clattering sound.

During the next eight days we had a spell of bad weather, which would not allow us to make long excursions. North-westers and south-easters alternately swept through the valley, bringing rain and snow in abundance. Generally we were enveloped in clouds and mists, and occasionally one or the other of the snow-covered giants appeared dimly " half cloud, half ghost," through the haze above us. Our meat began to run short, but with the help of the gun, our larder, when the weather cleared up for a moment, was replenished with native game, which was abundant near our camp. However, during that time, I repeatedly ascended the slopes of the Mount Cook range, made short excursions over the huge glacier in several directions, and continued to complete my geological, botanical, and zoological collections, which now began to assume considerable proportions.

The weather cleared up at last, and on the 12th of April, at daylight, we started to ascend the Mount Cook range. It was a cold but sunny morning, and with great expectations we climbed through the Fagus forest, which, for the first six or seven hundred feet intermixed with sub-alpine shrubs, covers the sides of the range. After leaving the forest we came to alpine vegetation, becoming still more characteristic about 1800 feet above the valley amongst the rocks, where we climbed along the crest of the mountain leading towards Mount Cook proper. But although the ridge, as seen from the valley, seemed quite smooth, it consisted of huge rocks, broken up into very sharp prismatic fragments, lying loosely upon each other, often with deep precipices on both sides, where one false step would have cost life or limb. Soon patches of snow appeared, which were remaining from the last storms, and over which we worked our way higher and higher. The view became every moment grander, and having reached an altitude of 6500 feet, I established my first station. Although the sun shone brilliantly from a cloudless sky, it was extremely chilly in the shade amongst the rocks, where we went to shelter ourselves from the icy cold wind. The thermometer at eleven o'clock stood below freezing point. Again on our road, the rocks became more and more broken; hitherto they had consisted of dioritic sandstones, but now slates, often of a serpentinous nature, made their appearance, and about 7,500 feet above the sea we came upon a chasm of about 10 feet wide, and, perhaps, 30 feet deep; the vertical stratum of clay slates between two others of dioritic sandstone having been here removed, and as it was impossible to round it, and we had no ladder with us to throw across it, we were obliged to retreat. The view from this point is admirable in the extreme. The bold tent-like form of Mount Cook proper occupied the foreground, surrounded by many peaks of every conceivable shape. Deep below us the great Tasman glacier carried slowly, but steadily, its heavy detritus load down to its terminal face. Now only could I form a true conception of the enormous extent of this remarkable glacier, of the vast snowfields at the head of the broad valley, which enveloped here some of the mountains so thoroughly, that no rocks were visible, and of the extent and number of the tributary glaciers joining it along its whole course. Also, the course of the fine Murchison glacier was now well visible, the bold Maltebrun range separating both glaciers, and contributing to their bulk by numerous branches, forming a conspicuous object in the centre of the panorama.

With a hand trembling from the cold, I executed a panoramic sketch of this grand alpine scenery to fix the bearings of the principal topographical features around us, my assistant, Mr. A. D. Dobson, having no little trouble to keep the stand of the instrument steady from the strong blasts of wind sweeping over this exposed height. Towards the south the view was not less characteristic. Here the Tasman valley on its whole extent was visible, with its network of innumerable branches of the rapid river, the placid watershed of Lake Pukaki, surrounded by rounded hills appearing on the horizon. A great deal of new snow had been collected on this majestic range which rose so beautifully before us, and we enjoyed the fine spectacle of witnessing, during our ascent, five avalanches fall from Mount Sefton, the thunder occasioned by them being reverberated by the echoes in the mountains around us.

It was quite late in the evening before we reached our camp again from this peculiarly interesting mountain trip, which gave me another insight into the great features of the Southern Alps. Another day was devoted to a geological examination of the Sealy range, and we then made the necessary preparations to return to lower regions.

It might, however, not be uninteresting were I to give here a few notes on the fauna and flora of this alpine region which is separated from the rest by huge glaciers and deep and broad torrents. I have before observed that although Lake Tekapo is only 2437 feet above the sea level, no Fagus forest is found growing anywhere near it or along the banks of the rivers by which it is fed, but on the shores of Lake Pukaki (1717 feet) and along the valley of the Tasman river, almost up to the terminal moraine of the Tasman glacier, small groves of the obtuse leafed *Fagus Cliffortioides*, the White Birch of the settlers, is found in many localities, and by which the vegetation obtains a more diversified character, many spots having a park-like appearance. Thus, close to our camp, several groves of well grown *Fagus* trees, producing a striking contrast in colour and form with the surrounding vegetation, were standing. They began some twenty feet above the valley and terminated about 600 feet higher. With them not only a number of the shrubs and trees usually found only in lower regions, such as several species of *Panax*, *Coprosma*, *Griselinia* and many others were growing most luxuriantly, but close to them stood true sub-alpine forms of *Olearia*, *Senecio*, *Cassinia*, and *Veronica*, growing mostly in well shaped semi-globular masses, and the two first filling the air with an exquisite aroma. Besides these, several kinds of needle-shape leafed *Dracophyllums*, *Plagianthus Lyallii* with its light green serrated leaves and large white flowers and the three remarkable *Coniferæ*, *Phyllolcadus alpinus*, *Podocarpus nivalis* and *Dacrydium Colensoi* were very conspicuous. It is thus evident that some of the principal representatives of the lower regions are here mixed with the sub-alpine and alpine flora. Everywhere huge plants of *Aciphylla squarrosa* and *Colensoi*, the Spaniards of the settlers, their flowering stems often ten feet high, were growing where they found favourable ground. It is difficult to give a conception of the variegated aspect of the vegetation in such a spot, as all shades from nearly white to dark brownish-green, bluish and yellowish tints are well represented, giving to the mountain side a motley or chequered appearance. However, I have not alluded to another feature of the flora of that region which still more beautifies the landscape, and this is the occurrence of a number of splendid herbaceous plants, and by which some of the most conspicuous and beautiful flowers in New Zealand are produced. Everywhere in shady spots or moist localities a rich herbaceous vegetation is growing, amongst which *Ranunculus Lyallii*, the *king of the Ranunculaceæ* with its large orbicular leaves and the fine leafed *Ligusticum Haastii* are the most conspicuous. Besides them *Senecio Haastii*, *Geum parviflorum*, several *Gnapheliums* and *Celmisias*, and many others, form a gay contrast to the stern features of th e landscape. The rich green deeply cut leaves and large black berries of the *Coriaria angustissima*, a *Coprosma* with a red, and a *Gaultheria* with a white berry, and several of our sub-alpine *Raoulias* and small ferns form a many coloured carpet below the former more conspicuous plants. Along the small waterfalls or rills several species of *Epilobium Myosotis*, *Euphrasia*, and many others, grow most abundantly. The shingle slips and rocky projections are also not without an interesting vegetation, showing that nature had clothed even these barren spots with some of her most charming productions.

The animal life in these regions is equally interesting, although its presence is not without some drawbacks. The principal inhabitants of the flat where our camp stood were a great number of Woodhens (*Ocydromus australis*) generally of large size, and a still greater host of rats by which we were sometimes much disturbed during the night. These rats all belong to the large grey Norwegian species, which thus had already reached the very heart of our Alps. The Woodhens were sometimes also a great nuisance. When leaving camp for the day, we had to be very careful that every small article was well secured, but notwithstanding this precaution we lost a number of things—for instance, pieces of soap were taken away from under our eyes whilst we were occupied with our ablutions; two Kakas which were left for a short time lying on a stone near the camp, were in a very few minutes, whilst the cook attended to the fire, hacked to pieces and the intestines pulled out. But as a woodhen at our last camp near the Jollie had run away with the case of a small minimum thermometer, and which, owing to the impenetrable character of the vegetation near the camp we were unable to recover, we were now very careful that a similar loss should not occur again. What gave still greater interest to the spot was the presence of a number of large green alpine parrots (*Nestor notabilis*) the Kea of the Natives, which visited constantly the small groves of beech trees near our camp; they came generally in small flocks, four to eight together, and were sometimes accompanied by two other species of *Nestor*, of which one was the common Kaka (*Nestor meridionalis*), whilst the other as to size, plumage, and habits, appeared to be intermediate to the two former species. As I had never seen the description of *N. Esslingii* I thought that this bird might be this species of which then only one specimen was known. However when my friend Dr. W. L. Buller examined a skin sent to him he found that this was not the case, but that it was a new species or variety which he named *Nestor montanus*. This bird is more brilliantly coloured than the common Kaka, moreover its flight is different and resembles more that of the Kea. I have seen it soar high in the air, drawing large circles like the former. Its notes are also peculiar, and as I had an opportunity to observe, it builds its nest in holes high amongst inaccessible crags. The Keas as usual came down to the fire, or perched on the tent poles; when sitting a few paces from us on the ground, we sometimes threw stones at them, when they simply jumped up so as to let the stones pass below them. On one occasion four of these Keas were sitting on a *Fagus* tree not far from our tent, when a large Quail hawk, *Hieracidea Novæ Zealandiæ* passed by. They all at once with loud screams went in pursuit, the hawk with a shriek of terror, tried to place himself out of their reach and flew as fast as he could; after a while, the Keas unable to get near it, returned to their former resting place. I secured a number of skins of this rare alpine bird, and may here observe that its flesh is very dark and has a peculiar aromatic taste with a flavour of resin. In the smaller water-courses were numbers of Mountain ducks *(Hymenolæmus malacorhynchus)*, which with Paradise ducks *(Casarca variegata)*, Scaups *(Fuligula Novæ Zealandiæ)*, and others obtained on the lagoons or along the creeks, formed a welcome addition to our stock of provisions.

However, the most interesting inhabitant of these Alpine regions is a very large bird of prey, with crepuscular and nocturnal habits, which visited our camp, first on the evening of April the 6th, when we were sitting round the fire. For a short time previously we heard the flapping of its wings, which became every second more audible. For a moment it sat down close to us, but before we could reach the gun, it rose and disappeared. I can only compare its flight with that of the New Zealand Harrier, and as far as we could estimate its size, it appeared to be as large as a good sized eagle. On the evening of the 8th, when occupied with the writing of my journal by candle light, the same bird flew against the tent with considerable force, and then settled on the ground at no great distance from it. A chance shot had, however, not the desired effect. As will be seen during the progress of my narrative, I met this large raptorial bird several times more, without however being fortunate enough to secure a specimen, and I must therefore leave it to future explorers of these Alpine regions, and to more fortunate circumstances, to obtain this *rara avis*. During the night we heard, besides the well-known call of the More-pork (*Athene Novæ Zelandiæ*), that of another owl, which I had never heard before; also that of another bird, which was not unlike the notes of the Kiwi. Every morning, at the break of day, when the weather was fine, we were awakened by the songs of numerous birds in the copses close to us ascending the mountain sides, amongst which the New Zealand Thrush (*Keropia crassirostris*), the Bell-bird (*Anthornis melanura*), and several of the smaller songsters which generally inhabit the lower regions, could well be distinguished.

Even on the great glacier itself, animal life was not wanting. There is in the first instance a grey stone coloured grasshopper, with a straight forehead, very abundant in the morainic accumulations; it also is very common on all the shingle slips throughout the Alps. Another inhabitant of the glacier is a very large black wolf-spider which, however, retreated so quickly at our approach, between the blocks of rocks, that we were unable to secure a single specimen, although we tried constantly to catch it. Of course, the ubiquitous Blue-bottle fly is also not missing. When taking our lunch on the centre of the glacier, sitting on an erratic block, and surrounded by ice, the Blue-bottle immediately appeared; and the same was the case when resting under the shelter of some rocks on Mount Cook range, nearly 8,000 feet above the sea. I also collected a number of insects and spiders, but with very few exceptions they were all identical with those obtained in the mountain regions nearer to Christchurch. Mosquitoes, there were none, but the plague of Sand-flies, which visited us in myriads, more than made up for their absence; and principally before or during rainy weather they were almost intolerable. There is not a drawing made or a page in my journal written during that time which does not bear ample marks of the blood these minute tormentors extracted from me, and against which protection was impossible. Fortunately after the night had fairly set in they ceased to torture us—but they were splendid alarums in the early morning.

On the 15th of April I broke camp, and descending the right bank of the river Tasman, we soon found, when we were about eight miles from its junction with Lake Pukaki, that the bad reputation which that portion of its course enjoys from the shepherds in the neighbourhood is not without foundation. Quicksands and swamps follow each other here in unpleasant succession, and as the banks, mostly ice-worn rocks, were too steep or too scrubby for the horses, we had to seek our way through this labyrinth. For two days we toiled on, being sometimes obliged to retrace our steps, after several hours march, to find a better road, and we gained at last the shores of the lake, but not without extricating the horses repeatedly with the greatest trouble, and having ourselves various unpleasant adventures. There we camped in the evening, and were awakened next morning by the bleating of sheep, which we welcomed as a sign of approaching civilization.

Lake Pukaki, which is a fine sheet of water, is surrounded like Lake Tekapo by a large wall of morainic accumulations, several miles broad. The view from its outlet up the broad valley of the Tasman towards the Southern Alps, with Mount Cook in the centre, and a wooded islet in the foreground, is really glorious; and if we imagine smiling villas and numerous villages and parks round its shores, there is no lake in Europe which for the magnificence of the scenery could be compared with it. Crossing the level alluvial deposits which separate the morainic accumulations of Lake Ohau from those of the former lake, we reached that third lake on April 21st. Although it is not so large as its two neighbours, it has beautifully clear water, the two others, as previously pointed out, being always rendered more or less opaque by finely suspended matter, the results of the gigantic ice ploughs grinding down, without intermission, the rocks at the head of their principal affluents. Here and there clumps of forest trees adorn the hill sides, by which its shores are rendered more picturesque than those of the two other lakes which, with the exception of the wooded islet in Lake Pukaki, are entirely devoid of timber. Lake Ohau is formed by the river Hopkins and its eastern main branch the Dobson, so named by me in honour of Mr. Edward Dobson, the then Provincial Engineer of Canterbury. I determined to ascend first the last named river, and to reach it by following the eastern shores of the lake. However, having travelled several miles, the mountain sides gradually became so steep, that we thought it impossible to proceed any further with the pack horses. We were confirmed in this surmise by an accident to one of them, which missed its footing, and rolled down to the lake, and was only saved by a large rock lying close to the precipitous shore. We therefore returned to Mr. Frazer's station, and crossed next day by a pass in the Ben Ohau range (3,992 feet high), usually used by that gentleman, which brought us to the upper part of the lake where, in a charming wooded gully, a shepherd's hut was situated amongst the beech trees.

The valley at the head of the lake continues for about five miles to have a breadth of about two miles, being formed by the delta deposits of the river, which has so far filled the lake, and through which it flows now very sluggishly. Where no fans of lateral watercourses reach the valley, the ground is exceedingly swampy and difficult to travel over till the valleys of the two main rivers are reached. Instead of taking to the river-bed we were therefore obliged to seek our way over the low rocky hillocks (true *roches moutonnées*) and the morainic accumulations between them which here border the eastern side of the valley. Many swampy water-courses had to be crossed, and a dense vegetation of Wild Irishmen and Speargrasses which generally covered the hill sides, made travelling very laborious. After several miles of this slow work we at last entered the river-bed of the Dobson, and camped at the edge of a small beech forest, on the evening of the 24th of April. Leaving again next morning, and advancing northwards, the character of the valley becomes more and more truly alpine; but the beauty of the exquisite scenery is still heightened by the magnificent vegetation, mostly consisting of *Fagus cliffortioides* (the White Birch of the settlers), which covers the mountain sides for about 1,000 feet, succeeded above by alpine vegetation, over and through which the rocky pinnacles, pyramids, and other masses—often shaped into fantastic forms—stretch towards the sky. Perpetual snow, first only accumulating in deep well-shaded localities, but augmenting in quantity the more we ascend the valley, and numerous small waterfalls, giving life and animation to the solitary landscape around us, make their appearance. At several spots on both sides of the valley, the forest has been destroyed, often in a straight narrow line down the mountain, as if a gigantic road had been cut from summit to bottom, whilst at others a whole hill side had been laid bare, both being the effect of numerous avalanches. After 14 miles, the valley contracts, and the river winds its course through an old moraine which lies across it. These ancient glacier accumulations are covered with a dense sub-alpine vegetation which is nearly impenetrable to horse or man; but as the river, owing to the favourable season (end of April) was very low, no difficulty was experienced in travelling along its bed, or by crossing or re-crossing it. The contrast between the eastern and western side of the valley becomes now very remarkable. On the eastern side dense forest, with deep valleys and gorges, in which small but splendid waterfalls come down like so many moving ribbons of silver; on the western, rocky walls, mostly naked and nearly perpendicular, many thousand feet high, scarcely ever offering room for the unchequered growth of alpine vegetation. The summit of this stupendous wall is covered with a sheet of snow thirty or more feet thick, but mostly too steep to allow the formation even of small glaciers on that side, which therefore descend towards the western valley. Near the river, and at some few localities of an easier gradient, I met with numerous remains of avalanches fallen during the end of winter and spring, and showing the enormous quantity of snow which must accumulate here to withstand the melting process of several months, during which the sun is particularly powerful in these deep alpine valleys. About a mile from the head of the valley, it was no longer possible to travel on horseback, owing to the enormous blocks by which the river-bed was strewn, I therefore continued on foot, and soon stood at the terminal face of the main glacier, which comes principally from the south-eastern slopes of the Moorhouse range; whilst another branch unites with it at the foot of the gigantic rocky wall which divides it from the Mueller glacier—this latter branch descends from the high range lying between the bed of the Tasman river and that of the river under review.

A second glacier descending into the valley a little below the former, owing to its peculiar form, narrowed in the middle to a mere thread of ice, and expanding in both directions, was named the Hour-glass glacier by me; its terminal face lies 3,816 feet above the sea. The nights now became rather cold, the thermometer, before the sun rose to a considerable height, generally standing below freezing point, sometimes as low as 20 degrees; but the weather was really magnificent, and we had bright days with a deep blue sky, and scarcely a cloud visible. On April 28th we retraced our steps, and then ascended the other western branch, which I named the Hopkins. In order to do so, we had to follow the Dobson nearly a mile down the main valley where both rivers flow a considerable distance side by side, so that we might avoid the swampy ground which, in addition to quicksands, offered us a serious obstacle to crossing nearer to the dividing range between both rivers. The ascent of the Hopkins which, when the river is low, does not offer any difficulty, reveals with every mile new and beautiful views. The mountains for more than a thousand feet are here covered with fine beech forests, above which alpine vegetation appears, which again is succeeded by craggy rocks, snow, and ice. Picturesque waterfalls enliven the scenery, appearing and disappearing between the dark green vegetation. After we had reached our first camp, about eight miles above the junction of both rivers, the series of fine days hitherto enjoyed came to an end, and rain and stormy weather set in, which kept us for several days in the same camp. Proceeding on our road on the 2nd of May, we found that the valley which for at least 15 miles has a considerable breadth, is filled in several localities by large morainic accumulations, through which the river has cut a gorge, and where we sometimes experienced a difficulty in passing.

Gradually the mountains became loftier, glaciers of the second order made their appearance on both sides—the forest line gradually descending and ending at 3,180 feet above the sea level, where sub-alpine vegetation takes its place. Here we camped in the evening. The valley had now narrowed so much that this was the last spot where we could expect to find feed for the horses. During the night it began to snow, but as it cleared up towards morning I ascended the valley to its termination, where I found a glacier of considerable size, which, unlike most glaciers visited during this journey, was very little soiled by debris on its surface. Its terminal face is situated 4,231 feet above the sea level. However the weather was too misty to obtain the necessary bearings to the summits of the glorious alpine chain in front, so that that portion of our task could not be accomplished. Next day the weather was again stormy and showery, but as our provisions were exhausted, we struck the tents to return to Lake Ohau. I regretted this the more as the sedimentary beds in this valley had a somewhat altered appearance, and more resembled some of the auriferous rocks in the Province of Otago, than I had previously seen anywhere in Canterbury. For two days, whilst we travelled down the valley, we experienced a succession of south-westers, with heavy rain—the swollen river giving us not a little trouble to cross.

On the evening of May 6th we reached the lake, and after crossing the Mackenzie Country, reached Burke's Pass on the 16th May. Some days were devoted to an examination of the sources of the Opuha, after which I returned to Christchurch, where I arrived on the 31st May, having been much retarded by a continuance of very bad weather. The beginning of October of the same year (1862), I presented a Progress Report to His Honor the Superintendent which was printed in the New Zealand Government *Gazette*, Province of Canterbury, Vol. IX., No. XVIII.*, in which some of the principal results of my topographical and geological explorations were given. This report was accompanied by several geological maps, a number of geological sections, and a table of altitudes.

The creation of the Philosophical Institute of Canterbury gave me also, a welcome opportunity, as its first President, to allude in the opening address, delivered in the same month, to other scientific researches and results, upon which I had not touched in the official geological report.

Visit to the Opawa Stream, 1862.

In September of the same year I paid a visit to the Opawa Stream (South Canterbury) where a piece of auriferous quartz had been found by two gentlemen residing in Timaru, but our search for other specimens was unsuccessful; moreover, repeated prospecting of the alluvial deposits did not reveal the least sign of the precious metal. There is no doubt, however, that some portions of the ranges in which the main sources of the Opawa take their rise, consist of rocks to a certain extent auriferous, to which I shall allude more fully when treating of the geology of that district. The goldfields in the neighbouring Province of Otago having in the mean time gained such large dimensions, and giving such magnificent results, it was of course of the greatest importance to the population of this Province to have the country examined where the Otago Goldfields reached nearest to the boundary line. My examinations of the eastern portions of the province had already shown—although there were some sedimentary rocks near Burke's Pass, which might be auriferous—that all the rest were of an un-auriferous character, and it was therefore very desirable to examine the rocks along the boundary line of both provinces and, if possible, to follow them to the West Coast by way of Lake Wanaka, where gold was reported to have been found across the Otago boundary line in this province. Having been prevented, six months previously, by a continuance of bad weather at the beginning of winter, from examining the river Hopkins and its tributaries as carefully as I intended, in order to settle the question if and to what extent auriferous rocks occurred there, I proposed to revisit that portion of the province.

---

* **Notes on the Geology of the Province of Canterbury, New Zealand, October 24th, 1862.**

Journey to the Waitaki, Lake Wanaka, and the West Coast, 1862-3.

Starting in the beginning of December, 1862, instead of going again through Burke's Pass and the Mackenzie Country, I selected this time another road, which would make me acquainted with a considerable portion of the boundary line between the two provinces. My first station was Timaru, where I made an examination of the coast line of this interesting locality, and its neighbourhood, and then proceeding to the Waitaki, I crossed this river at the lower ferry, and passed along its southern banks for a considerable distance, examining the geological features as I went along. They were, as I could observe, identical with those on the Northern or Canterbury side, the valley running across the different formations, which were striking nearly south-west and north-east. On December the 7th we reached the Ahuriri plains, evidently an old lake bed, after the retreat of the huge glacier into the Mackenzie Country, and now filled with alluvium. From here a magnificent view was obtained of the Southern Alps and their out-running spurs still deeply covered with snow. After crossing the Ahuriri river, we passed over the downs, mostly morainic accumulations, to Lake Ohau, and keeping on its western shores, we reached Mr. McKuen's station, from which we started on December 15th for the Hopkins. That river, when visiting it in the previous late autumn, was very different from what I now found it. Winter was then coming on, the snow of the preceding season had already, in the lower regions, disappeared before the powerful sun of the summer months, and consequently the water in the river was near its lowest level, as during the nights hard frosts had usually set in, and even the freshets in the river during the rainy weather, experienced when returning to Lake Ohau, were insignificant when compared with the usual size of the river in the spring season. Now in the middle of December large masses of snow still filled most of the depressions in the ranges. The river itself was high even during fine weather, and owing to the almost continuous rain in the higher ranges near its sources, was so swollen that it was often impassable even on horseback. The smaller tributaries too, which in winter were scarcely knee deep, were now rapid, angry-looking torrents, which often offered great difficulties in crossing. The fall of avalanches, endangering the lives of travellers, was still going on in the higher portions of the valley, which was now ornamented by a rich and varied vegetation in full blossom. The aroma of many of the flowering shrubs was really exquisite, and sometimes almost overpowering, whilst amongst others the magnificent *Ranunculus Lyallii* was growing in such a striking profusion, and was so crowded with its large white flowers, that it appeared as if the lower mountain slopes were still sprinkled with snow. Water was coming down everywhere from the mountain sides, and many a small rill, which in winter had only appeared like a silken thread, now poured down as a splendid cascade.

Instead of four or five days which I proposed for this prospecting tour up the river, it took me about a fortnight before I could accomplish the work. We examined first one of the principal western tributaries joining the main river, about twelve miles above the lake, but without results; the rocks, although having been subjected to considerable alteration in their structure, neither showing well defined quartz reefs, nor having furnished material for the formation of alluvial deposits, even should the gold have been disseminated throughout the rock. Continuing our journey towards the sources, the fall of the avalanches, broke the stillness of nature, and warned me to be careful, not only in selecting the road, but also in choosing a camping ground. Although most of the avalanches which now fell were comparatively small, the season being already far advanced, at several localities the enormous devastation they had caused was proof enough that some of them had been of colossal dimensions. At some spots, the whole forest, reaching about 1,000 feet above the valley, was thrown down, the stems of the trees, often of large size, lying over each other like so many reeds scattered over the ground; at others, the trees were only broken off above the roots, and carried down the mountain side, the remaining portion resembling a gigantic stubble field; whilst in some instances the whole forest, with the soil on which it had grown, had disappeared altogether, and only the rocky surface was visible from above the upper line of forest vegetation to the foot of the valley. Often at the base of these localities large mounds were formed, consisting of debris, vegetable soil, and trees—the latter generally broken up in small fragments, the whole mixed with large blocks of rock. It was evident that the unusually heavy falls of snow of the last winter had been the principal cause of the devastation, which was on a much more enormous scale than I had ever seen in the European Alps. Gradually but under great difficulties we reached the upper portion of the valley, and arrived at last, on December 19th, at our old camping ground. During the night an avalanche, apparently of more than ordinary dimensions, fell in the neighbourhood of our camp. The sound accompanying it was in the first instance like the firing of a great many guns of heavy calibre, or like a very loud peel of thunder, followed by rattling sounds lasting for several minutes, resembling the platoon firing of an army. The first crash was without doubt produced by the main fall of the avalanche, whilst the latter was the effect of smaller masses of snow and rocks being brought down in its trail.

On December 21, we attempted to reach the glacier at the head of the valley, in which we succeeded at last, but not without great difficulty, as the small torrents falling here into the main river were so swollen that they were exceedingly difficult to cross. Also, another impediment presented itself in the form of an enormous avalanche which lay across the whole valley, and through which the turbid water of the river had already eaten a subterranean passage, forming a cave over which the snow formed an arch. We climbed up about 80 feet to the surface of this remarkable avalanche, which was nearly a quarter of a mile long, and found on it good travelling ground. There were numerous fragments of rock lying amongst the snow, and remains of vegetation of the higher alpine localities torn away from their lofty abode. The descent into the river-bed was more difficult, the avalanche being here greatly destroyed and undermined by the waters of the river, which without doubt had been dammed up for some time; so that we could not descend directly into the valley, but had to take to the rocky mountain side which was separated from the snow wall by a yawning crevice, across which we had to jump. Having made the necessary examinations, the results of which, however, were not very satisfactory, as to the auriferous nature of the rocks, I retraced my steps to Lake Ohau, but my return, owing to the flooded state of the river, was not accomplished without great loss of time.

After having reported to the Provincial Government as to the unauriferous nature of the district, I started again on January 3, 1863, and crossing the Ahuriri, wended my way by the Lindis Pass to the valley of the Molyneux, which I ascended to the junction of the two outlets from Lake Hawea and Lake Wanaka, establishing my head quarters at Mr. R. Wilkin's station. A number of provision stores were erected close by on both sides of the river, and active life reigned here in consequence of the gold diggings in the neighbourhood, and the arrival and departure of prospecting parties in all directions. An examination of the shores of Lake Wanaka showed that, like the three lakes in the Mackenzie Country previously visited, it was encircled by enormous moraine walls, to the presence of which it doubtless owed its existence. The view from a small hill, consisting of micaschist—a true *roche moutonnée* rising above the alluvium near the station—is very extensive and grand in all its details. Beyond the foreground, consisting of well-grassed downs, appears the deep blue surface of Lake Wanaka, surrounded by high mountains of wild serrated forms, often a mass of barren crags, one rising grimly above the other; but above them all stands conspicuously the high and steep pyramid of Mount Aspiring, glistening brightly in its snowy white garment. The lake with many arms enters far between the spurs of the precipitous ranges, walls of rocks rising abruptly from deep water. In its contours it closely resembles the Lake of Luzern (*Vierwaldstätter See*), and it is, without doubt, one of the finest spots in New Zealand. Looking south, the aspect of the broad terraced valley, with the large river meandering through it, bounded by high rocky mountains on both sides, is also very striking and characteristic of New Zealand alpine scenery.

As I intended to reach, if posible, the West Coast by the head waters of the Makarora, the principal affluent of Lake Wanaka, Mr. William Young, Assistant-Surveyor, joined me here as topographical assistant, that gentleman having, at my request, been attached to me for this expedition by the Chief Surveyor of the Province, in order that I might have some help in the arduous task before me. On January 13th, 1863, I started for the head of the lake, following its western shores, and after crossing the broad delta of the Matukituki river, which advances far into the lake, we arrived on the afternoon of the next day at the station of Messrs. Stuart, Kinross, and Company. Having here ascertained that it would be impossible to continue my journey overland to the head of the lake with my horses, owing to the precipitous rocky nature of its shores, I availed myself of the kindness of Mr. H. S. Thompson, partner of that firm, who placed a boat at my disposal during my stay in this part of the country, and we started, therefore, on January the 19th, reaching the mouth of the river Makarora the same evening, and camping the next day at the Makarora bush, where a number of sawyers were at work—the goldfields on the Molyneux and its tributaries, which are mostly devoid of timber, offering them a splendid market for the products of their industry. This forest is of considerable extent, and contains a great number of fine pines such as Kahikatea, Totara and Matai, which grow here to large dimensions. Altogether the vegetation on the shores of Lake Wanaka with its neighbourhood, showed that its climate is very propitious.

Only very few plants of a sub-alpine character were here growing, the rest belonging to the vegetation found generally only nearer to both coasts.

Having ascertained, in former years, from the West Coast Maoris, that a pass existed at the head of Lake Wanaka, by which former generations had travelled across the island, but not being able to gather anything positive about this road from them, I went on my journey up to the Waitemate bush to consult an aged Maori on the subject, with which I was informed he was well acquainted. From him I heard that the track lay by the Wilkin, a main branch of the Makarora, joining it some miles above the lake, and that it would bring me in two days to the mouth of the Awarua river, on the West Coast; but when on the spot, and examiniug the physical features of the country, I was led to the conclusion that there must be some error in his description. Observing at the same time that the main chain at the head of the Makarora appeared singularly broken, I thought that possibly a pass might be found in that direction, and I determined, therefore, to try to cross the central chain there, and as the result has shown, my anticipations have been fully verified. After the preliminaries had been settled, we started on January 22nd, my companions being Mr. William Young, as Assistant Surveyor, and R. L. Holmes, F. Warner, and Charles Häring, taking four weeks provisions with us, so that we all had very heavy loads to carry. For the first sixteen miles our road led us along the broad valley, over flats covered with grass, or through forest vegetation growing to the banks of the river. Having travelled so far, we found that the base of the mountains on both sides approached nearer and nearer, till after a distance of a mile and a half, they formed a gorge, the river rushing between immense blocks of rocks, which lie scattered in its channel and on the mountain sides. Twenty miles above its mouth the Makarora comes from the east, through a deep chasm of vertical cliffs, showing its glacier origin by its semi-opaque colour; but the main valley still continues in the same north-north-west direction—a tributary, which I have called the Fish stream, flowing through it, joining here the Makarora. After travelling half a mile, we found it impossible to proceed up the bed of this stream, vertical cliffs rising abruptly from the edge of the water, which falls down over immense blocks of rock. We were therefore obliged to ascend to a considerable altitude on its eastern bank, and to continue our journey through dense forest along the steep mountain sides. After travelling for about three miles, partly over very rugged ground, we again met the Fish stream coming from the west, and still flowing in a deep and rocky channel; but observing still the opening in the high ranges before us, we crossed, and went again forward in the same direction, and soon arrived on the banks of a small watercourse, which we followed for nearly a mile. Observing that its banks, about fifteen feet high, consisted of debris, sloping as it seemed to me, on their upper surface to the north, I ascended, and found to my great satisfaction that the level of the swampy open forest had really a slight fall in that direction. Soon the small waterholes between the *sphagnum* (swamp moss) increased, a watercourse was formed, which was running in a northerly direction, and thus a most remarkable pass was discovered, which in a chain of such magnitude as the Southern Alps of New Zealand, has no equal.

From three observations on this pass, I found that its altitude was only 1,716 feet above the sea level, or 724 feet above Lake Wanaka (992 feet). At this point, the mountains on both sides reach their highest elevation, being covered with perpetual snow, and glaciers of considerable size. On the evening of January the 24th we reached a large stream coming from the west, being soon joined by several tributaries from the east. For three miles we followed this stream, flowing in a north-north-east direction, through a comparatively open valley, with occasional patches of grass on its sides, and arrived then at its junction with a large stream of glacier origin, and of the size of the Makarora, which came from the eastern central chain, and to which, according to the direction of His Honor the Superintendent, I gave my name. This river forms, before it reaches the valley, a magnificent waterfall, several hundred feet in height.

Next day, accompanied by Mr. W. Young, I ascended the mountain above our camp, which I named Mount Brewster, in order to use it as a central topographical station, and for geological examination, the glaciers of which give rise to the Haast, Makarora, and Hunter rivers. From the slopes of this grand mountain, from an altitude of about 6,500 feet, we had a most magnificent view over the Alps. Lake Wanaka appeared far in the south, its blue mirror-like surface set amongst wild rugged mountains. All around us rose peak above peak, their rocky pinnacles towering in grand majesty above the snow and ice upon their flanks, whilst deep below us, in narrow gorges, we could look upon the foaming waters of the torrents almost at our feet. The whole formed a picture of such wild beauty that it can never be effaced from my memory. The sea horizon to the west was not visible, but there was an indication that there was an opening in the huge chain by which the river would reach the coast.

When returning from our mountain ascent in the evening, heavy rain set in, which continued almost without intermission till February 13th, and during which time, under many difficulties, we were able to advance only eleven miles down the river, watching a favourable opportunity when the water went somewhat down, to cross from one side to the other, where necessary for our purpose. This part of the journey occurred unfortunately at the same time when we had the most inaccessible part of our route to traverse, being, in fact, one of the most rugged pieces of New Zealand ground over which, during my long wanderings, I ever passed. From the junction of the Leading stream with the Haast, the valley of the latter is still so broad, and the fall of the water comparatively so slight, that we could follow the river-bed from side to side; but after a few miles, the ranges on both sides approached nearer, presenting exceedingly steep slopes, whilst the river at the same time continues for several miles to form a succession of falls and cataracts. On both sides of the river the rocks rise perpendicularly, and the small channel through which it forces its way, is still encumbered by enormous rocks, often several hundred tons in weight, amongst and over which the river falls roaring and foaming. Moreover, the mountain sides, which we were continually obliged to ascend and descend for many hundred feet, were often covered with blocks of rocks of equal magnitude. The large fissures between these are generally overgrown with moss and roots, the latter sometimes so rotten that a hasty step throws the unwary wanderer, toiling under a heavy load, between the fissures, giving him great trouble to extricate himself. No level place of sufficient size to pitch our tent was here to be found, either on the mountain sides or in the river-bed, except in places liable to be flooded, as to our discomfiture we found out, on two occasions during the night. Amongst other curious places, we were camped for several days under an enormous overhanging rock, with a vertical precipice of 150 feet near us, and the thundering and deafening roar of the swollen main river, forming here a large waterfall as its companion.

At last we could observe that we came to lower regions, Totara, Rimu and Matai, often of considerable size, became mixed with the Fagus forest which, since we left the Makarora, had, without intermission, clothed the mountain sides. Fern trees soon made their appearance, forming small groves in the deep moist valleys, and which, considering we were still in the heart of the Alps, gave a strange aspect to the scenery around us. At last we left this region of rocks, precipices, and cascades behind us, and a fine river entered the main valley from the south-west, which I named the Burke. We reached the confluence of it on the evening of February 12th. Fine weather set in at last, and the barometer shewed us that we were only about 300 feet above the sea level. From this spot a most magnificent view over the southern termination of the distant Ritter range, and over the snow-clad Hooker range was obtained,—the more beautiful, as the ranges on both sides of the valley were covered to an altitude of nearly 4,500 feet with forest, and the foreground consisted of fine groves of large pine trees which, lower down the valley, grew on the very banks of the main river. It was only on the morning of February 14th that we were able to continue our journey. The Burke, although only slightly flooded, was impassable, and the main river above its junction, after several trials, we found too high to be crossed. We had just finished making a catamaran of dead trees to get across the Burke, no flax sticks being obtainable to make a mokihi, when a falling of the main river allowed us at last to proceed on our way to the West Coast.

After the junction of the Burke, the course changes again, the river running for seven miles in a north-east direction, the valley opens more, the fall of the water is much less, offering good fords, so as to allow us to use the shingle banks to travel on. Now and then small grass patches of a few acres in extent appear. It was towards the middle of the day when we observed that the river, before its junction with another large river, viz. the Clarke, set against its left bank, keeping close under vertical cliffs to this junction. I determined, therefore, to cross this important river above the junction; but when we came to its shingle bed, which is here about one and a half miles broad, we found the water of the first branch much discoloured. The day being hot and the sky cloudless, I mistook this occurrence for the usual discolouring of a glacier near its source, from the effects of a hot day. We therefore proceeded, and, after some difficulty, found a ford over this first branch; but branch after branch succeeded, each one larger than the former, and it was near evening when we tried to cross the last branch, which proved to be the most important. Several times we failed, but at last succeeded. Although we crossed in the Maori fashion, with a long pole between us, two of my party were washed away when near the opposite bank, and had to swim to shore with their loads on their backs. Had I not taken the precaution to have none but experienced swimmers in my party, a sad accident might have happened. As I afterwards discovered, the river at our first crossing had been still in a state of fresh, and although on returning from the West Coast we found the water low and clear, the river, according to marks set, having fallen considerably, we had still to cross it in five branches, some of them very deep, broad, and swift. The size of this important river, which drains the Southern Alps, from opposite the Mueller glacier to the north-west slopes of Mount Ward, is at least equal to that of the Rakaia in the plains. Its valley is about two miles broad, which, six miles above the junction, is divided into two main branches. On its western bank a fine grass flat occurs, about one thousand acres in extent, where we camped, and which is a real oasis in this constant wilderness of forest. This is, without doubt, the open grass country of which some old Maori spoke to me as existing in the interior, judging its value not by its extent but by the great number of Wekas (Wood hens) and Kakapos (Ground parrots) which, up to the time of our arrival, had here enjoyed an undisturbed existence, and which constitutes this spot a true Maori elysium.

After travelling about two miles over this open grass flat, we again arrived on the banks of the river, below the junction, being here divided into two branches. Although the mountains on both sides continued to be very high, and covered with snow, from which numerous waterfalls descended, the river had now a much slower course, being when flowing in one stream, three hundred to four hundred feet broad, and of the size of the Molyneux. Here all the signs of the great floods were visible which had occurred lately, detaining us so long in the gorges. Not only were all the rapids and shingle islands covered with masses of drift trees, many of them having still their green foliage, but also along the sides of the river quicksands were prevalent, which sometimes gave us no little trouble. At many places, on emerging from the forest on a shingle reach, we were greatly disappointed to find that after travelling a quarter of the distance over which it extended, we met deep backwaters, with quicksands reaching so far upwards from the next point, as to oblige us to return to the forest along the mountain sides, where travelling is very difficult. The river, after the junction of the Clarke, runs for about nine miles in a west-north-west direction, when it is joined by a large mountain torrent, coming down in a cataract from the western chain. The banks of the river, sometimes extending level for half a mile to the foot of the mountains, are generally covered with dense forest, in which the Rimu rivals in magnitude the still prevailing Black Birch. But small patches of open scrub occur also, which offer, occasionally, better travelling ground; the soil on many spots is very good, and the river, from the junction of the Clarke to its mouth, favourable for rafting. Now and then a rocky point, the outrunning spurs of the mountains, reaches the river, against which the water sets, and which we had to climb over, but generally a level travelling ground was prevalent. Having passed an important mountain torrent, which in the smallest fresh would be uncrossable, the river again changes its direction, and runs for six and a half miles south-south-west. The forest still continuing to be open, we pursued our way, in splendid weather, till we arrived at a point where the river changes its course to the north-west. We had some trouble to cross this point, rising almost vertically from the water's edge to a great altitude; but having conquered this difficulty, we were gratified to observe that the mountains gradually decreased in altitude, and that we were not far from the sea. For six miles we continued in this north-west direction, meeting with the usual travelling ground, shingle reaches, with backwaters and quicksands; the forest now beginning to be encumbered with Supplejack (*Rhipogonum scandens*), and the mountain sides sometimes covered with large blocks of rock, which, as they were very steep, and the whole vegetation interlaced with Supplejacks, gave us, at times, hard work. We reached, at last, a spot where the river-bed extended in width, and where a large tributary, which I named the Thomas, entered from the north-east, the valley of which divided the Coast range from the higher mountains inland.

On February the 18th, while crossing the last spur which extended from the Coast range into the river, we were at last rejoiced to observe the sea horizon over a large plain covered with dense forest, in which small conical hills, only a few hundred feet high, rose; and with renewed ardour we continued our journey; but we did not anticipate that a very arduous task still lay before us. From this point we were about six miles distant from the sea; the distance from the junction of the River Thomas with the main river being ten and a half miles, with a north-west by north course. The river-bed, which up to the crossing of this last spur, had offered us, between the mountains, occasional shingle reaches, dry water-courses, open scrub, and comparatively good forest travelling, set now against its northern bank, continuing so to its very mouth. As it was impossible to travel along its banks, we had to keep entirely to the forest, which now became almost impracticable. At many spots large Kahi-katea (*Podocarpus dacrydioides*) swamps occurred with the usual accompaniment of Kiekie (*Freycinetia Banksii*), high fern, and a network of Supplejack. At other places the forest consisted of fine trees of Rimu (*Dacrydium laxifolium*), but without losing its character of West Coast density, which defies description. It occupied us nearly two days to toil and cut our way through this region, till we arrived at a point where the river divided into two branches, of which one running in the above named direction, after a course of one mile, falls into the sea; whilst the other, the northern one, the right bank, which was still clothed with forest of the same description, found its exit one and a half miles north of the former. Observing here a good ford of about two hundred yards in width over the northern branch, we crossed to the island, and soon stood in the surf, giving three hearty cheers. This was on the evening of February 20th, and it thus had taken us thirty days to reach the sea-shore at the West Coast from Lake Wanaka, a journey which, on a good road, could otherwise be accomplished in four days.

The river, the mouth of which we had at last reached, was the Awarua, discharging itself into Wide Bay, about twenty miles north-east of Jackson's Bay. Nowhere could we observe any signs of Native inhabitants, who, as I heard afterwards from the Maoris, had not been living there for some time past. The view from this spot is very extensive. For a considerable distance, both north and south, a plain several miles broad stretches from the sea to the foot of the Coast ranges—the whole, as far as I could judge, covered with dense forest, in which the two fine species of pine, Rimu and Kahi-katea, were the prevailing trees. As far as the eye could reach, all the mountains to an altitude of more than 4000 feet were covered with dense forest, and no peaks visible above six to seven thousand feet, except one single conical mountain, partly covered with snow, which in a south-west direction rose prominently above the Coast ranges. A number of conical hills which, judging from an examination of two of them, consisted partly of granite, stood on the alluvial plains, and were conspicuous in the foreground, whilst a rocky islet, Taumaki, broke the horizon line of the ocean before us.

Being now very short of provisions, we had to start next day on our return journey, and were fortunately still favoured with fine weather, till we were a long day's journey from the Clarke, when the weather became again unsettled; so we travelled on with all speed, crossed the Clarke just in time, found our small provision depôt in good order, and arrived at the junction of the Burke on the evening of February the 25th. Showery weather had set in, but fortunately the rivers only rose slightly, so that, although their fording was not without difficulty, and we had to travel continually through the rain, we arrived at our starting point, the Makarora bush, on the evening of March 2nd, having been nearly six weeks absent. Being all in rags, nearly shoeless, and without any provisions, we returned next day to Mr. Thompson's station on Lake Wanaka, where we remained for a week to recruit our strength. During this time, I sent to Mr. Wilkin's station for fresh supplies, and wrote a report * on the successful issue of my journey to the Provincial Government, which was published in the Canterbury newspapers of April 1st.

On March 12th we started again to the head of the lake, and ascending the Makarora for about ten miles, I devoted several days to an examination of the geological structure of the ranges on both sides of the valley, and to ascertain what its prospects as a payable gold-field would be in the future. Gold was traced in this as well as in the valley of the Wilkin, which I explored next; but in such inconsiderable quantities, that its extraction could not well pay the miners—a conclusion which practical trials in the next few years have fully confirmed. The Wilkin is a large stream, the glacier sources of which are situated on the northern flanks of the Glacier dome. For the first ten miles the river-bed is broad, with small grassy flats on its banks. The view up the river is very grand, as two remarkable peaks, Mount Kakapo and Mount Kuri form the background of this glorious panorama. Frowning cliffs and steep snowslopes constitute their abrupt sides, and small glaciers radiate from them towards the valley. Gradually the banks approach nearer to each other, and the mountain slopes show conspicuously how deeply the rocks have been cut into by the huge glaciers during the Great Glacier period of New Zealand. The river-bed now assuming sometimes the character of a rocky gorge, we had to wend our way through dense forest, still clothing the steep terraced mountain sides, where we found snug camping ground, unabated rain keeping us twice for two days from continuing our journey. The last of these rainfalls, occurring on the 21st and 22nd of March, was one of the heaviest downpours I ever experienced. The river at our feet was an angry roaring torrent, and

* Discovery of a favourable pass to the sea, above Lake Wanaka: By Dr. J. Haast, Provincial Geologist.

we could distinctly hear how big boulders and blocks of rock were carried along, together with large trees, by the muddy rushing waters. Every small water-rill hanging on the steep mountain sides was now changed into a broad foaming waterfall. How enormous this rainfall was, may best be judged from the fact that the level of Lake Wanaka was raised over four feet in less than twenty-four hours.

As soon as the river had fallen sufficiently, we continued our journey towards its sources. Instead of being a broad shingle-bed with here and there a rocky gorge, and where travelling had been comparatively easy, the Wilkin now consisted of a series of rapids and waterfalls, often filled with enormous blocks of rock, and the valley rose so rapidly that within a few miles we had ascended to a region which was clothed with sub-alpine vegetation, having all the characteristics of a truly alpine country. Following the river for another day, we found its bed repeatedly obstructed by old moraines, often of enormous dimensions, and after observing that its main sources issue from two small glaciers descending from the central range, we retraced our steps to Lake Wanaka. At the end of March we returned to Mr. Wilkin's station, and after a few days' preparation, started for Lake Hawea, to which Mr. Robert Wilkin had kindly sent a boat, on a bullock dray, for my use, over from the Molyneux. Lake Hawea is like Lake Wanaka, surrounded on its lower side by morainic accumulations, encased one in another, and which have a higher level than those of the latter lake. The view up the lake is beautiful in the extreme, high rocky mountains appearing one above the other, forming a magnificent background; whilst a wild craggy peak, its perpendicular walls washed by the deep blue waters of the lake, forms a conspicuous object in the foreground. For several days we were detained here by bad weather, but managed, on April 5th, to reach the Hunter, the main affluent of Lake Hawea, after having first visited, on our road, the rocky islets rising from it. We followed the Hunter for a few miles, flowing sluggishly along through the swampy delta at the head of the lake, until its bed assumed the character of a true shingle river, where the shallowness of the reaches would not allow us to proceed any longer with the boat. Shouldering our swags again, we began our toilsome march, mostly through dense vegetation, towards the sources of the river, which have a glacier origin. The scenery is really splendid, the view up the straight valley, where a succession of craggy snow-covered peaks appear for many miles one behind the other, and the lower mountain sides mostly covered with luxuriant *Fagus* forest, is one of the most characteristic of our New Zealand alpine landscapes.

On April 15th we reached at last our highest camp in the valley, from which we ascended to the bifurcation of the two main branches, flowing in deep rocky gorges, and forming several fine waterfalls. Here we had to battle for several days with heavy rains, mists, and fogs, before we could accomplish our task, and then retraced our steps, ascending several high peaks on our return march, in order to complete my topographical and geological observations. On April 23rd, we were back at our old quarters at Mr. Wilkin's station at the junction of the outlets of both lakes, and left this beautiful spot shortly afterwards, returning by the Lindis Pass to the upper course of the Ahuriri, the fourth and least important main branch of the Waitaki river system. For several miles above the junction of the Lindis Pass stream, the Ahuriri flows in a deep rocky channel, whilst the broad valley on both sides consists of alluvial deposits; after which we found morainic accumulations of considerable breadth, crossing the valley from side to side. After travelling about two miles, we reached the upper edge of these old frontal moraines, but instead of finding, as usual, a lake formed by them, the whole broad valley for several miles upwards consisted of a huge swamp, through which the river wound its sluggish course, thus showing clearly in what manner all the lakes formed by the deposition of huge moraines across the valleys will gradually be filled up. After a distance of eight miles, another moraine crossing the valley was reached. Five miles higher up, the valley narrowed considerably, the channel of the river became rocky, and broken up in a number of rapids, the *Fagus* forest ceasing at an altitude of about 3500 feet. We had now entered into a season in which, amongst the alpine ranges, the winter soon sets in; and, in fact, the weather became now worse than we had hitherto experienced it. Having reached our highest camp on April 29th, we were unable to move for several days, owing to heavy snowfalls setting in. We were surrounded by a fine winter landscape; all the flats were covered deeply with snow, the river winding its course like a broad blue ribbon through them, the branches of the dark green beech forest being weighed down by their heavy snow load. The rocky projections of the mountains around us had all disappeared under the white garment, whilst a dull leaden sky hung heavily above all. However, as soon as the weather cleared up, both the topographical and geological surveys of the valley to its sources were, but not without considerable difficulties, accomplished.

At last we were able to return to lower regions, reaching the

Mackenzie Country on May 5th. The weather had now cleared up again, and fine cloudless days and cold bright nights followed the succession of wet stormy days experienced in the Ahuriri valley. Mr. W. Young, my topographical assistant, left me here, to continue his surveys in the lower Waitaki country. With great regret I parted with this gentleman, who had not only been a very cheerful, but also a very useful companion, having been accustomed for years to New Zealand bush travelling, and possessing at the same time a quick eye for discerning readily the topographical features of the country. After making some geological explorations in the Mackenzie Country, which detained me a few days, I returned to Christchurch, where I arrived on May 12th.

Besides the results of the geological and topographical work done during this journey, large collections were also obtained in zoology, and botany, so that considerable additions were made to the material brought from former explorations, which formed the foundation for a public Museum in Christchurch. After having arranged this new material in a large room allotted to me for the purpose in the Government Buildings, I presented, on May 16th, a preliminary report on the main results of this journey to his Honor the Superintendent.

Artesian Wells in Christchurch, 1863.

At the request of the Hon. John Hall, at that time Chairman of the City Council, I examined also into the practicability of supplying Christchurch with pure water by means of artesian wells, and furnished that gentleman, on June 19th, with a report on that important question, which was printed in the local papers at that time. From the numerous observations made by me in and close to Christchurch, as well as in many localities on the Canterbury plains, I concluded that the geological structure of the district was favourable to obtaining water by means of artesian wells, and I may be allowed to transcribe here the last sentence of that report, having reference to the subject:—"In summing up I may therefore confidently state, that the strata through which the borer has to go will not, by their nature, offer any serious obstacle, and that, reasoning by induction, all tends to confirm me in the belief that, long before the volcanic rocks are reached, a good supply of water will be obtained." The subsequent remarkable results of the borings by which an almost endless supply of pure water was obtained for Christchurch and its neighbourhood, have thus amply confirmed my views on the subject expressed in that report.

Malvern Hills Coalfields, 1863.

Since my last surveys in the Malvern Hills and the adjacent district, considerable discussions had taken place, as to the value of the different fields, and as to the quantity and quality of coal in each, therefore, by direction of his Honor the Superintendent, Samuel Bealey, Esq., I proceeded at the end of August, 1863, to that district, and examined once more the detached basin behind the Fourteen Mile Bush range, near the sources of Macfarlane's stream, visiting on my return the works of the Kowai Coal Mining Company. However, the latter having been abandoned for some time, I was not able to obtain a great deal of additional information on them. The results of these new examinations, together with a former report* on the same district, were published in a New Zealand Government *Gazette*, Province of Canterbury, on September 23rd, 1863.

Building Stones, 1864.

According to instructions received from the Provincial Government, to examine the districts around Christchurch, for the purpose of fixing the principal localities whence good building materials were available, I first visited Banks Peninsula, where I inspected all localities in which quarries had already been opened, and afterwards noted a considerable number of places where good building stones might be obtained advantageously. During these examinations I ascended all the principal peaks on Banks Peninsula, noted the main geological features, and studied the rather complex structure of that interesting volcanic system. Having accomplished this object, I proceeded to the Malvern Hills, where I examined a great number of localities, where building stones of fine quality and other rocks of economic value could be obtained, collecting a number of specimens in illustration. During this journey I ascended Mount Torlesse, Big Ben in the Thirteen Mile Bush range, and several other mountain summits, and being in the right season of the year, reaped a rich harvest of plants, amongst which were several new species, not before collected by me. During the month of January, 1864, I finally visited the Waipara and Weka Pass districts, and examined the large deposits of rocks possessing economic value, which cover there a considerable portion of the country.

---

* Reports of the Provincial Geologist on the Coal Measures and lignitiferous beds of the River Kowai.

On February 4th, 1864, I presented a report to the Provincial Government, on the building stones collected during these journeys, together with thirty-two specimens, which are now deposited in the Canterbury Museum. This report* was printed in the local newspapers on the following day.

Search for Coal in the Ashburton and Rangitata Districts and Continuation of Geological Survey, 1864.

Having during my surveys of 1861, near the head waters of the Rivers Rangitata and Ashburton, met with large fossiliferous beds of probably young palæozoic age, situated about sixteen miles apart from each other, amongst some of which a few small seams of fine coal were exposed, I was not then able to spare so much time for their investigation as I should have wished, the winter with heavy snowfalls having set in. A set of the fossil shells and plants collected during that journey in the localities in question, were sent by me to the well-known palæontologist, Professor F. McCoy, in Melbourne, for examination, who informed me that they were nearly all identical with those that accompany the Coal measures of New South Wales. I therefore proposed to devote some time towards a more detailed examination of the country referred to, and started in the middle of February (1864), for that district, beginning my surveys at the upper course of the River Hinds. Having ascended, first the southern, and afterwards the northern branch, to their sources, I examined afterwards the Gawler downs, a separated series of hills, consisting mostly of a large number of streams of melaphyre. Another day was employed in visiting the gorge of the Rangitata, where, in the vertical walls, beautiful sections are laid open, and where some of the most interesting phenomena in connection with the Great Glacier period of New Zealand can be studied. On February 24th I left the Hinds, and proceeded towards the sources of the Cameron, a river which joins the outlet of Lake Heron, shortly after it issues from this lake, both forming the South Rakaia branch. Having crossed the extensive morainic accumulations round this pretty lake, we reached the large shingle fan of the Cameron, which, together with another of nearly the same size, coming into this valley from the opposite side, has given its present form to the lake. Here travelling was easy, until we reached the gorge-like valley of the river

---

* Report on the Building Stones of the Province of Canterbury, New Zealand. First Series. By Julius Haast, Ph.D., F.G.S., Provincial Geologist.

itself amongst the high ranges. We now entered into a truly alpine region, and were surrounded by a rich vegetation, which grew also most luxuriantly along the mountain slopes for a considerable altitude. In front of us rose the majestic Arrowsmith range, the crenellated bold outlines of which were brought out still more prominently by a cloudless deep azure sky above us. Numerous snow-fields nestled on its flanks, from which a glacier of considerable proportion descended into the valley. About four miles from the glacier we had to camp, as it was impossible to take the horses any further, owing to the valley being often filled with enormous blocks of rock on both sides of the river channel, which itself became occasionally very rocky.

On February 27th we ascended to the glacier, which in honour of my companion during this journey, the Hon. J. Hawker, Speaker of the House of Representatives of South Australia, I named the Hawker glacier. This glacier, which is formed of two main branches, uniting about 1200 feet above its terminal face, descends to an altitude of 4478 feet above the sea. Its terminal face is 1500 feet broad, and the river issues from an ice cave about twenty feet high; it is only separated by a narrow but high rocky ridge from the Ashburton glacier, and surrounded by walls several thousand feet high, exhibiting well the stratification of the alternating sandstones and slates. Returning to Lake Heron, I remained there for several days to study the geological features of the surrounding country. The shores of this little lake are very characteristic, and give a clear insight into the great glaciation of the district, *roches moutonnées* abounding in its neighbourhood, of which the so-called Sugarloaf, a nearly perfect cone, 3822 feet above the sea, or rising 1557 feet above the lake on its eastern side, is the most conspicuous. I also made here, as afterwards in the Upper Rangitata district, a number of observations with the spirit-level, which proved that the numerous terraces, of which some occur as high as 5200 feet along the mountain sides, were not of marine origin, but simply either old morainic accumulations, remains of ancient river-beds, or the deposits of small glacier lakes—the waters of which were stowed up at considerable altitudes by the enormous ice streams, during their greatest extension. Nearly a week was devoted to a search for coal in the Clent Hills, but I was not able to find any larger seams than those previously observed, which only owed their existence to the presence of large flattened endogenous trees, the bark of which had been altered to coal. On March 12th I proceeded to the Rangitata, where, during a fortnight, I continued my search for coal in the Mount Potts range, in Mount Harper and other ranges, where rocks similar to those of the Clent Hills were observed by me, but without obtaining any more favourable results. Large collections of fossils were however made, and the observations on the glacial phenomena, here on a truly gigantic scale, continued. Finally, I visited the River Stour, a tributary of the Ashburton, where two years ago I had found a large rolled piece of green carbonate of copper, when I was returning to Christchurch during snowy weather. For several days I searched over the whole part of the range from which it might have come, but without success, and I arrived at the conclusion that it had been washed out from the morainic accumulations close by, and brought from the sources of the Rakaia. At the beginning of April, I returned to Christchurch.

Geological Survey of the Christchurch-Lyttelton Railway Tunnel.

The tunnel works in the Caldera wall having been pushed on with great activity by the contractors, Messrs. Holmes and Co., I began shortly after my return, to make a geological survey of the adits on both sides, and to note my observations on a section, at the scale of twenty feet to one inch. I did this with a hope that some important contributions would accrue therefrom to geology, this being the first case where a crater wall of an extinct volcano had been pierced in its whole length by a tunnel. As this work was continued day and night during the week by three shifts of eight hours each, I found it impossible to work during the usual time, and had to make use of the hours beginning at midnight on Saturday, and ending at the same time Sunday night, when the work was again begun by the miners. The Railway Engineer, Mr. Edw. Dobson, C.E., as well as the contractors, Messrs. Holmes and Co., gave me all the assistance in their power, during the number of years the work was progressing.

Some time had now also to be devoted to the classification and arrangement of the public collections, which had so much increased, that they already consisted of about 6000 specimens, I therefore made an arrangement with the Provincial Government to hand over the two rooms which I occupied in the north-eastern portion of the Government Buildings, in order that they might be used as a Public Museum. However, when the necessary preparations were nearly completed, it was found that the rooms to be given to me instead, could not be spared, and the opening of the Museum had to be postponed for a short time longer. On August 2nd, I presented to the Secretary for Public Works, the Hon. John Hall, a progress report* on the geological survey of the Province of Canterbury, which was published in the same year, by order of the Provincial Council.

Besides the geological information, notes on collections, forming the nucleus of the Canterbury Museum, lists of flowering plants, and tables of altitudes were given. At the same time I sent a paper to the Geological Society of London, in which I treated of the remarkable glaciation of the Southern Island of New Zealand during pleistocene times, and which was read on December 7th, 1864, and was printed with an appendix "On the Pleistocene epoch of New Zealand" in the Quarterly Journal of the Geological Society for May, 1865.†

Canterbury Plains.

Several important questions regarding the Canterbury plains having been raised, as to the flow of the River Waimakariri and other points having reference to engineering works, the Secretary for Public Works instructed me to report on the formation of those plains. During the winter months I visited several localities not previously examined, so that I became acquainted with all the rivers from the Ashley north to the Rangitata south, having followed their course from the sea to the point where they enter from the mountains on the plains. This report was furnished to the Secretary for Public Works on September 2nd, 1864, and printed by order of the Provincial Council.‡ As the principal portion of that report will be incorporated in the geological portion of this publication, I need not allude any further to its contents.

---

* Report on the Geological Survey of the Province of Canterbury, by Julius Haast, PhD., F.G.S. Provincial Geologist. Session XXII, 1864.

† On the Lake-Basins and Glaciers of New Zealand, by Dr. Julius Haast, F.L.S., F.G.S. with an introduction by Sir Rod. J. Murchison, K.C.B., F.R.S., F.G.S.

‡ Report on the Formation of the Canterbury Plains, with a geological sketch-map and five geological sections. By Julius Haast, PhD., F.G.S., F.L.S., Provincial Geologist. Session XXII, 1864.

New Zealand Industrial Exhibition, Dunedin, 1865.

The Provincial Government having accepted an invitation to have the Geological Survey of Canterbury represented in the New Zealand Industrial Exhibition, to be held at Dunedin in the beginning of 1865, I prepared a number of geological and botanical specimens, maps, and sections for exhibition, and proceeded on January 27th, 1865, to Dunedin, for the preparation of the necessary show-cases, and to study the contents of the Exhibition, which, considering the shortness of time and the limited resources of the Colony, may be pronounced to have been a most remarkable success. It doubtless marked a great stage in the history of the Colony, as here, for the first time, all its principal resources, and many of them of no mean order, could be examined under one roof. I also paid a visit to the principal goldfields of the Province of Otago, and returned to Canterbury towards the middle of February, when I devoted several days to a geological examination of the Timaru district, in reference to obtaining a supply of water for that town. A report on the subject* was handed to the Provincial Government, and printed in the same year, in which the result of my researches in respect to this important question are given.

---

* Report on the Geological Formation of the Timaru District in reference to obtaining a supply of water; with several geological sections. By Julius Haast, PhD., F.G.S., F.L.S., Provincial Geologist.

CHAPTER II.

FROM THE DISCOVERY OF THE WEST COAST GOLDFIELDS TO THE TERMINATION OF THE GEOLOGICAL SURVEY OF CANTERBURY, END OF JUNE, 1868.

JOURNEY TO THE WEST COAST, 1865.

I now prepared myself to start for the West Coast, to examine and report upon the goldfields opened up in the northern portion of the Province, and to trace the extent of the auriferous ground, not only as an assistance to the mining population, but also as a guidance to the Provincial Government. This journey to the West Coast taking place during the most remarkable period in the history of the Province, I shall offer here a transcription of a portion of a paper treating on the subject, which was read on February 11th, 1868, before the Imperial Geographical Society of Vienna, and printed in its Transactions,* and I trust that such account will not be without interest to the inhabitants of Canterbury and Westland, many of whom will have a lively recollection of those stirring times.

For several years past I had pointed out in my official reports, that on the West coast of this Island, and especially of this Province, extensive, and without doubt rich, goldfields were situated; but it was long before the gold-diggers from the equally isolated Buller goldfields (who were the first to go) went there. A few rich finds caused many miners working in the Otago goldfields at last to turn their attention

* Beschreibung einer Reise von Christchurch, der Hauptstadt der Provinz Canterbury auf Neu Seeland, nach den Goldfeldern der West Küste in Jahre 1865. von Dr JULIUS HAAST, Mittheilungen der K.K. Geographischen Gesellschaft in Wien, No. 4 und No. 5, 1868.

to them, and the peculiar charm of a perfectly unknown region, where it was reported, not only that the call of the Moa had been heard, but that the gigantic bird had even been seen; the thick primeval forest, and the mountain scenery, described as magnificent, exercised at the same time an additional power of attraction. In the autumn of 1864, several hundred gold-diggers went there from Otago as pioneers; they first worked in the Greenstone Creek, flowing into the Teramakau river, but after a few weeks they removed to the goldfields, discovered in the meantime at the Waimea river, six miles south of the Teramakau. The letters of these people to their friends, in which they described the extremely rich finds, and the repeated remark that brilliant "prospects" might be expected almost wherever a pick and shovel was put into the terrace, or bed of a creek prospected, soon had the effect of making the numerous diggers who were working in the Otago goldfields leave them in crowds, and set out for the West Coast. Besides the restlessness of a goldfield population, which is proverbial, the prospect of the mild winter on the West Coast, with its inexhaustible forests, presented such a favourable contrast to the severe continuous cold, and the violent snowstorms in the sub-alpine country of Otago, where there is great scarcity of firing, that it served as an additional incentive to migration. Quite 8000 gold-diggers set out from Otago for the new Eldorado. Towns like Queenstown and Kingston on the Wakatipu lake soon stood almost entirely deserted, and the few inhabited houses sheltered for the most part the female portion of the population, who only waited for decided news from the West Coast to follow their husbands with the children. Houses which a few months before could not have been bought for less than several hundred pounds were got rid of for a trifle; strange to say, in just the same feverish haste these very people hurried away from the place to which they had so lately come through numerous privations and dangers.

Whoever is acquainted with life in the goldfields, will understand that, with the gold-diggers proper, the whole population which follows in their train, immediately departed. Not only the storekeepers and packers, artisans, and publicans, but also the demi-monde, sharpers and idlers of every kind, resembling marauders who follow an army, moved like a living stream through the country. In the meantime the gold fever had not only attacked the population of the Otago province; all New Zealand, and even the Australian Colonies were more or less affected, and numerous steam and sailing vessels unloaded their living freight on the formerly desolate West Coast. Thousands of men who in consequence of their usually sedentary lives, were the least fitted to bid defiance to the elements, to carry heavy burdens on their backs, and at the same time put up with scanty and bad food, would not be warned, but followed in pursuit of the gold which, as report said, was so easy to obtain. Thus the clerk left his desk, the artisan his workshop, even doctors, lawyers, and merchants whose sphere of action was not quite what they desired, preferred to give up their professional position and domestic life in pursuit of the uncertain wealth in the distance. As a matter of course, most of these people returned without having attained any results, while many, terrified by the mountain torrents, and being to their advantage, soon sobered down, came back again when they had scarcely gone half-way.

This migration began in December, 1864, during the time I was occupied in preparing the results of my geological explorations for the Art and Industrial Exhibition in Dunedin, the capital of the Province of Otago. This was the reason that I was able to set out to follow the general stream to the West Coast, only towards the end of March, 1865. All those who did not prefer to come by sea had to travel over the "saddle," the only pass then known, and which leads from the sources of the Hurunui river to those of the Teramakau. The Government had sent out several parties in the beginning of the year, to the sources of the Rakaia and Waimakariri rivers, to see if any pass existed there through the Southern Alps, but meanwhile in order to facilitate the traffic in some degree, had despatched a number of roadmen under qualified engineers, to improve the bridlepath made some years previously, so that pack-horses could be brought from the East to the West Coast.

On the 29th March I left Christchurch with three horses, and accompanied by three men; the weather was glorious, as it nearly always is in the latter part of our summer, not a cloud in the deep blue sky, and travelling was pleasant and easy, as a well-made road only a few miles distant from the sea coast, leads from the capital for thirty miles north to the Waipara. What stirring life was on the road! waggons of all kinds came and went, bringing provisions and other goods to the Waitohi gorge, where the waggon road ends. An endless train of gold-diggers with pack-horses, packers driving horses before them, and even women walking stoutly along by the side of their husbands and often leading pack-horses, all going to the new Eldorado. Travellers on foot with heavy packs on their backs, and shovels and pickaxes in their hands, were also there, many of them having already come several hundred miles. It was easy to see from their appearance that most of them were accustomed to such journeys with their accompanying privations and hardships; but an experienced traveller could easily descry among them single groups whose outfit and appearance showed at once that they were novices, and hardly in the condition to bear the fatigues before them. After the Kowai river is crossed, the high road leaves the alluvium or littoral zone, consisting of drift sand which it has hitherto passed through, and ascends a terrace about fifty feet high, consisting of the older drift alluvium which forms the Canterbury plains.

After having traversed about eight miles of this monotonous grass-covered plain, the road enters the tertiary limestone range through which the Weka Pass leads to the Hurunui district. The road instead of leading over the Waikari plain to the Hurunui river goes towards the Waitohi, one ot its tributaries, where it enters the alluvial plain from the eastern slopes of the Southern Alps. The good high road which we followed hitherto, ends here, and only a small bridlepath leads farther into the country. The Waitohi enters the plains through a rather narrow valley with a small alluvial terrace, about 100 feet high on both sides, in which as well as in the underlying cliffs the stream has formed its present bed. Within a few weeks a small township had sprung up here, consisting mostly of tents, but a few people had already begun to erect wooden houses and shops, for the numbers of people who came were increasing every day. The traveller could not help being especially struck here with the feverish movement of a population hastening to a newly discovered goldfield. Many of the diggers and storekeepers who had brought loaded waggons from Otago, in the belief that they could take them at least to the foot of the saddle, which leads over the central chain, were now obliged to leave them behind and take their stores on with pack-horses. Many large waggons were therefore sold for a trifle, while others which did not immediately find a buyer were simply left behind. And what a busy active life was here to be seen, everywhere tents and campfires, around which several hundred persons were encamped, most of them making preparations for continuing their journey, and often speaking in different languages, English being of course predominant. During the whole of the afternoon and till late in the evening travellers kept arriving. As I observed the different groups, I could not help noticing in spite of the commotion and the noise, how very earnest the people were. There was very little drinking, and still less singing; each one was too much occupied with putting up tents, cooking, and especially with his preparations for the journey, and was thinking no doubt at the same time of the difficulties before him. At the Waitohi gorge I met several parties of diggers, who were on their way back to Christchurch, not being able to endure the hardships of the journey; they had found themselves compelled to make their way back overland, as soon as their means were exhausted. Most of them were dreadfully ragged, and looked quite famished and fallen away, and they could not say enough about the horrible condition of the road and the dangers they had gone through. The gold-diggers by profession did not however consider it worth while to listen to them, as they saw directly that they did not belong to the right class of men to undertake such journeys successfully. Although I was told that 40 miles farther on, immediately below the pass, provisions and oats might be bought, I wished to be quite safe, and sent two more horses on with provisions from here, that I might not be hindered in my progress.

Where the Waitohi enters the plain, the good made road ends, and only a bridlepath leads on towards Lake Sumner, into which the Hurunui falls, 16 miles from its source; and then, increased in volume, flows towards the East Coast, forming the boundary between the provinces of Nelson and Canterbury. This bridlepath, about 18 miles long, was originally formed by the sheep farmers who used the hilly ground in the Hurunui lake district as pasture land. The path continues for three miles along the northern terrace of the Waitohi river, a continuation of the Hurunui plain. This terrace consists of alluvium resting upon rocky cliffs, into which the present river has cut its way 100 feet deep, so that it is shut in on both sides by high perpendicular walls of rock. Here we leave the tertiary, and enter into a much older formation, palæozoic sandstones alternating with reddish brown clay slates. Here and there quartzose and diabasic slates occur, dikes of hyperite are also not rare, but their position does not offer any clue to their age. Altogether the geological conditions of this zone show a great similarity with the Mount Torlesse chain, of which this is without doubt the northern continuation. I searched here in vain for fossils, of which generally in our older rocks for more than a hundred square miles scarcely a trace has yet been discovered. Numerous parties crowded past us, scarcely allowing themselves a moment's rest, in order that they might not be too late for the golden harvest. After three miles the bridlepath leaves the principal valley of the Waitohi, and follows a little tributary from the north, which crosses the path about twenty times before the foot of the pass, 1858 feet high, is reached. Immediately at the beginning of the rush, the Provincial Government had sent on a number of roadmen to repair the worst places, to build bridges, to drain swamps, and where the bridlepath led along steep declivities, to make it less dangerous by blasting and earthworks. Although this had been done here, and notwithstanding the really splendid weather, the road was nevertheless in many places in a very bad condition, for the immense traffic of men and horses and the numerous herds of cattle which were daily driven towards the West Coast, had soon destroyed the generally temporary earthworks, so that in many places we had great difficulty in getting the pack-horses over the swampy ground. Here too, I met several people returning from the West Coast, covered with rags, and whose hollow features showed only too plainly traces of the unaccustomed privations they had endured. We now rode up the grassy saddle which leads between the mountains, about 3000 feet high, to the Hurunui river, without encountering any difficulties. In spite of the unpleasant change in the weather which had taken place, the road was very interesting.

Numbers of diggers on foot or on horseback, pedlars taking provisions on pack-horses, herds of cattle driven by stockmen on horses, and all going in the same direction, enlivened the landscape, the loneliness of which at other times would not fail to make an impression upon the traveller. Arrived at the saddle, a magnificent view opened out on the wild partly wooded rocky mountains, which bound both sides of the Hurunui valley; the river itself is not visible, as it flows in a deep gorge. Behind us lay the Hurunui plain, bounded by a succession of tertiary hills which form the horizon. At the northern declivity of the pass was a little swampy valley, which runs for a short space along the principal river, and afterwards enters it in a narrow gorge. After we had crossed this we had to ascend a drift terrace, along which the road goes for a short distance. The old alluvial deposits lie about 150 feet above the present surface of the river, but traces of higher, still older terraces, are also visible, 100 feet above the road on the mountain sides, consisting also of shingle deposits, out of which at some places rocks crop out. After a short distance, the foaming river washes against its southern bank, formed for the most part of wild rocky cliffs, between which the small remains of a luxuriant forest are here and there visible, for the romance of the district has been destroyed in nearly all the accessible places by the practical hand of the sheep farmer, in order to obtain food for his flocks. Burnt bare stumps, often of gigantic trees, show everywhere how great this destruction has been. At some places enormous declivities covered with taluses of debris descend from the mountains, four to five thousand feet high, into the valley, the crossing of which with horses, owing to their steepness, is often attended with great difficulty. The path continues along the mountain side for a few miles, often ascending three or four hundred feet, then again nearing the river-bed. At some places it had been necessary to blast the road through the hard bluish sandstone rocks, but in spite of the great improvements that had been made by the Government roadmen during the last two months, I found the road in many places so steep and narrow that the heavily laden horses could scarcely find room to pass by the often overhanging cliffs, or to obtain a foothold on the slippery shelving ground. Various accidents had already taken place here, without however any human life being sacrificed, only some horses and cattle having been lost.

The view of the jagged mountains, of the deep blue Hurunui rushing down its wild gorge, or of the romantic lonely valleys in which crystal streams trickled down, was really enchanting, and I was never tired of admiring the ever changing picture before me. After three miles, the valley opens out, and a little flat goes along the southern side of the river, on which Mr. Taylor's woolshed is situated. A storekeeper, who also sold spirits, had settled himself here, and was doing a good business. A great many gold-diggers had also erected their tents here, and a stirring bustle prevailed when I arrived towards evening. The rushing of the river and the melodious song of the birds woke me before daybreak, and on going out of my tent I found that many of the travellers had already taken theirs down, and were preparing to continue their march. The forest here on the southern side also is nearly all destroyed, whilst on the other side, on the steep rocky mountains, often 5000 feet high, it is preserved, as the country is too wild and inaccessible for the sheep farmer. A mile above our camping place we reached the so-called South Hurunui, near its junction with the principal river, where a tent for selling spirits was erected, and horses kept in readiness to take foot passengers over the river, which, when low, is about three feet deep, for the payment of a shilling. On the opposite bank the path ascends a terrace more than 150 feet high, and is comparatively easy, although here and there steep places still occur. Above this junction the valley assumes a less gorge-like character, and keeps on widening, until three miles westward it opens out completely. A wall of debris several hundred feet high forms the southern side of the valley, out of which grassy rounded *roches moutonnées*, 500 feet high, rise, and are a sign that we are in the neighbourhood of the glacier lakes. After the shingle wall, consisting of stratified subangular alluvium, is ascended, the path leaves the valley of the principal river and continues towards Lake Taylor, in a thickly grassed river-bed filled up with quarternary debris, leading us two miles further on to the remains of an old moraine. On the northern side the valley has been formed by a number of low *roches moutonnées*, all with their worn side towards the west. The contrast between these grassy rounded hills and the high rugged mountain, covered to a height of 4000 feet with dark beech forest, was very attractive.

On the evening of the 5th of April I arrived at the grassy shores of Lake Taylor (1948 feet), the deep blue surface of which is charmingly situated between the dark green beech forest, and in which the mountain, rising abruptly at its southern shore, with its rugged peaks more than 6000 feet high, is reflected. At the house of the hospitable runholder, Mr. Taylor, I received a most hearty welcome, while my men put up their tents on the shore of the lake. As this was good pasture ground, and firewood was close at hand, several butchers' stalls and huts for selling provisions had already been erected at this place, at other times so lonely. The numerous white tents on the shore of the lake looked quite cheerful, and as night came on I counted, in different directions, thirty camp fires. The benevolence of the excellent man whose guest I was, and who had already lived here many years, had been sorely tried during the last few months, but he nevertheless continued through the whole of the rush, which still lasted several months, to give willingly and without remuneration, flour, meat, tea, and sugar, to all those who were returning from the coast starving, so that they were able to continue their journey with renewed strength. Only those diggers went back overland who had not the means to take a passage in a steam or sailing vessel from the West to the East Coast.

During the next day I was occupied in visiting the different lakes, in order that I might become acquainted with the geological conditions in their neighbourhood. After we had ridden through the outlet of Lake Taylor, two miles long and half a mile wide, we crossed a saddle between two *roches moutonnées* which separate the Taylor Lake valley from a northern valley running parallel to it; here a little lake (Lake Mason) and several lagoons are situated, and in the Ice period it must have been the bed of another arm of the great Hurunui glacier. In the south, to our left, was a mountain range about 5000 feet high, the upper part of which consisted of wild jagged rocks, and it was easy to perceive from this how high the ice masses of this glacier had once reached, above which these rocks must have risen like an island. After two miles, in the course of which we had climbed over several moraines which cross the valley, we reached the Hurunui river, flowing 400 feet beneath us, in a broad valley. In order to descend to it, we had to climb over the very distinct side moraine of the former principal glacier, and then ride down five steep terraces, in doing which the path made by the cattle was of great assistance to us. The valley of the principal river is here a mile broad. After we had found a good ford to cross the river, we continued our way on the northern side of the valley, where at some places beautiful sugar-loaf shaped *roches moutonnées* occur, while behind them, mountains rise 5000 feet above the valley, the lower declivities of which are generally thickly covered with *Fagus Menziesii*. Numerous herds of cattle enlivened the solitary region, the vegetation of which was already quite sub-alpine. In some stony places the ground was covered with such thick masses of *Aciphylla Colensoi*, that it was only with difficulty we could pass through amongst its sharp bayonet-shaped leaves. *Celmisia coriacea*, and *spectabilis*, the gigantic New Zealand asters, were also very frequent, while the regular shaped bushes, often forming a half globe of *Veronica Colensoi*, *vernicosa* and *salicifolia*, *Olearia nitida*, and different *Cassinias*, *Coprosmas*, &c., covered the shore near the river-bed with their delicate leaves, and masses of blossom. The nearer we approached the Sumner lake, the more the high terraces walled in the river, till two miles from the lake it is quite confined between high shingle walls. Half a mile from the lake a moraine, situated about 250 feet above its surface, covers the valley, which, however, has been partly concealed or destroyed by the large cone of debris deposited by a mountain stream coming from the north, and flowing into the Hurunui. When we had ascended this cone, covered for the most part with thick beech forest, the peaceful deep-blue surface of the beautiful lake lay quite 150 feet beneath us, surrounded on both sides by high mountains which, for about 2000 feet above it, were clothed with thick forest. Before the shore can be reached, at least ten old beaches, fully preserved and extending over the valley in a half circle, have to be descended. It was indeed a great pleasure to be able once more to enjoy nature in her pure virgin solitude. The quiet mirror of the lake, only disturbed here and there by ducks and other water birds; the dark forest, with the rugged rocky peaks above it, reflected in the lake, formed a landscape of such exquisite beauty that I was very unwilling to leave it.

On Saturday, the 8th April, still favoured by beautiful weather, I left my kind host, and followed the human stream towards the west. The path leads along the southern shore of Lake Taylor, which, like most of our alpine basins, is shallow only 30 or 40 feet from the shore, then suddenly falls off and appears to become very deep. Several cones of debris, some of considerable extent, come down from the southern side of the mountain, and often stretch far into the lake. One of these has at its extreme point, a tongue, several hundred yards long, going towards the east, which rises like a dam above the surface of the water, and is a speaking testimony of the duration and power of the west wind, which prevails here. The western end of the lake is likewise formed by the high-walled debris cone of a mountain stream of enormous dimensions, which covers the whole valley, and leaning against the "Skor," like *roches moutonnées*, of the northern side, forms here several lagoons. The glacier furrows, with a slight fall towards the east, are visible on both sides of the valley. Half a mile from Lake Catherine the path ascends an old moraine, which likewise crosses the valley in a half circle, and is tolerably well preserved. On the ridge of this moraine the traveller has a charming view of Lake Catherine, 1742 feet above the sea level, lying below him and surrounded by little beech forests of a park-like character, between which the numerous white tents of the roadmen, with their camp fires, glimmered cheerfully. The valley of the Hurunui, above Lake Sumner, is already visible from here. As the old bridlepath along the lake was so dreadfully swampy that several horses had perished in it, a number of workmen were occupied here in forming a new road. This was already made for a good distance, but beyond this we had to pass a few places where the horses sank in so deeply that we had great trouble to get them through. A deep swamp fills up the level flat between the little Catherine lake and the large Sumner lake, which are united by a sluggish water-course. After any change in the height of the water in both lakes, the water runs from Lake Catherine into the Sumner Lake or the reverse, as there is only a difference of a few feet in the level of the two lakes. For instance, I found Lake Catherine some 7 feet higher than Lake Sumner, whilst in the spring after the melting of the snow in the high Alps, or after continuous rainfall, the principal lake is said to be higher. Separate *roches moutonnées* go from the southern side through the swamp, towards the mountains lying at the southern end of Lake Sumner, called the Big Brother range, the western end of which is covered with glacier marks, while the summits have kept their rough rocky forms. Similar *roches moutonnées* and remains of large side moraines are also visible on the southern shore of the Hurunui river above the lake, and over these we reached the western shore. Like all the shores at the head of our alpine lakes, this is formed by the delta of the river which flows into it, so that the lake is very shallow for some distance. The valley of the river itself continues in a straight direction, as broad as the lake, for at least ten miles towards the central chain without narrowing visibly; it is formed of masses of debris, over which the river hurries, in a number of branches, to the lake.

Going upwards from the shore of the lake, we followed along a grassy flat which occurs on the southern shore of the Hurunui river. A striking difference is here noticeable, when compared with the valley below the junction of the two principal branches. Instead of the deep gorge, the river has here a bed generally two miles wide, over which it spreads out in a number of branches, changing its course after each high freshet. Here and there, *roches moutonneés* of different sizes project out of it, often covered with thick beech forest. A similar luxurious forest vegetation ascends on both sides of the mountains for 500 feet; but, nevertheless, does not quite hide the numerous remains of moraines and glacier shelves. The predominating forest tree here, is *Fagus Solandri* with small finely cut leaves, reminding one by its regular shape of the European pines. In the eastern lower mountains and the Alps, the principal vegetation consists of this elegant kind of tree; whilst on the western declivities, *Fagus fusca* often six to eight feet in diameter, forms the chief vegetation. The range on both sides as far as the central chain, consists of a continuous chain, above which, isolated peaks project. Advancing on the right bank of the river for four miles, we came to a place where the principal branch of the river flows close under a perpendicular cliff, we had therefore to cross the river, which was very easily done, as the water was so low that it scarcely reached the horses' knees. Several storekeepers and a butcher had put up their tents here.

The path led now along the northern side of the valley, which consists generally of grassy flats. Five miles from the lake, although the valley is still tolerably wide, the river flows in a more narrowed bed, little terraces are formed on both sides, mostly covered with a luxuriant forest vegetation, which rises above the grass in smaller or larger groups not unlike a park, and consisting of either little thickets of beeches or bushes of *Scrophularineæ*, *Coprosmas* and *Compositae*. Of the first, different kinds of *Veronicas*, as *V. salicifolia*, *Menziesii*, *buxifolia* &c., form regular half-globe-like shrubs, while of the last, *Olearia nitida* and *Cunninghamii*, *Cassinia fulvida*, and several others, please the eye by their elegant forms and the variety of their tints. As soon as the view opens out to the west, the saddle which forms the pass lies before us, a clearly defined depression in the mountain range, which rises steeply above it 4000 to 4500 feet on both sides. About four miles from the pass, the road enters the forest and does not leave the river again, which now assumes the character of a true mountain stream, and rushes foaming over huge boulders ; from here it has to be frequently crossed.

The character of the landscape now becomes continually more extensive and grander. Roaring torrents come down from the northern sides of the mountain, and *Fagus Solandri* gives place to *Fagus Menziesii* which prefers a damper mountain climate : here and there isolated forms of sub-alpine *Senecios*, *Veronicas* and *Olearias* occur. The beautiful *Ranunculus Lyallii* with large cup-shaped leaves, and the delicate *Ligusticum Haastii* with deeply serrated leaves are found at the water-courses, while the *Aciphylla Colensoi*, which till now grew on the grass flats and open places, is replaced by the gigantic *Aciphylla Lyallii* with bluish-green, sharp bayonet-like leaves, and a flower-stalk often ten feet high. Everything showed that we were now ascending more rapidly, and approaching the pass. At the foot of the saddle two mountain streams, coming from the north-west and south-west unite and form the Hurunui. Here a blockhouse stands, built a few years ago by the party accompanying Charles Howitt, who was drowned in Lake Brunner while he was occupied in making a path through the bush and over the pass into the valley of the Teramakau ; it was now filled with provisions and belonged to a dealer, who was doing a very good business, but complained that his profits were very much lessened by the numbers of half-starving people who returned without any money. I found in the blockhouse, the provisions that I had sent on from the Waitohi gorge, consisting of flour, bacon, sugar and tea.

Unfortunately, in spite of the precautions that had been taken, the rats had already demolished a part of them. We passed rather sleepless nights, for the place swarmed with rats, and we had great difficulty in protecting our provisions from them. These animals were really quite a plague and left nothing untouched; I even found traces of their sharp teeth in the shot. They ate holes with inconceiveable rapidity in the flour bags, although we put them under our heads for pillows and tried to protect them in other ways as well as we could.

I calculated the height of this camping place, and found that it attained already 2662 feet. The influence of the damp climate which is peculiar to the west side of the Island, began already to be perceptible here. Up to this time we had been favoured with the most beautiful weather, lovely days and nights, without a cloud in the deep blue sky, but it now began to rain violently, and continued to do so with very little intermission until we reached the West Coast. Several parties of returning diggers passed during my stay here, most of them ragged, starving, and without money, real pictures of misery. They were nearly all novices who had never seen a goldfield before, and after they had spent the few pounds they brought with them, and had looked round in vain for a new claim, they had been compelled to return without having done anything. Labourers had easily found work in the towns springing up so quickly on the Coast.

Early on the morning of the 11th April, I set out to cross the pass. A fine rain fell as I left the camp and rode through the luxuriant beech forest, which however, after we had ascended 200 feet, began already to be stunted, and almost disappeared beneath the cosmopolitan lichen *Usnea barbata*, which covers trees and boughs with its white beard. It is worthy of observation that the boundary line of the trees is already reached here at a height of 2800 feet, while on the sides of the mountains bounding the Canterbury plains, it ascends to an altitude of 4600 feet. It is therefore evident that absolute height alone does not fix the forest boundary line, but that the upper forest boundary depends upon the winter snow-line, which in the heart of the Southern Alps sinks to 2100 feet, while near the sea it lies more than 2500 feet higher. The road, which till now had been tolerably good, began to get almost impassable, in consequence of the great traffic on the narrow bridlepath, and resembled a morass canal; sharp stones, roots, and dead timber, made progress very difficult; the horses sank up to their knees and could only work themselves out with difficulty. About 200 feet below the saddle the gnarled forest wood ends, and a striking sub-alpine flora begins, consisting of fine tree-like shrubs, often eight to twelve feet high, mostly Compositæ, among which *Olearia ilicifolia*, *nummularifolia*, and *Cunninghamii*, and *Senecio elæagnifolius*, are especially remarkable. The unpleasing sombre green colour of the beech forest in the valley is now replaced by different tints, very intense, varying from bright yellowish green to dark bluish green, and deep brown. Besides this, all the above-named Compositæ have the under side of the leaf covered with a white or yellow down, which gives the whole landscape a variegated appearance, especially when, as at many places, numerous shrubs of *Dracophyllum longifolium* and *uniflorum*, covered with dark brown leaves grow between them. Many bushes of *Panax*, with their bright green leaves reminding us of the river vegetation we had left, are also to be seen. The nearer we approached the summit of the pass, the denser became the vegetation. An undescribed, superb, tree-like *Dracophyllum*, not unlike the *Drac. latifolium* of the northern island, began to appear here (named afterwards *D. Traversii* by Dr. Hooker). The natives call it Nene. It has leaves a foot long running out into a slender point of a reddish brown colour in the upper part, between which the elegant flower panicle comes forth. This plant raises its tree-like crown gracefully above the other shrubs, and gives the region a highly peculiar character. The mist which had been falling began to change into rain as we arrived on the flat ridge of the saddle, at some places overgrown with *Danthonia flavescens*, the snow grass of the colonists, between which numerous specimens of *Celmisia coriacea Lyallii*, and *discolor* made their appearance. Other places were swampy and covered with *Sphagnum* moss, between which stood here and there little half globe-like bushes of *Dracophyllum rosmarinifolium* together with the large *Ranunculus Lyallii*, and one or two sub-alpine umbelliferous plants. This vegetation ascended on both sides of the mountains, bordering the pass for at least 1500 feet, before the real alpine flora began. The mountains on both sides, immediately above the pass, attain a height of about 7000 feet, and do not reach the line of perpetual snow. From earlier descriptions, I had expected to find higher mountains here; but I could, nevertheless, perceive them more towards the west, and on both sides of the Teramakau valley. Though the view westward was very much limited by the rain, which fell uninterruptedly, I was nevertheless able to perceive that the saddle shelved off more steeply towards the western side than the eastern, and that at the foot of the saddle a broad straight valley commenced. Although the ascent of the eastern side had been accompanied with difficulties, still we had been able to reach the summit of the pass without getting off our horses; now we could no longer think of riding. The unparalleled bad road led rather steeply downwards, either over smooth slippery blocks of rock, or through pools of slush full of roots and large and small stones, over and between which the poor horses tried to pick their way, panting and trembling, and often sinking up to their girths. Of course it was no better for the pedestrians, and I was now convinced that the famishing travellers, who had returned, had not at all exaggerated in their description of the horrible road. The change in the vegetation is very remarkable, as, after having descended several hundred feet, it is entirely different from that observed on the eastern side. The sub-alpine vegetation instead of going over into *Fagus Solandri*, is little by little supplanted by forms of trees, which we generally find on the West coast of the Island, and to the growth of which a damp climate seems particularly favourable. Some few of the shrubs on the saddle assume a treelike form, as for instance, *Olearia ilicifolia*, *Panax Edgerlyii*, while numerous trees of *Metrosideros lucida*, *Fuchsia excorticata*, *Weinmannia racemosa*, and several others are mixed among them and gradually supplant the sub-alpine vegetation. *Fagus fusca*, the black birch of the colonists, soon makes its appearance together with the two conifers *Podocarpus Totara* and *Libocedrus Doniana*, the Kawhaka of the natives rising far above the other forest vegetation with their erect stems and superb crowns. Twelve hundred to fifteen hundred feet below the saddle, on the steep declivity the forest has already assumed the character of the vegetation which we find everywhere in the lower mountains of the Alps near the West Coast. Descending about 850 feet, we came to the first considerable mountain stream, which comes out of a deep wide gorge on the northern side of the range and rushes over large blocks of rock to the valley. This stream was already more considerable than the Hurunui, three to four miles below the saddle. This crossed, we entered the forest again, which, for a short space, covering terrace-like ground, tolerably smooth and very mossy, much resembled a bottomless swamp. Continuing down the mountain, we passed several important tributaries from both sides, and after two hours continuous travelling arrived at the western foot of the pass. The valley widens here visibly, and is bordered on both sides by moraines twenty to thirty feet high. At a height of 1500 feet above the sea, it assumes the peculiarities before described of a broad shingle bed. The river has here such a considerable body of water, that even when it is low, the fords are difficult to cross, although good places can generally be found above the numerous rapids; higher up, where large boulders lie in the bed of the river and the current is very strong, it is very difficult for the traveller to obtain a firm footing, especially when the river is thick from long continued rain. Many accidents have occurred here, so that the people that had already been drowned in the Teramakau could be counted by dozens. The rocks consist of chertose beds alternating with clay slates. It was clear to me directly, that the Teramakau saddle does not lie in the geognostical mountain axis, but several miles east of it. This accounts for the great abundance of water in the Teramakau river, which is formed not only from the mountain streams by and near the water shed, but for ten miles receives many tributaries from the left side of the mountain range, the southern declivities of which feed the Waimakariri flowing to the east coast. A few rather important tributaries also come from the mountain chain situated to the north. As soon as we had reached the broad river valley the bridlepath ended, and in spite of the rain which still continued to fall heavily, we went on much more quickly between the bright green *Veronica* and *Olearia* bushes, a pleasing contrast to the darker forest on both sides. These shrubs intermixed with species of *Coriaria* (Tutu) and *Coprosma*, cover the islands in the river, which lie beyond the reach of ordinary inundations. Eight miles from the saddle we camped, while the rain continued to pour down in torrents. The rain lasted two days, only clearing up towards noon on 13th April. The clouds dispersed and the grand mountain landscape lay before us in all its beauty. The mountains lying opposite to us, about 7000 feet high, were covered for 2000 feet with thick forest, above which subalpine shrubs and grass appeared, replaced after another 1000 feet by wild bare rocks. The contrast of shapes and colours formed an indescribably beautiful picture, to the animation of which numbers of waterfalls, often falling several hundred feet, and increased by the rain, added not a little. A few hours after the rain had ceased the river began to fall, and the next morning had almost returned to its natural bed. When we consider that the mountains are very steep, and that the waters have only a proportionally short course, it is easily conceivable that these mountain streams must fall again just as quickly as they rise. The saddle we had crossed a few days before could be distinctly seen, but it appeared higher than when seen from the eastern side. The view to the west was rather extensive, the valley widened out considerably, and seemed to be closed in by a wooded range (the Hohonu range), through which the river, deviating a little to the south, had forced its way. We were now able to set out again, although the river, through which we had to pass several times, was still rather high. After four miles we came to a place where we found a great many travellers, who had not the courage to cross a dangerous looking ford. Most of them had already used up all their provisions, and begged me to leave them flour enough for at least one day, which I did, the more willingly, as I had been assured repeatedly that I should be able to obtain new provisions at the so-called Pakihi, a large forest meadow near Lake Brunner. After I had tried the ford and found it passable, we took the pack-horses over, and the other people soon followed. Towards noon we reached the mouth of the Otira, an important tributary; at its source a pass, like that of the Hurunui saddle, leads to the Waimakariri river, over which the high road to connect the east and west coast was being made. On the mountains to the south side of the river and west from the Otira valley, which have very wild forms, we could now observe some snowfields with small glaciers of the second order. The vegetation had changed very much since we left our last camp. We had long since left *Metrosideros lucida* and similar trees growing near the pass, behind. Along the rather wet track appeared, besides the Totara pine, white pines (Kahikatea, *Podocarpus dacrydioides*), and black pines (*Rimu* or *Dacrydium cupressinum*), which with their regularly-formed tops generally towered high above the other forest foliage; although here and there black beeches (*Fagus fusca*), 100 feet high, and 7 to 8 feet in diameter, were also to be seen. Delicate tree-ferns appeared in great abundance, especially in the gorge-like side valleys, among which *Cyathea Smithii* and *Dicksonia squarrosa* were especially noticeable for their height and circumference. Between this superb vegetation, the black stemmed creeper *Rhipogonum scandens* (the Supplejack of the Colonists) often forms an impenetrable net, while the ground, as well as the stems of the trees, is covered most luxuriantly with mosses, lichens, and ferns. The whole enlivened by numbers of feathered songsters, forms a scene of indescribable beauty. We had still to cross the river several times before we arrived at the opening, two miles broad, which leads to Lake Brunner. We now left the bed of the Teramakau, which deviates a little from the westerly direction it has had hitherto, and breaks through the coast chain, but the valley, downwards, continues broad, and never assumes the character of a gorge. Half a mile from the river the flat is covered with the shrubs generally growing in the open valley, such as *Leptospermum Coriaria, Olearia, Coprosma, &c.* Then the path ascends a little terrace, a few feet high, and enters a magnificent forest with gigantic trees, between which are to be seen tree-ferns, often as much as 30 feet high. After a mile and a half we came out of the high forest and the pakihi or paddock lay before us. This is the name given by the diggers to a grass-covered plain between one and two miles broad, bordered on both sides by thickly wooded mountains. This place, generally so desolate, was now highly animated. Cattle and horses were grazing peacefully in all directions. Numbers of tents were put up near the forest for the accommodation of gold-diggers, cattle-drivers, and storekeepers. It was used by those coming and going as a resting place, before resuming their tedious journey. Besides this, they let the cattle, for which there is very little food in the Teramakau valley, recruit here, since it is the last grassy place, near the coast and neighbourhood of Hokitika where feed grows. When the cattle are however once accustomed to the leaves of the trees and shrubs, some of which they like very much, they soon get into good condition again. In spite of the rainy weather there was active life and bustle here; no flour was however to be had, and people who had money to buy provisions were obliged to content themselves with fresh beef. The alluring grog shanty, as usual, was not missing. On a nearer examination of this interesting flat, I came to the surprising conclusion that even in the latest geological time, the Teramakau river must have flowed here. I could easily follow the old river-bed, divided into many branches, one part towards Lake Brunner, the other part towards Lake Poerua, situated to the north-east, the outlet of which falls into the first named lake.

The isolated mountain group which lies between the Pakihi and Lake Brunner and the Poerua Lake and its outlet into the first, is about 2500 feet high, thickly wooded, and is named by the natives Kaimonga. A few hundred feet from the northern bank of the Teramakau, where the Brunner lake opening begins, the ground is in some places swampy, and immediately little water-courses unite and form a stream which flows into the southern end of Lake Brunner. There is no doubt that these springs, rising near the river, are only river water filtered through the debris, and that consequently the surface of the water lies only a few feet under the northern bank of debris which confines the river towards the west. Should an elevation take place, which is very possible, in the shingle bed of the Teramakau river, it is easy to imagine that the river would again occupy its former course. I heard afterwards from the natives, that when the Teramakau had been very high they had taken canoes from it to Lake Brunner and to the Grey river, and indeed, in running water the whole way. The mountains on both sides show glacier polishings and remains of lateral moraines. The difference in height of all the glaciers on the east and west sides of the Southern Alps struck me of course at once, as Lake Brunner which formed the end of the Teramakau glacier lies only 227 feet above the sea level, while Lake Sumner, lying opposite, the end of the Hurunui glacier in the same period, has a height of 1735 feet above the sea and lies therefore 1508 feet higher. The cause of this difference which the present glaciers show in the same way, lies in the greater dampness of the climate on the western slopes, since six times as much rain falls on the west coast as on the east. I remained several days at the "paddock" in order to give my men and horses a little rest. During my stay, several parties of diggers arrived, who had travelled along by Lake Brunner and the western and southern slopes of the Hohonu chain, as it is not possible to follow the Teramakau river from here to the coast on foot, and the horses have generally to swim at the crossing places. These men were literally covered with mud, and gave such a description of the road that I thought it must be exaggerated; but I found afterwards, the so-called bush-track was so horribly bad, that no description could give any idea of it.

A few travelling parties had tried, in order to avoid the deep rapid ford in the gorge of the Teramakau, to take their horses with them along this path, but had either lost them or been obliged to return when half way. I therefore sent my pack-horses and my riding horse with one of my men down the river, to wait for me at the mouth of the Greenstone Creek, and went myself, accompanied by my two other men, along the dreaded bush track, because it afforded so much opportunity to study the geology of the country more closely, and at the same time, to visit Lake Brunner and the Greenstone Creek goldfields. We had therefore to take with us provisions for several days, together with tents and blankets, and started at noon on 18th April. For two miles we followed a well-trodden path over grassland, keeping on the western side of the valley. After we had waded through a broad swamp, we entered a forest and ascended a terrace, on which we soon had a foretaste of what we had to expect during the next few days. We sank to our middle in the half-liquid marsh, or had to climb over colossal tree stems which lay half rotten in it, or stumbled over blocks of stones and roots of trees. I do not think the best walker could possibly make more than a mile an hour here. Towards evening we arrived at Lake Brunner, on the shore of which we made our camp. This broad peaceful expanse of water, surrounded by the most luxuriant forest and animated by numbers of water birds, is surrounded at the north by the end moraine of a gigantic post-pliocene glacier, while at the southern end, on both sides of the opening, entering from the Teramakau, high mountains descend steeply towards it. The next morning we continued our journey, and as the rocky shore descends at most places steeply into the lake, the path could not be continued along it, and we had often to ascend cliffs, forming beautiful rocks covered with primeval forest. Although I was well acquainted with the luxuriance of the New Zealand forest in the lower regions on the western side of the Southern Alps, I could not resist, now and then, stopping to admire some particularly beautiful part, in which majestic pines and beeches, their straight stems generally covered with bright green mosses and parasitic ferns, were especially conspicuous. Beneath this leafy roof, scarcely admitting the daylight, grew smaller trees and shrubs, above which rose numerous charming arborescent ferns with their delicate fronds. Some of these (*Cyathea* and *Dicksonia*) were often 40 to 50 feet high. Here and there, where a little valley led towards the lake, we had a view of the deep blue water beneath us. The path was often very rocky, and even for New Zealand horses, accustomed as they are to such paths, presented insurmountable obstacles, as was shown by the skeletons of different animals, lying on or near the road at particularly dangerous places. These skeletons also showed that rats existed here in great numbers, for though the animals had not long fallen, the bones were gnawed perfectly clean. It rained during the whole day, and towards evening we camped at the Big Hohonu Creek, which flows into Lake Brunner. We had therefore, in spite of our efforts, only made seven miles. In this beautiful clear mountain stream and its banks I instructed my men to dig for gold; we found, to use a technical expression, "the colour everywhere." They were generally thin, small scales, often only slightly rolled, and could not, therefore, have been brought any distance. The rain did not cease during the night, and as we were making ready next morning to continue our journey, we were wet to the skin before we had taken the tent down. We now entered upon a terraced table land, which stretches from the western foot of the Hohonu chain towards the coast, and from which a few low hills rise here and there. The district is covered with the most luxuriant forest, and cut through by a great many little water-courses, which are generally closed in on both sides by banks, often perpendicular, from 40 to 50 feet high. The ground on this plateau is swampy and difficult to travel over, and when one considers that the people who go through it have to carry swags of 30 to 50lbs., it is easily conceivable that this piece of the road has rightly become notorious. Tipeni, a Native of herculean strength, and one of my former travelling companions in my first great West Coast journey, would not let me carry anything, and had therefore to carry a swag of more than 70lbs. weight, which he did with ease.

As soon as we arrived in the valley of the Greenstone Creek, we came to a broader road, which led to the gold-diggings situated higher up; it was, however, in no better condition than the part we had already passed. We soon met a great many people, mostly packers, who drove laden horses before them. I could not suppress my astonishment, as I observed the way in which these poor animals with their heavy loads worked themselves through these morass canals full of stems and roots, and it was wonderful to see them go up or down indescribably steep places, where we had to climb on our hands and feet and hold on to boughs. Certainly, accidents often occur; however, the gold-diggers must have provisions, and as the packers receive £2 to £3 per 100lbs. weight for a carriage of eight to ten miles, it is not an unprofitable business, if they are not too unfortunate with their horses. This explains also the enormous price of provisions on the goldfields, as the diggers working here use not less than £3 worth a week, of bread, bacon, and tea. Everywhere, in the river-bed, and on the terraces, often several hundred feet broad and only a little raised above the present surface of the water, diggers were occupied obtaining gold. The wash gold is fine, scaly, and very much rolled, so that there is no doubt it has come some distance in the great river-bed. The nearer we approach the confluence of the Greenstone Creek into the Teramakau, the greater grew the life in the valley; we found everywhere tents and canvas stores, often comfortably fitted up, and the people hard at work. Here I met my horses, which my man had brought in good condition. He had joined a large travelling party, and had been obliged to swim the river swollen by the rain, several times, in doing which a man and horse had unfortunately been drowned. Here, at the junction, the ground was covered only with forest and shrubs, and as my stock of oats had in the meantime come to an end, I had to buy a bushel, for which I had to pay £4 sterling. I only quote this to show what extravagant prices the traveller has often to pay in newly discovered goldfields, where the carriage causes such great expenses. At the mouth of the Greenstone Creek a little settlement had sprung up—numbers of tents and wooden shops, occupied by storekeepers, bakers, butchers, and publicans.

The weather at last cleared up, a deep blue cloudless sky arched over the majestic primeval forest; the effect was, as usual, magical; all the troubles we had endured were forgotten, and I gazed enraptured on the luxuriant forest landscape which surrounded me. I sent my horses down the river to the mouth of the Teramakau, six miles distant from here, while I went down in an hour in one of the numerous canoes which bring provisions here. The possessors of these canoes received £1 per 100lbs. weight, and as their little vessels can often bring up a ton of goods, and can go and come back in a day, it is very profitable, although terribly hard labour. The banks of the river consist mostly of tertiary clay marls, forming cliffs often 100 feet high, and covered with alluvium for 20 or 30 feet. An indescribably luxuriant vegetation covers the romantic shore on both sides, which, with the steep banks and the broad river, produce a lovely picture. A mile from the mouth of the river the valley opened out, and the deep blue sea lay before us. A little town had already sprung up at the mouth of the Teramakau, consisting of tents and tent houses, and active life and commotion prevailed everywhere, as, besides storekeepers and publicans, a number of artisans had established themselves here. At the seashore, what a remarkable sight offered itself to the spectator! Towards the south the beach resembled an animated high road—pedestrians, waggons, pack-horses, and riders, forming an animated group. Two large steamers were just passing-by bound for Hokitika, while on the distant horizon a whole fleet of ships lay at anchor in the Hokitika roadstead.

I thought with sadness of poor Whitcombe, who two years before, after he had crossed the central chain, had stood famishing on the then desolate shore, and longed to be at the Grey River, the only place on the coast where he could hope to find provisions. At the same time I could not repress a feeling of pardonable pleasure, on recalling the time when, six years ago, I had wandered for months on this desolate coast, and on the discovery of the treasures of coal and gold in the district of the Buller and Grey rivers, had thought of the consequences which this journey of mine might have on the future and well-being of New Zealand. The words written in my Nelson report of 1860, in which I prophesied a great and brilliant future for this district, had already been partly fulfilled, and if only the still untouched treasures of coal are raised,* this may be still more brilliant, and a much more lasting industry secured to the country than by gold-mining.

The next morning, April 21st, we started early for Hokitika, along the beach which, during ebb tide, offers generally fine travelling ground on a hard sandy bottom. The whole way appeared like a great main road rather than an ocean beach. Horses and riders, pack-horses and their drivers, men with swags, waggons drawn by horses or bullocks—the whole a picture of earnest activity—proved that we were advancing towards the great centre of the goldfields. At the mouth of the small Waimea river, distant about five miles from the Teramakau, we found a settlement of small extent, consisting of about thirty shanties and canvas houses, mostly stores and public-houses. There the road leaves the coast for the extensive diggings at the head of this creek. A similar but larger township was found at the mouth of the Arahura, which we passed after a march of a few hours. The nearer we approached Hokitika, the more the traffic became animated, and when we at last entered that city of yesterday, we could not conceal our astonishment that, in so short a time of only a few months, such a large place could have sprung up, which being literally built on sand, seemed at the same time healthy and clean. The principal street, half a mile long, consisted already of a large number of shops, hotels, banks, and dwelling-houses, and appeared as a scene of almost indescribable bustle and activity. There were jewellers and watchmakers, physicians and barbers, hotels and billiard-rooms, eating and boarding-houses, and trades and professions of all descriptions. Everywhere the English language would of course be heard in its principal dialects, as well as German, Italian, Greek, and French, and several other tongues. Carts were unloading and loading, and sheep and cattle driven to the yards; there was shouting and bell-ringing, deafening to the passers-by; criers at every corner of the principal streets, which were filled with people—a scene I had never before witnessed in New Zealand. Hundreds of diggers "on the spree" and loafers were everywhere to be seen, but principally near the spit and on the wharf, where work went on with feverish haste. Before arriving at Hokitika, I counted seven vessels at anchor in the road-stead, amongst them a large Melbourne steamer; whilst in the river itself, five steamers and a large number of sailing vessels were dis-

* This was written in 1866.

charging their cargoes, reminding us of the life in a European port. Owing to the shifting nature of the channel, which leads through the surf into the river, several vessels had been stranded, amongst which were two steamers; however, one of them, the *Stormbird*, was that day brought into deep water again. I pitched my tents in the Government camp, in which, in canvas houses, the Provincial Government Commissioner, Mr. G. Sale, and the other Government officers were living, and which contained also the Police camp, jail, and the offices of the Resident Magistrate and of the Goldfields Warden. For several days we had quite a deluge of wet weather, as it rained almost incessantly. During that time I wrote a report to the Secretary for Public Works, giving the results of my observations during the overland journey, which, with a number of others written subsequently, were printed by order of the Provincial Government, and presented to the Provincial Council.*

As soon as the weather had cleared up again, I started for the Waimea goldfields, to which the road was still in a most wretched state, owing to the enormous traffic along a swampy forest track, although the Government had already begun to corderoy the worst portions. In the evening we reached the Waimea township, for which room had to be made by felling a number of trees in the luxuriant forest, here clothing the whole country. Although surrounded by a large digging population, there was very little loafing to be seen here. Of course diggers were coming and going, but the whole intercourse had a healthy appearance, and showed that its mining population was busily engaged on its claims. During several days I visited all the principal diggings in the neighbourhood, making myself acquainted with the mode of occurrence of the precious metal, and following the main branches of the Waimea to near their sources. I also went to Fox's rush, and some other goldfields on Fox's and Red Jack's gullies, falling into the Arahura; afterwards, I proceeded to the sources of the Kapitea, and visited Gallaghan's and German Creeks and some others in the neighbourhood, and thus obtained an insight into the nature and extent of the goldfields in that part of the West Coast. As I shall treat of the nature of the goldfields in the geological portion of this report, I may only here state, that the whole goldfields, as far as visited, were found to be deposits of a very large river of pre-glacial age, those portions being only preserved

* Report on the Geological Exploration of the West Coast. By Julius Haast, PhD., F.G.S., Provincial Geologist.

which had not been reached during the Great Glacier period of New Zealand by the advancing gigantic glaciers, or by the enormous torrents issuing from them. For two days we were again detained at the mouth of the Teramakau, whence I sent another report to the Secretary for Public Works, on the results of my observations, and proceeded afterwards to Greymouth, which also showed ample signs of its wonderfully rapid progress.

Five years ago I had camped at this spot in solitude, with no European excepting three companions near me for a hundred miles, and only a few Maori whares in my neighbourhood, and now rows of large houses were built, and a busy life gave signs of healthy progress all round. Several days were devoted to a visit to the Grey Coal Measures, where I fonnd a hearty reception from the manager of the coal mine on the Nelson side. This Company then sold as much coal as it could bring down in its flat barges, carrying seven tons, taken down in one hour and twenty minutes, whilst it took four men four hours to bring them up again. The Canterbury portion of the coalfields was re-examined, and the fact ascertained, that the Coal Measures were there also of considerable extent, and would thus be one day of great value to the Colony. Returning to Hokitika on the 9th of May, I examined, on my way, several claims on the sea beach, which appeared remunerative, and which would thus offer additional ground for a great number of diggers, without any additional outlay. Intending to ascend the Hokitika river and its tributary, the Kanieri, I obtained, not without trouble, a canoe from the Maoris, for which I had to pay two pounds sterling a week (they had soon fallen into the European way of charging goldfield prices). Leaving the town of Hokitika next day, and ascending the river, we had to cross several shingle reaches, where the water formed rapids, before we arrived at the small township Kanieri, at the junction of the Kanieri river, and where I remained a day studying the interesting and instructive occurrence of gold. The numerous shafts sunk in the township itself and all around it, gave me a clear insight into the manner in which the auriferous beds had been formed.

On the following morning we had, for a few miles, a delightful paddle up the still and deep brown water of the Kanieri Creek, dammed back by the shingle bank the Hokitika has thrown across it at its junction; this passed, its course became very winding, rapid succeeded rapid, which to ascend gave us considerable trouble, whilst a number of large trees fallen across the water obstructed our passage considerably. We reached at last a spot about five miles above the junction, where further ascent was impossible, and where considerable mining operations—the so-called five mile diggings—were in progress. Here, as at the Kanieri township, the wash-dirt had very often been protected by younger morainic accumulations covering it, and having thus been preserved from destruction. At this place, again, I was detained by continuous rain for about a week, but our camping ground was so well sheltered that we never felt any wind, whilst, as I heard afterwards, a fearful storm had been raging along the coast, houses having been blown away at Hokitika and other settlements, and several vessels, amongst them the steamer *Waipara*, having been wrecked not far from the mouth of the Hokitika river.

On May 21st we were at last able to continue our journey, and reached in the evening the shores of Lake Kanieri, having travelled the greater part of the day over terraces, mostly swampy, the ground covered with *Sphagnum*, on which the principal vegetation consisted of kahikatea, totara, and manuka, mixed with *Phyllocladus alpinus* and kawaka (*Libocedrus donianus*), but all the trees were small and had a rather stunted appearance; but in the gorges of the tributary streams or along the banks of the river-bed, the forest vegetation was very luxuriant and magnificent, the presence of large arborescent ferns adding considerably to the beauty of the scenery. Lake Kanieri, although small, being about five miles long by two miles broad, is a very picturesque sheet of water, as it is surrounded on three sides by high mountains with bold outlines, the lower portions being covered with luxuriant forest. It owes its origin to a large semi-circular terminal moraine which crosses the valley from side to side, and through which its outlet has cut a passage. A low saddle is conspicuous near its upper end, leading into the upper Hokitika plains, where several *roches moutonnées* on both sides show distinctly that a portion of the Kanieri glacier had here joined the extensive Hokitika glacier during our Great Glacier period. Returning to Hokitika for a fresh stock of provisions, we started again on May 25th to ascend, this time, the main river, visiting first the Woodstock diggings on the left bank, where I observed a geological structure of the gold-bearing beds similar to that of the Kanieri township deposits. The river presented a very animated scene, a number of boats and canoes ascending and descending; tent houses or small settlements peeped in many spots from amongst the fine forest vegetation which clothed the banks on both sides, whilst in still more numerous localities, the smoke curling above the tree-tops betrayed the existence of human habitations. The weather was now very fine, and the view up the river upon the high mountain chains, rising abruptly at the end of the plains, exceedingly beautiful—the dark green vegetation ascending for several thousand feet, and contrasting strikingly with the pure white garment of snow with which the higher portions of the ranges were uniformly covered. Near the junction of the Kokotahi the Hokitika turns abruptly to the south-west and changes its character, becoming for more than a mile a deep slow flowing river, the shingle deposits of its smaller but more rapid tributary having dammed the waters of the main river back to a considerable extent. Its left bank consists of large morainic accumulations covered with forest vegetation, the right bank being low and covered with shrubs and ferns. The landscape has now undergone considerable change, a wide plain, mostly covered with *Veronica*, *Olearia*, *Coprosma*, *Leptospermum*, and *Coriaria* bushes, stretching to the high mountains. In the midst rises an isolated range, called Te Koi-itarangi, about 800 feet high, which has a *roche moutonnée*-like appearance. Some others, of which one has the form of a regular cone, stand at the foot of the outrunning spurs of the high ranges which bound the horizon.

We now left the busy abode of the mining population, and entered the solitude, although many trial shafts along the river-bed, and afterwards along the high banks near the gorge, proved that numerous prospecting parties had tried their fortune in many localities, without obtaining the desired result. An attack of fever, without doubt caused by being continually in wet clothes, kept me here for several days in the same camp; however, owing to the use of some strong doses of quinine, I soon felt much better, and was able, on May 30th, to reach the foot of the ranges, where the river enters the plain in a deep gorge, the vertical or overhanging walls on both sides of which consist of gneiss-granite. The water in this gorge was so deep, that we could nowhere find bottom with the large pole we had in the canoe, and there was no perceptible flow.

Passing through this really fine gorge, about half a mile long, we found the river-bed above it so rough and full of large blocks of stone, and the water so rapid, that we could not take the canoe any higher. We therefore continued our journey on foot, for some distance, to enable me to examine the geological structure of the district. In every prospect we obtained gold, but it occurred in such small quantities, that it would not pay for its extraction by the mining processes now in use. A wild mountain landscape surrounded us here, and as the river was flowing in a nearly straight valley for a considerable distance, the eye could follow the outlines of the spurs which appeared behind each other—those most distant getting generally higher and more rugged. Heavy rain set in again, which, however, did not prevent me from returning to Hokitika, and we reached it, owing to the swollen state of the river, in about three hours-and-a-half, having been three days ascending to the same camp. My two Maori companions had here ample opportunity to show their skill in guiding the canoe through all the obstacles in our way, of which drift trees were the most dangerous, but which they accomplished most successfully.

I have not yet alluded to the fine and extensive panoramic view, visible from the beach at Hokitika, and which stretches from the mountains in the north, to the Hooker range in the south. A chain of wooded mountains situated between the Totara and Wanganui rivers, their outrunning spurs nearly reaching the sea, are prominent in the south. They are about 2000 or 3000 feet high, wooded to the summit, and form a very interesting feature in the landscape. Above them rise, conspicuously, the highest summits of the Southern Alps—Mount Beaumont, Mount de la Beche, Mount Haidinger, Mount Tasman, Mount Cook, Mount Stokes, and the Moorhouse range. In very clear weather, other snowy mountains show above the horizon of the sea, but often so faintly that they very often may easily be mistaken for white clouds.

I now prepared everything to go down the coast, taking with me two Maoris and one European, and started with them on June 3. Having ascertained that, as far as the Wanganui river, provisions could easily be obtained, we took only tents, blankets, powder and shot, and my instruments, with us. The road leads, for the first five miles, along a fine sandy beach, where, two miles from Hokitika, the wrecks of the schooner *Glasgow* and another small cutter were being broken up. Another mile further and the steamer *Waipara* was lying on the beach. After six miles we left the sea beach, and, crossing the dunes we travelled along a lagoon, stretching from here without interruption to the Totara river. Its tranquil water, in which the beautiful forest vegetation reflected its rich foliage, formed a pleasing contrast to the heavy surf breaking incessantly on the sandy shores. At the mouth of the Totara we found two stores, of which one was kept by a ferryman. Already here, I would observe, that great changes are continually taking place in the position of the mouth of the rivers south of the Hokitika. The Totara, which, when surveyed only two years ago, had a straight entrance, runs now nearly two miles along the coast towards north before it falls into the sea; and it was then so deep at its mouth and along that channel parallel to the sea coast, that even on horseback it was difficult to cross. We therefore availed ourselves of the boat to reach the other bank, and continued our road to the Mikonui, the beach continuing to be of the some low, sandy character. The Mikonui is easily crossed on foot in three branches, reaching only to the knees when it is low, as it is generally the case in winter; but with the least fresh it is a matter of great difficulty, and can only be accomplished with a good horse. On the northern side of this river a store was established, whence many parties working in its branches obtained their provisions. On the southern side of the Mikonui, the features of the country soon change, and instead of a low, sandy beach, Boldhead appeared before us, which was reached after a walk of three miles. This interesting bluff, the first one of a great many succeeding each other towards south, rises about 150 feet above the sea-level, and forms very often an almost vertical wall, against which, at high water, the waves of the sea break furiously, whilst, at low water, it is possible to travel along it, even on horseback, on the boulders of which the littoral zone is here composed, or on small sandy beaches between them. This and all similar headlands, a hundred miles south, were formed by the retreat of former huge glaciers, which, in the era immediately preceding the present one, reached here the sea. When retreating, they heaped up in their former channel the debris which had, in the alpine ranges, fallen upon them, consisting of angular blocks, often of enormous dimensions, and silt. If anything will give to the geologist an insight into the power which glaciers have of destroying gigantic mountains, and of carrying their debris away into lower regions, a journey to that part of the West Coast will easily effect this object. At the same time the mineralogical character of the rocks themselves, of which these large cliffs are partly composed, shows clearly that by far the greater part has been derived from the very summits of the central chain—they being identical with those composing the moraines of the large glaciers on the eastern sides, without any sign of plutonic or typical metamorphic rocks amongst them, which appear only at the western base of the Southern Alps. And that the sea had already destroyed a great deal of these bluffs is well exhibited by the enormous blocks which were lying in the surf, often far from the shore; whilst others are ready to tumble from the loose matrix in which they lie imbedded, and of which these cliffs are mostly composed. One of these erratic blocks, consisting of folded clay slates, with innumerable quartz layers between the folds, is about thirty to forty feet in diameter, covered on its summit with a rich vegetation, and may justly be compared to the celebrated Pierre à bot, in the Jura.

When starting from Hokitika I was not able to ascertain exactly if it were possible to take horses down the coast with me, as the bluffs were described as being impassable for them; but during the first days of my journey, I heard from some returning diggers, that, at least, as far as the Wanganui river, horses had been taken.

It was with wonder and delight that I passed along this bluff, about three miles long, where the structure of morainic accumulation could be so easily studied, and we arrived, the evening of the 5th of June, near the banks of the Waitaha, which, like the other rivers more towards south, has excavated its bed in these ancient moraines. Here a store had been already established, and a ferryman had built a punt, waiting for a rush towards the south, which was confidently expected by him to set in soon. From the storekeeper I heard that he had only just returned from Lake Okarita, 32 miles south of the Waitaha, where, on the banks of that lagoon, fine pasture is to be obtained, and he added that there was good travelling ground, with the exception of some of the headlands, exceedingly dangerous to cross with horses; so I made arrangements at once with him to accompany me with two pack-horses, thus being enabled to accomplish in far shorter time the journey I had in view, than I had anticipated. But it was the 8th of June before I could start again, having been detained, first, by continuous rain, aud afterwards by a heavy freshet in the river, which prevented the storekeeper from getting the horses from the banks of the river a mile above his store, where good grass land, generally so very scarce at the West Coast, was to be found. Crossing the Waitaha, our road lay for about five miles along a sandy beach, after which we arrived at another low headland, consisting of lateral moraines on both sides, with alluvial beds in the centre. This shingle wall, about 50 feet high and nearly perpendicular, was mostly covered with a luxuriant growth of pendulous ferns of different genera and some marine everlastings, still in flower, giving it a most pleasing aspect, whilst on its summit appeared a fine forest growth, consisting

Printed by M. Jaffé, Vienna.

e.

Fran

of white pine and rimu. The whole was enlivened by many small waterfalls, which every few hundred yards, and often still nearer, dashed down from the summit, the heavy rains of the last few days having supplied them with a larger body of water than they usually possess. They were for that reason so numerous, that in one locality I counted fifteen close together. Towards night we camped near a small creek, and, as unfortunately the tides were very disadvantageous for travelling, high water being towards the middle of the day, we made use of the magnificent moonlight night, starting before four o'clock in the morning, to round the next headland before reaching the Wanganui river. Even then we had started too late, as we soon became aware. For about two miles we were able to travel on sandy beaches, or at least on patches of smaller shingle which had been deposited between huge rocks; but soon the tide rose, the boulders became larger and larger, and it was apparent that since my companion had returned, the surf had washed a great deal of sand away, previously deposited between the interstices of the huge rocks, and it was not without some trouble that we arrived, towards daylight, at the Wanganui. The ubiquitous storekeeper was not wanting here, and had established himself in a wooden hut, built from the remains of a former whaling station. Round a good fire in the hut several diggers were lying, who had just returned along the coast, from a trip with the *Bruce*, to Taitahi, near Bruce Bay, without being able to find any auriferous ground rich enough to induce them to set to work.

The view from the mouth of the Wanganui towards the east is very extensive, although the highest parts of the Southern Alps are here still hidden by moraine beds, and in the foreground of which a very interesting sugarloaf-like headland, Mount One-one, on the southern side of the river, at its mouth, is most conspicuous. Such an occurrence shows clearly to what an enormous extent the glacier accumulations have already been destroyed by the action of the present rivers and the encroaching sea.

Owing to the unfavourable tides, we had again to stay till the afternoon at the Wanganui before we could continue our journey, as we had to cross another bluff before reaching the Poerua river. We also crossed the Wanganui in a boat. The bluff between the two rivers is not at all difficult to pass, as a good sandy beach, from which only at intervals large erratic blocks rise, stretches to the Poerua river; and only the last piece, leading for a short distance along that river near its mouth, consists of waterworn flattened boulders, offering a very bad footing to a horse. The river is easily to be crossed on foot, reaching scarcely to the middle. An extensive view, taking in Mount Cook, and the other stately ice-clad summits near it, is obtainable when we round the next bluff, separating the bed of the last-mentioned river from Lake Poerua, a lagoon of a length of three miles, surrounded on three sides by glacier accumulations. A low sandbank, thrown up by the Pacific Ocean, forms its boundary to the west. Its northern arm, on which we camped, is nearly dry at low tide, and contained then drinkable fresh water. Great quantities of waterfowl are living here, giving animation to the quiet foreground, over which the giants of the Southern Alps show their magnificent forms in all their grave splendour. Round the lagoon itself, which gradually becomes silted up, a rich vegetation has sprung up, consisting, near the shore, of fine grass. It was really a treat to see the poor horses which, for the last three days, had been on short commons, enjoy a run and have a feed of succulent grass *ad libitum.* Here, again, we met a party of Italians and Greeks who were returning from the South, having prospected several rivers near Mount Cook; and although they were able to trace almost everywhere the existence of gold, they could not find ground rich enough to recompense them for bringing provisions so far. Arriving at the outlet of the Poerua, we found that the mokihi, or craft, made of flax-sticks, put together by a large party of diggers, was on the other side, and as we thought it impossible to cross on horseback without swimming, one of my Maoris swam across to bring the mokihi over, whilst we occupied ourselves to make another flax rope, so as to be able to direct it from both sides. It was just high water when Tipeni brought the clumsy concern over; but before we had made our preparations, the tide was running out so fast that one of the flax ropes broke repeatedly when it came in mid-channel, and we had the greatest difficulty in bringing everything over. In fact, once the mokihi was close to the surf, and the man whom we pulled across made himself ready for a swim, but at last we landed him safely. As we heard afterwards, a poor fellow was drowned here shortly before, his mokihi having been taken down by the current into the surf. We camped the same night on the southern side of the lagoon, in an old Maori whare, and started before daybreak to pass the most dreaded portion of the coast, Abut Head, which, when my companion had passed before, owing to favourable circumstances, was, with the exception of the southern end, or Abut Head proper, mostly sanded up. It seems that without being able to account for it, one heavy gale very often brings such an amount of sand with it, that nearly all the rocks between high and low water mark are covered with it. During one, or several gales, it remains in that condition, till at last another washes it all out again. Thus it happens that after nearly every heavy gale such great changes take place, that one cannot count with certainty on bringing horses round without very great trouble. For the first mile or so we had very fair travelling ground, but soon became aware that we had started too late, as the tide began to rise, covering the lower part of the beach, which consisted mostly of small boulders and sand, and we were obliged to take a higher line, where, from the nature of the huge blocks, we were often obliged to round them by waiting for the retreat of the waves, and then rushing through the water. So we toiled on, now and then caught by a great wave ; the feet of the horses slipped between the boulders, and were sometimes only extricated with the loss of a shoe ; and although the poor animals were bleeding and exhausted, we could not lose a moment, as the tide was rising. So we unpacked them with all haste, and brought them near high water line, where on examining the ground, I had discovered a better track, made by a party of diggers who had preceded us with horses. By filling up the interstices between the large boulders, and cutting through smaller cliffs of silt, they had made it possible to get round the last point before reaching the Whataroa river. It is here that Abut Head is situated, which rises almost perpendicularly several hundred feet from the sea. For a great distance enormous blocks of rock lie scattered in the surf, over which the waves dash with the utmost violence. Thus I again had an opportunity of observing that the digger, when once bent upon exploring a country, will not be beaten by any obstacle in his way, and that being often made an engineer by necessity, he will find at last his way to the proposed goal without flinching from his self-imposed task. Having at last brought the horses safely round the point, we returned to fetch their loads, and as the high tide would not allow us to cross the Whataroa (which, immediately south of Abut Head, reaches the sea), we had to wait till nearly evening in a cold south-wester, accompained by occasional showers. About four o'clock, the river had fallen sufficiently to allow us to cross, which had to be done in two branches ; and, although the water, owing to the cold weather, was exceedingly low, it reached in the first branch nearly to the armpits ; whilst in the second branch, being the largest, it was not so high, owing to its wide expanse. On the southern side we had to traverse a belt of forest, through which parties passing before us had cut a track, and it was already dark when we camped in an abandoned Maori pah, where the dense vegetation afforded us welcome shelter against the heavy south-wester continuing to blow during the first part of the night.

A glorious morning succeeded the bad weather; not a cloud was visible on the azure vault of heaven; and having crossed the Waitaki, a large river joining the Whataroa near its mouth, which, owing to its soft bed, was troublesome to horses and men, the latter having to carry the loads over in order not to risk the animals in the quicksands, we arrived at the Maori pah, lying on a small sand-spit. I use the habitual expression Maori pah, but a description of this settlement would give a very poor idea of such a Maori village, consisting as it did of three miserable low huts, in which a very old couple, and the widow of the late Chief Taitahi, with her children, were living. Owing to so many diggers having passed here, the greatest portion of their staple food—potatoes—was already gone, of which, of course, the Maori diggers got the lion's share, they would have to suffer a great deal of privation before they could expect a new crop. Evidence of a lamentable state of things was very visible, principally among the children, who were covered with sores and ulcers; living, as they did, upon any thing they could obtain, and greedily sucking the fat of the woodhens they were able to catch. And so what had given to the active population of the West Coast a golden harvest, had made these poor people still more wretched than they had formerly been. About a mile south of the Maori huts, and two miles from the mouth of the Whataroa, another headland had to be passed, but owing to the circumstance that high water was still towards noon, we were compelled to remain here the greater part of the day before we could continue our journey. But as the weather was really glorious—no cloud in the deep blue sky—I had plenty of work to do in sketching the magnificent scenery before me, and taking the necessary bearings of a great many of the principal peaks and valleys of that part of the Southern Alps. The view towards the sources of the Whataroa was exquisitely grand; but I shall not give a description of it till I speak of the view from Lake Okarita, which, for diversity of scenery and greatness, cannot be surpassed by any other landscape on the globe.

At three o'clock we could start, and rounding two smaller headlands, which were the former terminal moraines of the Waitaki glacier, we stood at last before that glorious panorama. The contrast between the ever restless sea—the gigantic waves coming and going without intermission—and the quiet watershed of Lake Okarita, with its numerons islands, surrounded by luxuriant forest, was most striking. Above the forest plains rose low hillocks, also clothed with the same intensely green West Coast vegetation, over which the Southern Alps appeared a mass of snow, ice, rock, and forest. As far as the eye could reach, mountain appeared behind mountain, all clad in their white garments, with which they are covered during the whole year almost entirely, becoming apparently lower until they appeared only as small points over the sea horizon—half cloud, half ghost, as a modern philosopher has said so well. But what struck me more than anything was the low position reached by an enormous glacier, descending north of Mount Cook from the ranges, and appearing between the wooded hillocks at the foot of the Alps; forming with its pure unsullied ice, broken in numberless seracs, a most remarkable and striking contrast to the surrounding landscape. The sun being near his setting, new changes were every moment effected; the shades grew longer and darker, and whilst the lower portion already lay in a deep purple shade, the summits were still shining with an intense rosy hue. Turning towards the sea, the same contrast of colours was exhibited, the sea being deep blue, whilst the sky was of such a deep crimson and orange colour, that if we could see it faithfully rendered by an artist, we should consider it highly exaggerated. But the beauty of the magnificent scene did not fade away even after the glorious orb of day had disappeared, because, as the night advanced, the full moon threw her soft silver light over the whole picture, and lake and sea, forest and snowy giants still were visible, but assuming, apparently, other dimensions, shapes, and colours. It was late at night before I could leave this glorious view, and my heart swelled with such a pure delight as only the contemplation of nature can offer to her admirers.

After a beautiful calm night, we found the whole country covered by hoar-frost, the minimum thermometer marking 29° 20', or nearly 3° below freezing point; but a cloudless sunny day followed, and I never got tired of admiring the wonderful landscape before me, the solitude of which appeared less severe when observing numerous horses feeding peacefully among the high grass in the foreground, a strange sight at the West Coast, where the uniform forest vegetation is totally unfit to preserve the life of that useful animal. The presence of so many horses indicated that a great number of diggers had their head-quarters here, from whence they prospected the country in the neighbourhood. The traces of the night's frost soon disappeared before the powerful sun, and we followed for more than three miles a well-beaten track along the banks of the lake, through high flax and small groves, consisting of *Coprosma*, *Veronica*, and dwarf totara bushes, intersected with grassy flats. Owing to the variety of means of human subsistence presented on the one hand by the sea, on the other by the lake and the open ground around it, it is easily understood that such a favourable locality would not escape the attention of the native inhabitants of this island; and this well-beaten track, the numerous remains of whata's (provision stores), palisadings around graves and huts, show that formerly a much larger population than that at present existing, had peopled these interesting shores. The sleek and spirited appearance of the horses, when compared with their usual miserable condition on the Coast, testified that the grass growing here alongside the lake was both abundant and nutritious.

About a mile from the outlet of the Okarita lake, which, like that of Poerua, is situated at its southern extremity, we fell in with an encampment, consisting of several tents and provision stores, mostly occupied by one man, the only representative of a prospecting party, who had left one of their mates behind to look after the provisions and horses during their absence. Being told that the headlands between the Okarita and the Waiau were impassable for horses, we left ours and part of our provisions behind, and proceeded at once to the outlet of the lake, which is so broad and deep that it can only be crossed with a mokihi. Some of the diggers had hollowed out from a drift tree a kind of canoe, about eight feet long—the stern, originally open, being closed with some sods, through which the water found its way during the passage. In this frail bark, kindly lent us by the diggers, and which we strengthened by a bundle of flax-sticks on both sides, we crossed two at a time, and camped that evening on the southern side, under the shelter of a manuka grove, and in a commodious whare, built a few weeks before by a large party of Natives who had gone south prospecting.

The next morning, June 14th, we continued on foot with heavy loads, so as to be prepared for a spell of bad weather, which might possibly overtake us when near the head waters of the Waiau. Lake Okarita is bounded on its southern side by a headland, formed by a lateral moraine, without doubt belonging to the Waiau system, and exhibiting by its rough anticlinal arrangement, that it formed the northern lateral moraine of that large postpliocene glacier. This accumulation, first only 40 feet high, rises as we advance towards the south, to at least 250 feet, indicating more than anything else the enormous denudation which must have taken place before the present glaciers would form the channels they now occupy. And if we consider that the accumulations come mostly from the highest portion of the central chain, the lower portion having been generally ground down by the ice, or become removed by the rivers issuing from below these huge glaciers, the philosopher is filled with admiration and wonder, when the great truth once more is revealed to him, that Nature, to obtain great results, uses gigantic but simple means, of which we have scarcely any true conception. Between the Okarita lake and the Waiau comparatively little water reaches the sea, which may easily be accounted for by assuming that a large spur runs in a south-westerly direction, from Mount Elie de Beaumont to the valley of the Waiau, so that only the water collecting on the western side of that spur could form small channels through those moraines.

There are two smaller rivers which we had to pass before we reached the Waiau, both being called the Totara, but generally easily crossable if they flow at all, their mouths being often closed by shifting sands of the sea-shore, behind which they then form lagoons; but when breaking through, for a few days often present an impassable barrier to the traveller. When we passed the first time, the northern Totara was running, but could be easily crossed, whilst the southern one was closed; and on our return, owing to the continuance of the fair weather and light south-west winds, we found them both closed, so that we could travel dry footed for eight miles along that well irrigated coast. At eleven o'clock we arrived at the mouth of the Waiau, where two diggers, who had been our travelling companions, left us; they were bound for a creek between the Waiau and Waikukupa, where some payable finds, according to rumour, had just been made by some prospecting party.

The view from the mouth of that river is most magnificent, as the valley, being straight and nearly two miles broad, allows us to gaze at the Southern Alps from foot to summit, having in the foreground the enormous ice masses of the Francis Joseph glacier appearing between the rich forest vegetation. The Waiau is a true shingle river, flowing in several branches through its wide valley, the semi-opaque bluish colour of its waters at once revealing its glacier origin. Owing to the cold nights it was very low, so that we could easily cross, it being scarcely above our knees when running in several branches. Numerous deep channels, now empty, and the enormous amount of drift-wood lying everywhere upon the shingle flats and spits, were indications enough to show that, with the least freshet, it would be impassable for travellers on foot; and I can easily understand that, during spring and summer, it is almost impossible to wade through it. Even in this season, the least rain makes it very dangerous to cross. A week before our arrival, when there had been a freshet in the river, a prospector, a capital swimmer, was washed from his feet, and drowned, before his mates could offer him any assistance. The river having a general tendency, at present, to keep principally on the northern side of its broad bed, we crossed it at once in three branches, and kept on the southern side, travelling partly in dry channels, over grass-flats, or sometimes, through dense bush, where a branch of the river sets close against banks covered with forest vegetation. This forest consisted either of pines intermingled with arborescent ferns, the whole interlaced by climbing plants, or—and what was still worse—of shrubs, the branches of which were not only grown to dense masses and towards the ground, but were still more closely united by Bushlawyers (*Rubus australis*) and Supple-jacks (*Rhipogonum scandens*). It was a herculean task to pass through bush of the last description when only a few hundred yards long; and we seldom reached the river-bed without having left part of our garments or skin in our battle with that unpleasant West Coast vegetation.

After two miles the bed enlarged still more, the river flowing in two principal branches on each side of it, with a large wooded island in the centre. Towards evening we camped about seven miles from the coast, near a grove of pine trees and arborescent ferns. During our journey up the river we had occasion to observe an abundance of animal life existing there; there were large numbers of woodhens, and my Maori companions soon made sad havoc amongst them. Next morning the same fine weather favoured us, and after four miles we arrived at the foot of the Southern Alps, which rose from the plains in all their majestic splendour. Here the main river turned towards south, and an important branch joins it from the south-east, coming also from a large glacier, which I called after Professor Agassiz, the illustrious naturalist. The valley of the main river narrows here considerably, and rocky points are washed by its water on the right side, consisting of a beautiful mica slate full of garnets; but even here,

having done so will afterwards feel surprised at the facility with which that wonderful and powerful plough of nature will furrow deep valleys and model *roches moutonnées*.

On both sides of that glacier, for a good distance, the mountains were covered with a luxuriant vegetation, amongst which beautiful rata trees, and in one locality Fuchsia bushes, then without leaves, covered a large extent of the mountain side, and were most conspicuous. It was in vain that even here, close to the glacier, where the large ice masses must, in some degree, refrigerate the surrounding atmosphere, I looked for characteristic alpine plants. There were neither spear grasses nor *Celmesias*, those gigantic New Zealand daisies, which are such an ornament to our higher vegetation, nor even any of the sub-alpine bushes and shrubs. One may easily imagine how extremely striking is the contrast between the stupendous ice masses, enclosed by that tremendous mountain chain, and the arborescent ferns, pines and other luxuriant vegetation which are in general only found in more genial parts of the coast.

On Monday, the 19th of June, we began to retrace our steps from the Okarita lake, and found great difficulties in passing some of the rivers, the entrances of which had been nearly choked up by the sands travelling with the current, so that they formed large watersheds. The weather, which hitherto had been so fine, began to be very boisterous; and from Lake Poerua to the Waitaha, we had mostly heavy rain, whilst the last day from the Waitaha to Hokitika, was one of those bright days which makes the remembrance of that journey a very pleasant one. I reached Hokitika on June the 23rd, and had to wait till July the 4th before I could proceed to Christchurch, the weather being so stormy that no steamer would venture out. At last the *Maid of the Yarra* crossed the bar to tender the *Omeo*, in which I returned, *via* Nelson and Wellington to Christchurch, where I arrived after a protracted passage, on the 15th of July. On July the 24th, I presented a Progress Report to the Secretary for Public Works on the main results of my examination during that journey, which was printed with the reports written during my residence on the West Coast, by order of the Provincial Government, and of which I have given the title on page 88.

From this report I may be allowed to quote here the concluding passage concerning my views on the extent of the West Coast goldfields, and which their further development during the last two years, has confirmed in every respect:—"To sum up the results obtained, the examination of the country under consideration has shown us that there is one large area belonging chiefly to the pliocene or great gold-drift formation, bounded in this province by the rivers Arnold and Grey to the north, and the Hohonu ranges, whence the eastern boundary line runs towards Abut Head, crossing the Arahura, Hokitika, Totara, and Mikonui, gradually nearer to their mouth, whilst the sea-shore forms the western boundary. In this triangle all the richest goldfields are situated. East and south of these lines younger or pleistocene strata have mainly been deposited, consisting of glacial beds, either moraines or glacier mud, fluviatile boulders, shingle, sand, or loess, amongst which in a lesser degree gold may be discovered, although from the great scarcity of auriferous assorted drift there is, in my opinion, very little hope of a goldfield of any extent. Again, east of these glacial deposits the western base of the central chain is reached, consisting of the rocks which have formed the original matrix of the gold. Here we may expect either to find quartz reefs, or, under favourable circumstances, in the smaller creeks and gullies, auriferous ground of older age, or formed during or since the pleistocene epoch, with coarser gold than near the coast, although experience has already clearly demonstrated in New Zealand, as well as in other parts cf the earth, that we can only expect rich ground when, after denudations on an enormous scale, aqueous agency, has repeatedly re-assorted the material derived from such sources, and concentrated the gold contained in it during numberless ages into much narrower limits." Not only are the principal goldfields here still being worked in the Province of Westland, where also the newly discovered Kumara diggings are situated, but I have no doubt that still other and equally extensive beds will be discovered, all belonging to the same pliocene fluviatile beds, running in a north-east and south-west direction, and gradually thinning out before Bold Head, south of the Mikonui river, is reached.

The track cut across the Hurunui saddle by the late Mr. Howitt, in the year 1862, and improved in the beginning of 1865, under the direction of Messrs. Edwin and Walter Blake, had become almost impassable, principally on its western side, from the enormous traffic. Moreover, its line along the northern boundary of the Province, was formed too far north for the inhabitants of the middle and southern portion of Canterbury. The Provincial Government therefore sent out several expeditions to the headwaters of the Waimakariri and

Rakaia, with instructions to examine them for available passes more to the south, across the central chain. Of course it was known that a pass near the headwaters of the main branch of the Rakaia existed, Whitcombe Pass, so named in memory of the late Mr. Whitcombe, an eminent engineer, who lost his life by being drowned near the mouth of the Teramakau, after having successfully accomplished the journey from coast to coast, and of which the survivor, Jacob Louper, has given a graphic and ample description. However, this Pass, then known only from this account, appeared to be surrounded by so many difficulties from an engineering point of view, that a further examination was thought useless. Haast's Pass on the other hand, at the head of Lake Wanaka, was too far south, and could only be made available for the most southerly portion of the Province, and principally for Otago. Of the expeditions exploring the headwaters of the northern rivers, that of the late George Dobson, C.E., was the most successful, he amongst others discovering Arthur's Pass, a deep depression in the central chain, leading from the sources of the Bealey, one of the upper tributaries of the Waimakariri, into the Otira, a large branch of the Teramakau. After this important discovery had been reported, the Provincial Government lost no time, and sent up Mr. E. Dobson, C.E., formerly Provincial Engineer, and at that time Resident Engineer of the Christchurch and Lyttelton Railway, to examine this and some other passes found about that time, with full authority to place the necessary work at once in the hands of the contractor. Mr. Dobson, after inspecting two passes at the head of the northern main branch of the Waimakariri, Harman Pass and the so-called Browning's Saddle, and another saddle at the head of the Hawdon stream, selected Arthur's Pass, as affording the most favourable physical conditions for a road between both coasts, and the work was at once taken in hand, and pushed on with great energy. The headwaters of the Waimakariri were explored by Messrs. Harman, Browning, Cahill, and Armstrong; whilst the two first-named gentlemen, together with Mr. E. Griffiths, examined the Wilberforce, the northern main branch of the Rakaia, and discovered a pass leading, as the explorers thought, to the sources of the Taipo, a branch of the Teramakau.

In the south of the Province great efforts were also made to look for a passage across the Southern Alps by the headwaters of the Waitaki, to the exploration of which I had devoted considerable time, and the results of which had conclusively shown that no passage existed there anywhere, except over glaciers and *nevé* saddles, only to be crossed by experienced mountaineers. At the request of the Provincial Government, therefore, I prepared a report on the possibility of finding a road to the West Coast across the Mackenzie Country, in which I gave copious extracts from my journals, bearing upon the subject, and by which, so far, the question at issue was settled.*

Journey to Westland by Arthur's Pass, returning by Browning's Pass. October, 1865.

Although the road over Arthur's Pass was pushed on all along the whole line with such energy as never before had been witnessed in the Colony, there was considerable dissatisfaction expressed in the Province that a road was not at once constructed over Browning's Pass at the head of the Wilberforce, notwithstanding that several Engineers had reported as to this alpine saddle being too high and unsuitable for the purpose. Their views were considered to have been biassed for some reason or other. The Secretary for Public Works therefore instructed me to visit both Passes, to report generally upon their physical features, and to take also a number of altitude observations with the barometer. In order to secure the greatest accuracy, three Aneroid barometers which I took with me were compared by Mr. R. L. Holmes, Provincial Meteorologist, regularly during four weeks, with the standard barometer in the Christchurch station, with which they were found to agree very closely. One of them was compensated for temperature, and found to work in the field very well, to an altitude of about 1800 feet, above which its readings were too high, and consequently of no value; whilst the two other instruments not only worked admirably together during the whole journey, and in all situations up to 5000 feet, but when returning, agreed with the Christchurch standard barometer within 2-100ths of an inch.

After these necessary preparations, I left Christchurch on October 2nd, to reach the West Coast by first visiting Arthur's Pass. I was accompanied by my friend Mr. R. L. Holmes, who had been my companion on my first journey across the Southern Alps, and by whose energy and perseverance the main objects of my journey were much furthered.

---

* Report on the Head Waters of the River Waitaki: Fol. Christchurch, 1865. By Julius Haast, Ph.D., Provincial Geologist.

Rakaia, with instructions to examine them for available passes more to the south, across the central chain. Of course it was known that a pass near the headwaters of the main branch of the Rakaia existed, Whitcombe Pass, so named in memory of the late Mr. Whitcombe, an eminent engineer, who lost his life by being drowned near the mouth of the Teramakau, after having successfully accomplished the journey from coast to coast, and of which the survivor, Jacob Louper, has given a graphic and ample description. However, this Pass, then known only from this account, appeared to be surrounded by so many difficulties from an engineering point of view, that a further examination was thought useless. Haast's Pass on the other hand, at the head of Lake Wanaka, was too far south, and could only be made available for the most southerly portion of the Province, and principally for Otago. Of the expeditions exploring the headwaters of the northern rivers, that of the late George Dobson, C.E., was the most successful, he amongst others discovering Arthur's Pass, a deep depression in the central chain, leading from the sources of the Bealey, one of the upper tributaries of the Waimakariri, into the Otira, a large branch of the Teramakau. After this important discovery had been reported, the Provincial Government lost no time, and sent up Mr. E. Dobson, C.E., formerly Provincial Engineer, and at that time Resident Engineer of the Christchurch and Lyttelton Railway, to examine this and some other passes found about that time, with full authority to place the necessary work at once in the hands of the contractor. Mr. Dobson, after inspecting two passes at the head of the northern main branch of the Waimakariri, Harman Pass and the so-called Browning's Saddle, and another saddle at the head of the Hawdon stream, selected Arthur's Pass, as affording the most favourable physical conditions for a road between both coasts, and the work was at once taken in hand, and pushed on with great energy. The headwaters of the Waimakariri were explored by Messrs. Harman, Browning, Cahill, and Armstrong; whilst the two first-named gentlemen, together with Mr. E. Griffiths, examined the Wilberforce, the northern main branch of the Rakaia, and discovered a pass leading, as the explorers thought, to the sources of the Taipo, a branch of the Teramakau.

In the south of the Province great efforts were also made to look for a passage across the Southern Alps by the headwaters of the Waitaki, to the exploration of which I had devoted considerable, time, and the results of which had conclusively shown that no passage existed there anywhere, except over glaciers and *nevé* saddles, only to be crossed by experienced mountaineers. At the request of the Provincial Government, therefore, I prepared a report on the possibility of finding a road to the West Coast across the Mackenzie Country, in which I gave copious extracts from my journals, bearing upon the subject, and by which, so far, the question at issue was settled.*

Journey to Westland by Arthur's Pass, returning by Browning's Pass. October, 1865.

Although the road over Arthur's Pass was pushed on all along the whole line with such energy as never before had been witnessed in the Colony, there was considerable dissatisfaction expressed in the Province that a road was not at once constructed over Browning's Pass at the head of the Wilberforce, notwithstanding that several Engineers had reported as to this alpine saddle being too high and unsuitable for the purpose. Their views were considered to have been biassed for some reason or other. The Secretary for Public Works therefore instructed me to visit both Passes, to report generally upon their physical features, and to take also a number of altitude observations with the barometer. In order to secure the greatest accuracy, three Aneroid barometers which I took with me were compared by Mr. R. L. Holmes, Provincial Meteorologist, regularly during four weeks, with the standard barometer in the Christchurch station, with which they were found to agree very closely. One of them was compensated for temperature, and found to work in the field very well, to an altitude of about 1800 feet, above which its readings were too high, and consequently of no value; whilst the two other instruments not only worked admirably together during the whole journey, and in all situations up to 5000 feet, but when returning, agreed with the Christchurch standard barometer within 2-100ths of an inch.

After these necessary preparations, I left Christchurch on October 2nd, to reach the West Coast by first visiting Arthur's Pass. I was accompanied by my friend Mr. R. L. Holmes, who had been my companion on my first journey across the Southern Alps, and by whose energy and perseverance the main objects of my journey were much furthered.

---

* Report on the Head Waters of the River Waitaki: Fol. Christchurch, 1865. By Julius Haast, Ph.D., Provincial Geologist.

The road from Christchurch to Porter's Pass was much enlivened by a number of diggers travelling to Hokitika, as well as by many large drays taking provisions, tools, powder, &c., as far as the foot of Arthur's Pass. After having made a number of observations on Porter's Pass, we continued our journey, and found that the road in its worst places had already been much improved by the numerous workmen stationed all along this line. Crossing Golding's Saddle from the Cass plains to the Upper Waimakariri we were already able to follow, for several miles, the new road, blasted along the mountain side, after which we were obliged to take the dog-cart into the river-bed as far as the Bealey, which gave considerable trouble, owing to the large boulders and the numerous channels to be continually crossed. Of the rest of the road along the mountain side, only about half the distance had been finished to a breadth of three feet, by which we took the other horses. Great activity reigned everywhere, the electric telegraph had already been finished as far as Lake Pearson, whilst the posts and wire were on the ground as far as the Bealey. The view obtained from this most picturesque road along the precipitous high ranges and the passage of which to the new comer seemed fraught with danger, is very beautiful. Deep below the road appeared the bed of the Waimakariri, with its numerous meandering channels, here and there small groves of beech trees forming a fine foreground to the grand landscape. The eye followed the broad river-bed far into the central chain, the alpine summits of which, covered with perpetual snow, rose high into the air; while the wild rocky buttresses, amongst and along which the road had to be carried, offered an additional charm to the whole picture. The numerous rock cuttings were particularly welcome to the geologist, as presenting a series of very fine and clear sections, in which the structure of the alpine region could be well studied. Before we reached the spot whence it was intended that the road should intersect the Waimakariri, we had to cross two branches of the river, which here sets against rocky and nearly perpendicular cliffs, along which we observed a number of men busily engaged blasting out the road. On October 6th we reached the newly founded township of Bealey, situated on the large shingle-fan which the tributary of the same name has advanced to a considerable distance into the bed of the main river. Several houses had been built, either constructed from logs, or covered with zinc or weather-boards, which, together with a good array of tents, indicated that a number of people had already congregated here. In fact, there were more than a hundred inhabitants who intended to settle in that locality whilst a considerable number of diggers and navvies passing to-and-fro made it their usual resting-place. At the same time, several parties of sawyers were also at work, preparing timber for a number of buildings still to be erected.

For a day we were occupied with taking a number of barometrical observations, and left on October 8th for the Pass, in company with Mr. Edwin Blake, one of the Engineers in charge. Following the broad shingle-bed of the Bealey, and crossing and re-crossing its clear water, I enjoyed very much the contemplation of the beautiful landscape around us. On both sides and in front of us rose fine mountain peaks, possessing magnificent outlines; but the effect was still heightened by the existence of luxurious *Fagus* forest, which not only clothed the mountain sides for more than two thousand feet above the valley, but also formed charming groves in the latter. After five miles, we reached Mr. Smith, the contractor's camp at the entrance of the Bealey gorge; here great activity reigned, and the principal work of blasting in order to ascend Arthur's Pass, had already considerably advanced. We now followed the road to the summit of the Pass formed in the lower portion in the deep gorge of the Bealey, and as at one spot the bridge across it was not yet finished, a number of workmen carried my dog-cart across. It would be impossible to describe in detail the grandeur of the scenery around us, as we slowly ascended to the summit of the Pass, and gradually exchanged the beech forest, which now had become dwarfish and covered with *Usnea barbata* (that peculiar pendant greenish white lichen) with the varied and beautiful sub-alpine vegetation of New Zealand. The Bealey had also become a wild mountain torrent, tumbling its foaming waters over large blocks of stone lying in its bed, and shut in by high rocky cliffs, where from every crevice vegetable life had sprung into existence. High above us, Mount Rolleston with its remarkably grand form, rose on our left side, harbouring large snowfields on its flanks, whilst on the opposite side of the valley several fine waterfalls hung on the rocky mountain sides. On the Pass itself, where the road had been blasted through large angular blocks of rock, mostly derived from morainic accumulations, a rich and varied flora surrounded us, amongst which the *Nene* (*Dracophyllum Traversii*, *Hooker fil.*) a small palm-like tree, belonging to the *Ericeæ*, and growing only on our low alpine passes, and the *Ranunculus Lyallii*, *Hooker fil.* are the most remarkable.

Having made a number of barometrical observations, we descended about a thousand feet to the camp of Mr. Wright, the contractor for the work on the northern side of the Pass. In descending, several conspicuous additions to the vegetation observed on the southern face of the Pass were met with, of which the *Rata* (*Metrosideros lucida Menzies*) forms the greatest ornament to the landscape, principally about Christmas time, when the whole mountain side, as seen from above, appears as one mass of bright scarlet flowers. In this camp we also met Dr. Stedman, who had been sent here by the Provincial Government to attend professionally, in case of accident or illness, amongst the numerous men at work upon these large and extensive works. I was now obliged to leave my dog-cart—the first which had ever crossed the Southern Alps—behind me, and continued my journey next day, packing my provisions and camp utensils. Descending into the gorge of the Otira, a wild alpine torrent, where we crossed over several newly constructed bridges, the magnificent scenery around us could not fail to make the deepest impression upon me, and which lost nothing of its glorious character by my having travelled shortly before amongst the highest mountains of the Southern Alps. The steepness of the mountains on both sides forming the gorge, the constant alternation between rocky precipices and luxuriant forest, large trees growing amongst perpendicular cliffs, wherever thin roots could penetrate, numerous small but charming cascades descending from both sides; below, the roaring mountain torrent, rushing down amongst huge blocks of rock, by which its passage was impeded; and above all, the deep blue sky of New Zealand—the whole forming a picture of indescribable grandeur and beauty. Numerous gangs of workmen were here occupied with blasting and road-making, and a few shanties, where provisions, fresh meat, and even Christchurch baked bread could be bought, had already been built between the rocky spurs. We were very fortunate in the weather when crossing, as this Pass, like all deep depressions in our alpine chains, is particularly subject to rain. The observations made during the progress of the work showed that, during the whole time there were scarcely three days in the week in which the men could proceed with the work, whilst in some months, the rainy weather was so continuous, that an average of one day and a half only in a week was obtained.

After four miles of this charming scenery, the valley opened, and we continued our journey over flats, covered with *Olearia nitida*, and *ilicifolia*, *Veronica salicifolia*, *Leptospermum*, some species of *Coprosma*, *Panax*, and others. Here I had the pleasure of meeting His Honor the Superintendent Mr. Samuel Bealey, and Mr. Edward

Jollie, the Provincial Secretary, who had come over from Christchurch to make themselves personally acquainted with the progress of the road. Arrived at the junction of the Otira with the Teramakau, I sent my horses back to meet me at the eastern foot of Browning's Pass, and continued my journey with another set of horses, which had come up from Hokitika to meet me here, and to convey my luggage to the western approaches of that last-mentioned Pass. For several days we were detained by heavy rain at the Taipo, and moreover were compelled to travel slowly, owing to the very bad state of the roads, which were only partly formed. In many places they were nothing more than deep channels of mire, interlaced with innumerable roots, in and above which a number of stems of trees and arborescent ferns were lying, and amongst which the horses had to pick their way. On the 14th of October we arrived at the Waimea, whence the road leads across the downs to the Kawhaka, a tributary of the Arahura, the whole country being the whole way covered with most luxuriant forest, consisting generally of pines, amongst which the numerous fern trees raised their graceful crowns. This is one of the finest portions of the West Coast road, and on a favourable day, the traveller who passes through this lovely country, cannot find terms adequate to describe his admiration or to express his delight. However, in those days, travelling along these tracks was a very arduous task indeed. Everywhere road parties were at work clearing a broad belt of forest away, and as the rainy weather continued, it was often with some difficulty that we managed to get the pack-horses along.

On the 18th of October we reached Hokitika, where, in my old quarters in the Government Camp, I found a hospitable welcome. After having paid a visit to the Totara diggings and to Lake Mahinapua, south of Hokitika, which owes its origin to morainic accumulations on its western shore, I prepared myself for the return journey by Browning's Pass. We left Hokitika on the 25th of October, crossed the river in a punt, and followed the road for nearly seven miles along its left bank, travelling mostly on alluvial terraces of quarternary origin, generally covered with Ake-ake bushes (*Olearia nitida.*) In order to visit the gold workings at and near Kanieri township, I crossed the river from Woodstock, and descended several of the shafts, which offered me a good insight into the geological structure of the auriferous beds, a subject to which I shall return in the chapter on the geology of the West Coast.

East of Woodstock—a small mining township—the road traverses a fine pine forest, which presented some difficulties for the passage of the pack-horses. We crossed the river at what was called the "long ford"—easily passed by horses, a boat being in readiness for foot passengers. Thence, we followed the river to the junction of the Kokatahi, passing over low sandy ground, either flood channels or low terraces covered with *Olearia*, *Veronica*, *Coriaria*, *Leptospermum*, and similar shrub vegetation growing along river-beds. From here to the junction of the Styx the track passes for about eight miles through level country, called Sherrin's Run. Over the whole, small groves of shrubs of the same character grow, with numerous patches of grass between them, intersected by small water-courses. A number of New Zealand quail (*Coturnix Novæ Zealandiæ*) rose before us, having till then been very little disturbed, but I understand they have long since become exterminated in that locality, as well as almost everywhere else in New Zealand.

The same evening we camped near the entrance of the Styx valley into the Hokitika plains, and had a magnificent view of the high ranges before us, of which the summits were still deeply covered with snow, whilst the numerous sugarloaf-like hills in the foreground told distinctly the history of the district. Entering next morning the valley of the Styx, now flowing between the ranges, numerous natural sections made me well acquainted with the geology of the district. The path leads for several miles along or in the river-bed, where we had to cross and re-cross, which was rather unpleasant, owing to the large boulders and the swift current; we then reached a bridle-path, cut on the left bank through the forest, where travelling was comparatively easy. We now crossed a huge moraine, stretching across the valley, and consisting principally of enormous blocks, representing all the rocks which form the summits of the Southern Alps. After a few miles, we had repeatedly to cross the river, now assuming the character of a mountain torrent. The fords were deep and rocky, with large blocks to pass over. The evening setting in, we camped in a small gully, where, owing to the altitude now reached, the black beech (*Fagus fusca. Hook. f.*) was now the predominent tree. Starting with fine weather from the Hokitika plains, after advancing a few miles into the valley, rain and sleet began to fall, and continued with little intermission till next morning, when we started again to reach the "Wooded Saddle." The valley gradually lost its gorge-like character, and opened up, leading us to a small grassy flat, 1800 feet above the sea level, on which *Ranunculus Lyallii* stood in full flower.

I had the pleasure of meeting here Mr. Malcolm Fraser, one of the Government District Surveyors (now Surveyor-General of Western Australia), who had charge of the road party working from here in both directions, and who kindly returned with me to his camp. A gentle ascent of about 800 feet through dense forest, changing towards the summit into thick sub-alpine scrub, brought us to the top of that first saddle. The road from the foot to the summit under the direction of Mr. M. Fraser was nearly finished, and offered fair travelling ground. The summit of the wooded saddle exhibits the same characteristics as Arthur's or Harper's Pass, and although I use the expression "wooded saddle," I think it very inappropriate, as it will convey an erroneous impression. The ground is covered with *Sphagnum* (swamp moss), grass and other herbaceous plants liking moist sub-alpine localities. Here and there small groves of sub-alpine shrubs, consisting of several species of *Dracophyllum*, *Olearia*, *Panax*, *Veronica*, &c., have sprung up on the drier spots, and cover both sides of the mountain slopes with a luxuriant growth, attracting the eye by the various and vivid tints of their rich foliage.

Some 80 feet below the summit of this first saddle Mr. Fraser's camp was situated, where we found a kind and hearty reception. Mr. Fraser having among his road party several miners who, four weeks before my arrival, had come over Browning's Pass, I endeavoured to prevail on some of them to return with me, to carry swags and provisions, but they all dreaded so much the journey, that I could only obtain the assistance of one of them, and the rest of my party had to be made up by some volunteers from his road gang. Starting the 28th of October, I kept for about a mile on Mr. Fraser's line, and descended afterwards into the bed of the Arahura to examine some auriferous ground near the junction of Griffith's Creek with the former river.

When starting from Hokitika, I was informed that the river, taking its rise on the western side of Browning's Pass, was the Taipo, by which name it was also designated by the discoverers of the Pass, but even then I was already under the impression that it would turn out to be the Arahura, and now, standing on its banks, I was quite certain I was right in my surmises. I had the opportunity of taking several bearings towards the head-waters of the Arahura on my various journeys, and from them I concluded that this river had its sources more towards south-east than the maps in my possession indicated and that it overlapped the sources of the northern branch of the

Kokatahi (Styx). From the banks of the Arahura, near the junction of the Kawhaka, I could observe that this river, after having passed the Lake Kanieri ranges, enters into a gorge amongst high mountains, where, without doubt, its course is deflected towards east-north-east, and then, turning at a sharp angle, will ultimately have a nearly northerly course. Had I not been so much pressed for time, I should certainly have devoted a few days to determining this fact, by following the river in question far enough to convince myself of its ultimate course. However, although my conclusions were much opposed at the time, further explorations have shown that my deductions were correct and that it is not the Taipo, but the Arahura, the principal sources of which are situated on Browning's Pass.

Having followed for a few hundred yards along the banks of the river, clothed with grass, we had again to take to the mountain side, covered with such a dense vegetation, that travelling became slow and laborious. We passed several mountain torrents coming from Mount Sale, mostly in deep rocky defiles, forming a succession of cascades. Some of them were filled with avalanches, over which we had to find our way. After three hours of this laborious work we arrived at a larger mountain torrent, falling over a succession of often vertical cliffs, but then nearly filled with a large avalanche, where, owing to the great steepness of the talus of snow, and the smooth surface of the highly inclined rocky banks, we experienced some difficulty in bringing the men over. This the miner, who had previously been over the ground, pointed out to me as the Harman stream; and, as I expressed some doubts, he assured me of the correctness of his statement, by telling me that, before crossing the Pass, Mr. Greenlaw had kindly furnished them with a tracing of the road, and this was the most important river all the way they had crossed. Advancing more up the main valley, the vegetation now became more stunted and gnarled, and consequently our progress was still slower. Towards evening we arrived at the *roches moutonnées*, partly covered by old moraines which stretch below the junction of the Harman with the Arahura, across the valley. The rain, which had lasted without interruption the whole day, did not cease during the night. Fortunately there were many shrubs of *Dracophyllum longifolium* growing in this locality, which even in their green state burn freely, and which enable the traveller in those regions, so much exposed to rain, to light a fire with comparative ease. This plant has needle-shaped leaves, generally of a brownish tint, and small bell-shaped white flowers. It is generally called a native heath by the Europeans. As some of the bushes grow to a height of ten feet with thick branches, it offers wood enough to keep up a cheerful fire.

Next morning we started again in a pouring rain After having crossed the highest point of the *roches moutonnées*, about 400 feet above the river, we had another piece of sub-alpine vegetation to cross, the density of which defies description. Working our way for half a mile through this thicket we arrived at an enormous avalanche coming from near the summit of Mount Sale and lying in a regular channel. This avalanche had been much larger, as was well shown when we descended it to the bed of the Arahura, just below the junction of the Harman stream, where in some places it formed a nearly perpendicular wall thirty to forty feet high. It was thus evident that shortly before, it had here filled the whole valleys of the Arahura and Harman to a great altitude, the gorges in which these rivers flow being then hidden altogether. That this channel, several hundred yards broad, is usually filled by avalanches, which fall repeatedly, was not only indicated by the configuration of the mountain side, but we were witnesses of another huge avalanche falling the next morning, when camped on the opposite side of the river, the thunder occasioned by it reverberating in the mountains. Guided by the miner, we followed, for a short distance the course of the Harman, climbing along the nearly perpendicular banks, through the close-growing vegetation, till he told me, looking at the large swollen torrent below us, that he did not recognise the country; but as I knew that our road must lead across that stream, I ordered the party at once to descend. On reaching the rocky banks of the river, now swollen and rushing with impetuosity amongst and over high rocks, the guide thought that he must be wrong, because when he and his companions passed here four weeks previously, they crossed no other water-course than the one we had passed the day before, and had seen no deep gorge like this; on the contrary, the whole country had been here covered with one uniform sheet of snow, on which they had walked across from Mr. Browning's flag-staff to the place we had left in the morning. It was thus clear that the whole deep gorge had been, for about 150 feet, filled up with snow, which had entirely obliterated the configuration of the country; and in looking up the river, in some places, remains of this huge avalanche were still visible in the form of snow bridges amongst the rocks. And the conviction forced itself upon me that a road, laid out in the way proposed by Mr. Browning, namely, to cross the Harman in this neighbourhood, and to ascend the avalanche channel, would not only be destroyed by the fall of the avalanches, but be of no use whatever for several months in the year, besides endangering the lives of the passengers travelling that way. I therefore made it a rule to note carefully all the different avalanche channels, to be able to point out where danger might be expected, and, if possible, to avoid it altogether in laying out the road.

Fortunately for my purpose I travelled along this route during the time of the year when these physical features are most clearly defined, and I may be excused if, for that reason, I enter into this topic, which has no direct reference to the object of my journey. As before observed, the Harman from the continuous rain was very high, and we were only able to cross it with the assistance of a rope we had brought with us. We ascended on the other side and camped upon a small grassy flat close to one of Mr. Browning's poles. Incessant rain continued during the whole of the day and the early part of the night, changing towards morning into snow, but which fortunately was followed by a fine bright day. Our blankets, provisions, and nearly everything else being thoroughly saturated, we were occupied for the greater part of the morning drying them, and it was only towards noon we were able to proceed on our journey. For a short time we had to travel through sub-alpine vegetation, but soon the gorge opened, and though the Taipo was still high, we were enabled to ascend along its banks, crossing from side to side, and travelling on a shingle reach. Half a mile higher up the valley widened still more, grass and alpine herbaceous plants made their appearance, and we advanced rapidly towards the Pass. Shortly after leaving our camp we passed the remains of several large avalanches, still partly over-bridging the river, whilst in other instances they were cut through by the river, forming on both sides perpendicular walls of snow. For about a mile or a mile and a half above the junction with the Harman, the adjoining mountains possess such physical features, that the fall of avalanches from the western slopes of Mount Harman is prevented, whilst several steep water or avalanche channels descend from the opposite side of the Twin Peaks range. The remains of these avalanches indicated clearly that in many places the river-bed for a considerable time of the year is concealed by them. This supposition was confirmed by my companion, who had travelled a month before the same road, and who assured me that for a great distance they had been obliged to scramble over the snow. After having ascended this distance, deep gorges from

Mount Harman begin to reach the main river, in which everywhere huge avalanches were still lying. Some of them were of such enormous dimensions, that their remains will last till late in the summer. The opposite side of Twin Peaks range, showing a somewhat terraced appearance, was here more free from them, and will therefore offer better travelling ground. As the guide assured me that it was too late to cross the Pass that day, although it was only half-past one o'clock, we remained camped on this good sized flat, covered with blocks of stone, grass, and alpine plants, of which the magnificent *Ranunculus Lyallii* had just began to bud. We camped under a huge erratic block, and although only about 3200 feet above the level of the sea, snow was still lying deeply in most localities over this flat. Opposite our camp, an avalanche was not only filling the deep gorge in which it had descended, but it had invaded the main valley, and the river for some distance had disappeared under it. The clouds were lying low on the ranges, when next morning, October 31st, we prepared ourselves to cross the Pass. A number of Keas (the green mountain parrot), flying past our camp or sitting on the rocky ledges above, broke the stillness of nature with their plaintive notes. From our camp to the junction of the outlet of Lake Browning with the Twin Peaks creek, about half a mile, the right bank was covered with a succession of avalanches, under which the river was concealed in many places, whilst the lower part of the mountains on the left side of the valley was mostly free from snow, till at last, about 300 to 400 yards below that junction, the water had entirely disappeared, and valleys and hill-sides formed one continuous mass of snow from which rocky points rose here and there. The whole country presented to the guide such a different aspect, that when we arrived at that junction, instead of crossing over to the right bank, and following along the outlet of Lake Browning to the summit of the Pass, he took the valley of Twin Peaks Creek, at the same time assuring me that he did not at all recognise the country. The fine weather had unfortunately ceased, and dense mist enveloped us, so that we could not see 20 yards before us. He led us up a valley, which exhibits in its natural state a deep rocky gorge, but which now was so entirely filled with snow that it had rather the appearance of a wide open mountain valley slightly covered with snow. The snow being soft, we toiled forward here for two hours, sinking often up to our waists in it; and although the guide assured me that this was the right road, the compass and the direction he had taken convinced me that he was going astray. The clouds became every moment denser, so that we could scarcely see a few paces before us; so at last, observing to our left that the mountains assumed soft downlike outlines, I refused to follow him any longer, and taking the lead, struck off towards the east. I soon had the pleasure of seeing the clouds becoming thinner, and of observing the mountains on the left side of the Wilberforce, with their brown vegetation, appear before me, and presently the valley itself with the Government camp came in sight far below us. The guide was leading us up the Twin Peaks, and the ground I had reached was that lying west of Lake Browning and some 600 feet above it. From the form of the basin in which Lake Browning lies, I could conclude that here the lake ought to be situated, although the enormous snow masses which were here accumulated obliterated all signs of it. After having crossed this snow plateau, we arrived at the Gap, where we had to descend. Here a wall of snow and ice, not only vertical but even overhanging, from 12 to 20 feet high, formed by snow drifts, had to be descended before we could reach the snowfields below it, for at least 200 to 300 feet, so steep that they could only be descended by cutting steps.

Having brought a rope and spade with us, we at once set to work cutting a channel back through this vertical wall until we reached the steep snow slope, and tying the first man who was working with the spade to the rope, and following him upon the stair-like steps, keeping the rope always tight, we descended slowly this steep upper part of the snowfields. Shortly after we had begun to cut through this perpendicular wall, which owing to its soft state did not offer any difficulty, we observed a large white flag hoisted up at Mr. Greenlaw's camp, and soon after we observed this gentleman with some of his men carrying spades, coming to our assistance, they appeared like tiny moving spots on the lower part of the snowfield. We were soon sitting on the snow, sliding down in a few minutes to the foot of the field about 1200 feet from the summit, where we were surrounded by shrubs and herbs in blossom, and breathing the soft spring air of the East Coast. A few rocks on the summit of the Pass rising above the snowfields, showed me, by the vegetation growing upon them, that we were in a truly alpine region ; plants like the alpine spear grass *Aciphylla Monroi*, the *Veronica epacridea*, found near the summit of Mount Torlesse, could here be collected. The gorge-like character of all the valleys, and the atmospheric conditions prevailing here account easily for the enormous amount of snow which accumulates near this depression, so as not only to cover deeply all the summits, but also to collect in such masses on the declivities, as to give birth to such numerous and large avalanches as were passed by me. And I may here add that many of them even in the highest Alps of Switzerland would be considered enormous. A few days before my arrival at Mr. Greenlaw's camp, one of his men was nearly killed by one of them coming from the summit of the Pass, and whilst we ascended the Twin Peaks Gorge, an avalanche fell from the western side, five minutes after we had passed the very spot.

After a short walk from the foot of the Pass we reached Camp Creek, where Mr. Greenlaw's camp, consisting of a well built blockhouse, was situated, and where we were most hospitably received. Mr. Greenlaw was in charge of the road party, which at the beginning of spring had been sent up to form a bridle-path over the Pass, but owing to the enormous accumulation of snow, he had not yet been able to do any work on the slopes of the mountain. In the meantime, a good bridle-track had been formed along the rocky banks of the Upper Wilberforce, which here is simply a mountain torrent. Although it was evident that it would take some considerable time before such a track over the Pass could be formed, owing to its great altitude and steep rocky nature, several of the sheep farmers on the Canterbury plains did not apparently think so, as we met several flocks of sheep, on our return journey, being already driven up, to be crossed over to the West Coast. Of course they had to return and wait for another season.

The difference of vegetation in such a short distance, and with such a slight difference in altitude—Mr. Greenlaw's camp being situated 3017 feet above the sea level, or 341 feet below the foot of the Pass—was most conspicuous. When I stood on the top of the Pass and looked down the valley of the Wilberforce, it being a dull day with an overcast sky, the whole vegetation assumed sombre brownish colours. Towards the evening the weather cleared up, the sun shone brightly, and the beautifully variegated tints of the sub-alpine vegetation displayed themselves in quite a different aspect, and appeared in all their splendour. There were some very large groves of *nene* (*Dracophyllum traversii*), surrounded by a great number of good sized shrubs of *Dracophyllum latifolium*, conspicuous from their brownish green tints, but they only brought out more vividly the richness of colour and form of the other foliage surrounding us. I think I have already observed that this remarkable tree-like *Dracophyllum* (*nene*) grows only near or on the alpine passes, where the moisture during the whole year is excessive. Next morning the party of roadmen, who had accompanied me, returned over the Pass, whilst in order to make another series of meteorological observations I remained another day at the camp; in the afternoon ascending Camp Creek for geological examination and for collecting plants. The rich alpine flora was already well advanced, many of the shrubs being covered with blossoms and flowers, and the whole air perfumed by their delicious scent. For about two miles Camp Creek has a nearly straight course, and forms a fine alpine valley; it then breaks up into a number of mountain torrents and cascades, many of them descending from Mount Greenlaw, a rugged mountain mass, closing the valley. In its lower portion it is covered with a luxuriant alpine vegetation, above which snowfields of considerable magnitude encircle its sides, whilst they in their turn are surmounted by nearly perpendicular rocky crags, several thousand feet high, only here and there allowing the snow to collect in smaller masses along the serrated summit.

On November 2nd we started on our return journey, although a heavy north-west storm raged with great fury. For about four miles the valley falls rapidly, numerous moraines crossing from side to side. In many of the smaller valleys or *couleés* on both sides, large avalanches were still lying. After crossing the Stewart branch near its junction, we continued our journey on a finely grassed flat, having the Waterfall range, exhibiting wild romantic forms, on our right hand, which well deseves that name, particularly during wet weather in spring. Three miles from Major Scott's station, we crossed the Wilberforce, and ascending the terraced banks continued our road through the longitudinal opening formed by the large isolated *roches moutonnées*, the Scott's Hills, which from here to the junction of the Harper with the Wilberforce, run along the left bank of the latter and the main range. The whole country showed clearly that it had undergone great glaciation; on the slopes of the main range as well as on the Scott's Hills, the effects of that glaciation wss well exhibited in numerous rock shelves, erratic blocks and remains of ancient moraines, although a number of huge alluvial fans or shingle cones, reaching sometimes far up the sides of the *roches moutonnées*, partly concealed these signs of the Great ice age. Towards evening, thoroughly drenched, we reached Major Scott's station, under whose hospitable roof, it took us some time to recover from the effects of the terrible storm which had chilled us so much that we could scarcely descend from the horses. During the whole night, the storm continued to rage without intermission and with unabated vigour, but in the course of next morning, the weather cleared up and became truly magnificent. However, the River Harper (a large tributary of the Wilberforce) which had to be passed on our road, was so much swollen that it was impossible to cross it that day.

The view from Major Scott's station is really very striking. First, Lake Coleridge lying like a deep blue mirror amongst the curiously shaped ranges, formed the centre of the landscape. A number of high hills, which from their remarkably regular form, have aptly been designated Sugarloaves by the settlers, appear in several directions; they mostly rise to the north of the great depression in which Lake Coleridge is situated. Before visiting this part of the country, I had often heard of these Sugarloaves, which were described to me as extinct volcanoes, their usual conical shape having suggested such an explanation; but when crossing this region, it soon became evident to me that these striking forms were simply the result of the enormous glaciation the country had undergone, and that these so-called Sugarloaves were simply *roches moutonnées* standing in the bed of several large glacier branches, of which the great Rakaia glacier had here been formed. The River Harper having fallen sufficiently, next morning, to be crossed without danger, we started on our home journey, being piloted across its still high and muddy waters by Major Scott. We now followed the longitudinal depression running to the north of Lake Coleridge and parallel to it, of which the level is about three hundred feet above the latter. With every step, the effects of the enormous glaciation become more manifest, all mountains and hills have not only the *roche moutonnée* form, but glacier shelves at different altitudes and lying one above the other, are cut deeply into the hill-sides. Some of these are so regular that the settlers have called them carriage roads, devil's highways, or by some similar epithets. Having passed several lagoons, either formed by old morainic accumulations, stretching across the valley, or by large shingle cones, we reached Lake Selfe (1962 feet), a charming spot, surrounded by small groves of *Fagus* forest and picturesque rocks. Several pretty waterfalls give animation to the peaceful scenery. Before a large valley crossing the longitudinal opening at right angles is reached, a succession of lagoons follows, entering Lake Coleridge six miles above its outlet. Here we camped for the night.

Next morning, November 5th, we again ascended to the same longitudinal valley, and, after passing a succession of lagoons and ponds, reached at last the upper end of Lake Coleridge. Crossing the small ice-worn ridge, by which its shores are here formed, we entered the large Rakaia valley, where the glacial phenomena became more simple but of a still grander character. Before reaching the Hon. John Hall's station, we at last crossed the remnants of the lowest moraine wall, of which traces have been preserved, stretching from the eastern foot of Mount Hutt to the Hororata river, and forming a large semicircle with a radius of eight miles. On November 10th we reached town again, and, after calculating the principal altitudes along the whole route, from the numerous meteorological observations made by me, as well as from corresponding ones taken in Christchurch and Hokitika, I presented on November 18th my report on that journey to the Provincial Government, giving also an analysis of the altitudes obtained, a description of the principal features of the country examined, and my views as to the value of the two passes. This Report* was laid before the Provincial Council on October 18th, and printed in Vol. XXIV. of the Journals of the Proceedings of the Provincial Council. Another report† was furnished by me in December to the Secretary for Public Works, on the West Coast goldfields, principally in reference to that portion which might be used for agricultural and pastoral purposes. The latter was laid before the Provincial Council on December 19th, 1865, and printed in the same volume. The great floods in the rivers of the Canterbury plains at Christmas, 1865, during which a portion of the Waimakariri flood-waters entered the Avon, gave rise to several visits to that river, for the purpose of examining its bed and the ancient channels on the lower fan, and, although no written report was furnished, I was repeatedly consulted on the subject by the Provincial Government. A Board of Conservators was instituted, under whose superintendence such well-devised works, for the protection of the lower plains, were executed, that since then, no serious overflow has taken place.

First Visit to Middle Waipara—1866.

Before starting again for a longer journey into the Southern Alps, I wished to examine the interesting region of the Middle Waipara, where, for some years past, Saurian bones and skeletons had been

---

* Tables of Altitude from Christchurch to Hokitika, by Arthur's and Browning's Pass, with notes and observations on the physical features of Browning's Pass. By the Provincial Geologist.

† Report of the Provincial Geologist in continuation of Correspondence relative to the disposal of Waste Land within the Goldfields on the West Coast.

found, as I was not only anxious to make a collection of these interesting fossils, but I hoped also to be able to fix the horizon in which they were embedded. On January 23rd (1866), I started for this region, where I remained for several days occupied in making a geological investigation of this highly important zone, although the weather remained unsettled, and we had some trouble with the rivers, which continued te be high and scarcely fordable. In the geological portion of this Report some details will be found on this district, of which it can truly be said that it offers us the key to unravel the relations in which our young secondary and old tertiary beds stand to each other.

Journey to the Head-waters of the Rakaia—1866.

I now prepared myself for a longer journey into the Southern Alps selecting the head-waters of the Rakaia for this year's campaign. Starting on March the 2nd, and returning on the 18th of April, all the principal source-branches of that river were examined, and the weather was so fine, that during nearly seven weeks of exploration, there were only two days in which I could not pursue my regular work in the field.

After having crossed the Acheron and ascended the alluvial terraces deposited upon morainic and lacustrine deposits, we arrived at the moraines lying across the eastern end of Lake Coleridge, a true lake basin, of the formation and physical features of which I shall speak in the sequel. The newly made road to Browning's Pass led across these moraines and along the hills on the southern side of Lake Coleridge, where well-defined glacier shelves give evidence that here—about 2000 feet above the present bed of the Rakaia—the whole valley was filled with enormous ice-masses, which terminated only on the Canterbury plains, six miles below the gorge; extending in a semicircle from the eastern base of Mount Hutt to the Malvern Hills. At some spots fifteen of these glacier shelves were visible, one above the other, with a fall of from 10 to 12 degrees towards the east.

Instead of following the new road to the ferry, near Goat Hill, I descended about 450 feet by the dray-road, which leads to the stations of Messrs. Palmer and Neave, on the banks of the Rakaia proper. The Wilberforce, which we had to cross near its junction with the Rakaia, was a little swollen from a previous north-west storm, but being here divided into several branches we forded it easily on horseback. Having decided to ascend, first, the principal branch of the Rakaia, of which the original name has been preserved, I followed the track leading from Mr. Neave's home station along the base of Mount Algidas to the Mathias branch.

Magnificent weather had set in, and the rivers fell very low, so that the crossing of the Mathias could easily be accomplished, even on foot. *Fagus Solandri*, the white birch of the settlers, hitherto the prevailing tree, now begins to occur more in groves, and sub-alpine shrubs and trees, belonging principally to the *Compositæ*, *Scrophularineæ*, *Rubiaceæ*, *Ericeæ*, *and Coniferæ*, are mixed with that handsome sub-alpine tree, giving to the landscape a park-like appearance, the effect of its fine shape and foliage being heightened by the various tints, from pale greyish green to dark brown, by which it is surrounded. This lower vegetation is succeeded by alpine meadows studded with flowers, over which the rugged weather-beaten rocks, forming gigantic peaks, rise in wild majesty. Before us the grand Arrowsmith range rose every moment more and more conspicuously, forming the background of the valley with its splendid peaks and needles.

Seven miles above the junction of the Mathias the river sets against its northern banks, which are covered with dense vegetation, and rise nearly perpendicularly above the water for a considerable altitude. It was therefore necessary to cross to the other side, and although the river was low, it was not a pleasant task, owing to its rapid fall and the large boulders in its bed. Our road lay now on the southern side across a grassy flat, mostly overgrown with the same dense vegetation met with on the banks of all our river-flats, namely, the spiny Wild-Irishman, and the bayonet-like Spaniard (*Aciphylla Lyallii*). We crossed some considerable water-courses, mostly from glaciers of second order, which here entered the valley from the Arrowsmith range.

Arrived at the point which projects farthest into the river-bed from that range, a very remarkable view opens before the traveller. The valley, still more than a mile wide, stretches for six miles towards the west, and is entirely covered by alluvial accumulations, often consisting of large blocks, over which the river, frequently divided into several branches, rushes with fury. The aspect of such a valley is bleak and cold in the extreme, for at a few miles distance it is not possible to distinguish the turbid water of the meandering river from its banks, and the whole forms one dark grey mass, ascending towards the head of the valley. There, instead of finding as usual, a large glacier filling the whole valley, I observed a true *roche moutonnée*, reaching halfway across from the southern side, whilst from the northern and opposite to it, a glacier of considerable dimensions crosses the remaining portion of the valley, abutting apparently against the almost vertical northern side of this rounded hill. But I may observe that west of this *roche moutonnée* there is another valley, and that between the glacier and the hill a torrent rushes down, washing the southern flanks of the former, and thus prevents it from abutting directly against the hill. High snowy ranges, in fantastic forms, rose above, but owing to their distance and the considerable width of the valley, they did not impress the mind with their truly gigantic dimensions, with which I became subsequently better acquainted.

The course of the river compelled us again to cross to the northern side, and, although I selected the best ford, the boulders were so large, and the rush of the water was so strong, that the horses could with difficulty stand against it. We camped on the evening of the 13th of March about a mile below the junction of the Whitcombe Pass stream, at the edge of the sub-alpine forest, where small grass flats offered feed for the horses, and where at the foot of an avalanche channel, formed last winter, a great quantity of firewood was easily procured without the trouble of cutting it.

On Wednesday, March 14, I started at daybreak, accompanied by one of my men, to ascend Whitcombe Pass. The Pass stream contains a good deal of water where it enters the valley of the Rakaia on a large fan, but loses itself by degrees in the shingle before reaching the main river, so that we crossed it dry-footed, following along the edge of the main river to its right hand bank. From here the remarkable opening through the Southern Alps is clearly defined, with the peak of Mount Whitcombe on its western side, raising its bold snow-covered summit above the lower ranges in front. After a mile we had to cross a torrent descending from a glacier of the second order, hanging on to the mountain side like a gigantic icicle. Here we had the first view of the saddle, apparently situated only a few hundred feet above us, and from this point of observation, appearing to consist of a shingle wall, not more than 100 feet high.

Owing to the aspect of the valley, and to its being accessible to more moisture from the west than other similar ones in the Alps, which are protected by lofty ranges in front, many shrubs and annual and perennial herbaceous plants, already in seed in other localities, were here still in full bloom, and I was able to collect many interesting specimens, of which several proved new to science. After half a mile of slow and tiresome travelling through vegetation so dense, that it often allowed us literally to walk on the top of the branches, we descended again to the river-bed, and an equal distance of climbing over huge boulders brought us to the shingle wall stretching across the valley, and along which the river flows on the eastern side, issuing from the central chain near the summit of the Pass. Even alpine shrubs disappear here, and ascending the saddle, a close grown carpet-like turf is found to cover the hill sides, except where shingle slips or rocks occur. This turf, notwithstanding the lateness of the season, was studded with innumerable flowers, mostly belonging to the orders *Ranunculaceæ*, *Compositæ*, and *Umbelliferæ*. Among them, a magnificent large *Ranunculus*, with yellow blossoms, was conspicuous; since described by Hooker as *R. Godleyanus*. A further ascent of about 40 feet over enormous blocks of rocks lying in a narrow channel, formed by two taluses of debris, brought us on to the summit of the Pass. The barometer at one o'clock read 25·94, thermometer 54·2 deg. It was a magnificent day, only a few *Cirrocumuli* rose in the north, disappearing soon amongst the wooded ranges forming the horizon towards the West Coast.

A considerable sized torrent descends on the western side of the Pass into a shingle valley, it is nearly straight for about eight miles, with occasional grassy flats on its banks. On both sides the mountain chain rose majestically above the valley, mostly covered with snow-fields, from which numerous glaciers descend, their outlets swelling the body of this, the most important of the sources of the Hokitika river. The contrast is very striking between these rugged alpine ranges and the quiet outlines of the West Coast mountains, 4000 to 5000 feet high, heavily timbered to their summits, which bounded the horizon, and through which the river forces its way in a succession of deep gorges. The stupendous mass of Mount Whitcombe rises here so steeply above the Pass, that only very little snow can cling to its sides, making it appear still higher and wilder. The reading of the barometer at that time in Hokitika, as I afterwards ascertained, differed only from that at Christchurch by 0·01 inch, and a double set of observations gave me, as mean result for the summit of the Pass, 4312 feet above the sea level. On skirting the wall of debris on the western side of the Pass, I came, after having descended about 30 feet, to the terminal face of a glacier, of considerable dimensions, descending from the north-eastern flanks of Mount Whitcombe, and filling a deep cauldron-like valley. When examining the other alpine Passes of the Province, I observed that invariably a glacier descended on each side, going in opposite directions; and although on the ranges above some of them, true glaciers lie, which are now several thousand feet above the watershed, the glacier shelves and remains of lateral moraines, with which the surrounding mountain sides are covered, show at once that much larger glaciers existed formerly in those localities. These extensive ice-masses have, without doubt, planed the central range on both slopes in opposite directions, till the ridge has been worn down to its present form. Here, on the Whitcombe Pass, this instructive phenomenon is still visible, as the Sale glacier reaches now across the valley, and if the Martius glacier would only advance a few hundred yards, the moraines of both, and perhaps even the ice-masses would meet on the summit of the Pass, although descending in different directions. Thus we observe how nature, to accomplish gigantic ends, uses very simple, but effectual means. In fact, no more simple method could be devised to grind down part of an inaccessible mountain chain than these ice-ploughs, or perhaps, better styled ice-planes, working in opposite directions, which thus open a passage through an otherwise impassable barrier, and allow commerce and civilization to unite the shores of this rich and beautiful island.

I spent the next day in arranging my collection and notes, and the following being wet, I was only able to continue my researches on the 17th March, when I started on horseback to visit the glacier stretching across the valley. It was a beautiful day, the atmosphere clear and pure after the rain, and the aroma of the white flowering *Carmichælia odorata* and the splendid *Senecio cassinioides* was so strong that the whole air was filled by it; the latter was, in many localities, so thickly covered with yellow blossoms that scarcely any leaves could be detected. We were able to ride to within 300 yards of the glacial cave, but then the raging torrent issuing from it set against the rocky banks, so that it was impossible to proceed any further. I therefore ascended the mountain side, formed by ice-worn rocks, and soon stood in front of this remarkable glacier, over which the wild stupendous mountains rose in sublimity and grandeur. I shall leave its description to another portion of my narrative, when giving an account of my ascent of Mein Knob, the remarkable *roche moutonnée* lying between the two glaciers. The glacier itself is near its terminal face, 150 feet high, entirely covered with debris. Its principal outlet flows from an ice cavern close to the mountain side. Large stones were continually falling down from the summit of the ice into the foaming waters below.

My next object being to try if I could not pass along the southern base of the glacier, we led our horses along the present bed of the river, consisting often of very large blocks of rock, in search of a ford, but had to return nearly a mile before I could find a spot where the horses were able to plunge through the swift and muddy water rushing over the large rocks, which offered very bad footing. Arrived at the southern terminal face of the glacier, I observed here also several minor streams issuing from below the ice, which rose in a nearly perpendicular wall, washed by another glacier torrent of considerable size. This latter was confined, on the other side, by the rocky walls of Mein Knob, forming a narrow gorge. I tried in vain to pass along, but, partly owing to the slippery nature of the ice against which the turbulent waters were flowing, partly to the huge blocks of rock falling from the top of the glacier, and the almost continuous shower of smaller debris, I had to give up the attempt to reach the upper part of the valley by skirting this, which I have named the Ramsay glacier. Two barometric observations taken at its terminal face give its altitude, above the sea level, 3354 feet. This glacier is, therefore, next to those at the head of the Pukaki system, the lowest on the eastern side of the central range of this Province.

The magnificent weather continued to favour us, and when I started next day, March the 18th, to reach, if possible, the upper part of the valley by ascending and crossing Mein Knob, no cloud was visible on the deep azure sky, and the atmosphere was so clear that every detail on the slopes of the snow covered giants around was distinctly visible. Fording the river not without some trouble, we reached the foot of Mein's Knob, on the opposite side of the valley and ascended its northern slopes, opposite the terminal face of the Ramsay glacier, and which consist in their lower portion of a great talus of loose debris, near the summit of steep, rocky cliffs, over which we climbed. Approaching the summit, the rocks disappear under a densely grown grass-like carpet of alpine vegetation, studded with flowers, but in many places of a very treacherous nature. The approaches to the summit are formed by gigantic blocks, with the interstices between them grown over, so that when walking, the foot often breaks through the covering of plants. The summit is about half a mile broad, and covered by a succession of bosses, amongst which, at different elevations, lie several small lagoons. The view from here is magnificent in the extreme, and can fairly rival that in any part of our Southern Alps. To the west a large valley opens, about three quarters of a mile broad, in which a glacier of considerable dimensions is situated. This glacier, which I named the Lyell glacier, reaching nearly to the western base of the hill on which I was standing, is entirely covered in its lower portion with debris, but higher up it shows its structure in many seracs, exhibiting peculiar green and bluish hues. Round the glacier rose peak upon peak, sending down their ice streams. Amongst them the rocky pyramid of Mount Tyndall was conspicuous, enveloped in vast snow-fields.

Although the view towards west was so magnificent, that towards north could equally claim my admiration. A high dome-shaped mountain, covered with snow and ice, which I named Mount Kinkel, lies between the two glaciers, separated from my station by a deep gorge, in which the outlet of the Lyell rushes down against the Ramsay glacier. Another majestic mountain range lies between Mount Kinkel and Mount Whitcombe, which I named Mount Ramsay. It is impossible to convey in words an adequate idea of the rugged character of this mountain and its eastern neighbour Mount Whitcombe; turrets, pinnacles, and minarets rise all along the serrated edges, and the rocky face is, in most instances, so steep that no snow can lie upon it. Mount Whitcombe, which when seen from the Pass, appears like a rocky pyramid, extends considerably in breadth, its outlines rugged in the extreme, can scarcely be surpassed by any other mountain. For several hours I was occupied taking the necessary bearings, and making a sketch of the glorious scenery before me, a copy of which was added with some others to my Report on that journey, published by the Provincial Government* and from which I am quoting largely. It was only towards evening that I reluctantly turned away from this panorama, which for diversity of scenery and its wild alpine character, is second to none in New Zealand.

* Report on the Head-waters of the River Rakaia, with Twenty Illustrations and Two Appendices. By JULIUS HAAST, Ph.D., F.G.S., Etc., Provincial Geologist. 1866.

On Tuesday, March the 20th, we retraced our steps, and at noon on the following day camped on the right hand bank of the Mathias, near its junction. When rounding the spur of the Arrowsmith range, the contrast, looking east and west, is very striking between the rugged character of the Alps and the singularly-rounded outlines of the eastern ranges. In the foreground and centre of the valley stands the characteristic Double Hill; above it appear the sugarloaf-shaped hills which surround Lake Coleridge, and over all, the long flat Thirteen-mile bush range bounds the horizon. Having observed shortly before, at the Francis Joseph glacier, on the western side of our Alps, how ice perceptibly rounds and moulds the rocks in its way, not much imagination was required to fill again the whole valley with a sea of ice, planing and furrowing those hills on a more gigantic scale. I may here observe that 1500 feet above Mein Knob, which, according to my calculation, lies 4437 feet above the sea, or 1083 feet above the terminal face of the Ramsay glacier, numerous glacier shelves and lateral moraines occur on the southern side of the mountain, which slope down so regularly towards the east that I could take their angle, which I found to be about 4 degrees on an average. Thus it appears that the valley was here filled with ice at an altitude of nearly 6000 feet above the sea, and yet this was certainly not during the greatest extension of the post-pliocene glaciers, judging from other phenomena observed everywhere in still higher regions.

I started on Thursday, March 22nd, to examine the sources of the Mathias, the most important tributary of the Rakaia above the junction of the Wilberforce. Six miles from the junction of the Mathias with the main river its hitherto broad shingle-bed narrows considerably, and a moraine, 40 feet high, crosses the valley, through which the river has broken a passage, exposing on the eastern side, its peculiar structure. Thus the same phenomenon which I had observed during previous explorations in some of the smaller tributaries of the Waitaki and Rangitata occurs also here, pointing either to a temporary halt of the retreating glaciers or to an advance of the present ones since the Great ice period. The natural features of the country under consideration would, in many instances, at least point towards the adoption of the latter hypothesis. Behind this moraine the valley widens again considerably, as in other rivers under similar conditions, and is filled with a large shingle flat from side to side. *Fagus* forest, which hitherto had prevailed on the lower side of the valley, ceases here, where the river-bed attains an altitude of 2400 feet, and dense sub-alpine vegetation, with its various tinted foliage, clothes the mountain side. For two miles more we kept along the eastern side of the valley, travelling mostly on the slopes of huge shingle-fans, and camped under the shelter of a dense group of *Phyllocladus alpinus* and *Dracophyllum longifolium*, the north-west winds blowing down the valley with great fury.

Next morning we started with the dawn, hoping to reach, if possible, the head of the valley. Four miles from our camp the valley assumes all the characteristics of a gorge, in which the river leaps incessantly over huge blocks. After another mile of perpetual climbing over such boulders and along taluses of debris, the valley received an important addition from the west, containing nearly as much water as the main river above. This torrent, which we had to cross near its junction, flows in a deep narrow gorge, having the appearance of a deep cleft, which has rent the chain from top to bottom. The higher we ascended, the more the valley narrowed and assumed a rugged appearance ; at the same time, the vegetation became strictly alpine, and many of the plants were still in full bloom, filling the air with a delicious fragrance. A mile below the glacier a large avalanche lay across the river-bed, forming a snow bridge from side to side, through which the water had formed a tunnel. Two very prominent peaks rose conspicuously above us, of which the south-westerly one, Mount Tancred, sends a glacier down to the valley ; its terminal face I ascertained to be 3788 feet above the sea. Another majestic peak, Mount Carus, lies in a north-easterly direction behind the former, but owing to the great steepness of its sides the snowfields on it are of much smaller dimensions. Another glacier descends from the ridge connecting the two peaks in a deep gorge, and terminates a quarter of a mile above the glacier previously described. Returning on the 24th of March to the junction of the Mathias, I devoted two days to the examination of the slopes of the Mount Rolleston and Mount Algidas ranges, and in preserving and putting in order my collections. I arrived on the 27th March at Goat Hill accommodation house, where I had my horses shod, and deposited the collections, which had already augmented so considerably that they formed quite a load for one horse.

We started on Wednesday, the 28th of March, up the Wilberforce, and kept along the western base of Goat Hill, on the large alluvial deposits brought down by the Boulder stream and Kakapo creek. Before reaching the junction of the Kakapo I observed the remains of a large moraine, crossing the valley and cropping out of the lower portion of the shingle-fan of that creek. Having crossed these morainic accumulations, the present shingle-bed of the river widens considerably, and the road leads over grassy flats to the bed of Moa creek, the most important tributary below the Cascade range. Magnificent *Fagus* forest clothes the lower sides of the mountains which, in the Cascade range, rise to a great height and are exceedingly ice-worn, whilst numerous water-falls, from whence the range derives its name, appear like so many silver ribbons on the bare rocks, and give a great charm to this part of the road. We camped on a large flat on the northern banks of the Stewart, enclosed on both sides by the shingle brought down by two tributaries, with some lower ground at the base of the mountains, where a chain of deep lagoons is situated. For nearly two miles the valley is more than a mile broad, and in this distance it is joined by three important branches, all coming from true glaciers of the central chain.

I started on the morning of Thursday, March the 29th, to follow the main branch. One mile above the junction of the western branch the valley turns towards south-west, and the hills on the right hand bank of the stream become remarkably low, and consist of stratified alluvium, as seen in a large slip of 200 feet high, reaching to within 100 feet of the summit of the ridge. Two miles above the turn, the Stewart—the bed of which had narrowed considerably and become exceedingly rough, the turbid waters falling very rapidly over large blocks—has a west and east direction, and another small tributary joins it from the south. A quarter of a mile of laborious walking brought us to a glacier nearly 200 yards broad, descending into two branches from a high dome-shaped mountain, which I named Mount Collet; its terminal face is 3584 feet above the sea. Enormous avalanches had fallen from the ranges on both sides near the terminal face, and covered it for a considerable distance with its masses, so as almost entirely to conceal the glacier.

The following evening we reached the so-called Greenlaw's hut, situated a mile below the southern foot of Browning's Pass, having followed the stock-road along the western bank of the Wilberforce, which offered fair travelling ground, except at a few spots where it was destroyed at the crossings of alpine torrents by heavy freshets. We started early on the following day to ascend the Pass, as I wished to get another set of observations, and to examine the geological features of the ranges. When I passed here, about the end of the preceding October, on my return from the West Coast, all the ranges were covered with a uniform sheet of snow; and I was therefore doubly interested to see this portion of our Alps in autumn, when they are most free from it. The southern face of the Pass was, with the exception of a large snow-hole in the Gap and a few minor ones in shady spots, entirely free from snow, but large snow-fields appeared on the slopes of the surrounding mountains flanking it. From the southern one, the Twin Peaks, the small Hall glacier descends; the outlet of which, after a few hundred yards rapid descent, precipitates itself over the vertical cliffs in a picturesque fall.

It was a cold morning, and the whole country was still white with hoar frost when we arrived at the foot of the Pass, having followed the bridle-track which leads to the terrace by which the shingle-slip is reached. Here the road ceases, and we ascended the shingle-slip about 600 feet, climbing along the vegetation on its eastern side till we came at last to the zig-zag track. cut up the eastern rocky spur, and although steep and staircase-like in some spots, it is nevertheless well laid out, and has proved a great assistance to travellers. About 9·30 a.m., we reached the summit of the Pass by this track, and I looked around me with great interest. How different the view now to what it was the preceding spring, when the whole surface was covered with one deep sheet of snow, hiding nearly all the remarkable physical features of this depression in the central chain. The snow had now entirely disappeared, except a few large patches in deep hollows on the hill-sides; and a picturesque lake lay at our feet, surrounded by hills mostly covered with a deep green alpine turf, thickly studded with flowers. Over them rose majestically the rugged forms of Mount Harman and Twin Peaks with their snow-fields and ice-masses glittering in the morning sun, which had just vanquished and dispersed the fog lying over them. The water of the lake was perfectly clear, and had in general a stony bottom; a few grebes (*Podiceps rufipectus*), were swimming upon it, and gave life to the otherwise solitary and tranquil scenery.

On the steep slopes leading to the lake a rich and varied flora was growing: early in the morning, flowers and leaves are generally covered with a thin coating of ice, which gives them a strange appearance, but this soon disappears when the sun breaks through the mist; and these plants, some in full bloom, others budding and which look so delicate, then prove their hardy nature by their bright and uninjured appearance. They were principally Compositæ, umbelliferous, and in a minor degree, ranunculaceous plants which constituted this interesting vegetation. Among the first named were those which formed a thick carpet of flowers, of which *Celmisia sessiliflora* and *Raoulia grandiflora* were conspicuous, also *Celmisia petiolata* and *Haastii* and some others of this remarkable genus, there were, besides, *Senecio Lyallii*, with a profusion of flowers, and the magnificent *Ranunculus Lyallii*, with its enormous orbicular leaves. Of umbelliferous plants the dwarf *Ligusticum aromaticum* was to be seen growing in a thick green mat, the pigmy flowers almost hidden amongst the leaves; but over all rose conspicuous the large *Ligusticum piliferum*, remarkable for its deeply cut leaves and its red, grooved stem. Several rare alpine species of *Euphrasia*, *Senecio*, *Ranunculus*, and many others, gave, in some spots, quite a gay appearance to the turf. On the small shingle reaches two of the woolly *Haastias* are very abundant, together with the gay *Ranunculus sericophyllus*, then in full flower.

What impressed me most was the fact that, although winter was rapidly approaching, many of them were just making their appearance, principally round the large snow-holes still lying in many places. When I visited Mount Torlesse two years previously, in the beginning of January, most of the alpine plants were already past flowering, at a corresponding altitude (5000 feet), consequently, here they were three months later. Looking for the causes of this remarkable difference, it will be found that one of the principal is the greater mean elevation of the country as compared with the isolated ridge of Mount Torlesse, rising from the Canterbury plains. The proximityof the latter mountain to the East Coast is another point of importance. But these causes would not suffice were it not that the depression in the central chain is a principal point of attraction for the moisture coming from the West Coast, which is there condensed and precipitated. At the same time I was much struck by the fact that the ranges on both sides, although only about 8000 to 9000 feet high, were covered with perpetual snow and glaciers, clearly proving that, owing to the enormous amount of moisture deposited from clouds almost continually passing through this opening, the line of perpetual snow must lie here much lower than in many other portions of our Alps. Even the vegetation close to and on these alpine passes differs, in many respects, from that of other alpine valleys which do not lead to any Pass. Thus, for instance, the large arboraceous *Dracophyllum Traversii* (the *nene* of the Maoris), is only found on the lower passes, or, as here, near its approaches, indicating that a larger amount of moisture is necessary for its luxuriant growth than our Alps usually supply.

Signs of the great glaciation of that part of the country are everywhere discovered in descending the down-like hills lying round the lake on the bridle-path to Hokitika; not only are all the rocks smooth and rounded, but erratic blocks and numerous lagoons are also present. I followed the well-selected track across these hills, descending far down the other side, for a geological examination, till I came to the place where I obtained good sections free from snow, during my first journey. When afterwards ascending the eastern slopes of Mount Harman, a large bird of prey passed within a few hundred yards of us; its large size, more pointed wings, and dark colour distinguished it at once from the New Zealand Harrier (*Circus Gouldii*), so common on our plains, but which I never observed in the alpine regions. Mr A. J. Mathias, my companion during this trip, had never seen it before, although he had lived several years in the upper valley of the Rakaia, and during that time he had closely observed the birds of that region, neither had the late F. L. Fuller, the taxidermist at the time attached to our Museum, who had collected New Zealand birds for several years, and knew well their peculiarities. We observed the same species (Eagle hawk ?) once more next morning, when returning to Goat Hill, above the junction of the Stewart with the Wilberforce, when it was pursuing a sparrow hawk, and flying very high above us. In the evening we reached the hut, after having obtained, during the descent, another set of observations at different points.

We returned on April the 1st to Goat Hill, where we arrived late at night, having first ascended during the day the eastern tributary below Sebastopol rock, and opposite the junction of the river Stewart. The next two days were fully occupied with arranging and packing my collections, which had increased considerably, besides washing and mending the clothes, to which our dense and prickly sub-alpine vegetation is a particular enemy, and preparing for a fresh start. We left on the 4th of April, intending to reach the sources of the main branch of the Harper, and followed the wide river-bed along the opening, disclosing here, on the right bank between Mount Gargarus and the low glacialised hills to the west of it, rocks of the same character as those observed previously in the same horizon. They form, in some localities, banks 12 to 15 feet high, covered with morainic accumulations and fluviatile deposits; in some places where the upper surface is exposed they exhibit striæ and rounded forms peculiar to glacialised countries. Before us rose the bleak Craigieburn range, consisting almost entirely from summit to bottom of one continuous mass of debris. In front, and apparently closing up the valley, rise some very interesting conical hills and other *roches moutonnées*, jutting out from the stony slopes of the Craigieburn range. They are mostly covered with a luxuriant vegetation, and some are so perfect in form that they have been mistaken for volcanic cones by the settlers. Advancing towards the junction of the eastern branch of the Harper with the Avoca, which is the principal one, a large opening is visible leading along the western slopes of the Cragieburn range towards the Canterbury plains, filled with a number of huge *roches moutonnées*. Magnificent *Fagus* forest covers most of the valley and hill sides of the Avoca above the junction, the river winding considerably between the picturesque ranges. This, combined with the splendid peaks on both sides, makes it one of the most beautiful valleys in our Alps. It thus presents us with a great diversity of views, very unlike those of our large alpine valleys, often so straight that, from the junction of the principal branches that portion of the Southern Alps, with its glaciers whence their sources are derived, are well discernible.

We camped twelve miles above the junction of the Harper with the Avoca, at an altitude of 3194 feet above the sea. For the last three miles the river-bed had already become very narrow, and assumed the character of a mountain torrent, flowing over great boulders, so that crossing it was not without difficulties. Here also the beech forest (the so-called white birch of the settlers), is growing luxuriantly along the banks, and for several hundred feet on the mountain sides. In ascending the valley next day, I observed that the *Fagus* forest grew to about 3800 feet, or 1370 and 1440 feet higher than in the valleys of the Rakaia proper and the Wilberforce respectively. As the aspect is nearly the same, at least as far as the Wilberforce is concerned, it is difficult to account for such a great difference, except that the narrowness of the valley under consideration may act as a funnel, through which the warm air of the East Coast ascends more easily than in the broader valleys. I observed here, growing on the grassy flats along the river, some shrubby *Veronicas*, as for instance, *Veronica lycopodioides* and *cupressoides*, plants which are common in the smaller branches of the Waimakariri and near Porter's Pass, but which I never observed in the other branches of the Rakaia. During the night, rain from the south-west set in, increasing towards morning; the barometer fell rapidly, and all seemed to point to a breaking up of the fine weather which had hitherto prevailed. Fearing that the river would rise so as to prevent our crossing, I started early to ascend to its sources.

After half-a-mile, travelling over great blocks or through dense forest, we reached the junction of a large tributary, joining the main valley, through a magnificent gorge, and flowing west and east. A little further on the forest began to open rapidly, and the fall of the water became much less. An enormous shingle cone reached into the valley, over which we continued our road. Numerous fine water-falls descend from both sides, and the water brought down by them soon disappears in the shingle. The *Fagus* forest ends here, and bold craggy mountains, covered with perpetual snow, and with small glaciers on their flanks, surround this remarkable valley. True alpine herbaceous plants were growing in small patches between the dry water-courses, but they soon partly disappeared under the snow which commenced to fall instead of rain. The wall of detritus consisted of morainic accumulations, partly covered on its western side by a huge shingle-fan. Some remains of large avalanches were lying on both sides; and climbing over very rough ground we came, at an altitude of 4749 feet, to a small glacier forming the source of the river. Its direction, as far as I could see, was north 20 deg. east, showing that it is situated on the southern slopes of the high mountains, on the opposite side of which lie the southern or main sources of the Waimakariri. The ground was already covered here with several inches of snow, and the temperature of the air fell to 33 deg. Fahr., so that we felt it exceedingly cold, as we were wet through from the continuous rain lower down. We returned in the evening to our camp; the snow continued to fall nearly all night, so that next morning the ground was covered to a depth of about fifteen inches, and the trees seemed to break under their heavy load. The appearance of the country with this white covering reminded me more of a winter landscape in Switzerland than any similar views I have seen in New Zealand, the pointed, well-shaped *Fagus* trees, now resembling very much the *Pinus silvestris* of that country.

The barometer rose during the night of Saturday, April 7th, the snow ceased to fall towards morning, and the clouds began to break, so everything promised a fine day. We retraced our steps, and presently the sun re-appeared. After a few miles travelling, the snow began to diminish rapidly in the valley, so that when we reached the junction of the Harper with the Avoca, it had entirely disappeared. Intending to reach Lake Selfe the same day, we travelled late at night, and were overtaken by a tremendous hail-storm from the south-east, during which we arrived at a hut lying above that picturesque lake.

For the next two days continuous north-west winds blew with vehemence. Great waves rose, and had I not seen it myself, I could scarcely have believed that such a surf could break on the shores of such a small lake. Lake Selfe lies with a chain of similar lakes or lagoons, of which the principal ones are called by the inhabitants of that part—the World, the Flesh, and the Devil—in a longitudinal depression running parallel to the course of the Rakaia above the gorge, and to Lake Coleridge.

I devoted a day to the examination of the Mount Ida range, and the small lake lying between the two northern separated hills forming its shores. Following the eastern wooded shore of Lake Selfe for half a mile, and after ascending the steep sides for about 450 feet, another saddle is reached, where morainic accumulations and glacialised rocks show themselves on both sides at every step. Descending this depression on the opposite side for about 70 feet, we reach Lake Ida, a small but very picturesque spot, with a fine growth of beech forest on one side. As we advance along its banks towards the east, we reach a spot about a quarter of a mile from its western end, where two large shingle deltas approach each other from opposite sides so close as almost to cut the lake in two; the intervening space is only about 40 feet wide, and so shallow that in wading across, the water does not reach above the knees, whilst on both sides it is very deep; very little debris is required, therefore, to divide it into two separate lakes. At its eastern side the lake is surrounded by remnants of a moraine, through which its outlet has formed a channel towards the Ryton: it lies 2304 feet above the sea. The solitude is enlivened by a great number of waterfowl, belonging to various genera and species, of which the Great Crested Grebe (*Podiceps cristatus Lin.*) is the most worthy of notice. Eels are also very abundant and of large size, judging from the fact that several of the birds which we shot, disappeared before we could reach them, drawn under water by those voracious fishes. On this occasion we had no dog with us, and had to depend on the wind, or a short swim in the cold water, to bring the birds ashore. I would not have believed it possible that eels could thus, in broad daylight deprive us of our booty, had I not been an eye-witness of the fact. I may here mention that in 1860 a large eel was hooked by one of my party from under a log near the sources of the Buller, and when opened, a whole full-grown mountain duck was found in its stomach.

In following the outlets of the World towards Lake Coleridge, and before reaching the valley of the Ryton, we passed on our right, Carriage road Hill, so called from a very interesting shelf sloping towards west, or opposite to the general direction of the great post-pliocene Rakaia glacier. This shelf, rising at an angle of about 9 deg. for several hundred feet, is about 15 feet broad, and as regular as if formed by the hand of man. It would be quite smooth had not some blocks of debris fallen upon it from the summit. There are similar but smaller terraces above and below it, all running in the same direction. At first I thought that perhaps unusually large beds of conglomerate, striking and dipping in this direction, had offered so much resistance to the denuding or disintegrating powers that these shelves had been preserved, but an examination of the strata proved conclusively to the contrary. There is, therefore, only one other explanation of these remarkable roads possible, which were so striking a feature to the first explorers that they named the range after them, namely, that the ice-masses descending by the valley, and uniting with those coming by the large Ryton valley, were stopped and compelled to ascend, in order to move on with the larger masses standing at a higher level. That the power of ice has been here unusually great, is well exhibited by the *roche moutonnée* standing opposite the junction of the valley of the World with that of the Ryton. This hill, named from its perfect form "Round Hill," is a very striking instance of the power of ice to plane down all sinuosities in its way, if only time enough is allowed for it.

Five or six terraces, together about 150 feet high, form both banks of the Ryton, which river brings the most important supply of water to Lake Coleridge. Ascending the terraces on the left bank of this river, we find ourselves on a plateau about 150 feet above the level of the lake, consisting of the former delta of this river and some minor rivulets coming from the Craigieburn range, and through which the latter have afterwards also excavated channels. Following the last of them in a south-easterly direction, we enter again the opening parallel to Lake Coleridge, where Lake Georgina and a smaller swampy lake are situated, bounded on both sides by glacialised hills. A small shingle-fan of about 10 feet, resembling all the others previously described, forms here also the watershed, the water flowing in opposite directions. It is thus evident that physical causes, recently in operation, have given to these remarkable parallel depressions their peculiar form, and that the action of enormous glaciers, at work in the epoch preceding the present one, the effects of which being little obliterated, can account only for the curious phenomena met with everywhere in this interesting zone. For several days I occupied myself examining the causes which have led to the formation of Lake Coleridge, and its present physical features, subjects full of suggestive instruction to the geologist. Mr. Charles Harper, under whose hospitable roof I met with a hearty reception, not only placed his boat at my disposal, but also accompanied me during two days on the lake, whilst I was examining its banks and taking some soundings in different parts. I devoted Thursday, the 12th April, to an examination of the lake. The strong north-west wind having ceased for a few hours, I was able to obtain some good soundings as far as the peninsula, but when we reached that spot, the wind came down the valley of the Wilberforce and up the lake with such force, that we had to retreat into the Peninsula bay, where numerous aquatic birds offered a good opportunity for increasing our collections. The peninsula, about 100 feet high, consists of well-rounded ice-worn rocks, true *roches moutonnées*. The former delta of the Ryton abuts against it, and in several localities amongst the rocks, old beaches are met with, the main part of these deposits having been destroyed during the lowering of the waters, when it came within reach of the waves during the strong north-west winds, which blow here very violently for a great portion of the year.

On Saturday, April 14th, I took the boat once more and went as far as the island, two miles north-west of the peninsula. It was one of those perfectly calm days which occur so very seldom in those regions, at least at that season. The lake, unruffled by a breath of air resembled a mirror, thus enabling me to land anywhere on the rocky island, which rose boldly from the glassy surface. I shall never forget the beautiful tints of the lake close to the land. The water, clear as crystal, allowed the eye to follow the perpendicular walls of rock for more than a hundred feet down, till the whole formed a deep purple region, through which the rays of the brilliant autumnal sun were unable to penetrate. The island contains an area of about three acres, rising 30 feet above the lake, and forms a ridge parallel to it with a gentle ascent from the north-west, so that we find the only shallow water round it, is on its subaqueous continuation towards the central chain. On the three other sides it falls very abruptly; so much so that at one spot eight feet from the shore, where I sounded, I only touched the bottom with 106 feet of line; whilst two chains further out it took 230 feet to reach it. Notwithstanding that the rocks are much water-worn, they show still in many spots striæ and flutings from the action of the glaciers. The island in fact is a true *roche moutonnée* (skör), of which the north-west face, which descends slowly is rounded, worn down, and striated from the almost inconceivable weight of a tremendous glacier, whilst its opposite face is rough and very precipitous. The vegetation on it is very rich and varied. Some enormous beech trees rose majestically over the dense undergrowth of shrubs, consisting mostly of different species of *Coprosma*, *Olearia*, *Panax*, *Leptospermum*, and many others, generally found on the shores of our alpine lakes, not omitting the beautiful rata *(Metrosideros lucida)*, which grows in large groves, and when in flower, must present a beautiful appearance. I was not a little surprised to meet with the Weka *(Ocydromus Australis)* on this small island; it doubtless obtains ample nourishment from the berries of the dense growth of shrubs and the insects which frequent them; but it is difficult to conceive how this bird, unable to fly, could reach this solitary spot, nearly a mile from the nearest land.

I devoted another day to an examination of the valley of the Acheron and Lake Lyndon. Following the small valley north of Barker Hill, I reached the former channel of the outlet to the lake, now partly concealed under newer fluviatile deposits. In many localities the remains of moraines, or rounded bosses of rock, stand above these fluviatile beds, by travelling along which I reached the banks of the Acheron, opposite the north-west slopes of the Thirteen-mile-bush range. Descending five or six terraces for about 150 feet, I crossed the river-bed and ascended to about an equal height on the opposite side, where I reached the bridle-path leading to the West Coast road, which passes Lake Lyndon. Three miles from this lake the path rises rapidly for about 300 feet on the slopes of a huge lateral moraine, crossing the valley from side to side, through which the principal branch of the Acheron, coming from Big Ben, has forced its way. Numerous angular blocks lie here everywhere on the summit; and several small lagoons without outlet give also to these beds the characteristics, peculiar to those glacier deposits. Behind them, towards Lake Lyndon, the valley opens again and forms a grassy flat, through which, near the moraine, the small creek, coming in the direction of Lake Lyndon, has cut a deep channel, showing in its banks that it is the former bed of a lake filled up with silt. Before reaching Lake Lyndon, we pass a remnant of this former lake, now mostly a large swamp. Behind it the valley still continues of a considerable breadth, and the road leads among tufts of snow-grass along the dry bed of a small water-course till we approach the lake. A shingle-fan, descending from the northern slopes of the Thirteen-mile-bush range crosses the valley here, to the existence of which, combined with that at its opposite end towards the Waimakariri, the lake, without doubt, owes its existence. Its level, when I visited it, was very low, and I found that not only was no water issuing from it and running towards the Acheron, but that the surface of the water was fully three feet below the point of outlet, and the intervening banks covered with grass.

Thus the Acheron takes water from the lake, except by leakage, only in spring or after heavy rain. My former supposition, therefore, that the large and ever-flowing springs forming the River Porter, and belonging to the Waimakariri system form the real outlet of Lake Lyndon, received additional confirmation. These springs are situated 205 feet below that lake, and at the northern foot of a large fan, formed by several creeks bounding Lake Lyndon to the north. I may here add that I passed Lake Lyndon on the 4th July of the same year. The lake was then so unusually low that it was divided into two distinct basins, of which the southern one was the largest, whilst the northern, or that situated towards the Waimakariri valley, occupied only a very small area. The level of the larger basin was, according to Mr. W. Blake's levels, three inches above the smaller one, although a narrow water-course was continually flowing from the former into the latter. Thus, if there were no subterraneous outlet towards the Waimakariri, it is evident that both basins would stand at the same level. Descending the River Acheron towards its junction, we observe, lying on the western slopes of the doleritic rocks previously described, alluvial beds well stratified, with every appearance of having been deposited in a lake as a lateral delta. In advancing towards its junction with the Rakaia, large beds of silt form high white cliffs, mostly consisting of an almost impalpable mud of a bluish white or yellowish colour, covered by banks of shingle, which show in many places by their flattened shape that they were deposited in a lake. Fighting Hill forms the boundary of this former large lake, and precipitous cliffs, several hundred feet high, situated here at the turn of the river, exhibit well how it was filled up by shingle brought down by the large rivers falling into it, covering and preserving the silt beds, so much more easily destroyed. Moreover, we can trace without difficulty how, after having filled the lake, the Rakaia divided into several branches, running towards the present gorge, and leaving one channel after the other, when they became gorged by masses of shingle.

I returned to Christchurch on Wednesday, April the 18th, after having visited once more the "Curiosity shop" on the Rakaia, to collect fossils. Owing to the indefatigable zeal of my collector, and with the assistance of my party, I brought about 160 skins of birds with me, several of them either new to science or at least very rare, and desirable objects for the completion of our own collection. Besides numerous geological and palæontological specimens, I collected several thousand specimens of dried plants, comprising the nearly entire flora of this portion of our alpine region from the slopes of the eastern ranges to the truly alpine zone near the line of perpetual snow. The observations I was enabled to make of the great glaciation of New Zealand, and of which such remarkable traces have been left with great distinctness on the grand landscape of the Rakaia valley and the Lake region situated in it, will be given in the geological portion of this Report. For several months I was now occupied arranging the collections, writing a report, and preparing maps and sections illustrating the physical geography and geology of the head waters of the Rakaia, which I handed to the Secretary for Public Works on June 20th, 1866, and which, by direction of the Provincial Government, was printed in the same year. For title, see footnote, page 129.

Christchurch and Lyttelton Railway Tunnel.

The tunnel works of the Christchurch and Lyttelton railway having advanced so rapidly that only a few chains towards the centre were yet to be pierced, I continued to examine carefully the highly interesting section thus offered, and sent a copy of that geological survey, a section drawn at a scale of 20 feet to 1 inch, together with about 200 geological specimens in illustration, to the Paris Exhibition of 1867.

First Excavations for Moa Bones, in Glenmark, 1866.

At the invitation of Mr. G. H. Moore, the New Zealand partner of Messrs. Kermode and Co., I proceeded at the beginning of December, 1866, to their fine property, Glenmark, where, during the drainage of some swampy ground, large quantities of moa bones had been discovered. That gentleman, on my arrival, not only presented most generously the large and unique collection of remains of these extinct gigantic birds to the Museum in connection with the geological survey, but in order that I might judge for myself of the mode of occurrence, he placed several workmen at my disposal, with whom for a number of days I made some very successful excavations, having been anxious to find some skeletons, of which at least some of the principal bones were still lying together. The results of these excavations surpassed my highest expectations, and towards the middle of December I returned to Christchurch, truly delighted with my success. The generous gift of Mr. Moore, and the bones excavated under my direction, filled a large American four-horse waggon. The taxidermist to the Museum, the late Mr. F. R. Fuller, articulated under my direction from this collection the first seven moa skeletons, which still form such conspicuous objects in the Canterbury Museum, and were the beginning of that remarkable collection, with no rival in the world.

Journey to the Waipara and Hurunui, 1867.

Before making my usual autumnal journey into the interior of the Province, I left on January 20th, to visit its north-eastern portion, with which I was still unacquainted. After first visiting Glenmark, I followed the broad valley of the Omihi, crossing near its sources into a branch of the Waikari, and from which the Cabbage-tree flat, the upper portion of the valley of the Greta, is reached. Crossing over into the head waters of the Motunau river, I examined, near Cave station, the beds of brown coal, and other minerals of economic value occurring there. From here I followed the Motunau for a short distance, and then passing over the Coast range, the "Burnt-hut" hills, I arrived at Motunau station, then belonging to Mr. Caverhill. Several days were devoted to an examination of the cretaceo-tertiary and young tertiary beds, tracing the brown coal seams, and collecting fossils. The small plateau lying between Motunau and Stonyhurst Station, which is deeply cut into by Blackbirch and other creeks, was next examined; after which, on February 5th, I crossed over Pendlehill into the Hurunui, which was ascended for some distance. A few days were devoted to an examination of the Greta and the lower Waikari, in the latter of which a fine series of fossils were collected in the middle tertiary beds, so well exposed along the banks of the river. Crossing the ranges again from the Waikari to Glenmark, and thence by the Weka Pass to the Hurunui, I was enabled to unravel the somewhat complicated structure of the different beds by which these interesting ranges are formed. Towards the middle of February I returned to Christchurch.

The Directors of the Christchurch High School wishing to introduce scientific instruction into their curriculum, I gave, at their request, a course of lectures on geology, in the Town Hall, which was well attended, and formed the beginning of a series of lectures which I delivered at that institution on the same subject, during subsequent years.

Further papers on the Geology, and Physical Geography of Canterbury were sent by me, about that time, to the Geological and Royal Geographical Societies of London, and printed in their Transactions*

EXPLORATION OF THE HEAD WATERS OF THE WAIMAKARIRI, 1867.

Having visited all the principal rivers, of which the glacier sources are situated on the eastern water-shed of the Southern Alps, with the exception of the Waimakariri, I devoted that year's autumnal journey to that purpose, starting from Christchurch on March 7th. After following the usual road to Porter's Pass, I remained there several days, close to the summit of the Pass, and camped in one of the gullies, during which, I ascended the Mount Torlesse and the opposite ranges for detail geological and botanical examinations. Another day was devoted to an investigation of the interesting cretaceo-tertiary and younger tertiary beds round Castlehill station, which form an outlier of considerable size amongst older palœozoic rocks, and where the calcareous sandstones have been washed and weathered into most picturesque forms. Passing by the charming Lake Pearson, the present conformation of which may be traced to two gigantic shingle-fans at both ends, which have dammed up the water, whilst in the centre, it is nearly separated by two steep shingle cones, reaching almost the centre of the lake, we arrived at the Cass plains. Lake Grasmere is situated here, and through it the River Cass flows diagonaly. As soon as we left Lake Pearson, we crossed over morainic accumulations belonging to the old Waimakariri glacier, and which at one time had also covered the whole lower country with its vast ice masses. To these morainic accumulations, Lake Pearson, Grasmere and several small lakes, subsequently to be mentioned, owe their existence.

---

* Notes on the Geology of the Province of Canterbury. By JULIUS HAAST, Ph. D., F.G.S. Quarterly Journal of the Geological Society for November, 1867, and Altitude Sections of the principal Routes between the East and West Coasts of the Province of Canterbury, New Zealand, across the Southern Alps, with Map and Sections. And, on the value of Barometric observations, taken on a rapid journey, for calculating altitudes. By JULIUS HAAST, Ph.D., F.G.S. Journal of the Royal Geographical Soctety, 1867.

Before reaching the Waimakariri, we crossed Goldney's saddle, and made rapid progress, the road along the ranges being finished and in good order. The splendid scenery upon which I had gazed with such admiration eighteen months before had lost nothing by being seen again. The broad river-bed, deep below us, with its numerous branches anastomosing and gradually getting narrower before it disappeared amongst the outrunning spurs of the Southern Alps, formed the central portion of the landscape. On both sides stood magnificent ranges, covered for several thousand feet with a fine uniform beech forest. As the eye followed them, the forest line gradually lowered, and before the central range was reached, it had disappeared, to give way to alpine vegetation, of which vivid green patches were visible from here. The background was formed by a high range, with large snow-fields between the rocky buttresses, from which several glaciers descended to lower regions. It is a truly New Zealand alpine landscape, only to be rivalled by one other on the whole West Coast road, and that of a different character, namely, the romantic valley of the Otira, not without justice, so highly praised for its beautiful and diversified scenery.

Arriving on March the 12th at the Bealey, we found this locality, where some 18 months previously a small township existed, now almost deserted, everybody, with the exception of the telegraphist and a sergeant of police in charge of the station, having left. So we had quite a choice of habitations, instead of being obliged to pitch our tents. During my stay at the junction of the Bealey, I once more visited Arthur's Pass, being able, in the almost continuous rock cutting along the banks of the river, to obtain very clear sections nearly up to the summit, whilst after the road had descended into the bed of the Otira, similar cuttings continued to offer reliable information concerning the geological structure of the central chain. The mountains on both sides of the Pass were ascended by us to a considerable height, and large and valuable collections made. The remarkable small rock wren *(Xenicus gilviventris)*, of which I had obtained several specimens previously, was also found to enhabit the large taluses of debris and the morainic accumulations leaning on the sides of the high mountains. Although we were rather late in the year for collecting flowering plants, a very rich flora was found to exist on the summit of the Pass, where, like on all the alpine Passes visited in Canterbury, a considerable area is covered with boggy ground, water-holes, and lagoons, in and around which, a rich harvest of rare alpine plants was made. The geological features proved to be similar to those observed on the

rinted by M. Jaffé, Vienna.

road.

slopes of the Southern Alps, at the head of the more southerly rivers. There is the same endless succession of sandstones, slates, shales, and conglomerates of the usual character, and jointed in the same manner, continuing to the junction of the two Otira main branches, to which I followed the beds in question.

On March 15th, we started for the sources of the Waimakariri, and after crossing the river above the junction of the Bealey, where, owing to the remarkable fine autumn weather we were enjoying, it contained very little water, we passed for several miles over a very large shingle-fan, here entering the main valley from the west, and which is such a conspicuous object in the landscape, when looking towards the Alps from the West Coast road. From the junction of the Crow river with the Waimakariri, the first true glacier, descending to about 4500 feet, was observed. It is situated at the head of the former tributary, and on the southern flanks of Mount Rolleston. Ten miles above the Bealey the valley begins to narrow considerably, and the spurs of the ranges now generally reach the water's edge. The weather, which hitherto had favoured us so much, now began to alter, and for two days rain poured down almost incessantly, in heavy showers. The high ranges around us, when visible through the clouds, appeared covered with a uniform sheet of snow, which quite altered the whole aspect of the country. However, in the intervals, geological, botanical, and zoological collections were made in the neighbourhood of our camp, and several specimens new to science were obtained.

On the 18th of March the weather cleared, and we started for the main sources of the river, which, owing to the opaque glacial colour of its waters, had previously been named the White river. Near the junction of the northern branch, the White river turns to the south, and its valley for about a mile and a half has still a considerable width ; here, at an elevation of 3094 feet, the growth of the *Fagus* ceases. The view up the valley, narrowing with almost every step, now assumes, every moment, a grander and more alpine aspect. A high peak, with noble outlines, appears at the head of the valley, from which a glacier of considerable porportion descends. The mountains on the left bank also rise high into the sky, they are also covered with perpetual snow, from which small glaciers and torrents issue. Several of the latter form beautiful waterfalls, by which the grand scenery is still more adorned. The mountains on the right bank rise almost perpendicularly for more than 3000 feet above the valley, so that only here and there can snow remain lodged on the lesser declivities. On both sides of the valley, clear signs of enormous glaciation are not wanting, and were also exhibited for many miles down the main valley, by numerous slightly sloping terraces along both banks, often as high as 3000 feet above the river-bed. About a mile above the junction of the northern branch with the White river, a low saddle—Harman's Pass—about 800 feet high, leads from the latter into the northern source-branch of the Taipo river. After two miles, the rocks on both sides now approach close, and for two miles more the river forms a series of rapids and smaller falls, possessing a different character from that of our larger glacier rivers near their sources. At several points old morainic accumulations cross the valley, through which the river has formed a narrow passage. The vegetation became now very rich, many of the alpine shrubs and creeping plants in seed, were visited by the Kea (*Nestor notabilis*), and an alpine variety of the Kaka (*Nestor montanus*), which, as we could observe, had also its nest, together with the Kea, amongst the nearly perpendicular rocks on the right bank. The latter (*N. montanus*) as we had repeatedly an opportunity of observing, can easily be distinguished from the common Kaka living in and near our beech forests, by its more soaring flight and peculiar notes.

Near its termination the valley is again considerably enlarged and has the form of an amphitheatre, into which the main glacier, about two hundred yards wide at its terminal face, descends to 4262 feet above the sea level. About half-a-mile from the head of the valley, at an altitude of about 6000 feet, a magnificent sight is offered to the traveller, by a large glacier broken up in the wildest and strangest forms, actually overhanging a perpendicular rocky wall about a thousand feet high, and only on one spot where a small rill could form, it descends for some distance in the shape of a gigantic icicle. During our descent of the valley, we had the rare sight of an enormous ice-fall of a portion of this glacier, pushed over the cliff and precipitated into the valley with a tremendous noise, warning us not to approach too near its channel, where, close by, on alpine meadows, a rich harvest of plants was obtained.

Another day was devoted to the exploration of the northern sources of the river, which, at its junction, showed by the colourless character and the comparatively small amount of its waters, that it did not come from a glacier source. For more than two miles the valley of the northern branch, as it is called, has quite a park-like appearance, small groves of beech forest growing on its grassy banks, which give it a charming variety. Two miles and a half above the junction the valley divides again, and a considerable stream descends from Mount Armstrong; half-a-mile further on, the so-called Browning's Pass is seen on the western side, (not to be confounded with the Browning's Pass at the head of the Wilberforce), 750 feet above the valley, according to Mr. E. Dobson's calculations, leading into one of the Taipo branches. The line of road to reach the summit of this Pass, begun by Mr. Dobson, and of which the details are given in his report upon the character of the passes through the dividing range of the Canterbury Province, is still discernible. The valley, at an altitude of 3981 feet above the sea level, is closed by a wall of rock, over which the river descends in a series of waterfalls, of which the lowest is about 50 feet, through a deep and inaccessible gorge. We were therefore obliged to ascend the rocks on the right bank in order to reach the sources. After climbing about 1000 feet along these rocky ledges, ice-worn and ice-scratched in a most remarkable manner, the valley opened up again, and amongst alpine meadows, three ponds were situated, the highest at an altitude of 5241 feet. From their outlets the northern branch of the Waimakariri is formed. High rocky walls surrounded us on three sides, with snow-beds, mostly of small extent only, lying in favourable localities, but without forming any glaciers. Some small glaciers of the second order were however seen descending from snow-fields of more considerable extent, reposing on the flanks of Mount Armstrong, and feeding the eastern main branch of the northern Waimakariri.

I remained till March 26th in the upper valley of the Waimakariri, occupied with geological researches, and adding to our botanical and zoological collections, to the completion of which my two companions devoted all their energy. Returning that day by the road to the Cass river which, after leaving the ranges, flows across an old lake-bed, formed after the receding of the huge post-pliocene glacier, we continued our road along *roches moutonnées* and amongst ancient moraines, over a remarkably glacialised country, to the Waimakariri, reaching the river again about three miles above the junction with the Poulter.

The whole triangular space bounded on one side by the Black and Craigieburn ranges, in which the sources of the Broken and Cass rivers are situated as far as the northern end of the Cass plains; on the second side, by the high ranges on the left banks of the Waimakariri forming the watershed between that river and the Hurunui;

and on the east by the Mount Torlesse range and its northern continuation, the Puketeraki range—was once covered by a huge glacier, above which some peaks, as for instance, Purple Hill, Magog, and Mount Binzer, stood as islands, whilst the greater portion of the smaller mountains having a *roche moutonneé* form, show that the latter were, during a considerable space of time, hidden below the great ice-sheet, and derived their peculiar forms from the astounding work of the great ice plough which had passed over them. When the great glacier retreated, a lake of considerable extent was formed, filling its former bed, and above which the isolated mountains and smaller ranges previously alluded to, stood as so many islands. Gradually this lake was filled with lacustrine deposits in its middle and deeper portion, whilst the mountain streams advanced at the same time with their shingle-fans, forming deltas. In course of time, the shingle deposits of the main river, advancing step by step, filled the whole with their enormous masses, resting upon morainic accumulations and lacustrine deposits. These shingle-beds form a plateau—a continuation of the Canterbury plains—the line being easily traced through the Waimakariri gorge. It is evident that the structure of these newer beds must appear very complex and bewildering, unless the key to the whole has been obtained. Thus in leaving the Cass and passing to the Waimakariri in an easterly direction, we first passed over alluvial beds, which, near Blackwater, a lonely tarn, give place to morainic accumulations ; they are succeeded by *roches moutonnées*, between them the road passes, after which the valley of the Waimakariri is reached, where I observed lacustrine beds overlaid by thick post-pliocene shingle deposits, situated at least 400 feet above the present bed of the river. Instead of following the river-bed to the junction of the Poulter, the road leaves it about a mile above, and ascends to the downs on its right banks, passing over a succession of morainic, lacustrine, and fluviatile deposits. Every moment the view becomes more extensive, the traveller beirg here surrounded by mountains at least 6000 feet high, whilst d:ep below him in narrow ravines, the Waimakariri, and Poulter flow. *Roches moutonnées* rise in every direction amongst the level terraced ground in the foreground, the continuation of which, on the right bank of the Waimakariri, is clearly visible from here. After descending to the Poulter by a well-laid-out road, and crossing the river, a number of terraces, one rising above the other, brought us again on to the plateau. Here the station of Mr. Minchin is situated, where, being most kindly received, I established my head-quarters. On this flat, a number of ice-worn hills rise above the younger deposits, amongst which the small but very pretty Lake Letitia is situated. Several days were devoted to examining the interesting structure of the newer beds and the effects of the enormous glaciation of the country, and of which I shall give some more details in the geological part of this Report. During this stay I followed the Esk—another branch of the Waimakariri—for some distance, where, besides the older palæozoic rocks, several younger outliers of greensand and calcareous sandstones occur, which have been broken through and covered by dolerites, to the hard nature of which they doubtless owe their preservation during the great ice age. Another excursion brought me to Lochnavar; which is reached by following the valley of the Esk for some ten miles, to a number of *roches moutonnées*, with a flat-bottomed valley between them, which brings the traveller into the broad valley of the Lochnavar. This remarkable valley, to which the small rill of water flowing in it does not stand in the least proportion, has numerous terraces on both sides. Above it ice-worn hills rise conspicuously—the whole having a most glacialised appearance.

Leaving Lochnavar station, and following its continuation towards the northern Poulter, we soon arrived at enormous morainic deposits, about two miles broad and reaching from one side of the mountains to the other, across the whole valley—the apex of the curves, formed by morainic accumulations, being directed towards the centre of the broad Lochnavar valley. Arrived on the banks of the northern Poulter, we looked down about 700 feet into the river-bed, deep below us, into which we had to lead the horses along a very steep slope, having all along a splendid view, in both directions, of the valley and the fine ranges bounding it. Whilst the valley of the river above the moraine was rather broad and well excavated, between the mountains, below it, it assumed the character of a deep rocky gorge, through which we had some difficulty in taking our horses to the junction of the Northern with the main branch of the Poulter. All tended to show that the channel below the moraine did not exist in the Great Glacier period, but that the Northern Poulter glacier, as shown by the size of the moraine, even after the glacier had already considerably retreated, still was nearly two miles broad, its outlet running in the broad valley of the Lochnavar as a large torrent, and joining the Esk in its middle course. This newly-formed gorge of the Northern Poulter is very wild and romantic, fine beech forest growing in every suitable spot; and a luxurious vegetation has sprung up amongst the bold rocky walls, wherever the roots can find a hold in the fissures, and through which the effect of the grand scenery is still heightened. As a sign that this gorge is very inaccessible and seldom trodden by the foot of man, I may mention that in two localities we met with a small flock of sheep, covered with long wool, and which evidently had never been handled by man. After four miles travelling, during which we had been obliged to cross the river at least forty times, the valley opened and the junction with the broad valley of the Poulter was reached, in which travelling became comparatively easy. In this valley, the formation of terraces 500 feet above the river, is well exhibited; whilst still 1500 feet higher, or about 2000 feet above the river-bed, glacier shelves, with regular, slight slopes, are very conspicuous. On April 1st I left this interesting district, and, returning by the road to the right bank of the Waimakariri, I examined for several days the corresponding area, which stretches to the western base of Mount Torlesse, and where also a number of ice-worn hills rise above the morainic, lacustrine, and fluviatile beds. Here, also, several small lakes and tarns have been preserved, amongst which Blackwater is the most westerly. They are mostly surrounded by remains of ancient moraines.

On my return journey I devoted a day to an examination of the coal-bearing beds near Lake Pearson, and several days to an investigation of the very interesting series of tertiary beds of different ages, forming the Castlehill series, and where a rich harvest of fossils was made. On April the 6th, I returned to Christchurch having made, with the assistance of my two companions, large geological, zoological, and botanical collections, which were deposited in the Canterbury Museum.

Journey to the Sources of the Waipara, 1867.

Towards the middle of April, I again left Christchurch, this time to continue the examination of the northern portion of the Province, with which I was not yet acquainted. First, I visited all the principal sources of the Waipara, ascending the dividing range, between this river and the Okuku, and where the scenery, although not so grand as in the more central portion of the Province, is still very attractive, owing to the occurrence of fine beech forests, wild precipices often bounding the valleys on both sides, with clear limpid streams running in them. To the middle portion of the Waipara, where, in a number of very beautiful and instructive sections, the nature of our middle and younger sedimentary beds is exhibited in a very remarkable manner, I devoted some time. It is here, near the so-called Rampaddock, that the remains of saurians occur in different localities, imbedded in septaria concretions. Owing to the want of proper tools, I could only collect a few of these remarkable remains, washed out of some of these calcareous concretions, which had been accidentally split. However, the real position of these saurian beds was fixed, and a great number of fossils were collected in the different beds underlying and overlying them. A few days were devoted to the source branches of the Kowai, and to Mount Grey, where several seams of brown coal were examined, after which the Okuku, a branch of the Ashley river, was followed for some distance. In this stream, where it enters the Canterbury plains, the oldest tertiary rocks are well exposed; on the other hand, in the front ranges, a succession of fine wooded gorges offers to the geologist a number of beautiful sections of the palœozoic sedimentary rocks. Here the peculiar tabular sandstones, covered with fucoid impressions, occur, which I have met with in many localities all over the province, and, amongst others, on the eastern slopes of Mount Cook. I also examined the rocks, where fine building stones of the same character as the Oamaru stone form perpendicular cliffs, and where now the White Rock quarries have been opened. Another day was devoted to the Moeraki Downs, a large young tertiary outlier enclosing small layers of inferior lignite, round which, during and shortly after the Great Glacier period, the Waimakariri, joined near the Ashley gorge by that river, at one time flowed. Standing on a fine autumn afternoon on the summit of these downs, it was with difficulty that I could tear myself away from the smiling landscape around me; the whole country as far as the eye could reach being dotted with farms of various sizes. In every direction cattle, horses, and sheep were feeding, the whole showing healthy progress of the province.

My next trip brought me on April the 27th, into the Upper Ashley plains, which can only be reached by crossing Mount Lee, the range which runs from Mount Thomas to the gorge of the Ashley. Mount Lee is covered within 200 feet of its summit, with beech forest, above which a luxuriant sub-alpine vegetation succeeds it. The bridle-path follows a leading spur from near the banks of the Gary, and occasionally offers charming views on both sides into deep wooded valleys, or over the wide cultivated Canterbury plains. The summit, 3482 feet above the sea level, once reached, a really fine and extensive bold rocky walls, wherever the roots can find a hold in the fissures, and through which the effect of the grand scenery is still heightened. As a sign that this gorge is very inaccessible and seldom trodden by the foot of man, I may mention that in two localities we met with a small flock of sheep, covered with long wool, and which evidently had never been handled by man. After four miles travelling, during which we had been obliged to cross the river at least forty times, the valley opened and the junction with the broad valley of the Poulter was reached, in which travelling became comparatively easy. In this valley, the formation of terraces 500 feet above the river, is well exhibited; whilst still 1500 feet higher, or about 2000 feet above the river-bed, glacier shelves, with regular, slight slopes, are very conspicuous. On April 1st I left this interesting district, and, returning by the road to the right bank of the Waimakariri, I examined for several days the corresponding area, which stretches to the western base of Mount Torlesse, and where also a number of ice-worn hills rise above the morainic, lacustrine, and fluviatile beds. Here, also, several small lakes and tarns have been preserved, amongst which Blackwater is the most westerly. They are mostly surrounded by remains of ancient moraines.

On my return journey I devoted a day to an examination of the coal-bearing beds near Lake Pearson, and several days to an investigation of the very interesting series of tertiary beds of different ages, forming the Castlehill series, and where a rich harvest of fossils was made. On April the 6th, I returned to Christchurch having made, with the assistance of my two companions, large geological, zoological, and botanical collections, which were deposited in the Canterbury Museum.

Journey to the Sources of the Waipara, 1867.

Towards the middle of April, I again left Christchurch, this time to continue the examination of the northern portion of the Province, with which I was not yet acquainted. First, I visited all the principal sources of the Waipara, ascending the dividing range, between this river and the Okuku, and where the scenery, although not so grand as in the more central portion of the Province, is still very attractive, owing to the occurrence of fine beech forests, wild precipices often bounding the valleys on both sides, with clear limpid streams running in them. To the middle portion of the Waipara, where, in a number of very beautiful and instructive sections, the nature of our middle and younger sedimentary beds is exhibited in a very remarkable manner, I devoted some time. It is here, near the so-called Rampaddock, that the remains of saurians occur in different localities, imbedded in septaria concretions. Owing to the want of proper tools, I could only collect a few of these remarkable remains, washed out of some of these calcareous concretions, which had been accidentally split. However, the real position of these saurian beds was fixed, and a great number of fossils were collected in the different beds underlying and overlying them. A few days were devoted to the source branches of the Kowai, and to Mount Grey, where several seams of brown coal were examined, after which the Okuku, a branch of the Ashley river, was followed for some distance. In this stream, where it enters the Canterbury plains, the oldest tertiary rocks are well exposed; on the other hand, in the front ranges, a succession of fine wooded gorges offers to the geologist a number of beautiful sections of the palœozoic sedimentary rocks. Here the peculiar tabular sandstones, covered with fucoid impressions, occur, which I have met with in many localities all over the province, and, amongst others, on the eastern slopes of Mount Cook. I also examined the rocks, where fine building stones of the same character as the Oamaru stone form perpendicular cliffs, and where now the White Rock quarries have been opened. Another day was devoted to the Moeraki Downs, a large young tertiary outlier enclosing small layers of inferior lignite, round which, during and shortly after the Great Glacier period, the Waimakariri, joined near the Ashley gorge by that river, at one time flowed. Standing on a fine autumn afternoon on the summit of these downs, it was with difficulty that I could tear myself away from the smiling landscape around me; the whole country as far as the eye could reach being dotted with farms of various sizes. In every direction cattle, horses, and sheep were feeding, the whole showing healthy progress of the province.

My next trip brought me on April the 27th, into the Upper Ashley plains, which can only be reached by crossing Mount Lee, the range which runs from Mount Thomas to the gorge of the Ashley. Mount Lee is covered within 200 feet of its summit, with beech forest, above which a luxuriant sub-alpine vegetation succeeds it. The bridle-path follows a leading spur from near the banks of the Gary, and occasionally offers charming views on both sides into deep wooded valleys, or over the wide cultivated Canterbury plains. The summit, 3482 feet above the sea level, once reached, a really fine and extensive panorama lies before the traveller, which can rival many of the most celebrated views in the province. Whilst in the east the eye sweeps over a large portion of the Canterbury plains, at the termination of which the characteristic mountain forms of Banks Peninsula stand above the sea horizon; in the other three directions, high mountain ranges rise one above the other, showing bold and picturesque outlines. Deep below us, immediately at our feet, appear the Upper Ashley plains, without doubt the bed of an extensive lake before the gorge had been cut so deeply into the range, so that its waters could be drained off. Descending by a steep path to Mr. Lee's station, where a hearty reception awaited me, and which is situated about the middle of the plains, I followed for two days the different source branches of the river to their mountain recesses, examining the eastern flanks of the Puketeraki range, the northern continuation of Mount Torlesse, for a considerable distance, cattle tracks as usual offering me a safe guide to fords and across swamps and swampy creeks. In several localities in this inland basin, small tertiary outliers were met with, as well as morainic accumulations and erratic blocks. Returning by the same picturesque bridle-track to the Canterbury plains, I proceeded finally to Oxford, examining on my way Starvation Hill, a small volcanic centre, of which the form of the crater is easily discernible. The country between this hill, which rises conspicuously above the plains, and the foot of the ranges, is of a swampy nature, and indicates that when the Waimakariri was flowing in a north-easterly direction, forming its wide bed on the northern side of the Moeraki Downs, a lake or at least a chain of large lagoons was formed between the out-running spurs, which in course of time were partly filled up by decayed paludal vegetation, and by silt and alluvial deposits brought down by the small creeks from the adjacent hills. Starvation Hill, like Burnt Hill, and a rocky projection in the bed of the Waimakariri a few miles below the lower gorge, consists of basaltic lava, to which, owing to its peculiar structure, the name of Anamesite has been applied, all three being the continuation of the same system, which forms the eastern boundary of the Malvern Hills.

Another day was devoted to a visit to View Hill, the basic rocks of which it partly consists, agreeing more in character with those of the small miniature volcano at Kowai Corner in the Malvern Hills. Some instructive sections are exposed to view, the gradual change in the lithological character of the older sedimentary rocks through the overflow of volcanic matter, being well exhibited. View Hill, standing about 200 feet above the plains, well deserves its name, as the panorama around the visitor standing on its summit is really beautiful, and of the most varied description. After visiting Burnt Hill, which rises about 300 feet above the plains, and which is only a portion of a *coulée* of basaltic rock flowing from several fissures, and reaching without doubt from near the sources of the Hororata to the southern foot of Mount Thomas, I returned to Christchurch on May the 2nd.

Collecting Saurian Remains in the Middle Waipara, June, 1867.

About the middle of June another visit was paid to the Waipara in order to collect saurian remains in Booby's creek. For this purpose I took a stonemason with me, but the continuance of very rainy weather caused the rivers to become so high, that very little could be done, even the smaller creeks being generally inaccessible. I was compelled, after several attempts, to desist from the proposed work. A few interesting specimens were however secured.

A Visit to Glenmark, and Heavy Floods, End of July and Beginning of August, 1867.

Wishing to make some more excavations in Glenmark, I proceeded there, this time taking with me the late F. R. Fuller, taxidermist to the Museum. On arriving there on the afternoon of July 30th the sky looked very angry. During the night it began to rain very heavily, changing next morning to snow, which continued for two days, after which, a regular downpour of rain lasted for another day. The small creeks round the house rose ten to twelve feet above their usual level, and were now raging impassable torrents, destroying everything in their way. It will be still in the recollection of the inhabitants of the Province that the floods caused by these snowstorms and heavy rainfalls were the greatest ever experienced since the colonization of the country, and no similar disaster, where a considerable portion of the lower plains north of the Waimakariri stood under water, has since visited us. For several days, owing to the soaked state of the ground, we were unable to do anything in the turbary deposits, but afterwards, when we could begin work, we obtained a fine collection of bones of every hitherto known species. A similar interesting collection was made from the banks of the Glenmark creek, where in the mean time we had been making excavations. They amply confirmed previous observations that, during the Great Glacier period of New Zealand, the different genera of the *Dinornithidæ* had already been in existence, continuing to flourish to a comparatively recent period. Towards the middle of August we returned to Christchurch bringing a large and valuable collection of *dinornithic* remains with us. Museum and Geological Survey Work occupied me now for several months without interruption, and a discussion about the occurrence of a Glacial period in Australia, before the Royal Society of Victoria, induced me to address to that learned body a paper on the subject, in which I pointed out that without doubt ample signs of such glaciation would be found in the Australian Alps.*

Some more Moa skeletons were now, under my direction, articulated by Fuller, and a series of others, more or less complete, were prepared for exchange with foreign countries, by means of which the Canterbury Museum has received in the last eight years, and is still receiving, such valuable returns that it can fairly claim as to the variety and richness of its collections, to hold an honourable position amongst the Museums of the Southern Hemisphere. The tunnel works having in the meantime been completed, I was occupied for a number of nights in finishing the survey of this highly interesting section, and collecting a large series of specimens in illustration, during which the Railway Engineer, Mr. E. Dobson, C.E., and the contractors, Messrs. Holmes and Co., continued to give me most valuable and ready assistance.

Journey along the Eastern Base of the Ranges, from the Gorge of the Rakaia to the Waitaki and to the Sources of the Hakateramea—1867-68.

Towards the middle of December I left Christchurch to begin geological work on the southern banks of the Rakaia Gorge. Having my head-quarters at Mr. Murray-Aynsley's picturesque station in that Gorge, I devoted several days to a thorough survey of that most interesting district, where, in the perpendicular rocky walls, often from six to seven hundred feet high, splendid geological sections are laid open. Amongst many other remarkable points of interest, the

* Notes on the Rev. J. E. Tennison Wood's paper "On the Glacial Epoch of Australia." By Julius Haast, Ph.D., F.R.S. Transactions of Royal Society of Victoria, Vol. VIII.

action of igneous rocks on brown coal-beds in contact with them can well be studied. Skirting the eastern foot of the ranges, I first visited the Northern Ashburton, ascending it to near its sources ; after which a week was devoted to an exploration of the Orari. Crossing by Tripp's Saddle into the Upper Opuhi plains, this river and the Opihi were both examined, and the occurrence of valuable seams of brown coal ascertained. I next proceeded to the Pareora, where I remained for several days occupied with studying the instructive geological features of the district. After having visited the Waihao, I ascended the Waitaki along its northern banks to the junction of the Hakateramea. This little river, which I followed to near its sources, was particularly interesting to me, the auriferous rocks of Otago being developed to a considerable extent on its left banks. End of January, 1868, I returned to Christchurch.

Geological Examination of Banks Peninsula, 1868.

During the month of February the Geological Survey of this isolated volcanic system was continued. Several of the highest summits were ascended, and the complex structure of this zone, which, as I advanced, continually presented new and instructive features, was studied, the details of which will be given in the Geological portion of this Report.

Journey to the Southern Portion of Westland, 1868.

Although for some time past the western portion of the Canterbury Province had been separated and formed into a County, under the name of Westland, I did not wish to hand over my maps and sections to the Provincial Government without having first paid a visit to the southern part of that district, with which I was still unacquainted. I had already fixed all the principal peaks in the central chain from the eastern side, as well as from my last station at the mouth of the River Waiau, some important bearings having also been obtained from the mouth of the Haast river; but there were many details which I wished to obtain and thus to make my map more complete than it would otherwise have been. Having been informed that the steamer *Bruce* would leave Hokitika beginning of March for Okarito, I left Christchurch on March the 3rd. Shortly after my arrival in Hokitika the steamer left and landed me early on the morning of March the 5th in Okarito. After engaging two miners to accompany me on my trip south, one of whom was Mr. W. Docherty, who had, on his own behalf, explored the headwaters of the Clarke and Landsborough some time previously, I obtained the loan of two pack-horses from a storekeeper living at Bruce Bay, who happened just then to be in Okarito for the purpose of procuring provisions. On March 6th we started for Bruce Bay, and having selected an ebb tide, we advanced rapidly on a hard sandy beach, the more so as we found the mouth of both Totaras, small tidal rivers, closed. When the water behind the bars, thrown up by heavy seas, has risen sufficiently high to force a passage, it is often for several days impossible to cross these otherwise unimportant lagoon outlets. The Waiau, which was crossed near its mouth, although the weather was very fine, was rather high, very thick and difficult to wade through, but Mr. Robinson, the Bruce Bay storekeeper, informed me that this was its usual height, except in the midst of winter, when I had ascended it some years previously. Wherever the morainic accumulations had retreated from the seashore the whole banks, principally where the coast formed shallow bays, had been worked by the gold-miners, but most of the claims were now abandoned. In the evening we camped two miles south of the Waikukupa river at the point where the old northern lateral moraine of the Weheka glacier forms a bold headland, and which can only be crossed at low water. Starting at midnight, and having moonlight in our favour, we crossed the several bold headlands which, between the point and the Weheka river, jut into the sea, having often to seek our way amongst the huge blocks of rock which lie here in the tideway, and to watch for a favourable opportunity, when the waves retreated for a moment, to pass a dangerous corner. Early in the morning we arrived at the mouth of that important river, where we had to wait for low water. Again on our road at eleven o'clock in the morning, in order to reach Bruce Bay in the evening, we crossed the broad Weheka without any mishap, and after travelling almost without intermission along high morainic walls, which most instructively show the form and size of the huge glacier which formerly extended so far, we reached the Karangarua, another large river of glacier origin, which, although broad and deep, was crossed without difficulty. Shortly after having passed this river, the moraines retreat from the coast, and a swampy low tract of country reaches to the very foot of the central chain, the coast-line forming a shallow bay known as Hunt's Bay. A number of gold-diggers had settled along this beach, built houses, planted gardens, and were following their avocation in a peculiar manner. Here during fine south-westerly weather large masses of sand are accumulating in and above the tidal boundaries. At such times only light winds are blowing, and the surf is consequently of no great force; but when an occasional north-west or north-east storm rages along the coast, the masses of sand deposited during the preceding fine weather are, as it were, undergoing a process of natural sluicing. Generally the greater portion of the sand is removed, but in favourable spots, sheltered either by a slight indentation in the coast-line or by some large pieces of drifted timber, its heavier particles remain; these consist of black iron-sand (both magnetic and titaniferous oxide of iron) associated with small garnets and with gold. These black layers are often one to two inches thick, and repose upon coarse quartzose sands. As soon as a storm has subsided, the "beachers" or "surfacers," as they are called, examine the coast-line near their houses. When they come upon one of the rich spots, the fine particles of gold being often visible to the naked eye, they at once remove the black layer of sand out of the reach of the tide, and wash it when convenient. By one of these "beachers," a countryman of mine, we were most hospitably entertained, the table being covered with several luxuries of the season which I did not expect in the abode of a "hatter,"* who are generally of a morose character, and do not indulge in any comforts of life. After leaving Hunt's beach and crossing several smaller rivers, we reached Makowiho point, where the northern Makowihi moraines abut against the seashore, and which, like those passed the previous day, offered a great deal of interesting information. The Makowihi river was crossed in a boat, and in the evening we arrived at the storekeeper's place, where I established my head-quarters for a time. I have not alluded to the magnificent ever-changing views which delight the wanderer as he advances from Okarito southwards. With every mile a notable change takes place. Mount Cook, which appears first like a sharp needle above Mount Tasman, gradually changes front and assumes that tent-like form to which the inhabitants on this side of the island are so accustomed. After leaving these splendid mountains behind us, the Moorhouse range with the bold Sefton peak, separated by a deep depression from Mount Holmes and Mount Cotta, forms the principal feature in the landscape. On a fine bright day, travelling on a hard sandy beach,

* In gold-mining communities those men who work for themselves are usually called hatters, amongst them many originals are found.

with the restless waves of the eternal ocean on one side, and the ever-changing foreground of rock, forest and small waterfalls on the other, over which the high serrated alpine peaks towering grandly, and appearing in such different forms as the traveller advances, that it is often very difficult to recognise them again,—is full of delight and invigorating enjoyment.

The next few days were occupied with examining the nature of the auriferous beds occurring in Bruce Bay, and in which polished stone implements of great age were found. Bruce Bay is formed by Heretanewha point, an ancient moraine advancing far into the sea, by which it is sheltered from southerly and westerly winds. Inland the moraine reposes upon metamorphic rocks, which form a nearly perpendicular ridge about 600 feet high, running inland for a considerable distance. It is densely wooded on the summit, about 200 yards broad, and falls just as precipitously on the opposite (south-western) side. Deep below us lay a flat covered with dense vegetation. A number of ponds are lying amongst the forest, and the whole has a very marshy appearance. It without doubt owes its existence, like so many other similar flats between the moraines, to the shingle bar thrown up between the two headlands, by which a deep indentation of the sea was cut off, the lagoon thus formed having gradually been filled up by alluvium brought from the mountain sides, and afterwards by decaying vegetation. In order to go south, where, owing to the very rough nature of the coast, it would have taken me considerable time to reach the mouth of the Haast river by land, I decided to hire a small boat belonging to the storekeeper, described to me as a whale-boat, but which, after all, was only a dingy with a square stern. Although Bruce Bay is one of the most sheltered spots on that portion of the West Coast, we had to wait a day before we could proceed on our hazardous journey, the surf being too heavy for the boat to be launched. At last, early on the morning of the 20th of March, the sea was so calm that we could venture to take the boat across the surf. It was a glorious bright morning, the sea smooth, and the air invigorating, as with a light breeze we proceeded merrily on our voyage. The mouth of the Piringa river was reached about eight o'clock, which river being well protected from the south by rocky cliffs and reefs, afforded us an entrance without the least trouble. I have no doubt that in years to come, when that portion of New Zealand is more settled, a good harbour can easily be provided in that locality. Before proceeding up the river, I examined the rocks on its southern banks, and found them to consist of grits, sandstones, and shales, identical in character with those of the Grey river, which led me to infer that some day workable coal seams would also be found on this portion of the coast, a conclusion which has since been partly confirmed by the discovery of some seams by Docherty a few years ago. The view up the river is most charming. The river-bed has a considerable width, possessing an alluvial flat on both sides, covered with luxuriant forest vegetation; wooded hills of moderate size and diversified forms bound the valley, the background being formed by the high serrated ridge of Mount Hooker, glistening with ice and snow. After a short interval, we proceeded up the river, which owing to its rapid current, was not done without great exertions, the boat having to be towed up all the time. After having ascended about three miles, the river water began to exhibit a division in two well-defined colours; water of the pale bluish tinge peculiar to glacier rivers during fine weather flowing on the one side, and of a dark brown colour on the other. Soon after, we reached the mouth of a southern tributary from which the dark brown water is derived, and which by a long shingle bar thrown up by the main river, has been dammed up for a considerable distance. We now advanced rapidly for about a mile on the broad and deep still water, bordered on both sides by magnificent forests, after which the bed narrowed considerably, and the current became gradually stronger; rapid succeeded rapid, and numerous drift trees lying across the creek now made our advance so laborious and slow, that we could not that evening reach the lake of which one of my companions knew the existence. We passed a terrible night, owing to millions of mosquitos, which together with a similar torment by day from legions of sandflies that had almost devoured us, did not improve our tempers. Next morning, after passing several very nasty rapids, the river again assumed another character, becoming broad and deep with scarcely any current observable, and now resembling a canal. Numerous waterfowl enlivened its surface, from which I obtained several rare specimens, as welcome additions to my collections. Although well accustomed to New Zealand forest scenery, I could never cease admiring the particularly stately trees which appeared in endless variety of form and feature with every new reach of the river. At last we reached the lake, which I named Lake Hall, after my friend the Hon. John Hall. It is a nice sheet of water about three miles long and two miles wide, with a promontory entering it for a considerable distance from the west, and surrounded everywhere by densely wooded hills of no considerable height. Merrily we pulled across it, and camped on the opposite side on a charming little flat. For two days we remained in this secluded spot, during which I examined its shores in every direction, and ascended the principal affluent from which its waters are derived. Waterfowl of every description abounded on the lake, and the calls of the Kiwi and Kakapo were frequently heard during the night. We also obtained a number of the large New Zealand bull-trout (*Galaxias alepidotus*), which provided us with a good meal. It took the bait much more readily than the eel, of which there were also many and very large ones.

On March the 12th, we returned to the mouth of the Piringa, after having first ascended the main branch of the river for some distance on foot. The high bluff on the northern side of the Piringa, which cannot be passed by travellers except by climbing over its summit, was next examined. On seeing the surf beating so strongly against the cliffs, it was clear that only rocks of such an almost indestructible nature as the melaphyres and brecciated greenstone beds which here stand out into the sea, can so effectually resist the fury of the waves. On the 13th of March, we embarked again in our little boat, and after having gone south about seven miles, I observed a change in the character of the rocks forming the coast-line, so I gave orders to land at what appeared to be a somewhat sheltered spot. Although the sea was very smooth, we had a very narrow escape of upsetting the boat amongst the breakers; however, after shipping a considerable quantity of water when in the surf, we landed on the beach near the mouth of a small creek, which one of my companions designated as the Awa-kai-kato creek, and in the neighbourhood of which the so-called Abbey rocks are situated. Several hours were devoted to an investigation of the interesting sedimentary rocks, occurring here along the coast, amongst which there are some excellent limestones. One of my companions, Mr. W. Docherty, has since discovered, in the same district, some valuable lithographic stone, which is now being quarried. In the afternoon, when I intended to continue my voyage south, the sea had risen, so that there was no chance of getting across the surf; we were therefore obliged to camp on that spot. Next morning a light rain was falling, and the sea appeared very smooth; however, in crossing the breakers, we got a thoro[illegible] wetting, and shipped a great deal of water. Gradually the wi[illegible] the north-west increased, and the sea became rougher every [illegible] our little boat behaved splendidly. We were now runnir down the coast, looking out anxiously for a spot where we might find a small-boat harbour. This portion of the coast, from Wakapohai to Taupari Kaka cliffs, is ironbound and wild in the extreme, and against it the broad waves of the Pacific break with fury. Now and then we ran close to the surf to see whether we could find a suitable spot for landing, but the coast seemed nowhere accessible. However, as the wind steadily increased, we at last selected a small sandy beach between two high rocky promontories, where the surf appeared to be not so heavy, and, keeping the boat steady, ran her in as quickly as we could. But this was not accomplished without nearly swamping the boat, which was half filled with water, and the beach was so sloping that all our strength and energy were needed to secure her.

The spot which we had chosen was most secluded and romantic. A small beach, about a hundred yards long, close to Arnott's Point, and bounded on both sides by huge rocky projections of wild forms, whilst behind us, a rocky wall, about 400 feet high, rose boldly, in the midst of which a small but charming waterfall descended. A rich vegetation had sprung up where a little soil had accumulated amongst these rocks, the line of the horizon above us being fringed with the crowns of the forest vegetation on the top of the cliffs. We only landed just in time, for the sea very soon had risen to such a height that no boat could have lived upon it; the rain came down in torrents, and a wild night followed. In this secluded spot we were detained for nine days, owing to the heavy surf keeping us prisoners, and although the weather was occasionally very fine, before the sea could sufficiently calm down that a boat might attempt to cross the surf, the wind would freshen up and the sea become very rough again. However, it was not altogether lost time, because it gave me ample opportunity to examine the district in every direction. Thus I worked my way both north and south of our camp, but not without occasional mishaps. There was scarcely any difference between high and low water—the latter being very treacherous—high waves occasionally running up and wetting us to the skin, and only our clinging with all our strength to the rocks prevented us from being washed out to sea. Many of the rocks consist of a very hard melaphyre (greenstone). Of such rock Wakapohai, Arnott, and Taupari Kaka Points consist; and it is easily conceivable that only rocks of such great hardness can effectually resist the enormous power of the ceaseless surf. Between these old submarine lava streams, which occur in many localities along this part of the coast, sandstones, shales, and conglomerates are embedded, and have been shaped into wild picturesque forms. In one of these excursions, I followed the coast to Taupari Kaka Point, about four miles from our camp, crossing the Kotohakorakora creek on my way. After having passed Arnott Point, we travelled mostly on a soft sandy beach, by which our progress was much accelerated. One of my companions informed me that eighteen months previously there had been scarcely a particle of sand the whole distance; that in fact, the sea had washed against the perpendicular rocks, and that when returning with a party of gold-diggers from the Haast river, they had to climb over large boulders which then formed the sea beach. Therefore here, as well as other portions of the coast, the sands which are thrown up during one heavy storm, are again washed away by another. From Taupari Kaka Point, which is the last rocky promontory before reaching Jackson's Bay, a very extensive panoramic view is obtained. The line of sandy beach stretches as far south as the eye can reach, and behind it appear wide forest-clad plains, which I have no doubt will some day be extensively used for agricultural and pastoral purposes, after the fine timber has been utilized and exported to less favoured districts. Above them rise the coast ranges, also covered with dark forests for a considerable height—a few snow-covered peaks towering above them. The ranges behind our camp were also repeatedly ascended. Their summits consisted mostly of grits and conglomerates, with black carbonaceous markings, similar to those in the Grey and Buller coal-fields, but I failed to find any proper coal seams. Owing to the impenetrable character of the luxuriant forest and usual thick covering of moss on the ground, it is exceedingly difficult to obtain in these ranges any clear sections, which can, therefore, only be observed along the coast line, in precipices, waterfalls, or similar exposed positions. From the summit of the range behind our camp, about 1500 feet high, we had a very fine view over the wooded coast ranges, some of the alpine peaks appearing in various directions above them, whilst deep below us, the blue sea lay spread out, looking very quiet and peaceful. My companion, Mr. Docherty, who had had great experience in kiwi and kakapo hunting, had a well-trained dog for that purpose with him. In this district, so seldom disturbed by man, these two night-birds were still abundant, especially the *Apteryx*, of which, sometimes, in one afternoon we secured as many as ten. I was thus able to study their mode of living, observe their holes and hiding places, and moreover, could, with the assistance of my companions, whom I taught skinning, prepare a large number of skins. On the 22nd of March, it seemed that at last we might manage to leave our little haven; so we made everything ready and stood by the boat for several hours; but, contrary to our expectations, the surf did not decrease, so we watched anxiously through the night for a change. With the first dawn of day we were again ready to start, and as the sea appeared a little smoother than usual, and there was the appearance of a fine day with a favourable wind to return to Bruce Bay, we watched our chance, and, although in passing through the surf we shipped a sea by which the boat was half filled, we were safely on our way just when the first rays of a brilliant autumn sun gilded the highest peaks of the Alps. It was a glorious morning; the Southern Alps lay before us in all their majesty, forming a panorama of indescribable grandeur, and a gentle breeze brought us speedily towards Bruce Bay, where we landed safely in the afternoon, after our somewhat hazardous trip, through which I became acquainted with some of the wildest coast scenery of Westland. Next day I started on my return journey to Okarito. On the northern banks of the Weheka, which I ascended for a considerable distance, we were detained by heavy rain for a short time. The small rills of water, which fall in great numbers over the perpendicular moraine walls along the beach, were so swollen, that most of them formed small waterfalls, descending in one clear leap, like the shoot from the roof of a house. To give some idea of their frequency, I may say that I counted fifteen of them in less than five minutes' walk. On March the 28th I arrived in Okarito. The steamer *Bruce* having arrived the same morning, I was fortunately in time to proceed by her to Jackson's Bay, Cascade Point, and Limestone-cliff Bay, George river, where we landed gold-miners and provisions, and through which a welcome opportunity was offered to me of gaining some knowledge of the southernmost portion of the coast of Westland. The weather was most splendid—the Southern Alps appearing on both trips without any clouds or mists hiding their grand features. On April the 1st I returned to Hokitika, and taking the coach, I reached Christchurch on the 4th.

The Provincial Council having decided some time previously to dispense with the Geological Survey on June 30th, 1868, as a Provincial Institution, the time was now rapidly approaching when the maps, sections, and other results of the Geological Survey had to be delivered to the Provincial Government. However, it was only towards the beginning of August, 1868, that the work was so far advanced that I could hand over the two maps of the Province, both on a scale of four miles to an inch, or of 1=253,440, one containing the result of my topographical survey of the interior of the Province (Southern

Alps proper), and the other containing the whole Province, geologically coloured, of which a great deal was, of course, only sketched in. These maps were accompanied by 138 sections on 24 large sheets. The public collections, which were arranged in three large rooms in the Government Buildings, consisted of 7887 specimens, of which 4312 were collected by me during the progress of the Geological Survey, and the remaining 3575 specimens were obtained from foreign countries, the whole forming a good nucleus for a Public Museum.

CHAPTER III.

THE CANTERBURY MUSEUM AND GEOLOGICAL EXPLORATIONS FROM 1868 TO 1876.

No provision having been made for the proper custody of the Museum, and being anxious that the collections which I had had such trouble to bring together should be cared for, I offered my gratuitous services as Honorary Director until the meeting of the Provincial Council, when final arrangements might be made for such purpose. On December 11th of the same year, the Provincial Council voted the sum of £1350 for the erection of a Museum Building in stone, the Government appointing me its Director at the same time. This vote was supplemented by the sum of £483 11s. obtained by voluntary contributions of the inhabitants of the Province, and the building was opened to the public on October 1st, 1870. It formed the nucleus of the pile of buildings now forming the Canterbury Museum, of which the frontispiece gives a faithful representation, and for the erection of which the Provincial Council has repeatedly voted ample funds. The architect of the building is Mr. W. B. Mountfort, who has also designed the Provincial Council Chamber, and many other public buildings in Christchurch.

In order that further and more detailed knowledge of the Geology of the Province should be obtained, and that I might collect further material for the Canterbury Museum, I accepted, with the permission of the Provincial Government, an offer of the Director of the Geological Survey for the Colony, to act as Geological Surveyor for that department, my first tour being in March, 1869, into the Southern Alps (Mount Cook and its neighbourhood.)* In the same year a

* Notes on the Geology of the central portion of the Southern Alps, including Mount Cook Reports of Geological Exploration during 1870-71. Geological Survey of New Zealand.

second visit was paid to the reported auriferous rocks in Banks Peninsula, a detail survey of the saurian beds in the Waipara* was made, and the remarkable Moahunter encampment at the mouth of the Rakaia investigated.† At the request of the Provincial Government, and in company with two of its members, several localities in the Opihi and Ashburton districts, reported to be auriferous, were inspected at the end of August, 1869, without however obtaining favourable results. End of November, 1869, I left Christchurch for a Geological Survey of the Amuri district, which occupied me about two months, when amongst others, very interesting saurian remains were discovered at the Amuri Bluff and in the river Jed. A further section of the district was examined during March of the next year, bringing me to the Hanmer plains.‡ On September 30th 1870, the new Museum building, in which the public collections had been arranged in the meantime, was opened by His Honor W. Rolleston, Esq., the Superintendent of the Province, and, as before observed, the building was thrown open to the public next day, a very successful Art Exhibition having been held in it during the month of February of the same year. The Provincial Government being anxious to obtain a detail survey of the Malvern Hills, principally in reference to the deposits of coal of various qualities abounding there, the Director of the Geological Survey entrusted me with this task, which occupied me from the beginning of November, 1870, to the end of January, 1871, and from the end of April to the end of May of the same year, of which the main results were shortly afterwards published.** Further journeys to the Malvern Hills were made in September, 1871, to inspect the progress of the different coal mines, and in November of the same year some irregular brown coal seams were examined near

* On the Geology of the Waipara district, Canterbury.—*Ibid.*

† Moas and Moahunters.—Presidential Address to the Phil. Institute of Canterbury. Transactions, New Zealand Institute, Vol. IV.

‡ On the Geology of the Amuri district in the Provinces of Nelson and Marlborough. Geological Survey of New Zealand. Reports of Geological Explorations during 1870-71, and notes on the Thermal Springs in the Hanmer Plains, Province of Nelson. Transactions of the New Zealand Institute, Vol. III.

** Preliminary Report on the Malvern Hills, Canterbury. By Julius Haast, Ph.D., F.R.S.. Reports of Geological Explorations during 1870-71, and Report on the Geology of the Malvern Hills, Canterbury. By Julius Haast, Ph.D., F.R.S. Reports of Geological Explorations during 1871-72.

the Gorge of the Ashley.* Middle of January, 1872, the Ashburton, Hinds and Rangitata districts were examined, principally in reference to their coal deposits, to which about six weeks were devoted, and of which the undermentioned Report† gives the results. During April of the same year the Shag Point district in the neighbouring Province of Otago was also surveyed by me, and the results printed in the same publication.‡ Fuller Geological Reports on both districts were printed in the same publication.** In June of the same year, 1872, I employed a collector in the Waipara district, by which the collections of saurian remains in the Canterbury Museum were further enriched, whilst excavations on a more extensive scale for *dinornithic* remains were made at Glenmark during the following month, the results of which surpassed my most sanguine expectations. During these excavations some more bones of that remarkable gigantic bird of prey were found, which I had previously described as *Harpagornis Moorei*; besides this new material, bones of a smaller species were obtained, which I named provisionally *Harpagornis assimilis*, both of which were described in the Transactions of the New Zealand Institute, Volumes IV. and VI.

Passing over a period of a year, during which I was fully employed with Museum work, and lecturing for the Collegiate Union, we arrive at the time when, according to a resolution of the Provincial Council in October, 1874, the Geological Survey of the Province, as a Provincial Department, was again instituted. Being appointed Provincial Geologist on the 1st of November of the same year, I started to the south-eastern portion of the Province on the 10th of November, to begin with an examination of the Waihao and lower Waitaki country, returning towards the end of December to town. Middle of January, 1875, I left again for the south, and after paying a flying visit to the Northern Ashburton and Mount Somers, to make an inspection of some coalfields said to exist there, I proceeded to Timaru, examining the

* Notes on the Geology of the Glentui, a branch of the River Ashley. Geological Survey of New Zealand. Reports of Geological Explorations during 1871-72.

† Report on the Coal deposits of the Ashburton district. *Loc. cit.*

‡ Report on the Shag Point Coalfields, Otago. Geological Survey of New Zealand. Reports of Geological Explorations during 1871-72.

** Notes on the Geology of the Clent Hills and Mount Somers districts, and Notes to accompany a Geological Map and Sections of the Shag Point district, Province of Otago. Geological Survey Reports, 1872-73.

country near the sources of the Pareora, returning in the middle of February to Christchurch. During the first journey to the south-eastern portion of the Province, I not only visited the low hills by which the area between the Lower Waitaki and Lower and Middle Waihao is formed, but proceeded also to the so-called auriferous reef country, near the head of the Northern Waihao, where a party of prospectors were then at work. I found that the narrow belt of auriferous micaceous schists, which from the Province of Otago strikes across the Waitaki, beginning about ten miles east of the junction of the Hakataramea with that river, and forming the left bank of that tributary, widens considerably near the sources of the Northern Waihao. This region narrows again towards Burke's Pass, and disappears entirely near the sources of the Opuha under newer and unauriferous rocks, of which by far the greater portion of the Southern Alps and their eastern outrunning spurs in this Province are composed. I may be allowed to mention that as far back as 1864, I alluded to the occurrence of this small area of auriferous rocks in that part of the Province, on page 3 of the Progress Report of the Geological Survey addressed to the Hon. John Hall. More than a week was devoted to a thorough examination of this auriferous district, during which I received valuable assistance from Mr. Michael Ford, the leader of a prospecting party sent out by the Waimate people, and who had just begun to sink a shaft on a supposed auriferous reef; the results of these investigations will be found in the Geological Chapter. A number of brown coal seams of average quality were also examined, and the existence of other minerals, and rocks of economic value in the district, was ascertained. In October of the same year, I made some detail examinations in the Waipara and Waikari districts, during which the remarkable ancient rock-paintings in the Weka Pass ranges were inspected. In December, several newly exposed coal seams in the Gorge of the Rakaia were surveyed, and all the coalfields in the Malvern Hills, of which several had lately been opened, were re-visited. In the beginning of February, 1876, I again left for the south, when the districts of the middle Kakahu, Opihi, Opuha, Tengawai, Pareora, and Otaio were investigated; during which a careful search for useful rocks and minerals was continued, and after which I returned to town, towards the middle of March.

My engagement as Provincial Geologist terminating on the 31st of March, 1876, all specimens, maps, and sections were deposited in the Canterbury Museum, and thus the actual work of the Geological

Survey of the Province had come to a close. I need scarcely add that a great deal of Geological work still remains to be done; the more the country is opened up by settlement, and new geological facts, brought to light by railway and road cuttings, tunnels, and mining enterprise, are made accessible to us, the more the usefulness of geological examinations will be confirmed. However, it will be seen from perusing this Report, that the principal features of the Geology of Canterbury have been fully ascertained, and that only details have to be worked out, for which purpose the lifetime of one single worker is far too short. In the Preface, the circumstances by which it has become possible to publish this Report have been stated, so that I need not refer to them again in this chapter, which has already assumed larger proportions than was intended at the outset; but it was urged upon me that a narrative of explorations, in which the physical aspect of a great deal of the country, its climate and natural history could be described in a popular form, would be very acceptable to the general reader, who would thus become better acquainted than in any other way with the whole subject treated of in the following chapters.

PART II.

PHYSICAL GEOGRAPHY.

CHAPTER I.

General Considerations.

Looking at a map of the earth on Mercator's projection, we observe isolated from all continents and far from the innumerable islands in the Pacific Ocean, two larger islands and some smaller ones, running in a south-west and north-east direction, and as my friend Professor Dr. F. von Hochstetter so justly observes, "situated almost in the centre of a great continental ring, which, with a rich and varied world of shores, encircles the great Pacific Ocean."*

These islands have, by Tasman, their first discoverer, been named New Zealand, and although consisting of two main islands and another small one, separated from the South Island by Foveaux Straits, and called Stewart's Island, they must nevertheless be considered as forming a whole. A large longitudinal mountain chain, running from south-west to north-east, forms the axis; beginning at the south-western end of the South Island, it runs to the East Cape of the North Island, separated by a broad gap formed by Cook's Straits. New Zealand thus forms a remarkable line of elevation in the Pacific Ocean, unconnected with any other continent or island, self-existing and independent in position, in *fauna* and *flora*, as if the creative Wisdom had thus indicated to mankind the high position destined for it in the future, under the hand of the Anglo-Saxon race.

* New Zealand, by F. von Hochstetter. Stuttgart: J. G. Cotta, 1867.

The south-west and north-east coasts of the Southern Island present us with picturesque fiords—enormous mountain masses rising here abruptly from the sea, and deep indentations running for many miles inland. The parallel between this coast and the south-western coast of America or those of Norway and Scotland is very striking, and just as South America has an insulated continuation in the Terra del Fuego, so we find Stewart's Island separated from the Southern Island by Foveaux Straits. May we not therefore attribute to one common cause the fact, that nearly every continent has been devastated by some destructive force coming from the West, until it has been arrested by huge mountain chains, forming a saving barrier to the low lands lying at their eastern base?

This longitudinal chain, appropriately called the Southern Alps by Captain Cook, reaches its highest elevation and greatest development in the Provinces of Canterbury and Westland, its principal watershed forming the boundary line between them. Extensive fields of perpetual snow repose on its slopes, from which large glaciers descend far into the valleys. I may also mention, that in the adjoining Province of Otago to the south—Mount Earnslaw and other peaks, and in the Northern Province of Nelson—the Spencer Mountains rise considerably above the perpetual snow-line, where also true glaciers, although of smaller extent than in the Southern Alps proper, take their origin. Numerous diverging ranges of large extent branch off from this stupendous chain, running towards the east coast, and when reaching the western foot of the Canterbury plains, are still of considerable altitude (six to seven thousand feet). As before mentioned, the divergent ranges or secondary ridges on the western side are far shorter, the Alps falling here abruptly towards the coast. Although the form and altitude of the divergent chains, branching off from the Southern Alps have been greatly modified by the effects produced during the great Ice Period of New Zealand, the position of their valleys, their direction and peculiar main features may be traced to abyssological disturbances having taken place during a much older period in the earth's history, and of which I shall treat more fully in the geological portion of this publication. However, a few characteristic points bearing upon the physical features of the country may here be shortly noticed, as, without doing so, it would be difficult to understand the structure of the chain under consideration.

As pointed out by me in previous reports, the Southern Alps consist almost entirely of stratified rocks of palæozoic age, thrown in huge steep folds, which have been so much denuded, that the synclinals or lower portions of the folds now form the summits of the mountain ranges, whilst the valleys are generally formed along the anticlinals or saddles. In some instances, the valleys run, at least for some distance, with the strike of the beds, but in others, diagonally or across it, and we have to search, therefore, for some other cause by which this peculiarity has been brought about.

Whoever examines our mountain ranges must be struck by the enormous waste which is going on without interruption amongst them. There are mountains 7000 to 8000 feet high, which are covered with angular fragments of rock from summit to foot, and from which only here and there strong buttresses of rock prominently stand out, more or less split up on their surface. In examining these angular fragments (usually called shingle in New Zealand, whence the expression "shingle slips" for these huge taluses of debris covering the mountain sides), we find that they have a polyhedrical shape, their planes being sharply defined, and cutting, as seen in the conglomerates, clean through even the hardest pebbles of which the latter are composed. If, on the other hand, we examine the rocks *in situ*, either on the mountain sides or in the river gorges, which in many cases have been cut through only in comparatively recent times, we observe that all these rocks are jointed in a very striking manner. These joints run in such various directions, and appear so conspicuously, that in many instances they conceal the original stratification altogether. The latter occurrence is chiefly observed where large series of very thickly bedded sandstones form the ranges. It is well known, and has been practically proved, that joints are the result of great pressure exercised upon the rocks, the joint having been formed at right angles to the direction of the pressure.

In the geological portion of this report, I shall return to this interesting subject, but wished to refer to it here so far as the physical features of the country have been influenced by this peculiarity in the structure of the rocks. There are mostly five distinct sets of joints observable, of which some are more or less conspicuous. In many localities, one of the principal joints generally appears at right angles to the stratification, the others passing in various but well defined directions. It is evident that the internal forces by which these joints have been formed must have acted from various directions, sometimes nearly opposite to each other. Mr. E. Dobson, C.E., when laying out the Otira road, made some important observations on the subject, in that district, and I may here be allowed to quote from his valuable report,* the principal passages having reference to the subject :—" The next feature to be noticed is the jointed structure of the rocks. Although they cross each other in all directions, apparently without order, there are two systems of joints which are to be met with throughout the whole valley of the Waimakariri, and which have an important influence on the configuration of the Passes. These are—(1st) A system of vertical cross joints at right angles to the stratification, and running in unbroken lines for great distances with such regularity that they might easily be mistaken for planes of stratification, were it not for the frequent occurrence of beds of trap rock, the outcrop of which marks unmistakably the true bedding. (2) A system of joints more or less inclined to the horizon, not running in parallel planes, but arranged in a series of curves radiating from a common centre. The effect of this system of jointing is to produce a rectangular arrangement in the plans and sections of the ravines; the rivers and water-courses running either on the strike of the beds or in the direction of the cross joints, or in a zigzag course, following alternately these two directions, as in the annexed sketch (fig. 2), which shows the character of the valleys connecting the Waimakariri and Teramakau, which have generally a northerly direction, thus making an angle of about 22 deg. with the strike of the strata. In consequence of the vertical position of the strata, and the inclined position of what may be called, for convenience of description, the horizontal joints, the sides of the ravines present either sheer precipices or dangerous slips, according to the extent to which the rocks have been loosened by exposure to the rain and frost; and the result is, that to form a road inside cutting through any of these ravines is simply impossible."

Mr. Dobson, in the same report, points out a very interesting and suggestive fact which had not before been noticed, namely—that all the principal valleys, from the Hurunui in the north to the Makaroa in the south, radiate as it were from a common centre, situated about 50 miles to the north of Mount Darwin, or about 40 miles west of Hokitika. This remarkable phenomenon is more than a coincidence, and it would not, therefore, be too rash to conclude that, during or

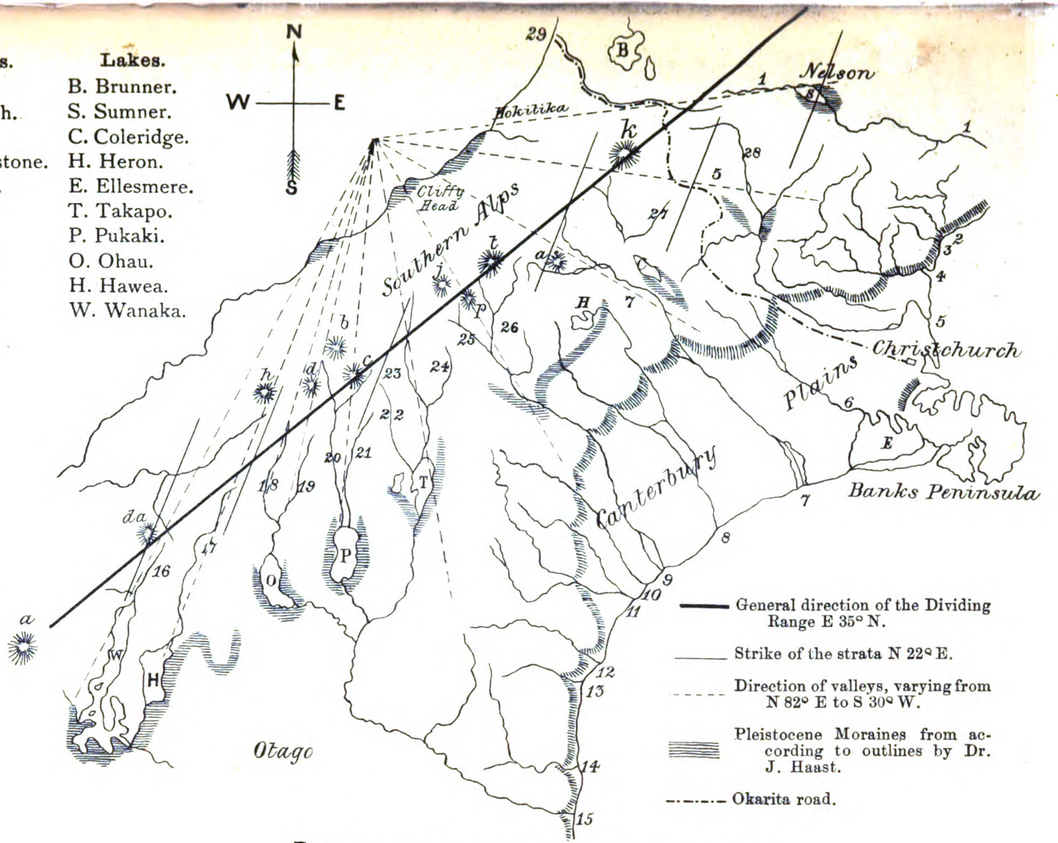
* Report to the Secretary for Public Works upon the Practicability of Constructing a Bridle Road through the Gorge of the Otira, and upon the character of the Passes through the dividing range of the Canterbury Province. By E. Dobson, C.E., Engineer of the Lyttelton and Christchurch Railway. With forty illustrations and an appendix.

shortly after the rocks now forming the Southern Alps had been thrown into the huge foldings they now exhibit, some abyssological force of enormous power, situated near that point had laid th foundation to this remarkable orographical feature by which the country appears starred; just as we find it in volcanic regions—Lyttelton Harbour, for instance—where, however, the fissures thus formed have been injected by volcanic rocks of a different character from those of which the system has originally been built up. Mr. Dobson, at the same time, observes (paragraph 39 of the same report): "it might be imagined that these radiating lines would form passes through the central chain at the head of the valleys, but he thinks that, with the exception of the Hurunui valley, this is not the case." However, a closer examination of the map will show that such depressions in the Southern Alps do generally exist, although the line, when crossing the water-shed, is sometimes a little deflected.

For those of my readers who are not acquainted with Mr. Dobson's able Report, I have annexed a copy of his ingenious map, on which all the principal features in question are clearly indicated. It is true, as before observed, that the Hurunui-Teramakau line shows this radiating structure most strikingly, but all the other valleys, although not so clearly indicated, have similar features: thus, to give a few instances—there is Harman's Pass at the head of the Waimakariri, leading into the Taipo; Sealy's Pass at the head of the Godley river, leading into the Whataroa; and the deep depression between Mount Cook and Mount Stokes, the direct continuation of the Tasman river and Hooker glacier valleys. A similar well defined opening is the alpine saddle between the Moorhouse range and Mount Holmes, at the head of the Dobson river; whilst Docherty's Pass, at the head of the Clarke river, might be pointed out as continuing the direction of the Makaroa line over Haast's Pass to the starting point in question.

N°5

Rivers.	Mountains.	Lakes.
1. Hurunui.	k. Kaimatau.	B. Brunner.
2. Waipara.	as. Arrowsmith.	S. Sumner.
3. Kowai.	t. Tyndall.	C. Coleridge.
4. Ashley.	j. Keith Johnstone.	H. Heron.
5. Waimakariri.	p. Petermann.	E. Ellesmere.
6. Selwyn.	c. Cook.	T. Takapo.
7. Rakaia.	b. Beaumont.	P. Pukaki.
8. Ashburton.	d. Delabeche.	O. Ohau.
9. Rangitata.	h. Hooker.	H. Hawea.
10. Orari.	da. Dana.	W. Wanaka.
11. Opihi.	a. Aspiring.	
12. Pareora.		
13. Otaio.		
14. Waihao.		
15. Waitaki.		
16. Makaroa.		
17. Hunter.		
18. Hopkins.		
19. Dobson.		
20. Tasman.		
21. Jollie.		
22. Cass.		
23. Godley.		
24. Macaulay.		
25. Havelock.		
26. Clyde.		
27. Harper.		
28. Poulter.		
29. Taramakau.		
30. Haast.		



THE GENERAL STRUCTURE OF THE SOUTHERN ALPS
reduced from a map by E. Dobson C.E.

Lyttelton Times, steam lith.

CHAPTER II.

Orographical Features.

Although in the first part I have given many details as to the physical aspect of the Southern Alps, and the divergent chains branching off from them in different directions, a short description of the principal orographical features will be necessary to understand the superficial configuration of mountains and valleys, by which the climate on both sides of the Alps has been so remarkably modified. On looking at a topographical map of Canterbury and Westland,* we observe that the general direction of the longitudinal chain running from Mount Rolleston near the northern, to Mount Aspiring on the southern boundary, is from north-east to south-west; also, that it generally consists of only one high central chain from which a number of ranges, some of considerable length, branch off on the eastern side, whilst on the western side, the outrunning ridges are so short that we can say that here this lofty alpine mountain system falls precipitously towards

* I was unable to give in the Geological map attached to this Report, the orographical features of the country, as such an addition would have seriously interfered with its clearness. However, the extent of the *nevé* fields, and the size of the glaciers descending on both sides, together with the general geological sections, will assist the reader to obtain an insight into the form, size, and other peculiarities of the Southern Alps and their secondary ridges. In the course of the year 1868, I finished my topographical work in the interior of the provinces of Canterbury and Westland and prepared a map, the scale of which, 4 miles to 1 inch, has enabled me to give with a greater degree of clearness than a smaller scale would have admitted, all the more remarkable features of these grand alpine regions, a large extent of which had, previous to my explorations, never been trodden by the foot of man. A copy of this map, of which the original hangs in the Canterbury Museum, was sent by me in 1869 to the Royal Geographical Society of London, and published on a smaller scale in their Journal of 1870.

The lower and middle courses of the rivers were all laid down by the Canterbury Survey Department, the work of which generally ceased when the country was not available for pastoral purposes. From thence all the principal rivers on the east coast, and some on the west coast, were chained by myself or my assistants to their sources, generally issuing from glaciers. In conducting this survey I repeatedly measured base lines, sometimes upon the glaciers themselves, to fix by triangulation the

the sea. However, this continuity is broken near Mount Holmes at the head of the Hopkins river, where the Southern Alps divide into two chains of equal magnitude, forming a large basin in which all the principal branches of the Haast river flow. Having obtained a length of forty miles, these two alpine ranges reunite on the western side of Haast's Pass in Mount Kinross, after which they continue without intermission as a single chain to Mount Aspiring.

Beginning our examination at the northern boundary of the Province, we observe, as already pointed out, that the Teramakau, the western river near that boundary, here advances far east of the geological axis of the chain. This river has its sources near a saddle—the so-called Harper's or Hurunui Pass, 3150 feet high. From here a chain of an average altitude of 7000 feet has a west-south-west direction till it joins Mount Rolleston, where the geological main axis of the chain is reached. This range is generally wooded on both its lower slopes, very luxuriantly on the Teramakau side; whilst on the southern or Waimakariri side, only open beech forest grows. The range close to the Hurunui Pass, divided by a deep saddle, is formed of Snowcap Peak and Mount McCrae; wild rocky ranges, where several branches of the Teramakau, Hurunui, and Waimakariri take their rise. Mount McCrae is separated from Mount Franklin by Walker's Pass—according to Mr. E. Dobson, 3619 feet high—leading from the Hawdon river (Waimakariri) into the Otihaki river (Teramakau). It is described as difficult of access, and with very precipitous slopes. Between Mount Franklin and Mount Williams, the next peak to the west, we find a similar Pass, named Goats' Pass

---

surrounding peaks and other peculiar features of the country. On the west coast I tried to use the coast line as base line for fixing the orographical features, but found in several instances, when fixing prominent peaks in the Southern Alps proper, that the results did not correspond. This discrepancy was sometimes so considerable, that I was obliged to rely entirely upon the bearings obtained on the eastern side. Since this map has been constructed I have been informed that the Colonial Marine Survey has found some serious errors both in latitude and longitude in that portion of the coast-line situated between Jackson's Bay and the mouth of the River Grey, which may account for the different results alluded to. Owing to the rugged and precipitous character of the western side of the ranges, the difficulty of obtaining provisions, the matted and almost impenetrable nature of the forest vegetation, covering the lower portions of the mountain sides, the wild and impassable mountain torrents, as well as from want of time, I was unable to obtain such good and exhaustive sets of bearings as I had anticipated. Thus I was only permitted to ascend a few of the western rivers to their glacier sources: in some other cases I obtained only a limited number of bearings, and in a few instances I had to fill up some portions of the map from eye sketches; but nevertheless, I may state my conviction, that it will be found that none of the more important features have been overlooked by me, when future explorers in years to come may have more leisure at their command, and less difficulties to contend with, than I had during the eight years I devoted to researches into the geology and physical geography of this portion of New Zealand.

by the late George Dobson, who first explored it. He describes it, although scarcely higher than Arthur's Pass, as being far more difficult of access. To reach it, the eastern branch of the Bealey has to be followed. On its northern slopes the eastern branch of the Otira takes its rise. The next peak, Mount Williams, reaches already above the line of perpetual snow. It is separated from Mount Rolleston by Arthur's Pass, 3013 feet above the sea level, over which the West Coast Road has been laid out. These two last-mentioned mountains, without doubt, belong already to the central chain proper, being separated from their north-eastern continuation, Mount Wüllersdorf, by the Teramakau. Mount Rolleston, about 8500 feet high, exhibits a truly alpine character, possessing considerable *nevé* fields, which, however, on the eastern slopes, do not form any true glaciers; towards the Crow river however, one of the upper branches of the Waimakariri, it sends down a glacier of the first order, the terminal face of which nearly reaches to the forest line, or to about 4500 feet. This is the most easterly glacier of the Waimakariri system. Mount Rolleston is connected by a high serrated ridge with Mount Armstrong, where the sources of the northern Waimakariri are situated, and of which I have described the principal features in the first part. Several cols, but of considerable height, Harman's Pass for instance, 3980 feet in altitude, separate it from Mounts Harman, Davie, and Greenlaw, a cluster of alpine peaks possessing considerable *nevé* fields, and giving birth to a number of true glaciers. Here the sources of the White river, the main branch of the Waimakariri, are situated on the eastern flanks; whilst on the southern slopes of the last-mentioned mountain, the principal source of the Avoca, belonging to the Rakaia system, issues, also from a glacier. On the western slopes of this cluster of peaks, the eastern head-waters of the Wilberforce take their rise, the northern slopes giving birth to the Taipo, the principal tributary of the Teramakau, and to the Arahura, both having a short and rapid course. Between these mountains and the western continuation (Mount Hall) Browning's Pass, 4752 feet high, is situated, it is difficult of access, and may be termed a true alpine pass. On the western side of Browning's Pass, the central chain rises again to a great altitude; it is called the Hall range, and its western summits above Browning's Pass have appropriately been named Twin Peaks. On the southern slopes of this range, a high saddle, which separates it from Mount Chamberlin, leads from one of the southern affluents of the Wilberforce into the head waters of the Kokatahi river, belonging to the Hokitika basin. It is, however, of no practical use. From here the Southern Alps run in one longitudinal chain for about twenty-two miles, without any considerable break, to Whitcombe's Pass, 4212 feet above the sea level, the direction of which, like that of Arthur's Pass, is with the strike of the palæozoic rocks on both sides. The average height of the principal peaks in this chain may be estimated at about 9000 feet; they have mostly a pyramidical form, bold outlines, and glaciers of a smaller size than those met with more to the south, but still of the first order, descending from them far down into the valleys.*

On the eastern slopes of this range, the eastern branches of the Wilberforce, Stewart, Mathias, and several important affluents of the main Rakaia branch have their sources, whilst the Hokitika river is fed from the western slopes. On the western side of Whitcombe's Pass, rises the magnificent pyramid of Mount Whitcombe, and from here to Haast's Pass, at the head of the Makaroa river, the Alps, with their enormous masses of snow and ice, form for nearly a hundred miles an impassable barrier between the two coasts to the traveller, except to the mountaineer who, alpenstock and ice axe in hand, can cross over several cols by ascending a glacier on one side, and, after passing over a *nevé* saddle, descending on a similar ice stream to the other. It is here that the physical features of the Southern Alps assume truly gigantic proportions, where some of the largest glaciers in the Temperate Zone are situated, and the sources of our principal rivers issue already as large impassable torrents from their glacier cradles. It would lead me too far to give here a detailed description of the principal features of this stupendous chain, and I have, therefore, to refer the reader to the narrative of my journeys, in which I have alluded to them; for those at the head of the Rakaia, to pages 118 to 143; for the Havelock, Lawrence, and Clyde, the three main branches of the Rangitata, to pages 3 to 16; for the Godley, Tasman, and Hopkins, the main

* Mr. G. Müller, Chief Surveyor of the Westland Province, to whom I am indebted for a great deal of valuable information, draws my attention, however, to a Pass which exists on the main Hokitika branch, seven miles above its entrance into the Hokitika plains. This Pass is situated east of Mount Browne, at the head of Pass river, and three miles from its junction with the main river, and is described by the Surveyor who discovered it, as very easy, even more so than Whitcombe's Pass. If this Pass were to lead through the Southern Alps, it would be of considerable importance, as being in a nearly direct line from the Rakaia by the Mathias branch into the Hokitika, the engineering difficulties being confined to the passage across the central chain. However, I fear that this saddle only leads into another eastern branch of the Hokitika, overlapping the Pass river. An examination of the fine map of Westland, on a scale of two miles to one inch, shows at a glance that it is situated too far to the west to be in the dividing range, the summits of which lie about five miles more to the east. The mountains at the head of the Mathias are very high, covered with perpetual snow, and as far as my examination went, there was no sign of any such considerable depression, which, in fact, would be nearly on a level with the upper valley of that important Rakaia affluent.

branches of the Waitaki, to pages 18 to 42; for the head-waters of the Waimakariri, to pages 145 to 152; and finally to those at the head of the Rivers Hunter and Makaroa, to pages 47 to 58. Similar descriptions in reference to the western aspect of the Southern Alps will be found on pages 92 to 105, and 158 to 165 of the same chapter. Characteristic photographs, taken by Messrs. E. P. Sealy, Grand and Dunlop, and the late Thomas Pringle, of the river-bed of the Waimakariri with the Southern Alps from the West Coast Road, of the head of the great Tasman glacier, of Mount Cook, and the Hooker glacier from the Müller glacier, of the Moorhouse range with the Sefton peak and the terminal face of the Müller glacier, and of the Francis Joseph glacier, reproduced, with the exception of the last-mentioned, in photo-lithography will, better than words can convey, give an insight into the characteristic features of the alpine chain under review. I may here observe that, with the exception of Kai-matau, at the head of the Waimakariri, and which is probably Mount Davie,* Ao-rangi† (Mount Cook), and Unuroa (the Arrowsmith range), the Maoris appear to have no names for the principal peaks in the central chain, which is astonishing considering that they have named almost every creek and every lake, even the smallest, on both slopes of the Southern Alps, although at present it is very difficult, if not impossible, to obtain reliable information about it. My friend, the Rev. James W. Stack, has, however, undertaken to obtain as much information as possible on the subject, which will be added as an Appendix to this report.

The highest summit at the head of the Rakaia, and which is visible from all prominent points, is Mount Ramsay, whence the principal ice masses of the Lyell and Ramsay glaciers descend; its altitude is about 11,000 feet. A number of high peaks, of which Mount Lyell is almost surrounded by large *nevé* fields, connect it with the Tyndall range. From here a lateral chain, scarcely inferior to the main chain, runs for about sixteen miles due east, culminating and terminating in the Arrowsmith range, where the glacier sources of the Cameron and

* The Maoris were never able to point out to me which mountain in particular they designated by this name. They always pointed to the central chain at the head of the Waimakariri, when I asked them where Kaimatau was situated.

† In a former publication I gave, from information received, the Maori name of Mount Cook, as "Ahoa-rangi" (Piercer of Heaven); Mr. Stack, however, is cruel enough to dispel the pretty illusion by pointing out that this is not correct the real name being Ao-rangi (cloud-capped), as he has ascertained from the aged Maoris.

southern Ashburton are situated. On the southern side of this hi[illegible] chain, the more eastern branches of the Rangitata take their rise; th[illegible] Havelock, the more westerly branch, coming from the central chain proper, or the Tyndall range, as I have here designated it. The south-western and highest point of the Tyndall range forms Mount Tyndall, a lofty mountain of a conspicuous dome-like form, situated at the head of the great Godley glacier. It is here surrounded by very large snow-fields; towards the Havelock glacier, it falls so steeply that only a comparatively small amount of snow can accumulate there.

I may here add that from Whitcombe's peak, a high alpine range, the Lange range runs for a considerable distance in a northern direction, its eastern slopes augmenting the waters of the Hokitika considerably, whilst the glacier sources of the Waitaha are situated on the opposite side. The Wanganui, another important river of Westland, reaching the sea thirteen miles south of the former, issues from the glaciers which are formed from the vast snow-fields opposite the sources of the Rakaia, and which encircle the summits of Mount Ramsay and Mount Lyell, and the north-western slopes of the Tyndall range. The vast snowfields of Mount Tyndall, Mount Petermann, and the Keith Johnston ranges form the magnificent Godley glacier, bein[illegible] in extent only second to the Tasman glacier. Mount Petermann, a sharp pyramidical peak, is separated on both sides by a deep *nevé* saddle from the two other ranges mentioned. Another important branch of the Godley glacier descends from the southern portion of the Keith Johnston and northern portion of the Hector range. From Mount Tyndall a divergent chain runs in a southerly direction, terminating at the junction of the Macaulay and Godley rivers; for about 18 miles it is covered with perpetual snow, having in Mount Forbes still a height of about 10,000 feet. From this chain, the Fitz-gerald glacier descends to within half-a-mile of the Godley glacier, under which its outlet flows. On the western flanks, lie the Forbes glacier, the outlet of which falls into the Havelock; on the south slopes, several glaciers are situated which form the sources of the Macaulay, whilst some others of smaller extent reach into the upper waters of the Godley ri[illegible] Excepting Mount Cook, which is visible from the summits of L[illegible]k's Peninsula, from Lake Ellesmere and Southbridge as well as from Timaru, Mount Forbes is the only peak of the Southern Alps proper which can be seen from the Canterbury plains; it appears at the head of the large Ashburton opening as a sharp pyramidical peak.

I have already pointed out that Sealy's Pass, a *nevé* saddle of about [illegible]000 feet altitude, leads from the Godley glacier into the head waters of the Whataroa, a rapid and large glacier river, reaching the sea about four miles north of the Okarito lagoon. It is important to note this fact, as it proves convincingly that owing to the enormous size of the Godley glacier, and the vast snow-fields from which it is formed, there is such a great amount of condensation of atmospheric moisture, and such a lowering of the mean annual temperature in this part of the Southern Alps, that the perpetual snow-line here descends considerably below 6000 feet. The Keith Johnston range on the southern side of Sealy's Pass, is separated from the Hector range by a high col; this latter range falls abruptly towards the Grey glacier, a tributary of the Godley glacier, whilst on its south-eastern slopes, large *nevé* fields feed the Classen glacier. At the southern end of the Hector range, Mount Beaumont rises, and from the West Coast stands out as a high rocky pyramid, with abrupt slopes and a nearly square summit; whilst, viewed from the Great Tasman glacier, it appears almost entirely enveloped in snow-fields of great extent, so that scarcely any rocks are visible. An important chain branches off from here, running to the south, separated from Mount Beaumont by a *nevé* saddle, about 8000 feet high. It first forms, on the southern side of the col, the Hochstetter Dome, the sides and summit of which are entirely hidden by snow-fields. This mountain is separated by a deep depression from Mount Darwin, a magnificent mountain about 12,000 feet high, resembling in its grand pyramidical form Mount Beaumont, as seen from the West Coast. Some of the principal glaciers of the New Zealand Alps have their origin here; the Tasman glacier from the south-western, the Classen glacier from the eastern, and the Murchison glacier from the southern slopes. The Agassiz glacier, and some other smaller glaciers north of it, descend from the western divide of Mount Beaumont towards the West Coast, forming the northern branches of the Waiau river. Between the Tasman and Murchison glaciers, lies the bold and picturesque Malte Brun range, appearing like an island, the Murchison glacier having at no distant date joined the former and thus surrounded this lofty snow-capped ridge. From Mount [illegible], the convergent range still continues its southern direction, where [illegible]rst in the Liebig range, the glacier sources of the River Cass, one of the affluents of Lake Takapo are situated, and then still further south in Mount Jukes, those of the river Jollie, one of the tributaries of the Tasman. From Mount Beaumont, the Southern Alps continue their south-westerly direction without interruption, forming the glorious peaks of Mount de la Beche, Mount Haidinger, Mount Tasman; and last, but not least, their crowning summit, Mount Cook, the latter being separated from Mount Tasman by a rocky comb of considerable altitude. Numerous tributary glaciers descend from the eastern slopes of these peaks, of which the one between Mount de la Beche and Mount Haidinger, and another between Mount Tasman and Mount Cook, which I have named the Hochstetter glacier, are the most important; the latter forming one of the finest ice cascades imaginable. From the western flanks descends the beautiful Francis Joseph glacier, the main source of the Waiau river, of the principal features of which I have given some details in the first part. Another glacier of similar size, and descending to the same low region, is the Prince Alfred glacier; its outlet forms the main source of the Weheka, one of the principal rivers on the West Coast. Some other glaciers of considerable size also descend here from the western flanks of the Southern Alps, of which the Balfour glacier is fed by the snow-fields on the western flanks of Mount Cook.

I may here allude to the curious fact, that for a long time the identity of Mount Cook, as seen from the West Coast, was disputed, even officially by members of the Survey Department, they mistaking Mount Tasman (or what some still persist in calling the Dome) for Mount Cook, the peculiar orographical features of the ranges causing this mistake. We are so accustomed to see Mount Cook in its peculiar tent-like form from the east coast, when we observe it from or near Bank's Peninsula, or from Timaru, that when it appears to us as a sharp pyramid or needle, standing behind another mountain of a dome-like form, we fail, at first, to recognise it. However, the explanation is very simple:—Mount Tasman, situated so much more to the west than Mount Cook, hides the latter almost entirely, not only as seen from Hokitika, but its northern aspect when we look against the front, as it were, of its peculiar tent-like form, is so very different from its appearance as seen from east or west, when on or near the same latitude, that the explorer is easily deceived. However, when advancing south along the coast, we observe that the beautiful peak, which at Hokitika appears to the left of Mount Tasman, gradually shifts its position, so that near the mouth of the Wanganui river its highest summit stands in one line with Mount Tasman, so as scarcely to be recognised by a casual observer. Near Okarito, Mount Cook already stands to the left, but still appears to belong to the somewhat lower mountain in front; but at the mouth of the Waiau, the deep depression between Mount Tasman and Mount Cook is well visible, the latter, however, here exhibiting the sharp needle form. Continuing our course still more towards the south this appearance gradually changes, so that on Gillespie's beach, south of the mouth of the Karangarua river, Mount Cook's form is the same as seen from the east coast, separated from Mount Tasman by a rocky ridge, which is so very steep that scarcely any snow can accumulate on it.*

I observed no col of any consequence in this portion of the stupendous alpine chain, the average height of which may be estimated at from 10,000 to 11,000 feet, and which finds its termination in Mount Cook, or Ao-rangi. This mountain not only rises so remarkably above all the others, but it is the more conspicuous, as on its southern side, as already mentioned, it is separated from Mount Tasman by a serrated ridge 8,000 to 9,000 feet high, and on its south-western side, from Mount Stokes by a snow covered col of the same altitude, well visible from the Hooker and Mueller glaciers. On the south-western side of this col, the New Zealand Alps soon rise again to a considerable altitude, so that the Sefton Peak is not much inferior to Mount Cook. They continue towards south-west under the name of the Moorhouse range to Mount Holmes, culminating in the Sefton Peak. From the south and south-western slopes of Mount Cook and the eastern slopes of Mount Stokes and the Moorhouse range the Hooker glacier takes

* Since this was written, I have seen "Notes on the Valley Systems on the Western Flanks of Mount Cook," by J. H. Cox, F.G.S. (Transactions New Zealand Institute, Vol. IX), who ascended the ridge on the southern side of the Prince Alfred (Fox) glacier, and whose notes confirm my former observations that the Francis Joseph glacier brings down the vast masses of snow from Mount de la Beche and the north-western flanks of Mount Haidinger, and the Prince Alfred glacier, those of the south-western flanks of Mount Haidinger, and the western slopes of Mount Tasman; the Balfour glacier being fed principally by avalanches from Mount Cook. This is one of those peculiar glaciers of which several are also found on the eastern side of the Southern Alps, formed in a manner different from the usual mode in which glaciers take their origin. Mr. Cox also states that the southern branch of the Weheka takes its rise near Mount Sefton, where glaciers of considerable size descend towards the valleys, as can even be seen from the coast. A glance at the map attached to this Report, will show the reader that this accords perfectly well with my observations, although I had to construct it, for that portion of the Southern Alps, from materia which in some essential points was far from satisfactory. As this map shows, only a small portion of the western flanks of Mount Cook drains towards the West Coast, but how the river Whataroa, as Mr. Cox suggests, could possibly take its rise from Mount Cook, is inconceivable to me. An examination of the map will prove that the snow-fields from which the glaciers feeding that river take their rise, are situated on the western slopes of the Hector and Keith Johnstone ranges, at least sixteen miles to the north east of Mount Cook. Moreover, the *nevés* of numerous other glaciers, such as the Francis Joseph, Agassiz, and several others, reach to the very summit of the Southern Alps between these two points; in fact, Mount Tasman (or "the Dome" of Mr Cox), which is situated north of Mount Cook, sends down from its large snow-fields the Prince Alfred glacier, thus cutting off all communication between Mount Cook and the north.

its rise, and its outlet, after uniting with the outlet of the Mueller glacier, forms one of the principal tributaries of the Tasman river. The last mentioned glacier is formed from the *nevé* fields on the eastern slopes of the Sefton Peak. The western snow-fields of this magnificent range, of which Mr. Sealy's photograph gives a fine representation, form the glacier sources of the southern branches of the Weheka and of the northern branches of the Karangarua, the southern declivities forming the Selwyn glacier at the head of the Dobson river and the north-western feeder of the Richardson glacier, the main source of the river Hopkins. Here a deep depression occurs, separating the Moorhouse range from Mount Holmes, a fine pyramidical mountain possessing large snow-fields on its slopes.

As before observed, from this peak the Southern Alps divide into two distinct chains, of which the western one runs in a nearly western direction to Mount Hooker; thence re-assuming the usual north-east and south-west line, as the Grey ranges, it reaches the lower course of the River Haast, which here cuts through this bifurcation of the central chain. On the southern banks of that river, it rises again above the perpetual snow-line till in Mount Kinross and to the west of Haast's Pass the two ranges re-unite. The eastern chain, forming the watershed between the River Hopkins and the River Haast, is also of considerable altitude, numerous glaciers descending from it. First as the Ritter range, and afterwards as Mount Ward, Mount Napoleon and Mount Brewster on the eastern side of Haast's Pass, it rises high above the snow-line and has some peculiar, charming features, its lower portion being mostly covered with fine beech forest.

On the south-eastern slopes, the glacier sources of the River Hunter forming Lake Hawea, are situated. In the basin thus formed between this bifurcation, all the main branches of the River Haast take their rise; the principal one, the Landsborough, draining the vast snow-fields of Mount Ward, as well as those of the Ritter range. Between Mount Cotta and Mount Hooker, Docherty's Pass, about 5000 feet high, at the head of the Clarke river, is situated, discovered by Mr. W. Docherty in 1864, and by which the explorer can descend to the sources of the Mahitaki river, and thus reach Bruce Bay. The western drainage of Mount Holmes and Mount Cotta is by the southern branches of the Karangarua. In the first part, I have already alluded to the principal characteristics of Haast's Pass (1716 feet above the sea-level), doubtless the lowest Pass across the Southern Alps throughout the whole Island.

Near it the sources of the Makaroa, falling into Lake Wanaka take their rise, being formed by glacier streams of considerable size descending from both sides of the Southern Alps. On the western side in Mount Kinross, a fine dome-like peak, the latter continue to the southern boundary of the Province as Mount Alba, Castor and Pollux, Glacier Dome, and Mount Aspiring. They still rise to a considerable altitude, covered with perpetual snow; but it is very clear that the Alps south of the Moorehouse range begin to lose their continuity, being now broken into sharp pyramidical peaks, seldom attaining an altitude of 10,000 feet, with deep but generally inaccessible saddles between them. The river Makaroa receives a considerable supply of water by the Blue river, the Young, and the Wilkin, all of which drain the eastern slopes of the Alps. Near the head of the Young, or of the north-western sources of the Wilkin, a Pass exists well visible from the West Coast, of which the Maoris gave me an account, but hitherto, as far as I am aware, it has not been reached by any European explorer.

Having now given a short outline of the orographical features of the Southern Alps proper, I wish to say a few words concerning the divergent chains, or secondary ridges starting from them and covering a considerable portion of the province. Again, beginning in the north at the Snowcup range, south of the Hurunui Pass, where the sources of the two main branches of the Hurunni and of the Poulter, a considerable branch of the Waimakariri, are situated, this mountain sends a chain in a southerly direction to Ashley Head. Here it bifurcates, the smaller branch, continuing the southern direction, terminates in Mount Thomas, the main branch continuing south-south-west as Mount Pember and the Puketeraki range to the gorge of the Waimakariri. This range is still 6,000 to 7,000 feet high, well visible from Christchurch, and abounds in splendid scenery, heightened by fine beech forest vegetation. East of the Upper Ashley, the mountains have more rounded outlines, they rise in the highest summits only to 3,000 or 4,000 feet, Mount Grey (3074 feet) being one of the most conspicuous. Between the Waimakariri and Raka a, the eastern continuation of Mount Greenlaw, is called the Black range, and although of considerable altitude, it does not reach the line of perpetual snows. It is separated from the Cragieburn range by a saddle named Sale's Pass, (after its discoverer, Professor G. Sale), leading from the sources of the Harper into those of the Cass. The Cragieburn range, still rising to about 7000 feet, is remarkable by being in its upper and middle portion nearly devoid of vegetation, the whole sides forming an almost continuous talus of debris. This large range is separated from Mount Torlesse and the Thirteen Mile Bush range (Big Ben) by the valley of the Acheron, Lake Lyndon, and the valley of the Porter. These two fine ranges, separated by Porter's Pass, forming such a conspicuous object from the streets of Christchurch on a fine winter's day when they appear entirely covered with snow, may be considered the southern continuation of the Puketeraki range. The highest peak of Mount Torlesse is 6136 feet high, whilst Big Ben, the summit of the Thirteen Mile Bush range, reaches only an altitude of 5224 feet. Both ranges are covered on the eastern slopes with large beech forests, of which the upper limit is about 4500 feet.

I have already pointed out that the divergent chain, between the Upper Rakaia and Rangitata rivers, rises in Mount Arrowsmith, still high above the line of perpetual snow. This is the more conspicuous, as its eastern continuation has been cut off entirely by the remarkable broad plains, former glacier channels, which here unite the valleys of the Rangitata, Ashburton, and Cameron with that of the Rakaia. However, the cluster of mountains, which lies here to the east of this broad old glacier course, rises still to a considerable altitude, of which the highest summits of the Mount Somers range reach about 7200 feet, whilst Mount Hutt, forming such a conspicuous object, as viewed from the Canterbury plains, is 6800 feet high. This is the highest mountain rising directly from the Canterbury plains. From Mount Forbes, at the head of the Macaulay, a magnificent chain runs south, forming mostly pyramidical peaks, but not high enough for the formation of snow-fields to any extent. This range, which forms the western boundary of the upper Rangitata plains, is called the Two Thumb range from the peculiar form of its twin summits, appearing as if two thumbs had been put against each other. Its southern continuation, Mount Sinclair, is considerably lower, although still 7022 feet high; further south, on the eastern shores of Lake Takapo, it is called the Dobson range, where its highest summit has now an altitude of 6271 feet, falling abruptly to Burke's Pass, 2464 feet. On the southern side of this pass, the continuity of the range is much broken by several passes, such as the Mackenzie and Hakataramea Passes, all former glacier channels for the enormous ice masses of the great Waitaki glacier during the great New Zealand Glacier Period, here passing over and between the ranges, which have lost much of their altitude and are worn down and rounded off, as observed in all glacialized countries. More to the south, longitudinal ranges, still 5000 to 6000 feet high, rise from the Hakataramea Pass, between this river and the lower Mackenzie plains to the Waitaki, another from the Mackenzie Pass to Mount Nimrod, where it subdivides, of which the western branch, running between the Hakataramea and Waihoa, reaches the northern bank of the Waitaki, whilst the eastern one, under the name of the Hunter range, finds its termination near the Waimate.

I have repeatedly alluded to the Great New Zealand Ice Period, or Glacier Epoch, and as this remarkable era plays such an important part in the Physical Geology of New Zealand, I may be allowed here to make a few remarks upon it for the general reader, the more so as there are scarcely anywhere alpine countries so easily accessible for the scientific observer, bearing such clear and distinct traces of the post tertiary Glacier Period, as the Alps of New Zealand. The action of the giant ice ploughs, as we may well call these glaciers, has essentially assisted in preparing the lower regions for the use of man, since by it the narrow valleys have been widened, the rugged mountains rounded off, and large plains have been formed. Thus we find everywhere, as soon as we penetrate into the New Zealand Alps, where even the outrunning ridges near the plains often attain a height of 6000 feet, that the valleys are distinguished by rugged forms, where the rivers which break through them have not only cut their bed deeply into the rocks, but have also formed such steep precipices that it is often impossible, even for the pedestrian, to pass along their banks, in order to reach the alpine lakes or plains situated in the valleys above. Inside of the eastern divergent chains, as soon as we enter the district of the earlier post tertiary glaciers, the valleys widen out to broad basins, the mountains on both sides—or even standing in the middle of the valley—have the recognised *roche moutonnée*, or ice-worn rounded-hill form, and the fall of the rivers is less rapid. At the upper end of these flats, which are filled up with drift, alluvium, and glacier deposits, and through which the rivers have cut their new bed, lakes, surrounded by distinct moraines, are generally situated. The regular occurrence of these earlier terminal and lateral moraines supply us with the incontestable evidence that these lakes have been formed by the retreat of the glaciers. These lakes are found in every possible stage; some have already disappeared, the delta of the principal tributary entering from the Alps having completely filled them up; others are very much contracted by the deltas of the main affluent and of the secondary water-courses descending from both sides; others again are great swamps, having become so shallow, through the enormous quantity of glacier silt deposited in them, that they also may soon disappear under the continually advancing masses of debris.

The extent of these flats, and of the lakes in them, stand in almost all cases in exact proportion to the extent of the present glaciers at the end of the valley, and, therefore, of course to the height, extension, and other orographical conditions of the alpine chains. The form and width of the valleys above the alpine lakes show in the most striking way that they must have once been the bed of great glaciers, to the action of which they principally owe their present form. They are frequently, even up to the present glaciers, of the same width as the lakes. On both sides of them, several thousand feet above the level of the valley, enormous moraines are found stretching along the mountains, so that one can often follow the terminal moraine at the lower end of the lake for twenty miles upwards. *Roches moutonnées* occur everywhere. However, where the colossal glaciers of the Ice Period have pierced through to the Canterbury plains, the secondary ridges are also rounded off and the valleys widened.

In the valleys several miles wide, the present rivers flow in numbers of branches, uniting and separating a hundred times, and changing their bed after each great fresh. At the same time they are often so straight, that one can see the glaciers from the lakes, as is the case, for example, at Lake Pukaki, from which the Tasman glacier, and Lake Takapo from which the Classen glacier can be seen. Indeed it does not require much power of imagination to bring before one the time when the glaciers were often fifty to sixty miles long and six to ten miles wide. In one of my official reports "On the formation of the Canterbury Plains," I have given a detailed description and explanation of these interesting and important physical geological conditions.

In order to understand the former occurrence of the great post-pliocene glaciers, we have to assume no change in the climate, but simply to consider the existence of the plateau-like mountain systems towering above the snow-line, the enormous snow masses of which might be sufficient to explain the existence and extension of the glaciers. A comparison with the Dovrefield in Norway might perhaps not be out of place here. I have also tried to show that the terrace formation which we meet with everywhere, even in the valley of the most unimportant streamlet, has not been brought about by an upheaval of the land, but only and entirely by the retreating of the sources and the gradual deeper washing out or excavation of the valleys. I have already remarked that most of the principal valleys contract before they enter the Canterbury plains from the lower Alps, but some of those which, in the Ice period, lodged particularly large masses of glaciers, form an exception to this rule. I will only quote one as an example: the Rakaia valley, which continues to widen without interruption until it enters the Canterbury plains, where it has attained a breadth of five miles. This is, however, quite natural when we find the last terminal moraine on the Canterbury plains themselves, where it extends over them in a half circle for ten miles, and shows clearly that the ice masses of this glacier were so enormous, that when they came out into the open plains they were able to extend into the form of a gigantic fan. It is, therefore, a matter of course that along the whole valley, from the sources of the glacier to the plains, not only the mountain sides exhibit signs of glacier action and are fringed by moraines of great extent, but that also the mountains in the valley itself must possess the *roche moutonnée* form. Indeed the shape of those in the neighbourhood of Lake Coleridge, a true glacier basin, is so peculiar that they have been named "sugarloaves," and the colonists mistook them to be volcanic cones, until I was able to make them acquainted with the real cause of their peculiar form. Thus the Southern Island of New Zealand owes it principally to the Ice Period that, united to the North Island, it can lay claim to the title of "Britain of the South," because by its operations have been formed the magnificent plains for agriculture, and the rounded hills and mountain sides so favourable for depasturing cattle and sheep. I have taken the liberty of making this digression, in order to explain the peculiar conditions which surround the traveller the farther he penetrates into the heart of the Alps, and which would remain a mystery to him had not geological researches supplied the key to their explanation.

The divergent ranges between the Takapo and Pukaki systems, although very high, are not extensive as they terminate at the northern boundary of the Mackenzie plains. The rivers Cass and Jollie have their glacier sources amongst them. Whilst this latter range consists of three parallel chains, the high mountain range which begins east of the rocky saddle between the Moorhouse and Sealy ranges, has only one water-shed, the eastern side draining into the Tasman and the western into the Dobson river. It is nearly forty miles long, and many peaks of its northern portion are covered with perpetual snow. As the Ben Ohau range, where it has lost considerably in its altitude, it slopes to the Mackenzie plains, near the outlet of Lake Ohau.

I have already given a description of the bifurcation of the Southern Alps south of Mount Holmes. The eastern chain at Mount Ward, a prominent peak, subdivides again and forms two large ranges, of which one, after skirting the western shores of Lake Ohau and forming the western boundary of the Mackenzie plains, ends six miles south of that lake. It is separated from the western range by the River Ahuriri, one of the tributaries of the Waitaki; this western range, also of considerable altitude, crosses into the Province of Otago, and after being intersected by a saddle called Lindis Pass, it continues as the Dunstan range to the junction of the Manuherekia with the Molyneux. On the western banks of the River Hunter, which washes the western foot of the last mentioned chain, the Young range rises and forms the southern continuation of Mount Brewster. It runs along the eastern banks of the Makaroa river, and of Lake Wanaka, where, gradually getting lower, it comes to a termination near the southern end of the lake. There is only one mountain system in the Province of Canterbury which is not connected with the central chain, namely, Bank's Peninsula; this system, even in quaternary times an island, was joined during the formation of the lower portion of the Canterbury plains to the main land. It rises to a considerable altitude, Mount Herbert being 3100 feet high. It abounds in deep indentations, ancient volcanic craters, of which several form remarkably fine harbours. Some of the western indentations, such as Lake Forsyth with the valley of Little River, and the Kaituna and Gebbie valleys, show clearly by their configuration that they owe their present form to marine action.

CHAPTER III.

Glaciers, Rivers, and Lakes.

Owing to the intimate connection in which, with the exception of a few minor streams, the glaciers, rivers, and lakes stand with each other, I have thought it most convenient to treat of them together, in order to avoid repetition. Measured with Amsler's planometer on the map of the Province of Canterbury, published before the secession of Westland, by authority of the Provincial Government, in September, 1866, on a scale of 10 miles to 1 inch, the area of both provinces is 17,963 square miles; there are, consequently 62 miles less than the amount given in later official records, which is:—For Canterbury, 13,583 miles, and Westland, 4442 miles; total, 18,025 miles.

Calculating the hydrographic basins on both slopes, those on the eastern side amount only to 13,353 square miles, whilst those on the western side reach 4610 square miles, which is caused by the fact, that some sources of the western river systems stretch across the boundary line between the two provinces, running along the main divide of the Southern Alps. It will be difficult to find another country with an area of such limited extent as these two provinces, possessing so many important water-courses, of which however none, with the exception of a few tidal rivers, are navigable. Of the hydrographic basins reaching to the main divide, or owing their origin to true glaciers, six are situated on the eastern slopes, namely—the Waimakariri, Rakaia, Ashburton, Rangitata, Waitaki, and Molyneux; and sixteen on the western slopes—the Taramakau, Arahura, Hokitika, Waitaha, Wanganui, Whataroa, Waiau, Waikukupa, Weheka, Karangarua, Mahitahi, Paringa, Haast, Okura, Waiatoto, and Arawata; the rest, of which the area will be found in the following list, having their sources in the secondary ranges. Of Banks Peninsula, forming an orographical system separated from the rest, I have only given the total area, the drainage being divided into portions too small for calculation by the process mentioned. With the exception of the Waitaki, of which the southern portion lies in Otago, the northern half of the Hurunui system, and a small portion of the Taramakau sources, both situated in Nelson, all the hydrographic basins are comprised within the boundaries of the two provinces. Exception must, however, be taken to the southern sources of the Molyneux, (the largest river in New Zealand), which are situated in this province, by far the greater portion of its hydrographic system being in Otago.

Areas of the Hydrographic Basins in Canterbury and Westland, according to their extent.

Eastern Slopes of Southern Alps.

	sq. m.
Waitaki, of which 3140 square miles are in Canterbury, and 1774 square miles in Otago	4914
Rakaia	1547
Waimakariri	1544
Hurunui, of which 538 square miles are in Canterbury, and 678 square miles in Nelson	1216
Opihi	967
Ashburton	884
Rangitata	869
Molyneux or Clutha, northern sources in Canterbury	685
Selwyn	491
Ashley	484
Waihao	324
Orari	298
Waipara	274
Pareora	259
Hinds	245
Makikihi	87
Kowai	84
Otaio	72
Motunau	71
Banks Peninsula	490

WESTERN SLOPES OF THE SOUTHERN ALPS.	sq.m.
Haast	540
Taramakau, of which 26 in Nelson and 417 in Canterbury	443
Hokitika	410
Arawata	281
Paringa	227
Wanganui	192
Whataroa	186
Grey and Arnold	184
Waiau	176
Weheka	175
Okura	164
Waitaha	155
Karangarua	136
Waiatoto	135
Arahura	133
Okarito	128
Mikonui	124
Mahitahi	124
Poerua	103
Waikukupa	98
Pauapeka	98
Stafford, Cascade, Hope, &c.	428

The river which is the most important and has the longest course, is the Waitaki, its length from the Tasman glacier, including Lake Pukaki, being 117 miles. Some of the West Coast rivers, although only 12 or 14 miles long, are nevertheless of considerable size, and notwithstanding they are flowing over a broad shingle-bed, they can only be crossed on foot after a continuation of fine weather. As pointed out in the first part, glaciers of considerable size are here situated near the termination of the outrunning spurs on the West Coast plains, and at altitudes of about 700 feet above the sea level, where pines and arborescent ferns are still growing most luxuriantly in the valleys and at the foot of the ranges. I think, therefore, that some observations on the occurrence of glaciers in such a low position. and on the causes to which we must attribute such a remarkable phenomenon, may not be deemed superfluous. I may therefore be allowed to insert here a portion of a lecture delivered in Christchurch shortly after my return from the West Coast in 1865, treating on the subject,* and add a few more observations in further illustration.

* Lecture "On the West Coast," delivered to the members of the Mechanics' Institute, on the evening of Monday, September 25, 1865. By Dr. Julius Haast. Fol. Christchurch, Ward and Reeves, 1865.

Although we then possessed only very scanty meteorological material from the West coast, I may state that the observations since taken for a number of years at the meteorological station at Hokitika have amply verified my views on the subject, as stated in the lecture in question. From the time that the first explorer set his foot on the West Coast of this Island to the discovery of the goldfields, the difference of rainfall on the opposite coasts has always been a topic of great interest. It is obvious that the quantity of rain falling will seem still larger when the explorer is travelling in a forest which, generally, before it is thoroughly dried after a downpour, is again soaked through by new showers.

When writing in 1865 on the subject, we had not sufficient data to go upon to determine, with accuracy, the differences, in inches, of the rainfall between the two coasts, although the valuable observations of Dr. Hector, in 1863, for seven months, from the first of June to end of December, showed that there fell, in the south-western part of this island, 87 inches, whilst in Dunedin it was only 23¼, proving that the quantity of rain was more than three times and a-half as great at the West Coast as at the East Coast. Concerning the difference between Christchurch and Hokitika, we had only reliable data since the 29th of April, 1865, when Mr. John Rochfort set up a rain-gauge at the latter town. From the 29th of April to the 3rd of July, 1865, inclusive, 67 days, 36½ inches of rain fell in Hokitika, whilst in the corresponding period it was only 7½ inches in Christchurch; consequently, about the fifth part. In the meteorological reports of the colony for the year 1875, the annual rainfall for 1874 is given for Hokitika as 104·480, and the mean for the previous eight years as 113·116; for Christchurch, as 22·790, and for the previous ten years as 25·727; consequently, although in some years the annual rainfall will be more than five times as much at Hokitika than at Christchurch, the average will reach to about four times and a-half.

As I observed already in former publications we have to seek the cause of that enormous difference in the position of the West Coast, so well exposed to the equatorial currents, which bring with them a greater amount of rain everywhere, where the same conditions exist, and of which I shall give only a few instances. The rainfall at the north-west coast of America is 80 inches; at Bergen in Norway, 83 inches; at Coimbra, in Portugal, 110 inches; and at Westmoreland, in England, as much as 134 inches annually. That there is also such a similar heavy rainfall at the western coast of South America we know from Darwin's classical works on that region. Like our own West Coast, the former is covered with a dense and uniform forest vegetation, which, of course, again favours the condensation of the clouds, and, consequently, the fall of rain; but these dense forests are generally not the cause of the rainfall, as popularly has been assumed, but are a consequence of it. It is obvious, from the fact of the snow-line, which owing to the equable and humid climate on the West Coast, is very low, probably about 6000 feet near Mount Cook, and from the fact that the fall of snow and condensation of moisture must be still greater in those higher regions, where equatorial currents come in contact with the cold surfaces of the Alps, that all necessary conditions exist not only for the formation of large glaciers, but also for their descent to much lower regions than at the east coast.

Standing at the sea-coast near Hokitika, I very often observed that the mountains bounding the West Coast plains were covered with nimbus or rain clouds, whilst we enjoyed fine weather near the sea. At the same time, very often, smaller freshets in the rivers could be observed, when not a drop of rain had fallen near the sea-beach, all confirming the still larger amount of moisture falling in the higher regions. The difference between the eastern and western side of the central chain is well exhibited by the great Tasman glacier, which, although of much larger dimensions than the Francis Joseph glacier, yet descends only to 2456 feet above the sea-level, whilst the latter reaches more than 1700 feet lower, namely, to 705 feet above the sea. It is true that particular circumstances—as, for instance, a large cauldron-like basin, sheltered from the sun's rays by Mount de la Beche and its outrunning spurs, in which these enormous snow masses can accumulate, is very favourable for allowing that glacier to descend to such a low positon above the sea-level, where arborescent ferns, pines, and other low land trees are growing. But if we compare its position with others in South America, we shall find that, from ranges which are not so elevated as our Southern Alps, even in latitudes corresponding with the northern end of Stewart's Island, enormous glaciers descend in latitude 46 deg. 50 min., according to Darwin, to the level of the sea, their terminal face being ultimately washed away and carried along as huge icebergs. Thus the conditions for the lowering of the snow-line and of the excess of moisture must still be greater in that part of America than in New Zealand, where the neighbourhood of Australia and Tasmania will certainly exercise some moderating influence, which in Terra del Fuego does not exist. From observations made in those and other regions, it is clear that the lowering of the snow line does not depend on the mean temperature of the year, but on the low temperature of the summer. The mean summer temperature in Christchurch in 1874 was 62 deg., and in Hokitika 58·9 deg., the difference in favour of the east coast being without doubt attributable to the clear and cloudless sky we so often enjoy during summer. Thus, the overcast atmosphere, in combination with the far greater rainfall, accounts for such a lowering of the snow-line on the western side of the Alps, when compared with the eastern slopes.

However, this deficiency of the Hokitika summer temperature is more than compensated in the winter, when, in Hokitika, in 1874, it was registered as 45·8 against 42·6 in Christchurch, the difference being 3·2 degrees; this fact thus fully confirming my previous opinion as given in 1865, when no corresponding observations had as yet been made at the West Coast. I may here add that the annual mean temperature was 52·6 in Christchurch, and 53·8 in Hokitika, or 1·2 higher at the West Coast during that year. The position of the Francis Joseph glacier is about 43 deg. 35 min., corresponding in the Northern Hemisphere with that of Montpelier, Pau, and Marseilles in France, and Leghorn in Italy, where the orange and lemon tree, the vine and the fig tree, are covered with juicy fruits, and where palm trees raise their graceful crown into the balmy air. Even in the European Alps, which lie some degrees further north, the average altitude of the terminal face of the larger glaciers is about 4000 feet, whilst we have to go twenty degrees more to the north, till we find, in Norway, glaciers descending to the same low position as the glacier under consideration, and to about 67 deg. north, according to Leopold von Buch, before the terminal face reaches the sea; consequently more than 20 deg. more towards the Pole than in the Southern Hemisphere, in Terra del Fuego.

All the principal meteorological phenomena encountered in the European Alps, and which have been described and explained so differently, according to the point of view taken by each writer individually, also occur here, the nor'-wester of New Zealand (equatorial current) being simply the föhn of Switzerland or sirocco of Italy. As formerly pointed out, the snow-fields and glaciers of the Southern Alps, when compared with those of Europe, are of much larger dimensions, especially if we take the altitude of the mountains into due consideration. That they were formerly of still more gigantic proportions is, amongst other indications, well shown by the line of lakes on both sides of the Southern Alps, and the enormous moraines surrounding them, which mark clearly the latest extension of the post-pliocene glaciers.

Discussions such as those which were going on some years ago between Professor Dove, of Berlin, and some of the principal scientific men of Switzerland, would have been much simplified had those gentlemen been acquainted with all the characteristic features of our nor'westers, being in every respect identical with the phenomena described by Professor Dove, with whose writings I am best acquainted, and with whose conclusions I entirely concur, as being the characteristics of the föhn. In fact, his description of the föhn from its first setting in on the Italian side of the European Alps, its crossing and effects on the Swiss side is such, that if we change the word Italian for western, and Swiss for eastern side, every inhabitant of this island who has travelled across it would consider it a faithful description of our nor'westers as travelling from coast to coast. However, I may point out that occasionally our nor'westers do not bring rain with them when crossing the height of land, having descended before they reached the Southern Alps, thus becoming deprived of the principal portion of their moisture on the sea or on the low lands lying at the western foot of the ranges. When these winds pass across the snow-fields of the Southern Alps, the cumulus clouds creeping up, disappear as by enchantment, and the sky remains of a deep blue colour, but the wind sweeping down the valleys is very hot, and the rising of the glacier torrents shows at once its effect. A theory tracing them to the interior of Australia would be difficult to prove.

The Waitaki.

Taking the rivers according to their volume, and the extent of the hydrographic basins they drain, the Waitaki, as previously pointed out, is the most important. The sources of this river rise in those regions of the Southern Alps, which are not only the highest, but where also snow-fields of the largest extent exist, from which a number of huge glaciers descend to lower regions. Amongst them, the great Tasman glacier, the main source of the Waitaki, is the most important, its length being 18 miles, whilst at its terminal face its breadth is still one mile and three-quarters; it is the glacier that reaches lowest in New Zealand on the eastern side of the Alps, as its lower extremity stands only 2456 feet above the level of the sea. For three miles from

Lake Takapo is fifteen miles long with an average breadth of three miles; it is not only surrounded by morainic accumulations like Lake Pukaki, but owing to the presence of large ranges on both sides, older moraines rising about 1500 feet above its surface, and looking like gigantic terraces, accompany its eastern and western shores. Its waters are also of a milky-white colour, and it possesses several islands situated in about its centre, consisting of a very hard semi-crystalline bluish sandstone very much ice-worn. Unlike Lake Pukaki, where we still meet with small remnants of *Fagus* forest, Lake Takapo, although only 2437 feet above the sea level, lies already above the forest line, only sub-alpine vegetation growing near its banks. The high mean elevation of the country is, without doubt, the cause of this peculiarity. The difference of level of Lake Takapo, between its highest and lowest water mark, is eight feet; the lake has been known to rise four feet in twenty-four hours during heavy rain, but it takes some weeks to fall again to its usual level. Lake Takapo receives another important affluent on its western side, namely, the Cass, the glacier sources of which are situated on the south-eastern and southern declivities of the Liebig range, its course being nearly due north and south, and about 22 miles long. A few miles below the delta of the Cass, another small stream, the outlet of Lake Alexandrina, joins Lake Takapo. The former is a small picturesque lake, partly surrounded by ice-worn rocks, partly by morainic accumulations, and lies 2460 feet above the sea level, or 23 feet above Lake Takapo. It is five miles long, and about half a mile broad, and was, without doubt, formerly a portion of Lake Takapo, from which it was cut off by the large shingle fan of the Cass river. The outlet of Lake Takapo issuing from its southern end is named the Takapo; it runs for a number of miles in a deep channel, where it breaks through the morainic accumulations by which the lake is here walled in; after leaving them it enters the post-pliocene alluvium beds of which the greater portion of the Mackenzie Country is formed, and although still fringed by terraces on both sides, its bed becomes broader and more shallow, fords over it being easily found by an experienced across country rider. After a course of 25 miles, it is joined by the Pukaki river, when, as before mentioned, the united river assumes the name of Waitaki.

Flowing for three miles in a south-south-west direction, it is joined by the Ohau, the outlet of Lake Ohau, which, after issuing from that lake, follows an east-south-east course of a length of thirteen miles. Lake Ohau, ten miles long, and averaging three miles in breadth, is a picturesque sheet of water lying 1837 feet above the sea level. Whilst the Ben Ohau range rises so abruptly from its eastern banks that it is impossible to pass along it on horseback, the mountains on the western side are distant from half a mile to two miles from its western shores, the intervening space being filled with gradually rising morainic accumulations forming terraced grounds reposing against the mountain sides. On both sides small groves of beech forest heighten the charm of the beautiful scenery; moreover, the water of the lake is perfectly clear, forming in calm weather a broad mirror for the serrated mountains along its banks. Here, also, several portions of the lake, which once stood at a higher altitude, have become isolated by the lowering of the waters to their present level, and now form lagoons amongst the morainic accumulations. Lake Ohau is the recipient of the River Hopkins, formed by the junction of the Dobson with the former, five miles above the northern end of the lake. They are both of glacier origin, the Dobson or eastern branch deriving its waters from the south-eastern slopes of the Moorhouse and the south-western slopes of the Sealy range; the Hopkins from the south-western flanks of the Moorhouse range, and the southern slopes of Mount Holmes. The Dobson has a south-by-east course; the Hopkins, a general south course, running south-west for the first, due south for the middle, and south-east for the latter portion. They are both about 24 miles long. In the middle portion, their beds are repeatedly narrowed by huge morainic accumulations, through which they have cut a channel of a gorge-like character, after which they enlarge considerably, and flow over broad shingle-beds. Before reaching their glacier sources, the valleys of both rivers narrow considerably, and assume the character of wild rocky gorges, so that in this respect they resemble most of the valleys in the Swiss and Tyrolese Alps, leading up to the glaciers. Where the Ohau enters the lake, the same extensive swampy delta has been formed as we observe at the head of the two other Mackenzie Country lakes. As pointed out in the first chapter, the valleys of both main branches of the Ohau river possess an additional charm by their lower regions being densely wooded with beech forest. Although their tributaries, even in fine weather, are sometimes very difficult to cross on foot, they have only very short courses.

I have already repeatedly alluded to the peculiar physical features al l our alpine rivers, namely—that they generally possess numerous and well-defined terraces in their upper and middle courses, being simply shelves cut in the solid rock along the mountain sides by a gigantic glacier. These shelves in many instances are situated as high as 3000 feet above the present level of the valleys, and are very characteristic of our alpine scenery, although I may add that the same features are also amply developed in the European Alps, the Himalayas of Asia, and the Rocky Mountains of North America. On ascending the mountains in these valleys, the size and extent of the shelves become still more manifest than when travelling only along the river-bed. The most westerly tributary of the Waitaki is the Ahuriri, the glacier sources of which are situated on the southern slopes of Mount Huxley, the southern continuation of Mount Ward. The valley of the Ahuriri is fifty-two miles long; for twenty-seven miles it has a southerly course, after which it turns gradually to the east, when, for twenty-five miles it runs in that direction, joining the Waitaki fourteen miles below the junction of the Ohau river. The river-bed of the Upper Ahuriri for about eight miles, is narrow and rocky, the mountain slopes on both sides rising abruptly; it then gradually expands, but is still repeatedly crossed by large moraines, through which the river has cut a narrow channel. Fourteen miles from the head of the river, the valley is nearly two miles broad, and is now, for seven miles, one large swamp through which the river sluggishly meanders from side to side. At the lower end of this strange fen, a huge moraine crosses from one side to the other, and it is at once evident to the visitor, that at one time a lake must have existed above it, but which in time was gradually so far filled up, that it has assumed this intermediate instructive stage. There is no doubt that if the present physical conditions now ruling in New Zealand, continue for a length of time, the shingle deposits brought by the Ahuriri into this huge swamp will gradually advance and fill it up entirely, in the same manner as the lakes once lying in the middle courses of some of the northern alpine rivers have been changed into alluvial plains, thus entirely effacing such large remnants of former glacier basins. The Ahuriri, where it issues from the fen, has cut a deep channel through the morainic walls, below which broad alluvial plains stretch from side to side. Here the river flows also in a deep bed with terraces on both sides, which, before the Lindis Pass stream is reached, is confined in a deep rocky channel, the alluvial deposits continuing to fill the valley, and resembling in every respect, those which we meet below the great moraine walls encircling the lakes in the Mackenzie Country plains.

South of Lake Ohau, the Ahuriri enters into the southern continuation of these plains where, for five or six miles, its bed is of great breadth (in the so-called Ahuriri plains) after which the rocky ranges approach close to each other again, forming a deep gorge which continues to its junction with the Waitaki. In the fork of the two rivers, Ben More, an isolated range, rises conspicuously, which during the Great Glacier Period stood as an island above the ice-masses, and along the eastern and southern base of which the two rivers have excavated their deep rocky gorges. The Waitaki, below this junction flows for 17 miles, generally confined to one channel, until two miles above the junction of the Hakataramea, the valley opens up, the river however, continuing to flow generally in one body, or if divided into two or more branches, it still has only a narrow bed. Nineteen miles below the junction of the Ahuriri, the Hakataramea river joins the Waitaki from the north. It is by far the most important tributary below the former, no other streams of any consequence joining it on the Canterbury side. On the southern or Otago side, only small affluents reach it, of which the Otomatakau and Marawhenua are the most important. Seventeen miles below the junction of the Hakataramea, the mountains recede on the northern side of the valley, which now opens up still more, the old alluvial deposits on both sides, which hitherto had only been narrow, become wider, the bed of the river itself also gradually enlarges, forming a number of anastomosing branches. The further we advance towards the coast, the more characteristic these features become. A series of small terraces are also formed without, however, ever assuming the vast proportion of the terraces in those rivers which have formed the Canterbury plains. The reason of this absence is obvious, the Waitaki glacier, during the Great Glacier period, being of such enormous dimensions that it reached far below the mouth of the Hakataramea, and stood at such a high level that the bed of the gigantic river issuing from it, was flowing seven or eight hundred feet above the present valley. Thus, the whole valley up to that altitude was covered with alluvial deposits, and although the period during which these beds were formed, is separated from us by a short space of time, geologically speaking, the size of the river was still so enormous that when the glacier after repeated oscillations, at last gradually retreated, it had so effectually destroyed its former bed that only here and there on the summits of the ranges between the Waihao and lower Waitaki, small portions of that alluvium were preserved, so that no terraces of any size could be formed.

The Rakaia.

The hydrographical system of the Rakaia, 1547 miles in extent, has its western boundary along the central chain from Mount Tyndall to Mount Harman, a distance of forty-eight miles in a straight line. The main branch, to which the native namè has been preserved, has for about twenty-one miles a straight west and east course, and a shingle bed from one to two miles broad, beginning at the very head of the valley, where, as described in the first part, the Ramsay glacier would abut against Mein's Knob, a high *roche moutonnée* advancing considerably into the valley from the main range, did not the outlet of the Lyell glacier undermine and wash the terminal face of the former away. The two glaciers at the head of the main Rakaia are of considerable size, although not reaching in magnitude the principal glaciers forming the sources of the Waitaki. The most westerly, the Lyell glacier, is eight miles long, and nearly a mile broad at its terminal face; it is formed by the *nevés* of the north-eastern slopes of the Mount Tyndall range, and the eastern slopes of Mount Lyell. The Ramsay glacier, having a southern course, is seven miles long, and has about the same breadth at its terminal face as the other; both being much more expanded in their middle portion. The first important tributary is Whitcombe's stream, which, issuing from the Martius glacier on Whitcombe's Pass, after a course of four miles, joins the Rakaia two miles below the Ramsay glacier. Thirteen miles below the same point, the Cameron joins the main river, bringing the united waters of the Cameron glacier which descends from the eastern slopes of Mount Arrowsmith, and of Lake Heron which lies about ten miles to the south.* Six miles below this latter junction, the Mathias, an important affluent, enters the main valley from the north-north-east. Issuing from the Neave glacier (3788 feet), it has a course of eighteen miles, the upper portion for about eight miles having a gorge-like character, whilst the last ten miles possess the usual features of broad shingle reaches, but the boulders in its bed are generally very large, and several ancient moraines cross the valley from side to side where the river is confined in a narrower channel. Several large affluents join the Mathias on both banks in its upper course, the most important tributary, however, being received ten miles below its glacier source, which comes from the north-west and drains the

* Lake Heron is four miles long, and two miles broad, being narrowed considerably in the centre by two large deltas.

eastern slopes of Mount Martius and of the Agassiz range. The Mathias, containing much less water than the Rakaia, has advanced with its fan considerably towards the main stream. At the same time, a very large shingle cone of the Chimæra creek, several miles in extent in each direction, preserving the base of Mount Algidas from the encroachment of the Rakaia, has given existence to extensive swamps, which are impassable for man or horse. Similar swampy tracts exist in nearly all our rivers, below the junction of an important branch. The main river itself, at its junction with the Mathias, flows in a narrower channel than usual along the northern base of Double Hill, but being bounded also on its northern side by rocks, which rise in an isolated hill to an altitude of 30 to 40 feet above the river, another instance that running water, when lowering its bed, will more easily cut through the solid rock than remove the beds of shingle deposited during the raising of its bed in an anterior epoch. Having passed Goat Hill, the hitherto easterly course of the Rakaia becomes now for eight miles east-south-east.

The Wilberforce, which, after the Rakaia, is the most important source branch of the whole river system, drains, together with its tributaries, a considerable portion of the Southern Alps, beginning at Mount Collet and reaching to Mount Harman, or a length of about fourteen miles. The main sources of the Wilberforce drain the eastern slopes of the Hall range and the western slopes of Mount Harman, both bordering the alpine depression called Browning's Pass (4752 feet), the lake on the summit of which forms, however, the main source of the Arahura (Westland). For seven miles the direction of the Wilberforce, which so far has the character of a true mountain torrent, is nearly south, after which it is joined by two other branches, the principal one turning to the west, I named the Stewart. Another minor one joins the main valley opposite, having its glacier sources in the cluster of ice-clad mountains, where lie also the sources of the Waimakariri, and of the Avoca, the main branch of the Harper. Between the junction of the eastern creek (Sebastopol creek) and the Wilberforce, Sebastopol rock is situated; it is remarkably ice-worn, showing that the large ice-masses from the three valleys, uniting here into one stupendous trunk glacier, were so gorged that for 2000 feet above the present river-bed the pressure on the surrounding mountain sides was enormous.

The Stewart has its principal glacier source (3584 feet) near those of the Mathias; its bed is generally broad, and no difficulties are railway line. In order to avoid repetition, I shall, when describing the formation of the Canterbury plains, return to this interesting subject. From the lower end of the gorge, the river continues its south-east course, which it commences at the junction of the Wilberforce with the main branch, for 37½ miles before it empties itself into the sea, 18 miles to the west of Bank's Peninsula. I may also mention, that below the junction of the two main branches no streams of any consequence, excepting the Acheron, coming from the north-north-east, join the Rakaia. The explanation of this absence of tributaries is easily found, in the fact that the huge morainic and fluviatile deposits of the Rakaia, even above the gorge, dip away from the river, so that a stream like the Selwyn has some of its sources on the high ground in the Rakaia valley, close to the gorge. When the river enters the plains, this fan arrangement of fluviatile deposits below the morainic walls, crossing from side to side, is still more conspicuous, and consequently the surface water, instead of joining the river, flows on the top of the fan away from it.

The Rangitata.

The river, the hydrographic basin of which next claims our attention, is the Rangitata, and although that portion of the Southern Alps proper which it drains is not so extensive as that at the head of the Waimakariri, next to be considered, it measuring scarcely ten miles along the summits of the Southern Alps, yet we find that the mountains there are not only of greater altitude; but, also, that the secondary ridges enclosing the system in question, are on both sides of such dimensions, that for a number of miles they are scarcely inferior in average altitude to the peaks in the central chain. The most southern branch of the Rangitata is the Havelock, which issues from a glacier of small proportions when compared with those at the head of the two rivers previously described. After a few miles, the valley enlarges to a breadth of more than a mile, and continues so wide for about fourteen miles to its confluence with the Clyde, having a nearly south-eastern course, which the river, for nearly seventy-eight miles as measured in a straight line, maintains to where it joins the ocean. The Havelock receives, in its course, numerous tributaries from both sides, of which the Forbes river, issuing from two glaciers that descend from Mount Forbes, is the most important.

The second main branch, the Clyde, has also its sources in glaciers of similar size to the former, its course to the junction having a length of thirteen miles; it receives several tributaries, of which the McCoy, joining three miles below the terminal face of the Clyde glacier, is the largest. The bed of this branch, for the first six miles, is generally not so broad as the former, the water, often running in one channel and even when very low, being difficult to cross. After the junction of the Sinclair branch, however, the river-bed widens considerably, now flowing generally in several branches, and where the Lawrence joins it, being over two miles broad.

The Lawrence, the third main branch of importance, has its glacier sources on the south-western slopes of Mount Arrowsmith; in its upper portion, the valley has generally a gorge-like character, and even in its lower course, its bed is often considerably narrowed by gigantic moraines, shingle cones and fans, which the river could only partially remove. This branch is thirteen miles long from its principal glacier source to its junction with the Clyde; from here to the entrance of the Rangitata gorge, the river flows in numerous channels, its actual shingle-bed being generally a mile broad, whilst the valley itself—in which morainic accumulations, lacustrine deposits and alluvium abound, with *roches moutonnées* raising their ice-worn summits here and there above them—is often three to four miles broad. These Rangitata plains, about 22 miles long, doubtless represent the same area in which in the course of the Waitaki, the Mackenzie plains are situated, but owing to the fact that the glaciers were not of such gigantic proportions in the Great Glacier Period, all the phenomena are here on a smaller scale. However, it is evident that when the great glacier, which once filled these plains retreated, and before the lower gorge was excavated, a lake of considerable dimensions existed here, which after being partly filled up in its upper portion, was drained in course of time by the lowering of its outlet. Numerous tributaries join the Rangitata in the middle course, of which the Butler, Potts, and Forest Creeks are the most important. From the upper plains, two broad openings lead into the valleys of the Ashburton and Rakaia, of which I shall speak more fully when treating of the Ashburton system. At the termination of the lower of these openings, the so-called Trinity valley belonging to the Rangitata drainage, the gorge of the Rangitata begins. For about six miles, the river has cut such a deep and rocky channel through the front ranges, that it is impassable for man or horse, the bridle-track leads therefore along the ice-worn hills bounding the gorge to the south, and where an ancient glacier channel can easily be traced. Where the river leaves the front ranges, it flows in a narrow gorge, about 600 feet deep with terraced banks on both sides, in which for the lower 300 feet, the alternating sandstones and slates, standing at a high angle, form perpendicular walls ; but soon the rocks disappear and fluviatile and morainic accumulations take their place. These high banks, although gradually getting lower as we ascend the Canterbury plains, continue to accompany the northern banks of the river, for thirty-two miles, to the sea coast, where they are still about twenty feet high. The southern banks, however, disappear nine miles before reaching the coast, the channel of the river, on the so-called Island, being liable to shift with every freshet. The Rangitata, like all the principal rivers forming the Canterbury plains, does not receive any tributaries in its lower course, their gigantic fan-like alluvial deposits being highest near their present river channels.

The Waimakariri.

The Waimakariri, another of the important rivers crossing the Canterbury plains, next claims our attention. If we draw a straight line from Mount Greenlaw to the Hurunui saddle, the watershed along the central chain belonging to its hydrographical system is thirty miles long, thus being of greater extent than that of the Rangitata; however, the mountains at the head of the northern river are not so high, nor the snow-fields so extensive, and consequently the amount of water coming from the Southern Alps proper is not so considerable in the Waimakariri, although the Poulter and Esk nearly make up for the difference. In fact, although the hydrographical basin of the river is nearly twice as large as that of the Rangitata, and within a few miles of the same extent as the Rakaia, it nevertheless ranks third as to the amount of water it brings to the sea. The main source of the Waimakariri is a glacier at the head of the White river, having its origin in the snow-fields on the northern slopes of Mount Greenlaw, 4162 feet above the sea-level. After receiving several tributaries of glacier origin, the White river, as it has been named from the peculiar colour of its water, generally thick from finely triturated matter, originating from the action of the glaciers on their rocky bed, unites five miles from its origin with the northern Waimakariri, which having a south-south-east course, meets the former at a right angle. That course is continued after this union of the two confluents, the valley enlarging considerably below it, and receiving, four miles lower down, the Crow river on its left bank, having its glacier sources on the southern slopes of Mount Rolleston. A few miles above this junction, the valley already assumes the principal characteristic features of all our large alpine rivers, a wide shingle-bed about a mile broad, in which the river meanders in numerous channels. Six miles below the Crow river, the Bealey, at the head of which Arthur and Goat's Passes are situated, enters the main valley; and seven miles lower down, the Hawdon joins the Waimakariri on its northern, and the Cass on its southern bank. Respectively twenty-one and twenty-five miles from the junction of the north branch with the White river, two of its most important affluents, the Poulter and the Esk join the river, which from that junction had followed a general east-by-south course. It now turns sharply to the south-by-west, or in the direction of the valley of the Esk. After a course of eight miles, and still having a bed of about half a mile wide, with high terraced flats on both sides, the Broken river joins it from the west, bringing the drainage from the Cragieburn range and the western slopes of Mount Torlesse. Before following the rivers through the gorge to the Canterbury plains, I wish to add a few words respecting the small lakes which still exist among the morainic accumulations, and lacustrine and fluviatile deposits in the district under review. In the first part, mention was made of the remarkable glacialized appearance of the country, and that after the retreat of the great glacier during the New Zealand Ice-period, a large lake had been formed, before the gorge which now passes between Mounts Torlesse and Puketeraki had been excavated. This lake became gradually filled by lacustrine and fluviatile deposits; but the glacier advanced again, excavated new channels, and deposited new morainic accumulations upon the older beds of similar origin; amongst these, several small lakes are still situated. Thus Blackwater, a small tarn, lies between the older morainic accumulations, protected by *roches moutonnées*, whilst Grassmere and Lake Sarah are the last remnants of a lake of considerable extent, where now the Cass plains are situated; the moraines east of Lake Grassmere, crossing the valley, being, however, still well visible. Lake Pearson, on the other hand, owes its preservation to two large shingle-fans on the eastern and western ends, by which its bed has been protected. Lake Letitia on the northern, and Blackwater, and other smaller tarns on the southern side of the eastern portion of the terraced plateau, are small remnants of the old lake once existing here. *Roches moutonnées* and morainic accumulations are visible everywhere, rising above the general level of the tableland, about 2100 feet in altitude. The Waimakariri, after having excavated its channel in this plateau of lacustrine and alluvial origin, then enters between the ranges, having on the northern side the Puketeraki range, and on the southern side Mount Torlesse. It has cut a deep picturesque gorge, the mountain sides on both slopes being covered with dense *Fagus* forest, through which no road has hitherto been constructed. For six miles, the distance measured in a straight line, the river winds through the gorge, running nearly south, after which it enters the Canterbury plains. Flowing about 300 feet below the level of the latter, the Waimakariri now assumes the character of a broad shingle river, and receives, after a course of two miles, the Kowai, which is its last affluent. For 41 miles the river flows through the plains, being again retained in narrow rocky banks at the lower gorge, four miles and a half below the junction of the Kowai. This gorge is about a mile long, the river, instead of lowering its bed through the alluvial deposits on both sides, having cut its way through the hard palæozoic rocks, of which the isolated Gorge hill consists. The slope of the plains in these upper and middle portions, being greater than the gradient of the present river-bed, the high terraced banks, which hitherto accompanied the river-bed, disappear about 12 miles from the mouth of the river, and the lower delta of the river is reached, which, as I have already shown in my report on the formation of the Canterbury plains in 1864, is still being formed by the river, which if not checked by artifical means will shift its channel in course of time as the deposition of alluvial beds advances.

The Ashburton.

Of the rivers of glacier origin, the last which has its sources and its whole course in the present Province of Canterbury, is the Ashburton, the main source of which is situated on the eastern slopes of Mount Arrowsmith, issuing from the Ashburton glacier, 4832 feet above the sea level. For the first ten miles the river flows in a more or less open channel between the ranges, where it is possible to follow its bed on horseback to within two miles of the glacier. It here receives several tributaries, of which one at the beginning of the Ashburton gorge, draining the eastern slopes of the Potts range, is the most important. It afterwards enters a deep, rocky gorge, where the traveller has to follow the rocky shelves and glacier terraces several hundred feet above the river, emerging, after a course of five miles, upon the Upper

Ashburton plains. Here the river expands again, and passing diagonally through them, after flowing another five miles, it re-enters between the ranges, without its valley, however, once assuming the character of a gorge. Several tributaries, mostly furnished by small lakes lying between morainic accumulations, join the Ashburton on these plains. The most important of them is Clearwater creek, the united outlet of Lakes Tripp and Acland, which after a tortuous course of six miles, measured in a straight line, falls into the main river on the right bank, near the beginning of the so-called Lower Gorge. Another stream enters from the opposite side, draining Maori lake, and some other small tarns. The so-called Lower Gorge of the Ashburton is 12 miles long, with well defined terraces on both sides, above which the mountains rise to no considerable altitude. The River Stour is the most important affluent here. It drains the southern slopes of the high and precipitous Mount Somers range. After issuing from amongst the ranges, the river enters the Canterbury plains, where, owing to its lesser size, it forms only low terraces, and after a course of 35 miles reaches the sea, 21 miles south-west of the mouth of the Rakaia. Owing to the peculiar conformation of this portion of the Canterbury plains, the Ashburton is the only glacier river which receives any addition on the plains themselves, being first joined by two smaller affluents, the Bowler's and Taylor's streams, and afterwards, 11 miles from its mouth, by the Northern Ashburton, the most important of its tributaries, being fed by the drainage of the large block of mountains between the Southern Ashburton and Rakaia, and separated from the Southern Alps by the Ashburton plains.

The Headwaters of the Molyneux.

Of the hydrographical basin of this, the largest river in New Zealand, only a small portion lies in this province, by far the greater part being situated in Otago. The most northerly branch of this fine river is the Hunter, the glacier sources of which are situated on the southern declivities of Mount Ward. After a nearly straight south-west course of 29 miles, and receiving numerous affluents from both sides, it empties itself into Lake Hawea, a fine sheet of water, situated in Otago, and considerably larger than any of the Canterbury lakes. The upper course of the Hunter has generally the character of a gorge, at the same time fine beech forests clothe its banks to within six miles of its glacier sources. Its middle and lower course, although sometimes narrowed by morainic accumulations and huge shingle cones, runs in a valley of considerable breadth, and has a broad shingle bed. The Makaroa is another important source-branch; its longest branch, the Fish river, has its glacier sources on Mount Dana. After a south-west course of nine miles, it enters the remarkable opening at the head of which Haast's Pass is situated, where it is joined by its principal confluent, the Makaroa, having its glacier sources on the south-western flanks of Mount Ferguson. The united waters now flow for 15 miles in a broad valley, and in a south-south-west direction to Lake Wanaka, being however, occasionally confined to a narrow channel by ancient moraines and huge deltas of mountain torrents. The Makaroa receives numerous tributaries, principally from the western side where the Southern Alps run parallel to it for a considerable distance; of these tributaries, the Young and the Blue rivers are worth mentioning, but the most important is the Wilkin, nearly equal in size to the main river, the principal sources of which are situated on the north-eastern slopes of the Glacier Dome, near the southern boundary of the Canterbury Province.

Lake Wanaka, of the beautiful and diversified features of which it is impossible to speak too highly, is 27 miles long, and, on an average, nearly three miles broad. It is much indented, and the picturesque mountains which surround it rise mostly with nearly vertical walls from its clear and deep blue waters. In its conformation it closely resembles the Lake of Zurich (*lac des quatre cantons*) in Switzerland, and whilst, like Lake Hawea, it is surrounded at its lower end by gigantic circumvallations of morainic deposits, it differs from our other alpine lakes by its low position and by the peculiarity that the Makaroa at its entrance has not formed a swampy delta; well grassed land reaching to the very margin of the water, which, had we no other proof, would alone be sufficient evidence of its great depth. Several well ice-worn islets rise above its surface, of which, however, one near the entrance of the Matukituki has been joined to the main land by the enormous fluviatile deposits brought into the lake by that river.

The Hurunui.

The Hurunui is the last river to be mentioned which has its sources on the eastern side of the Southern Alps, reaching the central divide. Its main sources descend from the ranges on both sides of the

Hurunui Pass, but are not of glacier origin. For the first eight miles of its course it has rather a narrow bed, although the valley is already of considerable width; it then expands and assumes the usual character of our broad shingle rivers, till 18 miles from the Pass it enters Lake Sumner. This small lake, with a length of seven miles and an average breadth of one mile, is bounded on its northern and southern sides by fine ranges, covered to a considerable height with beech forest. It owes its origin to the existence of large morainic accumulations at its eastern end, by which the waters brought by the river, after the retreat of the glacier, have been retained. North of it, and separated by a large isolated range, lie several other lakes, at various altitudes, of which Lake Taylor, the outlet of which joins the Hurunui three miles east of Lake Sumner, is the largest. Lake Katharine, nearly at the same level as Lake Sumner, without doubt formerly an arm of it, was cut off by the advancing delta of the Upper Hurunui. It communicates with the main lake through a huge swamp by a meandering creek, which, according to the height of the one or the other lake, is said to flow in a different direction.

For about seven miles after the Hurunui leaves the lake, its valley is of considerable width, morainic and alluvial deposits forming terraces on both sides. At the end of this distance, the most important tributary, the Southern Hurunui, joins it. The sources of this large stream are close to those of the North Hurunui in the central chain. After first flowing through a narrow valley, the Southern Hurunui enters, in its middle course, a small plain, once the bed of a lake, and in which *roches moutonnées* and morainic accumulations prove the presence of a large glacier in former times; after emerging from this plain, the confluent stream again flows through a narrow valley before uniting with the Hurunui. For the next ten miles, this river occupies a deep rocky gorge through the ranges, receiving numerous smaller tributaries from both sides. It then enters the Hurunui plains, where its channel widens considerably, bordered on both sides by high terraced alluvial banks which gradually sink, so that at the eastern termination of the plains, where the Waitohi joins on its southern banks, they are only a few feet above the river bed. For the next 30 miles, measuring along the principal bends of the river, its bed is mostly narrowed, rocky mountains of middle height forming its banks on both sides. Here also, before it enters the sea, the Hurunui receives numerous affluents on both sides, of which the Waikari is the principal one in Canterbury.

The Opihi.

Of the rivers of which the hydrographic basins lie entirely in Canterbury, but which have no glacier sources, the Opihi is the most important. Its principal sources are all situated in the high mountain chain beginning at Fox Peak and running in a nearly north and south direction to Mount Nimrod, by which the Waitaki system is bounded on the eastern side. Of the confluents of which this river is formed, the Opuha is the largest, the main sources coming from the eastern declivities of Fox Peak and the Dobson range. After passing through the Opuha plains, it enters amongst low palæozoic ranges till it joins the Opihi amongst the limestone hills, 20 miles above its mouth. The Opihi proper has its sources in the ranges near Burke's Pass, and after leaving these mountains, it flows for about 12 miles, diagonally, through the middle portion of the Opihi plains, when, meeting the old morainic accumulations which here cross the open valley, the river enters the Opihi gorge, a deep fissure, cut through a hill consisting of palæozoic rocks. This is certainly one of the most remarkable phenomena in the physical geography of New Zealand, where a river, instead of excavating its bed through loose alluvial and morainic deposits, has actually cut a deep channel through hard rocks. I have already noticed the same fact when speaking of the lower Waimakariri gorge. For a distance of five miles the Opihi flows through this picturesque gorge, its nearly vertical banks, about 600 feet high, being clothed with luxuriant forest; it then enters the limestone region where it is joined by the Opuha. After flowing for six miles through a broad valley with low limestone ridges on both sides, it is joined by the Tengawai, the main sources of which are situated near the Mackenzie Pass. This stream receives numerous affluents from the eastern slopes of the high ranges at the head of the Hakataramea. Its valley is generally broad, and bounded by low hills on both sides.

The Ashley.

The Ashley, although not of glacier origin, is of considerable size, and drains a large extent of country. Its principal sources are situated on the southern flanks of Ashley Head and the northern portion of the Puketeraki range. For eight miles it passes through the Upper Ashley plains, during which it receives numerous tributaries, mostly from the eastern slopes of the last-mentioned range; it then enters the gorge by which the old lake-bed, now forming that plain, has been drained, issuing, after a tortuous course of six miles measured in a straight line, into the Canterbury plains, where it has high terraced banks on both sides. Here it receives several affluents from the north, amongst which the Okuku is the most considerable. In its course across the Canterbury plains, its southern banks, for nearly 12 miles, are formed by the Moeraki Downs, which fall abruptly towards the river, but slope gently towards the south.

THE WAIPARA.

North of the Ashley, the River Waipara is situated. It drains the smaller ranges east of the Okuku branch of the first mentioned river. With the exception of six miles, where it crosses the northern extension of the Canterbury plains, its bed breaks through the mountain ranges, which, although of inconsiderable elevation, nevertheless offer fine scenery to the tourist. The banks of this river, in its middle course, are noted as the principal localities for the collection of Saurian remains of many genera and species. Building stones of good quality can also be obtained in abundance there.

THE SELWYN.

Another river, the Selwyn, is of similar dimensions to the former. Its principal sources are situated on the eastern slopes of the Thirteen-mile-Bush range. It consists of four main branches, the most northerly of which, the Hawkins, rising in Russell's peak in the Malvern hills; the second, the Wai-aniwa-niwa, has its sources near the saddle leading into the Selwyn near Hart's coal-mine. It drains a swampy district lying in the centre of the Malvern Hills. The Wakaepa, or Selwyn proper, rises on the eastern slopes of Big Ben, and after flowing through the Malvern hills in a succession of picturesque gorges, where it receives some important additions from the western slopes of the Thirteen-mile-Bush range, and the high banks of the Rakaia near Fighting hill, it enters the Canterbury plains, where it flows along the depression between the two huge shingle-fans formed by the Rakaia and Waimakariri, emptying itself into Lake Ellesmere, into which it has already advanced its delta considerably. The most southerly branch of the Selwyn is the Hororata, coming from Snowy peak in the Rockwood ranges, and joining the Selwyn 10 miles below the entrance of the latter into the Canterbury plains. After a continuance of fine weather, the channel of this river, on the plains, is generally dry with only here and there small water holes in its wide shingle bed.

The Hinds.

The River Hinds, the course of which in the Canterbury plains is along the depression between the huge shingle-fans of the Ashburton and Rangitata, resembles the last described river in many respects. The sources of its two main branches are situated in the ranges east of Pudding valley, which unites the middle Rangitata with the Ashburton plains; the two confluents, the north and south Hinds, joining at the eastern termination of the Gawler Downs.

The Orari.

Between the Rangitata and Opihi rivers the Orari system is situated. It drains the high ranges which, from the Two Thumb range, branch off in an easterly direction along the southern banks of Forest creek and Rangitata, below the junction of the former tributary. The different head branches, the Hewson, Mackenzie, and Orari streams, of which it is formed, and the main river below their junction till it has passed the Mount Peel range, mostly flow in gorge-like channels. Once entered upon the plains, the bed widens very soon and forms a broad shingle course.

The Waihao.

The Waihao rises on the south-western flanks of Mount Nimrod, drains the western slopes of the Hunter range, and receives also considerable additions from the range which accompanies the eastern banks of the Hakataramea. This eastern main branch and its more southern affluent, the western Waihao, are two mountain streams flowing first between high palæozoic ranges in deep rocky channels, and afterwards among the younger formations, where they have cut picturesque gorges in the limestone rocks. For the last 10 miles of its course the valley opens more, and the river-bed, for a few miles nearest the coast, is generally dry during the greater portion of the year, but showing from its broad shingle-bed that it is liable to heavy floods, when the stream is about a quarter of a mile broad.

The Pareora.

Finally, of the rivers which drain the eastern slopes of Mount Nimrod and the Hunter range, the Pareora is the most important. It flows mostly in a rocky channel, excepting the last eight miles, before reaching the sea coast, and for a few miles in the upper Pareora plains.

The Grey.

Of the rivers of the West Coast, the Grey in many respects is the most important. It forms the northern boundary of Westland, for a few miles only near its mouth, together with its tributary the Arnold, which issues from Lakes Brunner and Poherua. Lake Brunner (227 feet above the sea level), is a fine sheet of water, being four miles broad and six miles long. It lies in the continuation of the large opening leading from the valley of the Taramakau, west of the Hohonu range, into the Grey valley, the former channel of a huge glacier, of which the extensive terminal moraines now form its northern shores. A portion of that glacier branched off five miles south of Lake Brunner, and followed a broad valley in a north-east direction, in which the small but charming Lake Poherua (345 feet) is now situated. After a few miles in this direction the glacier followed a north, and then north-east course, uniting again with the trunk glacier near its termination. Between and above these two branches, the highest peak of the isolated Tekinoa range stood as an island. In the first part of this publication, I have already pointed out that in comparatively recent times, before the Taramakau had forced its passage through the ranges south of the Hohonu range, it had been flowing by Lake Brunner, and discharged itself as an outlet of this lake into the sea more towards the north, somewhere near the mouth of the River Kakawau (Saltwater Creek). The watershed between the Taramakau and the two lakes is exceedingly low, and if I can trust to some barometrical observations here made, an unusual rise of 10 or 15 feet in the Taramakau would bring its flood waters again towards Lake Brunner and its smaller neighbour.

The Taramakau.

Following the West Coast in a southerly direction from the Grey, the next river of importance is the Taramakau, the main sources of which are situated on the Hurunui or Harper's Pass, close to those of the Hurunui river. For the first 28 miles the direction of its course is west-by-south, after which, for the remaining 20 miles, it runs north-west. Five miles below the saddle the valley already widens considerably, the river flowing for a long distance in a broad channel, and receiving numerous tributaries, mostly from the southern side, of which the Otira, and principally the Taipo, a river of glacier origin, are the most important; in fact, the Taipo, at its junction, contains more water than the Taramakau. The sources of the former are situated on the southern slopes of Mount Harman, in that cluster of snow-covered mountains which the Maoris designate as the Kaimatau. Below the junction of the Taipo the valley narrows, the river breaking through the granite coast chain, and only enlarging its bed again near its mouth.

The Arahura empties itself into the sea, about 10 miles below the mouth of the Taramakau. Its main source issues from Lake Browning (4616 feet above the sea level), which lies close to the summit of Browning's Pass. After flowing for about eight miles in a northerly direction, between high snow-covered ranges, with precipitous banks, it turns to the west-north-west, keeping this general course to its mouth. It here flows through a succession of deep gorges for a distance of 22 miles, measured in a straight line, its valley becoming more open about nine miles from the coast. The portion of its bed between the Wooded saddle (Griffith's Pass), leading from the upper Arahura into the Styx and the junction of the Kawhaka creek, is unknown to me; however, it has been surveyed along its whole course by the Westland Survey Department, through which I received the description of its characteristic features,

The Hokitika.

The Hokitika is the next river which claims our attention. It drains a considerable portion of the Southern Alps, about 30 miles in extent along the divide, nearly of the same size as that drained by the Rakaia branches, to which its sources generally lie opposite. Its main branch owes its origin to the Sale glacier (4183 feet above the sea level), descending the north-eastern slopes of Mount Whitcombe, close to Whitcombe Pass. For about 13 miles it has a nearly straight north-north-east course, flowing in a deep channel amongst lofty snow-clad ranges, first over large blocks and afterwards in a narrow shingle-bed; then entering the wooded ranges, it forms a succession of waterfalls and rapids. It turns then to the north-north-west, and receives numerous affluents from both sides, those from the eastern ranges being the largest. After a course of six miles it enters the Hokitika plains, but before doing so, it flows through a deep gorge with rocky vertical banks, the water appearing stagnant, being so deep that no bottom could be felt with the longest pole available. Two causes combine for the formation of this remarkable gorge, nearly half a mile in length : first, the existence of very hard gneiss granite through which the river had to cut its channel; and secondly, the existence of a small mountain torrent below the gorge having thrown a large shingle cone across it. In the Hokitika plains the river, flowing for eight miles in a general north-north-west direction, has formed a broad shingle-bed; it then abuts against morainic accumulations, by which its course is deflected at a right angle, now flowing for five miles north-east, and becoming, for the last mile, deep and apparently stagnant; the Kokatahi, by which it is joined, having thrown a shingle barrier across the main river, near its junction. At this point, the Hokitika turns again to the north-north-west, which course it maintains for about eight miles to its mouth. The Kokatahi is an important affluent of the Hokitika, its sources being situated in the central chain, a few miles south of Browning's Pass, where a high alpine saddle, north of Mount Chamberlin, leads into one of the tributaries of the Wilberforce. It flows, for the greater portion of its course, in a deep rocky gorge. Near its entrance into the Hokitika plains, the Styx or Browning river leading by the Wooded saddle into the Arahura and to Browning's Pass, joins it on its northern bank. The Styx has a remarkably straight course, and is an old channel of the great Arahura glacier, which here sent a branch into the Kanieri basin. A mile lower down on the opposite side, the Taaroha, also a wild and rocky mountain torrent, empties itself. Its glacier sources are situated on the south-western side of Mount Chamberlin. After the junction of this latter branch, the Kokatahi follows a north-western course for six miles across the Upper Hokitika plains, and then, as before observed, it joins the main river. Five miles below this confluence, the Kanieri enters it on its northern banks. It issues from Lake Kanieri, and is, for nearly its whole length, a mountain stream, except for the last six miles of its course, where it is dammed back by the large shingle deposits of the Hokitika.

Lake Kanieri, a charming piece of water, possessing numerous deep bays, and surrounded by forest-clad mountains, is nine miles long, and on an average one mile and a half broad. Like nearly every lake on both slopes of the Southern Alps, it is surrounded at its lower end by a broad circumvallation of moraines, through which its outlet has cut a deep channel. It is fed exclusively from the mountains on both sides. A low and broad pass at its upper end, leading into the Styx or Browning river, proves that the former Kanieri glacier came by that valley. Finally, the Mahinapua creek joins the Hokitika river near its mouth. It is a sluggish water-course, but justly celebrated for the luxuriance of the forest vegetation growing along its banks. Four miles south of the Hokitika bar, it issues from Lake Mahinapua, which lies close to the coast-line, but is separated from it by a moraine wall about fifty feet high, the lowest remnant belonging to the Hokitika basin. This shows that a branch of the Hokitika glacier during its greatest extension, after passing Koi-te-rangi, an isolated *roche moutonnée* lying near the centre of the Hokitika plains, followed a straight course so as to reach with its terminal face the point where Lake Mahinapua is now situated.

The Mikonui.

Passing over the Totara river, having its sources in the Coast ranges, we reach the Mikonui, the sources of which are situated in the high chain branching off from Mount Whitcombe, and accompany the left bank of the Hokitika river in its upper course.

The Waitaha and Wanganui.

The two next rivers, the Waitaha and Wanganui, both containing a large quantity of water, take their rise in the central chain, their sources being formed by glaciers descending from Mounts Whitcombe and Ramsay.

The Poerua.

Travelling south along the coast, the Poerua is the next river originating from the central chain. Its glacier sources are derived from large snow-fields on the western slopes of the Mount Tyndall range. The Saltwater or Poerua lagoon, situated between it and the Whataroa, is a fine tidal estuary surrounded on three sides by densely wooded moraines, over which one of the finest views of the Southern Alps is obtained. It is the receptacle of the drainage of these extensive accumulations.

The Whataroa.

The River Whataroa is also a true glacier river, its main sources issuing from several large glaciers on the south-western flanks of Mount Tyndall and the western slopes of Mount Petermann, the Keith Johnstone and Hector ranges. After entering the lower ice-worn hills, its bed expands considerably and being nearly a mile broad, but after having received the outlet of the small Lake Rotokino, the river passes through a narrow gorge for about half a mile. It then again expands, and retains the character of a broad shingle river to its mouth. In the same lagoon that this river has formed at its mouth, the two Waitangis, the Waitangi-toana and Waitangi-roto, empty themselves. They are of inconsiderable size, drain a great deal of swampy ground, and their sources only go back to the front ranges which branch off Mount Maximilian.

The Okarito.

Nine miles south of the Whataroa, the outlet of the Okarito estuary empties itself into the sea. It is fed by the Okarito river, formed by the confluent streams leaving Lakes Mapourika and Wahapo, both of which lakes are surrounded by huge moraines and *roches moutonnées*, and fed by the western slopes of the Coast ranges. A low Pass leads from the head of Lake Mapourika into the upper valley of the Waiau river. The Okarito lagoon is an extensive estuary, seven miles long, and on an average nearly one mile broad. Of its grand scenic features, I have given a description in the first part. The two lakes in connection with it are of small size only, the largest one, Lake Mapourika, being about three miles long and one mile broad.

The Waiau.

The next river of importance is the Waiau, difficult to cross on foot except in autumn and winter, after a continuance of fine weather. It is formed by two principal branches which, although flowing in the same broad valley beginning at the western foot of the Southern Alps, 10 miles from the coast-line, unite only three miles from its mouth. The Totara or northern confluent is fed by several glaciers, descending from Mount Beaumont, in their lower portion densely covered with moraines. The southern and main branch, the Waiau, has its principal source in the Francis Joseph glacier, the terminal face of which in 1865, according to my barometrical measurements, was lying 705 feet above the sea-level. This magnificent glacier descends from the north-western slopes of Mount Haidinger, where large *nevé* accumulations are situated. Its distance from the sea-shore is 13½ miles. The outlet of this glacier, of which I have given a description in the first part, and of which a lithographic view from a photograph of the late

Thomas Pringle has been added, has for the first three miles of its course a northerly direction, in a narrow channel; it then receives the Agassiz branch, formed by the outlets of two small glaciers descending from a snow-field north of Mount De la Beche. Both are densely covered with morainic accumulations. After the entrance of both main branches into the broad Waiau valley, they have to their junction, and then to the sea, a nearly north-west direction, flowing generally in numerous channels with broad shingle reaches; excepting, however, that, three miles west of the Southern Alps, a large moraine crosses the valley, through which both branches have cut their way. This sign of the last glacier extension is very clear and fresh. It is almost needless to say that ancient morainic accumulations, several hundred feet high, accompany the broad river-bed of the Waiau on both sides, terminating in the Waiau and Omoeroa cliffs near the coast, about two miles distant from each other.

The Waikukupa.

Five miles south of the southern Waiau banks, the Waikukupa falls into the sea. It is only an inconsiderable stream, the principal source of which seems to be derived from a small glacier formed by a *nevé*, on the western declivities of Mount Haidinger.

The Weheka.

The next river, the Weheka, may be said to be, with the exception of the Waiau, the most important river on this part of the coast, draining from snow-fields by which the highest peaks of the Southern Alps are here surrounded. It is formed of several confluents, of which the northern, although the shortest, is the most important. This branch issues from the Prince Alfred glacier, the terminal face of which I calculated to be 702 feet above the sea level.*

This beautiful glacier is, with the Francis Joseph glacier, the lowest in New Zealand. Having already alluded to the characteristic features of the latter, which those of the Prince Alfred glacier resemble in many respects, and having also shown from the meteorological con-

---

* A few years afterwards, this glacier was visited by the Hon. W. Fox, and re-named by members of his party, the Fox glacier. Mr. S. H. Cox, of the Geological Survey, paid a visit to the same locality in January, 1876, and calculated the altitude of its terminal face to be only 660 feet above the sea level.

ditions of the western slopes of the Southern Alps, why these glaciers do descend to such low regions, I need not again enter into this subject, but refer the reader to pages 196 to 199. The Prince Alfred glacier is fed by an extensive snow-field stretching from the north-western slopes of Mount Tasman to the south-western of Mount Haidinger, and is separated by a high rocky ridge into two portions. From the terminal face of the glacier to its mouth, the Weheka has a nearly westerly course, about 12 miles long, the glacier thus being one mile and a half nearer to the coast than the Francis Joseph glacier. The next or middle branch uniting with the main or northern branch eight miles above its mouth, has a west-by-north course for seven miles, its main source being the Hector (Balfour) glacier, principally fed from the western slopes of Mount Cook. This glacier lies in a deep gorge, and although I could distinguish, from some hills which I ascended near the coast, several glacier channels both north and south of Mount Cook feeding the trunk glacier, no such continuous channels on that mountain, owing to its steepness, could be discerned; so that I believe a great deal of this glacier is formed by enormous avalanches falling upon it continually. The western branch uniting, after a north-north-west course for about eight miles, with the outlet of the Balfour glacier, is also formed by several streams issuing from glaciers on the western slopes of the Southern Alps, beginning at Mount Stokes, and reaching as far as Sefton Peak in the Moorhouse range. As before observed, many of the details in the map of this portion of the Southern Alps have been filled up from eye sketches only, although numerous bearings taken all along the coast, of the directions of the valleys, the size and position of the snow-fields, and of the glaciers formed at their lower extremities, have offered me ample material to lay down at least the principal features with some degree of accuracy.

Karangarua.

Four miles south of the Weheka, another large glacier river enters the sea. It is named the Karangarua. Its northern main branch has a length of twenty miles, and its valley has a nearly straight north-west course; it issues from a glacier which must be of considerable size, being formed by a large snow-field lying here on the western flanks of the Moorhouse range, well visible from the coast. Ten miles above its mouth, an important confluent joins the main valley from the south, and drains the Southern Alps for a considerable distance, as far south as the ranges east of Docherty's Pass. It has many affluents, issuing from glaciers of smaller size, formed opposite the glaciers at the head of the Rivers Dobson, Hopkins (Lake Ohau system) and Landsborough, main tributary of the River Haast.

Mahitahi.

Of the rivers between the Karangarua and the Paringa, only the Mahitahi deserves any notice, as it leads up to Docherty's Pass, draining the northern slopes of the Hooker range.

Paringa.

The main branch of the Paringa is formed by two confluent streams, of which the southern one issues from a glacier on the western slopes of Mount Hooker, and after a north-west course of about six miles, receives the northern branch—according to Mr. Gerh. Mueller, not of glacier origin. After this junction, the Paringa valley, for about eight miles, continues in the same direction, receiving three miles above its mouth the Hall river, a small stream issuing from Lake Hall, of which I have described the characteristics on page 161.

Haast.

The next river of importance is the Haast. It has, with the exception of the Taramakau, the largest course of any river in Westland, its most distant source, at the head of the Landsborough, being about forty-four miles from its mouth. Although the sources issuing from small glaciers near Haast's Pass, are neither so important nor so far distant as the former, they may be first alluded to, as being near that remarkable break in the Southern Alps, by which this river system was first explored by me. A small creek takes its rise from a swampy flat on Haast's Pass, about two miles long and half-a-mile broad, which, at its northern termination, joins a larger water-course, coming from the west. The united stream now flows in a northerly direction, and receives numerous tributaries, of which the most important is one from the east, issuing from a glacier on the western slopes of Mount Brewster. A few miles lower down, the

Wills, an important branch, joins it on the same side, draining the western slopes of the high snow-covered peaks at the head of the Hunter river, whilst two miles lower down, the Bourke, a large stream coming from the west, augments the volume of the river considerably. For five miles more, the Haast continues its northerly course, when it enters a broad valley running at a right angle to it, and having a general east and west direction. Here it is joined by the waters of the Landsborough, a broad glacier river, the main sources of which come from Mount Ward and some other peaks of the central chain. Its course is of a length of about 15 miles, with a westerly direction. * Near the junction of these two confluents, another important branch, principally draining the southern flanks of the Hooker and Gray ranges, and which I have named the Clarke, unites with the Haast. It has a nearly south-west course, and near its head waters, Docherty's Pass is situated. After this junction, the valley of the Haast trends for about eight miles to the west-north-west, when, after having received a considerable affluent from the north, it turns again at right angles to the south-west, keeping this course for about eight miles, when for the remaining 13 miles, it again resumes its former west-north-west course.

Okuru and Waiatoto.

Between the Haast and Arawata, the Okuru and Waiatoto rivers fall into the sea, of which the former has its sources on the western slopes of Mounts Dana, Kinross, and Bowen; and the latter on those of Mounts Castor and Pollux, all prominent peaks in the central chain.

The Arawata.

Of the remaining rivers, the Arawata, entering the sea in Jackson's Bay, is worth mentioning. I have only seen it at its mouth, but Dr. Hector, who has explored its upper course, describes it as a true glacier river. Its main source issues from the Haast glacier, descend-

* Mr. Gerh. Mueller, who has lately explored the Landsborough, kindly informs me that its course, as laid down in this map, is not quite correct, the main source, instead of coming from Mount Cotta, being situated on the western flanks of Mount Ward. The main valley, instead of running in a west-south-west direction, has consequently a nearly east and west course. At the same time, I wish to observe that, by a mistake of the draughtsman, the junction of the Landsborough and Clarke rivers has been placed about three miles above their real junction.

ing from the south-western slopes of Mount Aspiring. The valley of this river, about 26 miles long, has a nearly northerly course. South of this river, only smaller water-courses enter the sea, of which several at Cascade Point form a number of picturesque falls. I may finally observe, that none of the rivers in either province are navigable, all being too rapid and too shallow. However, some of them, such as Saltwater Creek, the estuary of the Ashley, the Waimakariri, and the Avon-Heathcote estuary (north of Banks' Peninsula), and the Grey, Taramakau, Hokitika, Piringa and Haast (at the West Coast), can be entered at highwater by small vessels and steamers. It is also possible to ascend many of our rivers with canoes and flat-bottomed boats, for a considerable distance.

CHAPTER IV.

PLAINS.

On both sides of the Southern Alps, and amongst the secondary ridges, plains, varying in size and character, have been formed by the disintegration and destruction of the rocks, from which this gigantic mountain system has been built up, the detritus being brought to lower regions, first by glaciers, and secondly by fluviatile action. As previously pointed out, when speaking of the orographical features of the country, the action of the huge glaciers formerly existing, has had a most beneficial effect in preparing the surface for a dwelling place of the human race, and for following the civilizing pursuits of agriculture and manufacture. Such useful results are especially apparent in this portion of New Zealand, where, without the occurrence of the Great Glacier period, the sea would still beat against the out-running spurs on both sides of the Southern Alps, instead of washing against the low shores of broad and fertile plains, by which the great mountain chain is now fringed. Owing to the peculiar configuration of our Alps, and the effects of sea currents and tides, the largest portion of these plains is situated on the eastern side of this island. The most prominent amongst these are the Canterbury Plains, which, by their position, nature, and general characteristics, form a prominent feature in this island, and are already the centre of a rich, industrious, and large population. They begin at the dolerite plateau of Timaru, and stretch without interruption to Double Corner, in a general direction from south-west to north-east, with a length of about 112 miles. Their breadth from a few miles at both extremities, north and south, augments as we advance towards their centre, having their greatest lateral extension near Banks' Peninsula, where, in a direction from east to west, they stretch a distance of nearly 50 miles to the base of the mountains. The Pacific Ocean is their boundary on the eastern side, where a long shore stretches in a line nearly from south-west to north-east—from Timaru to Double Corner being only interrupted by the volcanic system of Banks' Peninsula, which rises so conspicuously in the middle of that low shore, and to the existence of which a great portion of the loose strata composing these plains mainly owes its preservation from the destructive agencies of the waves and currents. The western boundary is formed by the outrunning spurs of the Southern Alps, having, as I have pointed out previously, by their disintegration, offered the material for the present configuration and other physical features of those plains. In their greater bulk they consist of the accumulation of post-pliocene torrents. Having had their glacier sources much nearer to Banks' Peninsula than in present times, the latter were able to throw the boulders, shingle, sand, and ooze, carried along with them, not only in greater masses but also on steeper slopes than the present rivers crossing them can do, for reasons given in the geological portion. These post-pliocene deposits of huge rivers, have covered with an almost uniform gradient the palæozoic, volcanic, or tertiary rocks, composing here the former sea bottom.

On my arrival in Canterbury, I was informed that the Canterbury plains had only such a slight gradient, that at the foot of the mountains they barely reached an altitude of 300 feet, and I was therefere somewhat surprised when the barometer revealed to me the fact, that this was a popular error, and that the upper portion of these plains was at least 1500 feet above the sea-level, having thus a fall of about 45 feet in the mile, or 1 in 117. Owing to causes, fully to be explained in the geological portion of this Report, the large rivers which built up their huge shingle-fans side by side, afterwards lowered their beds in course of time, so that at the intersection of the fans with the present river-bed, new shallow fans were, and are still, being formed. Below this line of intersection, some of the finest and most fertile agricultural land in Canterbury is situated. Although the Canterbury plains terminate at the sea coast near Double Corner, they continue across the middle Waipara for ten miles further north, being first about four miles broad and gradually getting narrower, ending at the Omihi saddle, which leads into the Waikari, a tributary of the

Hurunui. South of Timaru, a belt of fine alluvial land, of an average breadth of seven miles, which may be considered the southern continuation of the Canterbury plains proper, reaches to the Waitaki. It consists of plateau-like downs, having an altitude of about 600 feet near the foot of the ranges, by which it is bounded on the west. Gradually it falls to about 100 feet a few miles from the coast, where it forms a line of small inland bluffs. Numerous creeks have cut broad channels through the incoherent strata, of which these downs are composed. From their eastern termination to the sea coast, a belt of low lying, rich land, with a series of lagoons close to the sea, is situated, also extensively used for agricultural purposes. A glance at the Geological Map attached to this Report, will show us that these downs are simply the lower portion of the old Opihi valley, and that before that river broke through the small palæozoic ranges, the large river issuing from the extension of the Waitaki-Opihi glacier in the Great Glacier period, followed a southerly course to the Pacific Ocean. This river, breaking through the huge moraine across the Opihi valley below the present gorge, followed a south-by-east course, first receiving the Tengawai, then the Pareora, and reaching the sea coast after its junction with the waters of the Otaio. In this broad opening, the rich alluvial lands of the upper Otaio, Pareora, and Tengawai are situated. North of the Opihi gorge, this plain continues for 12 miles in a northerly direction, being at one time after the retreat of the great glacier, without doubt, a lake, which was gradually filled up by the alluvial deposits of the Opihi and Opuha branches, and contains now some very good agricultural land.

Near the mouth of the Waitaki, the shallow alluvial fan of that river is partly preserved, continuing about eighteen miles inland and having, on the Canterbury side, an average breadth of three miles. West of the township of Waimate, following the small Waimate Creek, and after passing through the Coast range, we reach the Waihao plains. It is evident that, before the Waihao river had cut its present channel, a lake was here situated, having gradually been filled up by the deposits brought down the Waihao. The last remnant of this lake is still to be found on the flat, now drained by the Waimate Creek. There is also some fine agricultural land in this basin. Ascending the Waitaki, and crossing the small gorge at the junction of the Hakataramea with that river, we reach the Hakataramea plains. Here on the western side of the river for nearly twenty miles, older alluvial deposits, along which the river has excavated its present bed, have been preserved. They are, on an average, about three miles broad and are all fit for the plough.

The Mackenzie plains are, with the exception of the Canterbury plains, the largest in the two provinces under review. However, owing to their great altitude, sloping from 3000 feet to about 1300 feet above the sea level, the lower portion only is available for agricultural purposes. Great have been the changes which took place before this portion of the country could assume its present configuration. The upper portion of these plains is formed by morainic accumulations forming large ridges running parallel to the course of the rivers above the lakes, and afterwards encircling the latter to a breadth of several miles. Below them, alluvial beds deposited by the huge torrents issuing from the glaciers, form shallow fans into which the rivers, as they laid their beds lower, have excavated a series of terraces on both sides. Ice-worn hills and small ranges rise here and there amongst the morainic and fluviatile beds, often with enormous erratic blocks on their summits and slopes. I wish finally, (omitting a number of smaller plains or basins on the eastern side), to allude to the Waikari-Hurunui plains which, with the Waiau-ua plains, form a large basin about thirty miles long and six miles broad. They are also the former bed of a large inland lake, in course of time, filled up by alluvial deposits brought into it by a number of rivers, and of which the deltaic deposits (or shingle-fans) can still be traced. Here also, some fine agricultural land is met with.

In Westland, along the coast, a fringe of more or less level land is situated, of which the triangular area stretching into the Grey plains across the Arnold river, is the largest and most important. It generally consists of older alluvium in which the richest of the Westland Gold-fields are situated, and of younger morainic accumulations and alluvium formed by the rivers once issuing from the extended glaciers. It forms a table-land rising gradually to 800 feet, above which a number of hills, consisting of tertiary strata, rise a few hundred feet more. It is generally densely wooded, so that to prepare it for agricultural or pastoral purposes, a great deal of work will be required. Thus it does not possess the same advantages with which the downs and plains on the eastern side of the Southern Alps are endowed, where in most cases the virgin soil can be ploughed at once without any further preparation. We have, however, to except some small area north of the Taramakau to Lake Brunner, the so-called Pakihi or Paddock, and a portion of the Hokitika plains, where some good grass land is met with.

A low alluvial plain stretches from the Tauperikaka, eight miles north of the River Haast, to Jackson's Bay, with a total length of thirty miles and an average breadth of four miles. It is covered with dense forests from which, in course of time, a large quantity of valuable timber will be extracted for exportation. Everywhere amongst the valleys, descending from the Southern Alps along the West Coast, a great deal of land will in years to come, be used by the settlers for farm purposes, principally when the mining industry on coal, gold and other precious metals has become more developed, and a larger permanent population has settled in that fine district.

PART III.

GEOLOGY.

CHAPTER I.

INTRODUCTION.

THE first mention of geological research in Canterbury, of which I can find any record, is in Dr. G. A. Mantell's paper on the remains of *Dinornis*, &c., collected by Mr. W. Mantell in the Middle Island of New Zealand—Quarterly Journal of the Geological Society of London, Vol. VI. (1850). Dr. Mantell there prints the notes taken by Mr. Walter Mantell during a journey from Mount Grey to the Waitaki. They consist, first of some observations on the character of Banks' Peninsula, the volcanic origin of which is correctly described, although the beds on the crest of the range were mistaken for metamorphic rocks. It is also mentioned that the Canterbury plains, consisting of slightly coherent gravel, are fringed by a series of newly formed hills of drift-sand, by which Banks' Peninsula, formerly an island has recently been joined to the plains. Mr. Mantell estimates however, that the elevation of the plains near the foot of the mountains is not less than 350 or 400 feet, consequently about a thousand feet below their actual altitude, and he distinguishes also between the older tableland and the deltas of more recent origin, which have been and are still being formed near the mouths of the rivers. Next, the character of the vesicular volcanic rock (at Timaru), is pointed out and mention made of lignite existing inland of Timaru, which is however described as being of a more bituminous nature than that occurring near Mount Grey.

In Dr. C. Forbes' paper "On the Geology of New Zealand, with notes on its carboniferous deposits"—(Quarterly Journal Geological Society of London, Vol. XI., 1855), we meet with a short description of the Canterbury plains, and the statement that they consist of a gravel formation, covered by alluvial deposits in the neighbourhood of the rivers. The author also observes that the plains are much cut up by immense dry water-courses, down which the mountain torrents must, at one time have rushed in great floods; he thus clearly recognised the character of the broad shallow water-courses on the fans, in which the rivers by which they were formed were flowing in succession. Dr. Forbes also visited the Mount Grey district, and by following the course of the Kowai, discovered a fossiliferous bed belonging to the Pareora formation, describing its contents correctly; he at the same time alludes to a seam of lignite, four feet thick at the foot of Mount Grey. Further on, he speaks of the gravel which forms the substratum throughout the Canterbury plains, and states his conviction that Banks' Peninsula, at a very recent period, must have been an island; he then correctly describes the chain of sandhills, having all the appearance of once having formed the sea shore from the mouth of the Waimakariri to the Waihora (Lake Ellesmere). He also points out that the soil covering the slopes of Banks' Peninsula consists of a yellow arenaceous clay, and that many specimens of the Moa are imbedded in it.

In the year 1864, after my researches in the Geology of Canterbury had already considerably advanced, Mr. W. T. Doyne, M.I.C.E., whose professional services shortly before had been secured by the Provincial Government, received instructions to report, from an engineering point of view, upon several of the rivers flowing through the Canterbury plains. In June, 1864, that gentleman furnished the Government with a very able report "Upon the Plains and Rivers of Canterbury," in which he also treated of the general characteristics of the Canterbury plains, and the rivers by which they were traversed or which take their rise in them, some interesting and instructive sections accompanying this Report, which was printed in folio at the *Press* office in 1864. A second report "Upon the River Waimakariri and the Lower Plains" was furnished to the Provincial Government, November 30th, 1865, by that Engineer. It was printed in folio at the *Press* office in the same year, and its value is enhanced by many illustrations, of which those proving the correctness of my fan theory, as put forward in my previous Report on the formation of the Canterbury plains, are very instructive. One of these illustrations on a reduced scale, has been added to this Report. Mr. Doyne in his second Report treats principally of the lower course of the Waimakariri, in respect to the tendency it has for changing its course in a southerly direction, and thus endangering Christchurch; of Kaiapoi Island; of underground streams, as well as of the formation of the Canterbury plains by fluviatile action, all based upon his levels: subjects to which I shall return in due time. I have already referred to Mr. E. Dobson's valuable Report (page 174 *et sequ.*), in which a considerable amount of interesting information in reference to the Physical Geography and Geology of the Central Chain is contained.

The following papers also deal with the geology of Canterbury and Westland:—Mr. J. Buchanan, of the Geological Survey of New Zealand, in 1866, visited the north-eastern portion of the Province, on his way to the Kaikoura district, and made some observations on its geological features, of which an account is to be found in his Report on the Kaikoura district.—Geological Survey Reports, 1866–67. Besides a number of notices in publications of a general character, Dr. J. Hector, F.R.S., published in the Reports of the Geological Explorations of 1870–71, "On the geological structure of the Malvern Hills district"; and in those of 1871–2, "Further Report on Malvern Hill Coal." In the same publication for 1872–3, Captain Hutton, F.G.S., gives a general Report "On the Geology of the north-east portion of the South Island, from Cook's Straits to the Rakaia"; in which, notwithstanding his short stay in the Province, a great deal of information is contained.

I do not wish to refer here to a number of papers in the "Transactions of the New Zealand Institute," treating of the age and time of extinction of the *Dinornithidæ* as I shall allude to them when treating of the subject which has given rise to so much controversial writing.

It will also be observed that the Great Glacier Epoch of New Zealand and the formation of the Canterbury plains have mostly been selected by other scientific writers for treatment, and although I wish to avoid as much as possible entering into controversies, I shall not fail to review concisely some of the contents of a few of the principal papers, in order to clear, in some degree, the haze which has been spread by several of the writers in question.

The following are the titles of the principal papers by other writers treating of Canterbury Geology, in the "Transactions of the New Zealand Institute":—

In Volume V, issued May, 1873, "On the date of the last Great Glacier Period in New Zealand," by Captain F. W. Hutton, F.G.S.

In Volume VI, issued June, 1874:—(1) "Notes on the Glacier Period," by A. E. Dobson, C.E., F.G.S. (2) "On the Extinct Glaciers of the Middle Island of New Zealand," by W. T. L. Travers, F.L.S. (3) "On the Glacial Action and Terrace Formations of South New Zealand," by J. T. Thomson, F.R.G.S. (4) "On the Fossil Reptilia of New Zealand," by James Hector, M.D., F.R.S.

In Volume VII, issued July, 1875:—(1) "Notes on Dr. Haast's supposed Pleistocene Glaciation of New Zealand," by W. T. L. Travers, F.L.S. (2) "On the Date of the Glacial Period"; a comparison of views represented in papers published in the "Transactions of the New Zealand Institute" in Volumes V and VI—by A. Dudley Dobson, C.E., F.G.S.

In Volume VIII, issued May, 1876:—(1) "On the old Lake System of New Zealand," with some observations on the formation of the Canterbury plains, by J. C. Crawford, F.G.S. (2) "On the Cause of the former Great Extension of the Glaciers in New Zealand," by Captain F. W. Hutton, F.G.S.

CHAPTER II.

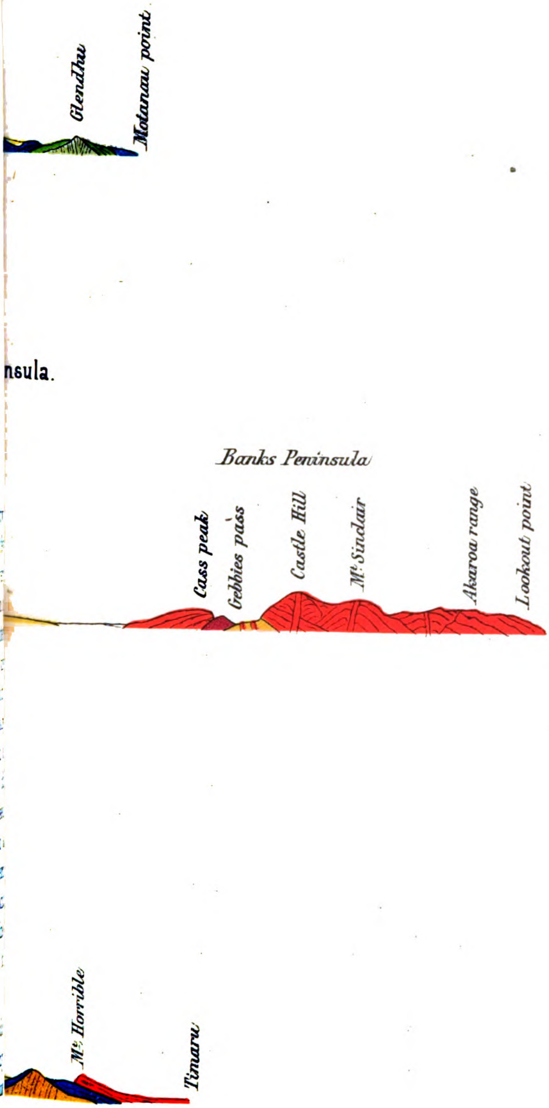
General Geological Structure.

Before examining the general geological structure of the two provinces under consideration, it will be necessary to devote a few moments to New Zealand considered as a whole, as it would be very difficult, without such a short review, to understand the conformation of this portion of the South Island alone. It has already been pointed out by Ferdinand von Hochstetter in the geological portion of the magnificent Novara work—(Geological portion, first part, first division, Geology of New Zealand)—that these Islands belong geologically together, and are portions of one and the same system which, with a south-west and north-east direction, forms a well-marked line of elevation in the Pacific Ocean. This longitudinal course is crossed by a second one nearly at right angles, that is to say, running in a nearly south-east and north-west direction. On this line, the northern continuation of the Northern Island is situated; also Cook's and Foveaux Straits strike in the same direction, conforming to a line N. 52° W., which, according to Dana, * can be considered the axis of great depression in the Pacific Ocean.

Not having at this moment, access to Dana's valuable work, I can do no better than translate from the above-mentioned publication of my friend, von Hochstetter, the passage having reference to it, and his conclusions based thereon, with which, moreover, I fully agree:—

* United States Exploring Expedition, Vol. X., p. 394, 395.

Plate IV.


Glendhu
Motanau point
nsula.
Banks Peninsula
Cass peak
Gebbies pass
Castle Hill
Mt. Sinclair
Akaroa range
Lookout point
Mt. Horrible
Timaru

"Dana has drawn attention to the fact that a line drawn from the Pitcairn Island (in the Paumotau Group) in a westerly direction passing north of the Society, Samoa, and Solomon Islands, to the Palaos Islands (East of the Philippine Islands), will form pretty correctly the boundary between the Atoll—or Low islands to the north and the High islands to the south. He denotes the broad arm of the sea between this line and the nearest High islands in the north-east, the Sandwich Islands—a plateau nearly 2000 nautical miles broad, and 6000 nautical miles long, dotted all over with about 200 Atoll Islands—as a great area of depression. Nearly all groups of islands belonging to this zone, strike in a south-east and north-west direction, and a line drawn from Pitcairn Island, in a N. 52° W. direction to the centre of the Japanese Archipelago, would be the central line of this area of depression, and the axis of its greatest depth. However, if we place this line on a map on Mercator's projection, it will be found that, beginning at Pitcairn Island, such a line drawn in a direction of N. 45° W. will reach the northern coast of the Japanese Island of Jesso, and will probably still more correctly form the middle line of the area of depression under consideration. Now if, according to the direction of the Southern Alps which form the highest chain of mountains in the islands of the Pacific Ocean, we take the mean longitudinal direction of the islands forming New Zealand to be N. 45° E., we observe then that two principal lines, the line of depression and the line of elevation, cross each other at a right angle. It is remarkable that the general geological importance of these two directions for the Pacific Ocean, is also strikingly observable in the confirmation of the eastern coast line of the Australian Continent. The east coast of Australia and the west coast of New Zealand form almost parallel lines, although separated from each other by nearly 1000 nautical miles. "The principal elevations of New Zealand, plutonic as well as volcanic, conform to the north-east direction of the line of elevation, whilst the great diagonal fissures by which Foveaux and Cook's Straits were formed lie in the direction of the great line of depression, to which also the third great area of dislocation which the northern portion of the Northern Island owes its origin to, also conforms."

Thus, looking at New Zealand as a whole, from a geological point of view, we observe that its principal characteristic feature consists of a high longitudinal chain, which runs from Windsor *Point*, the most westerly part of the South Island, to the East Cape, the most easterly point of the North Island. This great mountain chain, broken through by Cook's Straits, falls rather abruptly towards the west, having from the divide, only a breadth of about eight to ten miles. Towards the east it slopes down more gradually, a breadth of 50 miles not being uncommon. This remarkable chain, of which the geological structure is generally uniform throughout, is only the eastern wing of a huge anticlinal arrangement, of which the western portion has either been destroyed, or submerged below the Pacific Ocean. It has thus the same one-sided arrangement, so conspicuous in almost every alpine chain of which the geological structure is known. The axis of this anticlinal consists of granite and other plutonic rocks, which still, in some localities in Westland, are open to our inspection. This granite area is mostly confined to the northern portion of Westland between Lake Brunner and the Waitaha, rising in isolated mountains from the West Coast plains, and being generally detached from the Southern Alps, so that it is exceedingly difficult to find any contact between the plutonic rocks and the lowest beds which form the western slopes of the Southern Alps; a low saddle, if not a valley or broader depression, separating them from each other.

In the chapter on the Physical Geography of Canterbury, I have referred to Mr E. Dobson's interesting observations that all the principal valleys from the Hurunui in the north to the Makaroa in the south, radiate as it were from a common centre situated about 50 miles to the north of Mount Darwin, or about 40 miles west of Hokitika. It is a remarkable coincidence that the granitic zone, stretching from the south of the Waitaha round Lake Brunner to the west coast, 20 miles north of the River Grey, forms a segment of a circle round that point. A similar segment of a circle is formed by the eruptive and volcanic zone on the eastern slopes of the Southern Alps round Banks' Peninsula. An examination of the Geological Map of the two provinces, attached to this Report, will show that the different principal formations, according to their age, and the metamorphic action they have been subjected to, follow each other from west to east, while the general sections across the Island show this still more convincingly. Thus, beginning at the western slopes of the Alps, we find invariably, where open to our inspection (the deep gorges of the rivers, generally offering us clear sections) that the lowest beds consist of gneiss granites in many varieties of composition and texture. Sometimes they appear in hand specimens, and even in small exposed sections as true granites, but invariably when examining these sections over a larger space, we observe that the rock always shows a rough stratification; above and below, the rock has the usual texture of gneiss. These lowest beds stand at a very high angle, invariably dipping to the east. Veins of granite, sometimes of a very large grained texture, so that it even may be called giant granite, pass through them.

As before observed, the granitic axis is only exposed in Westland, the whole western wing of the anticlinal having disappeared. Exception must, however, be taken of a few localities, as, for instance, near Lake Hall, south of the Paringa river, where gneiss granite and gneissic beds dip at a high angle to the west of a granitic zone, so that they may possibly be a remnant of the western wing. As we advance towards the east, we find the eastern gneissic beds of great thickness, overlaid by mica, chlorite, and other metamorphic schists of similar origin, having, like the former, a high easterly dip. After four or five miles, these rocks usually alter to clay slates, semi-crystalline sandstones, and felstones, which, although mostly confined to the western slopes of the Southern Alps, in several instances form the divide, and even reach several miles across on to the eastern slopes of the central chain. They generally contain auriferous quartz veins. Upon them now reposes the great sandstone, conglomerate, clay-slate, and shale formation, of which by far the greatest portion of the Province of Canterbury is formed, and which, in many instances, can be followed without intermission for more than seventy miles to the east. I have named this extensive series of rocks, the Mount Torlesse formation. It forms, on the eastern side of the great anticlinal under consideration, a succession of huge folds, dipping throughout at high angles, but these folds are so much destroyed during numberless ages, first by marine action, and afterwards by sub-aerial causes of which the Great Glacier period is one of the most important, that at present the synclinals or troughs generally form the summits of the mountains, whilst the deep and broad valleys run often along the anticlinals or saddles. These beds, of a thickness of at least 25,000 feet, have been formed during a gradual depression of the sea bottom. A large island continent lying to the east of New Zealand, of which a portion of the Chatham Islands is a small remnant, being the country whence numerous rivers brought the material in the form of boulders, pebbles, sand, and ooze, into the ocean, and from which these beds were built up. During their formation, a number of sub-marine eruptions took place, by which diabasic ashes, and, in a few instances, diabasic streams, melaphyres, and amygdaloids were interstratified with them. These diabasic ashes, and altered beds in connection with them, offer us a splendid horizon for sub-division, which owing to the want of fossils in most localities for the examination of beds of such enormous thickness, is of great importance. These beds reach to the east coast, and it is evident that only after they had been deposited and consolidated, the great movement of the earth's crust took place, through which they were uplifted and folded.

The three sections of the Chromo-lithographed General Section Plate will offer to the reader a clear insight into the general features of the remarkable geological structure under review. Although faults and dislocations are not wanting, I have not hitherto found eruptive rocks anywhere amongst them, appearing to have been injected during the formation of the folds, or afterwards when further dislocations and faults were formed. The most careful search along the east coast has also not revealed any plutonic or eruptive rocks to which a part in the folding of these sedimentary strata might be assigned, and the *vera causa* of such enormous changes in the earth's crust has therefore to be attributed to single or repeated movements of a more general character, and to which I have alluded, when quoting fron von Hochstetter's classical work. The folding must have taken place, as before observed, shortly after the deposition and consolidation of the Mount Torlesse formation, which I consider to be of young palæozoic age. After assuming their present form—I mean to say, after the western wing of the anticlinal had almost disappeared—new sedimentary rocks were deposited along the western flanks of the central chain, being of deep water origin, and mostly in the form of slates, of which a great portion, in course of time, has undergone such considerable changes that some of the rocks have quite a metamorphic structure. This has partly been caused by the intrusion of granites, syenites, and hornblende rocks. They now generally stand at a high angle, and are, moreover, full of quartz and other mineral veins, containing gold and other valuable metals. Not having been able to distinguish between the western older crystalline metamorphic zone, of which I believe, as I have already stated, a remnant is still to be found near Lake Hall, and the metamorphic beds and the newer slates from which these latter have been derived, I thought it expedient to colour, in the Geological Map, the whole as old palæozoic, leaving it to a more detailed examination in future years to unravel the complicated relations in which they stand to each other. Although carefully searching for fossils whenever I had an opportunity, I was never able to discover any in these newer slates, nor am I aware that other geologists visiting the West Coast after me have been more fortunate.

On the eastern side of the central chain, no rocks of the same age have been recognised by me, although some of the beds forming the upper portion of the synclinals might be of younger age than the rest, but in the absence of fossils and all the rocks possessing the same lithological character, it has hitherto been impossible to trace any difference in age, the whole, without exception, appearing to belong to the same series. I may here add that the large area of crystalline metamorphic schists covering a considerable portion of Otago, and in which its principal goldfields are situated crosses near Lake Wanaka into the Province of Canterbury. It has been coloured, in the Geological Map attached to this report, the same as the gneiss granite formation in Westland.

It is evident that for a long time, the eastern ranges have undergone great denudations before any newer beds were formed. In fact, the general orographical conformation of the country in its main features and the lines of great valleys, and direction and form of the great mountain chains between them had already been fixed, before newer beds were deposited over them. We may thus conclude, from the evidence before us, that the Southern Alps after rising from the ocean had been forming high land above its level for a long period. I stated previously that on the eastern side of the eastern wing of the great anticlinal, no eruptive rocks of contemporaneous origin were existing; however, it is evident that such a remarkable folding could not have taken place without weakening the crust of the earth considerably in the direction of the strike of the beds. The folding of the strata having taken place in young palæozoic times, but before the auriferous slate formation at the West Coast was deposited, an enormous period appears to have intervened before new beds were formed, because we have to reach the latest mesozoic times before we can trace such beds with certainty. Eruptions on a large scale then began on the eastern side of the anticlinal, stretching from the Orari south to the Oxford hills north. The eruptions commenced with melaphyres, either in the form of crystalline rocks or as tufas and amygdaloids, and they were doubtless all deposited on the sea bottom, although no traces of marine fossils have been discovered in them. These basic eruptive rocks underwent in their turn, considerable denudations, before new outbursts, this time of an acidic composition, appeared in the same districts. They consist of quartziferous porphyries of great variety with their pitchstones and tufas, and generally follow the same line, partly surrounding Banks' Peninsula, as a segment of a circle. They either repose on the decomposed surface of the melaphyres or on the palæozoic rocks, generally appearing below the former, altered and impregnated with siliceous matter. In the tufas at their base we find impressions of leaves, but too indistinct for description, and trunks of monocotyledonous trees, often of enormous size, of which the bark has been silicified, showing its original structure, whilst the hollow interior appears as a dense mass of semi-opal or flint.

In Banks' Peninsula, where we meet with a partly altered nucleus of palæozoic rocks (schists), a small zone of quartziferous porphyry and tufa appears near it, which may be of the same age as the belt of acidic eruptive rocks west and south-west of it. Whilst the highest points of the older basic eruptions rise in the Clent Hills to 4212 feet, the acidic rocks reach a still higher level in Mount Somers, namely, 5240 feet, both being situated due west of Banks' Peninsula, and due east of Mount Cook.

It is a remarkable fact that here, where the Southern Alps attain their highest elevation, the mountains are not only much narrowed in lateral extent, but the island itself is also much compressed, notwithstanding the great extension of the eruptive rocks, if we do not take the Canterbury plains into consideration. It thus appears that the abyssological forces, by forming here the highest foldings, did so at the expense of the breadth; moreover, it is clear that the highest mountains, being the greatest condensers of humidity, could offer an enormous supply from their *nevés* to the gigantic glaciers at their base, and thus aid effectually in their own destruction.

A similar zone of basic eruptive rocks exists along the West Coast nearly opposite to that on the eastern side, but it would be difficult to settle their contemporaneous origin from lithological character alone, no fossils having hitherto been found in the tufas belonging to them and lying at their base. On the eastern side of the Southern Alps, the acidic rocks have furnished the material for extensive beds of tufas, and conglomerates reposing upon them, and from the palæozoic rocks similar beds have been derived in their neighbourhood. They form the lowest portion of an important series of beds which are of a highly economic value, not only in Canterbury but all over New Zealand. It is evident that the land was gradually rising, so that the porphyries came within the influence of the tides and currents of the sea, by which they were partly destroyed, and that afterwards a shallow sandy shore fringed them. The rising of the ground continuing, extensive beds of brown coal were formed, accompanied by clays, shales, and clay ironstones, after which the whole was again submerged below the sea level, and a series of fossiliferous beds formed, of which the exact age has not yet been ascertained, notwithstanding the abundance of fossil remains contained therein. The presence of Plesiosaurus and many other saurian genera in the Waipara, would point to a young secondary (cretaceous) age, whilst the character of the shells and the total absence of cephalopods, such as ammonites and belemnites would compel us to assign to them an old tertiary age. I have, therefore, in order not to make our nomenclature more cumbrous, adopted Dr. Hector's somewhat vague expression of cretaceo-tertiary for this formation.

The country continued to sink gradually for a considerable time, during which sands, more or less glauconitic or calcareous, were deposited, the uppermost bed being in many localities a highly calcareous glauconitic sandstone (known as the Weka Pass stone). On the western side of the central chain, the Grey Coal Measures and their accompanying shales, sandstones and limestones, form, without doubt, the equivalent formation, stretching all along the West Coast, where favourable circumstances for its preservation have existed. On both sides of the Southern Alps, during the deposition of this extensive formation, as well as at its termination, large eruptions of igneous rocks took place, by which the coalseams on the western side have undergone such remarkable changes that they have assumed all the characteristics of a true black coal, those on the eastern side being only affected locally. The eruptive rocks on the western side have generally more the character of melaphyres, whilst on the eastern, they are either doleritic, anamesitic, or basaltic.

During the whole tertiary epoch, oscillations of the ground have continued, the beds deposited in one period being partly, if not almost entirely, destroyed in another. The change of level in Canterbury and Westland was evidently greatest during the middle division of our tertiary epoch (the Oamaru formation), when some portions of Canterbury were at least submerged for 5000 feet, as shown by beds of that age being preserved to that altitude amongst the eastern divergent chains. New Zealand appeared then above the sea level, only as a number of high rocky islands, generally striking in a south-west and north-east direction, with narrow straits between them, and flanked on both sides by a number of smaller rocky islets, just rising above the sea level. It is evident, from the complicated structure of

Banks' Peninsula, that a long period of time was necessary before that volcanic system, as it now appears, could have been built up, there being at least three well-defined series erupted one after the other; in each case, the former craters having been partly destroyed before the new ones were formed. We have no fossiliferous beds in the neighbourhood to guide us as to the time when these volcanic eruptions took place, but I think that they occurred at the close of the Pareora formation, when the country rose again to, or above, its present level. Towards the end of the pliocene period, the country had nearly assumed its present form, but the mountains were higher and more plateau-like; the valleys not so deep and wide, and moreover, extensive cretaceo-tertiary and tertiary strata were lying on both sides of the high alpine ranges, often blocking up the valleys, or covering the lower regions with their deposits. The Great Glacier formation of New Zealand now made its appearance, the effects of which upon the configuration of the country were of great importance. The whole plateau-like central range was covered with enormous masses of perpetual snow, from which gigantic glaciers descended by every opening to lower regions, and which have left ample traces, of striking appearance, in all directions, on the West Coast for some hundreds of miles along the coast; on the East Coast descending as low as 700 feet above the sea level. We may say that even at present we are not yet at the termination of that period, the great glaciers, which have now retreated so far back amongst the ranges, after repeatedly advancing again, still continuing their work of destruction, the rivers which issue from them extending the plains along the sea shores of both coasts, whilst inland they excavate or raise their valleys and fill up lakes through which they flow. Along the sea coast sand dunes are still being formed, by which the land gains upon the ocean, whilst in other localities it is destroyed and the sea takes its place. And now, man, by his engineering works along the coasts, and at or near the mouths of rivers, by destruction of forests and virgin vegetation, by draining swamps, by planting trees, and other works necessary for the colonization of a country, also brings about material changes which, although at present scarcely visible, will be of the utmost importance in centuries to come, altering, or at least modifying, some striking physical conditions of the country.

CHAPTER III.

STRATIGRAPHICAL GEOLOGY.

General Synopsis and Description of Geological Formations.

Owing to the present still very unsatisfactory state of the classification of the stratified rocks in New Zealand, which, instead of being cleared up, has, especially with regard to the older beds, of late years become more entangled by constant alterations in the nomenclature—some of the most important beds, for instance, having repeatedly been shifted from younger palæozoic or older mesozoic to cretaceo-tertiary, and *vice versa*—I should only add to the confusion in which the matter has been left, were I to go outside the provinces with which I am specially acquainted, to make comparisons with fossiliferous districts in other parts of New Zealand, and to try to co-relate our older fossiliferous beds with those in all other provinces. I shall therefore confine myself, in this synoptical part, to giving a general description, adding a list of the principal fossils contained in each, and a short tabular statement, in which I shall try to co-relate the arrangement of Professor Hutton with my own.*

More than ten years ago, when intending to send a large series of fossils, mostly from our older beds, from Mount Potts, Clent Hills, Waipara, and Malvern Hills, to Europe, to be described by a Palæontologist of high position, the Director of the Colonial Geological Survey requested me not to do so, assuring me that he would obtain, at an early date, the assistance of a first-class palæontologist, and, in order not to complicate matters or to interfere with the work of the

* If the reader wishes to know something more about the matter, I wish to refer him to Professor Hutton's "Geology of Otago," Section II. Previous Observers, page 12.

Geological Survey of the Colony, I abstained from sending them, promising him that I would wait till the necessary descriptions could be made here. However, I am truly sorry to say that hitherto, probably owing to various causes with which I am unacquainted, this necessary work has not been accomplished, and thus I shall not be able to present, in the synoptical portion, such a clear statement of the fossiliferous contents of our older beds as I should have wished, and which would have enabled me to settle conclusively the question as to the age of some of the beds coming under our consideration.

Fortunately Professor Hutton, whilst engaged as Assistant Geologist on the staff of the Geological Survey of New Zealand, has worked out the tertiary fossils, describing all that are new to science, and lately he has continued this task by naming and describing a number of tertiary fossils collected by me during the last few years in the south of Canterbury, for which my best thanks are due to him. By such means, it has been possible to place the stratigraphical division of our tertiary beds and their co-relations in the most distant parts of the colony, on a sound basis; and moreover, this work, the continuation of the labours of Hochstetter, Zittel, Stoliczka, Unger, Stache, and Karrer, has shown that the main divisions proposed by Hochstetter, who has laid the foundations of a general knowledge of the geology of New Zealand, have been confirmed in their general outlines by the more extended labours of his successors.

The most important work, in which the first classification of the New Zealand formations is attempted, is the geological portion of the Novara Expedition publication :—"Reise der Österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, and 1859. Geologischer Theil, Erster Band, Erste Abtheilung, Geologie von Neu Seeland. von Dr. Ferdinand von Hochstetter."

From this volume, the synopsis, with some additions, was translated for the English edition of the more popular work of Hochstetter (originally published in German in 1863), which appeared in 1867. "New Zealand, by F. von Hochstetter."

The last classification was published by Professor Hutton, F.G.S., in 1875, in his Report of the Geology of Otago (page 26) with which I have co-related that proposed by me in the following synopsis, the same formations, with a few exceptions, occurring in both provinces.

Professor Hutton has also given some lists of tertiary fossils in the summary of his catalogue of the "Tertiary Mollusca and Echinodermata of New Zealand," which have been very useful to me :—

Table of Metamorphic and Sedimentary Formations in the Provinces of Canterbury and Westland, New Zealand.

HUTTON.	AGE.	VON HAAST.	AGE.
Manipori formation ...... Wanaka formation	Eozoic. Laurentian (?) Lower Silurian (?)	Gneiss Granite and crystalline metamorphic formations .... Westland formation in part	Azoic.
Kakanui formation	Upper Silurian (?)	Waihao formation	Silurian.
Kaikoura formation ...... Matai formation in part Putataka formation in part	Carboniferous Triassic. Lowr. Jurassic	Mount Torlesse formation	Carboniferous (?)
Matai formation	Triassic.	Not yet observed. (Westland formation in part (?)	
Putataka formation	Lower Jurassic.	Not yet observed. The eruption of Melaphyres and quartziferous Porphyries have occurred between this and the next formation.	
Waipara formation	Upper Cretaceous.	Waipara formation	Cretaceo-tertiary.
Oamaru formation	Lower Miocene.	Oamaru formation	Upr. Eocene or Lower Miocene.
Pareora formation	Upper Miocene.	Pareora formation	Upr. Miocene or Lower Pliocene.
Older glacier deposits ... Newer glacier deposits ...	Upper Pliocene. Pleistocene.	Great glacier formation Raised beaches .... Silt formation in part ...	Upr. to Post Pliocene.
Pleistocene deposits	Pleistocene.	Silt formation in part ... Estuary and littoral deposits .... Fluviatile beds .... Moa bones, kitchen middens, first traces of man	Quarternary.
Recent deposits................	Recent.	Recent deposits, kitchen middens containing shells, bones of man, seals, birds, &c.	Recent.

CHAPTER IV.

The Gneiss Granite Formation.

Proceeding now to give a short description of the several formations according to their age, the first claiming our attention is the crystalline metamorphic formation, which, from the lowest visible rock, I have named the "*Gneiss-granite formation*"—(No. 12 in the Geological Map). The greater portion of this formation is confined to Westland, and has been traced by me as far south as the Arawata river,* without break, in a north-easterly direction to the eastern side of Lake Brunner, where it enters the Nelson province. It consists of gneiss-granite, always the lowest bed when visible, syenitic gneiss-granite, laminated and protogene gneiss, mica schists in many varieties, the latter often inter-stratified with gneissic schists. The mica schist zone forms the central portion of the whole formation, where it often assumes the character of graphite and talcose schists. It is followed or overlaid by chlorite and hornblende schists, which may be said to form the third zone, but here also mica schists are often inter-bedded. The whole is capped by a quartzitic zone, divided into many beds by the occasional occurrence of metamorphic schists, but they are not so much altered, being merely micaceous, or chloritic schists. Of accessory minerals, the gneissic schists often contain cyanite or disthene; the mica schists, chiastolite, actinolite and garnets; and the chlorite schists, magnetic iron ore, often in large quantities. From the latter, the black iron sands, found all along the coast and from which so much gold has been extracted, are doubtless derived.

* From information kindly furnished by Mr. G. Mueller, the Chief Surveyor of Westland, and received since the Geological Map was printed, it appears that this belt, or at least a zone of igneous rocks, continues still further south, having been traced by Mr. Macfarlane, he Government Agent of the special settlement of Jackson's Bay. It strikes in the direction of the McKerrow mountains.

The whole series stands at a very high angle, and almost invariably dips to the east. The thickness of these beds is enormous; in some sections they are at least six miles broad. However—as for instance in the fine sections observed along the banks of the Haast river—the dip to the east is not constant, western dips also occurring, which might either be caused by faults or reduplication made by folding of the strata. Another point to consider is, if the foliation of the beds coincides with the original stratification. Though at present we do not possess the necessary data to settle this question definitely, there is great probability that this is the case, as the dip of the strata is generally towards the east, and at the same angle as the overlying formation, which has not undergone so much metamorphic action. The boundary between this zone and the next is only, as far as my observations go, a conventional one, the strike and dip of both being generally the same, the division having only been suggested by the lithological character of the next series, which is less metamorphic. However, I have no doubt that breaks and unconformities between them exist in many localities; these, however, in the short time at my disposal when crossing the Central Range, I was unable to trace.

Igneous Eruptive Rocks.

In the lower portion of this zone, on the western declivities of the Central Range, we first find a series of granite veins and dykes, of which the oldest were doubtless formed when the crystalline metamorphic formation was uplifted and brought into its present position, the granitic axis to the west being doubtless the main nucleus from which these veins were ejected. The granites are of a great diversity of texture and variety of composition, younger dykes consisting of granites of a different texture, sometimes passing through older ones, both being in some instances crossed by still younger greenstone dykes. However, in the upper portion of this extensive formation, I have not met with any eruptive rocks, either on the western slopes of the Southern Alps, or in the district around Lake Wanaka, of which I shall speak next.

Crystalline Metamorphic Formation East of the Central Chain.

Although in this zone the gneiss-granites and true gneiss schists—the lowest rocks visible on the West Coast—do not occur, the whole of the rock approaches not only in character that of the upper beds of that series, but it is also overlaid in the same manner by the next or Waihao formation both east of the Central Chain, and on the West Coast. The rocks only fill a small corner in this Province, at the head of Lake Wanaka—the River Wilkin forming the northern and western boundary—but they are extensively developed in the Province of Otago, where they form a large belt about fifty miles broad, stretching in a north-north-east direction across that province to the Otago Peninsula. In this zone, named by Captain Hutton "the Wanaka formation," the richest and most extensive gold-fields in New Zealand are situated.*

The beds of which this formation is composed consist of gneissic, mica, and chlorite schists more or less crystalline. They generally possess less inclination to the horizon than the same beds on the opposite slopes of the Central Range, their dip on the eastern and northern sides of the River Wilkin being on an average about 55 degrees, ranging from south-east to north-east; and on the western side, about 45 degrees, ranging from south to south-west. They thus form an anticlinal, being surrounded on all three sides by the same series of beds, which I have named the Waihao formation.

Near Lake Wanaka and along the upper course of the River Wilkin, the rocks consist of mica and chlorite schists; more towards the centre of the anticlinal, of quartzose gneiss and of a very crystalline mica schist, full of laminæ or lentil-shaped grains of quartz, often of considerable size, which cause the rock, when broken vertically to the foliation, to show a peculiar face. These laminæ of quartz are not uncommon throughout the beds, and always give to the schists an uneven appearance. Some of these mica schists are often much contorted, so as to suggest that they were very much pressed together, when in a soft or pasty state, by the quartzose or gneissic beds of a harder nature, between which they are enclosed. Corrugations on a large scale are also observable, having all the appearance of ripple marks, but they might, as Captain Hutton suggests, be explained by considering them due to the effects of expansion by heat on soft rocks under great vertical pressure, the compression thus produced having been relieved by numerous small corrugations, instead of by fewer and larger contortions—(Hutton and Ulrich's

* See Geological Map of Otago, in Hutton and Ulrich's Geology of Otago—Dunedin: Mills, Dick and Co. 1875.

Geology of Otago, page 30). Captain Hutton states, in the same publication, that nowhere in Otago a junction can be found between this formation, which he names the Wanaka formation, and his Manipori formation, extending all along the west coast of Otago, and as far east as the Te Anau and Maniporo lakes, but I have no doubt that his Wanaka formation is simply the upper portion of his Manipori formation, and that both ought to be united.

My own researches have shown that similar rocks to those found in the Lake Wanaka zone occur abundantly in the upper portion of my gneiss granite formation in many localities along the western slopes of the Southern Alps. Moreover, the absence of eruptive rocks, of which I could not find any trace in the Wanaka district examined by me, and which, according to Captain Hutton, are also wanting throughout the whole zone in Otago, is a further argument in favour of my view, as such rocks are also wanting in the upper portion of the gneiss granite formation in Westland.

I have already alluded to the fact that the greatest quantity of gold, both at the West Coast and in Otago, is derived from this formation, and I have no doubt that in many localities large lodes containing gold and other precious metals will be found. Nephrite, the ponamu or greenstone of the Maoris, is also found in this formation on the West Coast in Greenstone Creek, the Arahura, and some other localities; however, I have never observed it *in situ*, and I am therefore unable to say with what portion of the rocks forming this formation it is associated. The Canterbury Museum possesses, however, a specimen of nephrite, to which a small portion of the bed-rock, chlorite schist, is still attached.

CHAPTER V.

Westland Formation.

Before treating of the next, or Waihao formation, overlying the crystalline metamorphic (gneiss granite) formation, I wish to refer to that assemblage of older sedimentary and metamorphic beds lying west of the latter, and being generally in close proximity to the granite axis previously described. In order to avoid confusion, I have given it a distinct tint in the Geological Map, and placed it next to the gneiss granite formation in the table of reference. I am well aware, as already pointed out, that it consists of beds of more than one age, but owing to a want of more intimate knowledge of them, and having only had an opportunity of examining them in very few spots, distant from each other, it has been impossible for me, at present, to separate them.

Extent.

The boundaries in the Geological Map are, in many instances, only approximate, as I was unable for the greatest part to trace them myself. However, having had the advantage of obtaining a great deal of valuable information from Mr. Gerh. Mueller, the Chief Surveyor of Westland, and from several other friends in that province, upon whom I could rely, I believe that in a general way, the extent of this formation which promises to become, at no distant date, a large field for mining operations, will be found pretty correct. The Westland formation begins between the lower course of the Hokitika and Mikonui rivers, and stretches as far south as the Waikukupa, skirting the western foot of the Southern Alps. Small outliers occur between the latter river and the Mahitahi, after which it again attains large dimensions, covering a great portion of the country between the Paringa and Waita rivers. From here to the northern banks of the Arawata river, it appears to exist only as isolated hills. I have coloured the slate formation on the south bank of the last-mentioned river as belonging to another formation, next to be considered. It consists of an alternation of silky clay slate and bluish felstones striking south-west and north-east, and having a dip of 70 to 80 degrees to the north-west. It is very possible that these beds may also belong to the Westland formation, the more so as I have since been informed that rocks belonging to the gneiss granite formation have been discovered south of the Arawata river.

TEXTURE OF ROCKS AND POSITION OF STRATA.

The strata under consideration, judging from their lithological character, can however be divided into two main divisions, of which the first consists of gneiss and mica schists, and other beds of a similar highly metamorphic structure; and the other, of silky and mostly light-coloured slates, alternating with fine-grained sandstones and felstones. The former is well developed near Lake Hall, south of the Paringa river; and the latter in Mount Greenland on the northern banks of the Mikonui. The rocks near Lake Hall consist of fine-grained gneiss and mica schists with veins and dykes of granite, the latter often coarse grained—dipping at a high angle to the west.

Phyllites, altering to gneissic schists, also occur in this district. The principal locality in the other zone—a zone which I examined carefully, and which seems to cover the greatest extent of ground, but, by many gradations, appears to pass into the first—is situated on the northern banks of the Mikonui river. Bluish clay slates, with occasional beds of fine-grained sandstone, are here exposed in many spots. In Redman's Gully, they dip 60 degrees to the north-by-east. In some other places higher up the river, they are more inclined, and dip to the north-east. They are full of quartz veins, mostly of small dimensions; but none of them, as far as I am aware, have hitherto been found of sufficiently auriferous nature to be worth working. Some of the most interesting localities in that neighbourhood, as, for instance, Mount Rangitoto on the southern banks of the Mikonui, are unknown to me, but the Canterbury Museum possesses a large series of specimens, collected by many intelligent friends of that Institution, since my last journey in 1868 to the West Coast, from which it appears that the silky clay slates are altered in many localities by the intrusion of granites and syenites into micaceous and gneissic schist, the change from the one to the other being gradual and very instructive, as may be seen from a series of specimens.

It thus appears that there are at least two series of beds included in my Westland formation. Owing, however, to the short time at my disposal when at the West Coast, I was unable to separate these. One is probably of the same age as my gneiss granite formation, forming the western base of the Southern Alps, and the other of much later origin, the slates and sandstones belonging to it having, in their turn, become changed into metamorphic schists in many localities, by plutonic action.

Igneous Rocks.

The Canterbury Museum possesses a series of igneous rocks collected in this zone, which are very varied, ranging from a coarse-grained granite to a very fine-grained petrosilex. In the Geological Map, I have indicated the occurrence of granite in the isolated Mosquito Hill on the northern banks of the Haast river, but Mr. G. Mueller informs me that, according to his observations, the whole hill consists of blue clay slates with a capping of alluvium on the very summit. In 1863, when passing along the northern banks of this river, which, for some distance from the western base of the Southern Alps, had consisted of alluvium, I came, opposite the Mosquito Hill where I camped, upon a number of very large blocks of granite, mixed with some smaller fragments of clay-slate, showing convincingly, from their sharp edges and the manner of deposition, that they had not travelled any distance. Some of the blocks consisted of a very fine white hornblende granite with black and silvery mica, the latter in large concretions, and the hornblende crystals, also large and needle-shaped, which, from the contrast of colour, gave a very fine appearance to this rock. Another good-sized block with large crystals of felspar (orthoclose) and plates of mica, was traversed by veins of a fine-grained granite, the whole again crossed by veins of quartz. The clay slates were of the usual silky nature. The whole appeared to have either been brought by a slip from Mosquito Hill, or to be perhaps the remnant of a ridge which had once united that hill with a similar isolated hill lying opposite to it on the southern bank of the Haast.

Mineral Veins.

I am not aware that any auriferous reefs are worked in Westland in this formation, although I have no doubt that in years to come, important discoveries of such lodes will be made, the more so as the rich auriferous reefs at Reefton and its neighbourhood, situated more to the north, in the Province of Nelson, appear, judging from specimens collected in the mines, to occur in the same slates as we find them in Mount Greenland and many other localities. Lately the argentiferous galena lode discovered in Mount Rangitoto, south of the Mikonui, has attracted a great deal of attention. This lode is said to be, on an average, 12 inches thick, dipping at an angle of 35 degrees to the north-west. Judging from the specimens in the Canterbury Museum, received from that mine, this lode is formed of iron pyrites intersected by small strings of galena. Professor Bickerton, of Canterbury College, at my request, has made an assay of it, and found as follows:—"An assay of this ore gave 11.4 per cent. of lead. The lead, on cupellation, gave 82.5 ozs. of silver per ton of lead. Thus the ore gave 9.4 ozs. of silver per ton. This silver contained an appreciable amount of gold." Subsequently, another assay of a different specimen was made by this gentleman for commercial purposes, with, practically, the same result. These assays agree closely with the analysis made by the Government Analyst in Wellington, who obtained 10 ozs. 17 dwts. per ton. They are, however, very different from that made at the Melbourne University, which, according to the newspapers, reached as much as 735 ozs. per ton. I am unable to explain the great discrepancy in the results of the New Zealand and Australian analysis, unless the ore should contain sulphide of silver, or other rich silver ore diffused irregularly through it.

CHAPTER VI.

Waihao Formation.

I have given this name to a series of beds of considerable thickness reposing upon the crystalline metamorphic schists or the gneiss granite formation, from which they are distinguished by having undergone only partial metamorphism; the line drawn, however, is arbitrary, principally along the direction of the Southern Alps, where these formations gradually blend with each other. The character of the rocks in the eastern division, as I shall show in the sequel, is however far more distinct and constant, and, in many respects, different from that of the rocks of the central chain; but the latter, in their turn, often assimilate in their upper portion to those of the next, or Mount Torlesse formation, so that it is very often impossible to find the boundary line between them. Captain Hutton has named the same beds, occurring in Otago, the Kakanui formation, but as I find that our boundaries, where the rocks cross the Waitaki, do not entirely agree, so that he might include beds which I consider to belong to the next, or Mount Torlesse formation, I have thought it more convenient to give to that formation, occurring in the Province of Canterbury, a local name, selecting it from the River Waihao, where the rocks are largely developed and show well their peculiar structure.

Extent.

Starting from the northern boundary of the former united Province of Canterbury, this zone begins below the junction of the Otira with the Taramakau, where it covers a rather narrow belt of country situated entirely along the western watershed of the Southern Alps. Gradually it becomes broader, and, near Browning's Pass, crosses to the eastern side of the central chain, whence it continues to be largely developed as far as Whitcombe's Pass, the rocks on the western side of the Pass included. The summits of the Southern Alps continue to be generally formed of rocks belonging to this zone, till we reach Mount Cook, which consists of beds pertaining to the next, or Mount Torlesse formation. South of Mount Cook, in the Sealy range, the Waihao formation again becomes greatly developed, now increasing much in breadth, and being divided into two portions by beds of great thickness overlying them, which appear principally in the River Hunter, the eastern belt of the Waihao formation being the narrowest one. Another zone of the same formation enters the Province of Canterbury from the south, between the junction of the Hakataramea with the Waitaki and the mouth of that river, consisting of a series of ranges from 2,000 to 3,500 feet high, which are the apex of an anticlinal or saddle-back arrangement. They sometimes appear as high table-land, into which the rivers have cut deep gorges, and are bounded and overlaid on both sides by younger rocks. These younger rocks rise to higher mountain chains, on the eastern side as the Hunter, on the weatern as the Hakataramea ranges, situated on the right or western bank of the Hakataramea river. They continue as far as Fox Peak on the western side of the Opuha plains, getting gradually narrower where they disappear below beds belonging to the Mount Torlesse formation. Small outliers occur on both banks of the Pareora, Opihi, and Kakahu rivers, about their middle course. Judging from the lithological character of the altered beds occurring there, another outlier exists in Banks' Peninsula.

Position of Strata and Textue of Rocks.

Near the banks of the Taramakau, the rocks consist of fine light coloured silky clay-slates, nodular schists (Fruchtschiefer), and many other varieties belong to this group, alternating with quartzose schists, which dip to the south-east at an angle of 50 to 55 degrees. Near the sources of the river Styx, a tributary of the Hokitika, the same slate formation occurs in great abundance, but is sometimes more micaceous. There it also dips to the south-east, but at an angle of 70 degrees. Crossing into the head-waters of the Arahura, by the Wooded saddle, where the Waihao formation becomes more developed, the strata in Mount Sale are largely interlaminated with quartz, and dip now to the west-north-west at an angle of 65 degrees, so that here the occurrence of an anticlinal is proved. Still more to the east, at Browning's Pass, the dip alters again to south-east, 70 to 80 degrees; but near the summit of the central axis, westerly dips were again observed. Rocks of the same character, and in similar stratigraphical positions, occur at the head of the more southern branches of the Rakaia, and near the glacier sources of the Rangitata; but in those localities, the uppermost portion only of the formation under consideration appears, the interlaminations of quartz in the clay-slates (Phyllites), being either absent or appearing in a few instances only. Strata, rich in quartz, are either represented by felstones, or by a semi-crystalline sandstone, in which no particles of slates are enclosed.

On the western side of the Godley glacier altered sedimentary rocks occur, and the western tributaries of the Great Tasman glacier bring down blocks of rock from the very summits of the Southern Alps, possessing a similar texture. In the Sealy range, south of Mount Cook, and on the western banks of the Tasman river, we meet with foliated altered quartzose schists, argillaceous schists with numerous quartz veins, green calcareous phyllites, true clay-slates or phyllites, some of them passing into gneissoid schists, generally having a westerly dip of 70 to 75 degrees. In the upper course of the two main branches of the Hopkins river, which falls into Lake Ohau, they form the bulk of the ranges where I have traced all the rocks hitherto described. Some of the phyllites are full of lenticular concretions of quartz; in others, the quartz is more regularly interlaminated in small layers, of a few lines in thickness. They vary much in strike and dip, but when all the readings are put together, they prove that at least two anticlinals and synclinals exist, disappearing at last at Mount Hooker, where they are overlaid by newer rocks. Another portion of the country where this formation can be well studied, is situated in the basin of the Makaroa river. Here, on the northern or left bank of the Wilkin river, it appears to overlie conformably the gneiss granite zone, occuring round Lake Wanaka. The beds representing the Waihao formation, here consist of micaceous or fine grained, light coloured phyllites, often full of laminæ of quartz. They are often much contorted, and generally have a dip of between 60 and 80 degrees, varying from north-east to south-west. In crossing Haast Pass, and following the course of the River Haast, we travel upon them for a considerable distance, and are able to observe how the easterly dip changes to a westerly one; and that, after another synclinal has been formed, the easterly dip is again restored on the western slopes of the central chain, where we find them underlaid by the gneiss granite formation. I have spoken of the relation of the rocks in Jackson's Bay, coloured in my map as belonging to this division, when treating of the Westland formation. The rocks in the eastern zone, belonging to the Waihao formation, exhibit a somewhat different facies. There are some micaceous phyllites amongst them, but the principal portion consists of peculiarly altered brecciated arenaceous or micaceous schists, alternating with chertose beds, felstones, and greenish schists. Interlaminations of quartz are seldom met with, but very often, parallel to the bedding of the rocks, a congregation of small veins of quartz, somewhat chalcedonic in its nature, occurs at intervals, generally anastomosing and continuing its course over a long distance. In the upper course of the Waihao, there is a well defined anticlinal, the rocks dipping on the eastern side, 45 to 55 degrees to the east, and on the western side, 70 to 78 degrees to the west. On the eastern banks of the Hakataramea river, all the rocks, forming low ranges there, belong to this series. They are sometimes very micaceous, and dip about 60 degrees to the south-west. The outlier on both banks of the Pareora, above Mr. E. Elworthy's station, consists of greyish felstones and dark phyllites, dipping 81 degrees to the east-north-east; above them, beds of brecciated micaceous schists are largely developed. The most instructive outlier is the one in the Kakahu river, where some of the schists are so full of interlaminations of quartz, from six lines to three inches in thickness, that the whole appears as one mass of quartz. Other strata contain a close network of small quartz veins. They repose upon beds of highly altered limestone, interstratified with greenish and brownish diabasic ashes, and of beds of a quartzoze or chertose character. In some parts of the district, micaceous schists and felstones, intersected by a few well defined quartz reefs, in others, semicrystalline limestones, interbedded with micaceous phyllites, are predominant, apparently forming a number of small synclinals and anticlinals—a south-east and north-west dip, at angles often as high as 85 degrees, being the most frequent. Finally, the small zone in Banks' Peninsula, situated at the head of Lyttelton Harbour, and leading by Gebbie's Pass to Lake Ellesmere, and at the southern base of Castle hill, contains some of the same brecciated micaceous schists, alternating with chertose beds. The strata strike here generally from the north-west to the south-east, with a dip according to the localities, to south-west or north-east, and at a low angle.

Age and Thickness.

This combination of strata, which is of great thickness, resembles in many respects the rocks found in the Nelson Province, which form amongst other ranges, the Mount Arthur range. The latter has yielded fossils of old palæozoic, probably silurian, age. In some of the slates from the Waihao, traces of fossils are observable, but too faint for recognition. In some sections where the strike and dip are constant, I have travelled nearly ten miles without finding any change, from which we might assume that this formation is at least 40,000 feet in thickness. However, it is very possible that a reduplication of the strata has taken place here and there, which has become effaced, or was not observed by me, in which case the thickness of the formation would be much less.

Igneous Rocks.

In the longitudinal zone running parallel to the main axis of the Southern Alps, first alluded to, I found no traces of igneous rocks, but, in the southern portion of the province, in the ranges forming the western banks of the Makaroa river, numerous dykes of igneous rocks, generally of small dimensions only, have been injected into the phyllites. Some of them are melaphyres, often amygdaloidal, which, on the banks of the River Young, near its junction with the Makaroa, can be observed *in situ*. On the eastern declivities of Castle Hill, near the head of the Makaroa, large blocks of phyllite crossed by dykes of diorite and dioritic porphyry, were lying on the mountain side, having doubtless been brought down from near the summit. In these dykes, angular pieces of phyllite are enclosed. Similar rocks were met with in the upper course of the Haast river, in nearly every affluent coming from the west, so that there is no doubt that the strata belonging to the formation under review have, in the eastern portion of the folds, been broken through by igneous rocks for a long distance.

Mineral Veins.

The interlaminations of quartz forming regular layers in the micaceous schists and phyllites, as well as the smaller aggregations, or strings of quartz, occurring in great variety and under different conditions, are to a certain degree auriferous, but they appear to be so very poor that only under a combination of most favourable circumstances, payable gold-fields have been formed by their disintegration. In this province, no payable gold-field has been opened up amongst the rocks of this formation, and in Otago, according to Captain Hutton, only the Naseby Goldfields have exclusively been derived from it—(*Geology of Otago*, page 34). I only know of three reefs occurring in this formation on the eastern slopes of the Southern Alps, which might be termed regular lodes, but their unauriferous character has either been proved on closer examination, or they have not yet been tested. One of these reefs is situated in the small range between the two main Waihao branches. It consists of a yellowish, somewhat ferruginous quartz, and appears to be several feet thick, but it is much covered up, so that it is impossible, without clearing it, to obtain further details. Another is situated on the southern banks of the Kakahu river; it is about three feet broad, strikes south-west and north-east, and consists of a flinty quartz. An assay, made of stone taken from this reef, did not give the least trace of gold, and it is therefore evident that the wash-gold found in small quantities in the banks of the Kakahu river, is derived from the interlaminated quartz; just as in the Upper Waihao, where regular quartz reefs are entirely absent. Another reef of considerable thickness, near McQueen's Pass in Banks' Peninsula, has also proved to be unauriferous. In the Makaroa valley, the "colour," to use a miner's term, can be obtained everywhere in the alluvial deposits, but nowhere has ground been discovered in that district, derived from the rocks belonging to the Waihao formation, sufficiently rich to pay working expenses. Of other ores, nothing of value has as yet been discovered in this formation. Some of the micaceous schists, as for instance near the head of the Makaroa, are full of iron pyrites. In others, the grains, or interlaminations of quartz, contain small nests or concretions of mispickel, as for instance in the River Hopkins.

CHAPTER VII.

THE MOUNT TORLESSE FORMATION.

UNDER this name I include all that vast assemblage of rocks, of great thickness, which forms a number of huge folds, reaching in some instances from the East Coast to within 20 miles of the West Coast, and by which more than half of the Province of Canterbury is covered. Although the attempt has been made, both by Captain Hutton and Dr. Hector, to separate this formation in Canterbury into several divisions belonging to different periods very distant in age from each other, both basing their sub-divisions not only on the scant palæontological evidence we possess, but also on lithological character and stratigraphical position, a closer study of the sections has proved convincingly that such divisions were based upon erroneous observations and deductions. The following formations are said by Captain Hutton to be represented in Canterbury—namely, the Kaikoura, the Maitai, and the Putataka formations.* First as to his Kaikoura formation. Being acquainted with the district from which the name has been taken, I can state, judging from the lithological character and sequence of the beds, that his Kaikoura is the same as my Mount Torlesse formation, both mountain systems being in that respect alike. Captain Hutton correctly states that all the higher ranges—Mount Torlesse, the Thirteen-mile-bush Range, and Mount Hutt

* Report on the Geology of the north-east portion of the South Island, from Cook's Straits to the Rakaia. By Captain F. W. Hutton, F.G.S., in Report of Geological Explorations during 1872-73. Geological Survey of New Zealand.

included—belong to this formation, which he considers to be of palæozoic age, but he excludes from it all the lower ranges lying east of the former, to which he assigns a much younger age.

Thus to his Matai formation, which he now considers to be triassic, he assigns— although no fossils characteristic of that formation have ever been found in the whole Province of Canterbury or east of the Kaikouras—the western portion of the Malvern Hills, the Oxford Hills, and all the smaller ranges east of the sources of the Ashley river, notwithstanding that many of the rocks in those districts have sometimes a far more altered texture than those which compose the higher ranges lying to the west of the zone in question. And finally, the eastern portion of the Malvern Hills, the small ranges near Heathstock, and the isolated Black Hills, he places in his Putataka formation, to which he now assigns a lower jurassic age, relying principally on some impressions of ferns found in the Malvern Hills and in some other localities, which he considers identical with those obtained from some beds of Port Waikato, Auckland, and Waikava, Otago.

Now, considering the age of the Black Hills, where no fossils have ever been found, and judging from the lithological character of the rocks alone, they clearly belong to Captain Hutton's Kaikoura, or my Mount Torlesse formation, as they contain the same chertose altered beds as we find in the very heart of the Southern Alps. In fact, a series of rocks from that locality, and another from the River Cass (Upper Waimakariri) placed in the position of their sequence side by side, cannot be distinguished from each other, except by the labels attached to them. In regard also to the Malvern Hills, his whole arrangement cannot be accepted if we carefully study the sections in the district. These sections clearly show, first, that his so-called Putataka beds underlie his Matai beds, of which, amongst many other localities, a clear section is exhibited on the right bank of the Selwyn. On the northern or left bank of that river, the fern beds (his Putataka formation) are separated by an outlier of cretaceo-tertiary age (Hart's coal measures) from the higher ranges to the west, but crossing the river they can be followed on the southern side without any break till they disappear below that vast assemblage of rocks consisting of cherts, marbles, and diabasic ashes, alternating with large beds of sandstones, slates, and shales, overlying them conformably; consequently the fern beds cannot belong to Captain

Hutton's Putataka formation, as they are actually older than his so-called Matai formation, which he places to the west of it. The attached sections—No. 1 and 2 on section plate No. 2—offer all necessary details in illustration of this point.

Now, when we examine the relations of the beds which he assigns to his Maitai formation, with those of his Kaikoura formation, situated to the west of the former, including the whole of Mount Torlesse, we observe that exactly the same sequence and character are met with in both; that, in fact, they both are portions of a series of folds in which a succession of chocolate-coloured slates and cherts form a good horizon for recognition. Thus, between Russell's Hills (northern side of the Malvern Hills) and Mount Torlesse, a huge anticlinal occurs, the same rocks appearing on both sides, but dipping in opposite directions.—(See Section-plate No. 2, section No. 3.) Consequently, also, in this case, Captain Hutton's classification, based upon his observations made in a hasty visit to the district, does not hold good, and the whole series has to be included in the same formation, which I named the Mount Torlesse formation, from the large mountain system where I first studied it attentively. In several other localities I have been able to examine the relations of the different beds to each other in detail, always obtaining the same results. Amongst them, the most interesting one is situated in the Clent Hills, where I found, as far back as 1861, a series of beds, containing numerous impressions of ferns, and in the upper course of the Rangitata in Mount Potts, where I made a good collection of fossil shells. These collections were sent by me to Professor M'Coy in Melbourne for description, and I was informed by that gentleman that the former, the ferns, were of Jurassic, and the latter, mostly brachiopods, of upper Devonian or Lower Carboniferous age, both being identical with exuviæ found in the New South Wales Coal-fields. Although at the time I believed this Clent Hill series somewhat younger in age than the Spirifera beds, I demurred at this definition, owing to the fact that the position and sequence of the strata and the character of the rocks of which both are composed, are alike. Since then it has been shown, and as I think with conclusive evidence, that both these fossiliferous strata—the Spirifera and Pecopteris beds—occurring together in the New South Wales coal-fields, are of the same age and alternate with each other. The occurrence of Tæniopteris, which hitherto had been considered only of secondary age, seems to speak against a palæozoic origin; however, I may point out that the same objection was made to the Glossopteris in Australia, which has by overwhelming evidence been shown to be of palæozoic age. I do not think that the fragment of a leaf, however distinct, can unsettle all that stratigraphical geology has proved to be correct. *

There is some difference in the character of these old sedimentary strata, going from east to west. It appears that whilst in the ranges near the plains we generally observe true littoral beds—the deposits of large rivers entering here the palæozoic sea—further to the west, as for instance, on the banks of the Upper Rangitata, we find their horizontal equivalents as rocks of a different character. They consist of shales and shaly sandstones with marine shells, mostly brachiopods, showing that they were deposited in deeper water than the Clent Hill beds, and some distance from the palæozoic coast-line.

In confirmation of my statements, I shall now proceed to give the usual sequence of the lowest sedimentary rocks, as they appear in the Clent Hills district in an ascending order.—(See Section-plate, No. 2, section No. 4.)

The lowest beds are usually :

1. Slates greyish, sometimes very siliceous, alternating with sandstones, the latter gradually becoming of a coarser grain, so as first to assume the character of a grit, and afterwards of a pebble-bed.

Upon them repose:

2. Thick bedded conglomerates, in the Clent Hills several hundred feet thick. In these conglomerates occur large sometimes fucoid-like carbonaceous markings, as if from drift trees. Smaller beds of sandstone are interstratified, partly ferruginous, partly full of obscure remains of plants. Well-rolled boulders of greyish or greenish coarse sandstone, from the size of a child's head to that of a bean, form the principal portion of the rocks, mixed sometimes with boulders or pebbles of chert and lydian stone. Occasionally a few pieces of quartz, porphyry, and gneiss, which I found only after some search, connect the Clent Hill series with the beds of the Puddingstone Valley. In the latter, porphyry and gneiss occur in nearly equal

* The Rev. W. B. Clarke, the veteran geologist of New South Wales, has given an excellent and exhaustive *resumé* on this question in his various publications on the Sedimentary Formations of New South Wales, to which I wish to refer the reader.

proportions with boulders of sedimentary origin, whilst the sections of Trinity Hill show the gradual change from the one series into the other. These conglomerates, like the whole series to which they belong, are much jointed, often a system of four distinct joints being well developed, crossing each other at various angles, and cutting with sharp planes through the hardest boulders. The palæozoic outlier in the Gawler Downs belongs, without doubt, to this series.

3. Shales alternating with gritty sandstone, coal-sandstone, and bands of clay-ironstone now follow. Some of the sandstones are full of the impressions of fossil ferns, others full of those of roots or of drift timber. Flattened stems of trees are also enclosed, often of considerable size, the bark altered to a scaly powdery coal (culm)* the interior filled with sandstone, often of a much finer grain than the surrounding rocks. Amongst the fossil flora I observed, *Pecopteris*, (two or three species), *Camptopteris*, *Tæniopteris*, *Otopteris*, *Cyclopteris*, *Sphenopteris*, *Cycadites ? Palæozamia ? Taxites. ? Equisetites.* † The *Pecopteris* beds are usually distinct from the *Tæniopteris* beds. Some of the shales consist almost entirely of the leaves and stems of ferns. Amongst them the beds of sandstone are generally the most important, some of them having a thickness of over twenty feet, although generally the arenaceous and carbonaceo-argillaceous strata alternate rapidly with each other, and are occasionally only a few inches thick; the whole thus having a ribboned appearance.

This series is together also several hundred feet thick.

4. No. 3 is covered by conglomerate beds like No. 2, but of smaller dimensions.

---

* The following analysis of two specimens of this culm was made in the laboratory of the Geological Survey in Wellington :—

1, and 2, Bituminous Coals (Culm).

Colour intensely black, lustrous, very fragile.
Colour of powder black, that of ash light buff.
No. 1 cakes freely, the other even more so.

APPROXIMATE ANALYSIS.

	No. 1.	No. 2.
Water	2·27	2·12
Fixed carbon...	55·10	50·04
Hydro-carbon	11·95	13·44
Ash	30·68	34·40
	100·	100·

Evaporative power of No. 1 = 7·1
" " No. 2 = 6·5

† Dr. Hector has compared fossil plants found near Reefton, which also contain Tæniopteris, with the Rajamahal Flora of India.

5. The last series is overlaid by beds of shales and sandstones, the latter having sometimes a semi-crystalline structure, and being of considerable thickness.

6. Upon them repose very thick beds of a fine-grained sandstone, which has the peculiarity that its matrix or cementing medium generally decomposes to a white powder. Many years ago, comparing this rock with similar rocks in Europe, I applied to it the name of Kaolin Sandstone, with which it has a close resemblance, at least in outward appearance. Gradually this rock becomes more argillaceous, and is largely interstratified with shales.

7. The next horizon is formed of several beds of chocolate-coloured or brick-red slates. They are of various thicknesses, and alternate with greyish, greenish, or purple slates. They are more or less arenaceous, of a very distinct character, and have been traced by me over a great deal of ground in several localities in this province, as well as to the more northern portions of this island. From their lithological character and position, I believe them to be the horizontal equivalent of the cherts and diabasic beds which occupy the same horizon in the Malvern hills and elsewhere.

These beds are again overlaid by a series of beds consisting of clay slates, often of yellowish or greyish tints, semi-crystalline sandstones, changing into graywacke, shales alternating with bluish gray and greenish sandstones, cherts, and many other varieties of sedimentary rocks too numerous to mention. Comparing these beds with those in Mount Potts—the only locality in this province where, as far as my researches have gone, the fossil brachiopods alluded to occur—we obtain the following results:—The beds 1, 2, 3, and 4 of the Clent Hills series, are here represented by a great thickness of dark shales, often becoming so slaty that they may be termed clay slates, alternating with thinner layers of sandstone, sometimes with a ferruginous or calcareous matrix.

Amongst these deposits occur a few beds of conglomerate, which fairly may be termed bone beds, as in addition to boulders and pebbles of light coloured slates, they consist of great quantities of well rounded pieces of bones and broken shells. The bones are often of considerable dimensions. I was able to measure the proximal end of what was probably a humerus which I found to be eight inches across, and some other bones of similar dimensions; however, the bones, as before observed, were so much rolled, and the cementing medium of such considerable hardness that I was unable, with the tools at my command, to procure any characteristic specimens, but I have no doubt that they are of saurian origin. No teeth were visible amongst this bone breccia. Some of the bones appearing to have been much rolled, resemble the vertebræ of Ganocephalous reptiles of the carboniferous period; as for instance, those of Dentrorpeton, Hylonomus, &c. I fail to see any resemblance between these vertebræ and those of Ichtyosaurus, to which Dr. Hector has referred one of the vertebræ collected by me, in his paper * "On the Fossil Reptiles of New Zealand," and upon the strength of which he concludes the beds in question are of Triassic age.

The whole of these strata form a large anticlinal in Fossil Gully, and they are well and clearly exposed in this deep and rocky gorge for several miles. They contain the following genera, and probably species:—*Orthis spinigera, Spirifera (lineata, lata, oviformis, duodecimo-costata), Producta, Athyris, Euomphalus, Murchisonia, Orthoceras, Encrinites*, of which many resemble, or are closely allied to, Australian forms from the New South Wales coal-field series. † They are covered by the same succession of beds as occur in the Clent Hills, beginning with No. 5, and I may here observe that I was able to trace some of these upper beds, as, for instance, the chocolate-coloured slates, all the way from near the summit of the Mount Potts range, to the foot of Mount Potts, five miles to the south.

This is therefore good and, as I think, conclusive evidence that the Clent Hills and Malvern Hills plant beds, notwithstanding they

---

* "On the Fossil Reptiles of New Zealand," by James Hector, F.R.S. "Transactions New Zealand Institute," Vol. VI, pages 334 and 336.

† I have not the least doubt that in future years, both the shell and plant beds will here be found interstratified with each other, as this has been the case in the coal-fields of New South Wales, and consequently that also in New Zealand, it will be clearly proved that they cannot belong to such distant periods as the carboniferous on the one hand, and the jurassic on the other. Comparing them with well-defined European formations, they may, like the rhætic formation in the European Alps, be passage-beds, or represent the carbo-permian formation of the western portion of the United States (North America), where it has also been impossible to separate these two formations, which, in Europe, are so clearly and distinctly defined. When speaking further on of the Waipara formation, a similar difficulty will be placed before us, as here also the remains of mezozoic saurians and kainozoic shells are mixed with each other. Consequently, in this case, we have to deal with still another passage formation uniting two well-defined European divisions. Thus, had the geological nomenclature been based upon the strata of the Southern instead of the Northern Hemisphere, and the whole had been divided into periods, we should doubtless have included saurians with the lower tertiary division, and the definition of palæozoic forms would have been much different from that which has been obtained in European nomenclature. Stoliczka has shown also that the carbo-permian cannot be separated from the lower trias in the Himalayas, as these beds are also closely connected by passage-beds.

contain the remains of a plant closely allied to *Tæniopteris*, are nevertheless of great age, and if we adopt Professor M'Coy's conclusions for the Mount Potts fossil shells, at least carboniferous. Moreover, there is no doubt that they are of the same age as the formations which in New South Wales contain the fine coal-fields. The relations of these palæozoic beds are shown, for comparison in section 4, and whilst the more westerly Mount Potts beds exhibit only one huge anticlinal arrangement, those in the Clent Hills have undergone greater flexures, of which in a distance of three miles, six synclinals are clearly exposed in Fern Gully. The same sequence of the palæozoic sedimentary beds is shown in all the sections I examined, of which several of the annexed sections give the details, and to which I beg to refer.

As before observed, the more we advance towards the Canterbury plains, the more we are sure to find the conglomerates in exposed positions, having by their hardness, without doubt, resisted most effectually the disintegrating influences here at work for numberless ages. I have mentioned that the chocolate-coloured slates which overlie the fossiliferous beds forming the summit of the Mount Potts range, reach the Rangitata river-bed five miles more to the south. In order to show the huge dimensions of the foldings, I may state that these peculiarly coloured slates, with a series of more silicious beds, are again found on the opposite banks of the Rangitata, and are well developed in Butler's Creek, where it leaves the ranges, and, still further to the south, they cross the Forest Creek near its sources. Between these localities and the summit of the Southern Alps, I have been able to trace them five times more (they may occur still oftener), always standing at a high angle, and showing well the clearly defined anticlinal and synclinal arrangement of the strata. Beds of conglomerate and shales are always associated with them forming a lower horizon, and also the texture of the sandstones is always of the same character, having either a white kaolin-like matrix, or being of blueish or greenish colours with a hard semi-crystalline structure. Moreover, these latter are always true graywacke sandstones, whatever their other characteristics may be, small angular pieces of slate being enclosed in them. These pieces are not always of the usual dark bluish tints, but sometimes exhibit reddish and greenish colours, proving that similar slates to those which now alternate with the graywacke sandstones were also existing before this large series of beds was formed.

Texture of Rocks and Position of Strata.

I shall now proceed to give a general outline of the beds of which this formation is composed, and of their general features and sequence.

Speaking more specially of their arrangement, we may describe it as a continuation of anticlinal arches and synclinal troughs; but instead of finding the mountains to be formed by the arches and the valleys by the troughs, careful examination shows convincingly that exactly the reverse has taken place. Thus to give only one instance, whilst the enormous mass of Mount Cook occupies a synclinal trough, the broad valley of the Godley river runs along an anticlinal arch. The occurrence of such enormous changes by which the arches or mountains have been converted into deep valleys, and the troughs into high serrated mountains, will give us a faint idea of the amount of time which has elapsed, and the enormous waste which has taken place, before the Southern Alps assumed their present form. The general strike of these sedimentary beds is south-west to north-east, but varying considerably, sometimes even in short distances according to the numerous foldings and bends. The strata dip generally at high angles, and stand sometimes almost vertically, a south-east and north-west dip being the most usual. As the greater portion of the beds consist of sandstones of nearly the same character, we may describe the Southern Alps as sandstone chains. Alternating with the sandstones we find slates, shales, brecciated beds (graywacke), and conglomerates in almost endless succession, forming generally sharply defined strata. Here and there we observe inter-stratified with them diabasic beds, sometimes in the form of ashes. The sedimentary beds by contact with these ashes have undergone considerable changes, so as to assume all the characteristics of chertose rocks. Small beds of limestone, generally in the form of marble of whitish tints, are sometimes intimately associated with these eruptive rocks, whilst under all other conditions the absence of limestone is very striking, even rocks with a calcareous matrix being generally wanting.

Thus it is evident that we see before us the deposits of rivers falling into the palæozoic sea, and judging from the position and succession of the boulders of which the conglomerate beds are composed, we may conclude that a large continent or island existed to the east or south-east of New Zealand, of which probably the old sedimentary and semi-metamorphic rocks of the Chatham Islands are still a small remnant, whilst the main land has long since disappeared below the sea. We perceive, moreover, that according to the state of the rivers or the changes of the currents, the character of the deposits also changed, the pebble and conglomerate beds representing the immediate neighbourhood of the mouths of the rivers, whilst the fine-grained sandstones represent the littoral zone, and the clay-slates, and shales those regions of the bottom of the palæozoic sea where only fine particles of ooze could be deposited. The great scarcity of animal and vegetable remains in these rocks is very remarkable, and as we have no reason to believe that the sea was devoid of organic life, we either must assume that in many instances various agencies have been at work to destroy its record, or that from other physical causes animal life was very scarce. In order to explain more fully what I mean, I may point out that there are markings or obscure exuviæ of an Annelid in many of the shales, which rocks consequently could have preserved to us those of Mollusks had they been abundant. I have found these identical fossils near the sources of the Rangitata and of the Rakaia, in the very heart of the Southern Alps, near the mouth of the Hurunui, on the East Coast, and in many localities in the Malvern Hills, whilst sandy shales with markings of fucoid plants, identical in character, are met with in many localities, such as the Gorge of the Ashley, on the southern base of Mount Cook, and in the Four Peak range.

If we apply the late deep sea researches and their inductions concerning the Mediterranean, as given by Dr. Carpenter, F.R.S., and Mr. J. Gwyn Jeffreys, F.R.S., in the Proceedings of the Royal Society, Volume XIX, No. 125, to the physical conditions which might have prevailed in our palæozoic seas during the formation of the New Zealand strata under review, our difficulties under that head will be easily removed. We know that in our palæozoic strata there are beds of conglomerate of enormous thickness, the boulders of which they are composed showing that they must have been derived from ranges of great lithological variety, and indicating that they were brought down by large rivers, whilst the general character of the whole strata associated with these conglomerates indicates clearly that they could only have been formed from the sediment of such rivers. Thus it is easily conceivable that one of the conditions might have existed which now prevails in the more central portion of the Mediterranean to the prejudice of the existence of animal life, namely, *turbidity of the bottom water*. Of course this might have been only one of the causes of this remarkable scarcity of animal life, but I need scarcely point out of what value it is to the geologist now to be able to account for facts which, before the deep sea dredgings lately undertaken, could only hypothetically be explained. However, in one locality, there is ample evidence that animal life was not missing, by the occurrence of fossiliferous beds on the western side of Mount Potts, Upper Rangitata, for it contains many brachiopods and a few gasteropods, of which I have already given the principal genera on page 272.

The lowest beds visible consist of shales often very carbonaceous; of micaceous gritty, generally tabular, sandstones, mostly of light colours, some of them being full of fucoidal markings. The shales are often slaty, and have a peculiar serpentinous look; probably they consist of ashes or are altered beds. Associated with them are conglomerates, the matrix of which, mostly a quartzose ferruginous sand, is sometimes so little binding that it is easily decomposed when exposed to atmospheric action, but some of them are so hard that they form buttresses standing prominently out from the mountain sides, and then generally form the summits of the ranges. These conglomerates, like the succeeding beds, are often grouped in several horizons separated from each other by thousands of feet. They are overlaid by a series of compact diabases, diabasic tufas and cherts, with occasionally beds of more or less altered limestones between them. Where these latter occur, they very often constitute the summits of the ranges; thus, to give only one instance, they form in the Malvern Hills, the summits of the Flagpole Hill on the one side, and the Four Peak range on the other; while between them the saddle is an anticlinal, consisting of loosely cemented conglomerates of the lower beds. As before observed, the diabases of the Malvern Hills have a compact structure, and I may here add that the more granular varieties of the same rock occurring in the Nelson province, have without doubt been erupted in the same geological period, and are of a similar origin.

It is very striking that these rocks have such a large extension in our palæozoic beds, both vertical and horizontal, and that in this respect they closely resemble the diabases of the Hartz Mountains in Germany, where they are also interstratified in beds of considerable thickness, ranging from the lower devonian to the upper carboniferous period. Professor E. Kayser, of Berlin, has given an excellent monograph of these Hartz beds, in the Journal of the German Geological

Society for 1869, which is so applicable to our own Malvern Hill beds, that in most instances, if we would substitute for the German names such as Alrode, Lupbode, &c., our New Zealand names Selwyn, Flagpole Hill, they would describe and figure perfectly well our own sections. This shows once more convincingly, that however far the distance may be which separate two localities on the globe, the same abysso-dynamic causes were at work to build up the solid crust of the earth, under the same conditions, everywhere in like manner. Like the conglomerates, these diabasic beds occur in many localities all over this Province, but they are generally not so conspicuous as the chertose rocks, altered by contact with them, which often form turreted crests on the summit of the hills, or run up like walls on the mountain sides.

They are succeeded by sandstones, shales, and slates of various characters, of which a peculiar fine-grained sandstone, with a white decomposing matrix, is sometimes largely developed. In some localities, the latter is interbedded between the conglomerates and the chocolate-coloured slates or their equivalents, the diabasic ashes. The whole series is always of great thickness, folded in a remarkable manner, so that the beds stand at a very high angle, and sometimes even vertical. In some districts, rocks of the same facies forming beds of great thickness prevail. In others, beds of an arenaceous nature preponderate; whilst less frequently, shales or argillaceous beds of a slaty texture take their place. However, in many instances, the beds are very thin, and alternate with each other in a most remarkable manner, the divisions being sharply defined. I shall here give only one illustration to show this. On the left bank of the Godley river, near the glacier of the same name, where a high cliff rises from the water's edge, the ribboned appearance of the beds was so conspicuous that I measured a small portion of the section consisting of greyish sandstones and dark bluish clay-slates, the latter in a few instances gradually getting thinner in their higher portion, and disappearing altogether, a bed of sandstone taking their place. The whole beds dip at an angle of 46 degrees to the south-south-west, and follow each other in ascending order :—

8 feet	0	inches,	greyish fine-grained sandstone
,,	3	,,	dark clay-slate
,,	4	,,	greyish sandstone
,,	3	,,	dark clay-slate

8	feet	2	inches	greenish sandstone
	„	3	„	dark clay-slate, running out 12 feet above river
	„	4	„	greyish sandstone
	„	2	„	dark clay-slate
	„	3	„	greyish sandstone
	„	4	„	dark clay-slate
1	„	10	„	greenish sandstone
1	„	0	„	dark clay-slate
3	„	0	„	greyish sandstone
	„	4	„	dark clay-slate running gradually out
6	„	2	„	greyish sandstone
	„	9	„	dark clay-slate
4	„	3	„	greyish sandstone
	„	4	„	dark clay-slate

Above the latter bed, repose bluish greywacke sandstones full of small quartz veins, about 470 feet thick, after which another alternation of sandstones and slates, similar to the one given above, follows, succeeded by a series of shales of great thickness, overlaid again by bluish graywacke sandstone.

Extent.

This formation, as before observed, covers more than half of the Province of Canterbury; near the Hurunui, as well as at the Waimate, some of its outliers reach almost to the sea coast and from the northern boundary, it stretches to several miles west of the junction of the Otira with the Taramakau. From the Hurunui it recedes in a south-west direction inland, and forms all the higher ranges skirting the Canterbury plains and their southern continuation as far as the Waitaki. Rocks belonging to this series form, from the banks of the Taramakau for a considerable distance, the summits, and for several thousand feet the western slopes, of the Southern Alps, till we reach the northern sources of the Rakaia, where they retreat several miles to the east of the main divide. More to the south they again build up several of the highest peaks of the Southern Alps, as, for instance, Mount Haidinger and Mount Cook, of which we obtain clear evidence from the moraines covering the glaciers descending on both sides. From the gigantic ancient moraines along the West Coast, we can collect, in most localities, numbers of blocks derived on this formation, which is an indication of its presence in many inaccessible peaks. South of Mount Cook, the Mount Torlesse rocks strike more towards the interior, the boundary between them and the Waihao formation passing near the sources of the Ahuriri river to the neighbourhood of the Lindis Pass. They are here separated from the large outlier occurring on both banks of the Hunter river by a small zone of the Waihao formation, which crowns the ranges east of the Hunter river. Another outlier is situated not far from the West Coast, south of Jackson's Bay.

Thickness and Age.

Before concluding the somewhat imperfect sketch of this extensive formation, which has at least a thickness of 25,000 feet, and besides the fossils enumerated, contains only two other small and rather indistinct exuviæ, of which one resembles a tentaculite and a few tracks of anellides, I wish to point out that it is far from my thoughts to say that the whole of this formation is of carboniferous age. It is very possible, and even more than probable, that this huge assemblage of beds, by which it is formed may belong to several distinct periods, ranging from palæozoic to lower mezozoic; but owing to the want of fossils, such as have been found at Reefton (of devonian age), at Richmond in the Province of Nelson, and in the Moonlight range and other localities in Otago (of triassic age), or again in the south-eastern district of Otago (Captain Hutton's Putataka formation), it is impossible to divide this formation in Canterbury for the present at at least, into smaller groups, the more so as such attempts have hitherto only brought confusion into our geology. Nothing remains to be done but to make further detail examinations on a systematic plan, and to follow some of the more characteristic beds as far as they can be traced.

Igneous Rocks.

I have already alluded to the diabasic beds and their ashes, which are interstratified in many horizons between the strata of purely sedimentary origin; besides them, are a few dykes of hyperite, which might have been injected when the huge foldings were formed. In one instance, in Coal Creek, Rangitata, I found a bed of melaphyre, somewhat amygdaloidal, interbedded between two strata of sandstone, but it had probably been forced between them at a much later date, belonging to the formation next to be considered.

Relations to the Older Formations.

There is no doubt that great unconformity exists between this and the Waihao formation, of which clear proofs are to be found near Burke's Pass and the Waihao country. In the Southern Alps proper, the boundaries between the two formations are not so clearly defined, in most instances no break being visible. In such cases, it is impossible to define the boundary line between them, the facies of the rocks being the only guide. Amongst the localities where this unconformity is to be observed, one occurs near the head of the Stewart, one of the source branches of the Rakaia, another twelve miles up the River Hopkins, and again on the slopes of Mount Brewster, but generally in ascending the rivers, we cross from one formation into the other, without observing any difference in the strike and dip of the strata.

CHAPTER VIII.

The Melaphyre and Quartziferous Porphyry Eruptions.

Before proceeding to the next, or Waipara formation, it will be useful to treat separately of the intervening period when a series of eruptions, consisting of basic and acidic igneous rocks took place on a large scale along both sides of the Southern Alps, those on the eastern slopes being the most extensive. These eruptions had long ceased before sedimentary beds belonging to the newer era were deposited on their flanks, the material for them being generally derived from their disintegration and destruction. It is impossible to say, at least at the present stage of our knowledge, when the palæozoic rocks described in the previous pages were folded, crushed and denuded to such a remarkable extent, or when they appeared above the sea, and how long they remained above it under powerful atmospheric influences, being subjected at the same time to erosion by rivers or by the sea along the coast, but we can affirm with safety that this period, during which they were denuded to a remarkable extent, was a long one. Moreover, there is sufficient evidence to show that even the forms of several of the present main valleys were already indicated. Thus, when the next period of disturbance occurred, the main configuration of this Island was already so far sketched out that the addition of new rocks made no considerable difference in its outlines. These rocks, as previously observed, consist of two main groups, both of igneous origin, of which the older belongs to the basic and the younger to the acidic sub-division.

We have no data from which we can judge when those rocks appeared, but there is sufficient evidence to show that they broke through the palæozoic beds upon which they rest unconformably, after the latter had generally assumed their present positions, and their surface had already been denuded and partly decomposed; in fact, a very long period of time must have elapsed before the first eruption took place.

Extent.

In this group I include the melaphyres with their tufas and amygdaloids, the felsitic and quartziferous porphyries with their pitchstones and tufas of the East, and the melaphyres of the West Coasts. The first zone begins in this province on the southern declivities of Oxford Hill, where a small outlier of melaphyres and amygdaloids occurs. It then becomes largely developed in the southern portion of the Malvern Hills, and on both banks of the Rakaia, near the Upper Ferry. In this district, the melaphyres rise to an altitude of 2900 feet, and the quartziferous porphyries to 3019 feet (in High Peak).

Another small outlier of the latter is situated five miles from the beginning of the Canterbury plains, on the right bank of the northern Ashburton. On both banks of the southern Ashburton and Hinds rivers, both divisions of these eruptive rocks cover a large area, forming the summits of mountains of considerable dimensions, the basic rocks rising in the Clent Hills to 4100 feet, and the acidic rocks in Mount Somers to 5223 feet. The latter also crop up in one locality on the southern banks of the Orari. Another zone, possessing very interesting features, is found on Banks' Peninsula, consisting of quartziferous porphyry, pitchstones, and some tufaceous beds derived from them; whilst we meet, on the northern declivities of Mount Harper, with a small zone of melaphyre; on the right or southern banks of the Rangitata, between Forest and Coal Creeks, a large portion of the McLeod range consists of felsitic porphyry, amygdaloids and melaphyres, stretching across into the Upper Orari. In the more southern portions of the province, no eruptive rocks were observed by me *in situ*, but I found repeatedly boulders of similar porphyries in the lower Waihao, without however being able to discover the locality whence they became detached. I believe that the porphyries in the River Mandamus, north of the Hurunui, and in the Leslie Hills, north of the Waiau river, described in my Report on the Geology of the Amuri district (Reports of Geological Explorations during 1870–71, Geological Survey of New Zealand) form the northern continuation of this zone. On the West Coast, only basic rocks appear to have been erupted, by which, south of Bruce Bay, a considerable portion of the coast line is now formed. I have already stated that they appear to be of a somewhat younger age than the eruptive rocks on the eastern side, because if the sedimentary beds, consisting of conglomerate, grits, shale, and coal, with which the melaphyres are associated, and which are doubtless of the same age as the Grey Coal Measures, are contemporaneous with the cretaceo-tertiary formation on the eastern side, which is very probable, they ought to be classed with the basic rocks, making their appearance during that period. However, my reason for placing them with the former is, that they possess all the characteristics of true melaphyres, having, moreover, extensive beds of tufas and amygdaloids associated with them.

Character and Sequence of the Eruptive Rocks.—Melaphyre Series.

Although there are characteristic tufa beds interstratified with the melaphyres, no fossils of any kind have been found in them at present, and thus it is impossible to state when those eruptions, which were on a gigantic scale, took place, by which the melaphyres and their accompanying tufas were deposited upon the sea bottom. I can only repeat what I previously stated concerning them, namely, that they repose on the sedimentary strata, which, previously to the eruption of these basic rocks, had undergone great changes and denudations, and that since then no alteration of importance, except the rising of the land, has taken place. After these basic rocks were deposited, before the next, or acidic beds were formed, they, in their turn, underwent enormous denudations. I may here add, that generally in other countries the acidic formations (quartziferous or felsitic porphyries) constitute the lowest beds, whilst the melaphyres, or basic rocks, repose upon them—our beds thus differing in this respect. Of this denudation the isolated system of the Gawler Downs forms a notable instance, as it is only a remnant of a once continuous series of beds which all around have been removed, often for many miles.

Sometimes the melaphyres, principally where they occur in higher positions, lie directly upon the edges of the palæozoic rocks, but in most instances, they are preceded by beds of tufa, which often are so intermixed and blend so thoroughly with the decomposed sedimentary rocks below them, that it is impossible to fix the exact line of contact between them. These lowest beds are mostly wacke, more or less amygdaloidal, of brown and reddish tints, in some localities they are traversed by dykes of melaphyre of a compact texture. They are overlaid by regular *coulées* or streams of melaphyre. We may consider that some of the wacke and some of the amygdaloids are either ashes, deposited during submarine eruptions on the sea bottom, or if, at least, some of them were formed by regular *coulées* they have afterwards been so much exposed to hydrothermal action, that they have undergone great alterations and changes in their structure, whilst the melaphyres proper have been ejected during larger submarine eruptions, following each other in quicker succession than the former, by which the whole series became more protected. Some of the streams are of great thickness and extent, as I was enabled to trace them for from five to six miles continuously. Their number is also very great, into which fact the Gawler Downs, amongst other localities, give us a splendid insight. There, streams of melaphyres, many of them standing nearly vertical—a dip of 79° to 82°, generally to the E.S.E., being common—alternate for several miles in an almost endless succession with tufas of various character. Some of them, full of concretions of green earth, are true amygdaloids, or are full of geodes of agate, chalcedony, and all the numerous varieties of quartz usually found in these old basic rocks, vividly reminding me of Oberstein, in Germany.

The lithological character of the rocks under review is very varied. We find some of which the component parts are so distinctly crystallized that they could be mistaken for dolerites, others are more porphyritic, others so compact that they appear like basalts, whilst a few of them have a pitchstone-like appearance. When in an undecomposed state, they are generally black, with greenish, bluish, or reddish hues. They contain numerous minerals as accessories, such as agate, chalcedony, amethyst, jasper, calcareous spar, sphærosiderite, delessite, and epidote, but I was unable to find any traces of ores, and the different localities which were pointed out to me as containing copper ores proved unfortunately to consist only of masses of green earth, as accessories to the rocks, or colouring them intensely. Concerning their position, they are invariably found to be below the quartziferous porphyries. In the Malvern Hills they crop up along the sides as well as towards the centre of the acidic zone where the rocks belonging to the latter have been much denuded. In the gorge of the Rakaia, where fine sections are exposed, they occur in the centre, being flanked on both sides by the porphyries. The relations of these rocks to each other are still more clearly exhibited in the Ashburton-Hinds zone, where the melaphyres occupy the outer margin, the quartziferous porphyries forming the centre and covering the former. On Section-plate No. 3 I have copied from my field-books some of the most interesting sections, illustrating the relations in which these eruptive rocks stand to each other.

Quartziferous Porphyry and Pitchstone Series.

The basic rocks just described are, as previously stated, covered in many localities by a series of quartziferous porphyries and pitchstones, which in Mount Somers reach an altitude of 5223 feet. An examination of the junction of these two series of eruptive rocks in several localities, showed that the older rocks had undergone considerable denudation, or, at least, that their surface had been altered considerably by aqueous agency before the next beds were deposited upon them. Thus, for instance, among the Clent Hills, in Junction Creek, which joins the Stour, the uppermost beds of the melaphyres consist of a very decomposed amygdaloid, gradually changing into a green tufa of the quartziferous porphyries; upon them repose pitchstones, from a greenish-white colour gradually assuming a black tint, and becoming very vitreous. The porphyries which lie upon them, or, more correctly speaking, of which they form the lowest portion, have a hyaline base, and follow each other in many streams, but generally with a layer of pitchstone betweem them. The principal localities where these porphyries are found are in the Malvern Hills, Hinds, Ashburton, and Banks' Peninsula districts. Although of a great variety of texture and colour they resemble each other in their principal characteristics, a porphyritic structure with grains of quartz and small crystals of garnets (almandine) being predominant. I have already alluded to the fact that these porphyries lie directly in some localities upon the melaphyres, but in other places they repose upon the palæozoic sedimentary rocks, the streams of which they are composed following the outlines of the former sea-bottom, and being at the same time underlaid by a succession of truly sedimentary deposits of great variety. What gives these lowest beds forming the base of the porphyries a still greater interest is the occurrence of plant beds, and seams of brown coal, mostly of inconsiderable thickness, associated with them. The locality where the whole series can best be studied, is situated in the Cox Hills at the south-eastern base of Mount Somers. Upon the palæozoic sedimentary rocks, consisting principally of a coarse sandstone decomposing to a loose ferruginous gravel, repose thick beds of green sands, gradually altering to yellowish and white quartzose sands; thickness about 500 to 600 feet. They are capped by ferruginous shales three feet thick, overlaid by four feet of snow white sands. Twenty inches of shales, full of impressions of leaves, follow, but unfortunately with scarcely any pieces large enough for recognition. Some of these leaves, however, I believed at the time to be of a truly dicotyledonous character. Although, after repeated examination of a number of specimens received since my first survey was made, I am now inclined to refer them to the coniferæ. One of the most perfect of these fossil leaves has great resemblance with the Dammara of the overlying Waipara formation. These shaly beds are again overlaid by a great thickness of sands, mostly of a pure white colour, and with veins and irregular portions of yellow or salmon-coloured hues. The latter are covered by shales, with a dip of 46° to W.S.W., followed by three feet of a partially altered brown coal, showing sometimes still the woody structure; this seam is covered by 16 inches of gritty sandstone.

Then follow, in ascending order:—Twelve inches of yellowish or bluish tufaceous clays, six to eight feet of shaly beds, with indistinct remains of plants, three feet of bluish or greenish tufaceous clays, one to two feet of porcelain jasper, evidently altered and burnt by the next beds, which are of an eruptive character. These porcelain jaspers contain some lapilli, or even smaller blocks of pitchstone enclosed in them. They gradually alter into a whitish tufaceous mass, consisting of lapilli and ashes cemented together, without doubt the result of the destruction of pitchstones during an eruption. These beds are full of angular or sub-angular pieces of black pitchstone, evidently much decomposed, and from one inch to 20 feet in diameter; the whole having a thickness of at least 100 feet. They are capped by a stratum of pitchstone about 10 feet thick, upon which quartziferous porphyries follow, first with a hyaline, afterwards with a more felsitic matrix. This first great stream forms the lowest of a great succession of similar ones rising to the summit of Mount Somers, that is to say, the whole has a thickness of more than 3000 feet. Towards the Ashburton, the succession of the streams is not so well shown; but on the northern flanks of Mount Somers, where that fine mountain falls in some localities abruptly for more than 1000 feet in almost perpendicular cliffs, their position, nature, and succession, are well exhibited. Some of the *coulées*, occasionally of great thickness, have a more trachytic structure towards the centre, whilst the smaller ones are generally more hyaline, or at least felsitic, usually with selvages of pitchstone on both planes. In fact they may fairly be compared to lava streams of the present day, showing the same process of cooling, although, owing to different circumstances and mineralogical constituents, the magma out of which they originated naturally assumed different forms.

Examining the mineralogical structure of the acidic rocks in the Malvern Hills, we find that one of their principal characteristics, both in the porphyries as in the pitchstones belonging to them, is the occurrence of crystals of garnets of the red variety called almandine, as well as grains of bluish translucent quartz, both of which are seldom absent, being enclosed in a felsitic matrix. These series are most largely developed in several well-defined peaks and ranges, such as High Peak, Phillip's Range, Rocky Range, Rocky Peak, Mount Misery, etc.; also the lower portion of the Rakaia Gorge gives a capital insight into their characteristic features. They overlie not only the palæozoic rocks, through which they have broken, but also the melaphyres on the partly decomposed surface of which they appear in many localities. They have a longitudinal extension from west to east, dipping mostly towards the south, but have in some localities an anticlinal arrangement where they appear on both sides of the melaphyric centre. They rise to an altitude of 3019 feet in High Peak, the highest summit of the whole system, and the principal centre of eruption, but they have suffered considerable denudation in that portion of the country now occupied by the broad valley of the Rakaia. In their eastern portion in Mount Misery and Mount Pleasant, where they assume sometimes tabular forms, and are of great thickness, they overlie exclusively the palæozoic sedimentary rocks, but this contact is generally hidden by younger beds. In the western ranges, however, the said contact is clearly exposed in many beautiful sections, showing that they repose either on the melaphyres, or often directly upon the sedimentary palæozoic rocks. Following the contour of the former, they are often only 30 to 40 feet thick, as if they had been flowing in stream-like beds from fissures in the older sedimentary or basic rocks. They are accompanied by pitchstones, which mark the lines by which they were erupted, or where they came in contact with other rocks, and thus it is evident that they were subject to the same rules as volcanic rocks of younger origin.

Most of the higher ranges such as Rocky Peak, High Peak, Mount Misery, consist of such rocks, which having, doubtless, flowed from several centres, all forming rounded or conical hills, have cooled in that form. Many of these rocks have a trachytic appearance, without doubt from partial decomposition, to which they have been subjected for numberless ages, and which has affected them to a great depth. However, in some favourable localities, namely, in deep gorges and landslips, I was enabled to observe how this earthy appearance of the base gradually changes into a true felsitic structure. This gradation can be more easily seen in the different dykes of the same rock, which radiate from the small outlier east of Rocky Peak, and which have filled up fissures in the palæozoic rocks. The selvage of these dykes assumes sometimes the structure of an imperfect pitchstone, but the sedimentary beds close to them have been very little affected, the only difference being that generally they break into smaller polyhedral fragments than the same rocks a few yards further distant.

The principal centre of eruption appears to have been at the head of Rockwood Creek, at the base of High Peak, which is here surrounded by vertical cliffs very difficult of access. Here a synenitic granite porphyry occurs, which, however, I was not able to find *in situ*; it is identical with the *Porphyre Granitoide* of French authors. Dufrenoy's description of this rock from Signon and Aix applies fully to our rock specimen, No. 348. It has been traced by him and Elie de Beaumont in its gradual change into porphyry similar to that of High Peak, but never into granite. (See *Elie de Beaumont and Dufrenoy explication de la carte geologique de France, I.* 30). Similar rocks occur in the Thuringian Forest, also together with "*Felsitporphyr*," (see *Lehrbuch der Petrographie Zirkel, I.* 528), they contain quartz, felspar, and hornblende, the latter found sometimes in well-defined crystals, but mostly in scaly aggregations; the felspar is white, and, without doubt, Oligoclase. Besides this beautiful rock there appear in these precipices some brecciated porphyries, and others, more or less laminated; also, in the so-called Rocky Ridge east of High Peak some of the porphyries have a similar brecciated structure, through which other portions, of a more felsitic character in the form of dykes appear. Although this, in many cases, may be only an appearance, and the effect of a different state of cooling, or re-arrangement of the particles during the cooling, some of those dyke-like masses may nevertheless be real dykes which at various periods were ejected, and filled up fissures in the previously erupted rocks of the same description. Where the porphyries repose directly upon the palæozoic sedimentary beds, or upon the amygdaloids, at the junction they appear either as pitch-stones or they have a more or less tufaceous character, just in the same manner as a lava stream of younger origin which is stony in the centre, is always scoriaceous or tufaceous at the bottom, where it reposes upon other rocks. There is, however, one locality in the Gorge of the Rakaia where true tufas, and even shales appear immediately below the porphyries. Besides the crystals which have, doubtless, been formed during the cooling of the rock, these porphyries enclose sometimes small pieces of slate and sandstones either angular or having their edges rounded. These enclosed pieces are generally quite unaltered, but I observed one piece of sandstone which was remarkably fritted.

The quartziferous porphyries in Banks' Peninsula occur near and along the opening leading from the head of Governor's Bay to Lake Ellesmere, by Gebbie's Pass, and stretch as Manson's Peninsula far into Lyttelton harbour. They have broken through, and cover sedimentary rocks, probably belonging to the Waihao formation. At the base we also find tufaceous deposits, brecciated agglomerates, and shaly beds, with obscure markings of plant remains which might possibly belong to them. In texture and composition these porphyries, sometimes containing garnets, agree with those of the more western zone, whilst in other instances their compact, or sometimes felsitic matrix, is full of crystals and grains of smoky quartz. When treating of Banks' Peninsula, I shall return to this subject.

Even now when the *coulées*, although they have become greatly destroyed, possess in some localities a total thickness of 3000 feet, it is evident that before the next, or Waipara formation was deposited, these eruptive rocks had already been exposed for a considerable time to disintegrating agencies; consequently a long period must have intervened between the eruption of the acidic rocks and the deposition of the Waipara beds. Numerous specimens of fossil wood have been collected from the strata at the base of these eruptive rocks. Generally it occurs in flattened stems, some of large dimensions, the interior being filled with flint, woodopal or woodstone, and the bark alone preserving the woody structure, thus suggesting that these trees either belonged to the Acrogens or Endogens division. A few stems of trees have also been obtained exhibiting the woody structure throughout, but they have not as yet been microscopically examined, to settle whether they are the remnants of coniferæ or of dicotyledonous trees. Several of the most characteristic sections, both from the Malvern Hills and the Mount Somers district, illustrating the relation of the melaphyres and quartziferous porphyries to each other, and to the palæozoic rocks underlying them, have been added on plate No. 3.

The following analyses were made in the Laboratory of the Imperial Geological State Institute of Vienna by Carl Ritter von Hauer :—

White Quartziferous Porphyry with Garnets.—Mount Misery, Malvern Hills.

Silica	73·31
Alumina	11·00
Protoxyde of iron	1·55
Lime	5·32
Potash	4·70
Soda	2·44
Water	0·30
	98.62

With traces of protoxyde of Manganese.

Green Quartziferous Porphyry.—Snowy Peak, Malvern Hills.

Silica	76·00
Alumina	7·16
Protoxyde of iron	5·00
Magnesia	3·76
Potash	5·30
Soda	2·22
Water	0·66
	100·10

CHAPTER IX.

The Waipara Formation.

In the preceding notes on the "General Geological Structure of the Province," I have already given some details on the origin of this important formation, which although not of great horizontal extent, is nevertheless of considerable interest, both from a scientific and economic point of view. It was named the Waipara formation in 1866 by Professor von Hochstetter, the valley of that river being the principal locality in which the remains of numerous huge saurians were found, and placed by him at the same time in the jurassic group. However, when examining these beds more closely in the Waipara and Malvern Hills districts, and collecting their numerous fossil contents, I found that the impressions of plants in the lowest series consisted of dicotyledonous leaves, of which the following species are well represented:—*Fagus ninnisiana*, *Phyllites eucalyptroides*, *Loranthophyllum dubium*, *Griselinia myrtifolium*, and several others described by Unger from specimens collected by von Hochstetter in Auckland and Nelson, and considered by both authorities as indicating a true tertiary age. I also obtained remains of some conifers, amongst them the impression of a large araucarian cone and twigs, belonging without doubt to that division of pines which at present are still inhabitants of Australia, besides leaves and twigs of a dammara, resembling in many respects the kauri of the Northern islands. On the West Coast, on the other hand, although most of the plant impressions are dicotyledonous leaves, many of them are different from those found on the

East Coast; moreover, besides a small number of ferns (one of them a *Pecopteris*), there are numerous remains of Gymnogens and Endogens, which I have not found at Shag Point or in the Malvern Hills. However, when examining the whole series side by side, there is no doubt that a good many species of plants are common to all three localities, and that climate, soil, and altitude may easily account for the peculiarities of the flora in each district.

Now in regard to the fossil molluscs, both from the Waipara and the Malvern Hills, where the formation under review is most largely represented, it is true that a number of them are of the same species as in the Amuri district; but, as I have already pointed out in my previous reports, there has hitherto not been the least sign of the occurrence of belemnites, so frequent in the latter locality; and as all the other shells, with scarcely any exception, are still represented in the marine fauna living at present near the coast of New Zealand and Australia, I assigned to them, notwithstanding the presence of the saurian remains, an eocene tertiary age. However, as Dr Hector's researches have established the fact that all the principal genera and species of saurians found at the Amuri Bluff occur also at the Waipara, I have included for some years past the Waipara and Malvern Hill beds in his cretaceo-tertiary formation, leaving it to further research, and to a careful examination of the fossils collected in those localities by a competent palæologist to settle this question finally.*

Extent.

This formation, with the exception of a few inland basins, skirts only the foot of the Southern Alps on both sides. On the eastern side it is most largely developed south of the Hurunui. It forms part of the higher coast ranges stretching from the River Blyth to the Waipara; more inland it reaches from near the sources of the Glenmark Creek several miles across the middle Waipara to the northern foot of Mount Grey, and in the upper course of that river it is also well developed. It also occurs at the foot of the ranges where the Okuku and Gari rivers (tributaries of the Ashley) enter the plains.

---

* One of my scientific friends in Australia informs me that true belemnites have been found there in tertiary strata, hitherto considered as being of Miocene age; but I think further confirmation is wanted before such an important occurrence can be accepted as a well-established fact.

Another important zone forms the eastern portion of the Malvern Hills, in which more to the west a few isolated basins belonging to it have been preserved, for instance, in the upper course of the Wekaepa, or Selwyn proper, and on the banks of the Kowai, a tributary of the Waimakariri river. Important isolated basins are situated north-west of the Thirteen-Mile Bush range, at the head of Macfarlane's stream, and north-west of Mount Torlesse in the Broken River basin. Although there are a few localities south of the gorge of the Rakaia which, judging from the impression of leaves, might be referred to this formation, (as, for instance, some beds of shales on the southern banks of the upper Kakahu and some small outliers with seams of brown coal between the Opihi and Opuha), I have thought it more convenient not to separate these outliers from the next formation, by which they appear to be overlaid conformably. On the West Coast we can include the Grey Coal Measures as far as the Cobden limestone, and a portion of which crosses into Westland, with the Waipara formation. There is also a small outlier at the Kanieri, containing seams of coal of inconsiderable thickness, which has to be classed with it. For a great distance along the coast all rocks belonging to this formation are hidden below morainic accumulations till we approach the Paringa river, where several miles north of its estuary it is again largely developed, forming a strip several miles broad, and reaching to the Waita river. After a considerable interval we meet it again at Jackson's Bay, whence we can follow it to the southern boundary of the Province, always exhibiting the characteristic feature of littoral deposits.

Sequence and Character of Rocks, Position of Strata, Fossil Contents.

I have already stated that the last formation, consisting almost exclusively of igneous rocks of submarine origin was in its turn uplifted and brought within the influence of marine and sub-ærial action, so that the strata composing it were not only greatly destroyed, and their outlines considerably changed, but also beds of conglomerate, often of enormous thickness, were deposited along their base, of which we have a notable instance in the Malvern Hills. In other localities, where these eruptive rocks did not exist, the conglomerate was either formed from boulders and pebbles of palæozoic sedimentary rocks in the neighbourhood, or loose sandy beds were deposited. The latter were either derived from the disintegration of these palæozoic coast ranges, or formed, in many instances, of quartzose sands of light tints, mostly the result of the destruction of the quartziferous porphyries which have travelled so far along the coast, and have in consequence become disintegrated. I have before observed that the conglomerates, consisting of boulders and pebbles of quartziferous porphyry, are of local occurrence, but there is one exception in the outlier behind the Thirteen-Mile Bush range (Big Ben) to which I wish to allude. The base of the whole series in that distant locality consists of a loose conglomerate made up of boulders of quartziferous porphyry quite similar to that occurring on the eastern side of the ranges; and as this outlier is situated amongst the mountains in a depression, the base of which is about 2,800 feet above the level of the sea, and is surrounded by heights of 4,000 to 5,000 feet, it is difficult to understand whence the material for this conglomerate could have been derived, except from mountains of much greater altitude than at present exist, and from which the material was brought by currents over the summit of the ranges west of the Thirteen-Mile Bush range. A glance at the map will at once convey my meaning, and show how difficult it is to account for this occurrence in such a land-locked locality, separated from the range consisting of porphyries by a whole series of high mountains, unless we assume that the material for these beds was brought from another locality closer by, now hidden from our sight by younger deposits. In some localities, as, for instance, in the middle portion of the Malvern Hills, these conglomerates are of enormous thickness, about 6,000 to 8,000 feet, and are interstratified with ferruginous sands, fire clays, clay iron ore, shales, and small and irregular seams of brown coal, the latter sometimes partly altered and of no practical value. In other localities, including the Waipara, the lowest beds consist of loose sands, more or less ferruginous, about 100 feet thick, towards the upper portion of which small and impure seams of brown coal are interstratified. These beds follow the contours of the ancient shore line, dipping at the same angle. Thus, in the Waipara these sands and the brown coal seams dip 32 deg. to the east, in the Malvern Hills 19 deg. to the east-south-east. Whilst, as before observed, the brown coal formation in the Waipara is only represented by a few small seams of impure shaly coal, in the Malvern Hills it is of large horizontal extent, and many hundred feet thick, containing a number of seams, of which several are workable. At its base, and still separated by porphyry conglomerate, a bed about ten feet thick occurs, consisting almost entirely of fossil shells, of which a large white triangular Ostrea, different from any of the fossil oysters above the coal seams, is the most conspicuous. This oyster is accompanied by casts of Panopæa, Cardita, Tellina, Trigonia, and a few others too fragmentary to be made out.

In all the principal localities the brown coal series is covered by a bed of shell sandstone, containing a great number of fossil shells, of which the following are the principal genera and species :—*Dentalium majus*, (Sow.), *Pleurotoma*, *Turbo*, *Neptunea*, *Conchothyra parasitica* (McCoy), *Aporrhais*, *Scalaria*, *Turritella*, *Calyptræa*, *Neritopsis*, *Cypraea*, *Purpura*, *Natica*, *Panopæa*, *Lutraria*, *Eriphylla*, *Zenatia*, *Pholadomya*, *Lucina Americana*, (Sow.), *Astarte*, *Cytheria*, *Dosinia*, *Cardium*, *Isocardia*, *Myacites*, *Protocardium*, *Venericardia*, *Crassatella*, *Arca*, *Mytilus*, *Trigonia*, *Cucullæa alta*, (Sow.), *Cucullæa ponderosa* (Hutton), *Pectunculus*, *Pecten*, *Ostrea*, *Terebratella*, *Waldheimia*, *Rhynchonella*. The following exuviæ were also collected in the same horizon :—Saurian bones (waterworn, in the Malvern Hills) ; teeth of *Lamna*, *Hybodus*, and *Otodus ;* scales of *Hybodus ; Dicotyledonous* leaves ; *Araucarian* cone and branches ; leaves and twigs of *Dammara*.

Above the oysterbeds, (a local name appropriately given to the shellbeds), we meet either with a sandy clay iron ore (limonite) covered by glauconitic, and higher up by argillaceous sands, as in the Gorge of the Waipara, or with deposits of white quartzose sands with bands of ferruginous or calcareous sandstone, as in the Malvern Hills. The latter also gradually alter to sandy beds of a more argillaceous nature, both series being of a thickness of several hundred feet in the localities named. In the Waipara, the upper portion of these sands contains the remarkable concretionary nodules of limestone (Septaria) ranging from one foot to twelve feet in diameter, and enclosing besides saurian remains, specimens of Conchothyra parasitica, Cucullæa, and twigs and leaves of a Dammara. In all other localities these septaria are either missing, or when they do occur, never contain any saurian remains ; and instead of them, (as, for instance, on the banks of the Selwyn river), layers, several feet thick, of a somewhat calcareous and micaceous sandstone, divide the sandy beds into a number of banks. In the Broken River basin the large black oyster continues to occur in the sands for a considerable distance, lying either singly or in banks.

The remains of fossil Reptilia from these septaria, collected by Mr. Hood, myself, and others, have been described by Professor Owen in the "Transactions of the British Association for the Advancement of Science," 1861, p. 122, *et seq.*, and in the "Geological Magazine," February, 1870, Vol. VII, p. 49, and by Dr. Hector, in the "Transactions of the New Zealand Institute," Vol. VI, p. 333 *et seq.*, the latter summing up the main results as follows (page 334):—

"The general result is that portions of 43 individual reptiles, mostly of gigantic size and all of aquatic habits, and belonging to at least 13 distinct species, have been discovered. These species represent two distinct groups, the first with flat or slightly biconcave vertebrae, being true *Enaliosaurians*, belonging to the genera *Plesiosaurus*, *Mauisaurus** (*gen. nov.* allied to *Elasmosaurus* of Cope), and *Polycotylus* (Cope); and the other having procœlian vertebrae, as in most recent *Lacertilia* and *Crocodiles*, but provided with swimming paddles, and therefore representing probably the order *Pythonomorpha* of Professor Cope.† This order is represented in the collection by two distinct genera, *Liodon* (Owen), and *Taniwhasaurus*,‡ (*gen nov.* allied to *Clidastes* of Cope.) In addition there are several fragmentary remains, which, for the present, I only venture to place provisionally under one or other of these groups, and two vertebrae, which appear to belong to an exceptional form of the genus *Crocodilus*."

The following species have been obtained in the Waipara, of which remains are in the Canterbury Museum:—

Plesiosaurus	*Australis*	...	Owen
,,	*Crassicostatus*	...	,,
,,	*Hoodii*	...	,,
,,	*Holmesii*	...	Hector
,,	*Traversii*	...	,,
,,	*Mackayii*	...	,,
Polycotylus tenuis		...	,,
Mauisaurus	*Haastii*	...	,,
,,	*latibrachialis*	...	,,
Liodon haumuriensis		...	,,
Taniwhasaurus Oweni		...	,,

* After Maui, the traditional discoverer of New Zealand.

† "On the Fossil Reptilia of the Cretaceous Rocks of Kansas," by Professor E. D. Cope. "Preliminary Report on Geology of Wyoning," F. V. Hayden, 1871, p. 385. "I have not been able to refer to the original paper, by Professor Cope, in the 'Trans. Amer. Phil. Soc., 1868-70,' for the definition of this order.

‡ After the Taniwha, or fabled sea monster of the Maori.

There are also some other fragmentary portions of bones in the Canterbury Museum which appear to belong to species as yet undescribed; but as the explorations of the beds by the Geological Survey of New Zealand is being actively prosecuted, I have no doubt that considerable light will be thrown upon the occurrence of these remarkable saurians, of which many have their nearest allies in the mesozoic beds of the North American Continent.

The next bed in ascending order is of great thickness, and consists principally of greensands, the grains of glauconite being often so numerous that the rocks appear almost black. Sometimes marly or argillaceous beds are interstratified with these greensands. There is generally found in this horizon a great sameness of character in all the sections examined. A few saurian bones have been discovered in these greensands, but they are very scarce, generally very fragmentary, and seem to indicate that the true enalosaurians now neared their extinction. In the Malvern Hills these green sands gradually get lighter in colour, and are capped by quartzose sands in light tints, the whole forming cliffs 300 to 400 feet high. In the more northern portion of the Province the former alter by degrees to argillaceous and calcareous deposits, forming sometimes small beds of chalk marls, or even chalk-like limestones, which are succeeded by a glauconitic, calcareous sandstone. This last is the highest bed in the whole series, and by it the interesting Waipara formation is closed in that district and its neighbourhood, where it forms generally high cliffs and bold escarpments. In the Malvern Hills, on the other hand, the calcareous beds are entirely missing, the uppermost arenaceous deposits belonging to this formation being covered by several *coulées* of basic rocks, with sometimes beds of palagonite tufa between them. In some localities a break seems to occur between the upper and lower calcareous series, as, for instance, in the Weka Pass ranges, where the lower, more calcareous strata are sometimes separated from the glauconitic massive upper beds by a small band of greensand containing concretions of a more calcareous nature. However, in many other localities this small bed does not occur, and the boundary between the two series is either gradual or sharply defined. Moreover, the upper beds are found to be always conformable upon the lower where the latter exists, being, in fact, a continuation of the same series, and owing to the sinking of the land, of greater horizontal extent than the more calcareous beds underlying them. Such a concretionary structure in the middle of the calcareous series is, however, not uncommon, and occurs also in the next or Oamaru formation, of which a notable instance is found in the Otaio, where the lower calcareous beds are divided from the upper more glauconitic ones by a layer, possessing a similar concretionary structure, the same fossils being found above and below the division. Whatever may be the origin of this layer, in any case it is a proof that important changes did take place, by which the mode of deposition and lithological character of the rocks were considerably influenced, without, however, causing a break of any consequence in the continuity of the beds. The lowest chalk marls have yielded hitherto no fossils except a number of foraminifera, of which I have recognised several species as being identical with those described by Karr and Stache in the palæontogical portion of the great Novara work. The upper beds, offering the well-known building stones in the Waipara, Weka Pass, and Castlehill basin, contain a number of shells and other exuviæ, but the former mostly in the form of casts, generally difficult to recognise.

The following is a list of the genera and species, represented in the Canterbury Museum :—*Mammalia*—Cetacean bones. *Aves*—Small fragments of bones. *Pisces*—Teeth and vertebræ of *Carcharodon*, *Lamna*, *Oxyrhina*. *Mollusca*—*Nautilus*, cast; *Pleurotoma*, cast; *Voluta elongata* (Hutton), cast; *Scalaria rotunda* (Hutton), cast; *Struthiolaria*, cast; *Solarium*, cast; *Imperator*, cast; *Cerithium*, cast; *Cardium*, cast; *Arca*, cast; *Lucina*, cast; *Cytheria*, cast; *Mactra*, cast; *Lima*, cast; *Pecten Hochstetteri* (Zittel); *Pecten Williamsoni* (Zittel); *Ostrea; Waldheimia*. *Crustacea*—Carapace of crab *(Porcellana)*; *Balanus*, two species. *Echinodermata*—*Schizaster rotundatus* (Zittel); spines and portions of plates of *Cidarites*. *Actinozoa*—*Turbinolia*, several species; numerous fragments of *Bryozoa*.

The Cretaceo-Tertiary Period in Westland.

As this formation presents some peculiar features I have thought it more convenient to offer a short outline of it separately. The beds begin also on this coast with coal-bearing deposits, and terminate with limestones, proving that a gradual subsidence of the country during their formation took place. They are of enormous thickness, surpassing in that respect the beds on the eastern side of the central range, which have been co-related with them. The clearest and most complete section is open to our inspection on the banks of the lower Grey, where we can follow the complete series from the Brunner coal mines to the Cobden limestones, the whole having a thickness of at least 5000 feet. The lowest beds consist of breccia, often very coarse, and having the appearance of being derived from morainic accumulations. They are succeeded by arcose micaceous sandstones and shales, with a number of coal seams interstratified with them, of which the largest one has an average thickness of 15 feet. Clays more or less micaceous cover them, containing a number of fossils, of which the following are the principal ones:—*Fusus*, *Murex*, *Panopæa*, *Cardium*, *Ostrea*, *Inoceramus*, *Terebratula*, *Kleinia conjuncta* (Hutton). I was told when visiting last the Brunner mines that an ammonite had been found in these clays, but my informant did not know what had become of the specimen. Upon the clays very thick beds of ferruginous sandstone, with concretions of clay ironstones, have been deposited, which appear to be unfossiliferous. These again are overlaid by greensands, sometimes quite black from grains of glauconite, which then appear to form the whole mass. The greensands are covered in their turn by dark marls gradually getting lighter in colour, upon which finally a more or less glauconitic limestone reposes, generally described as the Cobden limestone, and forming the uppermost bed of the whole series. It contains some shells and a number of Echinodermata, of which the following are the principal ones:—*Scalaria*, *Inoceramus*, *Leda*, *Ostrea*, *Lima*, *Pecten*, *Terebratula*, *Nummelites*, *Macropneustes spatangiformis* (Hutton), *Macropneustes cordatus* (Hutton), *Macropneustes Australis* (Hutton), *Eupatagus Greyi* (Hutton), *Meoma brevipetalata* (Hutton), *Schizaster Lyoni* (Hutton), *Turbinolia*. I have lately looked over the fossils, collected by me in this formation as far back as 1860 and 1865, and have been much struck by the absence of all the leading fossils of the eastern side, such as *Ostrea*, *Trigonia*, *Cucullæa*, and many others overlying the coal seams; whilst the *Cardium* of the Grey is also a different species from the one found in the co-related beds of the Waipara.

More to the south the strata belonging to the same horizon succeed each other in the following order. The lowest deposits of the whole series examined by me on both banks of the Paringa river, are again formed of conglomerate, arcose, micaceous coal sandstone, and shales, with small seams of coal, forming the highest ridge of the small coast ranges. This series is overlaid by green sands, arenaceous sands or sandstones of a rather incoherent texture, containing sometimes concretions of ferruginous limestone, upon which numerous *coulées* of melaphyre follow, alternating with brecciated beds with a calcareous matrix, and changing on the one hand into a melaphyre tufa, on the other into almost pure limestone. These igneous rocks form the greater portion of the iron-bound coast, having by their hardness hitherto so effectually resisted the never ceasing action of the powerful surf. More to the north of the Abbey rocks, the sections are not only more complicated, but the eruptive rocks seem to occur at various horizons, and are accompanied by beds of limestones, of which one consists of the lithographic limestone now being worked by Messrs. Docherty and McArthur. Marls, sandstones, and conglomerates appear above this limestone, and thus form the highest beds in this series, which more to the south seem all to have been destroyed. The whole is almost devoid of fossils, and those which I found consisted only of imperfect casts in some of the green sands, amongst which, however, I recognised Panopæa, Natica, and a small radiately striated Pecten. Some of the greensands are so full of fucoid impressions, that the whole forms a mass of flattened stems, lying across each other in all directions, so that many of these beds may best be described as fucoid sandstones. The lower beds have generally an inconsiderable dip to the west, whilst the upper series, including the *coulées* of melaphyre, stand at a very high angle, sometimes almost vertical. The lower conglomerates consist mostly of pebbles of quartz, and are thus easily distinguished from the upper conglomerates, formed of all the different kinds of rocks of which the lower portion of the central chain and the granitic outliers are formed. As before observed, it is difficult to co-relate these beds with those of the East Coast, owing to the absence of characteristic fossils; however, similar streams of basic rocks have been erupted at different intervals in the Malvern Hills during the cretaceo-tertiary period, so that in that respect similar features on both sides of the Alps are presented to us, in what I consider to be the same horizon.

Igneous Rocks.

The most important zone on the eastern side of the central chain, where igneous rocks are largely developed, is situated in the Malvern Hills. In one locality at the Kowai corner, they form a small hill of a crateriform appearance, with a lava stream running in a southerly direction. The rocks on the summit of this little system are granitoid, whilst some dykelike projections, passing through them, have a fine grained texture. Here also the rule holds good that that portion which has cooled more slowly in the form of dykes is more compact and fine-grained, than the streams which have a more porphyritic structure; besides the example just given, the dolerites in the Acheron show this difference very conspicuously. The felspar in some of these latter beds is most probably nepheline. Another series here to be considered is the youngest. It occurs all along the eastern side of the district, forming large sheets of doleritic rocks, which have flowed over the bottom of the sea, and afterwards, when being raised to form subaerial hills, have protected the beds of loose quartzose sands below them. There are several streams, mostly close together, which in the Harper's hills and the Dean's range show all their characteristic features. The first stream flowing over the sands has generally had a vitrifying influence; the sands have been melted for a few inches, or even one foot, and have been changed into a flint-like rock. In other localities doleritic tufas overlying the sands have protected them so effectually, that no change is visible. Between the lava-streams, having a thickness varying from a few feet to nearly 100 feet, sometimes, layers of pitchopal occur, often enclosing stems and leaves of plants; in some other localities palagonite tufas have been formed. The basic rocks under review have the peculiar character to which the name of anamesite has been given by Leonhard, some of them are scoriaceous, having the vesicular cavities lined with sphærosiderite. The latter variety would offer good material for mill stones, a similar rock being extensively used on the continent of Europe for that purpose.

It might perhaps be useful if I allude here to the various characteristic features and age of these different basic rocks, which have during that whole period made their appearance, and through which some important changes have taken place in that district. There are *three* important divisions in the basic or basaltic rocks appearing during this geological period in that part of New Zealand:—First.—Rocks coeval with or even prior to the formation of the principal Brown coal beds, the latter having been altered effectually, both vertically and horizontally, by the former. Second.—Rocks appearing only after the deposition of the calcareous fossiliferous beds overlying the Brown coal series, or even after the formation of the greensands. Third.—Rocks of which the extensive streams of anamesite consist, forming a well defined horizon, and closing an important geological epoch in the district. The rocks of the first division are very peculiar. They have a dark greenish colour, are granular, and resemble in hand specimens some eruptive (diabasic) rocks of older origin. Some of them have the peculiar greenish tint which an admixture of chlorite usually gives, although I do not think it exists in them.

In Germany, rocks of this character are named hyperites, but I have no doubt that the analysis of the New Zealand rocks will show that this resemblance is only apparent. No doubt the peculiar conditions under which these rocks made their appearance may account for their structure. They were, doubtless, deposited in shallow water, or even some of the beds might be of sub-aerial origin. Two forms of texture are easily identified, both occurring in the dykes and the *coulées* or streams. One of them more compact, although still having a doleritic and sometimes a porphyritic texture, with small grains or imperfect crystals of felspar interspersed. Another more granular and amygdaloidal, the pores and cavities either lined with sphærosiderite or filled with chalcedonic quartz. Some of the streams are of considerable dimensions, Mr. M. B. Hart having passed through one which has a thickness of about 75 feet. There are two localities where dykes belonging to another series occur, having been erupted during the formation of the greensands above the saurian beds. These dykes have quite a basaltic texture. Their being of deep-seated submarine origin may account for this difference in texture. In any case we have to classify them with the next series—the true doleritic rocks of which many have a porphyritic or even granitoid texture. They have been erupted after the formation of the coal-bearing beds, often dislocating and altering them in a most remarkable manner, and having preserved portions of these formerly more extensive strata from entire destruction.

The igneous rocks on the western side are different in texture, and resemble some of those varieties of basic rocks on the continent of Europe, to which the term melaphyre has been applied, but they are also different from the basic rocks underlying the quartziferous porphyries on the eastern flanks of the Alps. The basic rocks, north of the mouth of the Paringa, occur in different textures, of which a porphyritic melaphyre is the most conspicuous. It has a compact black matrix, containing a large number of hornblende crystals, and grains of magnetic iron. The hornblende crystals enclose sometimes very small grains of a yellowish green mineral, possibly olivine. The melaphyres at Arnott's point have also a compact black matrix, sometimes with a blueish tinge, enclosing small crystals of felspar (labradorite ?), and hornblende; the joints are filled with carbonate of lime. The rock breaks in such small polyhedric pieces, that it is almost impossible to secure a properly sized specimen for the cabinet. It forms here *coulées* of 15 to 30 feet in thickness, alternating with layers of brecciated wacke. The latter has also a compact black matrix and angular pieces of melaphyre, wacke or compact rocks of indistinct character, generally of reddish or brownish tints, often resembling porcelain jasper, are enclosed in it. The enclosed pieces are often surrounded by calcareous spar, also appearing in strings and veins, and filling up all the interstices. Small cavities in the calcareous spar are again filled with zeolites, of which crystals of apophyllite, sometimes with a highly lammellar structure, and of a beautiful brick-red colour, are most conspicuous. Other zeolites, as for instance, stilbite and analcime, are also present. In the *coulées* of melaphyre, near the contact with the brecciated wacke, pieces of the latter are usually enclosed. At the southern extremity of the melaphyres at Tauperikaka Point, the rocks have a compact black matrix, with greenish or bluish tinges. Besides very small crystals of hornblende, they contain also grains of magnetic iron and minute crystals of felspar, too small for recognition. They have a somewhat tabular, but sometimes an irregular columnar structure, and are here of very great thickness; as, notwithstanding the *coulées* are standing at a very high angle, they not only form the coast-line, but reach far into the sea in the form of small islets and rocks, against which the surf breaks with vehemence. South of Jackson's Bay, both melaphyres and brecciated wacke occur, but my stay was so very short that I could devote no time to a closer examination, beyond observing that in lithological character they resembled the rocks previously described, and that they formed a considerable portion of the coast. Finally, I wish to say a word on the nomenclature, and the changes which are necessarily to be made in it, in order that all the beds belonging to the same formation may be brought together. Although Professor von Hochstetter gave the name to this formation in his synopsis of the New Zealand formations, he followed only Professor Owen, who basing his opinion upon the occurrence of *Plesiosaurus Australis*, thought that the beds in which this saurian occurred were probably jurassic, an opinion which I shared till the other fossil contents became known to me. I then was forced to the conclusion, that as high up as the Weka Pass stone they could not be separated from the series containing not only the Grey and Shag point Coal Measures, but also the older Brown coal series found all over New Zealand. In fact, there is enough evidence before us to lead us to believe that the Buller and Pakawau Coal Measures, and also all the older Brown coalfields in the Provinces of Otago, Nelson, and Auckland, which latter were hitherto classed as older tertiary, have to be included in the Waipara formation.

CHAPTER X.

The Oamaru Formation.

In order not to crowd the small Geological Map attached to this Report with too many tints, I have coloured this formation and the next, or Pareora formation, the same; however, I shall not fail to give a concise description of each, and moreover shall add such characteristic sections that the reader can easily follow me. The Oamaru formation, where best developed, is of considerable thickness and variety in the nature of the rocks of which it is composed. It lies either on the slopes of the Waipara formation conformably or unconformably, as the case may be, or directly upon the younger palæozoic rocks.

Extent.

In the northern portion of the Province it covers a great deal of ground, where it forms Mount Brown, the Deans, Mount McDonald, and a number of well defined peaks as far as Mount Vulcan on the southern banks of the Motenau river, near the sea coast. Some of the calcareous greensands, forming small hills in the Hurunui plains, may also belong to this formation. South of Mount Brown, the Oamaru beds partly surround Mount Grey, where the so-called White Rock quarry is situated amongst them. They continue to the northern banks of the Ashley river, where their traces are lost. We meet them again at the so-called Curiosity Shop, a small outlier surrounded by post-pliocene alluvium and morainic deposits, on the left bank of the

Rakaia, six miles below the gorge, and well known to the settlers of this Province for years past as a favourable locality for collecting fossils. We find also south of the Rakaia, strata belonging to the same system, where the Taylor branch of the Ashburton enters the plains, and meet with them still more largely developed on both banks of the southern Ashburton, as well as near the sources of the northern Hinds. They also fringe the Canterbury plains from the Orari to the Kakahu, after which they cover a considerable extent of country, from the middle course of the Opihi north to the Otaio south. Another large zone extends along the middle course of the Waihao branches, and along both banks of the lower Waitaki. During the deposition of this formation, the land sank so considerably that we find now within the alpine ranges beds belonging to it, as high as 5000 feet above the present sea-level. Moreover, it is evident that at one time, wherever favourable chances prevailed, deposits belonging to that formation must have been formed all along the eastern slopes of our Alps, because in many spots small outliers (which have escaped the general destruction) belonging to this formation, have been preserved. Of these localities, those of the Esk, in the Broken River basin west of Mount Torlesse, on both sides of Lake Heron, in the River Potts (east of Mount Potts), between the upper Opuha and Opihi, and near the sources of the Hakataramea, are the most important ones. The Oamaru formation seems to be entirely absent from Westland.

SEQUENCE AND CHARACTER OF THE ROCKS; POSITION OF STRATA.

The beds belonging to the Oamaru formation resemble often in sequence and character of the rocks those of the preceding Waipara formation. They in most instances begin also with littoral deposits, and end with calcareous strata, the latter formed in deeper water. In the northern and middle portions of Canterbury earthy carbonaceous deposits are sometimes associated with them, the lowest beds generally consisting of quartzose sands more or less glauconitic; in the southern portion the formation begins usually with white under-clays, upon which one or several seams of Brown coal have been deposited, some of which will be of economic importance in the future. Above these Brown Coal Measures the further sequence of the beds is nearly the same everywhere. In order to make this more obvious, I shall here enumerate the sequence of the beds in some of the principal localities as they follow each other. On the banks of the Waipara the following sequence is exposed to our view.

On the calcareous greensands repose under the Deans and at Mount Brown, partly conformably and partly unconformably, greyish and greenish calcareous sands, sometimes glauconitic or argillaceous, sometimes containing small beds of clay marls, the stratification of which is only shown by beds of a harder nature, consisting of a coarse sandstone, which is formed of the same material, but cemented by a calcareous matrix. When they repose conformably upon the calcareous greensands of the Waipara formation, they dip south-east 15 deg., but sometimes they have been deposited on the denuded edges of these older beds, when a dip of as much as 71 deg. to the south is not uncommon. These beds, sometimes several hundred feet thick, rarely contain any fossils, however I obtained from them *Waldheimia lenticularis*, *Scalaria lyrata*, and *Turritella* (probably *ambulacrum*, Sow.), and portions of *Turritella gigantea*, *Cucullæa alta*, as well as a cup-shaped *Bryozoon*. They are overlaid by dark bluish sands, generally calcareous, in which *Waldheimia sinuata* (Hutton) and a small black *Pecten* are frequently met with. In these sands, thin beds of rusty coloured tufaceous, or brecciated limestone occur, becoming as we ascend the series more and more frequent and of broader dimensions, till we reach the uppermost bed, 30 to 40 feet thick, by which the summit of the Deans and Mount Brown, and more to the north Mount McDonald and Mount Vulcan and their eastern slopes, have been formed. Some of the harder beds consist almost entirely of fragments of shells, others of corals, being in fact a true coralrag; others contain innumerable specimens of a remarkable cup-shaped *Bryozoon;* others are partly formed of a *Selenaria*. *Waldheimia lenticularis*, *Pecten Hochstetteri*, and *Caratomus nuperus* (Hutton), are also very numerous. These upper beds, more to the south-west, alter to a calcareous and glauconitic sandstone, resembling in many respects the Weka Pass stone. The White Rock quarries near the Okuku have been opened in them. In the Malvern Hills the whole series is missing, and we only meet with it again in the small outlier on the northern bank of the Rakaia, remarkable for its richness in fossils, the beds consisting here of arenaceous strata of little cohesion, often altering to greensands. They are separated in banks by small layers of fine clay, resembling sometimes Fuller's earth. There are also concretions of these clays in many places which have the appearance of having filled hollows, in which formerly organic matter was enclosed, such as driftwood. Some of the layers are full of shells, echinodermata, and teeth of fishes; the large cup-shaped bryozoon occurs in numerous specimens, and small pieces of bones are also occasionally found. In the list of fossils which have been described from this formation the principal species indicated have been found in this locality. Owing to the occurrence of *Pecten Hochstetteri* and some other fossils from the Weka Pass beds, I formerly thought that the Curiosity Shop beds were of the same age as the Weka Pass stone, but further research, aided by the description of the fossils, has shown that they have to be classed with the Oamaru formation.

More to the south the Oamaru formation appears to take entirely the place of the Waipara formation, unless we assume that some of the isolated Brown coal basins, situated on the banks of the Ashburton and Opihi, belong to the latter. I allude here principally to the beds on the banks of the North Ashburton, near the junction of the Stour with the Ashburton, and to another locality near Lake Heron. The Oamaru formation is of some importance to the Ashburton and Rangitata districts, as it contains large beds of limestone, and other deposits of similar economic value. Although still of considerable extent, we observe only remnants of a well-developed formation, once covering uniformly the whole portions of the lower country, but which, owing to extensive denudation, principally by glacier and fluviatile action, has now disappeared in most localities. The most complete section of these beds is to be observed on the northern banks of the Ashburton between Limestone Bluff and the Two Brothers. It shows that we have before us beds of various character, ranging from deep sea deposits, through others of intermediate character, to shallow water and estuary beds. This section also fixes the time when the submarine eruptions took place, the former channels of which, now filled with basalts, we observe in several localities. The following succession of beds was observed by me, near and at the Limestone Bluff (section No. 1 on plate No. 5), and is here given in descending order :—

No. 1—Limestone, white on the summit of the ridge, in flaggy layers, consisting principally of pieces of shells and corals, and offering splendid material for the limekiln. Strike 290 deg., dip towards east-south-east 55 deg.	about 15 feet.
No. 2—Changes into arenaceous limestone, forming thick beds without divisions	„ 70 „
No. 3—Dark brown volcanic tufas, with numerous lapilli of basaltic lava enclosed	„ 15 „

No. 4—Gradually this tufa becomes harder, formed of stratified layers of brown or dirty green colours, alternating frequently with each other, and becoming glauconitic towards the bottom ... ... about 20 feet

No. 5—Being underlaid by tufaceous calcareous sandstone ... ... „ 40 „
Gradually altering to—

No. 6—Calcareous greensands, becoming towards the centre almost black, from grains of glauconite ... „ 30 „

No. 7—The latter are cut off from the lowest beds by several layers of shell limestone, consisting mostly of fragments of shells, and enclosing specimens of *Pectunculus*, of a small white *Ostrea*, and casts of a bivalve (*Mesodesma ?*) ... ... „ 10 „

No. 8—The lowest beds of the whole series are formed of quartzose sands of light colours, and of considerable thickness, which will be valuable for glass-making.

No. 8 reposes on the slopes of much decomposed quartziferous porphyry.

More towards the centre of the section, and near the channel through which issued the submarine eruption, the beds 5 to 8 are missing. Here repose directly upon the palæozoic rocks, occurring as a small outlier, thick beds of a tufaceous or agglomeratic character. In some localities, such as the Two Brothers, they consist entirely of palagonite tufa of an uniform texture, whilst a little nearer to the centre of eruption the compact dark mass contains numerous fragments of the same rock enclosed, but of a somewhat lighter colour. On the opposite side of the river, at the base of Mount Somers, portions of the same beds are extensively developed, but only the higher series are exposed to view. Of these, the district around the so-called Mount Somers caves, amongst other localities, is the most conspicuous and well-known example. The caves owe their formation to a small creek having washed out its way at the junction of the beds Nos. 1 and 2. The palagonite tufas are here the lowest beds visible. The calcareous beds contain a number of fossils, connecting them with those of the Curiosity Shop at the Rakaia. Another outlier of the same series, and proving that these beds extended once over a considerable portion of the country, is situated at the head of the northern Hinds (the so-called Limestone range), where the same succession of beds was also observed by me. On the southern banks of the Rangitata, at Coal Creek, the succession of the strata is the same, with the exception that the lowest beds are formed of lignite overlaid by greensands.

In advancing still more to the south, the Oamaru formation is largely developed, and gives to the country, by the conformation of the calcareous greensands usually constituting the uppermost beds, its peculiar features, namely, soft outlines where this uppermost bed has not been cut into, and rocky precipices and cliffs along the banks of the rivers and their tributaries. It is easily seen that the Oamaru formation usually conforms to the outlines of the underlying palæozoic rocks.

The following is the sequence of the beds on the southern banks of the Kakahu:—The lowest bed consists of shales about 10 feet thick, often arenaceous with imperfect impressions of dicotyledonous leaves. In some localities it becomes more argillaceous and is formed of valuable fireclays. A seam of Brown coal of inferior quality, 20 inches thick, and full of concretions of iron pyrites, lies above it, and is capped by 18 feet of shales, after which a similar seam of Brown coal, 17 inches thick, follows—dip east-north-east 15°. Upon it very dark greensands repose, divided in several layers by more calcareous beds in variegated colours, partly green and partly brown. Above them follows a bed of about two inches thick, formed entirely of Turbinolia, then more greensands, 30 to 40 feet thick, upon which a sandy limestone follows containing a number of fossils, amongst them *Cucullæa alta*, (Sowerby), *Pectunculus globosus* (Hutton), *Turritella ambulacrum* (Sowerby), and a number of others which seem to be undescribed, as no mention of them is made in Hutton's catalogue of Tertiary Mollusca of New Zealand. These greensands sometimes contain fossil wood quite honeycombed by toredos. They gradually get lighter and more calcareous, till they are succeeded by chalk marls and calcareous greensands, of which the upper bed is sometimes full of harder glauconitic concretions, or it is divided by layers of similar composition into smaller banks. Only in the Upper Kakahu, and on the banks of the Waihi, concretions (Septaria), similar to those of the Waipara, are found, accompanied by fine specimens of *Ostrea Wuellersdorfi*, but hitherto no fossils of any importance have been obtained from them. Finally, I wish to give the general characteristic features of another section, close to the southern boundary of the Province, exposed on the eastern slopes of Elephant Hill, not far from the Waitaki, on the upturned edges of the Waihao formation.

White underlays, 30 to 40 feet thick, form here the lowest bed of the Oamaru formation, then follows, in ascending order, a seam of brown coal, 12 feet thick, dipping 12 degrees to the east by north. This brown coal, of fair quality, is mostly formed of peat vegetation in which a great number of flattened stems and branches are enclosed, generally arranged in distinct layers (Glance coal), the other layers being more dull, and sometimes of a brown colour. Above this seam of coal sharp white quartz sands, about 10 feet thick, lie, which, in descending, gradually run out, and fireclays, about six feet thick, take their place, reposing directly upon the coal. Then follows, a characteristic bed of quartz conglomerate or pebble bed with a highly ferruginous matrix, consisting sometimes of more or less angular pieces of slates, sandstones, and rounded pebbles from the Waihao formation.

This bed varies very much in thickness; in some districts it is only a few inches thick, in others 30 feet. The presence of this conglomerate in many spots all over the ranges, and where the rest of the formation has been thoroughly destroyed, shows convincingly that the Oamaru formation was once of far greater extent. In some isolated spots it has effectually preserved the lower beds, including the brown coal seams; in others the whole, with the exception of a few fragments of the conglomerate, has been washed away. Quartzsose sands follow, gradually altering to green sands, with *Cucullæa*, *Turritella*, *Pecten Hochstetteri*, *Scalaria lyrata*, and *Waldheimia lenticularis*. In their upper portion these sands become so filled with grains of glauconite that the rock looks quite black. They are succeeded by claymarls altering to calcareous greensands. These characteristic rocks are sometimes massive, sometimes divided into banks by layers of a more calcareous nature, the latter standing out as protuberances. In some localities they are quite full of grains of glauconite, in others this mineral is less frequent. Fucoid casts are sometimes common; in other places the whole rock appears to consist almost entirely of minute pieces of corals, echinoderms, and shells.

Principal Fossil Contents.

The following fossils have been collected in this formation. Some of the localities are given:—

Mammalia.—Portions of cetacean bones.

Aves.—*Palæeudyptes antarcticus* (Huxley), Curiosity Shop, Broken River.

Reptilia.—Teeth of *Crocodilus*, sp. Waihao.

Pisces.—Teeth of *Carcharias*, *Notidanus*, *Myliobatis*, *Lamna*, *Oxyrhina*, *Zygobatis*, *Carcharodon*, *Pycnodus*, *Pristis*, *Sargus*, and some other genera.

Mollusca.—Class Pteropoda.

Fossils.	Authority.	Localities.
Dentalium conicum	Hutton	Broken River.
" " var. ...	"	Waihao.
" tenuis	"	"
" giganteum	Sowerby	Waitaki, Waipara.

Class Gasteropoda.

Fossils.	Authority.	Localites.
Pleurotoma sulcata	Hutton	Broken River.
" hebes	"	Waitaki.
" latescens	"	Mount Brown.
" Buchanani	"	Waihao.
" Awamoensis variety ...	"	"
Triton minimus	"	Broken River.
Ancillaria hebera	"	Broken River, Waihao.
" Australis (?)	Quoy	Waihao.
Voluta pacifica, var. C.	Lamark	Waipara.
" elongata	Hutton	Broken River, Waihao.
" Kirki	"	" "
Mitra Enysii	"	Waihao.
Marginella dubia	"	Broken River.
" ventricosa	"	" "
Natica solida	Sowerby	Common.
" Zealandica (?)	Quoy	Waihao.
" ovata	Hutton	Common.
Lunatia sutularis	"	Waihao.
Scalaria Browni	Zittel	Common.
" lyrata	"	"
Struthiolaria senex	Hutton	"
" sp.	—	Kakahu.
Turritella gigantea	"	Common.
" ambulacrum	"	"
Cladopoda directa	"	Waihao.
Calyptræa maculata...	"	Broken River, Waihao.
Crypta striata	"	" " "
Cylichna Enysi	"	Broken River
Turbo superbus	Zittel	"
Gibbula nitida	Adams	" "

Class Lamellibranchiata.

Fossils.	Authority.	Localities.
Panopæa plicata	Hutton	Common.
„ Worthingtoni	„	„
Mactra attenuata	„	Broken River.
Cytheria Enysi	„	Broken River, Lake Heron.
Dosinia subrosea	Gray	„ „
„ magna	Hutton	„ „
Tapes curta	„	„ „
Cardium patulum	„	Waipara, Broken River.
Hemicardia sp.	—	Acheron
Protocardium serum	Hutton	Broken River.
Venericardia media	„	Weka Pass, Waitaki, Acheron.
Lucina divaricata	Lamark	Broken River.
Astarte Australis	Hutton	Kakahu.
Crenella elongata	„	Broken River.
Modiola albicostata	Lamark	„ „
Pinna distans (?)	Hutton	Waihao.
Cucullæa Worthingtoni	„	Common.
„ alta	Sowerby	„
„ attenuata	Hutton	Waihao.
Pectunculus globosus	„	Broken River.
„ laticostatus	Quoy	„ „
Leda semiteres	Hutton	„ „
Limopsis insolita	Sowerby	„ „
Pecten Williamsonii	Zittel	Common.
„ Chathamensis	Hutton	Broken River.
„ Fischeri	Zittel	Common.
„ venosum	Hutton	Waihao.
„ Hochstetteri	Zittel	Common.
„ Hectori	Hutton	Broken River.
„ Hutchinsonii	„	Common.
„ Beethami var. B ...	„	Waihao.
„ athleta	Zittel	Common.
„ multiradiata	Hutton	Curiosity Shop.
Lima paleata	„	„ „
„ bullata	Born	Broken River.
„ lævigata	Hutton	Opuha.
Placunanomia incisura	„	Rangitata, Mount Brown.

Class Brachiopoda.

Fossils.	Authority.	Localities.
Waldheimia lenticularis	Desh.	Common.
„ concentrica	Hutton	Broken River, Rangitata.
„ triangulare	„	Waitaki.
„ sinuata	„	Common.
„ patagonica	Sowerby	Broken River.
„ gravida	Suess	Common.
Terebratella Gaulteri	Morris	Curiosity Shop.
„ Suessii	Hutton	Common.
Rhynchonella nigricans	Sowerby	„
„ squamosa	Hutton	Broken River.

CLASS ECHINODERMATA.

Fossils.	Authority.	Localities.
Pentacrinus stellatus	Hutton	Curiosity Shop.
Cidaris, several species fragmentary	—	Common
Echinus Enysi	Hutton	Broken River.
Caratomus nuperus	"	The Deans, Waipara.
Hemipatagus formosus	Zittel	Curiosity Shop.
" tuberculatus	"	" "
Amphidotus sulcatus	Hutton	Waihao.
Brissiopsis alta	"	Waitaki.
Hemiaster posita	"	Curiosity Shop, Mt. Somers.
Meoma Crawfordi	"	Common.
" tuberculata	"	Broken River.
Schizaster rotundatus	Zittel	Waitaki, Curiosity Shop.

CRUSTACEA.

Fossils.	Authority.	Localities.
Harpactocarcinus tumidus	H. Woodward	Double Corner.

IGNEOUS ROCKS.

I have already pointed out that during the deposition of the upper calcareous strata, eruptions of basic rocks have taken place. At the Limestone Bluff, amongst other localities, beds of lapilli and ashes have been formed between these eruptions, on the southern side of the Ashburton. In other localities, these volcanic tufas are represented by palagonite tufa, of which a specimen was analysed by the Chevalier Charles de Hauer, the results showing that it corresponds very well with the analysis of specimens obtained in other countries.*

I think that the dykes found at the entrance of the north Ashburton, consisting of a basic (doleritic) rock, at the gorge of the Rakaia, and at the Acheron, where the rock has a more granitoid texture, have been erupted about this time. More to the south, the submarine eruptions have taken place on a still larger scale, of which the dolerite plateau

Analysis of Palagonite Tufa from the Two Brothers, between Rivers Ashburton and Northern Hinds.
(CHEVALIER CHARLES DE HAUER.)

Silica	45.12
Alumina	13.41
Sesquioxyde of iron	14.09
Carbonate of lime	8.45
Lime	4.95
Magnesia	1.48
Potash	0.34
Soda	0.40
Water	11.88
	100.12

upon the lower end of which the town of Timaru is situated, is the largest remnant. The best section to be obtained of the relations between the dolerites and calcareous rocks, also forming here the uppermost beds of the Oamaru formation, is in Mount Horrible, about 12 miles from Timaru, rising 1138 feet above the sea-level. From here to the sea, the *coulées* of dolerite can be traced almost without intermission, showing first that they gradually get thinner as we advance towards the coast, and also that their fall is very slight, being for the last seven miles only about 90 feet in the mile, or 1 foot in 58, the inclination indeed being almost imperceptible. Thus one of the streams, which on Mount Horrible, where they appear almost horizontal, is about 50 feet thick, dwindles down to four feet near Timaru. The streams consist of a basic rock (Anamesite), porous, and resembling the uppermost beds in the Malvern Hills. Upon the calcareous greensand, forming the upper bed of the Oamaru formation, and which is often so rich in carbonate of lime that it can be used for the limekiln, a bed of volcanic tufa reposes, sometimes changing into an agglomerate, after which the first lava-stream appears. Then follow a number of tufaceous beds with some smaller lava streams between them, till the uppermost *coulée* is reached, having like the lowest one also a thickness of about 50 feet. This anamesitic rock is extensively quarried near Timaru, and forms a valuable building stone for that town. A similar *coulée* occurs at the Waihi Bush, between the River Waihi and Hae-Hae te Moana creek, both affluents of the Opihi. There also it covers strata of a calcareous nature, belonging to the Oamaru formation. More to the south, no volcanic rocks of any kind are to be observed, but in the greensands underlying the calcareous beds, lapilli of basic lava are not unfrequent. They might have some connection with the volcanic eruptions during which the lava-streams near the Otepopo river in Otago were ejected, and which are found in a similar position. There is thus sufficient evidence that submarine volcanic eruptions were of not unfrequent occurrence in our tertiary seas.

Age and Thickness.

From the nature of the lowest beds of this formation, we must conclude that they were only deposited after the strata forming the Waipara or cretaceo-tertiary series had undergone considerable changes, and a large amount of denudation. Moreover, it is clear that these older marine beds, in many instances, were uplifted from the ocean, and that the newer beds were deposited upon them, either as littoral or even as fresh water deposits; however, there is no doubt that afterwards the country sank again considerably below the sea-level, because beds belonging to this formation can be traced in the Southern Alps to an altitude of 5000 feet, unless we assume that some portion of the ranges underwent greater subsidence and elevation than others, for which, at least on so large a scale, no evidence can hitherto be found. Thus after the cretaceo-tertiary beds had been raised in succession to near or above the sea-level, during which they were so much destroyed that only in favourable localities some portions were preserved, new beds, first of littoral origin, and afterwards, as the country gradually sank, of a more pelagic character, were deposited above them. Of course the beds in question are not quite coeval, although occupying the same relative positions, as it is evident that those strata in the higher regions, or where the sinking of the ground was slower than in other portions of the country, must be of somewhat younger origin, a fact which may in a great measure account for some want of uniformity in their fossil contents. I wish also to point out another difficulty, the solution of which is of considerable importance for the classification of the beds in question. In the greensands of the Kakahu and Waihao a number of fossils have been collected by me, which Captain Hutton places with the Pareora formation, as for instance, *Turitella ambulacrum* and *Pleurotoma Buchanani.* These greensands are overlaid by calcareous greensands, with all the characteristic fossils of the Oamaru formation, on the edges of which the Pareora formation reposes unconformably, consequently a careful study of the more extended collections from these beds is needed to settle this point to my satisfaction. Concerning the age, I have already pointed out that it is exceedingly difficult to assign to these beds their exact position, when using for them any European nomenclature. However, as Dr. Zittel and Dr. Stache have both come to the conclusion, after studying carefully the fossils collected in this formation by Professor von Hochstetter, that they ought to be classed with the upper Eocene, I do not see any reason to depart from this opinion; although Captain Hutton, in his Report on the Geology of Otago, is inclined to include them with the lower Miocene. The thickness of the whole series of beds belonging to this formation is very considerable, and might in the average be 1500 to 2000 feet. In conclusion, I wish to say that I have adopted Captain Hutton's designation of Oamaru formation for this assemblage of beds, as the first fossils collected and described were derived from that locality.

CHAPTER XI.

The Pareora Formation.

In speaking of the Oamaru formation, I have already stated that I had included with it in the Geological Map attached to this Report, the next, or Pareora formation. The latter is generally found reposing on the edges of the former, or where the Oamaru formation occurs in basins, towards its centre. It generally owes its preservation to harder calcareous beds, often consisting almost entirely of fossil shells, which are interstratified with more sandy and incoherent strata.

Extent.

Starting from the north-east portion of the Province, we find a well-defined zone of the Pareora formation beginning five miles north of the Motanau, and thence following the coast to some miles south of the mouth of the Waipara, where the Canterbury plains begin. Other portions occur in the Blythe, Greta, and Waikari rivers, where they form conspicuous cliffs. After crossing a small saddle of palæozoic rocks at the head of the Waikari, we meet it again in the valley of the Omihi and Glenmark creeks, whence it follows the eastern foot of the ranges as far as the Okuku river, forming also outliers on both banks of the Ashley river, of which that called the Moeraki Downs on its southern banks is the most important. We also find it well-developed in the upper course of the Waipara, near Heathstock. Between the Waimakariri and Rangitata, at a few isolated spots inland, the Pareora formation is only represented by small outliers; but uth of the last-mentioned river it begins on the banks of the Kakahu assume larger proportions, covering on the banks of the Opihi, reora, and Otaio, a large extent of country, and reposing generally conformably on the Oamaru formation. Between the lower course the Waihao and Waitaki the low hills bounding the Waitaki plains e also formed of Pareora beds of considerable thickness. The incipal outliers of this formation are found in the Broken River sin, and near Lake Heron, where they occur nearly 3,000 feet above e sea-level. In Westland, from near the northern banks of the rey to the Hokitika river, the same formation is also extensively veloped, containing a great number of fossils, of which several have therto only been found in that area. These western beds form aptain Hutton's Kanieri group, and are considered by him to belong the lower portion of the Pareora formation.

SEQUENCE AND CHARACTLR OF ROCKS, AND POSITION OF STRATA.

The principal beds of this formation consist mostly of bluish or reenish argillaceous sands, with harder calcareous, mostly fossiliferous eds interstratified with them. One of the best and most extensive ections is situated on the left, or southern banks of the Waipara, here the strata which immediately repose upon the Mount Brown eries consist mostly of arenaceous and argillaceous beds, clays, sometimes marly or loose marine sands. The clays often enclose concretions f sandy limestones, and also harder beds of the same rock, impregnated with lime and alternating many times with each other. In them we meet at the foot of that mountain, and often in a perfect state of preservation, with a great variety of fossils, as, for instance, *Voluta pacifica*, *Natica solida*, *Struthiolaria* (several species), *Lutraria solida*, *Cytheriz Enysi*, *Dosinia* (two species), *Venericardia intermedia*, *Pectunculus laticostatus*, *Lima crassa*, and many others. These beds are either of littoral origin or shallow water deposits. They are overlaid by beds of conglomerate, mostly formed of small river shingle, deposited in a shallow estuary, and consisting of the debris of the palæozoic ranges near the upper course of the Waipara; but the destruction of some of the older tertiary rocks has also furnished material for their formation. These beds are together of a thickness of about 300 feet. Some contain two species of oysters, of which one is *Ostrea Nelsoniana*, which sometimes forms regular beds. There occur, also, some casts of gasteropods, mostly filled in the interior with crystals of calcareous spar. The beds are capped by loose marine sands, sometimes very calcareous, full of fragments of shells, and of a light-yellowish or greenish colour. Here and there harder bands of calcareous sandstones stand out from them as protuberances. The same *Ostrea*, *Pectunculus laticostatus*, and *Pecten secta* occur in them. Between them beds of conglomerate are interstratified, and the interstices between the pebbles mostly filled up with calcareous spar. The beds along the banks of the Motanau river and of Motanau island consist of similar strata, also resting upon the Oamaru formation, apparently conformably. The lowest beds consist of bluish sandy clays, with rolled pieces of shells, sometimes forming regular layers; they are divided in numerous banks by beds of calcareous sandstone six inches to two feet thick, standing out as protuberances. Sometimes the latter is separated in lenticular shaped masses, lying side by side in the sands. The uppermost deposit consists of a thick layer of hard fossiliferous calcareous sandstone, sometimes forming cliffs along the sea coast for a considerable distance, and in which most of the shells appear only as casts. This bed dips near the mouth of the Motanau river 10 deg. to the south-east.

There is a great similarity in the rocks belonging to this formation, owing, without doubt, to the same physical conditions prevailing during their deposition. The occurrence of small beds of lignite in them is only an exception. The principal localities where such beds have been met with are situated in the Moeraki Downs, at the mouth of the Waipara, in the Broken River basin, and in White Rock creek, a source branch of the Pareora river. The strata belonging to this series lie either conformably upon the Oamaru formation, or, what is still more usual, unconformably upon it. In many localities, as, for instance, in the Pareora and Waihao rivers, the calcareous greensands have become greatly denuded before the Pareora beds were deposited above them, or which is more commonly the case, along them, when the former stood as islands in the tertiary sea. From the sections attached to this chapter the relations of the beds to each other can easily be made out, so that I need not enter here into a more minute description.

The Kanieri group at the West Coast resembles in many respects the Pareora beds on the East Coast. The lowest bed visible consists of bluish sandy marls, glauconitic at their base. In them calcareous nodules are of frequent occurrence, containing generally fossil shells, or cetacean remains. Gradually they alter to ferruginous sands, with layers of fossiliferous sandstone having a calcareous matrix, interstratified with them. Upon them reposes a thick bedded conglomerate, apparently the highest bed in the series; occasionally rolled pieces of shells and cetacean bones are enclosed in it.

In the list of fossils found in this formation, I have indicated those which are only found in the Westland series, the beds of which generally dip so slightly that they sometimes appear in a horizontal position.

Pareora Formation.

The following fossils have been obtained in the beds belonging to this formation :—

Mammalia.—*Cetacea* : In the lower Waipara, several vertebræ; also, portions of lower jaw. In Westland, at Kanieri, and the Waimea, a number of bones.

Mollusca.—Class Pteropoda.

Fossils.	Authority.	Localities.
Dentalium Mantelli	Zittel	Waitaki, Waihao, Mt. Harris
,, irregularis	Hutton	Kanieri
,, lævis	,,	,,
,, solidum	,,	Pareora, White Rock River Waikari, Mount Harris
,, giganteum	Sowerby	Waikari, Waitaki
,, conicum	Hutton	Broken river

Class Gasteropoda.

Fossils.	Authority.	Localities.
Murex, sp.	—	Mount Harris, Pareora
Typhis hebetans	Hutton	Mount Harris
Turbinella brevirostris	,,	White Rock River
Fusus tegens	,,	,, ,,
,, plicatilis	,,	Pareora
,, dentatus	,,	Mount Harris
,, Australis	,,	Waitaki
,, dilatatus	Quoy	White Rock River
,, Crawfordi	Hutton	Mount Harris
,, colus (?)	Linn.	White Rock River

CLASS GASTEROPODA—*continued.*

Fossils.	Authority.	Localities.
Neptunea mandarinus	Duclos	White Rock River
„ nodosus, var. *r*	Quoy	„ „
„ (Sipho) costatus ...	Hutton	„ „
Acus nitida	Hinds	„ „
Pleurotoma Buchanani	Hutton	White Rock River, Pareora
„ Awamoensis	„	Mount Harris, Pareora
„ Wanganuensis	„	White Rock River, Waikari
Drillia fusiformis	„	Mount Harris, Pareora
Defranchia excavata	„	White Rock River
Clavatula Haasti	„	White Rock River, Mt. Harris, Pareora
Bela robusta	„	White Rock River
Buccinum Robinsonii	Zittel	Kanieri
„ inflatum	Hutton	Kanieri, White Rock River
„ carinatum	„	Broken River, Waikari
Triton minimus	„	Pareora
„ Spengleri	Chemnitz	Waitaki
Cominella subnodosa	Hutton	White Rock River
„ ordinatis	„	„ „
Ancillaria Hebera	„	Waitaki, Pareora, Waikari
„ sp. undetermined, probably Australis	—	White Rock River
„ pomahaka	Hutton	Kanieri
Voluta pacifica, var. *r*	„	Mount Harris
„ „ var. C.	„	Broken River
„ corrugata	„	Waikari, Kanieri
„ pseudorarispina	McCoy	Broken River
„ subplicata	Hutton	Mount Harris
Turbinella brevirostris	„	White Rock River
Mitra apicalis	„	Mount Harris, Waitaki
„ Enysii	„	Broken River
Marginella albescens	„	„ „
Cassidaria sulcata	„	Kanieri
Natica Zealandica	Quoy	White Rock River
„ solida	Sowerby	Kanieri, Waipara Gorge, White Rock River
„ ovata	Hutton	Common
Sigaretes subglobosus	Sowerby	Waitaki
„ carinatus	Hutton	White Rock River, Pareora
Scalaria Brownii	Zittel	„ „
Eulima acciculata	Pease	„ „
Conus ornatus	Hutton	Waitaki
„ Traill	„	Waitaki, White Rock River
Struthiolaria cincta	„	Common
„ tuberculata	„	Broken River, White Rock River
„ scutaluta	Desh.	Waitaki
Cerithium rugatum	Hutton	White Rock River, Waikari, Pareora
„ nodulosum	„	Broken River
Turitella rosea	Quoy	Broken River, White Rock River

Class Gasteropoda—*continued.*

Fossils.	Authority.	Localities.
Turitella Haustator concava ...	Hutton	White Rock River, Waitaki Broken River
„ tricincta	„	Waikari
„ „ var. B. ...	„	Waitaki
„ bicincta	„	Kanieri
„ gigantea	„	Common
Calyptræa maculata	Quoy	„
Trochita dilatata	Zittel	Waipara Gorge, White Rock River
Crypta costata	Desh.	„ „
„ contorta	Quoy	Pareora, Broken River
„ incurva	Zittel	Waipara Gorge
„ profunda	Hutton	Common
Trochus granosus	Lamark	Kanieri
Turbo superbus	Zittel	Broken River
„ imperialis	„	„ „
„ Stolizkii	„	Pareora
Cyclostrema helicoides	Hutton	White Rock River
Cladapoda monilifera	„	Broken River
Gibbula, sp.	—	Pareora

Class Lamellibranchiata.

Panopæa Zelandica...	Quoy	Kanieri
„ Worthingtoni	Hutton	Mount Harris, Waitaki Point, Pareora
Saxicava arctica	Linn.	Tengawai, Waipara Gorge
Corbula dubia	Hutton	Motanau
„ sulcata	„	Mount Harris
Mactra inflata	„	Motanau, Waipara Gorge
„ scalpellum	Desh.	White Rock River
Lutraria solida	Hutton	Lower Waipara, Kanieri
„ sulcata	„	Motanau
Zenatia acinacis	Quoy	Tengawai
Psammobia lineolata	Gray	Motanau, White Rock River, Pareora
„ sp.	—	Waitaki
Tellina sp.	—	Pareora
Chione vellicata	Hutton	Common
„ Stuchburgi	Gray	Waitaki
„ Yatii	„	Broken River
Cytheria Enysi	Hutton	Lower Waipara, Broken River, White Rock River
Callista elegans	„	Kanieri
Dosinia subrosea	Gray	Common
„ Grayi	Zittel	Motanau, Lower Waipara Gorge
„ magna	Hutton	Broken River
Tapes intermedia	Quoy	Motanau
„ curta	Hutton	Broken River

CLASS LAMELLIBRANCHIATA—*continued.*

Fossils.	Authority.	Localities.
Cardium striatulum	Sowerby	Motanau
„ spathiosum	Hutton	Broken River, Mount Harris
Venericardia intermedia	„	Waitaki, Lower Waipara, Pareora
Lucina divaricata	Lamark	Pareora
Crassatella ampla	Zittel	Broken River
„ attenuata...	Hutton	„ „
„ Trailli	„	Mount Harris, Pareora
Modiola albicosta	Lamark	Lower Gorge Waipara
„ sp.	—	„ „ „
Arca sp.	—	Broken River
Pinna sp.	—	Motanau
Trigonia pectinata (?)	—	Pareora
Cucullæa ponderosa var. B... ...	Hutton	Waikari, Broken River, Pareora
„ Worthingtoni	„	Waitaki
„ alta	Sowerby	Common
Pectunculus laticostatus	Quoy	„
„ globosus	Hutton	„
Limopsis insolita	Sowerby	Mount Harris
„ Zealandica	Hutton	Waitaki, Tengawai
Solenella Australis	Zittel	Mount Harris
Leda semiteres	Hutton	Waihao
Pecten scandula	„	Kanieri
„ secta	„	Kanieri, Motanau
„ Hochstetteri	Zittel	Waitaki
„ accrementa	Hutton	Motanau
Lima crassa	„	Lower Gorge Waipara, Pareora
„ colorata	„	Pareora
Placunanomia sp.	—	Waitaki, Rangitata
Ostrea Nelsoniana	Zittel	Motanau, Lower Waipara
Anomia trigonopsis	Hutton	White Rock River

CLASS BRACHIOPODA.

Rhynchonella squamosa	Hutton	Broken River
„ nigricans	Sowerby	Waihao
Waldheimia lenticularis	Desh.	Waitaki

ANNULOIDA.—CLASS ECHINODERMATA.

Astropecten Sandersoni	Hutton	Waikari
Echinus sp.	—	White Rock River
Arachnoides Zealandiæ	Gray	Double Corner

ACTINOZOA.

Turbinolia sp.	—	Broken River

Igneous Rocks.

No igneous rocks have been found in this formation in the Provinces of Canterbury and Westland, so that the volcanic disturbances which we were able to trace in the formations previously described had already ceased in this part of New Zealand. However, Captain Hutton believes that both in the North and South, in Marlborough, and Otago, volcanic action was not dormant during the deposition of the Pareora formation. He refers the basaltic tufas between Lyndon and the Hanmer plains in Marlborough, and the basaltic rocks of Moeraki, to that period, both of which I consider, however, to be of greater age, and to belong to the Oamaru formation.

Age and Thickness.

The beds belonging to this formation contain a large number of species of which, according to Captain Hutton, who has carefully studied them, 37 per cent. are identical with living forms, and consequently they ought to be classed as upper miocene. Considering that we are not yet fully acquainted with the molluscan fauna of our seas, except with that of the Littoral Zone, it is very possible, that when dredging operations can be carried on on a large scale, many of the species we now believe to be extinct, will be found still living. Consequently the number of living species will be augmented. In such a case, the age of the Pareora formation would be lower pliocene.

Although in many localities the beds of which this formation is composed are only a few hundred feet thick, in others, as for instance, in the middle and lower Waipara and the Waihao, they have an aggregate thickness of as many thousand feet, arenaceous material in the form of sands having been deposited in great abundance along the coasts in a shallow sea.

The name Pareora formation was first applied by me to these beds, in 1864, when examining the Pareora river, where they are well developed, this designation being adopted by Dr. Hector and Captain Hutton. It includes tho Kanieri group (lower portion), of Captain Hutton, and the Awatere group (upper portion of von Hochstetter).

CHAPTER XII.

Banks' Peninsula.

Hitherto I have not made any mention of Banks' Peninsula, beyond alluding to the small zone of palæozoic sedimentary rocks situated at the head of Lyttelton Harbour, probably belonging to the Waihao formation, of which a portion is considerably altered, and of another zone in the same locality consisting of quartziferous porphyries, pitchstones, rhyolites, and tufas, partly covering the former rocks. This chapter will be devoted to a description of the geological features of that remarkable volcanic zone as a whole, tracing its origin from the first eruption of quartziferous porphyries and the deposition of tufas and agglomerates in connection with them, to the extinction of the volcanic foci by which it has been built up.

When standing on the Canterbury plains the most striking feature in the landscape is Banks' Peninsula, rising so remarkably above the sea horizon, that its regular form at once attracts our attention. First we observe a series of mountains, of which the summits are all nearly of the same altitude, which, as it appears to us, as far as our eye can follow their outlines, form nearly a circle, from which a great number of ridges slope with a nearly uniform gradient towards south, west, and north. Above them, in the centre, stands conspicuously a higher truncated mountain with precipitous escarpments, assuming, according to the position of the traveller, a different aspect. The rim of the lower mountains in front rises to an average height of 1600 feet, whilst the central system attains an altitude of 3050 feet. On reaching Banks' Peninsula from the sea, we find that several deep indentations, forming splendid harbours, enter far into the outer rim of the mountains, passing for a considerable distance along the higher central range. Similar indentations are also found to exist towards the Canterbury plains, but they have either been already filled by alluvial deposits forming fertile valleys, such as the Kaituna valley, or they appear in the form of a lake (Lake Forsyth). In examining the nature of the rocks of which the system under consideration is composed, we find that, with the exception of a small zone at the head of Lyttelton Harbour, the whole is composed of volcanic rocks; that the deep indentations are ancient crater walls, so-called calderas, into which a channel with precipitous walls, the barranco, leads; and that they consist of a series of lava-streams, with agglomerates consisting of scoriæ, lapilli, ashes, and tufas interstratified with them. These beds have all a qua-qua versal dip, that is to say, they all incline outwards from the centre of the cavity. The higher mountains in the centre consist also of volcanic rocks of a similar composition, which appear either horizontal or, when the direction of the lava-streams composing them can be ascertained, are found to flow into the calderas previously formed, from which we can at once conclude that they are of younger origin. Finally, we find mostly in or near the centre of these deep cavities, or calderas, either a small island or a peninsula stretching so far into these harbours. They consist also of volcanic rocks, having been preserved above the last centre of eruption. This last sign of vulcanicity is on a smaller scale than the previous ones. The whole of Banks' Peninsula, measuring along its longest axis from north-west to south-east, has a length of 31 miles, with a greatest breadth of 20 miles, and if we do not take the numerous indentations into account, it has a circumference of 88 miles, which corresponds closely with that of the base of Mount Etna.

In the Geological Map attached to this report, I have marked with circles, more or less perfect, according to the preservation of the lips or rims, all the principal centres of eruption which I have traced during my surveys, and I have no doubt that the remnants of others, which have escaped my observation, and are for the greater part concealed under younger lava-streams, will be found during future examinations. On the line between Lyttelton Harbour and the head of Akaroa Harbour, the highest portion of the Peninsula is found where the small craters of Mount Herbert and Mount Sinclair are situated. Having thus given an outline of the general features of the volcanic system under consideration, I shall now proceed to offer a short history of its origin, which will at the same time serve as an explanation to the general sections added.

The oldest rocks in Banks' Peninsula form a small zone of palæozoic sedimentary strata, possessing a slightly altered structure, many of them forming beds of chert, others, peculiar light-coloured brecciated schists; however, sandstones and dark clay-slates are also represented. This zone has a north and south direction, and reaches to the southern watershed of McQueen's Pass, which leads from the head of Lyttelton Harbour to Lake Ellesmere. Near this Pass, slates appear as high as 600 feet above the sea-level. On the western slopes of Castle Hill, the south-western continuation of Mount Herbert, 2900 feet high, which rises so conspicuously above Lyttelton Harbour, they reach an altitude of nearly 1000 feet, where they are overlaid by the older lavas, forming the Lyttelton Harbour caldera. Thus a sub-marine hill stood here in the young mesozoic sea, of which portions of the summit and the slopes were gradually covered by agglomerates and brecciated beds. These beds were formed during and after the eruption of quartziferous porphyries, of which here and there portions of the *coulées* have been preserved. Some of these quartziferous porphyries resemble in every respect those from the Malvern Hills and Mount Somers. They are also accompanied by pitchstones, porphyritic from the presence of numerous well formed crystals of sanidine or glassy felspar, and occasionally of garnets. Other portions of the quartziferous porphyries, as for instance, the whole *coulée* of which Manson's Peninsula is formed, have a rougher, more trachytic matrix. They are full of grains and small crystals of white greyish or smoky quartz. The brecciated beds have a hard felsitic matrix, and the angular fragments of rocks enclosed in them belong to a variety of eruptive rocks of many colours, and of different texture, often forming a rock of striking character. They appear conspicuously on the summit of Gebbie's Pass, having been washed into cliffs of picturesque forms, and covering the palæozoic sedimentary beds from one side of the Pass to the other. On the southern side of this Pass, about 200 feet above the sea-level, occur two beds of shales with stems and roots of carbonized plants, but too indistinct for recognition. They are associated with coarse sands. Each of them is about 50 feet thick, separated by about 130 feet of loose conglomerate, the whole standing at a very steep angle, dipping 76 degrees to the south-south-west. They are situated at some distance from any locality where the brecciated porphyry agglomerate upon which they appear to rest, crops out. Thus they will be of more recent age than the former; however, no clear section is exposed anywhere, from which this point could be settled quite satisfactorily. After the formation of the brecciated agglomerates, new eruptions of acidic rocks took place, now in the form of rhyolites, the highly liquid matter reaching the surface through broad channels, of which one has been preserved as a large dyke, forming a beautiful section on the northern side of Gebbie's Pass, not far from the summit. The dyke is here about 100 feet thick, half of which is formed by the central portion, consisting of a whitish rhyolite with a fine laminated structure, breaking in prismatic blocks; the rest on both sides, where in contact with the agglomerates, has cooled more rapidly, and has assumed the character of an obsidian. This obsidian is greenish or brownish black, very brittle, and imperfect crystals of sanidine are enclosed in it. This dyke can be traced for a considerable distance upwards. Where overflowing and covering the agglomerates it forms the highest peak on the western side of Gebbie's Pass, well visible from Lyttelton Harbour. The rock here is divided into small pentagonal columns, with a vertical arrangement; lower down the Pass, the same *coulée* has a tabular structure. There is no evidence from which we can conclude when these beds were raised above the sea, but there is no doubt that this was accomplished in connection with volcanic disturbances close to them, beginning probably towards the latter part of the tertiary period, when the foundation of the oldest crater in Banks' Peninsula was laid. It is, however, clear that before and during that time, these quartziferous porphyries and agglomeratic beds underwent considerable denudation and disintegration, because we find at their base deposits of thick bedded sandstones, consisting almost entirely of grains and crystals of quartz, not very strongly adhering together, an imperfection detracting considerably from the value of this otherwise beautiful freestone. That these quartzose sands were deposited over a considerable area can be concluded from their occurrence in different localities, at considerable distances from each other, the principal ones being situated at Ohinitahi (near the head of Lyttelton Harbour), at Little Quail Island (between Quail Island and the mainland), and some way inland in Charteris Bay. Little Quail Island has been preserved under peculiarly favourable circumstances, as close by numerous volcanic eruptions have taken place, of which the latest formed the greater and highest portion of Quail Island.

Owing to the fact that agglomerates, consisting of volcanic boulders and pebbles, occur about 1,500 feet above the sea-level on the flanks of Castle Hill, I came to the conclusion, during my first examination of Banks' Peninsula, that the volcanic rocks of which it has been built up were mostly of submarine origin; but further and more detailed search has since proved, that although there are a few beds, which might be of marine, at least all the older portion is of subærial origin. The boulders and pebbles in question have either been rounded by attrition during their ejection, or they have been rolled in brooks descending along the slopes of high volcanic ridges, which were mostly destroyed before or during the formation of the Mount Herbert system. Moreover, no marine shells or exuviæ of other marine animals have ever been discovered in the tufaceous deposits interstratified with the lava-streams; whilst the existence of timber which has assumed the character of an altered coal, and is obtained in these deposits near Akaroa, points, from the manner in which it occurs, to a land origin, which, moreover, is indicated by numerous beds of laterite, representing, doubtless, ancient soils.

The oldest crater, of which the principal boundaries can be traced at the present time, is the Lyttelton Harbour caldera, having a general diameter of about two miles, the centre of which is situated a little to the south of Quail Island. The general structure of this crater, even before the Christchurch and Lyttelton Railway tunnel was entirely pierced through, could easily be made out by studying the numerous sections exposed in many directions, and by ascending the steep escarpments of the caldera wall, where a succession of streams of stony or scoriaceous lava, interstratified with beds of agglomerates, ashes, tufas, and laterites can be traced to the very summit. Still clearer sections are open to our inspection if we follow the barranco or entrance into the harbour, forming sometimes vertical cliffs of considerable altitude, and where the whole series of beds can easily be followed. However, the most interesting and complete insight was obtained in the railway tunnel passing through the caldera wall, and of which, as the work gradually advanced, I prepared a careful section. The main results of this survey, together with a description of some portions of the tunnel, of which sections in chromo-lithography have been added, will be offered at the end of this chapter. The succession and dip of the lava-streams and the intervening beds can also be made out by following the slopes of the ridges between the deep valleys washed out on the outer side of the crater wall, where it will be found that the lava-streams forming the lip of the crater have generally a slighter inclination than those lower down, the dip of the upper ones being only nine degrees in the average. In the tunnel the dip is greater, an inclination of twenty degrees not being uncommon. It is evident that the building up of such a huge system during numerous eruptions, often of great magnitude, could not be accomplished without a great destruction of portions of the beds previously formed, taking place, the point of eruption in the crater shifting continuously about the centre. If, at the same time, we examine the lava-streams and the interstratified agglomerate and ash beds along the water's edge, we have to come to the conclusion that all the eruptions by which the caldera wall was formed from summit to bottom, occurred under the same physical conditions.

For forming a true conception of the manner in which the crater wall of Lyttelton Harbour was raised, I cannot do better than refer the reader to the observations which have been made by excellent and competent geologists of the changes which occurred in Mount Vesuvius and Mount Etna in recent times, during violent eruptions. It has been made evident that these eruptions, principally at the beginning, could not have occurred without great convulsions taking place in the earth's crust, so that earthquakes of considerable vehemence must have preceeded them. After the crater was once formed, by the ejection of lapilli, scoriæ and ashes, over which streams of stony lava had been cooling, so as to preserve them from destruction, it existed either in the form of a large cauldron filled with liquid lava, resembling some of the volcanoes in the Sandwich Islands, or after partial solidification it formed a large rocky plain with a number of smaller vents over which ashcones were built up, or with numerous fissures from which vapours and gases issued such as, before the great eruption of 1822, the crater of Vesuvius appeared, as described by Sir Charles Lyell in his Classical Principles of Geology. During that eruption, the whole of this rocky plain was blown out, and an immense abyss formed, which was partly filled up by portions of the walls, more than 800 feet of which had been carried away by the explosion, so that the altitude of the mountain was reduced from 4200 to 3400 feet. Similar occurences have without doubt repeatedly taken place during the building up of the Lyttelton caldera wall. Examining into its formation and beginning our observations in the harbour, we find that many lava-streams have been preserved which have cooled in their ascent; others lie horizontal for a short distance, and are then seen to descend, conforming to the gradient of the underlying lava-streams, or agglomerate beds. In many instances we have also clear evidence, that considerable destruction of the beds previously formed had taken place before new streams flowed over the lip of the crater, or before beds of ashes, scoriæ and lapilli, were deposited anew. The tunnel section in this respect is also very instructive. Thus, in course of time, the great crater wall was formed, rising to an altitude of nearly two thousand feet, and having a diameter of more than five miles at its crest. It is clear that close to the vent, from which scoriæ and ashes were thrown out in large quantities, the greatest thickness of the agglomerate beds ought to be formed, and this, in fact, is the case, as the largest beds, having sometimes a thickness of several hundred feet, are situated within the inner side of the caldera wall. The lava-streams here between these agglomerates are irregular in their direction, and mostly of small dimensions. The more we advance towards the outer slopes of the caldera wall, the less frequent become these agglomeratic or tufaceous layers, whilst the lava-streams, which towards the centre have the greatest bulk, and are very stony and compact, become now gradually more and more numerous, but of smaller size and more porphyritic or scoriaceous, according to the laws by which the flow, dimensions and cooling of the lava-streams are regulated. It is, moreover, evident that many of them, owing to want of material, scarcely reach half way down the slopes of the caldera wall, that others rapidly thin out, and that many which for some distance, after flowing over the lip of the crater, had been of large dimensions and stony, become, long before its outer edge is reached, thin and scoriaceous, so that here streams of five feet in thickness are not uncommon. Although the tunnel does not offer us the necessary data to judge of the breadth of the lava-streams, we have for that purpose ample evidence in Godley Heads, the sea wall near Sumner, and many other localities. There are streams which are 500 feet broad, others only 30 to 40, but all without exception are somewhat scoriaceous on the bottom, where the lava flowing over cold ground cooled more rapidly. In many instances this is well exhibited by the existence of a small bed of laterite, a brick-red coloured rock, sometimes only a few inches thick, which doubtless was a layer of soil on the decomposed upper portion of a lava-stream, or agglomerate bed exposed for a considerable time to atmospheric action before the new eruption took place. The lava in the larger streams and in its central portion, principally very stony and of a blackish colour, gradually becomes, as we approach the surface, more porphyritic, with a more open texture, and assumes pinkish or lilac tints, till it changes into scoriæ. The decomposition or alteration is here often so great that it is impossible to trace the top of the line of contact between the surface of the stream and the bottom of the overlying bed, both forming a layer of coarse agglomerate. In other instances the rough, uneven scoriaceous surface of the lava-streams has been well preserved, the hollow spaces being filled up by ashes and ejecta, in which case they resemble many of the recent lava-streams which I examined in Mount Vesuvius and Mount Etna shortly after they had issued from the crater.

From the cliffs outside Lyttelton Harbour and at Sumner a very fair idea can be gained how the whole assemblage of beds was formed, the lava-streams and agglomerate beds in turn filling up pre-existing hollows, and thus forming and equalising the surface. In other sections it is observable that when the lava-streams were flowing at a higher angle than usual they shrunk considerably, whilst where hollows were in their course, which they usually filled out, they became very thick. The lava of which the caldera wall under consideration has been built up, consists of basic rocks, changing from a dolerite to a fine-grained basalt. Some of the lava-streams, however, as previously pointed out, show also a remarkable difference in the structure of the rock of which they are composed, the central portion being a compact basalt with a few crystals of augite, basaltic hornblende, and labradorite, whilst the upper portion consists of a lighter coloured porphyritic dolerite, sometimes so replete with good-sized crystals of labradorite that the greater portion of the rock is formed of that mineral. Again, most of the lava-streams on the inner slopes, or on the rim of the caldera wall, are of a compact basaltic nature, and consist, lower down and more distant from the centre of eruption (becoming at the same time much thinner), of a greyish doleritic rock full of crystals of labradorite, augite,* basaltic hornblende, and rubellan. Even in the most compact streams olivine is seldom present.

There is a great difference in the texture and character of the rocks forming the innumerable lava-streams, according to the conditions under which they have cooled and consolidated, so that, judging from hand specimens only, a great variety of rocks can be made out. However, as it is possible to follow in many lava-streams the gradual change from a compact black basalt into an almost earthy or scoriaceous vesicular lava, passing through all the varieties of a porphyritic or crystalline granular compound, which could be claimed as anamesites or dolerites, I have thought it best to include the whole series under

* In some of the tufas, augite in well formed crystals, often of large size, is not of unfrequent occurrence.

the general term, "basalt." Of secondary minerals, we find, either lining or filling cavities, sphærosiderite, carbonate of lime, (in the form of calcareous spar and aragonite, of which the latter is the younger), chalcedony, hyalite, opal, jasper, natrolite, mesotype, iron pyrites, and several others.

The internal structure of the lava-streams is generally massive, but being divided by more or less numerous joints into polyhedric blocks, some of them have a tendency to spheroidal structure, each polyhedric piece exfoliating with concentric layers with a hard kernel in the centre; such a structure is principally observable when the rock is partially decomposed.

Dr. Hector, at my request, had a number of specimens obtained by me during the tunnel survey, analysed at the Colonial laboratory at Wellington, the main results of which, embodied in three tables, will be found attached to this chapter. I have added to Dr. Hector's nomenclature, based without doubt upon the amount of silica contained in each specimen, the terms by which I designate them in accordance with the occurrence, character, and nature of each. I have also added the analysis of a remarkable trachyte, forming a lava-stream of considerable size, and having an average thickness of eighty feet, which is interstratified between two others of a basic character. This peculiar stream occurs between Lyttelton and the pass to Sumner. It is the only trachyte lava known to me as having flowed from any of the different centres of eruption of Banks' Peninsula, all the other acidic rocks, as I shall show in the sequel, having been ejected into fissures of more recent date. This lava-stream consists of a white vesicular trachyte rich in quartz, resembling closely some of the domites of the Auvergne, from which, however, it is distinguished by its larger amount of silica, although it approaches it again in its considerable percentage of potash. A vertical dyke, about eight feet thick, of a peculiar flaky, silky trachyte passes through this lava-stream, narrowing, however, in its upper portion. Although this acidic lava is rather soft and friable in small pieces, it has nevertheless resisted the disintegrating agencies at work far better than the hard basaltic lavas and agglomerates in its neighbourhood. The analyses of Nos. 10 and 191A, the specimens for which were taken from two small basaltic lava-streams, agree very well with the analyses of basaltic rocks from extinct European volcanoes, made by Rammelsberg, Engelbach, Streng, and others. The rock No. 180, of which there are several streams towards the centre of the tunnel, some of considerable size, and which has as high a percentage of silica as 65·57, presents some peculiar features not found in any other rocks in the Peninsula. It has a brownish black colour, with a somewhat waxy lustre, and resembles a palagonite tufa, from which it is, however, distinguished by its high amount of silica, which would place it with the trachytic rocks; small crystals of felspar with a high vitreous lustre are disseminated through it. The small (not uncommon) cavities or fissures are either filled or lined with sphærosiderite, and some of the joints are covered with a fine coating of the same mineral.

Returning to the orifice or orifices from which the material for the formation of the caldera wall was ejected, and to which also the numerous dykes, mostly having a vertical position, intersecting it, can be traced, it appears that the principal focus of eruption was situated a little to the south-west of Quail Island, as the greatest portion of the dykes radiate from here, and the eastern and southern sides of Quail Island, and the shores near Charteris Bay, are formed of tufaceous agglomeratic and brecciated beds, in which a number of angular blocks of rock are enclosed, having all a very bleached appearance. Many of these blocks are trachytic or porphyritic, others are porcelain jaspers and chalcedonies, and the whole has the peculiar altered look of rocks which have for a long time undergone the action of gases, vapour, and heat at the mouth of a volcano. The whole is so intersected with dykes, between which in many instances the bed rock has been washed away, that they look like remnants of the spokes of a gigantic wheel, of which the centre was situated at the spot close to Quail Island, as previously pointed out.

Another centre of eruption is close to Manson's Peninsula, which consist of quartziferous porphyry. A great number of dykes can be traced crossing that Peninsula, having the peculiarity that they generally stand well out in relief on its western or outer side, whilst on the eastern or inner side they have been washed out; these dykes are of various thicknesses, ranging from 3 to 25 feet, and have mostly a vertical position, forming protuberances all along the ridge. For the greatest part they radiate from a point in the centre of the shallow bay, situated east of that Peninsula. However, near its northern point the system of dykes becomes more complicated. First, two dykes five and six feet broad, cross each other, of which, the one pointing towards Quail Island is the younger. Close to the end of the Peninsula, the crossing point of three dykes of considerable size is reached, the oldest pointing to the centre of the bay, the second towards Raupaki, and the third or youngest again towards Quail Island. At the extremity of the same Peninsula there are such a number of dykes intersecting each other in all directions, that it is impossible to trace their relations in detail, without devoting considerable time to it. However, it is evident that not far from this spot all the principal centres of eruption seem to have been situated. It is here also that some of the dykes divide into several branches, and others anastomose repeatedly. The most striking fact in connection with the system of dykes of the Lyttelton caldera, and to which I have devoted considerable attention is their size, longitudinal extent, and constancy in direction. From the researches of numerous observers, it has been proved that all the dykes of Mount Vesuvius and Mount Etna do not extend much beyond the centres of eruption, so that they advance only a short distance, and, rapidly thinning out, soon disappear, a fact which my own observations along the crater walls of both mountains have amply confirmed. However, I have no doubt that other volcanoes similar in construction to Banks' Peninsula, and differing as considerably from these two European volcanic mountains, will be found to possess their systems of dykes developed in the same manner. During a number of years, it has been well ascertained by me that the dykes radiating from the several centres of eruption situated not far from each other, continue in many instances without notable interruption from the former mouth of the crater to the outer slopes of the caldera, where they disappear below the sea, or under the deposits now forming the Canterbury plains. Very often the principal dykes rise nearly 2000 feet above the sea level. They are well visible from the harbour to the summit of the rim of the caldera wall, above which, in some instances, they stand prominently as a wall, often six or eight feet high. Where proper measurements of the same dyke can be obtained for a long distance, it has been found that generally, as it advances towards the outer circle, it diminishes in breadth; however, in other instances, this is not the case, as repeatedly I have found some which, after narrowing on their outward course, considerably enlarge again before reaching the foot of the caldera. Thus to give a few examples, the large dyke of trachyte, which is crossed in the railway tunnel, about 29 chains from the Heathcote end, is first seen west of the town of Lyttelton, near Naval Point, where it is nearly 40 feet thick. On the summit of the caldera wall, not far from the top of the Bridlepath, it has narrowed to 23 feet 9 inches, after which it gradually gains in proportion, so that in Thompson's quarry it has enlarged to 26 feet, a breadth which it still has in the tunnel. A mile beyond the quarry the spur along which its course can be followed, runs out in the Heathcote valley, where it disappears below the Loess.

Two remarkable dykes, reaching the summit of Dyke Hill, about 2000 feet high, west-south-west of Castlehill, are very conspicuous. They both project boldly from the mountain, with a space of 35 feet between them. The eastern one is 18 feet, and the western 12 feet broad. Two similar dykes exist on the opposite side, and run up the caldera wall behind Raupaki. To mention a few others, there are some important dykes south of Dyer's Pass, which, after crossing Manson's Peninsula, are again met with at Ohinitahi (Governor's Bay), and of which several, after ascending to the very summit of the caldera, reach to the foot of the Peninsula near Cashmere, being extensively quarried in different localities along their course. These dykes, like many others which cross the caldera wall towards the Canterbury plains, mostly all radiate from a point lying in the centre of the Bay, formed by Manson's Peninsula on the one side, and Potts' Peninsula on the other, both of which consist of quartziferous porphyries, and between which this newer focus has been formed after the greatest portion of the caldera wall had already been built up. There is also the large dyke which crosses the Lyttelton-Sumner road at right angles, on the very summit of Evans' Pass, and which is repeatedly passed by the road winding in and out the different bays before reaching that Pass. It can be followed to Taylor's Mistake. Everywhere along the sea cliffs at and near the entrance of Lyttelton Harbour, numerous dykes, mostly all in a vertical position, can be seen pointing towards the centre of that harbour. A few, however, stand in a slanting position, and others have a tortuous course. As one of the remarkable changes which some of the dykes have undergone since their formation, I may also mention one which is well exposed in the seacliffs at Ohinitahi, Governor's Bay; here, a dyke of domite, about nine feet broad, crosses in a nearly vertical position the so-called trachyte sandstone deposited on the slopes of the quartziferous porphyry. After its solidification, a new fissure, about three feet broad, has been formed parallel to its direction, and running along its centre, which has been injected from below by domitic matter, but slightly different from the former; however, instead of continuing to the top of the cliff, about twelve feet above the sea-level, the new dyke is seen to turn from its vertical, to a nearly horizontal position, and to thin out considerably at the same time, disappearing altogether when it touches the side wall of the bed rock. The older dyke, above this change of direction, is considerably shattered and broken.

Before proceeding, it will perhaps be useful if I offer a few remarks on the causes which led to the formation of these remarkable dykes. I consider this the more important, as nowhere, as far as I am aware, do they exist in such great numbers, nor do they possess such a large longitudinal extent, as in the volcanic system under consideration. It appears to me that the immediate cause of the formation of a radiating system of dykes may be traced to the choked-up vent or chimney of a volcano, the mouth of which, after an eruption of considerable dimensions, is thoroughly filled up, either by its sides falling in, by the cooling of ascending lava-streams, or by both causes combined. When, from abyssological origination, masses of steam and gases have collected below this vent, and new matter is ready to be erupted, an enormous effort of nature will be necessary to clear out the old, or form a new chimney, which cannot be accomplished without a series of violent earthquakes, succeeded by an enormous explosion, by which the mouth of the volcano is cleared out or newly formed, and of the magnitude of which we can scarcely form a conception. A similar effect, on a gigantic scale, must have been produced repeatedly by the compressed masses of gases and steam during the formation of the Lyttelton caldera wall, when the upper portion of the closed-up volcano was not only removed, but vast quantities of ashes, scoriæ, and lapilli were thrown out, together with lava-streams which flowed in various directions. Before, or during these eruptions, molten matter in a high state of fusion, generally rushed up in the fissures which had been formed at the time, radiating from the focus like the spokes of a wheel. An examination of these dyke rocks will show at a glance that most of them are quite different in composition and character from those of which the lava-streams have been formed. The latter, as already explained, with one notable exception, alluded to on page 332, all consist of true basic rocks—basalts often assuming a doleritic texture, the dyke rocks being generally acidic, having either the composition of a trachyte or domite. We are able to judge of the more or less high state of fusion in which the molten matter ascended the open fissures from the effect produced on the walls on both sides. The trachytic matter forming the dykes, which are principally developed on the eastern side of the caldera wall, has evidently been in such a condition that it could exercise a most powerful effect on both walls of the fissure, the rocks often, for several inches, being changed to tachylite, a peculiar basic volcanic glass, quite distinct from obsidian. This change in the character of the rock is most observable when the dykes pass along tufaceous or agglomeratic beds. Here the reddish or light purple rocks have been altered to a black vitreous mass, containing small crystals of felspar. The dômitic dykes, mostly confined to the western half of the caldera wall, seem not to have excercised such a great influence as the former, as in most instances the walls on both sides of the dykes are only slightly hardened. However, there is no constant rule; large dykes, as for instance, the huge domitic dyke at Governor's Bay, running for a considerable distance parallel to the coast, and forming such a conspicuous object along the picturesque beach road, lately constructed, has scarcely made any alteration on either side, whilst smaller dykes of the same rock, only a few feet in thickness, are sometimes accompanied by a well-defined selvage of tachylite. The same may be said of the basaltic dykes of which, however, by far the greatest part has caused no visible alteration along the walls on either side. The trachytic varieties, of which, most of the dykes on the eastern side of Lyttelton Harbour consist, are formed generally of a peculiarly lustrous and flaky rock, sometimes vesicular with small crystals of sanidine. This rock has a light greyish colour, and its small cavities are lined by sphærosiderite. On both sides of the dyke the rock is generally tabular—parallel to the direction of the flow, and is massive in the centre with polyhedric joints, of which the principal ones appear at right angles to the flow. There are also a few trachytic dykes, principally small ones, where the sides, for half an inch to one inch, consist of a rather brittle obsidian, doubtless the effect of rapid cooling. Some very thin thread-like dykes, about one to two inches thick, consist entirely of that peculiar form of acidic volcanic rock.

The chemical analyses of the same dyke, No. 17, of Carl Ritter von Hauer, and of 29A centre, and No. 29B side, made in the Colonial Laboratory are very instructive, because they show us that there is a great difference in the composition of the same dyke, if the specimens to be analysed are taken from different localities. The specimen analysed in Vienna in 1863 was obtained from near the summit of the hill, whilst the two others were taken from the tunnel shortly after this dyke had been crossed by the miners. It is interesting to observe, that although the appearance of the rock is in every respect similar in both localities, the chemical constituents vary so very considerably. Thus, whilst the specimen from near the summit is very rich in lime and almost wanting in alkalis, those from the tunnel contain only the usual percentage of the former mineral, and the amount of soda is even in excess of that usually obtained in these acidic rocks. The other rock, of which mostly all the dykes towards the head of the harbour are composed, is of a domitic nature. It has a whitish claystone matrix, with a number of small crystals of felspar (sanidine). The dykes themselves show a tabular arrangement on both sides, parallel to their direction, the centre being divided first by polyhedric joints, of which the horizontal ones are the most prominent. Each prismatic portion thus formed has generally a spheroidal concretionary structure, the central nucleus consisting of a very hard kernel. This latter arrangement is beautifully shown when the spray of the sea has had access to the dykes, through which process decomposition has been much accelerated. A number of gigantic rosettes have been formed, in which yellowish and pinkish tints bring out more vividly the remaining white colour of the rock, other portions being veined and stained by a dark yellow ferruginous colouration. Fine examples of these rosettes are to be seen in Governor's Bay, near Mr. Potts' residence, and close to Little Raupaki. Some dykes of a more compact nature consist of a greyish rock containing small crystals of sanidine; others have to be referred to the trachydolerites, of which the principal mass is dark ash grey, with numerous crystals of felspar, of which many are striated (oligoclose ?), and in which smaller crystals or grains of hornblende are embedded. The dykes Nos. 44 and 55 passed in the tunnel, and of which an analysis has been made in the Colonial Laboratory, belong to this class.

There are also some dykes, often of great magnitude, consisting of a basaltic rock, of which that remarkable dyke at Sumner, near Morton's Hotel, is a well-known instance. Here the face of the nearly vertical cliff, by which the spur terminates, is nearly 200 feet high, and consists of a series of scoriaceous lava-streams and agglomeratic beds, from their nature having offered much less resistance to the waves of the sea, than the dyke passing through them. This dyke has been left standing free for a distance of about 100 feet, and is six feet six inches broad, striking from N. 20° E to S. 20° W., reaching to the summit of the cliff; but higher up the spur it cannot any longer be traced, so that in all probability it does not reach to the summit of the caldera wall. Taken along its whole face it stands vertical, although its course is a little tortuous and wavy. I add a faithful sketch of the locality on Plate, of sections No. 6, from the pencil of Mr. E. Dobson, C.E., from which it will be observed that this dyke forms a conspicuous object in the landscape. The first owner of the ground used it for a wall, and has broken a doorway through it. It consists of a hard tabular basalt with crystals of hornblende and labradorite, and sounds like a clinkstone when struck with the hammer. The tabular arrangement is parallel to the flow, with no cross divisions at right angles to it, except on both sides, where the rock has a polygonic structure (see sketch on the same plate), the horizontal divisions being four to six inches deep.

Another dyke of a similar character, reaching to the very summit of the caldera wall, is the one in which Mr. Fred. Thompson opened up a quarry many years ago, and which afterwards has been worked by Mr. Ellis. This dyke, having a direction of nearly west and east and pointing towards Little Quail Island, is about 18 feet thick, and like many others, is not quite vertical, having a dip of 85 deg. towards the north. It stands several feet above the ground, forming quite a rocky wall, and consists for the first 20 feet from its summit of a grey porphyritic rock full of crystals of labradorite and basaltic hornblende. It is a handsome building stone, being much liked in Christchurch, and amongst other buildings it has been used in the erection of the Bank of New Zealand, and for ornamental work in the Provincial Council Chamber. On the southern side, the dyke has a tabular structure for 6 feet 9 inches, and on the northern for 5 feet 6 inches, the centre consisting of a homogeneous mass, which can be quarried frequently in blocks of large size, indeed as large as 10 feet by 6 feet. In quarrying downwards, the rock gets gradually darker in the centre, and after a short distance assumes the character of a black dolerite, containing crystals of labradorite, augite, and hornblende, and is of such hardness that it is useless for building purposes; the sides, however, still continue for some distance lower down to consist of the same greyish dolerite, of which higher up—to use a quarryman's expression—the heart had been formed (see section, plate 6). It is thus evident that the sides and upper portion, by cooling more rapidly and not being subjected to so great a pressure, could assume a more porphyritic texture than the centre of the dyke, resembling the basaltic rock of which the main mass of the larger lava-streams is formed.

In studying the position of the dykes it becomes manifest that they have been formed at different times; however, the altitude of their uppermost portion does not indicate their age. I have nó doubt that many of them, which scarcely reach above high-water mark, are not older than others of the same petrological nature, which reach to the very summit of the caldera wall. In the present state of our knowledge it is impossible to solve this interesting question in all its bearings, and I can therefore only suggest that dykes containing rocks of exactly the same lithological character have most probably been formed during the same eruption. It is also evident that a number of dykes were formed long before the whole of the caldera wall was built up, and that they were partly destroyed during one of the next eruptions. One clear instance of the occurrence of such older dykes is to be found near Cliff's Cove in Lyttelton Harbour, where several trachydoleritic dykes were injected when the rest of the caldera wall was at least 1000 feet lower than at present. They pass through a basaltic lava-stream, which latter was afterwards partly destroyed along with them, the whole possessing now a nearly straight surface, upon which a large bed of agglomerate has been deposited. There are a great many instances of this kind. However, what is of the greatest interest in the history of the volcanic systems under consideration is the predominating acidic character of the dykes when compared with the basic lava-streams. In Vesuvius and Etna all the dykes are formed by the same kind of rock as the lava-streams are composed of, but they are generally more compact, having, as Lyell suggests, cooled and consolidated under greater pressure. It is evident that they owe their existence to the same subterranean efforts by which the lava-streams were ejected from the mouth of the crater, the fissures in which they were formed being evidently filled up from the same focus, and about the same time as the eruption of the lava-streams took place. But such a simple process cannot be admitted for the greater portion of the dykes of Banks' Peninsula, which must owe their existence to paroxysmal perturbations in the earth's crust, distinct from those during which the caldera walls were built up. It is evident that a great portion of the lava-streams and agglomeratic beds which once formed the crater of the volcanic system of Lyttelton Harbour, must have been blown away, or at least removed during one of those violent outbursts of subterranean forces necessary to clear the choked vent of the volcano, similar to those by which in recent times the upper portions of active volcanoes have repeatedly been destroyed under the eyes of the trembling population in the neighbourhood.

For an explanation, we might go back to Durocher's views, that all igneous rocks, even the most modern lavas, are derived from two distinct magmas which co-exist below the solid crust of the globe, each of them occupying a well-defined position. According to this distinguished French chemist, the uppermost portion is occupied by the acidic magma, which, besides being of lighter specific gravity, possesses a larger amount of silica and less iron oxyde than the other or basic magma. From the upper layer the granites, porphyries, and trachytes, according to his views, are derived, the zone of contact producing rocks of an intermediate character, such as trachydolerites. If this theory is correct, we have to admit that not only the dyke rocks were injected in rents formed during earthquakes, or immediately before volcanic eruptions had taken place from the opened chimney of the volcano, but that in each case the molten matter was furnished both from the upper and lower stratum of incandescent matter below the hard crust of the globe. There is, however, one great difficulty which crops up here, and which I wish to point out, and that is, the presence of dykes of basic rocks and of others of an intermediate character. If all the radiating fissures without exception had been filled up by acidic rocks, this would go far to prove the existence of such an upper acidic incandescent magma; in which case we should be forced to the conclusion that the chimney of the volcano reached lower down to the lower or basic layer. But it is difficult to understand how all the radiating fissures over an area of 12 miles in diameter could pass through the solid crust of the earth and through the fluid acidic magma, and how the lower basic rocks could be injected into them from below without disturbing the acidic magma, which certainly should have been forced up before. This difficulty might, however, be met by the suggestion that the radiating fissures in this instance did not reach so far down as the fluid acidic magma, and that the material for the formation of the dykes had been furnished from the crater itself, but it is scarcely conceivable that for a distance of six miles and for an altitude of several thousand feet the molten matter would have been forced in all directions from the central axis of eruption along these fissures often only a few feet wide. Mr. R. Mallet, in the "Transactions of the Royal Society (Phil. Trans. 1873,") has proposed another theory, namely, that the principal cause of vulcanicity is to be sought in the compressing and crushing action taking place beneath the crust of the earth, and by which such a great amount of heat is generated that a fusion of rocks, often on a large scale, is easily produced. This theory would so far explain very well the difference in the composition of the rocks varying according to the depth where the crushing action was actually taking place; thus, if the same action were to act upon granites, trachytes, and other acidic rocks, the result would be the production of trachytes, whilst if basic rocks were fused, basalts would ascend towards or to the surface. Here, however, another great difficulty presents itself in the fact that, although the number of volcanic eruptions during which the caldera walls were built up, must have been very great, no trachytic lava streams, with one single exception, have made their appearance, the whole series being of a basic, whilst most of the principal dykes are of an acidic nature. In such a case, the crushing of acidic rocks would have exclusively taken place when the dykes were being formed, and never when lava-streams issued from the crater's mouth, which is altogether improbable.

Although I have carefully read every work accessible to me in English, German, French, and Italian, treating on vulcanicity, I have not been able to find either any account of the existence of dykes in other volcanic regions converging so regularly to a few centres close to each other, or continuing over such a large area, (always keeping the general direction with which they set out,) as do those of the Lyttelton caldera, or again offering an explanation for the difference in the composition of the dyke rocks when compared with the lava streams or agglomeratic beds through which they pass. Mr. R. Mallet's excellent paper on the "Mechanism of Production of Volcanic Dykes," and of those of Mount Somma, in the "Quarterly Journal of the Geological Society of London, No. 128, Nov. 1876," in which an exhaustive account of the physical features of the dykes in the old caldera wall of Mount Vesuvius is given, unfortunately does not contain any physical theory to account for the mode by which fissures are produced, forming, when filled, volcanic dykes. If we take the heterogeneous nature of the material of which the caldera wall has been built up into account, it is astonishing that the dykes show such a remarkable regularity, always starting from a few points not far from each other, from which they radiate in all directions. It is still more remarkable to observe that all dykes which are cut by the Christchurch and Lyttelton railway tunnel have such a constant direction that they all, with one or two exceptions, appear to converge to one single axis behind Quail Island, a fact worthy of note, if we consider the distance, which is more than four miles, measured to the most distant dyke in that tunnel. The only dyke with which I am acquainted, showing some remarkable irregularity, is the one in which the so-called Ellis Quarry is situated. This dyke, which strikes nearly east and west, goes out about 400 feet below the summit, where a saddle intersects the spur. Shortly above its lower termination it sends off a smaller branch in a south-west direction, also ceasing after a short course. Whilst the main dyke does not appear any more above the surface, the smaller south-western branch crops up again on the other side of the depression, now gradually changing its direction, so that, in its lower course, about 300 feet above the plains, it crosses the spur in a south-east and north-west direction. The whole system of dykes in the Lyttelton caldera wall is thus very different from the dykes of Mount Somma, of which, in his paper, Mr. R. Mallet gives us such a lucid and suggestive account, and of which many are fractured, displaced, and crushed, and have at the same time a wedge-shaped form. We can therefore safely assume that the fissures and dykes in the Lyttelton caldera were only formed after the latter had been so thoroughly consolidated that, after the formation of the fissures and their filling up by the principal dykes, no more changes of any importance took place in them; and that, moreover, the forces by which the walls of the volcano were starred from top to bottom, must have been far deeper seated and more effective than the agencies by which Mount Somma was rent.

Leaving for the present the Lyttelton caldera, the genetic history of which will also serve to explain the mode of formation of the other calderas of the volcanic system under consideration, I shall now proceed to treat of another volcanic focus, either contemporaneous with the former, or at least formed shortly afterwards. Of this second centre of eruption, which is so greatly destroyed or hidden by lava-streams and agglomeratic beds of younger age, ejected from other volcanic foci, that only a portion of the western caldera can be made out, the vent was situated somewhere in the valley of the Little River. All the rocks are similar in character to those of the Lyttelton caldera.

The system next in age, and distinguished both by its size and the splendid preservation of its nearly entire wall, is the Akaroa caldera. I should only have to repeat myself were I to give a description of the lava-streams, their mode of deposition, and of the beds of agglomerate, ashes, and tufas interstratified with them, by which this caldera wall has been built up, as it resembles closely the one at Lyttelton. The lava-streams consist also of a basaltic rock, but sometimes a little different from that obtained in the former, it being more silky in appearance and containing more olivine. When porphyritic, the crystals of labradorite and augite are well formed; the scoriaceous lava is not so porphyritic, and has generally a reddish colour. Most of the ashbeds are also different, being of greater thickness before they alter to agglomerates, and having a peculiar chocolate purple colour. Only one other similar bed is found in the Lyttelton caldera, at Quail Island, the last centre of eruption. The tufaceous beds contain sometimes small portions of wood, so much altered as to assume a nearly anthracitic character. Iron pyrites (marcasite) has also been found in the same deposits. Most of the secondary minerals examined from the Lyttelton caldera have also been collected in Akaroa Harbour Another distinguishing feature in this harbour is the preservation of a portion of the sides of the old crater, which reaches to the very centre of the volcanic vent, from which the whole caldera wall around it has been built up. This portion forms a peninsula, owing doubtless its preservation to the existence—if I might thus express myself—of a core of a peculiarly hard lava, which has been found nowhere else in Banks' Peninsula, consisting of a very granitoid trachyte, containing crystals of quartz and sanidine, and forming at the southernmost point of the Akaroa Peninsula a hill several hundred feet high. Between this hill, which in former times was crowned by a strongly fortified Native pa, and the caldera wall, a succession of tufaceous and agglomerate beds, mostly of reddish-brown or purple tints, have been preserved, and, as it is perfectly evident, have repeatedly undergone great changes. They are intersected by numerous dykes belonging to two systems, of which one consists of domitic rocks, running mostly from north-west to south-east, the other of basaltic rocks having generally a south-west and north-east direction. They are generally not quite vertical, and have sometimes a slightly tortuous course. Beautiful sections of the innumerable lava-streams and the agglomeratic and other beds of similar origin of which this system has been built up can be obtained all around Akaroa Harbour and in the barranco leading into it. The walls of this caldera have an average altitude of 2500 feet, rising in Saddle mountain to 2750 feet above the sea-level. Below that mountain a portion of the older caldera wall of the Little River vent is hidden; the Devil's Peak, 2050 feet high, lying to the south-west of the former mountain, being doubtless a remnant of the latter system.

After the formation of the Akaroa volcano, a long space of time must have intervened, so that great changes by denudation and disintegration could take place before new eruptions followed at different intervals. It is very probable that during that period of comparative repose the barranco leading into the Lyttelton caldera was forming, and that the upper portion of the quartziferous porphyries, with the quartzose sandstones resting on their flanks, both forming a portion of the caldera wall where now Gebbie's and McQueen's Passes are situated, together with the lava-streams and agglomeratic beds on both declivities were partly removed; of the latter some remnants are still to be found near Lake Ellesmere, where the road crosses Gebbie's Flat. After this period of quiescence new eruptions took place from two principal centres, of which the best preserved and highest is situated near the summit of Mount Herbert. It rises on the southern side of Lyttelton Harbour, while the other is found north of the Akaroa caldera, the highest remaining portion being designated Mount Sinclair (2800 feet). I am unable to say which of the two is the earliest, but I shall first speak of the Mount Herbert system, that being the most conspicuous. Several new vents were opened near the rim of the Lyttelton caldera, by which a volcano was built up by lavas-treams, ashes, and other ejecta, rising much above the remnants of the former system. Although much disintegrated, the remaining portions of this newer volcano still rise in Mount Herbert to 3050 feet, and in Castlehill to 2900 feet—the altitudes are taken from the Admiralty chart, with which my own calculations from barometrical observations closely agree. These remains of the newer volcanic cone consist of basic rocks, agreeing much more with those of the Akaroa than with those of the Lyttelton caldera. These basalts are fine-grained, with a peculiar silky lustre, and contain sometimes large crystals of labradorite and small needles of basaltic hornblende. They have often a tabular jointing. Others are lighter in colour, and resemble some of the South American andesites. The scoriaceous lavas have generally a brownish colour with a reddish tinge. Descending for a considerable distance from the summit of both mountains, we find that the lava-streams lie nearly horizontal, and are interstratified with beds of agglomerate, tufa, and laterite .The agglomerates are generally formed of more or less angular pieces of rocks ejected from the volcanic vent, but in the one instance alluded to previously, there occurs a bed at the base of the newer volcanic deposits, consisting of rounded boulders or pebbles, mostly of small size, the origin of which is not yet quite clear to me. These fragments might either have been rounded by attrition during their ascent from the volcanic vent and before they had found a final resting place, or they might have been rolled in a water-course descending from near the summit of a volcanic cone, of which at present the remains are only to be found in Mount Sinclair, which in that case would be of greater age than the Mount Herbert system. The principal lava-streams which issued from this volcano, and have been preserved, run in a northerly direction into Lyttelton caldera, and can be followed from the summit of Mount Herbert to the sea. They form that remarkable assemblage of streams bounded on one side by Rhodes' Bay and on the other by Charteris Bay, and it is in following them from Diamond Harbour that the summit of Mount Herbert—where the most extensive panoramic view of this part of New Zealand can be obtained—is reached with the least difficulty. The remnants of several craters on and near the summit of Mount Herbert, of which about one-half of the rim in each case has been preserved, can easily be seen; the principal ones are open towards Lyttelton Harbour and the Kaituna valley.

The other system, of which the remaining caldera wall rises in Mount Sinclair to 2800 feet, intersects both the Little River and Akaroa calderas. Its barranco at the entrance to Pigeon Bay leads into the sea. It consists of rocks similar to those described as forming the Mount Herbert system, and its relations to the latter are rather obscure and complicated, as the lava-streams of both mix with each other, and owing to dense forest, generally clothing the slopes, no clear sections can be obtained to settle several important points in connection with them. It is an important fact, that the formation of dykes ceased after the older caldera walls of Banks' Peninsula had received their present form, and before the Mount Herbert and Mount Sinclair systems had been built up. All the lava-streams belonging to these two systems, even on their very summits, have never been fissured in any way, so as to prove that the volcanic energy by which the dykes were formed had already spent itself, or at least, if still existing, could not reach so high as to bring its effects under our observation.

To facilitate their task to those of my readers who have an opportunity of examining the remains of both volcanic systems now forming Lyttelton Harbour, I shall here offer the necessary data to distinguish between them. The older caldera wall beginning on the northern side of Gebbie's Pass rises soon to a considerable altitude, forming seven prominent peaks, as far as Dyer's Pass (957 feet). They are called the Seven Brothers, of which the two highest (the Knobs) reach an altitude of 1880 feet. On the northern side of that pass Cass' Peak rises to 1660 feet, and from here to Mount Pleasant (1615 feet), of which the summit is situated behind Lyttelton, the caldera wall is much broken, one of the principal saddles being the Bridlepath (1080 feet) formerly much used by riders and travellers on foot between Lyttelton and Christchurch. Between Mount Pleasant and One-tree-hill (2310 feet) on the southern side of Lyttelton Harbour, the barranco or entrance passing through the caldera wall has been formed. Separated from the last-mentioned mountain by a saddle about 1200 feet high, appears Rhodes' Sugar Loaf (2005 feet), of which the western continuation, after half a mile, disappears under the slopes formed by the lava-streams of Mount Herbert. Then follows the newer Mount Herbert and Castlehill system, terminating in a precipitous slope on the western side of Kaituna Pass. From here to the southern side of Gebbie's Pass opening, the older caldera wall, rising again to a considerable altitude, continues without any other break, falling abruptly towards that latter pass.

We arrive now at the last stage of volcanic action, of which any clear signs have been preserved, and which again took place in the very centre of Lyttelton Harbour. This time the new eruption was doubtless of submarine origin. It appears that the country had sunk gradually, at least 300 feet below the sea-level, when from the present centre of Quail Island and in the neighbourhood, eruptions of basaltic rocks repeatedly took place, the lava-streams being generally separated by beds of conglomerate which were formed between the eruptions. The magnificent sections open to our inspection on Quail Island give us a good insight into the *modus operandi*, and I have added, on plate No. 6, two illustrations of them to those showing the more general characteristics of Banks' Peninsula. The oldest portion of that picturesque island, the vertical cliffs of which towards Lyttelton form such a conspicuous feature, is its eastern side, where the island narrows in the centre. Here a series of beds have been preserved, with all the appearance of having been deposited close to the mouth of a volcano. They consist of ashes, tufaceous beds, and breccia, enclosing blocks and fragments of rock of all possible shapes, but which have all undergone such considerable changes that their lithological character has been considerably altered. There are many fragments resembling porcelain jaspers, some are chalcedonic, others are quartziferous porphyries, trachytes, and other eruptive or volcanic rocks; but the whole is so bleached or altered in colour by gases and vapour, that the different constituents are unrecognisable, so that their original texture can only be guessed at. The whole is intersected by a perfect network of dykes, all of a trachytic nature, of which the greatest number point to two centres, both a little to the south-west of Quail Island, although a few also come from the west. Before reaching the north-eastern point the whole group disappears below a series of basic lava-streams, which have all issued from a shallow crater now forming the centre of the island. The rock by which this small volcanic system, and a few others of still smaller size situated in and near Charteris and Rhodes' Bays, have been built up, consists of a fine-grained basalt containing grains of magnetic iron ore, and grains and concretions of olivine. It has either a columnar or tabular structure, or breaks in large prismatic blocks. These basaltic lava-streams have been well exposed by denudation on the north-eastern face of Quail Island. The vertical cliff, about 200 feet high, consists here of four lava streams, of which the uppermost and most important one is about 45 feet thick. This lava-stream has the peculiar feature of possessing only irregular prismatic jointings, where it issues from the vent with a fall of about 15 degrees. For the rest of its course, where it has only a slight inclination towards the horizon, it is divided into two clearly defined parts, of which the lower one lying directly upon a bed of rounded conglomerate is divided into a series of regular vertical columns having four to six faces, whilst the upper one has only the irregular prismatic joints, which the whole stream possesses close to the crater's mouth. The lower lava-streams are also jointed in the same manner, the whole series being separated by beds of conglomerate and ashes. The conglomerate consists mostly of waterworn blocks of rock, sometimes of large size. All the rocks of which Banks' Peninsula is built up have contributed, but trachytic and domitic and bleached or altered rocks are the most numerous, proving that a greater portion of the older crater wall must have been existing when these last eruptions took place. The newer basalts, of which the streams themselves are composed, are, however, also well represented, whilst the older basic rocks, of which the original caldera wall has been formed, are, if not entirely wanting, at least of very rare occurrence. Many of the boulders have the appearance of having been much decomposed before they were deposited in their present position. They are interstratified, covered or mixed up with beds of ashes and scoriæ, from which we can conclude that the lava-streams were preceded by a clearing out of the vent, during which the ashes and scoriæ were ejected. The presence of a bed of chocolate-coloured tufa, resembling some of the so-called aqueous lava-streams (lava d'aqua of Italy), reposing directly upon the remnant of the older crater wall, shows that similar causes, as obtained in the ancient Kingdom of Naples, were also here in operation.

I examined repeatedly the conglomeratic and agglomeratic beds in question for fossils, but in vain, not the least sign of marine shells or other organic life being in existence. The vent of the last eruption lies just below the remnant of the ancient crater wall, exposed in the north-eastern face of Quail Island. The loose agglomerate beds, of which it consists, are mostly of a red colour, and, like the domite dykes by which they are crossed are much altered. The chocolate-coloured tufa bed on the western corner of the cliff is covered by a large conglomeratic deposit, similar in its nature to those which are interstratified on the eastern side with the basaltic lava-streams. It rises to the summit of the island, and is overlaid by a number of streams of basalt which form the whole western side of the island, with the exception of a very few spots where remnants of the older crater are exposed to our view. After the formation of Quail Island, and the few other small centres of basaltic discharges already pointed out, no other volcanic eruptions seem to have taken place, Banks' Peninsula rising afterwards a few hundred feet and maintaining with the exception of small oscillations, its present level; at the same time it remained surrounded by the sea for a considerable period. There is clear evidence, as I shall point out in the sequel, that even during its occupation by an autochthonic population, the straits round the island had not yet been closed by the driftsands and shingle advancing from the south. During this period, without doubt of long duration, the deposits of loess were formed on its slopes of which I shall treat in one of the next chapters.

TABLE I.—*Chemical Analysis of Sixteen Rock Specimens, from the Christchurch and Lyttelton Railway Tunnel, made in the Laboratory of the New Zealand Geological Survey, Wellington, given in tabular form.*

No.	Name, according to Dr. Hector.	Sp. G.	Silica.	Alumina	Iron. oxides.	Manganese. oxides.	Lime.	Magnesia.	Potash.	Soda.	Loss by Ignition	Name, according to Geological Position and Lithological Character.
180	Trachytic porphyry (vesicular, with iron salts in cavities ...	2·374	65·57	15·67	5·98	traces	2·88	traces	(9·28)		·62	Tufaceous lava
218	Porphyritic claystone (porphyry or phonolite)	2.453	62·15	22·11	5·37	1·20	1·20	·40	—	6·38	1·19	Trachyte dyke from centre
234C	Scoriaceous trachyte	2·507	61·99	13·08	8·65	4·42	2·21	traces	1·61	4·22	3·82	Vesicular trachyte, fragment from an agglomerate bed
29B	Trachyte	2·590	61·38	20·60	2·57	1·19	2·18	·40	—	9·70	1·98	Trachyte dyke, from side
29A	Porphyritic trachyte	2·374	60·69	17·75	3·83	1·21	1·20	1·43	traces	13·10	·79	Trachyte dyke, from centre
227	Ferrocalciferous phonolite	2·303	54·18	19·25	8·99	3.16	3·13	2·07	3·77	3·98	1·47	Phonolitic boulder from an agglomerate bed
55	Porphyritic basalt ...	2·608	53·55	13·79	15·41	—	3·45	2·64	(10·35)		·81	Porphyritic basalt
44	Trachydolerite ...	2·724	53·48	17·69	14·23	traces	6.91	·20	(5·69)		1·80	Trachydolerite dyke
183	Amygdaloidal claystone	2·352	53·47	16·35	9·23	traces.	3·65	1·73	4·42	5·77	5·38	Trachydolerite dyke
196	Porphyritic dolerite	2·797	53·03	18·01	(5·18)		7·24	3·10	(11·79)		1·65	Porphyritic basalt
7	Claystone	2·568	50·38	28·27	1·73	—	8·46	1·35	—	8.08	1·73	Scoriaceous dolerite
28	Trachydolerite ...	2·729	49·85	15·75	8·39	traces	7·57	4·19	·41	9·84	4·00	Porphyritic dolerite
23	Altered claystone ...	2·120	48·35	24·15	(10·79)		(4·87)		·91	4·42	6·51	Laterite
191A	Vesicular dolerite ...	2·314	47·24	14·23	16·60	—	7·71	3·16	1·97	2·37	6·72	Porphyritic basalt
10	Vesicular claystone (ferrocalciferous) ...	2·723	46·79	17·46	15·52	2·22	7·33	3·17	·44	5·05	2·02	Porphyritic basalt
51A	Bole	2·089	44·78	15·66	16·87	·60	2·02	5.02	(2·69)		12.36	Bole, partly altered to a laterite

Table II.—*Decomposed by Hot Acids.*

No.	Name, according to Dr. Hector.	Sp. Gr.	Silica.	Alumina	Iron.	Manganese.	Lime	Magnesia.	Potash.	Soda.	Loss by Ignition	Name, according to Geological Position.
218	Porphyritic claystone (porphyry or phonolite)	2·453	52·78	12·34	16·87	—	7·87	traces	—	3·40	6·74	Trachyte dyke
29A	Porphyritic trachyte	2·374	44·41	11·10	19·53	4·14	6·95	1·39	—	6·93	5·55	Trachyte dyke, from side
28	Trachydolerite ...	2·129	39·99	19·99	17·69	traces	6·32	2·86	1·14	1·16	10·85	Porphyritic dolerite
29B	Trachyte ...	2·590	37·15	25·63	6·41	5·11	7·70	traces	—	5·18	12·82	Trachyte dyke, from centre
10	Vesicular claystone (ferrocalciferous) ...	2·723	28·97	9·67	37·94	7·59	4·15	4·84	—	—	6·84	Porphyritic basalt

Table III.—*Undecomposed by Hot Acids.*

No.	Name, according to Dr. Hector.	Sp. Gr.	Silica.	Alumina	Iron. oxides.	Manganese. oxides.	Lime.	Magnesia.	Potash.	Soda.	Name, according to Geological Position.
29B	Trachyte	2·590	65·81	19·68	1·87	·47	1·17	·48	—	10·52	Trachyte dyke, from centre
218	Porphyritic claystone (porphyry or phonolite)	2·453	64·16	24·20	2·90	1·46	—	·26	—	7·02	Trachyte dykc
28	Trachydolorite ...	2·129	63·98	10·75	2·42	traces	6·73	4·03	—	12·09	Porphyritic dolerite
29A	Porphyritic trachyte	2·374	63·39	18·85	1·23	·72	·25	1·43	—	14·13	Trachyte dyke, from side
10	Vesicular claystone ... (ferrocalciferous) ...	2·723	54·18	20·70	6·20	—	8·67	2·48	·62	7·15	Porphyritic basalt

The specimens analysed were taken from the following localities:—

No. 180 Tufaceous lava, from a stream about 10 feet thick from Lyttelton end.

„ 218 Trachyte dyke, rapidly thinning out in the tunnel, 21½ chains from Lyttelton end.

„ 234C Fragment from agglomerate bed No. 334, vesicular trachyte, section No. 1.

„ 29B Trachyte dyke, from side, tabular jointing, section No. 5.

„ 29A Same dyke, from centre.

„ 227 Phonolitic rock, fragment from an agglomerate bed, 16½ chains from Lyttelton end.

„ 55 Porphyritic basalt, from a large stream, 42 chains from Heathcote Valley end.

„ 44 Trachydolerite dyke, 18 feet thick, 13½ chains from Heathcote end.

„ 183 Trachydolerite dyke, about three feet thick, 38½ chains from Lyttelton end.

„ 196 Porphyritic basalt, from a lava-stream about 10 feet thick, section No. 2.

„ 7 Scoriaceous dolerite, section No. 6.

„ 28 Porphyritic dolerite, section No. 5.

„ 23 Laterite, section No. 5.

„ 191A Porphyritic basalt, from the centre of a small lava-stream, about 7 feet thick, 35 chains from Lyttelton end.

„ 10 Porphyritic basalt, section No. 6.

„ 51A Bole, partly altered to laterite, 40 chains from Heathcote end.

Analysis made at the Laboratory of the Imperial Geological Institute of Austria, Vienna, by Carl Ritter von Hauer.

Flaky vesicular trachyte.—Banks' Peninsula, from the large dyke near the Bridle-path, in which Messrs. F. Thompson and Co.'s quarry is situated (*No.* 29 *of Tunnel Section.*)

Silica	62·80
Alumina	20·62
Protoxyde of iron	2·00
Lime	7·54
Magnesia	·87
Water	5·66
	99·49

The result of the analysis of this rock, of which the specimen sent was beginning to show a little decomposition, is very striking, as alkalis are entirely missing, and lime is present in such large quantities.

This rock deserves, perhaps, another name, as the perfect resemblance with the sanidine trachyte of Kühlenbronn, is only one of a superficial character.

The following analyses were made in the Laboratory of the Imperial Polytechnical Institute of Vienna, under the direction of Prof. Dr. A. Schrotter, at the request of my friend Prof. Dr. F. von Hochstetter, by the different chemists, the names of whom are appended to each.

A.—Black Dolerite Lava from Banks' Peninsula.

(V. Alder.)

	Per cent.
Silica	51·097
Alumina	17·389
Sesquioxyde of iron	9·492
Protoxyde of iron	6·050
Carbonate of Lime	2·852
Lime...	6·967
Protoxyde of manganese	0·521
Magnesia	3·074
Oxyde of titanium	0·791
Potash	0·396
Soda	1·147
	99·781

The specimen was dried in a dessicator at a temperature of 110 deg. Centigrade (Celsius) and lost by that operation 0·860 water.

B.—Dolerite Lava from Banks' Peninsula.

(H. J. Rossmeissl.)

Silica	54·616
Alumina with traces of oxyde of titanium...	18·042
Sesquioxyde of iron	7·053
Protoxyde of iron...	4·192
Lime	6·817
Protoxyde of manganese	0·971
Magnesia	2·163
Potash	1·235
Soda	3·910
Water	1·003
	100.002

The water was expelled at a temperature of 100 deg. Centigrade (Celsius).

M

These two specimens A and B, taken from the same lava-strean the tunnel, show by their analysis that they are more closely alliec the dolerites than the trachytes, as, according to Bunsen, a norr pyroxenic dolerite ought to have only 48.47 silica, whilst this l from the tunnel has 54.616, and has at the same time all the ot ingredients which constitute a normal dolerite in lesser proport than it ought to have. They are the two prevailing rocks occurr near the northern end of the tunnel, and a comparison of th analyses proves well, although so very different in their litholog character, that they possess nearly the same constituents.

Labradorite, large Feldspar Crystals occurring frequently embedded agglomeratic beds in Banks' Peninsula.

(J. Schapringer.)

				Per cent.
Silica	...	...	...	55.89
Alumina	...	...	...	29·23
Sesquioxyde of iron		...	...	1·68
Lime	...	...	...	12·43
Magnesia	...	...	...	0·65
Soda	...	...	...	0·69
Potash	...	...	...	0·24
				100·81

No loss by drying the specimen in the dessicator.

Analysis made by Professor A. W. Bickerton, F.C.S., at the Laborat of Canterbury College.

Vesicular Trachyte (Domite) from a Lava Stream, one mile east of Lyttelton.

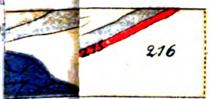
Specific gravity ... ... 2·44

Adherent moisture		...	...	1·000
Loss on ignition ...		...	...	·900
Silica and insoluble matter ...			...	73·170
Alumina	...	...	...	15·630
Iron	...	...	...	2·340
Manganese	...	...	...	trace
Lime (Ca. O.)	...	...	...	1·635
Magnesia	...	...	...	·324
Sulphuric Acid ...		...	...	·686
Potash	...	...	...	3·527
Soda, loss and undetermined			...	·776
				100·000

ions

Betw

Bet



tween

5 Bet

ns cor

Scale

ging

scoria

nd Moabones

The Christchurch and Lyttelton Railway Tunnel.

In the Historical Notes on pages 62 and 156, I have alluded to the geological survey undertaken by me during the progress of the interesting and instructive work of passing through the caldera wall of a large extinct volcano. I prepared at the time a section at the scale of 20 feet to 1 inch, and have reduced, for this report, some of its most interesting portions to half that size.—*Vide* coloured Plate III.

The direction of the tunnel is N. 14° W. The first trial shaft was commenced in January, 1860, and the permanent works under contract with Messrs Holmes and Co., began in July, 1861. The tunnel was laid out, and its execution solely superintended by Mr. Edward Dobson, C.E., Provincial Engineer. It was brought to a successful termination on May 25, 1866, when both adits met near the centre. The opening for railway traffic took place on December 9, 1867. The total length of the tunnel is 8598 feet, and if we deduct from this 365 feet on the northern or outer side, and 105 feet on the southern or inner side, formed by slope deposits and loess, there remains 8128 feet of rock of volcanic origin, of which the caldera wall has been built up. Classifying the rocks according to their lithological character, we find that the crater above the present water-line consists of—

61 lava-streams, having the character of a stony compact or porphyritic basalt.

54 lava-streams, formed of a scoriaceous basaltic and doleritic lava, some of them changing so gradually into agglomeratic beds that the line between them cannot be clearly defined.

39 beds of agglomerates, a few of them changing into scoriaceous lava, but most of them consisting of scoriæ, lapilli, and other ejecta, imbedded in ashes. A few of them have a brecciated appearance.

19 beds of laterite, clays, and slope deposits, partly or wholly burnt by overlying lava-streams, and

1 small layer of bolus—together 174.

These beds are intersected by 32 dykes, 18 consisting of trachyte lava (of which five do not reach to the roof of the tunnel), and 14 of a basic nature (five of them being intermediate in character, trachydolerites). One of them comes from the top of the tunnel.

Beginning at the southern or Lyttleton side of the tunnel, we observe that a large bed of loam has been deposited upon the volcanic rocks, being thickest on the lower portion of the caldera wall. This peculiar rock, which, when in small pieces, is easily pulverised between the fingers, has a remarkable consistency and solidity when in large masses, and is of subærial origin. It may be designated as loess, an expression now extensively used in Europe for similar deposits. It owes its origin to various processes, of which rain, wind and vegetation are the principal factors. This bed of loess, which in some localities, is more than 100 feet thick, changes gradually before we reach the volcanic rock, to a true slope deposit, consisting of fragments of rock more or less rounded, the lines of junction being often impossible to trace, owing to the decomposition of the volcanic rocks immediately below the slope deposits. The greatest amount of agglomerate, consisting of scoriæ, lapilli, and ashes is, as might be expected, congregated on the inner side of the caldera wall, not far from the focus of eruption. These more or less incoherent beds, of which each was probably formed during one eruption, have generally an inward as well as an outward dip, of which the beds 232 to 241 close to the entrance of the tunnel in Section No. 1, and extending 20 feet still more to the south, than shown in that section, form a notable instance. They were without doubt deposited on the lip of the crater. Near the Lyttelton end they are much disturbed. Two stony lava-streams cross these agglomerate beds, and we have to assume that after No. 231 was formed, the lava-stream 233, ascending from the mouth of the crater, had consolidated over it, being in its turn covered by a new talus of ejecta sloping inwards to the crater's mouth. After these latter beds, 234 and 234A were formed, a new stony lava stream, No. 237, ascended, in which case Nos. 231, 234, and 238 to 241 were three distinct agglomerate beds, covered and preserved on their inner slope by stony lava-streams, consolidated during their ascent. Or, to offer another explanation, we might regard these two stony lava streams, 233 and 237, as having broken through the huge accumulations of ejecta which were heaped up all around the crater's mouth—a phenomenon frequently observed during violent volcanic eruptions, when a huge cinder cone is formed in a short time. A similar occurrence seems to have taken place more towards the centre of the tunnel (Section No 4), about 60 chains from the Lyttelton side, where a large stony lava stream, No. 167, is seen to ascend through the agglomerate bed or beds, Nos. 166 to 168. The lava stream, 163, in close proximity, might be considered to be the continuation of the former, which here flows down the steep side of the cinder cone. Gradually, as we retreat from the focus of eruption, the agglomerate beds decrease in number and size, but they still are occasionally present even close to the mouth of the tunnel near to the Heathcote entrance. Some of them (as, for instance, No. 11, 11 chains from the Heathcote end, Section No. 6), consist in their lower portion of fine ashes, or lava d'aqua, and above of scoriæ and lapilli, so as to suggest, that first fine ashes had been thrown out or had been brought down the side in the form of a mud stream, on the top of which large ejecta were afterwards deposited. Another agglomerate bed having an anticlinal or saddle arrangement is 22A, 17 to 20 chains from the Lyttelton end.; it was evidently deposited on the rim of the crater, of which the uneven surface is well visible in its lower portion. After its formation, two more agglomerate beds were deposited over it, 216 and 227, and 211 and 228 in the section, each being separated from the other by a bed of laterite. Moreover, it is clear that, whatever may have been its origin, the lowest portion of this and several other agglomerate beds must have been deposited when in a state of high temperature, as the argillaceous bed below it has been burnt red, so as to take all the characteristics of a laterite. All round Banks' Peninsula, agglomerate and ash beds are visible in the cliffs, but they are like the lava streams of small vertical extent only, and we have to approach more towards the centre of eruption, when we wish to see them in their greatest dimensions.

The largest and most numerous stony lava-streams are met with towards the centre of the tunnel, where the basalt of which they are composed possesses the greatest hardness and crystalline texture. More towards the boundaries of the volcanic system, the lava-streams are much thinner and, at the same time, more porphyritic, amygdaloidal or scoriaceous, and it is very instructive to follow some of the lava-streams which form clear sections in the deep valleys radiating round the Peninsula, from the summit of the caldera wall to their termination at its foot, and to note the gradual change in their size, and in the texture of the rocks of which they are composed. I have already alluded to the lava-stream 237, nine chains from the Lyttelton end (Section No. 1), but in connection with it, I may here mention that the first shaft sunk by Messrs. Smith and Knight, the English contractors, unfortunately reached it soon below the surface of the ground, and continued all the way through it to the roof of the tunnel.

This was one of the principal causes that the firm, being unacquainted with the formation of the crater wall, abandoned the contract so soon. The first stony lava in the tunnel, flowing down the slopes of the crater wall, is a small stream, No. 214, about 22 chains from the Lyttelton end. Several others of similar dimensions follow, till we reach stream 206 (Section No. 2), which might be the continuation of No. 237 (in Section No 1), 11½ chains from the Lyttelton end. This stream throws a great deal of light, by its configuration, on the manner of the flow of liquid lava. After flowing down the slopes, we see it shortly afterward ascend again (No. 202) over a bed of agglomerate, and, after having reached the apex of the latter, descend again (No. 200), diminishing rapidly in size, the rock now becoming highly porphyritic and lighter in colour. The largest stony lava-stream of the whole series, of which Section No. 3 gives a portion, begins about 41 chains from the Lyttelton end, and continues without interruption to 52½ chains. Consequently, taking its angle of dip into account, it is more than 500 feet thick. More or less porphyritic on both sides, the whole central portion consists of a very hard basaltic rock, ringing to the hammer, irregularly jointed, with here and there a tendency towards spheroidal structure. This huge stream gains an additional interest from the existence of three caves in its centre, which, however. have partly been filled up with thin plates of basalt of the same texture as the lava-stream, and which lie more or less horizontal. They are coated over and often cemented together by sphærosiderite. Sometimes they lie in such regular order, and so loosely upon each other as if they had been artificially placed in that position. The open space, or cave proper, is always on the southern side of each cavity. The only explanation I can offer as to their formation is that gases have been enclosed in this portion of the lava-stream, which, in course of time, were absorbed, and that liquid matter from the upper portion of the stream found access to the cavities, gradually filling them up, but that the channels of communication were stopped before the whole of the gases still remaining in the southern parts of each had been absorbed.

Another stream of large dimensions is No. 14, beginning 20 chains from the Heathcote end (Section No. 6). It is over 100 feet thick, has a jointed structure, the central portion being spheroidal, with concentric layers. All the stony streams in the tunnel above the latter are very thin, but it is possible that the scoriaceous basaltic lava (the violet beds of the section) which overlie them, are only their upper portion, the bottom of the streams, owing to their thinness and to the distance from the centre of eruption, not having been able to cool to the stony compact form. I may, however, observe that the boundary line between both kinds of rock is in many instances very distinct and clearly defined. These scoriaceous beds occur throughout the tunnel; they are sometimes of considerable dimensions, some of them being over 100 feet thick. In speaking of the formation of the Lyttelton caldera, I have already pointed out that it has been built up by volcanic rocks belonging to two distinct divisions, of which the basic rocks have furnished all the material for the lava-streams, agglomeratic and tufaceous beds, whilst the principal portion of the dykes owe their origin to the acidic division. As might be anticipated, the dykes are most numerous near the focus of eruption, thus we find the greater portion of them near the Lyttelton side, several of them not reaching to the roof of the tunnel. Of these dykes, No. 29 is the most important. It consists of a soft flaky and lustrous trachyte, and possesses, like most of the other acidic dykes, the characteristic feature that it is accompanied on both sides by a selvage of tachylite, sometime two or three inches thick. This change in the character of the bed rock is especially visible when the dykes pass through agglomeratic or tufaceous beds. It shows clearly that the volcanic matter ascending by these fissures was in such an intense state of fusion that it was able to alter the rocks on both sides so thoroughly for such a distance. In some instances the dyke rocks themselves have a selvage of tachylite, the bed rock being unaltered. It is worthy of notice that the basaltic dykes have not produced the same effect, the rocks on both sides being generally unaltered. Large beds of loess, similar to those deposited on the inner side of the caldera wall have also been passed through on the Heathcote side. Of minerals of secondary origin found in the tunnel, the most diffuse is sphærosiderite which usually coats the pores and cavities of scoriaceous lavas. Of others, calcareous spar and aragonite are the most conspicuous. The latter is younger than the former, having often been deposited upon the surface of the calcareous spar in the small geodes. In a few localities, hyalite fills small clefts, or is found in a stalactitic form.

I shall close this chapter by offering a few observations on some other physical features of the beds through which the tunnel has been excavated, and as I noted them on the large section during the survey. Forty chains from the Heathcote end, a scoriaceous lava-stream fifteen feet thick, and accompanied on both sides by beds of laterite and agglomerate was passed, which was so loose and full of water that the ground had at once to be heavily timbered. All the cavities in the lava are lined with sphærosiderite, on which crystals of calcareous spar have been deposited. At 40¾ chains on the same side, in a bed of laterite, four feet above the floor of the tunnel, a small spring was struck, drying up a few months after; 35½ chains from the Lyttelton end, the lava-streams, when first passed through, were so wet that the workmen could scarcely continue the work. In these streams, all the cellular cavities were either lined with sphærosiderite or filled with calcite. Sixteen chains from the Lyttelton entrance, in the agglomerate bed No. 228, and from a fissure reaching from the roof of the tunnel, a copious spring flows which has a constant temperature of 65·20 degrees Fahrenheit, consequently 12·20 degrees above the mean temperature of Christchurch—about 53 degrees. Several eels have been caught near this spring, in the drain which runs from here to the mouth of the tunnel. There being no connection with any other water-course, these eels must have ascended by the spring; they belong to the species *Anguilla Aucklandii* Rich., and have properly developed eyes. During the construction of the tunnel, it was frequently observed in the north or Heathcote end, that the water rose in the floor before a south-west gale, and subsided before the gale lulled; no observations could be made to ascertain whether the state of the tide had anything to do with this. The height to which the water rose was somewhat under half an inch. After the earthquake of August 17, 1868, this spring in the tunnel increased to such an extent that it laid the rails slightly under water; after a few days it decreased again to its former volume.

CHAPTER XIII.

THE ALLUVIAL GOLDFIELDS OF WESTLAND.

ALTHOUGH it is beyond the scope of this Report to give an exhaustive account of the goldfields of Westland, I wish to offer at least some remarks upon the formation of those beds in which the principal workings are situated. They are of various character, and may be classed as alluvial, glacier, and littoral deposits. The alluvial beds from which the largest amount of gold has been, and is still being derived, have been formed during, or at least immediately after, the termination of the Pareora formation (Captain Hutton's Kanieri Group.) In previous chapters I have already pointed out that before the advent of that formation, and during the time the Oamaru series was deposited—the land having sunk several thousand feet below its present level—calcareous strata, finely grained, from the nature of the deposited material, were thrown down. These deposits, partly by raising the bed of the ocean, but, and principally by the upheaval of the Islands, assumed gradually a shallow-water or littoral character. It is at the same time evident that many oscillations occurred, judging from the strata under review, although a gradual rising was predominant. Thus we find, to give the general features, that the lower finer grained limestones were followed by claymarls and clays, the latter becoming more and more arenaceous, till the uppermost beds, consisting of a loose ferruginous sandstone, are reached. These last form the uppermost marine bed, as they are everywhere succeeded by others of a very different character, to which we may assign the name of the Great or Lower gold-drift of New Zealand. Instead of marine strata, deltaic and fluviatile beds appear, consisting of boulders, shingle, gravel, sand, and loam (silt), where the precious metal has been retained which has been brought down from the ranges. For an enormous lapse of time these ranges have been subjected, first to marine and afterwards to subærial denudation. Thus, where this lower gold-drift has been preserved, which, owing to its peculiarly loose character, could only happen under very favourable circumstances, it is obvious that the precious metal contained in it must be abundant. To this conclusion we must arrive, if we consider that during the gradual rise of the land, great denudation of the rocky surfaces of the Island went on continually, in which the gigantic glaciers took a considerable share, and that the rivers becoming larger were able to destroy not only greater masses of rocks, either by undermining their banks and rolling boulders of greater size along, but also by carrying the gold derived from the destruction of those sources farther with them towards the sea. As soon as rivers of any size reached the rather shallow sea, deltas of large dimensions were formed, where the gold was ultimately deposited.

In my Report on the formation of the Canterbury plains, I have shown how such fanlike beds are formed, and how they are liable to be destroyed, or to be covered by fluviatile deposits of more recent origin. That also the marine young miocene or older pliocene beds, immediately underlying the great gold-drift, underwent considerable denudation in many localities, is well exhibited by ranges consisting of these rocks, situated from four to eight miles from the coast line, and 600 to 800 feet high, falling steeply in many places towards the east. They often form true razorback ridges, running parallel with the direction of the central chain. Remains of the great gold-drift are still preserved on the summit of these ridges, thus showing that these older alluvial beds, in many instances assuming the texture of a conglomerate of considerable hardness, covered uniformly the whole zone, and that since their deposition remarkable denudation has there taken place. In this older alluvium the principal goldfields of Westland are situated, of which the Greenstone, Kumara, Waimea, Kanieri, and Ross diggings are the most important. It is especially in those localities that favourable circumstances have existed for a preservation of these deposits. If we examine these beds with care, and follow them a considerable distance, we find that they consist mainly of the alluvial deposits of a large river, coming from the north-east through the present Grey valley, skirting the western foot of the Hohonu range where the Greenstone diggings are situated. This river was joined by several tributaries as far south as the Totara river, their deltaic deposits having considerably raised its bed. The auriferous alluvium, forming a plateau washed by the sea, and reaching to the western foot of the Southern Alps, was afterwards to a considerable extent preserved from destruction by the outrunning ridge between the last-mentioned river and the Mikonui. The lithological character of the boulders, of which this alluvium consists, gives us at once an insight into the nature of the beds from which they are derived. There are associated with them, dioritic sandstones, graywacke, conglomerate and breccia, clay, graywacke, and silicious slates, and diabasic rocks all of which are found near the summits of the Southern Alps, together with the fine-grained, light-coloured schists, characteristic to that formation. But a very considerable part of the alluvium consists of metamorphic and plutonic rocks too numerous to mention, but clearly indicating that the longest course of the river went through rocks of that description, and that the greatest denudation has taken place amongst them. It is evident, therefore, that the boulders, gravel, and sand, of which those alluvial deposits are mostly composed, must contain a great deal of gold, which, however, would not be worth extracting, had not nature herself concentrated the precious metal in numerous localities by sluicing the original accumulations on such a gigantic scale as can only be effected by natural physical forces. This West Coast plateau, besides being intersected by a number of large rivers, is nearly separated from the higher mountains forming the outrunning spurs of the Southern Alps by small streams running generally in a northern or southern direction, before joining the main river. The consequence is, that for a long period it has remained almost intact, till smaller water-courses, derived from the surface drainage, began to form channels, taking their source on the plateau itself, which has the character of a swampy plain covered with manuka scrub and other vegetation peculiar to moist localities. I have already stated that the older alluvium covers the highest young tertiary ranges, which are of an altitude of about 800 feet, and repose unconformably upon the cretaceo-tertiary strata near the Grey. Of these facts I met numerous instances during my various journeys across these goldfields, where sharp razorback ridges have been formed, still bearing a distinct capping of sub-angular boulders on their summit. It is thus evident that when we meet with the original deep channels or leads, where during a long lapse of time the gold could concentrate, a rich harvest may be expected by the gold miners. To such old channels of concentration some of the goldfields of the Greenstone, Waimea, Kanieri, Ross, and the lately discovered Kumara diggings belong, Another class of goldfields owes its existence to the destruction of the old alluvial beds, when the gold disseminated through them has become concentrated in the present water-courses or on those narrow terraces fringing them, which were formed when the river stood at a higher level. The broader and more numerous the terraces, the less are the chances of the existence of rich leads. In illustration I have copied from my note-books a few sections from the Waimea district on plate 5. No. 5 gives a section near Waimea township, where the high banks on both sides consist of somewhat micaceous claymarls belonging to the Kanieri formation, topped by alluvium. The river flows here in two branches with a large island in the centre formed of newer alluvium. The working of this bed, although only two feet thick, has proved very remunerative. Ascending the Waimea Creek we find that its channel gradually narrows, and that a mile above the township it runs in a deep gorge cut into the Kanieri beds (Section No. 6.) The alluvial beds along the river are here about 15 feet wide, reaching only a few feet above the present level of the water; they have proved to be exceedingly rich in gold, whilst the terraces on both sides, about 20 feet above the water, have been remunerative only when several favourable conditions united. The third section (No. 7) is from the lower course of the Kopitea, a small water-course reaching the sea north of the Waimea. The old river bed is here very wide, the tertiary cliffs standing a considerable distance from each other, and the low terraces between them being of considerable breadth. This valley was thoroughly prospected in 1865, but no payable ground could be detected, although everywhere very fine scaly gold in minute quantities was to be obtained. Some of its small tributaries proved, however, of considerable richness. In some instances this auriferous drift occurs either amongst the morainic accumulations, as, for instance, on the Kanieri river, about six miles above the township of that name, or the lower beds containing the precious metal have been preserved by them from destruction. This is well shown in the cliffs at the junction of the Kanieri with the Hokitika river, where old pre-glacier alluvium is immediately covered by silt, over which again an ancient moraine has been accumulating. This alluvium, without doubt brought down in the bed of a large torrent issuing from a glacier then not far distant, often contains a considerable quantity of gold, generally scaly and waterworn. On the Kanieri flat these alluvial deposits have also yielded a considerable quantity of gold. After sinking 30 to 35 feet, where the boulders, having always their edges somewhat rounded, became of large size, a bed of rather incoherent sandstone is reached, forming the bottom of the auriferous deposits. Here amongst blocks of eight feet in diameter coarse gold was found, and often in such large quantities that it was well visible to the naked eye. Nos. 8 and 9, on plate 5, give some details of these interesting sections. It is thus clear that the huge torrent issuing from the glacier not far away, deposited a considerable amount of coarse gold amongst the large boulders; the greatest portion, however, became so finely divided, or was washed to such distances, that at present it is inaccessible to mining operations.

In the descriptive part of this publication I have already alluded to the black sand beachers, who watch the coast principally in such localities where small indentations favour the preservation of magnetic or titaniferous ironsands. These sands always contain a certain amount of fine gold, derived from the enormous destruction of auriferous rocks going on without interruption: first in the rivers draining the Southern Alps, and afterwards along the sea coast. I may here observe that some of the quartz conglomerates belonging to the Grey Coal Measures, on prospecting, have been found to yield a certain amount of gold. If these operations should prove to be of a payable nature, a great deal of additional ground for mining enterprise will no doubt be opened up.

CHAPTER XIV.

(A) Raised Beaches.

Before proceeding to treat of the Great Glacier Period of New Zealand, I consider it convenient to speak first of two other formations, partly deposited before this important era in the geological history of this Island began. The first of these formations consists of a deposit of marine shells, raised about 100 feet above the sea level, near the mouth of the Motanau river, situated in the northern portion of the East Coast. This bed, which I was not able to trace to the south, contains, according to Professor Hutton's researches, only recent shells, with the sole exception of *Mactra rudis*. It is thus of post pliocene (or quarternary) age, but I am unable to say if the deposit in question is of pre-glacier age, no morainic or alluvial deposits, formed during the Great Glacier period being found in its proximity. One fact, however, is certain, namely, that the land in post pliocene times in the northern portion of the province along the east coast stood at a lower level than at the central and southern portions. Thus, whilst the raised beach near Motanau rises about 100 feet above the sea level, gradually getting lower and disappearing near the mouth of the Waipara altogether, in all the more southern portions of the coast, where the country has not been subjected to fluviatile action, only beds of loess or silt are met with near the sea level. They either cover the hill sides for several hundred feet or form downs of large extent.

If such beaches had been formed on the lower slopes of Banks' Peninsula we should certainly have ample evidence as to their existence; however, beyond a small oscillation averaging at most 15 to 20 feet in vertical height, no rising of the ground has there taken place. Everywhere on the lower slopes, where the volcanic rocks are not exposed, thick beds of loess invariably cover them. And even where shells occur as high as six to eight feet above high water mark, it is very possible that they might have been placed there by the agency of an exceptionally high tide. The same may be said of the Timaru plateau, consisting in its upper portion of beds of loess, which can be followed about ten miles inland. Either volcanic rocks or loess beds form bold cliffs along the seashore, where splendid sections are open to our examination, but nowhere is there any sign of raised beaches or littoral deposits, any marine shells found at the foot of the cliffs having been brought there by the tides. Still more to the south, there is ample evidence that the cliffs of loess now situated several miles inland were at one time washed by the sea. Deposits of boulders and sand travelling northwards with the sea currents, and enclosing sometimes to the west of them lagoons and marshes, gradually shut these cliffs off from the ocean. The most careful examination has never revealed the least sign of any raised beaches amongst them.

The following shells have been collected in the bed in question occurring near Motanau:—*Fusus corticatus*, *Fusus dilatatus*, *Fusus plebæus*, *Buccinum costatum*, *Struthiolaria nodulosa*, *Calyptræa maculata*, *Crypta contorta*, *Imperator imperialis*, *Rotella zealandica*, *Polydonta tiarata*, *Gibbula nitida*, *Siphonaria denticulata*, *Ampullacera avellana*, *Dentalium pacificum*, *Mulinia notata*, *Tellina deltoidalis*, *Mactra rudis*, *Mesodesma cuneata*, *Mytilus magellanicus*, *Modiola albicosta*, *Pecten laticostatus*, *Pecten zealandia*, *Terebratella rubicunda*, and *Rhynchonella nigricans*.

(B.) The Loess Formation.

When speaking of Banks' Peninsula, I have already referred to the remarkable slope deposits, by which the middle and lower slopes of this isolated volcanic system are extensively covered. They consist of an unstratified yellowish loam, friable in small pieces, but very tenacious and consistent in large masses. This loam, to which in the future I wish to apply the term loess, consists mostly of argillaceous matter with small grains of felspar, minute fragments of mica and hornblende, with some small per centage of carbonate of lime. It contains also remains of land shells and moa bones, the latter generally surrounded by marly concretions. The eminent German traveller and geologist, Baron von Richthofen, has thrown a great deal of light upon the mode of its formation, through his researches on the nature of loess deposits in China, where they cover districts of enormous extent, and reach a thickness of 500 to 1500 feet, measured in a vertical direction. He has shown in his last publications, that the loess in China could only be of subærial origin deposited by agencies, which at the present time are still at work in forming that rock. Atmospheric currents, together with the growth of grass and other vegetation during an untold number of years, are the principal agencies by which the loess has been deposited. In the first instance, rain-water running down the more or less steep slopes of the country carries with it fine particles, which are partly retained by the grass or amongst its roots, whilst the wind blowing across the land takes up a great amount of fine sediment, afterwards also partly caught and retained by the grass. However, a third and most important agent is to be found in the roots of the plants themselves gradually decaying, and thus raising the ground. There is a peculiar vertical capillary texture observable in the true loess, deriving doubtless its origin from the decaying of the numberless rootlets during many past generations of grasses, to be also noticed in numerous localities in Banks' Peninsula. Thus von Richthofen correctly styles the loess beds a grave-yard of innumerable generations of grasses. Of course I do not wish it to be understood that all beds of the nature of loess have been formed in that way. Many have been deposited in lakes and lagoons, others by rivers overflowing in heavy freshets the low ground along their banks; but the general character and position of the principal loess (or loam) beds in this province prove clearly that they have been formed by the *modus operandi* pointed out by von Richthofen. There is, however, one difference which I wish to point out, and that is the absence in the Canterbury beds of the peculiar small marly nodules so common on the Rhine, the Danube, and China, where they are named loess babies, little loess men, and stone ginger—if we do not consider the large marly concretions surrounding the moa bones their equivalents. The remarkable regular concretions assuming so many curious forms obtained in the gorge of the Rakaia and near the junction of the Acheron, have been formed in argillaceous beds of lacustrine origin. They resemble the so-called Morpholites of Ehrenberg found at Denderah in Egypt, or the Marlekor of Sweden, both having been collected from similar deposits of clay, in which they occur often with a linear arrangement. The land having been gradually raised for several hundred feet after the formation of the Pareora beds, all that portion of the country, not being subject to fluviatile action, now became exposed to physical conditions favourable to the formation of loess. The deposition of these beds where the ground has remained in its virgin state, is going on still without interruption. It may therefore truly be said, that the loess formation, commencing in pliocene times, has not yet come to its termination. Thus during the Great Glacier period of New Zealand, next to be treated—beginning towards the end of the pliocene and ending in the post-pliocene period —during quarternary and recent times, the loess beds have gone on accumulating steadily, so as to reach such a considerable thickness, as we find them amongst other localities on the lower slopes of Banks' Peninsula and on the Timaru plateau. Where they occur in the neighbourhood of the channels formed by the great glacier rivers, they are sometime overlaid and preserved by fluviatile deposits. In some other instances loess beds of smaller extent are interstratified with the latter. Finally towards the end of the Great Glacier period, when the rivers descending from the Southern Alps began to lay their channels lower by cutting into and removing the fluviatile deposits previously formed by them, the remaining portion of the plains became in its turn, and wherever favourable circumstances presented themselves, extensively covered by loess beds formed in the manner previously described. These beds, on close examination, are easily to be distinguished from the deposits of silt or ooze formed during great freshets, when the muddy waters spreading as one broad sheet over the country in the neighbourhood of the river channels, cover it with deposits resembling to the casual observer the former, in their lithological character.

Extent.

I have already alluded to the fact that the volcanic system of Banks' Peninsula having doubtless remained above the sea level since its formation, and being at the same time not subjected to fluviatile denudation possessed most favourable conditions for deposition of loess. In the north of the province the downs rising from the Canterbury plains at the foot of Mount Grey and reaching as far as the Ashley and the Moeraki Downs, are capped by these beds under review. In the Malvern Hills they are also well represented. More to the south

they appear again on the southern banks of the Orari, stretchin
the Timaru plateau. They also cover the *coulées* of volcanic rocks,
which this plateau is formed. They reach to near the summit of Mo
Horrible and gradually thin out, as we follow them from the s
Some of the cliffs, formed entirely of loess are 70 to 80 feet high, a
exhibit throughout the whole section exposed along the sea, a
in railway cuttings, the same characteristic features. South
Timaru they again overlie younger tertiary sedimentary strata a
form undulating downs reaching several miles below the Waihao, aft
which they have generally been destroyed by fluviatile action. A
outlier is situated about 15 miles above the mouth of the Waita
south of Elephant Hill. In some localities they cap the shing
formation of the Canterbury plains to a thickness of ten feet. I
Westland, in some sheltered localities, beds of loess have also bee
noted by me.

Plate II.

THE PROVINCES
of
ANTERBURY and WESTLAND
NEW ZEALAND
during
THE GREAT GLACIER PERIOD
by
JULIUS von HAAST PH.D. F.R.S.

Scale.
1 5 10 20 30 40 Miles.

CHAPTER XV.

THE GREAT GLACIER FORMATION.

General Considerations.

In treating of the Physical Geography of Canterbury, I have already alluded to the Great Glacier period of New Zealand, as having played such a conspicuous part in the latest history of the two provinces under consideration, that its effects are manifest everywhere as soon as the explorer advances towards the mountains. It would be beyond the scope of this Report to give all the details collected by me during the progress of the Geological Survey, on this interesting formation; the more so, as the principal results have already been laid before the public in several publications. Of these, my Reports on the formation of the Canterbury plains, and on the head waters of the river Rakaia —published by authority of the Provincial Government—are the principal ones, and to them I have to refer the reader who wishes to obtain fuller information on the subject. When, in 1862, I published my first account of the drift formation of Canterbury, I had, with the imperfect data before me, come to the conclusion that the Glacier period in New Zealand had begun during a submergence of the country, and that the country had gradually risen during that period to as high a level as it occupies at present. This conclusion was forced upon me by observing a few miles below the gorge of the Rangitata a series of beds resembling the boulder clays of Europe. Some minute pieces of shells were found by myself amongst them, appearing, from a careful examination, to be portions of a *Unio*; others, somewhat larger, and of which one fragment had the markings of *Venus* (Chione) *Stuchburyi* of our seas, were given to me as having been extracted from the same beds, but a few years later I ascertained that they had been found by my informant at the foot of the cliff. They were doubtless obtained from a kitchen midden of a Maori encampment. A further reason for adopting such a theory was, that I met with apparently horizontal terraces and lines, together with erratic blocks high in the mountain ranges, some of them 5200 feet above the level of the sea, whilst other newer deposits, derived from lateral moraines and descending the valleys, had partly obliterated them. The latter I interpreted correctly, whilst the former (as on the other side of the valley the mountains were often not so high as to suggest the explanation that large inland lakes could have existed), I mistook for old sea beaches. However, when these old lines and beaches were examined by me with the spirit level in hand I found that they had either a slight fall, scarcely noticeable to the naked eye, and thus in that case were the banks of ancient river channels, or, in other instances, where the beaches were really horizontal they proved to be the margin of ancient glacier lakes, the waters of which had been dammed up by enormous ice masses crossing tributary valleys. Fine examples of this latter physical feature I observed in the Upper Ashburton and Rangitata plains, and on the right bank of the Tasman river opposite to the junction of the River Jollie. Moreover, if the country had been submerged for several thousand feet, Banks' Peninsula would, even admitting the possible occurrence of a great unequal ratio of subsidence between east and west, have been at one time entirely, or at least for the greater part, below the level of the sea, and in consequence, would have offered a very favourable locality for the stranding of icebergs, and the deposition of their detritus loads. However, after the most minute examination, I was not able to find the least sign of any boulder or pebble of other than local origin; therefore, the conclusion was forced upon me that the origin of these well-defined beds of the Alps was not of glacial or marine, but of glacier or subaerial origin, and all further observations both on the east and west slopes of the Southern Alps have amply confirmed that view.

In fact the results of my researches proved, that already during the beginning of the Pliocene period the country previously submerged to a considerable depth, had begun to rise gradually, and when emerging again above the sea level, appeared in a plateau-like form, but with some depressions which had existed before the tertiary submergence, now partly obliterated. As soon as the country had risen so high as to reach the line of perpetual snow, the accumulation of *névés* began, being the more considerable as glaciers and large rivers had not yet begun their task of ridge making, in contradistinction to the action of waves and currents of the sea, on submerged lands, tending to wear off all eminences, and filling the submarine valleys with the debris. Another important cause for still greater accumulation of enormous *névés* must be assigned to the fact, that when the country had risen to its present level during the Glacier period, the drainage channels were only very imperfectly formed, consequently, a very serious impediment for the flowing off of the glaciers was first to be overcome before the snow-fields could get rid of their annual increase. If we admit that only the same amount of atmospheric precipitation fell in the plateau-like ranges, as at the present time—about 115 inches in Hokitika and 100 inches at the Bealey—and that it took, to say the least, only a few centuries before the drainage system was properly developed, and supply and discharge somewhat balanced, it is evident that the snow-fields must have assumed such enormous proportions that we can scarcely form a conception of their dimensions. When once the channels were formed, or the proper outlet was reached, the *vis a tergo* of the ice mass must have been of inconceivable power. That there was a blocking up of the ice masses in many portions of the Southern Alps is clearly shown by the anastomosing of the glaciers, of which the Rakaia, Ashburton, and Rangitata form notable instances.

Returning to the physical features of the country at the beginning of the Great Glacier period, it is evident that the configuration of the area now forming the Canterbury plains would have been a broad arm or channel of the sea running along cliffs of tertiary rocks from Timaru to Double Corner, and surrounding Banks' Peninsula as an island, whilst at the West Coast the ocean would have reached generally to the very foot of the Southern Alps. As before observed, the waters derived from atmospheric sources had only partly begun during the emergence of the land to open an outlet for themselves from the higher regions, cutting at the same time into the tertiary strata, which filled in favourable localities pre-existing valleys, and skirted the foot of the Alps to an altitude of 4000 feet. Under these circumstances the *névés*—considering the insular and peculiar condition of New Zealand, its principal range or backbone running from S.W. to N.E., therefore lying at right angles to the two principal air-currents the equatorial N.W. and the polar S.E., both bringing moisture with them —soon attained such an enormous extent, even if we do not take the want of efficient drainage channels into account, that the line of perpetual snow descended to a much lower position than it occupies at present, even had the level of the land not been raised to a higher elevation than it now occupies. The natural consequence of such enormous accumulations of snow was the formation of glaciers of gigantic proportions, descending in course of time by the pre-existing or newly formed channels towards the sea, grinding down the rugosities of bottom and sides. The action of the glaciers beginning to lay open the rocks of the higher ranges soon offered sufficient material for morainic accumulations, first on the glaciers themselves, and afterwards at the terminal faces. The scooping action of the ice plough having once begun to eat into the plateau-like ranges, not only in the main course of the glaciers, but also in the lateral valleys, became more extended every day, and furnished more and more material for the formation of huge moraines. In their turn these moraines were destroyed by the great torrents issuing from the glaciers, and ample material was furnished for building up fan-like courses for the former. Boulders, sand, and ooze raised considerably the sea bottom along both coasts of this island, and the low land at the foot of the alpine ranges was more or less enlarged according to the physical features obtaining. It will thus be seen that without invoking the aid of cosmical causes, which might or might not have existed, I attribute the great glaciation of New Zealand to physical causes still now in operation, although on a much smaller scale, and without even assuming that the country had risen to a higher level than it occupies at present.

As I shall show, when treating of the morainic accumulations along the West Coast, it is clear that there at least the land could not have stood at a higher level. We are forced to this conclusion when we examine into the nature of the deposits occurring there. Of course I need scarcely point out that the more plateau-like ranges at the beginning of the Great Glacier period must have been considerably higher than they are at present, without assuming a change of level since then, because the destruction, brought about by the action of the ice masses upon them, must have been enormous. To make my view on the point clearer, I have added an ideal section No. 1 on plate No. 7, delineating the form of these plateau-like ranges, as they must have appeared after their emergence from the sea at the time when they stood nearly at the same level as we find them now. Taking the enormous destruction since then into account, of which this island at every step we take bears ample testimony, I think that, assuming a higher altitude of about 2000 feet for the central range to be not too great an estimate, the mean elevation of the country (an important factor in our calculations) would have been still greater, and from its form, still more favourable for the accumulation of vast snow-fields, by which the limit of the snow line would have been considerably lowered. I think, therefore, that I have made a very moderate estimate in assuming that the snow line was then 1000 feet lower than it is at present, taking all the combining physical conditions into account. When we consider the enormous amount of detrital matter brought down by the rivers into lower regions, the formation of the Canterbury and Westland plains, the huge morainic accumulations all above the sea level, and the still greater amount deposited in the sea, by which the sea bottom round New Zealand must have been considerably raised, it is clear that an almost inconceivable waste must have been going on for a long period of time to shape our Alpine ranges into their present form. I have introduced into this ideal section the actual section, No. 2 of the general plate, in which the existing perpetual snow-fields have been shaded with a darker tint. Considering their small size compared with those of the Great Glacier period, and the fact that still glaciers of such considerable extent can be produced by these so greatly diminished snow-fields, it is evident that the prodigious *névés*, accumulating at that time on the higher plateau-like ranges, must have been able to form glaciers of such gigantic dimensions that we can scarcely form a conception of it. During the geological examination of the two provinces I have become acquainted with the boundaries of the principal glaciers during the period under consideration, and I have thought that their delineation on a map would convey, better than words can do, an idea of the peculiar form and enormous size they once possessed. In the map attached to this Report all the information at my disposal has therefore been given. Many of the glaciers had doubtless still greater dimensions than those marked in the map; but in that case the morainic accumulations near their former terminal face have either been washed away by the sea, or they are now covered with alluvium. The area of the largest glaciers now existing in our Alps has been shown by a darker tint, so that a comparison between both periods can easily be instituted.

Before proceeding to give a short outline of the principal glaciers of the Great Glacier period in New Zealand, it may be useful first to state my reasons why I consider that the relations of land and sea, as far as the level of the latter is concerned, were nearly the same as they are at present. A great deal has been written to show that the period in question occurred either during a partial submergence of the land, or when the latter stood at a higher elevation than it does at present. It would lead me too far were I to notice here in detail the different theories, but all the principal objections in the principal papers on the subject will be fully answered in the following *resumé* of the points at issue.

In alluding to the loess beds deposited on Banks' Peninsula I have already pointed out that they have never been disturbed, and we can therefore safely assume that they would have protected marine strata reposing on the volcanic rocks, had they ever been existing. Moreover, the formation of the Canterbury plains in their upper portion by morainic, and in their middle and lower portion by fluviatile accumulations, is beyond a doubt. Doyne's levels have amply confirmed my views, that the different river systems have formed huge fan-like accumulations. At the same time all the boulders are sub-angular, and all the sand and ooze of fluviatile origin, with the exception of some beds belonging to the loess formation. Where, at the lowest portion of the plains on the northern banks of the Rakaia and near Lake Ellesmere, and in a few other localities to the north of Banks' Peninsula, a small fringe of marine shingle has been deposited only a few feet above the present sea level, these beds can easily be recognised at a glance. The broad flattened form of the stones distinguishes them at once from the sub-angular fluviatile shingle or boulder deposits near them.

In the anniversary address of 1874, delivered as President of the Philosophical Institute of Canterbury on March 5th, and printed in Vol. VI. of the Transactions of the New Zealand Institute, I have answered the arguments of Captain Hutton, the former chief exponent of the submergence theory, who, in his report on the Geology of Otago seems now to have abandoned it altogether, and adopted the theory of greater elevation. However, in his Report on the North-eastern Districts of the South Island (Geological Survey Report, 1874) he has stated as his own observation, that there exists between Mount Hutt and Fighting Hill, at the narrowest part of the middle Rakaia valley, a shingle bar, according to him, exactly resembling a bar across a sound or harbour of the sea. I may, therefore, be allowed to offer a section of the locality in question on plate No. 7 (No. 3), giving the details, so as not to leave on the reader of that report any wrong impression. In several previous reports I have shown that after the retreat of the great Rakaia glacier a large lake was formed behind the rocks and morainic accumulations, through which in time a channel was cut; gradually this lake was filled up by glacier mud (silt), and by shingle and boulders brought down by the rivers emptying themselves into that lake, the latter generally covering the deposits of silt. A careful examination of these shingle or boulder beds—of which some small layers are flattened by wave action of the ancient lake, the greatest portion, however, having the usual sub-angular form—proves beyond a doubt that all the rocks occurring at the head waters of the Rakaia are represented, but no others. They are, without exception, of sedimentary origin, belonging either to the Waihao or Mount Torlesse formations. Were they brought into their present position by marine action, we should find an assemblage of rocks, such as we meet at present on the shingle accumulations between Lake Ellesmere and the sea; in which, besides the sedimentary rocks of which the Southern Alps are built up, the quartziferous porphyries and melaphyres of the Rakaia, Ashburton, and Hinds, the felsitic porphyries of the Rangitata, the dolerite of the Timaru plateau would be represented, together with all the peculiar semi-metamorphic rocks found near Mount Cook and the Waihao country brought down by the Waitaki, and taken north by the currents and swell of the ocean, till they find a resting place near the northern slopes of Banks' Peninsula. We also meet near the slopes of Fighting Hill, and on a much larger scale on those of Mount Hutt, with the remnants of ancient moraines, between which several terraced river beds occur.

In proceeding to examine the evidence offered us by the extensive and remarkable morainic accumulations at the West Coast, our task has been much facilitated by the destruction they have undergone from marine action, so that we can study without difficulty their origin and mode of formation. It is easy to trace each of these huge post-pliocene glaciers, its frontal, lateral, and central moraines deposited during the retreat to its present position, to examine the material of which they were built up, and thus to form a clear conception of the *modus operandi* of their deposition, and their partial destruction afterwards, by rivers on the one hand, and the sea on the other. It will be observed that in the map in illustration of the Great Glacier period, I have drawn the principal western glaciers as having had a much greater extension than the morainic accumulations that are still preserved, and form such conspicuous cliffs along the West Coast. The reasons for doing so are the existence of enormous erratic blocks standing above the sea in front of the moraines, and the breaking of the surf in many localities far outside the coastline, so as to show that the morainic accumulations continue outwards for a considerable distance below the level of the sea. Examining in that district the intervening spaces between the ancient moraines, we find that they consist generally of level swampy or marshy ground. This at once suggests that when the glaciers advanced far beyond the foot of the ranges they must have extended either upon low level ground, or actually must have entered the sea for a long distance; the latter assumption gains in strength by observing that in front of the swampy ground, between the morainic accumulations, a shingle or sandspit has evidently been thrown across, the material having travelled, as it does at the present time, in a northward direction. Thus the sea appears to have once entered far between the glaciers and the morainic deposits flanking them, being cut off in course of time in the same manner as Lake Ellesmere during its greatest extension was separated from the sea by similar deposits of shingle and sand, both travelling in a north and south direction towards what is now Banks' Peninsula. The lagoons thus formed between the ancient glaciers or their deposits were in course of time filled either by decaying vegetation and silt, or near the slopes of the Alps by the deposits of water-courses descending from the secondary ridges. When standing on some prominent elevation amongst the West Coast moraines, and looking over these low swampy forest covered plains, dotted over in many localities with numerous ponds, it is easy to restore the picture as it must have appeared during the Great Glacier period.

Let us now examine if we have at present in the Arctic or even the more temperate regions, any analagous glaciers of the breadth of several miles, advancing 12 to 15 miles into the sea, till their frontal portion is washed away. I have already alluded to Darwin's researches in South America, showing that in latitudes corresponding to the northern end of Stewart's Island or to the latitude of Central France, glaciers of considerable size enter into the sea, their terminal face being ultimately washed away and carried along as huge icebergs; and as the mountains where their *névés* are situated are not nearly so high as the Southern Alps, similar conditions to those prevailing in New Zealand during the Great Glacier period must still reign in these latitudes.

Turning towards the Arctic regions, we find that amongst others the Iceblink Glacier on the shores of Greenland advances into the sea, forming a promontory 13 miles in length. A submarine bank formed of morainic accumulations in the shape of a semicircle lies a few hundred yards in front of it; only occasionally blocks of rocks or debris in larger masses are scattered over the surface of this remarkable glacier. Its thickness is estimated at 5000 feet, and thus the ice grinding upon its bed with prodigious force must form silt in enormous quantities. Judging from the observations made upon the mountains in the Polar regions, also during our Great Glacier period, by far the greatest portion of our Southern Alps was doubtless covered with perpetual snow, so that the New Zealand Glacier period, in order that such an immense quantity of morainic matter could be transported, must have been of very long duration. Taking all these facts into consideration, there is nothing startling in the assumption, that in the height of that period in New Zealand, the West Coast glaciers advanced the same distance into the sea as the Iceblink Glacier does at the present time; an assumption forced upon us when we consider the character of the deposits between the morainic accumulations forming the coast line. Thus, whilst the nature of the beds formed during the Great Glacier period along the east base of the Alps, where they are not destroyed or covered by fluviatile deposits, clearly indicates that they could not have been formed during a submergence of the land, the western morainic accumulations and the littoral beds between them go far to prove that no considerable rising of the land could have taken place; in fact, it appears that the same relations of land and sea obtained then, as we find them at present. I may here observe that as far back as 1867, in a paper read before the Geological Society of London, I proposed that the Ice age of New Zealand should be named the Great Glacier epoch, whilst in a former paper read before the same Society on January 15, 1865, I brought forward many reasons to show that the climatic conditions of that period must have been nearly the same as they are now, a conclusion confirmed by Captain Hutton, who from the examination of a number of pleistocene and pliocene fossil shells, drew the inference that the climate during those times was not colder than it is now. (See Captain Hutton's Paper "On the Cause of the Former Greater Extension of the Glaciers in New Zealand," Transactions N.Z. Institute, Vol. VIII, page 383 and *sequ.*) He has also followed my example and adopted the name of Glacier Period for the era during which the New Zealand glaciers reached their greatest dimensions.

In a paper by Count Gaston de Saporta, in the Compte rendu of the Seventh Session of the "Congres International d'Anthropologie et d'Archéologie Préhistoriques," Stockholm, 1876, Vol. I, some further interesting conclusions on the same subject are offered to us. The learned author in examining a series of fossil plants collected in quarternary tufas at Moret (Seine et Loire), France, of which several —such as the *Ficus carica*—now only grow in the south of France, comes also to the conclusion that during the Glacial period of Europe (or, as he now proposes to call it more correctly, the Glacier Period of Europe) an equable temperate but moist climate was reigning, that this period continued during a long space of time, and that in the valleys, on the slopes of the Alps and of other mountain chains, there was ample room for the existence of a rich animal and vegetable life. Count de Saporta does not assume that the level of the country stood at a higher level than it does at present, but believes that the elevation of the mountain chains from the tertiary seas, together with greater humidity of the temperature, were the principal causes of the extension of the glaciers. He further concludes, that this extension took place before the quarternary period, and that probably already during pliocene times the phenomenon reached its apogee. Consequently the views of this eminent palæontologist are quite in accordance with those advocated by me for nearly fifteen years at the Antipodes, and thus similar simple but effectual causes are assigned on both hemispheres to have produced the remarkable extension of snow-fields and glaciers, of which a delineation has been attempted for Canterbury and Westland in the map attached to this publication. As already pointed out, we find dinornithic remains not only in the silt and loess beds, but they are also met with in the alluvial deposits formed by the large torrents once issuing from the gigantic glaciers, and even in the morainic accumulations themselves. There is thus ample evidence that the moa existed and flourished during the whole of the Great Glacier period. Now if we examine the map illustrating this chapter, and remember that by far the greatest portion of the Canterbury plains, together with smaller plains of similar origin in other portions of this Island, did not exist, it is difficult to conceive how these large birds could have been flourishing on such comparatively small space of ground—bounded on all sides by vast snow-fields, glaciers, and great torrents. It has been shown by me, and as I think so far conclusively, that there has been neither a great rise or fall of the land during the Great Glacier period, and there remains therefore, if we wish to admit a greater extension of the land in that era, only one other possibility, namely, that from some cosmical or physical causes the level of the sea might have stood at a lower level than it stands at present. We have been always accustomed to hear it stated as an axiom that whilst the land sinks or rises, the level of the sea is always the same. It will thus appear heterodox to believe in the level of the sea undergoing, according to changes in the crust of the earth or in the configuration of the land (not to take cosmical agencies into account), more or less considerable oscillations. However, I am convinced that future researches will tend to prove that such changes have repeatedly taken place, and that the character and distribution of plants and animals have been greatly governed by them. Mr. A. R. Wallace, in his valuable work on the Geographical Distribution of animals, when speaking on the same subject quotes the views of Mr. T. Belt,* and gives afterwards his own views on the subject. I can do no better than quote his own words.

"One of the most recent, and not the least able, of the writers on this question (Mr. Belt) shows strong reasons for adopting the view that the Ice period was simultaneous in both hemispheres; and he calculates that the vast amount of water abstracted from the ocean and locked up in mountains of ice around the two poles, would lower the general level of the ocean about 2000 feet. This would be equivalent to a general elevation of the land to the same amount, and would thus tend to intensify the cold; and this elevation may enable us to understand the recent discoveries of signs of glacial action at moderate elevations in Central America and Brazil, far within the tropics. At the same time, the weight of ice piled up in the north

---

* Since this chapter was written I have had the advantage of perusing a paper by the same author, "The Glacial Period in the Southern Hemisphere," in the "Quarterly Journal of Science," July, 1877, in which Mr. Belt amplifies his views on the same subject, making special reference to the Canterbury plains. In the notes on the formation of the plains, added to this chapter, I have explained once more fully that "the sheets of gravel do not wrap round the hills, and are not spread right across the water-sheds between the different river systems," but that we have a series of large fans of fluviatile deposits before us, according to the bulk of the former glaciers, of more or less size, and that between these fans smaller streams, not being of glacier origin, flow. Doyne's levels have confirmed this conclusively. Of course the more we advance towards the coast the more these fans become shallow, but they never lose their character, and the numerous narrow and deep channels higher up the plains by which the latter are furrowed, become gradually broader and shallower, showing that the waters flowing now less rapidly and having more room to expand, spread over a larger area. Some of the sections in my first paper on the formation of the Canterbury plains may have helped to suggest a wrong interpretation of the points at issue, as owing to insufficient altitude observations, and the want of corresponding readings near the sea shore, the true form of the fluviatile fans in question was only imperfectly given.

would cause the land surface to sink there, perhaps unequally, according to the varying nature of the interior crust of the earth; and since the weight has been removed the land would rise again, still somewhat irregularly; and thus the phenomena of raised beds of arctic shells in temperate latitudes are explained."

"Now it is evident, that the phenomena we have been considering—of the recent changes of the mammalian fauna in Europe, North America, South temperate America, and the highlands of Brazil—are such as might be explained by the most extreme views as to the extent and vastness of the ice-sheet; and especially as to its simultaneous occurrence in the Northern and Southern Hemispheres, and where two such completely independent sets of facts are found to combine harmoniously, and supplement each other on a particular hypothesis, the evidence in favour of the hypothesis is greatly strengthened. An objection that will occur to zoologists may here be noticed. If the Glacial epoch extended over so much of the temperate and even parts of the tropical zone, and led to the extinction of so many forms of life even within the tropics, how is it that so much of the purely tropical fauna of South America has maintained itself, and that there are still such a vast number of forms, both of mammalia, birds, reptiles, and insects, that seem organised for an exclusive existence in tropical forests? Now, Mr. Belt's theory of the subsidence of the ocean to the extent of about 2,000 feet supplies an answer to this objection; for we should thus have a tract of lowland of an average width of some hundreds of miles added to the whole east coast of Central and South America. This tract would, no doubt, become covered with forests as it was slowly formed, would enjoy a perfectly tropical climate, and would thus afford ample area for the continued existence and development of the typical South American fauna, even had glaciers descended in places so low as what is now the level of the sea, which, however, there is no reason to believe they ever did. It is probable, too, that this low tract, which all round the Gulf of Mexico would be of considerable width, offered that passage for intermigration between North and South America, which led to the sudden appearance, in the former country in post-pliocene times, of the huge megatheroids from the latter—a migration which took place in opposite directions, as we shall presently show."

Without giving altogether my assent to such theory, it nevertheless will be of some use to apply it to New Zealand, and to see what the effects of the lowering of the sea level for 2000 feet would have been.

In the first instance the plateau-like ranges would rise still 2000 feet higher above the sea level than assumed by me, and consequently the size of the snow-fields would not only become of still larger extent, but for this reason would descend to a still lower position. At the foot of these high ranges a plain of considerable extent, sloping gently downwards to the sea, would surround the three islands and unite them into one, Cook's and Foveaux Straits forming both broad valleys. In these plains a luxurious vegetation would spring up, offering ample nourishment for a great number of birds, of which the extinct *Dinornithidæ* were forming the most conspicuous part During such physical aspect of the land these large birds would have found an almost unrestricted passage from one part of the united New Zealand to the other. Moreover, peculiar climatological conditions then reigning would soon slightly differentiate the species, to become still more decided when through the rising of the ocean the valley of Cook's Straits would again become an arm of the sea. Such a submergence would, if the theory in question is correct, have occurred at different times, judging from the fact disclosed to us, that the glaciers repeatedly advanced and retreated. Consequently, along the East Coast the glacier torrents would build up their great shingle fans, gradually decrease in velocity and flow at last as broad rivers through rich gently sloping lands for a considerable distance. A different state of things would obtain at the West Coast; here the retreat of the sea would also lay dry a belt of slightly sloping level land along the base of the Southern Alps, and over it the large glaciers would advance fifteen to twenty miles, throwing up their lateral moraines on both sides. The ocean rising again, so as to assume its former level, the waters would of course advance between the morainic accumulations; the same process as already described would then take place. Shingle and sand-bars with lagoons, often of considerable extent, behind them, would be formed. These lagoons would gradually be filled up with decaying vegetation and the accumulations of fluviatile character brought down from the slopes of the mountains forming their eastern boundary. Although, as before observed, I am not as yet in a position to pronounce for or against Mr. Belt's theory, I have nevertheless thought it only right to show that, so far, all the physical conditions of New Zealand during the Great Glacier period, and the abundant animal life then existing, could be explained by it, and I shall leave it to future days to adopt or reject this ingenious theory, when still more facts have been accumulated and more light thrown upon this interesting period of the Earth's history.

Extent and Characteristics of the Glaciers.—Eastern Slopes of the Southern Alps.

It is natural that the highest portion of the Southern Alps, where the most considerable glaciers in New Zealand are still found, must in the Great Glacier period have given birth to the largest ice-streams, of the enormous size of which we can scarcely form a true conception. Although in the map in illustration of this chapter the outlines of their former size are given, I think that an enumeration of the characteristic features of some of these glaciers, as to size, form, dimensions, and remnants of their morainic accumulations will be of some interest to the reader.

The Waitaki Glacier.

The lowest portions of morainic deposits belonging to this glacier, which I was able to trace, are situated on the left bank of the Waitaki, six miles below the junction of the Hakataramea, rising about 600 feet above the valley. From here to the sea the ranges bordering the Waitaki are mostly all capped by alluvium, showing that at one time the bed of that river has been lying at least 600 feet above its present level. This is very conspicuous on the ranges between the lower Waitaki and Waihao. Calculating from the position of the present *névé*-fields of the Takapo, lying about ten miles more distant than those of the Tasman glacier, the total length of this post-pliocene glacier was at least 112 miles.*

During the greatest extension of the glaciers under review, four principal and some minor branches came down by the valleys of the Takapo, Pukaki, Ohau, and the Ahuriri, which uniting in the Mackenzie plains formed a trunk glacier of a breadth of about thirty miles. As the accumulating ice masses could not be discharged by the valley of the Waitaki alone, several outlets were formed in the depressions between the mountain range on the eastern side of that plain. These depressions are now known as the Burke's, Mackenzie, and Hakataramea Passes. Of these secondary branches the one

---

* When publishing in 1865 some notes on this and a number of other post-pliocene glaciers, I could only give the results of my examinations up to that date. Since then, further and more detailed researches have shown the existence of morainic accumulations far in advance of the limits formerly assigned to them.

descending by the last mentioned pass was the most important, being six to eight miles broad, and uniting again with the main glacier about six miles above its terminal face. A division or forking of this Hakataramea branch took place where now the upper waters of the Waihao are situated. The Burke's Pass branch was also of considerable size. It received a large addition from the Fox Peak range, coming down by the valley where now the Opuha plains are situated. A broad moraine was thrown across the valley of the Opihi, and a river—with which some miles lower down the Mackenzie glacier outlet united—issuing here from the terminal face formed high and broad alluvial beds. These can be followed for nearly thirty miles in a southern direction as far as the Otaio. The great Waitaki glacier must have had in its middle portion, judging from the terraces and *roches moutonnées* situated here, a thickness of about 5000 feet. On some of these peculiar isolated ice-worn ranges in the Mackenzie plains *blocs perchés* are not uncommon. After a time this glacier retreated and then maintained for a considerable period about the same position. This phase may best be described as the Lake period, because during it the rocks forming the bed of the glacier were either excavated so as to form a true rock basin, or the terminal and lateral moraines were heaped up so high, that when the glacier retreated, the outlet flowed into the hollow thus made, forming a lake. The retention of the water between the walls was doubtless assisted by the enormous amount of silt, brought down below the glacier from higher regions, by which the morainic accumulations were made impervious. To this important epoch Lake Takapo, Pukaki, Ohau, and the large swampy region in a similar position in the Ahuriri valley, owe their existence. The sections Nos. 4, 5, and 6 on plate 7 will give the characteristic features of the morainic and other deposits surrounding these lakes. The southern portion of Lake Pukaki lies entirely in the plains. The morainic accumulations rise to 250 feet above the level of the lake, whilst even in its northern or upper portion where the slopes of the Ben Ohau range, either cut into by glacier shelves or covered by lateral moraines, form its western boundary, the eastern is still formed by the moraines. There is a distinct series of old lacustrine beaches along the shores of Lake Pukaki, rising about 200 feet, one above the other, clearly indicating that after the retreat of the glacier the waters forming the lake stood at a much higher level. There were several outlets, which were abandoned when the central one cut its channel deeper into the frontal moraine.

They now form natural roads to reach the shores of the lake. The frontal moraines of Lake Pukaki are about three miles broad, forming a series of walls enclosing each other. As we advance from the lake towards their outer edge they gradually get lower, till at last only here and there a chain of small hillocks, the upper portion of the last visible moraine, appears above the alluvium. The same is the case with the lateral moraines, showing a similar arrangement. Already abreast of the central portion of Lake Takapo high ranges rise on both sides, on the slopes of which the glacier has either cut deep shelves or thrown its lateral moraines against them, now rising in steps nearly 2000 feet above the level of the lake. Higher up in the valleys of the Tasman and Godley rivers these signs of former glacier power can be traced to an altitude of nearly 4000 feet on the mountain sides, accompanied by deposits of former glacier lakes, having stood at a high level. All these phenomena present us with clear evidence of the enormous size and power of the mighty ice-streams once descending here to lower regions. Only in a few localities are there faint traces of frontal moraines having been preserved in both these main valleys. They are more conspicuous in the two main valleys forming the Hopkins river, the principal feeder of Lake Ohau, as well as in the upper Ahuriri.

The Rakaia Glacier.

The glacier next in size has doubtless been the Rakaia glacier, having been at least of a length of 58 miles. The farthest point down the Canterbury plains on which morainic accumulations are visible is the so-called Woolshed Hill, seven to eight miles below the Rakaia Gorge. This hill rises about 100 feet above the plains, it has a triangular shape, and consists of shingle and sand, from which in many places angular blocks of sandstone, felstone and slates appear above the surface. If we consider that the gigantic torrential rivers issuing from the post-pliocene glaciers had the power of destroying easily beds of such incoherent nature as the morainic accumulations, which barred their passage, it is natural that only in very favourable cases such deposits could have been preserved. It is thus evident that the lowest points to which the post-pliocene glaciers reached are not always traceable, but the occurrence of such isolated beds as the Woolshed Hill so far away from the principal morainic accumulations shows us that we can scarcely fix the limits to which the huge ice-streams of the

New Zealand Glacier period reached. These Woolshed Hill beds having, doubtless, been formed by the Great Rakaia glacier, it is evident that the latter must have had truly enormons dimensions at some time. We can conclude from the characteristic features of the valley of the Rakaia, that during the extension of the glacier it was filled with ice from side to side, and that it was hollowed or scooped out in a very striking manner, principally above those localities where beds of peculiar hardness crossed it. The occurrence of these very hard rocks is the principal cause of the formation of Lake Coleridge. Where these beds occur we find that their remaining portions stand out in very bold characteristic forms, as *roches moutonnées*, having given rise to such names as Gibraltar, Sebastopol, &c. (See section No. 2 on plate 7.)

The main glacier coming down by the valley of the Rakaia, of which we can trace the limits with certainty, reached into the plains a few miles below Rockwood, and crossing them in a semicircular band abutted against the south-eastern slopes of Mount Hutt. It is also evident that the hard melaphyres, porphyries, and porphyry conglomerates stretching across the valley where at present the gorge of the Rakaia is situated, formed a great barrier to the advance of the glacier, until these rocks were sufficiently ground down or removed to allow the glacier to advance beyond. There is also evidence that when the post-pliocene glacier retreated, a large lake was for a long time formed above the gorge, which in course of time was filled up with glacier mud (silt), and at the same time with shingle deposits brought down by the glaciers and rivers. These shingle-beds cover invariably the beds of silt. The formation of the gorge is of still younger origin. Morainic shelves occur also at an altitude of 500 to 600 feet on the northern and 200 to 300 feet on the southern side of the Snowy Peak range, thus showing the height of the glacier above the valley and its general slope. The great Rakaia glacier, besides its principal outlet by the main valley, had another branch descending to the plains by the valley of the Selwyn, having probably had at an early period of its existence very large dimensions before the barrier across the main valley, formed by the porphyritic rocks, had been scooped out sufficiently by that great ice-stream. Another important branch of the Rakaia glacier passed along the broad opening now occupied by the Cameron river, uniting with the glaciers from the Cameron and Ashburton valleys, and further on with a branch of the great Rangitata glacier. The united ice-stream descended the valley of the Ashburton, and reached some distance beyond the front ranges, where a few portions of the frontal moraines are still preserved about two miles from the eastern foot of the limestone hills near Mount Somers; total length about sixty miles. In the second period of its existence, when the large lake above the gorge of the Rakaia was formed, this branch after its retreat produced in its turn Lake Heron. The frontal moraines on the southern side of that lake are still well preserved, and the bed of its former outlet towards the Ashburton is clearly defined. The present outlet of the lake, however, uniting with the River Cameron, has now a reverse flow to the upper Rakaia.

In the river bed of all the Rakaia branches, remnants of morainic accumulations mostly of a frontal character are met with, showing that the glaciers of which the trunk glacier was formed when retreating remained either stationary for some time, or what is still more probable, may be taken as the boundary of the new advance of the glaciers, after a temporary retreat to higher regions. Although the space at my command will scarcely allow me to go into details, I think that I should give here one striking example, proving that in some cases the latter theory is supported by most remarkable facts. The Rakaia, opposite Fighting Hill, makes a sharp bend towards the south before it enters the gorge proper. Here the banks consist first of 70 to 80 feet of lacustrine deposits (silt), above which about 400 feet of river shingle repose. The whole section shows most instructively how the river slowly advancing with its delta, has gradually filled up the large lake once existing here after the retreat of the glacier. At this bend begins a remarkable channel running with an average breadth of 200 feet for about three miles in a straight line. After ascending four well marked river terraces in its course, it abuts against a small *roche moutonnée* of quartziferous porphyry standing in the centre of the valley, not far from the ferry. It was doubtless formed after the river channel A (section No. 7 on plate No. 7) had been excavated by the Rakaia, but before any lower ones had been hollowed out; because if we continue its course in a N.W. direction, it is parallel with the course of the river now flowing here, 500 to 600 feet below it. It is evident that when this small glacier advanced in such a striking manner, the great Rakaia lake had not only entirely been filled up by river deposits, but the Rakaia had already begun to excavate its bed into these deposits, by which four well defined terraces had been produced.

This remarkable channel is so striking a feature in the country that it had not escaped the notice of the earliest settlers, by whom it was generally known as "The Railroad," and a number of theories were propounded to account for its formation. One of them, believing that a set of faults was running here parallel to each other, was sure that there was a coal-field below; another, by no means wanting in intelligence, was certain that it was made by the hand of man, as an artificial cover for an army. It was also described to me as a river-bed, partly uplifted or sunk across its course, and only after repeated careful examination was I able to assign to it a purely glacier origin. This glacier channel, as before observed, ascends four river terraces, crossing them diagonally as they gradually approach the lower gorge. Here, where the river has cut through a bar of quartziferous porphyry, they all unite, the river having cut almost straight down for six to 700 feet, leaving nearly perpendicular walls on both sides. If I can trust to some Aneroid observations made at both extremities, the frontal moraine lies about 20 feet above the starting point on the banks of the river. Here, not far from the starting point, a small but well marked frontal moraine crosses the glacier channel (section No. 8). At (B) it crosses a deep channel, in which a branch of the Rakaia was once flowing; the lateral remains are here very low, being scarcely five feet above the floor. The glacier then ascended the slope of the first terrace, having about 30deg. inclination, and possessing an altitude of about 20 feet. On this slope the lateral moraine is well developed on both sides. From the summit of the terrace the glacier channel continues in the same direction, with well defined banks on both sides, rising about 18 feet above its bed, but standing only six to eight feet above the fluviatile deposits of which the terrace is formed. The glacier has thus been able to lay its bed to that extent lower—some 10 to 12 feet. After half a mile, another small frontal moraine crosses the channel at (C). Having followed the first terrace for about a mile, the second terrace, about 20 feet high, is reached, with a small lagoon at its foot (D). After ascending also this terrace the lateral moraine gradually gets lower, now being only ten feet high, and another small terminal moraine (E) has been thrown down. Two more terraces are afterwards ascended, 10 to 12 feet high. Having reached the highest level of the old river bed, the channel then ascends gradually towards the *roche moutonnée* lying in front of it. The ground assumes now a more hummocky surface, and the lateral moraines are less marked. Numerous erratic blocks lie about, and several small channels for the outlet of water are well defined. At two spots only, before the glacier channel reached the highest level of the valley, small outlets have been in existence. They are, however, very faint, and the lateral moraine has not been removed. It appears, therefore, that the water melting during the advance of the ice, has been leaking through the incoherent shingle bed forming the floor of the glacier, otherwise it would have certainly cut through the lateral moraine, consisting all along of silt only, with rarely any boulder or erratic blocks amongst it. The glacier channel is always stony, the stones being either rounded or sub-angular, but in several instances quite angular. Near the termination of the glacier channel none of the blocks have lost their sharp angles. In a word, the whole forms one of the most interesting geological phenomena I ever met with—a glacier channel nearly three miles long and only about two hundred feet broad, passing straight over a plain, ascending four terraces together about 80 feet high, without furrowing to any depth the alluvial shingle beds of the broad valley, and being bounded at the same time by banks of silt. It is evident that a very large quantity of ice must have existed higher up the valley from which this narrow strip received the necessary *vis a tergo* to overcome all obstacles in its way, the larger glacier after the separation of this branch following without doubt the broad river bed where now the gorge of the Rakaia is situated. (See No. 9, ground plan of Railroad glacier on Plate No. 7.)

The Rangitata Glacier.

This glacier was also of considerable size, having been about 48 miles long. It reached during its greatest extension several miles into the Canterbury plains, crossing the front ranges—before the present lower gorge was cut—by a saddle to the south of it. After its retreat to higher regions a lake was formed behind the front range. This lake in course of time was partly filled up by alluvium, partly drained by the formation of the lower gorge. Morainic accumulations, numerous glacier shelves, terraces and *roches moutonnées* in the middle Rangitata, bear ample testimony to the wide-spread glaciation of the country during that remarkable period. The Rangitata glacier was anastomosing with the united Rakaia-Ashburton glacier by the large opening in which now Lakes Tripp and Acland are situated, receiving afterwards again a branch of the latter by Trinity Valley. After the partial retreat, it continued to send a branch into the former mentioned broad opening, where several frontal moraines round Lake

Tripp are still well preserved. The arrangement of the beds, owing their deposition to glacier action can be well studied on the banks of the lower Potts, a tributary of the Rangitata, crossing diagonally the Lake Tripp valley, and of which section No. 11, plate 7, gives the details. Several erratic blocks lie on the surface, below which bed No. 1 appears. It is about 60 feet thick, and consists of morainic accumulations, containing a large number of enormous angular blocks of rock imbedded in yellowish silt. It is separated by a sharply defined line from No. 2 grey moraine, also full of large angular blocks in which the interstices are filled up by coarse greyish detritus, thickness about 15 feet; No. 3, yellow moraine, also replete with huge blocks, of which, however, a number have rounded angles, thickness about 90 feet; No. 4, very hard fissile, yellow and white fine glacier silt, having a horizontal position, some of the layers being as thin as a sheet of paper. This bed has doubtless been deposited in a glacier lake. It changes towards its upper portion gradually into sand and fine gravel; towards the bottom it is however sharply defined, thickness about 40 feet. It reposes on No. 5 grey moraine, consisting of a great number of mostly large and perfectly angular blocks, thickness about 100 feet. Below this last deposit a bed of a thickness of about 80 feet is visible, consisting of till, sand and silt, alternating repeatedly with each other. The character of the beds for the lowest 100 feet could not be ascertained, as they are covered by a talus of debris from the deposits above. It is thus clear that at different times various conditions prevailed here. The upper deposits are either lateral moraines of the Potts glacier branch once joining the Rangitata glacier, or they belong to the latter when it divided here in two branches, of which one travelled towards the Ashburton opening. No. 3 was probably a ground moraine. The peculiar conditions of this assembly of beds go far to prove that glaciers when advancing again after their retreat, do not always clear out their former channels of morainic deposits accumulated therein, and that even under favourable circumstances the finest glacier silt, when protected by moraines of comparatively inconsiderable thickness, is so thoroughly protected that no change in its stratification can take place.

The Waimakariri Glacier.

This glacier in the height of the Great Glacier period obtained also a considerable size. It was at least 54 miles long, reaching as far as the middle portion of the Malvern Hills, where on the western slopes of Abner's Head large morainic accumulations have been preserved. There is also ample evidence to show that during its greatest extension the Rakaia and Waimakariri glaciers joined by the pass, on the summit of which Lake Lyndon is now situated. In the Historical Notes of the survey I have already alluded to some of the characteristic features, as showing such abundant signs of the effects produced by the enormous glaciers of the district, so that I need not dwell further upon it.

The Clutha Glacier.

Looking at the size and form of Lakes Wanaka and Hawea, both surrounded by morainic circumvallations of no mean size, and considering the physical features of the Clutha valley, ample evidence is offered to us that an enormous glacier, to the former termination of which my travels have not extended, must have descended by this valley. It is however evident that this glacier, one of the largest in New Zealand, reached much beyond the mouth of the Lindis, and received a further accession by the Kawarau Valley from the Lake Wakatipu glacier, the main branch of which descended by the valley of the Mataura. The length of even that part of the Clutha glacier from its beginning at the head of the Lake Hawea valley to the junction of the Lindis is 68 miles. The immense morainic accumulations near the sea-coast, north of the mouth of the Taieri river (Otago), described by Professor Hutton in his "Report on the Geology of Otago," page 62, might be the frontal moraine of this glacier.

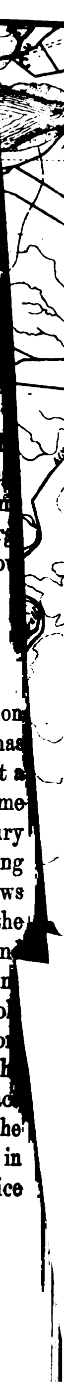
(B) Western Slopes of Southern Alps.

In several portions of this Report I have already given some account of the most striking characteristic features displayed by the deposits of the Ice-age along the western slopes of the central chain. Whilst the remains of the most northerly moraines in Westland belonging to the old Taramakau and Arahura glaciers, consisting of a large circumvallation around the lower end of Lake Brunner (227 feet), and a smaller one in the valley of the Arahura, do not reach the sea within twelve miles, the next ones belonging to the great Hokitika glacier are separated from the sea-shore by a small strip of low land of recent littoral origin only. The next large moraine belonging to the Mikonui-Waitaha glacier forms already a very conspicuous object in the landscape, rising as Bold Head, a remarkable headland, from the coastline. It was doubtless the frontal moraine of a huge glacier descending so far towards or into the sea, and its structure can well be studied by passing along it. Rising in the centre to about 250 feet it consists principally of till, with numberless blocks of all sizes and shapes, mostly angular, imbedded in it. These blocks are derived from the Mount Torlesse and Waihao formations, typical metamorphic or igneous rocks being of rare occurrence. Some of the imbedded rocks are of enormous size, often larger than the celebrated Pierre-à-bot in the Jura. One of the most striking examples is the large block lying in front of the centre of this Bold Head moraine, to which the latter owes, without doubt, in some degree its preservation. This block, consisting of contorted clay-slate with layers of quartz, is from 30 to 40 feet in diameter, and covered on its summit with a luxuriant vegetation. In the upper portion of the confused mass of morainic accumulations are two large deposits of fine glacier silt, in which also angular blocks of various sizes are imbedded. However, what gives an additional interest to Bold Head, is the existence of an alluvial deposit 30 to 40 feet thick, having a considerable slope to the south, and separating the morainic beds into two distinct portions. It contains a quantity of subangular shingle and gravel, its greatest portion being derived from the metamorphic and igneous rocks at the western base of the Southern Alps, a clear proof that at least one great oscillation during the Glacier period took place, when these oldest rocks became exposed in their turn to fluviatile action. Bold Head has also a considerable slope towards the East. It then joins a ridge forming its eastern continuation, and rises again, gradually and steadily, till it abuts against the western foot of the Alps.

Having passed along a long sandy beach of several miles in length, we come to the morainic accumulations of the Wanganui glacier, reaching for a distance of more than ten miles from the Pukuaro cliff north, to the northern banks of the Puerua River south. These deposits consist of the united moraines of the Wanganui and Puerua channels, both draining a considerable portion of the Southern Alps. It is a wild piece of coastline, of which the photo-lithographic view of the Wanganui Bluff, with Mount Oné-Oné in the distance, gives a faithful representation. It is evident that, owing to the resistance offered, all the headlands consist of those portions of the moraines in which the greatest number of large blocks are enclosed; in fact, they correspond generally with the central and lateral moraines. At the same time their partial destruction has offered the means for their further protection by depositing at their base large masses of rocks, extending into the sea for a considerable distance, and against which the waves break violently but ineffectually; whilst the softer beds between them not having this protecting talus, are, if not constantly, at least during the frequent gales along this coast, quite unprotected from the fury of the waves, and are much less able to withstand their destructive power. The observer passing along this Bluff must come to the conclusion that a great portion of it has already been washed away, as for a considerable distance erratic blocks lie in the sea. Some of them are of enormous size, of which a remarkable instance is seen in the view of the Wanganui Bluff. A section of this portion of the coast No. 3 on Plate 8, shows the somewhat complicated character of these deposits. Beginning in the north we have first a true lateral moraine, consisting of the usual detrital matter, blocks of all sizes imbedded in sand and silt, the whole having a rough anticlinal arrangement. All these rocks are derived from, or at least from near, the summit of the central chain, and belong to the Waihao and Mount Torlesse formations. The southern slopes of this moraine disappear below an alluvial bed, forming a vertical wall of about 30 feet altitude. The latter consists of a well stratified bed of subangular boulders and gravel deposited here by a large river—after the retreat of the glacier—towards the sea. Although generally consisting of the same kind of rocks as those enclosed in the moraines, the presence of true metamorphic and igneous rocks proves the retreat of the glacier to such a high position, that the lower slopes of the Alps were exposed to glacier and fluviatile action. After one mile and a half a new moraine, having the same rough arrangement as the former, rises again below the fluviatile deposits. It represents doubtless the central moraine, belonging to the same glacier as the former. A new river bed of similar length follows, and then a third moraine, the southern lateral moraine of the same glacier, makes its appearance. Thus, with the facts before us, we can conclude that the northern branch, forming the trunk glacier, was here about five miles broad, consisting of two principal branches higher up, and being covered with comparatively scanty morainic matter only.

A small creek (Camp Creek) separates the last-mentioned beds from far larger morainic accumulations, rising several hundred feet above the sea-shore. They have been brought down by a glacier of nearly the same breadth as the former, but it appears that it has been covered entirely by detrital matter near its termination (like the present Tasman glacier on the eastern side of the Southern Alps). The two lateral and the central moraines are however best developed, all three exhibiting anticlinal arrangements, and the largest blocks of rocks, often closely packed, are found in them. The two intervening spaces are made up either of fine detrital matter, or of glacier silt, with angular blocks of small size scattered through them. An ancient river bed, similar to the one already described, reposes upon the morainic accumulations between the central and the northern lateral moraines. At the foot of the southern lateral moraine the river Wanganui enters the sea, and on its southern side, somewhat in front of the rest, the Wanganui Sugarloaf, called Mount Oné-Oné by the Natives, rises conspicuously from the sea. It is doubtless, like Bold Head, a true frontal moraine, being joined by a low ridge with another higher one, which forms the Puerua Bluff. This latter has at its southern extremity also the rough anticlinal stratification peculiar to lateral moraines. It would be impossible to give in a small section the details of the arrangement these glacier beds exhibit. There are numberless changes, from an assemblage of enormous angular blocks, to the finest glacier silt, deposited in such thin layers that one hundred or more form one inch, and often changing gradually from one into the other, or alternating with each other. The moraines of the united Waitaki-Whataroa glacier (the latter in the map erroneously named the Makaroa) rising in Abut Head to an altitude of about 400 feet, have an arrangement similar to that of the former, and consist also exclusively of rocks derived from the Waihao and Mount Torlesse formations. In some localities the whole wall consists of enormous fragments of rocks only, showing that the destruction in the higher portion of the Alps went on at such a gigantic scale, that we can scarcely form a conception of it. Two miles south of Abut Head, forming the southern bank of the Whataroa, a series of smaller morainic deposits make their appearance. They form the southern boundary of this glacier system. South of Lake Okarito the extensive glacier deposits of the Waiau glacier begin. They have a breadth of about ten miles, and exhibit the usual arrangement of the detrital matter. However, no alluvial beds are deposited above or between them. The Weheka-Karangarua moraine is also of considerable proportions, but unlike all the former, metamorphic and igneous rocks occur occasionally amongst the enclosed fragments at its northern end. Advancing towards the south the metamorphic rocks become gradually more numerous, till they form at the Makowiho Bluff the greatest portion of t morainic accumulations. At this Bluff the blocks of rocks of which moraines are composed closely resemble in lithological character th of which the circumvallations round Lake Wanaka are form Another interesting feature of the Makowiho Bluff is the occurre of an ancient river bed, about fifty feet thick, deposited agains lateral moraine, covered by younger morainic accumulations. further proof that oscillations in the position of the glaciers to place also on the western side of the Alps, and that when advanc again over a deposit of such comparatively incoherent nature, a gravel bed, the glaciers were doing so without destroying it to a appreciable extent, we find in the valley of the Waiau. The l moraine reaching the sea-coast was formed by the Paringa glac It is however greatly destroyed.

The lowest signs of the Haast glacier were traced to about twel miles from the coast. I have not ascended the Arawata high enou to reach the ancient morainic accumulations in that river bed. So intelligent miners have however informed me, that deposits with lar angular blocks are broken through by that river about ten miles abo its mouth.



(C) The Formation of the Canterbury Plains

This chapter would be incomplete were I not to offer a few notes on the formation of the Canterbury plains, about which so much has been written, and so many theories have been brought forward, that a matter of apparently so much simplicity has in course of time become quite obscured. Since my report on the formation of the Canterbury plains was published iu 1864, all the levels, surveys, engineering works, together with well-sinking, have amply confirmed my views that the Canterbury plains are of fluviatile origin, that, with the exception of some morainic accumulations in the upper portion an the drift sands round Banks' Peninsula, and the partial lacustrin deposits filling the former extension of Lake Ellesmere, the who of the plains were formed by the deposits of huge rivers issuing fro the frontal end of gigantic glaciers. Mr. J. T. Thomson, th Surveyor-General, in a paper on "The Glacial Action and Terrac Formation of South New Zealand," published in Vol. VI of "The Transactions of the New Zealand Institute," gives a diagram in illustration of the fan theory on page 329, and alludes to the sluice


Papanui
Riccarton
CHRISTCHURCH
Avon
and
Heathcote
Estuary
LINCOLN ROAD
Sumner
PORT HILLS
LYTTELTON
PORT LYTTELTON

deposits; such as they are formed at the present day on flats like Gabriel's Gully and Weatherstone, conforming in every respect on a small scale with the deposits formed at the termination of the gigantic glaciers duringthe Great Ice period. Professor Hutton in his various writings has been contending that the Canterbury plains must be of submarine origin, and that afterwards they have been raised above the sea level, when the rivers excavated their present channels, as terraces could only be formed during a rising of the land, and he brings forward a formidable array of scientific authorities in support. However, similar terraces, as I have pointed out previously, occur in all Alpine regions, in the European Alps, the Himalayas, the Rocky Mountains, and many other localities, where in several instances there is overwhelming evidence towards proving a subsidence of the lands since post-pliocene times. I should not have alluded to this question did not Professor Hutton in his last work, "Geology of Otago,"* still persist in claiming for the Canterbury plains a submarine origin, although he adopts for the former province the theory that the land during the Great Glacier period stood at a higher level than it possesses at present. As according to him, river terraces prove elevation, he fails to explain how the beautiful and perfect series of terraces in the Clutha valley could have been formed during subsidence, and it is thus difficult to reconcile his statement, that the plains in Otago "have certainly been formed in the way suggested by Dr. Haast." I wish here once more to repeat that the Canterbury plains on either side of the Malvern Hills are not on the same level; on the contrary, the difference is very considerable, and as the railway and other levels have shown, the fans of each river are quite distinct. The sections of the Canterbury plains attached to this Report, Nos. 1 and 2, on plate 8, drawn from more correct information than I formerly possessed, will, I trust, settle this question definitely. The diagrams in Mr. Thomson's excellent paper, previously mentioned, giving the curves of several valleys and the theoretical bearings of the question at issue, further confirm my views, that the Canterbury plains have been exclusively formed by the accumulations of the rivers still flowing through them.

Advancing now to a consideration of the general laws by which the formation of river beds are regulated, first, as far as I am aware,

---

* "Geology of Otago;" Hutton and Ulrich (page 91).

proposed by Italian engineers and natural philosophers, the following formulæ will conclusively show that all the principal physical features can be explained by them :—

1. "*The more a river advances from its sources, the less will be the declivity of its bed.*" Or stated differently—"All rivers dispose their beds in the lower course on a less slope than they had in the upper, so that the declivity diminishes in proportion to the distance they have to run from their sources." This law holds good for slowly flowing rivers, depositing ooze only, as well as for rivers and torrents, rolling boulders, gravel, and shingle, because the largest material is gradually left behind.

2. "*The greater the ordinary body of water is in a river, the less will be the slope of its bed.*" Or, stated in other words—"The slope of the bed of a river will diminish in the same proportion in which the body of water is increased."

These two natural laws will be quite sufficient to explain all the principal phenomena which our rivers exhibit, the more so as none of them south of Banks' Peninsula have formed a delta properly speaking. The only river possessing such complete features is the Waimakariri, which in its lower course shows great resemblance with the lower part of the Po, in the Plains of Lombardy, which for many centuries has caused anxiety for the safety of the surrounding country, its bed having been raised gradually by embankments to such an altitude that it runs in many localities above the level of the plains on both sides.

We must conclude that the Canterbury plains are formed by the outlets of enormous glaciers, large torrents bringing down with them the morainic matter, thrown in their course at the terminal face, raising their beds and shifting their channels at the same time so as to form fan-shaped fluviatile accumulations, consisting of shingle, gravel, sand, and glacier mud. In applying the preceding rules, we shall find that as the sources of the post-pliocene torrents were at the terminal face of the glaciers, they lay much further to the east than the present ones, and at the same time, those glaciers being on such a gigantic scale, the torrents issuing from them must naturally have been so much the larger. In consequence we ought not to feel any astonishment at observing, if we take into account both circumstances of the retreat of the glaciers combined with their diminution, that the rivers cut new courses into the older deposits in recent times, the more so when we consider their volume was so greatly reduced. It is thus now easily understood that, for instance, the post-pliocene fan of the river Ashburton was so enormous, and that as the then glaciers, all assisting in the formation of these large deposits, shrunk back to their proper valleys, the outlet from the one remaining Ashburton glacier does not stand in any relation with its former fan. Consequently it has not been able to lower its channel to any extent, whilst the Rakaia, which is still the outlet of considerable glaciers, and has retreated much more than the former, has been able to cut its channel much deeper, and to prepare a much more uniform gradient for its bed.

As the mountains began to become gradually eaten into by the action of the descending ice-masses, sharper ridges and peaks were formed, so as to lessen the extent of the surface where perpetual snow could accumulate to feed those glaciers, which consequently began to retreat. Therefore the sources of the rivers which now cross the plains were lying, in the post-pliocene epoch, much nearer to the sea, their fans were much steeper, and they continued to build them higher and higher, changing their apex continually, and at the same time forming with their lowest portion the shore line of the ocean.

All my observations show at the same time that the three great post-pliocence torrents, namely, the Ashburton, Rakaia, and Rangitata were united without doubt in one large water-course before they reached the sea, having a common fan at their mouth, following the law that rivers which unite, endeavour to do so by the shortest line. This fact is well illustrated near the present mouth of the river Hinds. This river flowing between the fans of the Rakaia and Ashburton above the point where they united into one, has been forming a swamp of considerable extent, being four to five miles broad and eight miles long. It has partly been drained by natural water-courses, partly by artificial drains under process of formation, all passing through the higher shingle beds in front. The united existence of such a fan is also instructively shown at the coast, where the sea has worn away the protruding arc between the southern bank of the Rakaia and the northern bank of the Rangitata. These cliffs, consisting of true river shingle and river sand, are at the south side of the Rakaia about six feet high, and rise gradually to an altitude of 70 feet near the mouth of the Wakanui Creek, four miles north of the Ashburton river, where consequently the united fan has suffered the greatest destruction. Having reached this altitude the coast cliffs towards the south diminish in height, so that near the mouth of the Ashburton they only rise to 18 feet.* A few miles north of the Ashburton we reach again the line, where the sea-coast meets the level of the fan under consideration.

To understand fully the combined action of the agencies at work, it will be necessary to remember, that the largest fan was necessarily formed by the most extensive glacier, and in consequence the fan of the post-pliocene Waimakariri could not reach so far into the sea, as did the united Ashburton one, built up by the southern rivers. In adopting the present data before us as the basis of reasoning, we shall find that, as before observed, the united southern fan began near the mouth of the Rangitata, advanced into the sea till it attained a breadth greater by several miles than that which it now possesses near the mouth of the present Wakanui Creek, and crossed again near the mouth of the Rakaia, of which a portion has been, and is now being, washed away. Continuing the same arc of this fan in a north-west direction we shall reach the Selwyn several miles above its junction with Lake Ellesmere, where the fan of the Waimakariri joined it, and, in consequence, the Selwyn, like the Hinds, is flowing upon the junction of both fans. During this post-pliocene era a narrow arm of the sea ran along the western foot of Banks' Peninsula, as shown by the drift sands and raised beaches surrounding it here. The oceanic swell south of Banks' Peninsula travelling towards the north, assisted by the action of the waves, very soon began to disintegrate the post-pliocene accumulations. The shingle and sand derived from that destruction, travelling northwards, were augmented considerably by the material of the same nature brought down by the rivers, and, assisted by the two prevailing winds, finally formed a dam from the mouth of the Rakaia to that isolated volcanic system, becoming every year more considerable. A peninsula was soon originated, the connecting isthmus being that dam or broad shingle spit behind which an arm of the sea formed a bay, moderately deep and comparatively sheltered, with an entrance to the north of Banks' Peninsula. Into this bay the Selwyn, Waimakariri, and probably, at one time, the Rakaia fell. Gradually the shingle and sand brought down by the northern rivers, the Waipara and Ashley, travelling with a northerly swell towards the south, threw, in their turn, a bar across the opening of the bay, thus forming a large

* From observations of Mr. C. W. Adams, Geodetical Surveyor, kindly furnished to me.

lagoon, of which Lake Ellesmere is only a remnant. Of this occurrence we have sufficient evidence in the immediate neighbourhood of Christchurch and Kaiapoi; and still up to the present time the topographical features of the ground which rises close to the western foot of Banks' Peninsula, only about twenty-six feet in its highest neck above the sea, having on both sides low swampy ground, would give additional evidence to such a theory, were not other proofs sufficient.

I have already pointed out that there has been an oscillation of about twenty feet, the upward movement occurring towards the end of the Great Glacier period. This rising of the country was of course of great importance for the low ground forming in front of the shingle fans. Thus with the rising of the country this large lagoon became partly filled either by the shingle of the rivers falling into it, (of which the Waimakariri was the most important in throwing its fan nearly across it), or assisted by the silt which the rivers had in suspension, and which was thrown down all over the lagoon in the form of loam and clay. Moreover, drift sands invaded it from its eastern shore, coming from the north, giving additional breadth and stability to the banks which separated it from the Pacific Ocean. At favourable localities, just rising to or near the surface of the water, vegetation began to spring up, forming swamps, which with the assistance of bog-mosses (*Sphagnum*) and other aquatic or semi-aquatic plants forming peat, raised considerably the ground, so as to form a suitable locality for the beginning of forest vegetation. Many were the slight oscillations taking place, through which the rivers changed their channels, and either removed the clays deposited in the lagoon, or buried below their newly-forming shingle-beds the peat swamps, vegetable soil, and even forests, of which well-sinking in the neighbourhood of Christchurch has offered many illustrations. In this way those swamps were either covered or partly drained, whilst others, not so favourably situated, continue to this day to remain in the same condition, as, for instance, portions of the Rangiora swamp. Many of the raised beaches are easily traceable, and with them the former western banks of the great Lake Ellesmere extension. This accounts also for many peculiarities we meet in the centre of this ancient, partly drained and filled lagoon, which, without such an explanation, would be unaccountable.

It has been before stated, that the declivity of a river diminishes in proportion to the distance it has to run from its source, and it is thus natural that the rivers now traversing the Canterbury plains have lessened their fall, although still having the character of true torrents, descending in their course at a more uniform but lesser rate than the post-pliocene fans of the former larger rivers. They have, in consequence, according to their present size and position of sources, cut more or less deeply into these deposits, but reach a point where they intersect the line, below which the old fan falls more considerably, and thus the present rivers, instead of excavating, begin to fill up, raising their beds above the older deposits and forming new fans. The present rivers repeat simply on a smaller scale the action of the large post-pliocene torrents forming the upper plains; they also debouch from a gorge, although the sides of it consist only of shingle, and spread fan-like over the lower grounds, the axis of the course of the river changing so as to build it up regularly. Consequently it has been found by actual survey, that the contours taken at an equal distance from the beginning, or perhaps better stated, from the emergence from the older beds, have an equal gradient and altitude. Thus, as before said, the higher this point lies above the junction of the river with the sea, the larger will be the radius over which the river can roam and raise its bed. It was, therefore, of the greatest value to the district to ascertain not only the exact spot where the recent accumulations begin to spread over the older ones, but also to find, by careful measurements, what is the ratio of the present rise above the level of the sea, as well as above a given spot of the plains of older origin. The fact, however, that only the Waimakariri, and in a minor degree the Rangitata on its southern and the Rakaia on its northern banks, for a small extent are subject to such an occurrence, is worth recording, and shows distinctly that the two last-mentioned rivers flow on the sides of the large post-pliocene deposits described previously. Here some rich alluvial land is situated, and thus those small strips, endangered by the aberrations of these rivers, are of far greater importance than a look at the map at first might suggest.

In the following four tables the data collected during a number of years, as to the fall of the plains, and the rivers which formerly built them up, are given. They are taken from my Report on the formation of the Canterbury plains, to which a number of details obtained since and also some corrections have been added.

Table I.

Showing the Fall of the Canterbury Plains.

Name of Rivers.	———	Difference between two Stations.	Length of Plains.	Fall of Plains Per Mile.
		Feet.	*Miles.*	*Feet.*
Rangitata ...	From beginning of gorge to mouth ... *mean*	1443	32	45
	From beginning of gorge, 1443 feet, to railway crossing 292 feet	1151	23¼	49½
	*From railway crossing 292 feet to sea ...	292	8¾	33⅓
Ashburton	From Two Brothers to sea ... ... *mean*	1500	35½	42¼
	From Two Brothers 1500 feet, to railway crossing 305 feet	1195	25	48
	*From railway crossing 305 feet to sea (50 feet above sea level)	255	10½	29
	*Plains between Rakaia and Ashburton (railway crossing), altitude above sea 412 feet, cliffs 60 feet	352	12½	28
Rakaia ...	*From gorge to sea ... ... *mean*	1480	37½	39½
	*From gorge 1480 feet, to railway crossing 378 feet	1102	21½	51¼
	*From railway crossing 378 feet to sea ...	378	16	23½
Waimakariri	From upper gorge to sea ... ... *mean*	1580	44	36
	From junction of Kowhai 1410 feet, to lagoon at gorge hill 1182 feet	228	5	41½
	From lagoon 1182 feet, to the so-called 18th mile peg 355 feet...	827	18¾	44
	*From 18th mile peg 355 feet, to last raised beach near North-road 33 feet...	322	13¼	24¼
	*From last raised beach 33 feet to sea ...	33	4	8
Selwyn ...	From entrance into plains to Lake Ellesmere	790	29	27¼
	From entrance into plains 790 feet, to railway crossing 214 feet	576	16½	35
	*From railway crossing to Lake Ellesmere	214	12½	18

* The numbers to which an asterisk has been prefixed are results obtained with the spirit-level, by the Public Works Department.

Table II.

***Showing the Fall of the Rivers of the Canterbury Plains, from their sources to the Sea, and their intermediate gradients.*†**

Name of Rivers.	———	Difference between two Stations.	Length of Rivers.	Fall of Rivers Per Mile.
		Feet.	*Miles.*	*Feet.*
Rangitata ...	Whole course from the Clyde Glacier, main source 3762 feet to sea ... *mean*	3762	75	50
	From Clyde Glacier 3762 feet, to junction with McCoy 3269 feet...	493	3	164⅓
	From junction of McCoy 3269 feet, to junction of River Havelock 2192 feet	1077	11	98
	From junction of Havelock with Clyde 2192 feet, to beginning of Canterbury Plains 1180 feet	1012	29	35
	From beginning of Canterbury plains to railway crossing 257 feet	923	23¼	39¾
	*From railway crossing 257 feet to sea ...	257	8¾	29
Ashburton ...	Whole course from Ashburton Glacier 4823 feet to sea... ... ... *mean*	4823	67	72
	From Ashburton Glacier 4823 feet to Camp Creek 3717 feet	1106	4	276½
	From Camp Creek 3717 feet, to junction with Clearwater Creek 1832 feet ...	1885	16	117¾
	From junction of Clearwater Creek to beginning of plains, near Two Brothers 1400 feet	432	11½	37½
	From Two Brothers 1400 feet, to railway crossing 300 feet	1100	25	44
	*From railway crossing 300 feet to sea ...	300	10½	28¾
Rakaia ...	Whole course from Ramsay Glacier 3354 feet to sea ... ... *mean*	3354	85	39½
	From Ramsay Glacier to junction of Cameron 2034 feet	1320	13	101½
	From junction of Cameron 2034 feet to junction of Mathias 1688 feet ...	346	6	57⅔
	From junction of Mathias 1688 feet, to junction of Wilberforce 1357 feet ...	331	9½	35
	From junction of Wilberforce 1357 feet, to Gorge Island 875 feet	482	19	25½
	*From Gorge Island 875 feet, to railway crossing 372 feet	503	21½	23½
	*From railway crossing 372 feet to sea ...	372	16	23¼
Waimakariri	Whole course from Waimakariri Glacier 4162 feet to sea... ... ... *mean*	4162	93	44¾
	From Waimakariri Glacier to junction of two main source branches, 2607 feet	1555	5	311

TABLE II—*continued.*

NAME OF RIVERS.		Difference between two Stations.	Length of Rivers.	Fall of Rivers Per Mile.
		Feet.	*Miles.*	*Feet.*
Waimakariri	From junction of two main source branches to junction of Crow River 2273 feet,	334	4	83½
	*From junction of Crow River to junction of Bealey River 2065 feet	208	5	41⅗
	From junction of Bealey to junction of Esk River 1562 feet	503	21	24
	From junction of Esk River to junction of Kowhai River 1003 feet*	559	17	33
	*From junction of Kowhai River to White's old Accommodation House in river bed 605 feet	398	15	26¼
	From White's old Accommodation House 605 feet, to tidal boundary	605	22	27½
	From near the crossing of the North-road to sea		4	
Selwyn ...	From entrance into plains to Lake Ellesmere ... ... *mean*	767	29	26½
	From entrance into plains 767 feet, to railway crossing 212 feet	555	16½	33½
	*From railway crossing 212 feet, to Lake Ellesmere	212	12½	18

TABLE III.—*Showing the Fall of the River Waitaki.*

For comparison I may offer the principal data in my possession of the main branch of that River, and after its junction with the other branches of the Waitaki to its mouth.

Tasman ...	‡From the Tasman Glacier 2456 feet, to Lake Pukaki, 1717 feet	739	25	30
	From outlet of Lake Pukaki to mouth of Waitaki	1717	82	21
Waitaki ...	If Lake Pukaki should be filled up by the River Tasman, the River Waitaki would show the following results ...	2456	117	21
	The beginning of the old post-pliocene fan of the River Pukaki, the main branch of the Waitaki, is situate 150 feet above that river at the lake, which shows that the former outlet of that enormous glacier would have had only a fall to the sea of	1967	82	23

* The numbers to which an asterisk has been prefixed are results obtained with the spirit-level, by the Public Works Department.

† The length of the Rivers is taken by following their general direction.

‡ As for that river, the last three miles before it enters the Lake is almost without any fall, it flowing through swampy deltaic ground, I have calculated two miles less for its course than it actually has, so as to give a more correct result of its gradient.

Table IV.

In order to prove that the larger the river, the greater its power of scouring its channel, and consequently of lowering its bed, the following data will not be superfluous. The rivers follow according to their volume.

Rivers falling per mile, in feet :—

	Waitaki.	Rakaia.	Waimakariri.	Rangitata.	Ashburton.
From sources to sea ...	21	39½	44¾	50	72
From beginning of plains to sea	23	23½	28	37	39¾

Table V.

The following data will show the difference in the fall of the post-pliocene rivers, from the beginning of the plains at the foot of the mountains to the sea, for the calculation of which the surface of the Canterbury Plains offers us the necessary data :—

Rakaia, 39½. Waimakariri, 36. Rangitata, 45. Ashburton, 42½.

CHAPTER XVI.

THE QUATERNARY AND RECENT PERIODS.*

(A) First Appearance of Man in this Island.

It has already been pointed out that no exact boundary can be drawn between the Great Glacier, and the Quaternary periods, that in fact it is impossible to say, when the former ceased and the latter began. The same can be said still more truly of the era during which the Loess beds were deposited, the process of their formation still going on uninterruptedly at the present time. However one natural division might be proposed for New Zealand, namely to begin the Quaternary period there, where we meet the first sign of the presence of man. This line of division is however one liable to be shifted further back in course of time, when more discoveries in our younger beds are made, the results of extensive railway and road cuttings, well sinking, and mining operations, by which our knowledge in that respect will greatly be advanced in years to come. Or should, as it is not impossible, man already have lived in New Zealand during the latter part of the Great Glacier period, this proposed division would be no more of any value, and another more constant one would have to be adopted.

* In this chapter I have included the recent period, during which, by the different agencies incessantly at work upon our globe, new deposits are in course of formation. This was the more necessary, as the recent accumulations blend in many instances so thoroughly with those of quaternary age, that it would be impossible to draw a line of demarcation.

In the last chapter I have already pointed out, that the different morainic accumulations, now forming for several hundred miles a succession of cliffs along the west coast, have become united by a sand or shingle bar, thrown across the small bays between them, and that judging from the breadth of these deposits, a considerable space of time has been necessary for their formation. In the Historical Notes on page 160, I have already alluded to the fact, that polished stone implements have been found in auriferous deposits in Bruce Bay, and I may now add, that these beds, are a portion of the bar between two extensive morainic accumulations, Heretanewha Point to the south and Makowiho Point to the north. In Volume II of the Journal of the Ethnological Society of London, an account of this remarkable find has been published by me, from which, the fact in question being of considerable importance for the elucidation of the age and mode of formation of these beds, I shall here offer the following extracts.

Where at the west coast ancient level strips of land exist close to the sea, we find that the usual forest vegetation grows to the water's edge; but generally the level ground is of quite recent origin, as the land is gaining upon the sea, and new ground is continually formed. In localities of this nature we observe that the more we advance from high-water mark inland, the more luxuriant becomes the vegetation, exhibiting three distinct belts of peculiar growth. This is well shown in Bruce Bay (section 4, plate No 8). There is generally above high-water mark a zone 50—100 feet broad, consisting of fine drift-sand, usually forming small hillocks, amongst which a great mass of drift-wood is decaying, but in which no other vegetation, except a few fungi on the rotten wood, makes its appearance. Then follows a second belt, also of sand, 80—150 feet broad, in which the drift-wood has already entirely disappeared. It is covered by vegetation, peculiar to such localities, consisting of sedges, rushes, and a few plants of higher organization. The following plants grow principally in this second or "*Coprosma-acerosa* belt," as I propose to call it; namely, *Coprosma acerosa*, *Juncus maritimus*, *Desmoschœnus spiralis*, *Scirpus maritimus*, *Leptospermum scopiarum*, *Euphorbia glauca*, *Convolvulus soldanella*, and *Discaria toumatou*.

A third distinct zone follows, from 300—500 feet broad, commonly called the "scrub-belt." The main mass of its vegetation consists of *Coriaria ruscifolia*, *Coprosma petiolata*, *Coprosma Baueriana*, *Veronica salicifolia*, *Fuchsia excorticata*, *Griselinia littoralis*, *Phormium tenax*, and some other shrubby plants, generally with a dense undergrowth of ferns belonging to the genera *Asplenium*, *Polypodium*, *Lomaria*, &c. The boundary between the first and second belt is not so distinct as that between the others, especially between the "shrub" and "forest belt," which is generally sharply defined.

In Bruce Bay, where the ground is rather swampy, the vegetation of this last-mentioned belt consists of the following trees:—*Podocarpus dacrydioides*, *Podocarpus Totara*, *Dacrydium cupressinum*, *Libocedrus Doniana*, *Weinmannia racemosa*, *Metrosideros lucida.* Several species of *Coprosma*, *Pittosporum*, and fern-trees, as, for instance, *Cyathea Smithii* and *Dicksonia squarrosa*, grow between and below them, while the *Rhipogonum scandens*, the "supple-jack" of the colonists, interlaces the whole with its numerous flexible stems. Where the *Kiekie* or *Freycinetia Banksii* occurs, which is not unfrequent, this forest zone is almost impenetrable.

When I arrived in 1868 in Bruce Bay the two auriferous leads situated in the beginning of the second and third belts had already been worked out, and the miners were exclusively at work ont he third lead, situated in the forest-belt, where they had to sink 13—15 feet before the auriferous beds were reached. After having removed the large trees growing here, sometimes 4 feet in diameter, and standing closely together upon 8—12 inches of vegetable soil, in which the roots run horizontally, the miners passed through the following strata before the auriferous sands were reached:—

	ft.	in.
Flattened beach-shingle mixed with black sand	4	0
Black sand containing a little gold	0	2
Quartzose and black sands alternating repeatedly with each other	1	1
Large flattened shingle with some black iron, and quartzose sands, but not auriferous enough to pay for the extraction of the gold	6	5
Fine black sand, a little auriferous	1	0
Very coarse gravel	1	7
Auriferous black iron-sand, which is the layer of wash-dirt excavated for sluicing	0	6
	14	9

This last layer reposes upon a bed of coarse gravel, which, being cemented by an argillaceous matrix, has materially assisted to retain the fine gold in the black sand above it.

From an examination of the section it will be seen that a long period of time must have elapsed before such a succession of beds could be ormed, because it is evident that the beaches have not been always receiving new additions, but deposits have been thrown up and again partially removed according to the prevailing winds. If we examine the different belts of vegetable life following each other with such distinctness, as we go inland, additional evidence is offered that considerable time was necessary to change the *Coprosma-acerosa* belt into the scrub-belt, and a still longer period had to elapse for the formation of a sufficient thickness of vegetable mould to allow the forest-trees to grow to such large dimensions. In the same forest, many and larger trees are lying prostrate on the ground, and in all stages of decay; sometimes their former existence being indicated only by long mossy ridges, so that we may safely conclude that the present forest vegetation is not the first one, but that it was preceded by trees of the same species, and often of large dimensions, formerly growing there.

In one of the claims in this last described forest-belt, on the bottom of the wash-dirt, reposing directly upon the argillaceous gravel, a party of miners, consisting of S. Fiddean, J. Sawyer, and T. Harrison, found a stone chisel and a sharpening-stone lying close to each other; the former was broken, having been accidentally struck by the pick when the miners were loosening the wash-dirt. The stone chisel is made of a dark greenish chert, and is partly polished; the sharpening-stone is formed of a coarse greyish sandstone, which I found *in situ* about ten miles south of this locality, near the mouth of the river Paringa. The two stone implements now in the Canterbury Museum, were found a few days before my arrival, and it was quite accidentally in looking at the claim that I heard of their discovery.

I measured carefully the distance from high-water mark to the exact spot where they were discovered, and found it to be 525 feet, crossing the different belts as follows:—

	feet.
First, or drift-wood belt	63
Second, or *Coprosma-acerosa* belt	95
Third, or *Coriaria* belt	330
Fourth, or White-pine belt	37
	525

The beds through which the miners had been working were quite undisturbed, and some very large trees had been growing just above that portion of their claim near the centre of which these stone implements had been found. Owing to the dense forest covering the ground everywhere on the west coast of this island, these beaches are generally used for travelling, the favourable time of the receding tides being selected. I can easily imagine, therefore, how these stone implements may have been left behind. When travelling with Maoris along that coast I have, during a rest of a few moments, seen them repeatedly pull out a piece of greenstone and polish or cut it until the *mot d'ordre* to proceed was again given by me. In the same way the owner of these implements may have set to work, and when starting again either forgotten them or left them behind when surprised by an enemy.

When writing the paper, from which so far I have given the principal contents, I was under the impression that the Moa-hunters had not possessed any polished stone implements, but used only roughly chipped ones, and that the fine series of such implements found in a *câche* in the Moa-hunter encampment at the Rakaia belonged to a later period, having accidentally been buried there, however the excavations in the Moa-bone Point Cave, of which I shall offer the principal results in the sequel, have established the fact beyond a doubt that the former Moa-hunters used both kinds. Thus it is evident that we cannot divide the former inhabitants of New Zealand into two distinct races, from their having exclusively used unpolished or polished stone implements corresponding with the palæolithic and neolithic periods of Europe. To the former belonged the now extinct Tasmanian aborigines, possessing only crudely chipped stone implements, whilst the Australians, standing not much higher in the scale of civilization than the Tasmanians did, generally used only polished stone implements. Exception must however be taken as to the manufacture of spear heads, used in Northern Australia, being simply chipped from pieces of obsidian and of the stone implements of some of the Natives of Western Australia, which are of a very primitive type.*

Therefore, if a race so much inferior to the Maoris, as the Natives of Australia are, possess and possessed polished stone implements, it is not to be wondered at that a race so far advanced as the Moa-hunters should also have possessed them, as I shall show in the sequel. The Morioris or Native inhabitants of the Chatham Islands have used until quite lately, both polished and unpolished stone implements, according to the work to be performed by them. For the purpose of manufacture, polished stone tools were necessary, whilst for cutting up whales,

---

* "The hatchets found in Western Australia appear to point to one of the lowest types of creation, their stone implements being so primitive, that, unless the stones were found in gum and fixed to handles, I scarcely think it would be credited that they had ever been used for the important duties they had to serve."

On the Stone Implements of Australia, etc. by Jas. C. Cox, M.D., F.L.S. Proceedings of Linnean Society of New South Wales, Vol I, Page 22.

or severing their extremely tough sinews, chipped flint implements were in request. The Moa-hunters in their turn in order to cut through the hard sinews of the *Dinornithidæ* were also obliged to use similar primitive implements, forming them either by splitting off a flake from a hard sandstone boulder, or taking when the material was obtainable, either flint, obsidian, or quartz, as offering the best cutting edges for the purpose. I have been informed that a number of polished stone implements, similar to those obtained at Bruce Bay have been found in some other auriferous beds at the West Coast, all testifying to the long period during which that portion of the country was occupied by man.

The facts at our disposal on the eastern side of the Island, confirm fully the observations made on the opposite coast. One of the most interesting localities where a great deal of valuable information was obtained by me, is the so-called Moa-bone Point Cave, and the sand-dunes adjacent to it. In the previous chapter I have shown how in post-pliocene times from the material brought down by the enormous glacier torrents, forming huge shingle-fans at the foot of the glaciers, two bars were thrown across the sea near Banks' Peninsula; one to unite the northern or Waimakariri-Ashley deposits with the northern slopes, another to connect the southern or Rakaia-Ashburton beds of the same nature with the southern slopes of that isolated volcanic system, behind which a large lake was formed, of which Lake Ellesmere is the last remnant. Of the northern bar we can trace the inner or western shores through Kaiapoi to the neighbourhood of Woodend. In this large fresh water lagoon (occasionally an estuary basin) the Waimakariri, Selwyn, and sometimes the Rakaia, discharged their waters, having an outlet near the north-western slopes of Banks' Peninsula, of which we can easily trace the lines of dunes and shingle by which the eastern shore of that lake was formed, being in the beginning very narrow, and only gradually, as more and more material was added, assuming a greater breadth. Thus, we are able to follow the different lines of these earliest-formed beds from the mouth of the Waipara, where they are comparatively narrow, along the eastern boundary of Christchurch to the northern foot of the Peninsula, gradually becoming broader, and diverging more and more.

It is an important fact that the ovens and kitchen middens of the Moa-hunter are confined to the inner lines of the dunes. Thus it is evident that when the former inhabitants of this part of New Zealand existed principally upon the chase of the Moa, the sand dunes had scarcely reached the foot of the Peninsula, where now the Ferry road crosses the Heathcote, and consequently that the whole breadth of the sand dunes from opposite that locality to the Sumner bar, where they have now their south-eastern termination, have been formed since.

These series of sand dunes have a breadth of several miles, and consequently a long period of time must have necessarily elapsed duing which they were gradually built up by wind and waves. During quaternary times, or the Moa-hunter age, the extensive estuary of the Heathcote-Avon in its present form was not yet in existence. Close to the cavity now called the Moa-bone Point Cave, and on its western side, a hard doleritic lava-stream, now passed through by the Sumner road cutting, reached for some distance into the sea, forming a small headland, against which, principally on its eastern side, the waves of the Pacific Ocean broke with considerable force. Masses of rock were detached by the surf, being taken along in an easterly direction for about a quarter of a mile, forming a ridge, gradually becoming lower and losing itself amongst the sands. The formation of this ridge principally took place when this portion of the Peninsula was some twelve or fifteen feet lower than at present, the upper line of boulders being about sixteen feet above the present high-water mark. When the land rose again, the sea was cut off by this boulder ridge from the entrance of the cave, a hugh rock lying here nearly across, protecting it at the same time from being filled up by the deposits of drift sands now forming on the flat, close to it. A second and lower line of boulders was formed in front of the former about five feet above the present high-water mark, with a small terraced space behind it. Since then, other deposits, formed in the Avon-Heathcote estuary, have been added as a small belt in front of this last line of boulders, brought into its present position by the action of the open sea. In section No. 1, Plate No. 9, I have given the necessary details in illustration of these points.

It will also be seen from this section that most valuable and conclusive evidence is offered to us, as to the time of the first appearance of the Moa-hunters, and their disappearance from the field, when these gigantic birds became either extinct or were driven to less congenial localities inland, and I therefore shall in the following pages offer a condensed account of my excavations in that cave and its neighbourhood, together with some conclusions upon the results obtained.

The entrance of the cave, about forty feet from the crown of the Sumner road, which has here an altitude of 18·59 feet above high-water mark, is situated nearly five feet lower, or 13·64 feet above high water, taking the level of the surface for our line. An opening, about 30 feet broad by eight feet high, being, however, much narrowed by a huge rock, leads into the cave, of which I found the floor slightly sloping down. The cave itself consists of three compartments, of which the first one possesses by far the greatest dimensions, running nearly due north and south, and being 102 feet long, 72 feet broad towards the middle, and about 24 feet high. From its termination, by a small passage, a second cave is reached, which is 18 feet long, 14 feet wide, and about 11 feet high; its direction being north by west to south by east; at its southern end a small passage, three feet high, by about 2·50 feet broad, leads into a third or inner chamber, which is 22 feet long, with an average width of 16 feet, and about 20 feet high, running again like the principal cave, due north and south; its floor being about eight feet above high-water mark. An examination of the surface beds showed that the floor of the main cave was, in some localities, covered with the remains of European occupation, in many others by the excrements of goats and cattle, introduced into Canterbury by the Europeans in 1839; but that everywhere below them, when visible, portions of shells of mollusks were occurring, the same species as still inhabit the Estuary close by, and had served as food to the Natives of the islands visiting the cave in former times. Towards the end of the main cave these beds gradually thinned out and were mixed with each other, till at the entrance to the second cave, marine sands, the former floor of the cave, reached the surface.

The excavations undertaken under my direction in this cave, during the latter part of the year 1872, and of which the details were given in my communication to the Philosophical Institution of Canterbury, "Researches and Excavations carried on in and near the Moa-bone Point Cave, Sumner Road, printed in Vol. VII. of the Transactions of the New Zealand Institute, page 54 and *sequ.*" have made us acquainted with the following general facts:—

A nearly level floor of marine sands existed, resting upon the rocky bottom of the cave, these sands being 4½ feet above high-water mark at the entrance of the cave, and gradually rising to 8 feet near its termination. There is no evidence from which could be concluded when the big block at the entrance of the cave fell down from the roof to narrow the former so considerably, but I have no doubt that this took place before the sea had left the cave entirely, by being shut out by the boulder bank in front of the entrance, the crown of which rises 16 feet above high-water mark. However, both the boulder bank and this rock at the entrance of the cave, prevented the drift sands from entering and filling it, so that when the Moa-hunters landed with their canoes in some of the nooks of the rocky shore in the vicinity, they found a capital shelter in the cave, whilst the Peninsula, then probably an island, and the opposite shores of the main land offered them a fine hunting ground. It appears from the examination of the sea sands, that the first visitors of the cave entered it only occasionally, and still more rarely used it as a cooking place. This might have taken place after the waves of the sea had been shut out from the cave by the formation of the boulder bank in front of it, probably assisted by a rise of the land, but it is possible that at exceptionally high tides the water still entered the cave, as some of the broken Moa-bones, and of the boulders of which the cooking ovens in the south-western portion were formed, were imbedded nearly twelve inches deep in the sands. The bed of ashes and dirt which here, and in a few other places, underlies the next or agglomeratic bed, clearly proves that before the last-mentioned deposit was formed, fires had been lighted occasionally upon the sands. The discovery of drift wood in the cave, often of considerable size, of several seal skeletons, and of a portion of a lower human jaw, is a proof that during the deposition of the sands it was easily accessible to the waves of the sea.

In these marine sands blocks of rock of all sizes are imbedded, having fallen from the roof, and possessing a more or less rounded shape, such as is exhibited by scoriæ, formed during the flow of a large lava-stream in its upper and lower portions. When the waves of the sea finally retreated, a great number of these fragments fell for a considerable time from the roof, forming a nearly uniform layer of an average thickness of six inches above the marine sands, and being generally thicker where the cave is highest. This fall was, without doubt, caused by the interior of the cave gradually getting drier. During the whole time of the formation of this remarkable deposit, the cave appears to have been occasionally inhabited, as evinced by the great number of bones and of small quantities of charcoal and ashes enclosed in the bed under consideration. Above this agglomerated bed another remarkable layer has been deposited, generally three to four inches in thickness, mostly consisting of refuse matter from human occupation and of ashes, so that I adopted the name of dirt-bed for the same. It was especially in some localities, as for instance, near the entrance of the cave, replete with kitchen middens of the Moa-hunters. During its formation or even afterwards, the fall of the rocks from the roof did not cease, as all the beds upwards, even those of European origin, have small lumps of such scoria, or even larger blocks imbedded in them. But now, after the formation of the dirt-bed, as it were at once, the Moa-hunters disappear from the scene; but not without affording an insight into their daily life, by leaving us some of their polished and unpolished stone implements, a few of their smaller tools made of bone, a few personal ornaments, as well as fragments of canoes, whares, and of wooden spears, fire sticks, and other objects too numerous to mention; but by which the fact is established that they had reached already a certain state of civilisation, which in many respects seems not to have been inferior to that possessed by the Maoris when New Zealand was first visited by Europeans.

That after the depositions of the dirt-bed the cave remained uninhabited for a considerable space of time, is not only proved by the clear line of demarcation between that layer and the shell bed above it, in which no moa-bones were found, but also by the deposit of blown sands about a foot thick at the entrance, and gradually thinning out as it advances towards the interior of the cave. Then follows a series of shell beds, consisting of the remains of the following species, now still inhabiting the estuary:—*Chione stutchburyi* (Cockle); *Huai* or Pipi, *Mesodesma chemnitzii*, Pipi; *Amphibola avellana* (Periwinkle) Hetikutiku, and *Mytilus smaragdinus* (Mussel) Kuku; interstratified or intermixed with them occur a number of ashbeds, with pieces of flax, cabbage tree leaves, charred wood, and remains of mats, wooden and stone implements.

Some of the shell-beds, generally in their lower portion, are much decomposed. The whole series has near the entrance of the cave, a thickness of more than 8 feet, gradually thinning out, so that in the centre of the cave it has dwindled to about 4 feet, and disappearing altogether near the termination of the first or principal cave. The thickness and sequence of the beds, and the identity of species proves clearly that a native population, living principally upon the mollusks now inhabiting the estuary, have occupied every part of the cave during a very long period, that portion near the entrance being of course preferred. It is thus evident that when the Shellfish-eaters came upon the scene, the Moa-hunters had not only disappeared for a considerable time past, but the estuary had also since then been formed, or perhaps more correctly stated, the sands had gained so much upon the sea shore, that the purely marine species had disappeared from the neighbourhood of the cave, the estuary species taking their place. On the top of these deposits, formed by an aboriginal population, beds of minor thickness, the result of European occupancy together with dung of goats, sheep, cattle and horses, had in many localities been accumulated.

In the lower, or Moa-hunters' beds, were bones of the following species :—*Dinornis robustus*, *Palapteryx crassus*, *Euryapteryx gravis*, *Euryapteryx rheides*, *Meionornis casuarinus*, *Meionornis didiformis*, *Aptornis defossor*, *Aptornis otidiformis*, of which those of *Meionornis didiformis* and *Euryapteryx rheides* were the most numerous, and tracheal rings and portions of eggshells of Moas. Besides them remains of the following Mammals were obtained :—Ziphioid whales, sea leopard, *Stenorhynchus leptonyx*; fur seal, *Arctocephalus lobatus (?)* and *cinereus*; small fur seal, *Gypsophoca subtropicalis*; dog, *Canis*, sp. Porpoise.

Of birds still belonging to the *Avifauna* of New Zealand, the following species were represented :—*Graculus punctatus*, spotted shag; *Eudyptula undina*, small blue penguin; *Anas superciliosa*, grey duck; *Graculus carbo*, black shag; *Graculus varius*, pied shag; *Graculus brevirostris*, white throated shag; *Ossifraga gigantea*, nelly; *Apteryx australis*, large kiwi, *Nestor meridionalis*, kaka; *Stringops habroptilus*, kakapo, and some other undetermined species. The Kiwi and Kakapo are long extinct in the Peninsula, and now only found on the western side of the Central Chain in this part of the South Island. There were also a few bones of Oligorus gigas, hapuku.

The upper or shell beds were principally made up of *Mytilus smaragdinus*, mussel; *Chione stuchburyi*, cockle; *Mesodesma chemnitzii*, pipi; *Amphibola avellana*, periwinkle; *Mesodesma cuneata*; all four numerous; *Lutraria deshayesii*, kokotu, about thirty of them lying very close together on the dirt-bed, of *Mactra discors*, *Voluta pacifica*, *Turbo smaragdinus*, *Unio aucklandicus*, and *Haliotis iris*, a few of each. Besides them, most of the mammals and birds already enumerated as occuring in the lower beds, were also represented, except of course the extinct *Dinornithidæ*.

Close to the cave, numerous kitchen middens, both of the Moa-hunters and Shellfish-eaters are situated. When speaking of the position of the cave, I alluded already to the two lines of boulder deposits running from the western headland in an easterly direction, and gradually diminishing in height and size. Between them and the foot of Banks' Peninsula, near the cave, drift sands very soon accumulated, by which a quarter of a mile to the east these boulders were gradually covered. About 200 feet east of the cave, the mountainous portion of Banks' Peninsula recedes nearly a quarter of a mile to the south, the low ground being here also covered by drift sand, many acres in extent, the highest points 30 feet above high-water mark. On this flat, first the Moa-hunters, and afterwards their successors, the Shellfish-eaters, had extensive camping grounds. Although in many places the kitchen middens of the older and newer occupants, owing to the changeable nature of the shifting sands, have become mixed up so as in many cases to make it impossible to fix a clear line of demarcation between them; in other instances that peculiarity of the sands has caused them to be very well preserved, and the space between both sets of beds sharply defined. In the first instance we find that the Moa-hunters had numerous cooking places amongst these dunes, situated often closely together, which after use became filled up to some extent by the refuse of their feasts, whilst very often a larger heap of broken bones, eggshells, etc., had been thrown a few feet from the oven. In other instances they show distinctly that before the shell-fish eating population visited this locality, the refuse heaps of the Moa-hunters had already been covered with sand, and became thus protected from their successors. In another spot, without doubt by rain and wind, a portion of the dunes upon which the refuse heap of the Moa-hunters had been deposited, had become partly destroyed. The same spot had afterwards been used as a camping ground by the Shellfish-eaters, their kitchen middens having been thrown over the side into a hollow, thus covering as it were unconformably the former deposits of human occupancy.

Thus also here, the distinction in age and character of the beds under review is well established. My friend the Rev. J. W. Stack to whom I am greatly indebted for most valuable assistance, readily afforded to me during a number of years, in elucidating the ethnological question in respect to former populations, informs us that the native traditions* considered uncertain, ascribe the shell heaps to a tribe Te Rapuwai or Ngapuhi who spread themselves over the greater part of the Island, and

---

* From Traditional History of the South Island Maoris, by the Rev. J. W. Stack, Transactions of the New Zealand Institute, Vol. X., page 61.

that it was in their time, that the country around Invercargill is said to have been submerged, the forests of Canterbury and Otago destroyed by fire, and the Moa exterminated.

From the fact, that events occurring in such distant eras are referred to one and the same people, we can safely conclude that the traditions respecting them are more than uncertain. The shell heaps which can be traced from the mouth of the Waipara to Banks' Peninsula, occur always in the more westerly portion of the sandhills. They exist often in several rows, so as to suggest that gradually as new dunes were formed along the coast, the Shellfish-eaters advanced also with their cooking places, so as not to be too far from the seashore, where they collected their food, and obtained the necessary firewood from the drift timber. That the human occupation of this Island dates back for a considerable period we have another clear evidence in the numerous ovens lining the banks of the old Waimakariri channel, crossed by the Southern Railway line about eight miles from Christchurch. The river at that time was evidently falling into the large lake existing then (Lake Ellesmere extension). The channel in question must have contained a large body of water, or the Natives would not have used it as a favourable camping ground. There are several other localities at the East coast, whence important evidence is offered to us as to the character, and mode of life of the autochthones inhabiting New Zealand during the Quaternary period. In several papers, the results of my researches in the ancient Moa-hunters' encampments on both sides of the River Rakaia near its mouth have been offered to the public (See Transactions of New Zealand Institute, Vol. IV., page 66 and *sequ.*), to which I have to refer the reader, as I can here only give a short *résumé* of the same.

The principal and best preserved Moa-hunter encampment is situated on the northern bank of the Rakaia close to its entrance to the sea, where it is joined by the little Rakaia. The Canterbury plains run here uninterruptedly to the banks of the latter tributary, forming vertical cliffs about 12 feet high, whilst towards the main river they are bounded by two terraces of four and eight feet altitude. This old dwelling place of the Moa hunting population was therefore situated in the triangular space thus formed, and covered an area of more than twenty acres, a portion of the property of Mr Cannon, to whose courtesy and kind assistance during my researches, I am much indebted.

On the lower terrace, proofs of more recent, or as I may term it, Maori occupation are chiefly to be found, but some ovens and kitchen middens of the Moa-hunters occur also there. The principal settlement was however situated about sixty yards from both rivers, and judging from the lines of Moa ovens and kitchen middens, the dwelling places followed the same direction as the terraced ground. The ovens consist in the centre of five to six rows, but near the banks of both rivers they diminish considerably in number. They are either empty or nothing but loess, silt, or vegetable soil lies upon the stones of which they are built up, or they are filled with heaps of broken bones, chips of chert and knives of sandstone, this refuse sometimes also forming heaps in close proximity to the ovens. All these remains are invariably covered by three to six inches of soil having the character of loess. Some of the ovens are of an oval shape eight feet long and five feet broad, others are more circular and about eight feet in diameter. The outer rim is generally built up with larger stones, similar ones fill the interior, piled in four to five layers upon each other, of which, of course, many by the intensity of the heat have been split into angular fragments. From five to eight of these ovens are usually lying together, with intervals of about 20 yards between them and the next group, the ground between them having probably been the camping ground of the Moa-hunters. Here large flat stones, 10 to 12 inches long and six to eight inches broad are also found, together with a longish round boulder also of large dimensions; they were doubtless used for breaking the bones in order to extract the marrow. All these stones without exception, had to be carried from the rivers or sea shore to the plains, and their great quantity testifies that for a long time, this locality must have been a favourite resort of the interesting people inhabiting the country at that distant period.

Proceeding to an examination of the kitchen middens or refuse heaps, we observe that by far the greater portion consists of Moa bones, belonging to several species, identical with those obtained in the turbary deposits of Glenmark. As pointed out in former publications *Meionornis casuarinus* is there the most common species, then follow according to their number *M. didiformis*, *Palapteryx elephantopus*, *Euryapteryx gravis* and *rheides*, all living doubtless in droves, whilst—*Dinornis gracilis*, *struthioides*, *maximus* and *robustus*, mostly represented by a few specimens only, had probably solitary habits. The same rule holds good in the Rakaia kitchen middens, where the more or less frequent occurrence of bones belonging to the different species enumerated above, coincides closely with observations made on the subject in Glenmark. Of the smaller species of our extinct

Avifauna, *Cnemiornis* is also represented by a few bones. We obtained also, bones of *Rallus pectoralis*, *Larus dominicanus*, *Porphyrio melanotus*, *Diomedea melanophris*, *Limosa uropygialis*, and of several ducks. Apteryx bones were missing; but this may be easily explained by the distance of timber covered country from the encampment. A remarkable feature, is the total absence of the bones of the Weka (*Ocydromus australis*), a bird at present found all over the Island in great numbers. This fact is still more striking after the same observation has been made, amongst the kitchen middens in the Moa-bone Cave, and outside amongst the sandhills. Could this bird have been confined during the *Dinornis* era to the forest regions, kept there by the attacks made upon it by the large birds, or was it not yet an inhabitant of this portion of New Zealand?! The different species of seals till now frequenting the coasts of New Zealand, are also represented by a number of bones, so as to prove that they also were used for food. Another interesting fact here, as well as in the Moa-bone Point Cave, is the frequent occurrence of tympanic bones of whales, all belonging to the smaller species living near the New Zealand coasts. These bones are mostly in a fragmentary state, having been broken in such a way, that the interior cavity or lower surface remains intact. It is difficult to understand for what purpose these bones might have been brought up to the encampment. The dog is always represented in these refuse heaps, being in some localities so abundant, that quite a collection of skulls, lower jaws and limb bones, belonging to numerous specimens, mostly of the same size, could be made. This dog is of a size between the dingo and fox, powerfully built, the skull is rather short to its breadth, the canine teeth are generally flatter and sharper, than in the domestic dog, and have in many instances a well defined front and back edge. The premolars in comparison with the molars are much smaller than either fox, dingo, or any of the domestic dogs of which skulls are in the Canterbury Museum. The measurements of the skulls, both from the Rakaia, and Moa-bone Point Cave, agree very well with those of the ancient Maori dog given by Dr. Hector in Vol. IX. of the "Transactions of the New Zealand Institute," page 248.

From the manner the dog bones are broken and mixed with Moa-bones, it is evident that the dog was also considered a favourite food by the Moa-hunters, but it is difficult to believe that it was domesticated by them. Although I have examined thousands of bones collected in these refuse heaps, many of them very minute and delicate, I never was able to find the least trace that they had been gnawed. The same observation was made by me at the Moa-hunter encampment, at the mouth of the Shag river, Otago. Thus, we are compelled to believe that the Moa-hunters only chased the dog then living in a wild state in New Zealand, without having as yet domesticated it. It is difficult to conceive how that animal could have come to New Zealand, unless brought by some vessel and then become feral, as afterwards the domestic pig did after Captain Cook's visit. We know from the researches of Messrs. Lartet and Christy in the caves of southern France, and of the Rev. J. M. Mello in the Robin Hood Cave in Derbyshire, that the European palæolithic hunters had evidently no domestic dog, but in both localities all traces of *canis familiaris* are entirely missing. Admitting the Maori traditions, which state distinctly that they brought the domestic dog (Kuri) with them from Hawaiki, it is evident that these kitchen middens of the Moa-hunters must date back to a period much anterior to their arrival in New Zealand. No human bones were found in connection with these kitchen middens, so that there is strong presumptive evidence for believing that the Moa-hunters were not addicted to anthropophagy.

The number of stone implements and flakes in these refuse heaps, obtained by digging or turned up by deep ploughing all over the field, is very large. Well shaped flint implements are however rare. Some of them are of the palæolithic spear shaped pattern of Europe, others are of the oval shaped hatchet type, others resemble knives, scrapers, awls and saws of the same period. They are all flat on one side, all blows having been struck on the other. The flakes generally having a sharp cutting edge, were doubtless used for the purpose of cutting through the sinews and ligaments of the big birds. They are made of flint, palla, quartz, chalcedony and obsidian. Cores are found sometimes in the same kitchen middens, showing how these flakes were there and then broken off when wanted. The most primitive form of stone implement however, and one of the commonest is the fragment of a hard silicious sandstone broken off with a single blow from a large boulder. The latter was always selected in such a form that, if fractured in the right way, it would yield a sharp cutting edge. These primitive knives are mostly three to four inches long by two to three inches broad, the edges of some of them have been manufactured into a saw by a number of small chips having been taken off on both sides.

In the fine and interesting volume of the "United States Geological Survey of 1872," published by Dr. Hayden there occurs the following passage, page 653, in the article "On Remains of Primitive Art in the Bridger Basin of Southern Wyoming," by Professor Jos. Leidy. "I may take the opportunity of speaking of a stone implement of the Shoshone Indians, of so simple a character that had I not observed it in actual use, and had noticed it amongst the material of the buttes, I should have viewed it as an accidental spawl. It consists of a thin segment of a quartzite boulder, made by striking the stone with a smart blow. The implement is circular or oval with a sharp edge, convex on one side, and flat on the other. It is called a 'teshoa,' and is employed as a scraper in dressing buffalo skins. By accident I learned that the implement is not only modern, as I obtained one of the same character, together with some perforated tusks of the elk, from an old Indian grave, which had been made on the upper end of a butte, and had become exposed by the gradual wearing away of the latter."

The figure of this "teshoa" a name which I wish to adapt for similar stone implements in New Zealand, is so like one of the latter that it would be impossible to distinguish them if placed side by side. At the same time I wish to observe that the description and figures of the flint-flakes, roughly chipped, found in Indian graves, etc., are so much like those obtained in the Moa-hunter encampment that there is no doubt that the former aborigines of New Zealand employed the same mode of manufacture and used the same form of rude stone implements as the primitive races of Europe and North America.

No polished stone implements were found in any of the kitchen middens, but a number were obtained scattered over the fields after the ground had been ploughed. They were mostly manufactured from chertose rocks; Mr. Cannon however found a considerable number together in a *câche* Some of these stone implements are of considerable size and finish, some are partly finished, others only chipped in the form of adzes and chisels. Also a few greenstone (Nephrite) adzes were found in the same field, but as in the kitchen middens of the Moa-hunters never any implement made of that material, or chips, or flakes were obtained, we must conclude that the greenstone was not yet discovered at that time ; it is therefore evident that the few worked Nephrite implements are of later origin, the Maori track for the crossing place of the Rakaia passing over the same piece of ground. Discussions as to the possibility of prehistoric people having both chipped and polished stone implements in use have often taken place in Europe. Judging from the implements of the Moa-hunters it is beyond a doubt that they used both, and thus it can truly be said, that they have lived in a palæolithic and neolithic period combined into one. That in the palæolithic period in Europe, the period of the Mammoth and Rhinoceros, only chipped stone implements were used, cannot be denied; but I think it has been proved beyond a doubt, that also during the neolithic period in Europe, when polished stone implements were used for the purpose of warfare and manufacture, the chipped implements were not discarded, in fact, for many uses the latter were indispensable, as for instance for carving and cutting; in that respect, therefore, the Moa-hunters may fairly be considered as having reached the same stage of advance as some of the prehistoric neolithic people in Europe.

Considering the Moa-hunters from an anthropological point of view, it is of the utmost difficulty, at least for the present, to state with any degree of exactness if they belonged to a race different to the Polynesians, who according to the traditions of the natives now inhabiting these islands, immigrated to New Zealand some six hundred years ago, in a number of canoes, from Hawaiki, or if the mixed character exhibited in the Maoris, has been imported with them, this having been caused by intermixture with Melanesians and Negritos on their advance towards New Zealand. It would be beyond the scope of this chapter to bring all the evidence forward, which has been adduced from both sides to prove the one or the other, some of the principal traditions are however here given The late Rev. Richard Taylor states in the second edition of "Te Ika a Maui" from what he considers reliable traditions, that the Hawaiki immigrants not only found, when they landed on the coast of New Zealand a black (Melanesian) population, but they also discovered kitchen middens with Moa-bones and flint implements." If these traditions can be relied upon it shows at any rate that the black race before the arrival of their successors had been hunting and probably extirpating the Moa. So when relating the tradition of Manaia, Taylor quotes from Sir George Grey:—"When he arrived at Rotuhu, at the mouth of the River Waitara, he stopped there and behold there were people, even the ancient inhabitants of the islands, but Manaia and his followers slew them. They were killed and Manaia possessed their abode, he, his sons, and his people, of those men that Manaia and his followers slew that the place might be theirs." According to Taylor, the same is recorded of Turi who "went on shore and dwelt at Patea and slew the inhabitants thereof" (page 14). This aboriginal race was remembered as the Maero and Mohoao, or wild men of the woods (page 15). Enumerating on page 290, the arrival of the original canoes in New Zealand, he adds a footnote to No. 12 Te Rangi ua mutu, which came to Rangatapu "On the arrival at that place they saw stones like English flints and Moa bones. It is there that I also discovered a large quantity of the bones of the *Dinornis*. The stones were the stone-flakes used as knives which are still there found by the side of the ancient ovens, a proof of their having belonged to a more ancient race than the Polynesian."

The Rev. W. Colenso, F.L.S., in his excellent essay "On the Maori races of New Zealand," Vol. I. Transactions of the New Zealand Institute, on page 394, answers the question, Were there autochthones? —as follows. "Possibly, or rather, very likely—(*a*) From the fact that no large island like New Zealand, however, distant from the nearest land, is uninhabited. (*b*) From the fact, that nearly all the numerous islands in the Pacific, though vastly smaller in size, teem with population. (*c*) From the fact of a remnant, at present existing in the Chatham Islands (the nearest land to New Zealand), of a race which is allowed by the present New Zealander to be truly aboriginal, and before them in occupation. (*d*) From their traditions and fear of "wild men" in the interior. (*e*) From the allusions and even direct statements in their traditionary myths of their having found inhabitants on their arrival in the country, both at Waitara on the west coast of the North Island, and at Rotorua in the interior. But if there were, which appears very probable, they have been destroyed, or become amalgamated with the present race."

So far for the Northern Island. The traditions of the South Island according to the valuable researches of the Rev. James W. Stack, published in Vol. X. of the "Transactions of the New Zealand Institute" are not so distinct, but it is nevertheless evident, that before the Waitaha went to dwell in this Island other tribes of people had been in existence. Mr. Stack calls the traditions concerning the first, fabulous; and the second, uncertain. He states that the Kahui Tipua, or ogre band, a mythical race, are said to have been the first occupants of this land, they are described as giants and sorcerers. They were succeeded by Te Rapuwai or Nga ai tanga a te Puhirire, who have left traces of their occupation in the shell heaps, found both along the coast and far inland. Then follows Waitaha, one of the original immigrants from Hawaiki, the founder of the tribe, who came in the canoe Arawa; he or his immediate descendants peopled the South Island, they are consequently the first inhabitants claiming to have been immigrants from Hawaiki.

It is very peculiar that the traditions of the Kahui Tipua or ogre band, speak only of Weka hunts, whilst the shell heaps, much younger in age than the kitchen middens of the Moa-hunters, are said to have been formed by the second set of inhabitants, Te Rapuwai. Although a number of human skeletons have been found in sandhills, swamps, or covered with a deep layer of soil, having to all appearances been long in the ground, there is no sufficient evidence to conclude that they date back to the time when the Moa was still in existence. There is however, strong probability that the burial place near the Moa-bone Point Cave, described in Vol. VII. of the "Transactions of the New Zealand Institute" was used by the Moa-hunters having their encampment on the other side of the outrunning ridge close by, but there is no direct evidence to form such a connection.

Moreover, the two skulls obtained in this burial place are very defective, and have undergone such prolonged maceration, that they have become much deformed by the weight of the superincumbent soil. However, so much is certain, that they possess some characters in many respects different from true Polynesian skulls. Besides these skulls, the Canterbury Museum possesses several others obtained from similar localities, but unfortunately they are in the same defective state; some of them, are brachycephalic, others dolichocephalic, but all of them of small size, in that respect approaching the Negrito type. The skeletons were, with one or two exceptions, found in a sitting position, the knees close to the chin, and generally having several (mostly three) polished stone implements with them, always placed near the middle of the body. It is evident that the Melanesian or Papuan affinities in some of these skulls must be very great, because this has not only been pointed out repeatedly by some of the most experienced craniologists, but even their being Maori skulls has been denied altogether. In the year 1868, I sent to the late Professor C. G. Carus, two Maori skulls obtained from some sandhills near the Selwyn; but that eminent physiologist upon examining them, informed me that I must have made some mistake, as these skulls could not be of Maori origin, but must have belonged to some other race. Unfortunately, before my answer arrived in Dresden, the illustrious octogenarian had in the meantime passed away, but Professor Leuckart, in Leipsic, was kind enough to compare them with (what he calls) a genuine Maori skull, and has informed me that they cannot be distinguished from the latter. However, it may be possible, that the Maori skull in question when compared with a large series of others, may also prove to be of a different type. When Dr. Filhol, the French naturalist paid us a visit some years ago, he collected a number of skulls in the sandhills, on the east coast of Otago, which are now in the Paris Museum. Professor C. de Quatrefages, another celebrated craniologist, under whose charge that Museum is, informed me, in one of his letters—"Les cranes que nous possedons ont permis d'affirmer la présence d'un élement Papoua parmis les Maoris."

The last, and no mean authority, writing on the subject, is Professor W. H. Flower, F.R.S., the eminent conservator of the Museum of the Royal College of Surgeons, in London. In a lecture lately delivered before the Royal Institution of Great Britain, the following passage occurs, which strongly confirms the opinions of the two former naturalists:—"The Maoris, or native population of New Zealand, if true Polynesians, as is usually supposed, have departed considerably from the Samoan type. They are darker in colour, have usually more curl in their hair, stronger beards, more prominent and aquiline noses, longer heads (the average cranial index of all that I have measured 75), rather lower orbits (89), and slightly wider though still leptorhine noses (47). It is possible that this change of type may have taken place, simply as the result of three or four centuries isolation under different conditions, and is therefore something similar to that which appears to be in process among the English in North America; but it is very suggestive of an admixture of Melanesian blood, as every one of the points mentioned, form an approximation more or less pronounced towards that race. Although it has been doubted by some authors, it is asserted by others, that there are Maori traditions indicating the existence of an aboriginal population, though probably not a numerous one, upon these islands before they were invaded from Rarotonga, in the beginning of the fifteenth century. If this were the case, they were probably Melanesians, and their absorption into the ranks of the conquering race would cause the physical changes noted above." We thus observe that there is a general agreement as to the mixed character of the Maori race, whether the same be based upon an examination of the skulls from ancient graves, or of those of the present population.

There is still another point of considerable importance, to which I wish to draw the attention of the reader, namely—the ancient rock paintings found in many portions of this Island. They prove beyond a doubt, that New Zealand many centuries ago, has been visited by a people having different manners, customs, and religious conceptions, than the Maoris possess. In Vol. X. of the "Transactions of the New Zealand Institute," I have offered a fac-simile and description of those found in a shallow cave in the Weka Pass ranges. From their partial state of preservation, notwithstanding they have been so well sheltered from atmospheric influences, they bear the stamp of considerable age upon them. This conclusion is strengthened by the fact, that a series of newer paintings and of a different character, have at various periods been executed over them. The traditions of the Maoris—who, like everything they cannot understand—ascribe them to the Ngapuhi, a somewhat mythical people. However, the strongest proof of their being foreign to native handicraft, is the character of these paintings, consisting as they do of primitive representations of serpents, lizards, whales, quadrupeds, many of them in monstrous forms, together with drawings of other objects, representing probably weapons, implements or clothing, all of which the Maoris do not possess, nor do they know their use. But the most important portion of these drawings for the elucidation of their meaning, are certain letters or symbolic signs. Being aware that a bronze bell with an ancient Tamil inscription, had been found in the Northern Island, now in the possession of the Rev. William Colenso in Napier, I compared these signs with the letters on the bell, as published with Mr. J. T. Thomson's paper,—"Ethnographical Considerations of the 'Whence the Maori,'" in the "Transactions of the New Zealand Institute," Vol. IV., and found that there was a strong resemblance; I came therefore to the conclusion that these drawings had been made by some people coming from, or having had some intercourse with, Indian or Malayan countries. This opinion was strengthened by an examination of the drawings by the Rev. R. Pargiter, who living for many years in Ceylon, and thoroughly conversant with the Tamil and other Oriental languages, came to the conclusion that although none of the figures have the exact form of any single Tamil character, there is nevertheless a great resemblance. Mr. Pargiter makes however another important suggestion, that some of these so-called inscriptions may be the signatures of the artist, as according to his experience, the Tamil natives have a peculiar way of combining two or more letters to one character, difficult to decipher, except by the writer and those best acquainted with him. Since that account was published, the rock paintings in question have been examined by Mr. A. Mackenzie Cameron, M.S.B.A., Interpreter of Oriental languages to the Government of New South Wales, in Sydney, who has made early alphabets and symbols his special studies. Mr. Cameron after the closest investigation into the subject, has come to the conclusion, that the peculiar figures above alluded to, consisting either of three circles near each other, or two joined circles, the so-called spectacle ornament, are Oriental pre-christian symbols and not letters, and as such, carrying with them the evidence of high antiquity. He considers them to be the Trinity symbol, the pictorial expression of the ancient religious creed of India, and which was carried by the Buddhist Missionaries all over the world. Mr. Cameron states that these symbols are found alike on great Buddhist Temples in India, on the Bhilsa topes, on the standing stone of Aberdeen, and on the Dingwall stone in North Britain.

From a linguistic and ethnological examination of a few words associated with the oldest New Zealand traditions, Mr. Cameron aduces further arguments to associate the so-called mythical races in this Island with some of the oldest inhabitants of India. An examination of similar rock paintings in this Island, not uncommon in some parts in the interior, and a study of their contents, will doubtless throw considerable light on the former inhabitants of these islands, and clear away some of the haze by which the ancient history of the autochthone race of New Zealand has been surrounded.

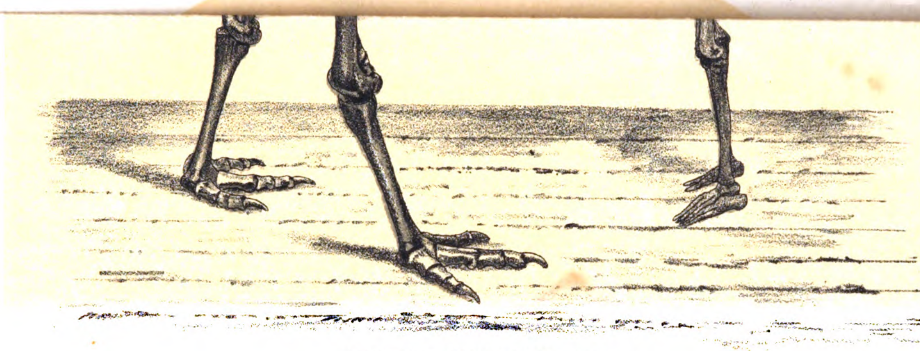
From the material collected in the Moa-bone Point Cave, and at the Rakaia Moa-hunter Encampment, on both sides of the river, and at some other localities, we can form a good conception of the mode of life of the people at that distant time. Owing to the perfectly dry soil in the Moa-bone Point Cave, many objects have been preserved, which, under ordinary circumstances would have decayed. Thus we obtained several portions of canoes, of totara piles belonging to a Wata (provision store), and of spears; their apparatus for obtaining fire, both by circular motion, and rubbing lengthwise, and a fork made of manuka wood. Of smaller or ornamental objects, the following are worth noticing:—the canine tooth of a dog, and some marine gasteropod shells bored at the base, a few pieces of Moa bones, partly prepared for fishhooks, a needle made of the humerus, and an awl made of the distal end of the tibia of *Ossifraga gigantea*, and ornaments made of the humerus of the albatross, probably to be suspended from the neck; also a number of polished and chipped stone implements and flakes were obtained.

To sum up the evidence as to the presence and mode of life of quaternary man in this part of New Zealand, the following points may fairly be considered to have been so far proved:—

1. There existed in quaternary times an autochthone race in New Zealand, having, like the present inhabitants more or less strong affinities with the Melanesian type.
2. This race hunted and exterminated the Moa, including in this native word all the different species of the *Dinornithidæ*.
3. Banks' Peninsula was at that time either an island, or if already a Peninsula, the driftsands now fringing the sea shores north of the Peninsula, were in some localities several miles narrower than they are at present.
4. The quaternary population did not possess a domesticated dog.
5. A species of feral dog was contemporaneous with the Moa-hunters, and was killed and eaten by them. No gnawed bones of any kind were ever found in the kitchen middens.
6. The total absence of any bones of *Ocydromus Australis* (Weka) in the kitchen middens is very striking.
7. The Moa-hunters used both polished and chipped stone implements.
8. They cooked their food in the same manner as the Maoris of the present day do.
9. They were not cannibals.
10. They did not possess implements of greenstone (Nephrite).
11. There are some native traditions, although of a mythical character, that one or several races inhabited this island before the arrival of the first immigrants from Hawaiki, if such an immigration is admitted.
12. A considerable period of time elapsed, as evidenced by an examination of the deposits in the Moa-bone Point Cave, and in some other localities, before the shellfish-eating population appeared on the scene.
13. The kitchen middens of the Shellfish-eaters following a line nearly parallel to the present coast line are also ascribed to have been formed by a somewhat mythical people.

It will thus be seen, that my former views, published in 1871, when these important ethnological questions were first critically examined by me from a geological point of view, have with one exception been fully confirmed by further more extended researches. This exception is the occurrence in Moa-hunter kitchen middens of polished stone

(h)



SKELETON OF
DINORNIS MAXIMUS (OWEN)
with that of a
MORIORI (CHATHAM ISLANDS,)
FOR COMPARISON.

Lyttelton Times lith.

implements, together with chipped ones, a fact proved beyond a doubt, during my excavations in the Moa-bone Point Cave. However, this does not lessen in any way the proofs of their age, because as previously pointed out, well finished polished stone implements have been found at the West Coast, in beds, the great age of which cannot be doubted.

(B) The Dinornithidæ or Moa.

This chapter would be incomplete were I not to offer a few observations on the *Dinornithidæ*, the great extinct wingless birds of New Zealand. It has been the good fortune of the Colony, that some, if not the very first Moa bones discovered in New Zealand, were handed over to Professor R. Owen, F.R.S., the illustrious pupil and successor of Cuvier, and from that date, November, 1839, or for nearly 40 years that great comparative anatomist has continued his work on our extinct *Avifauna*, on the ample material gradually furnished to him from the Colony. The first description was given in the "Proceedings of the Zoological Society of London," for November, 1839. For several years the material accumulated, so that Professor Owen in a paper communicated November 28, 1843, to the same Society could already describe six species, of which *Dinornis giganteus* was the largest, and *Dinornis otidiformis* the smallest, all from specimens collected in the Northern Island. In the course of the next 35 years, twenty more papers on the same subject were published by him in the same Transactions, now dealing however mostly with a number of species of the *Dinornithidæ* and a few other birds, belonging to some other orders, all having been obtained in this (the South) Island.

Mention must here, however, be made of an important paper published in the "Annals and Magazine of Natural History" of August, 1844, written by the Rev. W. Colenso, F.L.S, who as far back as 1838, began to devote much attention to our extinct *Avifauna*. It bears the title, "An account of some enormous fossil bones of an unknown species of the class *Aves*, lately discovered in New Zealand." In this interesting paper the writer gives some valuable information and correctly places the fossil bones closely to Apteryx.

The following species were described by Professor Owen, from this Island*:—

		Average height.
Dinornis	maximus	10 feet 6 inches.
„	robustus	8 „ 6 „
„	ingens (Palapteryx) ...	6 „ 0 „
„	gracilis	5 „ 3 „
„	struthioides	5 „ 6 „
„	casuarinus	4 „ 10 „
„	didiformis	4 „ 2 „
„	elephantopus	5 „ 4 „
„	crassus	4 „ 2 „
„	gravis	4 „ 6 „
„	rheides	4 „ 2 „
„	geranoides	

Dinornis giganteus, *dromioides*, and *curtus* described from bones, obtained in the Northern Island, have hitherto not been found in this Island, where they are doubtless represented by nearly allied species. There are still several species of the *Dinornithidæ* of both Islands, mostly of small size, still undescribed, of which, however, the Canterbury Museum possesses only single bones.

Besides these struthious birds, remains of some other remarkable birds contemporaneous to them and of considerable size, when the orders they belong to, are taken into account, have been discovered with them. The following were described by Professor Owen:— *Rallidæ*: *Aptornis otidiformis*, *Aptornis defossor*, *Notornis Mantelli*, the latter said to be still living in the south-west corner of this Island in mountainous regions, *Anatidæ*; *Cnemiornis calcitrans*†

To complete this list, mention has here to be made of a gigantic raptorial diurnal bird, of which, two species were discovered in the turbary deposits of Glenmark. They were described by me in Vol. IV. and VI., of the "Transactions of the New Zealand Institute," as *Harpagornis Moorei* and *assimilis*. I may however mention as already

* The different sizes added, represent the mean height of a number of specimens of each species in the Canterbury Museum. All these species with the exception of *geranoides* have been found in this province.

† Dr. Hector, F.R.S., in Vol. VI., of the "Transactions of the New Zealand Institute" has given also a description of this species, at the same time pointing out its anserine cha racter.

stated in the second memoir, *H. assimilis* may probably be the male of *H. Moorei*, a point which the scanty material at my disposal, would not allow me to settle satisfactorily.

There are still some naturalists who think that the division of the bones of our extinct *Avifauna* into so many species is a mistake, and that future researches will prove that what appeared to Professor Owen as several well-defined species, were after all, only various stages of age and growth of one and the same kind. However, in this respect, the collections of the Canterbury Museum bear a strong confirmation of the correctness of the great English anatomist's conclusions. We possess, not only young bones of each species, from the chick to the full grown bird, where—to take only one bone as guide—the tarsal epiphysis of the metatarsus is not yet quite anchylosed,* but we have of each species a series of specimens of generally two well distinct sizes, from which we may conclude that they represent the male and female bird of such species. In some instances, we possess four distinct sizes, which might represent the two sexes of two distinct but closely allied species.

Referring to the list of species, it will be seen that Professor Owen includes all the *Dinornithidæ* under one genus *Dinornis*, and abolishing even his former genus *Palapteryx*, thinking that the back toe (*Hallux*) was only a small functionless appendage to the foot. Although I was of opinion that the back toe might prove a good distinctive character for the grouping of the different genera, there seems, judging from the discovery during the last few years of several nearly complete skeletons in Otago and Canterbury, all probability that Professor Owen's views on that point are correct. However, I believe there exist many more distinctive features of great usefulness for the separation of the principal groups, and that my attempt in 1874 to make such divisions, is a step in the right direction. I then proposed the following sub-divisions:—*A.* family *Dinornithidæ*; *a.* genus *Dinornis.* 1. *Dinornis maximus.* 2. *Dinornis robustus.* 3. *Dinornis ingens.* 4. *Dinornis struthioides.* 5. *Dinornis gracilis*; *b.* genus *Meionornis.* 1. *Meionornis casuarinus*; 2. *Meionornis didiformis.* *B.* family *Palapterygidæ*; *a.* genus *Palapteryx.* 1. *Palapteryx elephantopus.* 2. *Palapteryx crassus*; *b.* genus *Euryapteryx.* 1. *Euryapterys gravis.* 2. *Earyapteryx rheides.*

* We possess amongst others, the leg bones of a specimen of *Dinornis maximus* which is in size only second to the largest bones we have, but in which this immature character in the metatarsus is not yet quite effaced.

Anybody examining the skeletons of the different species ranged under the proposed genera, will at once admit that they have many natural and distinct characteristics in common, separating them at once from the other proposed genera. Professor Owen, in his last Memoir (XXI), has drawn attention to the generic sub-divisions of the *Dinornithidæ* as proposed by Reichenbach in an excellent work "Das natürliche System der Vögel," 4to, 1849 and 1850. I wish however, to point out, that when Reichenbach published his work, comparatively little was known of the osteology of the *Dinornithidæ*, the third memoir of Professor Owen having scarcely been printed. Consequently the eminent German ornithologist had not material enough upon which to place a sound basis for his proposed sub-divisions, and I am convinced that otherwise, they would have been somewhat different, and more in accordance with the genera into which the *Dinornithidæ* have naturally to be classed. Thus instead of separating *D. giganteus*, *struthioides* and *ingens*, into three genera, he would certainly have united them, they having all three some of the principal characters in common. The same can be said of *D. didiformis* and *casuarinus*. However, as more facts are gathered, more light will be thrown on this question, which after all is of minor importance, and only a matter of opinion till a still larger number of complete skeletons have been secured.

Professor Owen having described at some length in several of his memoirs on *Dinornis*, the affinity our struthious birds bear with those of other countries, and having pointed out at the same time, the peculiarities in which they vary from them, it would have been unnecessary for me to add anything to the subject, had not the attempt been lately made by Professor Alphonse Milne-Edwards, in Paris, to show from a comparison of the remains of the extinct ornithic fauna exhumed in Madagascar, Mauritius, and Rodriguez, that in some distant ages New Zealand formed portion of a large continent or of a group of more or less extensive islands in the Southern Hemisphere, which at one time were in some way connected with each other.

He thinks that additional confirmation can be obtained from the ascertained occurrence of different *Ocydromidæ*, such as the *Aphanapteryx* and the *Miserythrus Leguati*, which latter, he informs me (letter to me, dated Jardin des Plantes, Paris, Aug. 3, 1873), bears close resemblance to our common woodhen (*Ocydromus Australis*). However enticing the tracing of close affinities must be to the naturalist-philosopher, I believe, that it would be rather rash to conclude the connection of two such distant insular groups from a few forms of birds only. Leaving the general question alone for the present, to which I shall return shortly, it is impossible for me to conceive that two countries, which in all other respects have such a dissimilar and distinctive flora and fauna could have been united in any way, without having left other living proofs of such connection in their present endemic organic life, not to speak of fossil remains. We know that Madagascar is a zoological sub-province of South Africa (Ethiopian region), but that it has a fauna so peculiar, that it must have, according to Sir Charles Lyell, been separated from Africa probably since the Upper Miocene era. New Zealand, on the other hand, although it may have been formerly of larger extent, has never been more than an oceanic continental island from a zoological point of view, a theory first propounded by Darwin and Wallace, and with which I fully agree. It would be a rather difficult task to prove upon such slender grounds as the presence of a few species of struthious and ralline birds may afford, that both countries might possibly have been connected. Moreover, the difference in the anatomical structure of the three Madagascar species of *Aepyornis* and of the New Zealand *Dinornithidæ*—using this latter term in a general sense—is so enormous that I fail to see how they possibly could prove that connection in any way.

I cannot agree with Professor Alphonse Milne-Edwards, that the *Aepyornis* stands nearer to the *Dinornis* than to the Ostriches, Casuaries and Emus, except in so far that the fossil bones of Madagascar and New Zealand have a more pachydermal type, than the living species above-named. But I may point out, that the fossil *Dromornis Australis* of Australia shows similar characteristics, and I am sure if fossil remains of struthious birds in beds of post-pliocene age were discovered in Africa, America, and Asia that they would exhibit a similar pachydermal character. Judging from Professor Milne-Edwards' own excellent memoirs on the *Aepyornis* and the fine casts of the unique fossil bones in the Paris Museum, he was good enough to send to the Canterbury Museum I am unable to trace their relationship with our *Dinornithidæ*. It appears to me that the Madagascar species are separated from the former by many fundamental differences, such as (to point out only a few) the pneumatic foramen in the femur and the straightness of the trochleæ of the metatarsus. And although I am convinced that the struthious character of *Aepyornis* has sufficiently been proved by the eminent Paris comparative anatomist, I can easily understand that there was at first some show of reason for placing it amongst the sarcoramphous vultures, as has been done by Professor Bianconi.

However, speaking of the principle itself, I wish to point out, if we were to decide from a few isolated species in two distant countries which show some or even a close resemblance to each other, that these countries must have once been connected in some way, we should in many instances form erroneous conclusions. We might as well say, that because there are struthious birds in Australia, the Malay Archipelago, Africa, America, and Asia, all these countries have been connected with New Zealand, or because marsupial remains have been found in secondary rocks in Europe and several species of opossums are living in America, these countries had also been united with Australia.

Speaking from a general point of view, I wish to add, that the attempts to trace the geographical relations of the fauna and flora of a country can easily be exaggerated, and thus a theory be ridden to death which otherwise would be very useful. Can the explanation of any specific resemblance in two distant countries not be found in many instances at least, in the adoption of more simple natural causes, such as the transport by icebergs, or on floating islands, by birds, etc., and of which Sir Chas. Lyell, in his great work, the "Principles of Geology," gives many striking instances? However, where the theory of land connection is not admissible, and where also others, which have hitherto been applied, fail, might we not assume that similar climatic and other physical conditions could produce similar specific characters under the great law of evolution? It is a most difficult problem to say what constitutes a species, and therefore might it not be safer to believe until the impossibility of such an hypothesis has been demonstrated satisfactorily, that there exists a similitude as well as an identity of species under certain given conditions. In one word, might we not throw out the conjecture that in two more or less distant countries which never were directly united, some forms of organic life can and do exist, which show what to us appears identical specific characters, because the cause or causes of their evolution were identical or nearly identical, and thus a considerable number of supposed changes in the level of many countries of which we do not find geological records, can be dispensed with. It is true, that instances to be explained by the migration or accident theories are of more frequent occurrence and more easily proved, but I think it would be just as interesting, where these cannot be admitted, to trace in all its bearings the similitude of species in distant countries. This view would, at least, open up a field of fresh research, and afford a new illustration and confirmation of the great theory of evolution.

(C) Occurrence of Moa-Bones and Time of Extinction of the Dinornithidæ.

In the previous chapter I have already pointed out, that the oldest beds containing Moa-bones, are proved to belong to the Great Glacier period, where they occur in morainic accumulations and silt-beds as well as in fluviatile deposits, formed by rivers having issued from the terminal face of gigantic glaciers during that period. Here they have been traced as low as 100 feet below the surface. In the loess deposits they are also of frequent occurrence where their existence has been proved to a depth of more than 50 feet. Advancing to the quaternary period Moa-bones are found in turbary deposits or in silt or loess on the plains or lower hills, in caves and in fissures of rocks, in fact everywhere where favourable conditions for their preservation prevailed. In common with all those colonists arriving in New Zealand, after Moa-bones had for some time been discovered, their nature investigated, and the knowledge thus obtained spread throughout the country, I was under the impression that the extinction of the Moa by the hand of man was rather of recent occurrence, till geological research has shown me clearly that such an impression is totally fallaceous. In my Presidential address to the Phil. Institute of Canterbury, of 1871, I ventured first to give my views on the subject, and a continuation of further researches has not only strengthened the foundations upon which my reasoning was based, but I am happy to say has been the cause of bringing out a series of papers, either against or in support of my theories, and containing much important matter, which when once sifted will be of great value from an ethnological point of view for all time to come. It would be impossible to go over the whole question in this chapter, or even to review the principal papers written on the subject, which would fill several good sized volumes, and I have therefore only prepared a short *résumé* tracing the gradual knowledge obtained—in chronological order. The reader can then judge by himself, how far the theory advocated by me has any claim for acceptance.

The first publications in which we find ample material concerning these Islands are those relating to the voyages of the illustrious Captain Cook. That admirable observer, who gives us such a faithful account of the animal life of New Zealand, made enquiries, through his interpreter Tupia, during his first journey, concerning the native traditions. On his second visit he obtained further intelligence from a native Chief, in Queen Charlotte Sound, given in the "Voyage to the

Pacific Ocean," Vol. I, Page 142, in the following words. "We had another piece of intelligence from him (Tawaihurua) more correctly given, though not confirmed by our own observations, that there are snakes and lizards there of enormous size. He described the latter as being eight feet in length, and as big round as a man's body; he said they sometimes seize and devour men, that they burrow in the ground, and they are killed by making fires at the mouth of the holes. We could not be mistaken as to the animal, for with his own hand he drew a very good representation of a lizard on a piece of paper as also of a snake, in order to show us what he meant." It is strange that so close to the Wairau plains where Moa-bones have repeatedly been found, the Maori chief should not have made mention of a still more wonderful animal, a bird of such gigantic size as the Moa was, and we must therefore conclude that it was not an oversight on his part, but simply a want of knowledge. Passing over the publications describing the visits of Captain Vancouver, Admiral d'Entrecasteaux, and Captain King in which no trace of any traditions concerning the Moa can be detected, we reach the time when the Northern Island was chosen as a field for missionary work, during which extensive travels were made by the missionaries and their friends in various directions. A series of books full of valuable information were published during a number of years on New Zealand, giving the results of the researches of these hardy and intrepid pioneers of civilization—researches the more arduous as they had to combat the damaging influence of some of the lowest European outcasts then living with the natives. We owe some other valuable publications to the fate of castaway sailors, who were compelled to stay a number of years amongst the tribe to whom they owed the preservation of their lives.

The first of the former works with which I am acquainted is a "Narrative of a voyage to New Zealand during the years 1814-15 in company with the Rev. Samuel Marsden" by John Liddiard Nicholas: London, 1817, 2 vols. Although Mr Nicholas has collected many native traditions, speaks of the natural history of the country, and has travelled from the Bay of Islands as far as the Thames, the former existence of a large bird or even the word Moa is never mentioned.

The next publication to which I wish to refer is Professor Lee's "Vocabulary of the Maori language" published in 1820. The Cambridge Professor obtained the necessary material from several intelligent missionaries, but principally from personal intercourse with the great Maori chiefs Hongi and Waikato, then residing in England. If the term Moa did not exist in this vocabulary we might assume that it had been overlooked by these Maori chiefs, both of the highest rank, and therefore well versed in the traditional lore and the natural history of their country, but the word is correctly given and explained to mean "a stone, also a name of a person, and of a place." Will it not appear to the unbiassed and unprejudiced reader a very strange occurrence, that the two great Maori chiefs should have failed to give to their European inquirers, at least some account of the remarkable traditions of these wonderful birds, had they known anything about them?

Lesson (Voyage autour du monde de la corvette *La Coquille Zoologie*, page 418, Paris, 1828) speaks of the occurrence of the Kiwi* in the following words :—"Les naturels nous parlèrent fort souvent d'un oiseau sans ailes dont ils nous apporterent les debris qui nous parurent celles d'un Emou. Les naturels chassent ces oiseaux avec des chiens et les nomment Kiwi-Kiwi. Nous ne doutons point aujourd'hui que ce soit l'Apteryx Australis de Shaw." Nobody will accuse me of special pleading if I ask why the natives did not bring any Moa-bones to the French Naturalist so eager to obtain those of the Kiwi, if they had known of their existence or at least recognized them as bird bones.

The next work "The New Zealanders" published in the "Library of Entertaining Knowledge," in 1830, contains principally the adventures of John Rutherford, who stayed about 10 years, from 1816 to 1826, amongst the New Zealanders, as a prisoner. He is described in the Work as "evidently a person of considerable quickness and great powers of observation" (page 278) and having been made a Chief, travelled with his tribe in many directions, and although he gives some interesting notes on native traditions, and the natural history of New Zealand, no mention is ever made of the Moa.

"An account of New Zealand," by the Rev. William Yate: London, 1835. This missionary who stayed a number of years in New Zealand, and made considerable travels in the Northern Island, gives copious notes on the Botany, Zoology, including an account of the Kiwi, but no mention is made of the Moa. We arrive at last to the first work, that of J. S. Pollock, who resided in New Zealand, between the years

* I may here mention that the first Kiwi skin was brought to Europe in 1812 by Captain Buckley of the *Providence*.

1831 and 1837, in which a gigantic bird, said to exist, is first mentioned. When speaking of the Kiwi, or as he calls it the Kiwi-Kiwi, the following two passages occur:—"That a species of the Emu, or a bird of the genus *Struthio*, formerly existed in the latter (northern) island, I feel well assured, as several large fossil ossifications were shewn to me, when I was residing in the vicinity of the East Cape, said to have been found at the base of the inland mountain of Ikorangi. The natives added that, in times long past, they received the tradition, that very large birds had existed, but the scarcity of animal food, as well as the easy method of entrapping them, had caused their extermination." —Vol. I, page 303.

"I feel assured, from the many reports I received from the natives, that a species of *Struthio* still exists on that interesting island (the South island), in parts which, perhaps, have never yet been trodden by man. Traditions are current among the elder natives, of Atuas, covered with hair, in the form of birds, having waylaid former native travellers among the forest wilds, vanquishing them with an overpowering strength, killing and devouring, &c. These traditions are repeated with an air of belief that carries conviction to the younger natives, who take great delight in the marvellous and improbable."—*Ibid.*, page 307-8.

It will be observed, that also here the word Moa does not occur, and that the traditions quoted are more or less of a fabulous character. About the same time several missionaries, the Reverends William Colenso F.L.S., Williams, Taylor, and some others, began to collect Moa-bones in the North Island, mostly washed out from the banks of rivers, but, according to the Rev. W. Colenso, a close observer, never thought by the Maoris of that time (between 1836 and 1840) to be those of a bird.*

Gradually, the so called Maori traditions have been growing from the few fabulous legends—such as for instance, that of a huge bird with the face of a man, that it lived on air, and had wattles (according to the Rev. W. Colenso)—to those more or less circumstantial accounts of which the latter volumes of the New Zealand Institute contain so many versions. An eminent student of Maori lore who for the present does not

* "Believe me no Maori of thirty or thirty five years ago ever once supposed the Moa-bones to be those of a bird, they always obstinately denied it. That they have since done so is entirely owing to the Pakehas (letter to me dated Napier, July 13th, 1871.)"

wish to enter the arena, tells me that "this can easily be explained by the old rule of Maori etiquette, viz. of commonly assenting to leading questions, especially when asked by a superior, and indeed such was often done, to put a stop to importunity." The South Island has always been pointed out as being the last refuge of the Moa, but both the Rev. I. F. H. Woehlers, of Ruapuke, and the Rev. James W. Stack, as well as Mr. Alexander Mackay, Native Commissioner, who all three for many years past, enjoyed excellent opportunities of obtaining accurate information from the natives, and have been collecting most carefully their traditions, have shown that with the exception of a few fabulous allusions, nothing whatsoever is known of the Moa by the natives.

Similar fabulous traditions exist according to the late Mr Sherbrook Walker, in the Friendly Islands, of an enormous bird and gigantic lizard, a small hill in the Island of Eua being still called Te Moa (Moa dung). Also in many other countries, such mythical allusions to extinct gigantic animals are not wanting. of which I may be allowed to quote here a few in illustration. Commencing with Australia, Dr. S. Bennett gives an account of the natives about the Diprotodon in the "Annals and Magazine of Natural History" for April, 1872. In Buffon's "Natural History" we find several traditions of the North American Indians about the Mastodon. Similar traditions, according to Pallas, exist in China and Tartary, of the Mammoth, and Dr Otto Finsch, who only lately has returned from a journey through Siberia, collected several fabulous legends concerning the same gigantic animal from the Ostiacs. In several of my papers treating of the Moa question I have explained how we may account for the freshness of some of the Moa bones, and how even the skin, sinews, and feathers could be preserved. In most cases this explanation was an easy one, either the geological position of the bones showing their undoubted age or one portion of the very same individual bird being quite as much decomposed as the generality of the Moa remains are, whilst the other is in a remarkably fine state of preservation (as for instance the Tiger Hill skeleton in Otago), or some very favourable and exceptional circumstances could be pointed out, to which the Moa-bones owe their remarkable preservation. In the same publication, I have also given some examples from other countries, proving how the remains of animals doubtless extinct for a great number of years, have under the same favourable conditions been preserved in a striking manner, to which I wish to refer the reader. Since then another and most wonderful instance has been recorded in a paper, "L'age du Renne en Maconnais—Memoire sur le gisement archéologique du clos du charnier à Solutré, Departement Saone et Loire, par H. de Ferry and A. Arcelin, read at the third meeting, August 28th, 1868, of the International Congress of Prehistoric Archœology, at Norwich, published in Vol III of the Transactions of that Meeting, page 319, and *sequ.* In the kitchen middens of the prehistoric people at Solutré who killed and ate the mammoth, reindeer, and horse, the bones were found in such a perfect state of preservation that they might be taken for fresh. Here is the principal passage having reference to it, page 328 : "à part quelques os brûlés, formant un résidu noir et cendreux tous les débris d'animaux sont comme nous l'avons déja dit, d'une conservation étonnante. On pourrait les croire frais, certaines cornes de renne sont encore extrêmement dures, et dégagent quand on les travaille, l'odeur de la corne fraîche. Les os fragmentés ont concervé une quantité considerable de leur gelatine."

As these kitchen middens date back to a period when quite other meteorological conditions existed in Central Europe, when a fauna different from the present, and containing the mammoth, the reindeer, the horse and some others, now mostly extinct, peopled that country, and served as food to a prehistoric race many thousand years ago, I need scarcely dwell any longer on the subject, the more so as some of the best preserved Moa-bones, with skin, sinews, and feathers found in the Earnscleugh caves were accompanied by the bones of the *Anas Finschii*, an extinct duck having considerable affinities with the miocene *Anas Blanchardii* of France. As that duck has well developed wings, its extinction cannot be traced to the hand of man, or other recent causes, but must be referred to others obtaining in an era far antecedent to ours. I have added to the illustrations a photolithograph of *Aptornis otidiformis*, a skeleton of a gigantic Rail, standing two feet seven inches high, and a lithograph of a fine skeleton of *Dinornis maximus*, ten feet six inches high, with the skeleton of a Moriori, from the Chatham Islands, for comparison at its side. These three skeletons are preserved in the Canterbury Museum.

(D) Glenmark.

This chapter would be wanting in completeness, did I not offer a few notes on the now farfamed locality Glenmark, the property of my friend Mr G H Moore, to whose generosity Science is deeply indebted for the invaluable collections of dinornithic remains, forming the pride and chief attraction of the Canterbury Museum. Glenmark is doubtless the spot which has furnished the largest quantity and variety of Moa-bones. These have been made available for the elucidation of the anatomy of these wonderful struthious birds, and a large number of Museums all over the World have received representative collections from the same source. Owing both to the fact that Moa-bones occur in beds of greater age close to these turbary deposits, and that their relative positions can easily be traced, Glenmark offers at the same time, a favourable spot to prove first, that there is no difference in the osteological characteristics of all the species and sub-species, whether they occur in the upper and lower beds, and secondly that all the different species, as it were, have appeared together, and have afterwards become extinct about the same time.

A small water-course, the Glenmark Creek, flowing in a nearly north and south direction, joins the Omihi a few miles above its junction with the Waipara. The alluvial deposits of the Omihi having thrown a bar across the valley of the Glenmark Creek, here at one time a lagoon about half a mile in length was formed, which in course of time was filled up by turbary accumulations. It is in these deposits that the principal stores of dinornithic remains have been preserved. The valley has here an average breadth of a quarter of a mile, gradually widening till the termination of the broad outstanding ridge between the two valleys is reached. From here the Glenmark Creek flows across the alluvial deposits of the Omihi. Above the Glenmark station the valley by degrees contracts, and the water-course flows in a narrow channel either cut in limestone rocks or in post-pliocene alluvium, the latter about a mile above the home station being about 70ft thick. Here in several spots Moa-bones, generally in a fragmentary condition are not unfrequent, covered at least with 60ft of subangular river shingle. I collected here the remains of a number of species including *D. maximus*, *elephantopus*, and *didiformis*, together with a few bones of *Aptornis* and a fragmentary humerus of *Harpagornis*. The occurrence of such a variety of forms proves beyond a doubt that even during the Great Glacier period, all the species were already existing. The bones from this deposit are very heavy and impregnated with carbonate of lime.

A quarter of a mile lower down the creek, another section is exposed in a nearly vertical cliff, on the left bank. It consists in descending order of 16 feet of sands, often very ferruginous, repeatedly alternating with layers of river shingle, mostly of small size.

2 feet layer of sandy peat, much compressed
3 „ ferruginous sands, sometimes argillaceous
3½ „ river shingle, with a ferruginous matrix
4½ „ argillaceous sands
4 „ river shingle, rather coarse

This lowest bed reposes on bluish micaceous sands, belonging to the Pareora formation, and dipping 14 degrees to the south by west. In the peaty layer the bones of a skeleton of *Palapteryx crassus*, were lying together. We were able to extract many of the principal ones but several of them were either broken, or had become flattened by the superincumbent weight of the strata. Descending the creek towards the Glenmark Station, and approaching the spot, where the turbary deposits have yielded the great harvest of Moa-bones, we find that the valley has enlarged to a breadth of nearly a quarter of a mile. Here the creek makes a sharp bend, flowing nearly at right angles to the direction of the valley, from the eastern to the western side, and exposes a fine section (No 8, on plate 9) exhibiting the following beds in descending order.

No. 1. 8 feet of Loess
„ 2. 4 „ of small river shingle consisting of palæozoic sandstone and old tertiary limestone
„ 3. 1 „ of sandy silt
„ 4. 6 „ of small river shingle, well stratified
„ 5. 1½ „ of peaty layer, containing a great number of Moa-bones
„ 6. 10 „ of river shingle cemented together by a ferruginous matrix

The lowest few feet cannot be observed as they are covered over by recent accumulations, and a talus from above. All these beds have a dip of about seven degrees, towards the centre of the valley, where the inward dip ceases, so that they appear to be horizontal. There is however a small inclination down the valley. Nos. 3, 4, and 5, are here of much broader dimensions, the peat bed No. 5 being nearly three feet thick. In the last mentioned layer, we obtained not only nearly every species of the *Dinornithidæ*, but also a few remains of *Cnemiornis* and *Aptornis*, together with a broken femur of *Harpagornis*. The bones are all very heavy and fossilized from calcareous matter filling the pores, consequently they are very different in character, from the bones occurring in the turbary deposit lying on the top of the banks, about one hundred yards lower down the valley. This is the more important, because the bones in both beds belong all to the same species notwithstanding their great difference in age. Section No. 8, on plate 9, gives the details of the relations of these deposits to each other.

Close to the bend of Glenmark Creek, a small rill, now scarcely containing any water, comes down from the outrunning ridge here about 200 feet high, bounding the valley on the eastern side. It has a very short course, its source being on the summit not far off. This rill however, instead of falling into the creek, loses itself in the swampy ground on the top of the terrace, where doubtless a lagoon of considerable extent existed, before the turbary beds were formed. It is evident that a long lapse of time has been necessary to fill this pre-existing hollow with turbary deposits, and other material brought into the lagoon, and that during all that time the deposition of Moa-bones went on at intervals. I do not know if Moa-bones are found all over the bed of this former lagoon, many acres in extent, but as far as I have examined the deposits over an area of 500 feet in length, by 200 feet in breadth, they occur mostly in patches. The most important fact in connection with the remarkable accumulation of dinornithic remains in this locality is their occurrence along the small rim of water previously alluded to, to the height of more than 20 feet above the surface of the turbary deposits, where it forms a broad swampy delta. We dug here in several localities and found invariably in the lower portion of the peat, large stems of trees mostly white pine, so soft that the spade cut easily through the wood, together with Moa-bones, but although the latter in not a single case were rolled, those of a complete or even nearly complete bird were never found lying together. It is thus clear that the bodies of the birds which perished here in crossing were only partly retained, partial decomposition having freed some of the bones, which either were taken lower down the Creek, or found a resting place in the lagoon.

Where the small water-course enters the valley there was sometimes quite a network of timber, often of very large size, lying on the bottom. Covered by these trees or retained amongst them the dinornithic remains were of frequent occurrence. In some few cases the three principal leg bones with the pelvis and one or two dorsal vertebræ were found together in their natural position, the great mass consisted however of odd bones belonging to all known species, and to individuals of all sizes from the chick to the aged bird, brought there by freshets from what may have been the crossing place a little higher up. This small creek in all its ramifications and with its deposits has been traced for a considerable distance during my excavations, and it has been found that the floor of the former lagoon was very uneven, so that even near the centre, the bottom clay beds rise sometimes to the surface. It is near these localities where the greatest harvest of Moa-bones was made, the carcasses or portions of birds having evidently been washed here against the banks and deposited in considerable quantities. I may here add that in that portion of the turbary deposits examined by me, the upper portion consists generally of from 4 to 7 feet of black peat, very pure and scarcely mixed with any other matter; below it 2 to 3 feet of more impure peat follow, reposing on a clay bottom. These lower peat beds have a somewhat reddish hue—principally when large quantities of Moa-bones are imbedded in them. They contain also large quantities of flax leaves, seeds, and stems of Raupo, and pieces of drift timber of various kinds. There are however other spots situated in several directions amongst the turbary deposits explored, where other causes have been in operation to form also considerable accumulations of dinornithic remains.

If we consider the nature of such a swamp as the Glenmark valley must have possessed at one time during the Moa age, there is all probability that it resembled closely some still at present in existence in New Zealand, where amongst the more solid ground already formed a great number of deep water holes are scattered over its surface. These deep stagnant pools, as ample experience has shown, are very dangerous to cattle and horses. When once a beast has fallen into them, there is no chance for it to escape from drowning. It is evident, looking at the physical features of the country, that the Moas had in this neighbourhood one or several crossing places to go from one side of the valley to the other, where a rich vegetation on the low ranges offered them doubtless ample food. Occasionally during this crossing one bird or another may have fallen into the water holes, and it would also not be too hazardous to assume that, when from some cause or other, a drove of Moas took fright, they have been driven or rushed across the same locality, where in their headlong course a great number of them may have perished in the same manner; the confirmation of such an hypothesis is furnished by the fact, that over the whole area under consideration are found what may be called regular nests of Moa-bones; bones of 20 to 30 individuals of all sizes and ages are lying together closely packed in spots about five to six feet in diameter, whilst all around for some distance not a single bone is found. Moreover all the bones of the individuals perished in that particular spot, are found there together, and I was sometimes enabled to extricate with some care the greater portion of the same skeleton from the closely packed mass of the bones. These nests were consequently very different from the larger deposits, where to all appearance generally only portions of the carcasses had been drifted together.

It is impossible to give even approximately a number of the individuals, of which the skeletons have been preserved to us in these remarkable turbary deposits. Naturally, we obtained only a very small portion of the bones over that portion examined by me. A great number of them have of course decayed, others have been deposited at so great a depth that they were inaccessible, the turbary deposits being in many localities of such considerable thickness, that although a number of deep drains have been cut, we were not able to reach the lowest layer, usually containing the Moa-bones. However it is certain, that the number of specimens here imbedded must have reached a thousand, if not more. In Vol. I of the Transactions of the New Zealand Institute, I have published a list, giving the numbers of complete sets of leg bones, to all appearance having in each case belonged to the same individual, giving a total of 144 adults, and 27 young birds. This list included Mr. Moore's donations, and the results of my excavations up to the 15th February, 1868. However after that period, the largest excavations yielding most abundant material were undertaken, of which hitherto it has not been possible to draw up a full account. From that former list it appears that *Meionornis casuarinus* was the most numerous, forming more than a fourth, while *M. didiformis* represented more than a fifth of the total. They were followed by *Palapteryx elephantopus*, *Euryapteryx gravis*, *P. crassus*, and *E. rheides*. The smaller genera of *Dinornis* proper, such as *gracilis*, *struthioides*, together with *maximus*, *robustus*, follow next in number, *D. ingens* being represented only by a few individuals. Although unable at present to give even approximately the number of individuals obtained in the later and more extensive excavations, the proportions of the different species to each other agree in a general way with the published list.

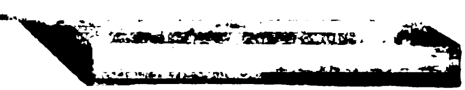
We obtained of smaller species, during the former and more recent excavations, remains of five to six specimens of *Aptornis*, a few bones of *Cnemiornis* and of *Anas Finschii*, and portions of a skeleton of

Harpagornis assimilis. Of species still living in New Zealand, *Apteryx australis* and *Oweni* and *Nestor*, were represented by several individuals, together with a few bones of several of our aquatic birds, and a lower jaw of *Sphenodon punctatum.*

Opposite to these large turbary deposits on the right bank of Glenmark Creek a small water-course joins the latter, the banks of which for some hundred yards above its junction consist also of similar turbary beds, in the average 50 feet wide. In draining this creek it was found that these beds were of a depth of 8 to 12 feet, their lower portion being largely mixed with drift timber, and containing also a very considerable number of Moa-bones. The excavations in this locality gave also splendid results, and the same proportions as to the frequency of the different genera and species observed on the other side obtained also here. However the most remarkable discovery made consisted of the bones of *Harpagornis Moorii*, so named in honour of Mr G. H. Moore, the owner of Glenmark, proving that contemporaneous with the Moa a huge bird of prey existed closely allied to *Circus* and doubtless acting as scavenger, if not feeding on the young and enfeebled old birds.

Professor Owen in his XXI Memoir on *Dinornis* quotes Professor Cocchi's opinion that *Dinornis crassus*, *elephantopus*, *giganteus* (*var. robustus*) and *Dinornis ingens* belong to the neolithic or recent period, while at the same time that illustrious English comparative anatomist thinks, "that certain remains from the fluviatile deposits in the North Island representing the species *Dinornis giganteus*, *ingens*, *struthioides*, and *didiformis*, of a heavier and less recent character than the bones from the South Island, have come from birds which lived in post-pliocene, quaternary, or even earlier times."

The turbary deposits of the South Island being so very rich in Moa-bones, it has been found far easier, and more expedient to send to England large collections made amongst them, than from the glacier or older fluviatile deposits. The bones found in the latter two deposits in this island are in the same if not sometimes more fossil condition, than those from the Northern Island, collected in similar beds. I have examined a whole series of Moa-bones from the Northern Island, obtained from sand-hills, kitchen middens and turbary deposits. They are quite similar in preservation to those collected in this Island from beds of the same character. The Glenmark sections, better than any other with which I am acquainted, show clearly that all the species of our *Dinornithidæ* have



ph. Easter & Wallis.

Printed by M. Jaffé, Vienna.

Skeleton of Aptornis otidiformis Owen
in the Canterbury Museum.

been living simultaneously, first appearing in the Great Glacier period and reaching to quaternary times, when they became extinct by the hand of man, and through other physical causes previously alluded to. Consequently the conclusions of Professors Cocchi and Owen, quoted above, cannot be sustained, when we take the occurrence of Moa-bones in the series of beds now examined over both Islands into account.

It has repeatedly been advanced as a proof of the recent extinction of the different *Dinornis* species, that the bones of the *Notornis* have been found in a few localities, together with those of the former, while afterwards that gigantic rail was discovered to be still living in some lonely parts near the west coast of this Island. A similar argument might be adduced to prove the recent extinction of the Mammoth, and the Woolly Rhinoceros in Europe, because the fox, the wolf, the hare, and a number of other animals, still living in the same part of the world were contemporaneous with those extinct gigantic mammals. I wish, however, to point to the striking fact, that in none of the localities examined by me, yielding such a rich harvest of Moa-bones, any remains of *Notornis* have ever been discovered. We must therefore conclude, that this bird was either extremely rare in the regions referred to, or that it then existed only in the more mountainous regions of these Islands. However, nothing was known of the exact habitat of the Takahe, (*Notornis*) till Sir George Grey—to whom I owe this valuable communication—obtained the information from some aged Maoris in the extreme South of this Island, that this rail is still now living on the mountains of the neighbourhood above the forest region, where numerous lagoons are dotted over the glacialized surface of the ranges. I now believe that the remarkable tracks I observed in similar mountain regions near the head-waters of the Rakaia were also those of this bird. At the same time it is possible, that the large bird of prey met with in the heart of the Alps, and to which I alluded on pages 37 and 135 may be the Movie or Hokioe of the Maoris, or even the *Harpagornis* of which the bones were first obtained in the turbary deposits of Glenmark.

CHAPTER XVIII.

Economic Geology.

In several chapters of this publication mention has already been made of various rocks, minerals, and ores of economic value found in the two provinces under review, such as gold, coal, limestone, and several others. It will, however, be useful to offer, in a more connected form, an account of all the mineral substances, known to us at present, which are either already being extracted from the earth, or may be used in the future for manufacturing or agricultural purposes. An examination of the Geological Map of both Provinces will disclose the fact, that whilst the country on the north-western side of the Alps is rich in gold and coal, the eastern side has not been so favoured. At the same time it may be safely expected that payable mines of other ores will be opened all along that western slope. On the eastern side, by far the greatest portion, consisting of rocks of young palæozoic origin, with a few unimportant exceptions, is devoid of any of the more valuable materials for the use of man. This is the more striking and disappointing, as rocks with the same fossils contain the rich and extensive Coalfields of New South Wales. However, in the younger rocks, fringing this older sedimentary series or forming small outliers in it, some valuable brown coal-beds have been preserved to us, thus making up in some respects for the want of the older coal measures.

Coal.

All the coalfields situated on both sides of the central chain, belong to the Waipara and Oamaru formations, those in the former being most valuable and extensive. Beginning with the Waipara formation on the western slopes of the Southern Alps, the first locality where coalfields—one of the best in the Colony—exist is situated about six miles above Greymouth. The principal seam of these coal measures was discovered by me in 1860, and described in my report on the western districts of the Nelson Province, published by the Provincial Government in 1861. Owing to the many faults existing, and the density of the forest, it then appeared that besides the principal seam, several others were in existence. However, a careful examination of the Geological Survey Department, extending over a number of years, has proved that there are only two workable seams, an upper seam of about three feet, and a lower or main seam of 16 feet in thickness, separated from the upper by about 35 feet of grit. The principal and most accessible portion of this coalfield, although considerably faulted, is situated on the northern side of the Grey river, the coal on the southern or Westland side being more limited in extent. Several shafts, of which the principal one is 635 feet deep, have here been sunk, the coal having been reached at various depths. It is a fine bituminous coal, clear and homogeneous, burning to a fine metallic coke, about 66 degs. in the average, and very useful for steam, manufacturing, and home purposes. From the Table of Analyses of coal made at the Colonial Laboratory it will be seen that it is in every respect a very superior coal, the value of which together with that of the Buller coal measures cannot be overrated.

It is a remarkable fact that this coal, although not being of greater age than the principal brown coal seams on the eastern side of the dividing range, has nevertheless undergone such an enormous alteration throughout, that it has the character of coal of far greater age, and in some respects is superior to coals from New South Wales. It is, therefore, evident that some abysso-dynamic agencies have been at work to accomplish this metamorphism throughout the whole Grey and Buller coalfields, which did not extend to the eastern side of the Alps, where the coal is only locally altered, the cause of the alteration being always traceable to volcanic rocks in close proximity, erupted during or after the formation of the coal seams. The seams existing near Lake Kanieri, at the Paringa, and near Jackson's Bay, although containing coal of good quality, are too thin for practical use, but I have no doubt that the extensive Waipara beds near the Paringa river will yield in years to come workable seams, by means of which the central portion of Westland will be settled by a population more stationary than a gold mining community generally is.

Passing over to the eastern slopes of the Alps, the most important district in Canterbury where coal-bearing strata of some extent have been proved to exist, is situated some 30 to 40 miles west from Christchurch. This district, called the Malvern Hills, was first examined by me in 1861-62, but more systematically during 1870-71, the results of my surveys having been published in the Reports of Geological Explorations during 1871-72. Since that report has appeared, a few more discoveries have made us acquainted with several new localities where coal crops out, of which the principal one is that where the Springfield Company has opened up a colliery a few years ago. In the publication referred to, I have shown that only those portions of the coal seams which were subjected to igneous action, have undergone metamorphism in the immediate neighbourhood, and to such a local extent, that sometimes the upper portion of large coal seams over which a basaltic lava-stream has been flowing, is altered to an anthracite coal, whilst the lower portion has remained an unaltered brown coal. The same limited effect has been produced where the volcanic rocks in the form of more or less vertical dykes have ascended through the carboniferous strata, the coal seams being affected in a similar manner on both sides of the dyke, for a short distance only. The surveys of the coal measures under consideration have proved that during the sinking of the land the material for the formation of brown coal seams was accumulating all over the district under review, only those portions having been preserved where favourable circumstances were existing, such, for instance, as the *coulées* of basaltic rocks having flowed over them. In other cases, hard fossiliferous sandstones have acted in the same manner. Consequently we find that the coal seams not only are fringing the slopes of the palæozoic ranges, appearing in that case as marginal seams, and at altitudes from 800 to 1500 feet, but outl'ers of more or less extent occur up to 3500 feet above the present sea level. Of the marginal coal seams, those in which the Canterbury Colliery (Jebson's), the Homebush Colliery (Deans'), and the Wallsend Colliery on the northern bank of the Selwyn, are situated, have not been altered by volcanic eruptions, the large *coulées*. of anamesite by which the upper series of the Waipara formation is here covered, being too far distant to have had any appreciable effect upon the coal seams.

Beginning with the Canterbury Colliery, we observe that the whole series from the first seams worked in 1861 to the ferruginous sandstone forming its base, stretches 12½ chains along the banks of the river, dipping on the average at an angle of 19 degrees to the south-east, and thus possessing a considerable thickness. In descending order there occurs, first a set of two seams, consisting of

	ft.	in.
Brown coal	2	8
Shale	2	6
Brown coal	1	2

These two seams were worked in 1861. Three and a half chains from this drive, now abandoned for some time, Mr Jebson first began to work, extracting coal from three seams of 11 inches, 14 inches, and 20 inches respectively. These seams were separated by small bands of fire-clay and micaceous shales. Afterwards Mr Jebson went lower down into the series, and six and three-quarter chains from the first workings, a new mine was opened, from which brown coal of fair quality is now extracted. This set consists of two seams, each about two feet thick, dipping 18 to 19 degrees to the E. S. E., with two feet of fire-clay between them.

The next locality where brown coal of good quality crops out is in Surveyor's Gully, a small tributary of the Selwyn, in which I observed in 1870 two seams of coal, the lowest one being six feet thick. On this seam repose 2 feet 6 inches of shale, upon which another workable seam of three feet in thickness follows.

To reach the coal at a lower level the Homebush Colliery was opened in 1872 about half a mile lower down the valley, when the following strata were passed through (section No. 6 on plate 3), beginning with the lowest bed.

	ft.	in.
a. Shale, only exposed in part		
b. Brown Coal	2	8
c. Shale	1	6
d. Brown Coal	0	6
e. Shale (*micaceous*)	1	6
f. Brown Coal	1	10
g. Shale (*argillaceous*)	3	0
h. Brown Coal	3	6
i. Shale, with small seams, and streaks of coal...	30	0
k. Carbonaceous Shale	3	6
l. Light Shale	4	5
m. Coal	2	0
n. Shale	46	0
o. Ironstone	3	0
p. Quartzose Sands, only exposed in part ...		

The seams *f* and *h* are being worked. It will be seen from this list that the large seam of 6 feet observed higher up the valley has not been met with, but I have no doubt that either one of the seams enumerated above enlarges further on, or that two seams will join to form a thicker one. Two remarkable breaks in the otherwise regular seams (sections No. 5 and 6 on plate 9), which I wish to notice here, bear upon this point. In the one case the seam *h* continues quite regularly for a number of chains in the workings on the left bank of Surveyor's Gully, after which it disappears altogether, and a new seam of about 2 feet thick, separated from the former, by 1 foot 6 inches of shale takes its place, gradually thickening. It is thus evident that both seams have been formed in two separate basins, the lower being of course older than the upper one. A similar and still more clearly defined occurrence was observed on the opposite or right bank of Surveyor's Gully, when the same seam *h* enlarged at one time to a thickness of 7 feet 9 inches with a band of shale of 2 inches in the centre. However, after 6 yards, the upper seam thins out rapidly, the lower one only continuing.

Of the new ventures lately opened none is of greater interest from a geological point of view than the Springfield Colliery. It is situated at Kowhai corner, where a volcanic eruption of dolerites has taken place, the rock forming on the summit of a nearly isolated hill a crateriform rim, from which a lava-stream has run in a south-easterly direction. This lava-stream, together with a dyke of a fine grained dolerite of considerable thickness, forming a projection above the Waipara beds, has preserved the lower deposits from destruction. The coal has at the same time been partially altered. When I visited the mine in 1876, the following beds were exposed in ascending order:

	ft.	in.
Brown Coal	2	11
Shale	4	2
Coal	4	0
Shale	2	1
Coal	1	0
Shale, only exposed in part		

I understand that whilst the other seams have diminished, the 4 feet seam has improved in thickness the more it has been opened up, being now 4 feet 6 inches thick. Section No. 5 on plate 3 gives a section of the colliery under consideration, whilst No. 7 on the same plate shows the principal details of the Kowhai corner hill more to the north-west, where the neck or vent of the volcanic eruption has been laid open by several trial shafts and adits. As a matter of course, the sedimentary strata have here undergone great changes by faulting crushing, and metamorphism. In this locality I examined a number of sections, from which it appears that the coal seam nearest to the basic rocks has become so much altered that it consists of a brittle anthracite coal, whilst those seams separated only by 10 to 15 feet of shale contain only a hydrous brown coal.

There are several other localities where coal seams partly altered have been worked, as for instance, Hart's and Hill's (Cordy's) collieries, but either the seams were too thin, or the outlier of too small an extent (Hart's and Kowhai). In other instances, the demand was not sufficient, or the coal seams too difficult of access, other collieries being nearer to the consumers. There is, however, no doubt that in years to come, all these localities where coal seams of workable brown coal exist, will form a nucleus for population and industry.

Of the localities in the valley of the Rakaia, where coal seams occur, I wish to mention two, the first of them not so much on account of the extent of the coal seams, but for the manner in which the latter have become altered to a fine anthracite throughout. In the valley of the Acheron the brown coal measures repose unconformably upon palæozoic rocks without any porphyry conglomerate between them. The former consist first of 20 feet of black shales with several small seams of coal changed to anthracite, and of a thickness of 2 to 14 inches; the main seam of an average thickness of 4 feet 2 inches follows next. It is very pure throughout, and has been changed by the action of the dolerite, principally close to the channels of eruption, to a fine anthracitic coal. It dips in the locality where Mr. Oakden obtains his supply of coal, N. N. W. 39 °., whilst near the dolerite stream it shews together with the shales a false stratification, dipping apparently W. N. W. 70 °. This seam is covered in ascending order, by about 7 feet of black or iron grey shales; 8 feet of loose sands coloured black by carbon; 24 feet of dark coloured shales, which for the last 10 feet before we reach the dolerite have been greatly altered, so as to assume a greyish white colour and the character of a porcelain jasper, but still preserving the markings of obscure remains of plants enclosed in them. These beds, following generally the surface outlines of the palæozoic rocks appear in several localities as isolated patches from below the morainic accumulations or the post-pliocene alluvium, both together forming the upper deposits of the whole district. In the upper portion of the valley no large seams are visible, and only three small ones of 1, 3, and 5 inches appear between the shales.

Section No 3 on plate No 4 gives the details of this interesting and instructive section.

In the so called chasm on the left bank of the Rakaia gorge, another series of coal seams (section No 8 on plate 3) is exposed, which will be of some value in future years. The terrace consists here in descending order of about

150 feet Alluvium	...	...	bluish tint
30 " "	...	...	reddish tint
100 " "	...	...	bluish tint

consisting throughout of river sand and river shingle. Below the last mentioned deposit the first visible bed consists of ferruginous shales followed, in ascending order, by

	ft.	in.
Fine Brown Coal (Pitchcoal)	5	2
Conglomerate consisting mostly of pebbles of Quartziferous Porphyry	6	0
Coal	1	9
Grey shale	0	3
Coal	12	6
Shale, only exposed in part		

The last seam consists of a fine hard pitch coal interstratified with numerous small layers of glance coal.

In the more northern portions of the province, coal seams of economic value are of rare occurrence. There is a seam near the source of the Motanau, 4 feet thick, which one day may be useful to the district. Another seam of similar thickness is exposed near the source of a creek falling a few miles north of the mouth of the Motanau into the sea, but it is difficult of access. In the Waipara and its tributaries the beds corresponding with the coal seams of the Malvern Hills consist, with the exception of a seam in Boby's Creek, only of a very shaly lignite, and of inconsiderable thickness. Of the outliers containing brown coal of good quality, those behind Big Ben and at Craigieburn might also here be mentioned.

Oamaru Formation.

As previously stated, there are a number of coal seams of some economic value in the Oamaru formation, stretching from the northern

Ashburton to the Waitaki; however they are generally confined to localities of less extent than those of the preceding formation. As far as I am aware, no seams of any value are found at the base of this formation north of the Kowhai river, the first seam of any thickness (about 4 feet) being found near the southern foot of Mount Grey. It doubtless lies at the base of the Oamaru formation. It is a lignite, the woody structure of most of its component parts being still clearly discernible. After crossing the Rakaia, small outliers with brown coal have been preserved in many localities, consisting generally of one seam only, but of considerable thickness. Thus, for instance, the seam on the right bank of Taylor's Creek two miles above its entrance into the Canterbury plains, is at least 28 feet thick. It consists of a lignite of fair quality, but stands at a very high angle (70 degs.). A similar seam exists on the western slopes of the Clent Hills, in the Upper Ashburton plains, of which section No. 9 on plate 3 gives the details.

In ascending the hillside close to the Clent Hill station, and after passing through 10 to 12 feet of shingle deposit, the lowest beds belonging to this outlier are reached, consisting of—

42 feet of loose ferruginous sands dipping E.S.E. 76 degs., and containing pockets and concretions of ferruginous clays. Upon them reposes—

A band of clay marls 12 inches thick, full of casts of a *Cypris* and of a *bivalve*, allied to *Cyrene*, thus proving the fresh water origin of the beds under review. They are overlaid by—

14 feet of arenaceous sands gradually becoming sulphurous, separated in many layers by small bands of clays, through which the whole obtains a well stratified appearance; they are succeeded by a bed of under-clays, several inches thick, upon which reposes a large seam of—

Brown coal, dipping E.S.E. 63 degs., 28 feet 6 inches thick, separated by several small bands of shales into different banks.

This seam of brown coal, of fair quality, is covered by loose quartzose sands, first white and afterwards assuming yellowish tints, which, 80 feet above the coal seam, abut against the palæozoic rocks, here forming steep cliffs and being greatly decomposed, the whole overlaid, as before stated, by post-pliocene alluvium.

There are some other coal seams near the Canterbury plains, either in small outliers, or skirting the ranges; for instance, in the bight formed by the junction of the Cox range with Mount Somers, a series of seams of lignite occurs having an average dip of 14 deg. towards N.N.W., and reposing on quartziferous porphyry. This series begins with beds of porphyry tufa, and fire-clays, covered by a succession of shales, alternating with seams of coal, two to five feet thick—the coal consisting of distinct layers of earthy brown coal and lignite, the latter exhibiting quite clearly the woody structure. Another series of coal seams, situated on a spur on the Cox hill ranges, about five to six hundred feet above the foot of these hills where they rise from the Canterbury plains, seem to skirt the ranges. They consist of deposits similar in character to those previously described, also reposing on porphyry tufa. There is first a lower seam of 2 feet 6 inches, separated from an upper seam 2 feet 4 inches by 4 inches of shale covered by fire-clay. These strata dip 35 deg. to the N.W. by W., and consequently appear to dip below the quartziferous porphyries of which the ranges consist. However, it is apparent, from the ridges rising in front of the series, that a small lagoon was at one time here formed by the sea, and filled up in couse of time by the above described beds.

Another basin, already of practical value, is situated in the neighbourhood of the junction of the River Stour with the Ashburton. It occurs in a depression amongst the quartziferous porphyries, which, before the main river had cut through their eastern boundary, formed here, doubtless, a ridge of considerable dimensions, behind which the sedimentary beds of lacustrine or littoral origin could be accumulated. This basin, somewhat triangular in shape, is about two miles in breadth and length. It appears that the porphyries had already undergone considerable denudation before the newer beds were formed, they having been deposited on the sides of steep escarpments and cliffs. The lowest beds consist of porphyry tufas, lying generally at a high angle, and following the outlines of the spurs. They are of great variety in colour and texture, often with a fine ribboned appearance, white and yellowish colours being predominant. They are well exposed in Coal Creek; gradually they become darker, and are succeeded in that locality, by shales upon which a seam of brown coal of good quality reposes, 14 feet in thickness, of which however only the lower portion of 8 feet was extracted, when I visited the locality in 1871. Since then another method has been adopted, the coal seam being stripped and its whole thickness worked. This coal has a dip of 8 deg. towards the S. S. E.

The seam is capped by shales, with smaller seams of brown coal interstratified, and sandy clay marls, overlaid unconformably by post-pliocene alluvium. Section No. 11, on plate 3, gives the details of this locality.

On the opposite side, and on the southern banks of the River Ashburton, I discovered another portion of the same basin, consisting of porphyry tufas, shales, and two seams of brown coal, about 4 and 5 feet thick, separated by a few feet of inferior coal, or shale. However, as the outcrop was very much decomposed, the two might possibly belong to one seam; this can easily be ascertained by opening up the ground, which is here also covered by post-pliocene alluvium. The deposits in Alexander Creek, a tributary of the River Stour, are doubtless only a portion of this larger Ashburton-Stour basin; the coal seams are, however, too small and too irregular to be of any practical value.

In the southern portion of the Province in several localities, brown coal of fair quality has been discovered and is partly worked, but the seams are always irregular and do not extend over a large area without either thinning out or becoming of very inferior quality. I have alluded already to the occurrence of a workable seam at Elephant Hill, on page 310 (section 4, plate No. 5). Similar coal seams are also found at the base of the Oamaru formation in the middle course of the different Waihao branches, but they are as previously pointed out, sometimes of indifferent quality, and often unworkable or difficult of access.

Section No. 7, on plate 9, makes us acquainted with the geological features of the Oamaru formation in the middle course of the Opuha, where it leaves the small palæozoic ranges, forming the eastern boundary of the upper Opuha plains. The sequence of the beds is as follows:—

On the palæozoic rocks repose—

No. 1. White quartzose sands with some harder layers, containing impressions of dicotyledonous leaves, and some pieces of drift-wood changed into lignite.

No. 2. Seam of brown coal 8 feet thick. It consists of a good dull brown coal, containing a number of layers of glance coal.

No. 3. Quartzose sands gradually becoming ferruginous.

No. 4. Ferruginous sand with harder calcareous beds (fossiliferous).

No. 5. Greensands, gradually becoming marly, the upper bed—

No. 6. Consisting of the characteristic calcareous sandstone, known as the Oamaru or Weka Pass building stone.

And finally, I wish to allude to another occurrence of coal in the southern portion of Canterbury, which in years to come may be of considerable importance to the district. The coal seams in question are situated in the Otaio district, and exposed in the river-bed not far from where it leaves the palæozoic ranges. For about 100 yards post-pliocene alluvium forms the banks of the river, after which a series of deposits of shale and brown coal is exposed, but not sufficiently to take any reliable measurements.

Then follow in ascending order:—

Shales, thickness about	4 ft.	6 in.	
Brown coal	3 „	0 „	
Dark sandy shale	2 „	0 „	
Brown coal	1 „	4 „	dip 13 deg. to N.E.
Shale, blackish sandy...	1 „	2 „	
Brown coal	6 „	0 „	

For about six chains the continuation of these beds is covered by alluvium, after which greensands capped by calcareous sandstone appear, the latter forming everywhere the uppermost beds of the series in the district. The principal coal seam consists of a fair brown coal, with layers of glance coal interstratified.

A number of outliers belonging to the Oamaru formation occuring far in the interior, contain sometimes thick coal seams, but they are generally difficult of access, and of limited extent.

Pareora Formation.

No lignite seams of any value have hitherto been discovered in this formation, although in many localities small deposits have been met with, in which the stems of trees show conspicuously their form and woody structure.

I may mention that many of the inferior brown coals and lignites are burned extensively in several parts of Germany and Austria for obtaining the ashes, to be used either in the manufacture of glass or as valuable manures.

In the reports of Geological Explorations for 1871–72, a *résumé* of all analyses made of New Zealand Coals by Mr. W. Skey, which are of some practical value, are given. I have selected for republication from that schedule those analyses having reference to Canterbury and Westland, thinking that they will be useful to the reader for comparison.

Schedule of Canterbury and Westland Coals which have been analyzed at the Colonial Laboratory. (*See Report of Geological Explorations during* 1871-2, *page* 172 *and sequ.*)

Locality.	Variety.	Evaporative Power.	Fixed Carbon.	Water.	Ash.	Nature of Coke.	Laboratory Number.
WESTLAND—							
Grey River Coal-field	Bituminous Coal	8.10	62.37	1.99	6.20	Cakes strongly and forms valuable Coke	331
Grey River Coal-field	Bituminous Coal	7.39	56.86	1.16	5.49		1240
Kanieri... ...	Bituminous Coal	7.42	58.69	0.86	21.11	Cakes strongly	970
CANTERBURY—							
Acheron (Rakaia)	Anthracite Glance Coal	11.55	89.91	3.17	7.92	Non-caking	609
Kowhai (Waimakariri) ...	Hard Glance Coal	10.33	80.01	6.50	2.54	Non-caking	607
Hart's Colliery...	Hard Glance Coal	9.05	69.62	2.77	12.69	Non-caking	608
Rakaia Gorge ...	Hard Glance Coal	8.30	64.51	6.76	7.46	Non-caking	228
Hill's Colliery ...	Hard Glance Coal	7.94	61.10	1.60	1.90	Non-caking	...
Hill's Colliery ...	Soft Glance Coal	6.81	53.30	9.98	2.75	Non-caking	1016, *d*
Canterbury Colliery	Brown Coal	5.73	46.02	21.66	5.33	Non-caking	617
Big Ben ...	Brown Coal	5.71	45.00	12.00	1.90	Non-caking	...
Craigieburn ...	Brown Coal	5.62	44.62	15.54	4.58	Non-caking	98
Homebush Colliery	Brown Coal	5.58	44.50	17.50	6.78	Non-caking	1016, *a*
Hill's Colliery ...	Brown Coal	5.22	41.22	20.74	6.35	Non-caking	1233
Coal Creek, Ashburton ...	Brown Coal	5.05	39.60	8.80	12.40	Non-caking	...
Motanau ...	Brown Coal	5.03	40.37	18.15	5.37	Non-caking	107
Church Reserve, Selwyn ...	Brown Coal	4.65	36.06	11.40	3.20	Non-caking	...

POSTSCRIPT.

Since the above was written, a series of new analyses of Malvern Hill Coal has been made at the Colonial Laboratory, by Mr. S. H. Cox, F.C.S., containing several specimens from collieries not included in the former Schedule. Being, therefore, of interest to the public, I have added it to this Chapter.

No.	Description of Locality.	Fixed Carbon.	Hydro-Carbon.	Water.	Ash.	Evap. Power.	Remarks.
1 *a*	Homebush 3½ft. seam...	41.3	34.2	21.9	2.6	5.3	Brown Coal
1 *b*	Homebush, 7ft. seam ...	47.7	30.9	19.2	2.2	6.1	Brown Coal
2	Springfield Lower Portion of 4½ft. seam ...	47.9	41.8	6.3	4.0	6.1	Pitch Coal
2 *a*	Springfield Upper Portion of 4½ft. seam ...	63.2	23.6	3.2	10.0	8.1	Glance Coal
3	Wallsend Top, 3ft. seam	39·7	35.9	18.8	5.6	5.0	Brown Coal
4	Canterbury Colliery ...	49.1	24.9	24.1	1.9	6.3	Brown Coal
4 *a*	Canterbury Colliery ...	41.4	34.9	18.2	2.5	5.7	Brown Coal
5	Williamson's Seam, near Springfield	61.9	26.8	0.9	10.4	8.0	Glance Coal
							(All non-caking)

Building Stones.

The older formations, owing to the numerous well defined joints generally passing through the rocks in different directions—the cause of the polyhedric debris, or shingle covering our mountain sides—have hitherto not yielded a single building stone, except for coarse rubble work. Latterly however the attempt has been made in the Malvern Hills and the Kakahu river to utilise some deposits of marble for ornamental purposes. Some blocks of fair dimensions have been brought to Christchurch and Timaru, but I am not aware if specimens of similar sizes may be obtained in any quantity.

Both the Waipara and Oamaru formations are capped by a calcareous sandstone (or perhaps more correctly named an argillaceous limestone), which may be considered one of the best building stones in the Colony. This stone, easily cut by the saw when quarried, has an even texture, hardens on exposure, and can be worked with great facility. It occurs in several tints from a greyish to a yellowish white. This building stone (Oamaru formation) has for years past been exported from Oamaru to Australia and other Colonies, and similar stone from the White Rock quarries north of the Ashley and some other localities has gained much favour with the public. There have lately been opened quite a number of quarries in the Canterbury province in many localities, as for instance in the Weka Pass, the Waipara, Rampaddock, and Mount Brown, at the Ashley and in Castlehill basin. In the southern portion of the province the same free stone is of common occurrence, and will no doubt be extensively used, and exported in years to come.

Besides this calcareous stone, there are a few deposits of sandstone occurring in the Waipara and Oamaru formations, which might prove useful for building purposes, although they are generally of too incoherent a nature for outdoor work. Some of the gritty sandstones of the Grey coal measures, at the West Coast, will however make an exception, as they may be classed with the best building material of that kind. Of igneous rocks, some of the fine grained granites and syenites in Westland, and of the quartziferous porphyries of the Malvern Hills and Mount Somers might be utilised for monumental buildings, although their hardness, and consequently the difficulty of working them, has hitherto prevented their introduction. The Anamesites at Timaru have however been already extensively used for a great number of buildings in that town and its immediate neighbourhood, and I have no doubt that the same material from the Malvern Hills will be quarried in years to come for the same object. They also would form valuable millstones.

Amongst the volcanic rocks of Banks' Peninsula, a number of very fine building stones of various colours, qualities, and value exist. For rubble buildings two kinds of rock have principally been used of late years, of which one is a dolerite flagstone, from the so-called Guise Brittan quarries, and another a porphyritic dolerite lava obtained principally in Tait's and Greig's quarries. Besides these two characteristic rocks, taken from well defined lava-streams, there are a number of dykes offering excellent building and dressing stones. Many of them will rub to a fine face. They are all mostly of a trachytic nature.

Limestones.

The palæozoic rocks, although generally remarkably deficient in lime, nevertheless yield some deposits of value for the lime-burner. There are several localities in the Malvern Hills, such for instance as the

Four Point range on the right, and Frank's Knob on the left bank of the Selwyn, as well as in the Middle Kakahu, where excellent limestones and marbles, the latter sometimes consisting of nearly pure carbonate of lime, exist in considerable quantities. Some of the calcareous deposits of the Waipara and Oamaru formations will also burn to good lime, either for the usual building purposes or for hydraulic work. Some of the flaggy limestones, consisting mostly of minute pieces of shells and corals, as for instance at Mount Somers caves, form excellent material for the limekiln.

The lithographic stone obtained at the Abbey rocks, West Coast, in good sized blocks, although not able to compete entirely with the Solenhofen and some other Bavarian stones, will nevertheless be of considerable use for transfer work, and many other purposes where the partially veined appearance of the surface is not a drawback. Otherwise its quality is excellent. At the same mentioned locality and at the Grey an almost inexhaustible supply of very good limestones for the kiln is available.

Clays.

In the yonnger palæozoic rocks in connection with shaly beds and conglomerates, as for instance in the Malvern Hills, the Clent Hills, and a few other localities, there occur some indurated clays (shales) which in times to come will doubtless be extensively used by the potter. Both the Waipara and Oamaru formations are rich in clays of various character, and useful for many purposes.

There are some very fine fire-clays in connection with the coal seams in the former, for ornamental work (Terracotta) and for more general purposes such as drainage pipes, earthenware, fire bricks, and many other objects, which formerly had all to be imported from the home country. The Malvern Hills are particularly rich in fine pottery material, and a siliceous conglomerate (ganister) its component parts mostly derived from the disintegration of the quartziferous porphyries is also abundant there. I may add that some of the fire-clays from Almerode, near the Meissner, are of such excellent quality that they are exported in considerable quantities to the United States of North America (see Zinken, Braunkhole, Vol. 1, page 550). Considering the expense incurred for railway and sea carriage from the centre of Germany to the United States, it appears to me, that under favourable circumstances, some of our fire-clays could also be exported with advantage.

There are some white plastic clays in the Oamaru formation, as for instance in the valley of the Kakahu river, and in the Waihao basin, which some day will also be extensively used for manufacturing purposes.

Sands.

In some former chapter mention has been made of the fact, that large beds of quartzose sands exist in our younger formations, the Waipara formation containing the richest deposits. Generally, they are not quite pure, having some slight admixture of clay, iron, and a few other mineral substances. There are, however, several of these layers of a snowy white colour, being an exact counterpart of the sands of the Brown coal formation in Rhenish Prussia; and as the sands of that country are derived from the decomposition of quartzose trachyte, so the sands of our brown coal beds are portions of decomposed quartziferous porphyry. These sands in Germany are of great value for the manufacturing of glass, and are extensively used for that purpose, and it is worthy of notice that some of these sands, when of great purity, such as those of Bardenberg, Herzogenrath, and Nievelstein, are exported in great quantities to Great Britain for that industry—(Zinken, Braunkohle, Vol. I, page 600). In Bohemia, too, many manufactories of glass are supplied from the products of similar beds. The conclusion, therefore, that the manufacture of glass on a large scale will soon be introduced in New Zealand is not too hazardous; at the same time, we may expect that at no distant date, glass sands will be exported in considerable quantities to England and other countries, principally in ships where ballasting is necessary.

Ores.

Having already noticed the occurrence of gold and of some other ores in Westland, little remains to be said of the presence of metallic riches in Canterbury, the geological features of the latter province unfortunately not being favourable for their presence. However, even the negative evidence is valuable, as it will, or it ought to be, the means of saving the pockets of many colonists who, either guided by incorrect statements of mineral prospectors, or by deceptive appearances, would otherwise invest their money on mining adventures which, as the geological evidence before us proves, must be certain failures.

Gold.

On page 264, I have already given a description of the interlaminations and smaller aggregations of quartz, in the Waihao formation, which to a certain extent are auriferous, and of a few reefs found in the same series of beds. Besides the small samples of gold obtained in the Upper Waihao, washed from little patches of alluvium, there is not the least doubt that, from the disintegration of the rocks of the same formation, forming the eastern watershed of the Southern Alps, gold in small quantities has been liberated, as evidenced by the fine scaly gold obtained from some rivers of the Mackenzie Country.

However, the necessary conditions for the formation of a payable goldfield have in all cases been shown to be altogether wanting. The opaline nature of the quartz reefs at McQueen's Pass (Banks' Peninsula) showed at once, according to the experience gained in other countries, that they would not be auriferous, a point to which I directed attention at the time. Since then, this has been confirmed by a number of analyses made at the Colonial Laboratory (5th Annual Report, 1870) showing that the average amount of water in nine specimens from that locality was 2.73 per cent, the average of five other specimens from other reefs known to be auriferous, giving only an average of .54 per cent. The gold said to have been obtained during the gold fever of 1865—70 in the Malvern Hills, near Oxford, or even on the very Canterbury plains and in several other localities, proved to be either iron pyrites, or to put upon it a charitable construction, had been lost by some accident.

Similar errors occurred in many spots amongst the siliceous slates (cherts) belonging to the Mount Torlesse formation, which were mistaken for reefs, and where actually gold was sometimes found in small pores, also as I trust, got there by some fortunate chance, from the pockets of an anxious prospector, wishing to gladden the heart of some unlucky shareholder. Even amongst the white marbles of the Malvern Hills, standing at a very high angle, and mistaken for quartz, notwithstanding that its nature was repeatedly explained to enquiring prospectors, trial shafts were sunk in search of the precious metal. In those days the Provincial Geologist was the most unpopular man in Canterbury, because, instead of pandering to public opinion, he tried to save the pockets of the people, and the useless expenditure of valuable energy, worthy of a better cause. And he has had at least the satisfaction that many of his fellow colonists, who in those days considered him

almost an evil omen when he came near their goldfields, have now recognised that at that time he only was doing his duty towards them, and the people at large.

COPPER.

A specimen of carbonate of copper was found by me in 1863 in post-pliocene alluvium in the Stour Creek, a tributary of the Ashburton. In vain I searched the Mount Somers range on the left bank of that creek, there being not the least appearance of any metalliferous lodes. The specimen may have been derived from the morainic accumulations brought down the valley from the central chain, although I was not successful in searching for similar ores amongst the moraines covering the glaciers at the head of the Rakaia and other Alpine rivers. Except iron pyrites no other ores were ever observed in the sandstones and slates of the Mount Torlesse, and the semi-metamorphic rocks of the Waihao formation, making up the accumulations on the eastern glaciers. The Melaphyre zone has also been repeatedly examined for similar purposes, but in vain. The green colouration of those rocks has often been mistaken for copper, but in all instances it has been shown to be the result of the presence of delessite or green earth, both hydrous silicates. The green rock on both banks of the Selwyn (Upper Gorge) mistaken for copper, consists simply of diabasic ash with some iron pyrites.

IRON AND MANGANESE.

In the Mount Torlesse formation there occur some small and irregular lodes, containing carbonate of iron and oxyde of manganese, the latter often forming only a coating on the joints. Nothing has, however, hitherto been found in sufficient quantity to be of economic value. Some deposits of clay iron stone are existing in the Clent Hills and some other localities, where beds of conglomerate and shale with impressions of ferns and small and irregular deposits of culm occur. In the lower portion of the Waipara formation, bands of clay iron ore (Spathic iron) are not uncommon, and they are of such thickness that they can be worked with advantage in many places, such for instance as the Malvern Hills, where coal and limestone are within easy reach. An analysis has been made at the Colonial Laboratory, Wellington, of a specimen of clay iron stone (Spathic iron) from the Malvern Hills (9th Annual Report, 1874, page 22).

Spathic Iron Ore, massive, and striated with bands of the pure carbonate in crystals.

The following is its approximate composition:

	per cent.
Protoxide of Iron	51.2
Manganese Oxide	0.8
Alumina	1.8
Lime	0.3
Magnesia	0.4
Carbonic Acid with a little Phosphorus and Sulphur ...	31.2
Water	0.7
Silica	13.6
	100.00

Another form of iron ore is also not uncommon in the lower portion of the Canterbury plains. This is bog iron ore (*limonite*). It occurs there as a modern marsh deposit. It is, however, of inferior value. In Westland, clay iron stone has been observed on both sides of the Paringa river near its mouth, and in the Grey district. On the northern side of the Paringa, in the Bluff, a small lode of hematite occurs. In course of time there will doubtless be an iron industry of some importance in connection with the Grey coal measures, when once the difierent beds of clay iron stone have been fully traced, and labour is more easily obtainable for metallurgical industries.

Other Ores.

On page 259 I have already alluded to the occurrence of argentiferous galena on Mount Rangitoto, and I may now add that specimens of galena have also been collected near Jackson's Bay, and some localities between the Hokitika and the Haast rivers. However, the information obtained with the small specimens submitted to me by prospectors has been of such a vague nature, that I can only state the fact of its occurrence without being able to give any information about the position or nature of the lodes.

Water Supply.

Finally I wish to add to this chapter some observations on the artesian water supply, either already obtained in and near Christchurch or highly desirable, over the greater portions of the Canterbury plains, and some other districts:—

To this subject of great practical importance I have already alluded on page 58, when speaking of my report, written in 1863, on the possibility of obtaining a supply of artesian water for the City of Christchurch, and in my report on the Formation of the Canterbury Plains in 1864, when the borings had been crowned by such excellent results, I offered further observations on the natural process by which such ample supply of pure water has been stored up. There have been several causes in operation to form in the Christchurch district inclined porous beds, enclosed between impermeable strata, by which the water is retained—if not stored in a basin—and is compelled to flow downwards until it finds means of escaping. It is evident that for Christchurch and its neighbourhood, the bottom of the former greater extension of Lake Ellesmere, filled up by silt, sands, fluviatile and turbary deposits, underlying that city, is the source from which the greatest portion of the artesian water supply is derived. Part of these beds have therefore been deposited in the form of a basin, in which artesian water is generally obtained with some degree of certainty. For those artesian wells however situated to the east of the former eastern shore of that lake, the water can only be derived from gently inclined littoral beds, having been formed below the surface of the sea. That this is the case is conclusively shown by the depth the borer has to go before reaching the water retaining stratum, lying near Riccarton at 54 feet, whilst near the sea-coast it is only reached at 136 feet. It is natural that the deposits filling up such a considerable portion of the former Lake Ellesmere extension, according to the seasons or the advance of the deltas of rivers, or having been formed on the bottom or along its shore, must all be of a very different character.

Moreover, below the lacustrine beds, there also exist a number of layers formed in an arm of the sea, once surrounding an island (now Banks' Peninsula), formed of shingle, sand, clay and ooze; these in their turn would offer the necessary conditions for the formation of water retaining beds. It has been successfully demonstrated that below the stratum from which in Christchurch the usual flow of artesian water is obtained, one or more of these beds exist, containing also an abundance of water, which when tapped, rises to a higher level than the former. Thus, to give a few instances, at the North Town Belt, water was first obtained at a depth of 76 feet, having only a surface flow; the same well continued to 136 feet, gave a splendid supply rising six feet higher. At the Whately road public well the water was reached at 74 feet, with scarcely a surface flow, but when the same well was sunk to 166 feet the water gained 9 feet in height. The numerous borings all over Christchurch and its neighbourhood have given us a clear insight into the nature of the deposits by which the Lake Ellesmere extension was filled up. The bottom of the water-bearing stratum consists invariably of a bed of shingle, mostly of small size, upon which a deposit of sandy clay reposes. Above this the character of the beds changes incessantly, and often within very short distances from each other.

In some places the deltaic deposits of rivers reach from near the surface to the water-bearing stratum, as for instance, in Upper Riccarton, where after passing through 76 feet of shingle, water is obtained. It rises however, only within six feet of the surface. Near the foot of Banks' Peninsula, near Waltham, the shingle continues for about 100 feet till water is reached. At Middle Riccarton however, the shingle begins at only 50 to 60 feet below the surface.

In some parts of the district deposits of shingle are met with only near the surface, as in Cathedral square, and in Cashel street west, in others it forms only the central portion of the deposits passed through. Thus in Armagh and Chester streets east, shingle begins at 27 to 33 feet below the surface, continuing for about four feet, when it is underlaid by sandy deposits continuing to the bottom, about 98 feet. In some other portions of the city, as for instance in Hereford street east, there are deposits of silt, peat and sand for about 33 feet, after which the remaining 60 to 65 feet are formed by well cemented shingle before the water is reached. In other places again, only sands, greyish, yellowish, or blackish, with occasional deposits of peat, driftwood, and silt have been passed by the well-borer. We have also good evidence of the character of the deposits in the Lower Heathcote district, in a brick well sunk a few years ago for obtaining a water supply for Lyttelton, and of which the details were kindly furnished by Mr. H. B. Huddleston C.E. This well reaches a depth of 40 feet, the whole consisting of sandy silt, such as is now being formed in the estuary of the Heathcote. At depths of 6½ and 25 feet from the surface, two layers of Estuary shells were passed through, each about six inches in thickness, consisting mostly of specimens of *Chione Stuchburyi* and *Amphibola avellana*, still now living in the Heathcote estuary. Also a great deal of driftwood was met with.

To give a few more examples, I shall here offer the details of two artesian wells sunk to the east of Christchurch, in order to show the nature of the ground passed through. An artesian well bored a quarter of a mile east of the Slaughter yard amongst the Sandhills passed through the following strata:—

100	feet	of clean sand mixed with sea shells
9	„	„ clay
2	„	„ very small shingle
1	„	„ large boulders
112	feet,	when water was reached.

Another artesian well, not far from the Green bottle Lake (about 1 mile from the sea shore) gave the following section:—

ft.	in.	
18	0	blown sands
0	3	white clay
36	0	(blown ?) sands
1	0	clay
37	0	sands
0	6	shingle, scattered
21	0	sands
5	0	yellowish clay full of vegetable remains
0	9	very coarse shingle
119	6	

I may here mention that, although I am speaking of the boring of artesian wells, the method now universally adopted is merely to drive down a pipe with a conical plug, and that this is done to a depth of about 80 feet in a single day. Total cost per well £6 to £7.

The rise of the artesian water above high tide mark is about 20 feet in the average, consequently whilst in the highest western portion of the town the water does not reach to the surface, it is rising at New Brighton, opposite the bridge (depth of well 134 feet), to 13 feet, and on the mudflats, near the Heathcote bridge (depth of well 124 feet) to 17 feet. In many parts of the town the water still rises to such a height that by means of rams the water can be brought into the upper portions of the houses, whilst in others it has fallen so low that it can only be obtained by means of pumps. Considering the number of artesian wells scattered over such a comparatively limited area as that of Christchurch and its neighbourhood, and of which about one-half is allowed to run waste night and day, it is evident that the supply of water required must be enormous, and that its gradual diminution could be anticipated with some degree of certainty. However, experience has shown that the height to which the water rises has scarcely been affected in those localities where the wells are more scattered, to about 3 to 4 inches only—except in particularly dry seasons, whilst in those parts of the City where the wells are very numerous and a great deal of water is required, the decrease in height has been about four feet. Thus the artesian wells near the Museum and in the Domain have lost only a few inches, whilst near the intersection of Cashel Street with High Street, the loss in height has been estimated at four feet. The size of the pipes is usually $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter, those sunk by the City Authorities and some private establishments are of larger size (2 inches). I do not know how many artesian wells are in existence in Christchurch, but I believe there are close upon a thousand, aud a similar number may exist in the suburbs and adjoining districts. The result of several analyses have shown that the water is remarkably pure. It is beautifully clear, and having the mean temperature of Christchurch (about 53 deg.) all the year round, it is delightfully cool and refreshing in summer. The analyses of Professor Bickerton, F.C.S., have shown that its constituents vary in different localities, the total solids, however, never exceeding 4 grains per gallon.

There are two sources from which the water is derived, first from leakage of the rivers, and secondly from rainfall on the plains. Whilst, however, the heaviest freshets in the Waimakariri have never had the least influence upon the water supply, the wells have been known to rise four to five inches after heavy south-west rains, a continuance of dry weather for several months lowering them just as much. It appears, therefore, that the amount of water derived from leakage of the rivers, is constant and not in any way influenced by their volume at the time. In confirmation, the following observations made by Dr. Ll. Powell, F.L.S.. will be of interest. Dr. Powell placed a gauge upon his artesian well in Worcester Street west in the early part of 1875. During that year the water stood at an average of 25 inches in the glass tube. On November 28, after four days of heavy south west rain, it reached 29 inches, its greatest height during that year. The strongest North-westers with heavy floods in the Waimakariri did not however make the least alteration in the position of the column of water. On October 27th, 1877, the level had fallen to $20\frac{3}{4}$ inches, whilst at the beginning of Nov. 1878 it only reached to 13 inches, during a time when fierce Nor'-westers had been raging for some days. Dr Powell made also the observation that invariably when the artesian well on the next section (the Wesleyan parsonage) about 30 feet distant from his own is running, the level of the latter sinks at once half an inch. I need here scarcely point out that it would be very important to have all the obtainable information as to the underground water supply of the district carefully collected, and mapped, and sections prepared. Such documents would be of the greatest usefulness, their study leading us to conclusions the value of which cannot be overestimated.

The sinking of wells on the Canterbury plains in many directions (many of them reaching to a considerable depth), has proved that these plains consist invariably of river shingle and sand, cemented more or less by a ferruginous matrix. In a well between the Ashburton and Rakaia, sunk about 15 years ago, near the main road, where a supply of water was reached at a depth of 220 feet, the shingle at the bottom became much cleaner and incoherent, resembling the small shingle in the Rakaia river-bed. For a number of years past I have urged on several occasions upon the late Provincial Government to undertake trial borings of artesian wells over the most waterless portions of the Canterbury plains, but without success. The obtaining of an ample supply of water by such means would have been of immense value to the country, and would have promoted the settlement of many thousands of acres of land which are now comparatively useless. I still believe that it is well worth the expense upon those portions of the plains where artificial irrigation has otherwise to be resorted to. The copious natural springs in many parts of the lower plains, giving birth to a number of small creeks, such as the Avon, Heathcote, Little Rakaia &c., sufficiently prove that also higher up water-bearing beds are existing, which run out on the plains at no inconsiderable altitude above the sea level.

I am sorry that similar wells have not been sunk at Timaru, where there is all probability that good water by means of artesian borings might also be got without too great a cost.

CHAPTER XIX.

ALTITUDES.

General.

North-Eastern District.

		Feet.
†	Mount Alexander	2452
†	Black Hill, near Motanau	1800
†	Mount Cass	1723
†	Mount Montserrat, Cass Range	1493
†	„ Totara ditto	1822
†	„ Vulcan ditto	1342
†	Pendel Hill	1728
†	Ned's Farewell, North of Motanau	1107
†	Burnt Hut Hill ditto ditto	1202
†	Glendhu Peak ditto ditto	1367
†	Sailrock ditto ditto	1101
†	Ben Lomond	1565
†	Moore's Hill, North	940
†	„ South	1442
†	Mount Donald	1605

* Altitudes obtained with the spirit level by the Public Works Department.
† Altitudes obtained by the Trigonometrical Survey of Canterbury.
O. Altitudes obtained by the Trigonometrical Survey of Otago.
A. Altitudes from the Admiralty Charts.
All other altitudes have been calculated by me from barometrical observations.
Datum line—High-water mark

Hurunui and Waipara District.

		Feet.
†	Mount Mason	2787
†	„ Hilton	2013
†	„ Lance	2535
†	„ Arden	2375
†	Hamilton Range	2568
†	Highest point of Limestone Range on Western side of Weka Pass Creek	1430
†	Horsley Downs	1265
†	Waitohi Plains	978
†	Island Down	1163
†	Mount Macdonald	1406
†	Black Hill, North	1312
†	„ Middle	1824
†	„ South	1796
†	Hurunui Mound	897
†	North Deans	1879
†	Mount Brown	1608
†	Glengarry	478
†	Seadown	598
†	Mount Grey	3064
†	„ Thomas	3354
†	„ Karetu	3177
*	Junction of South Hurunui with Hurunui	1416
*	Eastern foot of Hurunui (Harper's) Pass	2300
*	Terrace on Southern side of Waipara	248
*	River-bed ditto ditto	192
*	Terrace on Northern ditto	217
*	Weka Pass Hotel	451
*	First Weka Pass Bridge	550

Middle Eastern District.

†	Burnt Hill (near Oxford)	1210
†	Upper Gorge Hill, Waimakariri	2093
†	Mount Torlesse	6434
†	Mount Torlesse, ridge above Waimakariri	4029
†	Trig. Station, Kowhai Bush	1271
†	Moraine Hill, near Kowhai	1231
†	Kowhai Corner Hill	1425

		Feet.
†	Little Gorge Hill (Waimakariri)	1024
†	Gorge Hill ditto	1171
	„ „ lower end on plains (lagoon)	886
†	Racecourse Hill	897
†	Big Ben, Trig. Station	4646
	Thirteen-Mile Bush Range	5224
	Brown Coal Beds behind Big Ben, where the Creek cuts through the main seam	2891
	Summit of Dolerite ridge above it	3160
	Junction of Kowhai with Macfarlane's stream	1787
	Coal Measures in Kowhai, entrance of Adit	1424
†	Little Racecourse Hill	1012
†	Russell's Peak	3946
†	„ Range	2726
†	Abner's Head	1902
†	Wether Hill, left Bank Selwyn	2265
†	Flagpole Hill, right bank Selwyn	2939
†	Cairnhill (Malvern Hills)	1634
†	Mount Misery ditto ditto	1910
	„ Pleasant ditto ditto	2116
	Yorkie's Pass ditto ditto	1563
	Rocky Peak ditto ditto	2763
	Pass between Rocky Peak and Pullwoolpeak	1687
	Rockwood Home station (verandah)	1370
†	High Peak	3177
†	Snowy Peak	2917
†	Little Snowdon	2095
†	Four Peak Range	2410
	Wai-anianiwha, where it enters the plains	797
	Basalt-ridge, between Selwyn and Wai-anianiwha... ...	1192
	Hart's Coal Pit	1015
	Saddle above Hart's Coal Pit to Wai-anianiwha	1162
	Upton's Flat (verandah of house)	1383
	Precipice Point Selwyn	964
	Saddle between High Peak and Snowy Peak	2491
	Hill's Pass to Upton's Flat	1816
	Harper's Hill, summit	1334
	The Hon. John Hall's Station (verandah)	765
†	Barker's Hill (near Lake Coleridge)	2941
†	Rabbit Hill (Lake Coleridge)	3924

		Feet
†	Bryant's Hill	1593
†	Woolshed Hill	1210
	Curiosity Shop beds in Rakaia Valley	651
	Windwhistle House	1532
	Upper Acheron Flat, junction of two branches	1684
	Snowdon verandah	1664
	Shoulder of Fighting Hill, where old road crosses	1797
	Bed of Acheron where road crosses	1202
†	Pudding Hill south of Rakaia	2849
†	Double Hill (approximate)	2230
†	Prospect Hill „	2891
†	Small Lake Hill, South of Lake Heron (approximate)	2472
†	Trinity Hill ditto	3335
†	Harper's Knob, at Junction of River Potts with Rangitata	2745
†	Gawler Downs	2099
	Mount Hutt	7016
	Ribbonwood Range, near Lake Heron	5862
	Mount Harper	5216
	Sugarloaf, Rangitata (*roche moutonnée*)	3268
	„ Lake Heron ditto	3822
	Mount Somers	5240
†	„ Peel	5633
	Rocky wall surrounding Lake Coleridge, East of Sheep Range	2087
	Junction of Whitcombe Pass stream with Rakaia	2958
	Mein's Knob, between Lyell and Ramsay Glaciers	4437
	Greenlaw's Hut, in Valley of Wilberforce	3041
	Two stones on Southern Foot of Browning's Pass	3392
	Saddle above Browning's Pass leading into chasm	5321

Banks' Peninsula.

†	Herbert Peak	3014
	Castlehill	2900
†	Mount Pleasant	1638
*	Observatory above Railway Tunnel	1230
	Bridle Path to Lyttelton	1080
†	Mount Evans	2308
†	Pigeon Bay Peak	2043
†	Mount Duvauchelles	2406
†	Mount Bossu	2336
†	Laverick's Peak	2478

	Feet.
† Cass' Peak	1780
A Devil's Peak	2050
A One Tree Hill	2310
A Rhodes' Sugarloaf	2000
A Mount Berard	2500
A The Knobs	1880
Dyer's Pass...	937

South-Eastern District.

† Blue Mountains, South Peak	5376
† „ „ North Peak	5356
† Four Peak Range, South Peak	4811
† Waitohi Hill, near Orari	2274
† Kakahu Limestone Hill, northern side	939
† Kakahu Hill, behind Bush	1307
† Trig. Station at Upper Opuha, near Messrs. Walker and Clogstoun's Out-station	1579
† Geraldine Hill	773
† Mount Horrible	1272
† „ Misery near Mount Horrible	1798
† Waimate Hill, Waihao District	1268
† Mount Studholme ditto	3562
† „ Blyth ditto	3299
† „ Pudding Hill ditto	1137
† „ Yellow Hill ditto	2185
† „ Two Peaks ditto	3395
† „ McLeod's ditto	3012
† Elephant Hill	1673
† Station Peak, behind Meyers' (Waitaki)	2905
† Mount Dryburgh, Hakataramea	3025
† Gorge Hill ditto	2089
O Ben Moore	6111
O Totara Peak	5876

Southern Alps.

O Terrace Peak, near head of Lake Hawea	6800
O Triplet Peak, ditto ditto	7064
O Mount Albert	7065
O „ Aspiring	9949
O „ Pollux	8633

		Feet.
O	Mount Castor	8588
O	„ Alba	8268
O	Oblong Peak	7640
O	Cleft Peak	6769
O	Mount Nix (Mount Stewart)	9101
A	Mount Cook	13200
O	„ „	12460
A	„ Tasman	12320
	Mount Dobson, near Lake Takapo	6271
	Observation Peak, Macaulay River	7862
	Mount Sinclair	7022

Miscellaneous.

Line of Perpetual Snow South-Eastern side of Mount Cook	7800
„ „ „ Western ditto ditto	6900
Limit of *Fagus* Forest in River Hopkins	3180
„ „ „ „ Dobson	3280
„ „ „ „ Rakaia	2430
„ „ „ „ Wilberforce	2360
Limit of *Fagus* forest on Mount Brewster	4320
„ „ Alpine shrub vegetation on Mount Brewster	4920

Western slopes of Southern Alps.

	Western foot of Hurunui Pass	1781
*	Junction of Otira with Hurunui River	812
*	„ „ Taipo „ „ „	375
	„ „ Waimea „ „ „	148
	Sale Glacier, source of Hokitika River	4183
	Hokitika River, where it enters the plains	429
	Junction of Kokatahi with Hokitika	173
	Francis Joseph Glacier, terminal face (Waiau)	705
	Prince Alfred Glacier „ „ (Weheka)	702
	Brewster Glacier „ „ (Haast)	4810
	Junction of Leading Creek with River Haast	1510
	„ „ Wills „ „ „	723
	„ „ Burke „ „ „	382
	„ „ Clarke „ „ „	246
	Mount Brewster, first peak near source of River Haast	7200

River Waitaki.

	Feet.
Great Tasman Glacier, terminal face	2456
Junction of Hochstetter Glacier, ditto	4850
Murchison Glacier, ditto	3540
Mueller Glacier, ditto	2578
Hooker Glacier, ditto	2691
Junction of Hooker with Tasman River	2296
„ „ Jollie „ „ „	2014
Great Godley Glacier, terminal face	3583
Classen Glacier, ditto	3528
Junction of Grey with Godley Glacier	4832
Separation Glacier between Mount Forbes and d'Archiac ...	4382
Macaulay Glacier, terminal face	4375
Junction of River Macaulay with River Godley	2611
Huxley Glacier, terminal face	5242
Faraday Glacier, ditto	4723
Richardson Glacier, ditto	4231
Selwyn Glacier, ditto	4311
Hourglass Glacier, ditto	3816
Junction of River Dobson with River Hopkins	2086
„ „ Holmes' Creek „ „ „	2190
End of terminal moraine, Ahuriri Valley	2464
Junction of Pukaki with Takapo River	1547
„ „ Ohau with Waitaki...	1475
„ „ Ahuriri with ditto	1168
„ „ Hakataremea with ditto	781
Lowest moraine accumulation in Waitaki Valley	716

Molyneux River.

Junction of Fish Creek with Makaroa	1362
„ „ Blue River with ditto	1210
„ „ Wilkin with ditto	1058

Rangitata River.

Havelock Glacier, terminal face	3909
Forbes Glacier, ditto	3837
Clyde Glacier, ditto	3762
Tyndall Glacier, ditto	3950
Lawrence Glacier, ditto	4061

		Feet.
Junction of Forbes river with Havelock River	... ...	2871
„ „ M'Coy River with Clyde River	... ...	3269
„ „ Lawrence River with ditto ...	... ...	2284
„ „ Havelock River with ditto ...	... ...	2192
„ „ Potts' River with Rangitata ...	... ...	1762
„ „ Pudding-stone Valley stream with ditto	...	1440
Where Rangitata enters Canterbury plains	... ...	1180
Banks above it, uppermost terrace ...	... ...	1443

Ashburton River.

Ashburton Glacier, terminal face ...	... ...	4832
Junction of lower branches	... ...	2511
„ „ Clearwater Creek with Ashburton	... ...	1832

Rakaia River.

Ramsay Glacier, terminal face	... ...	3354
Lyell Glacier, ditto	... ...	3568
Martius Glacier, ditto	... ...	4268
Junction of Whitcombe stream with Rakaia	... ...	2958
Hawker Glacier, forming Cameron River	... ..	4478
Junction of two Glaciers, forming Hawker Glacier	...	5667
„ „ River Cameron with Rakaia ...	... ...	2052
Neave Glacier, forming River Matthias ...	... ...	3788
Junction of two main branches of Matthias	... ...	2236
„ „ Matthias with Rakaia ...	... ...	1688
Stewart Glacier, terminal face	... ...	3584
Junction of two main branches of Stewart	... ...	3090
„ „ Stewart River with Wilberforce	... ...	2374
Camp Creek junction with ditto ...	... ...	3041
Junction of River Harper with River Avoca	... ...	2103
„ „ Western branch ditto ...	... ...	2531
Avoca Glacier, terminal face	... ...	4749
Junction of two source branches of Avoca	... ...	3416
„ „ River Harper with Wilberforce	... ...	1610

Waimakariri River.

Waimakariri Glacier, source of White River terminal face	...	4162
Ponds, sources of, Northern Branch ...	... ...	5141
Junction of Poulter River with Waimakariri	... ...	1621
„ „ Porter „ „ „	... ...	1361

Lakes.

		Feet.
	Lake Hawea	1073
	" Wanaka	992
	" Pukaki	1717
	" Ohau	1837
	" Takapo	2437
	" Alexandrina	2460
	" Acland	2205
	" Tripp	2228
	" Heron	2255
	" Browning	4616
	" Coleridge	1694
	" Selfe	1962
	" Ida	2304
*	" Lyndon	2743
	" Taylor	1948
*	" Sumner	1735
*	" Pearson	2085
	" Letitia	2079
	" Blackwater	2023
	" Poerua	345
	" Brunner	227
	" Kanieri	468
	" Hall	229
	" The World	1980
	" Georgina	1823
	" Catherine	1740

Passes.

*	Hurunui (Harper's) Pass	3150
*	Arthur's Pass	3013
	Harman's Pass	3980
	Browning's Pass	4752
	Whitcombe's Pass	4212
	Haast's Pass	1716
*	Porter's Pass, leading into Waimakariri country	3097
	Lake Lyndon Pass, from Rakaia into Waimakariri	2747
	Burke's Pass, from Opihi to Lake Takapo	2464
	Walker's Pass, from Opihi to Waihi	2984
	Tripp's Pass from Orari to Opuha	2255

		Feet.
	Pass between Cass and Godley Rivers, near Huxley Glacier	6565
	Fraser's Pass, between Lake Pukaki and head of Lake Ohau	3992
	Pass between Selwyn and Hawkins	1687
	„ „ Rubicon and sources of Kowai	3705
	„ „ Mount Somers and Mount Somers Range ...	3684
	„ „ Sources of North and South Hinds ...	3025
	„ „ Ashburton and Rakaia, near Lake Heron ...	2290
	„ „ Ashburton and Rangitata, near Lake Tripp	2360
	„ „ Hurunui aud Waitohi	1858
*	„ „ „ „ lower	1242
*	Weka Pass	860
	Pass between Lake Selfe and Lake Ida	2396
	„ „ The World and the longitudinal valley skirting Craigieburn range	2327
*	„ „ Kapitea and Taramakau	575
*	„ „ Waimea and Kawhaka	560
*	„ „ Wainihini-hini and Kawhaka	1006

Levels of Principal Points, Canterbury Railways.

*	Christchurch Railway Station, Colombo Street ...	15.97
*	Addington „ „ ...	30.50
*	Southbridge Junction „	88.79
*	Rolleston „ „	181.48
*	Selwyn River, Ordinary Water Level	211.50
*	„ „ Average Surface of River Bed... ...	209.87
*	Selwyn Railway Station	220.80
*	Rakaia River, Ordinary Water Level	331.50
*	„ Bridge, Rail Level	342.30
*	„ Railway Station	347.51
*	Ashburton „	323.09
*	„ River, Average Surface of River Bed ...	300.00
*	Hinds „ „ „ ...	275.00
*	„ Bridge, Rail Level	282.00
*	Rangitata North, Top of Terrace	370.04
*	„ River, North Branch—	
*	„ „ „ North Side	326.36
*	„ „ „ South Side	332.50
*	„ „ South Branch—	
*	„ „ „ North Side	338.00
*	„ „ „ South Side	341.50

		Feet.
*	Orari River, Average Surface of River Bed	250.00
*	„ Railway Station...	238.77
*	Temuka „	55.62
*	„ River, North Side	40.13
*	„ „ South Side	44.19
*	Opihi River, North Side	49.64
*	„ „ South Side	52.28
*	Washdyke Railway Station	9.10
*	Timaru Railway Station	10.00
*	Pareora River, North Side	13.00
*	„ „ South Side	21.00
*	Waimate Junction Railway Station	31.00
*	„ Railway Station	174.00
*	Waitaki North Railway Station	71.00
*	„ River, Ordinary Water Level	32.00
*	Waimakariri River, South Branch—	
*	„ „ South Side	2.94
*	„ „ North Side	7.00
*	Kaiapoi Railway Station	6.50
*	Rangiora „	90.09
*	Ashley River, North Side	101.00
*	„ Bridge, Formation Level	109.42
*	South Kowai River, Average Surface of River Bed ...	117.11
*	North Kowai „ „ „ ...	119.11
*	Amberley Railway Station	136.86
*	Cust „	423.73
*	West Oxford „	800.38
*	West Eyreton „	387.15
*	Southbridge „	74.86
*	Bealey's Road „	389.09
*	Horndon Junction Railway Station	646.45
*	Malvern „	962.69
*	Hawkins River, Average Surface of River Bed ...	683.00
*	Homebush Railway Station	707.40
*	Whitecliffs „	940.27
*	Pleasant Point „	203.45
*	Albury	750.45

West Coast Road, by Arthur's Pass.

*	Cook's Accommodation House	228·00

		Feet.
*	White's Accommodation House	631·23
*	Southern base of Little Racecourse Hill	979·39
*	McRae's Accommodation House (formerly Willis') ...	1273·54
*	Southern Bank of River Kowhai	1424·47
*	Centre of bed of River Kowhai	1393.62
*	Riddle's Accommodation House, foot of Porter's Pass ...	2060·
*	Summit of Porter's Pass	3097·
*	Lake Lyndon, high-water line	2743·
*	Springs, sources of River Porter	2535·
*	River-bed of Porter, where road crosses	2266·
*	Summit of Terrace, on its Western side	2491·
*	Bed of River Thomas	2197·60
*	Accommodation House near Mr. Enys' Station (stable of Cobb and Co.)	2374·
*	Top of Terrace of Broken River, Eastern side ...	2390·
*	Bed of Broken River	2094·
*	Top of Terrace on the Western side	2350·
*	Road near summit of Parapet Rock	2750·
*	Bed of small Creek near Shanty	2583·
*	Top of Craigieburn Saddle	2619·
*	Lake Pearson	2085·
*	Road crossing River Cass	1874·
*	Saddle between Cass and Waimakariri (Goldney's Saddle)	1929·
*	Bed of Waimakariri, between the two cuttings ...	1808·
*	Crossing of Waimakariri	2044·
*	Bealey Township (Police Reserve)	2130·
*	Southern foot of Arthur's Pass (Smith's Camp) ...	2497·
*	Arthur's Pass (highest summit)	3013·
*	Southern foot of Moraine	2666·
*	Summit of Moraine	2825·
*	River-bed of Otira, first bridge	2035·
*	Junction of two branches of Otira, near the Stockyard ...	1450·
*	Bed of Taramakau, near junction of the Otira, where the road joins the main river	731·
*	Western bank of River Taipo, near junction of Taramakau	355·
*	Waimea, where the road leaves the Taramakau ...	168·
*	Foot of Terrace	159·
*	Summit of highest Terrace	652·
*	McClintock's Store, near Kawhaka Creek	422·
*	Junction of Kawhaka with Arahura	104·

For the altitudes of the rivers crossing the Canterbury plains and the Plains themselves, the reader is referred to the Tables on page 403—6. The Chief Surveyor of Canterbury, Mr. J. H. Baker, and the District Engineer, Mr. G. P. Williams, have kindly furnished me with a number of altitude observations, by which this list has gained much in value. In all cases where altitudes of points, which I had previously calculated from barometric observations, were amongst them, I have substituted them for my own, as having been obtained by more reliable methods. In my reports on "The altitude of the country between Hokitika and Christchurch, by Arthur's and Browning's Passes," and on "The head waters of the River Rakaia," I have discussed at length the value of barometric observations when compared with those obtained by the spirit-level, at the same time giving the results of both methods in a tabular form. In this list only the spirit-level altitudes along the West Coast Road are given, as obtained by Mr. Edward Dobson, C.E., formerly Provincial Engineer of the Canterbury Province, to whom I am indebted for them.

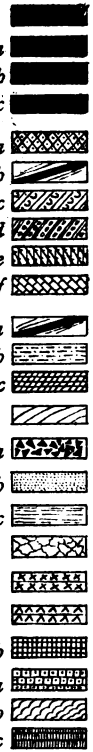
FINIS.

PRINTED AT THE "LYTTELTON TIMES" OFFICE, CHRISTCHURCH, CANTERBURY, N.Z.

No. 1.

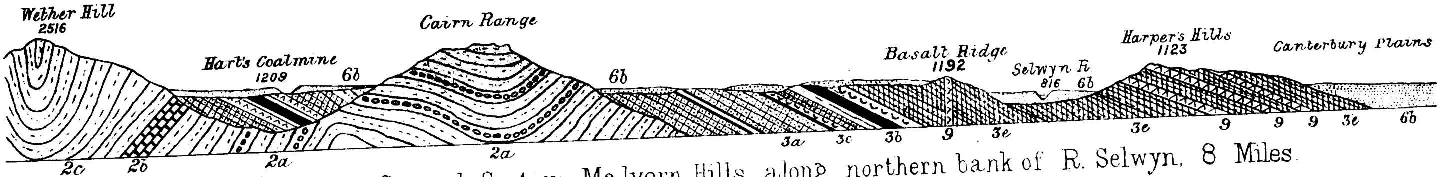
REFERENCE TO SECTIONS 2 TO 9.

Formation	Beds	No.
	Waihao Formation	1
Mt. Torlesse Formation	*Conglomerate, Plant, and Shell Beds*	2a
	Limestones, Cherts, Purple Slates, Diabasic Beds	2b
	Sandstones, Slates, and Shales	2c
Waipara Formation	*Conglomerates, Sands, &c., Lowest Beds*	3a
	Coal Formation	3b
	Fossil Beds	3c
	Septaria Beds	3d
	Green Sands	3e
	Calcareous Sandstones	3f
Oamaru Formation	*Coal-bearing Beds*	4a
	Green Sands	4b
	Calcareous Sandstones	4c
Pareora Formation		5
Post Pliocene Formation	*Morainic Accumulations*	6a
	Fluviatile Deposits, Silt, and Loess	6b
	Littoral and Recent Fluviatile Deposits	6c
	Melaphyre	7
	Quartziferous Porphyry	8
	Dolerites, Basalts of Waipara and Oamaru Formations	9
	Palagonite Tufa	9b
Banks' Peninsula	*Older Lavas*	10a
	Mt. Herbert system	10b
	Youngest systems	10c

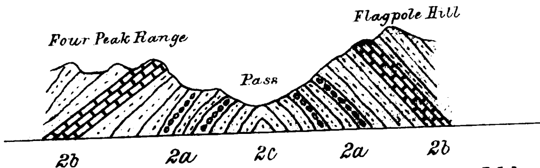


Lyttelton Times, steam lith

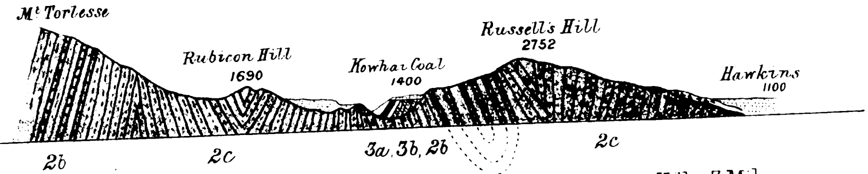
Nº 2 Sections



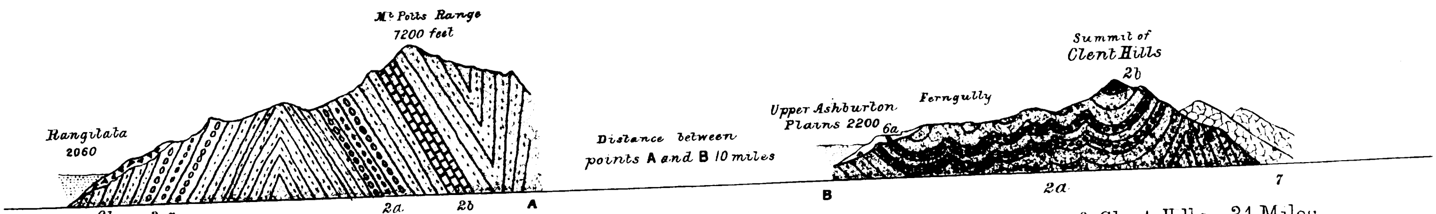
Nº 1. General Section Malvern Hills along northern bank of R. Selwyn. 8 Miles.



Nº 2 Hill's Pass Malvern Hills 1 Mile.



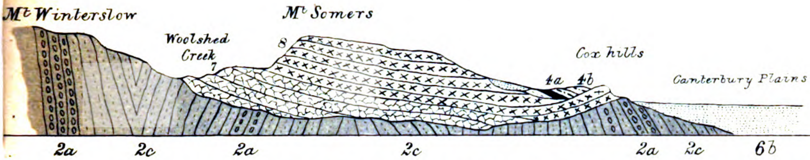
Nº 3 From Mt Torlesse to Hawkins valley. Malvern Hills 7 Miles



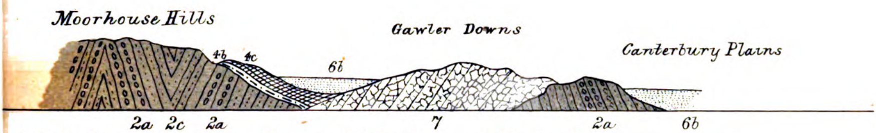
Nº 4. From western slopes of Mt Potts, Rangitata, to eastern slopes of Clent Hills. 21 Miles

Lyttelton Times steam lith.

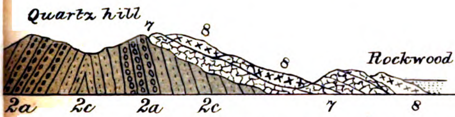
N° 3 Sections

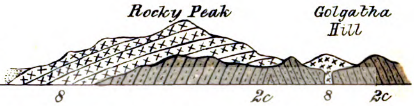


N° 1. From Southern slopes of Mt Winterslow, to Eastern slopes of Cox Hills, 7 Miles.

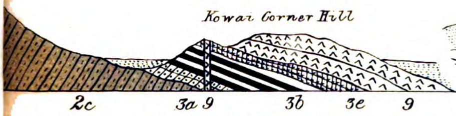


N° 2 From Eastern slopes of Moorhouse Hills, to Eastern slopes
of Gawler Downs, 11 Miles.

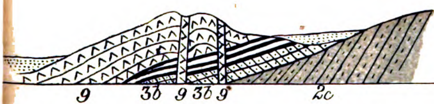




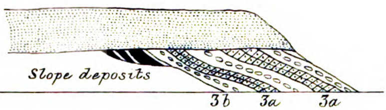
N°3 From Quartz Hill, to Rockwood, N°4 Rocky Peak, Malvern Hills, 2 Miles
Malvern Hills, 3 Miles.



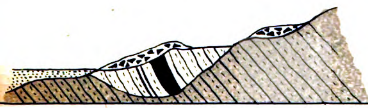
N° 5 Section Springfield Colliery, 2 Miles. N° 6 Section Homebush Colliery.



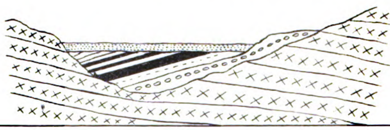
N° 7. Section Kowai Corner Hill.
Northern side 1 mile.



N° 8 Chasm Valley, Rakaia
Gerard's Coal seams



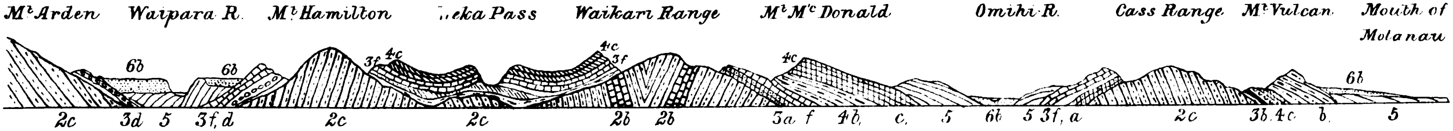
N° 9. Section Clent Hill
Coal seam



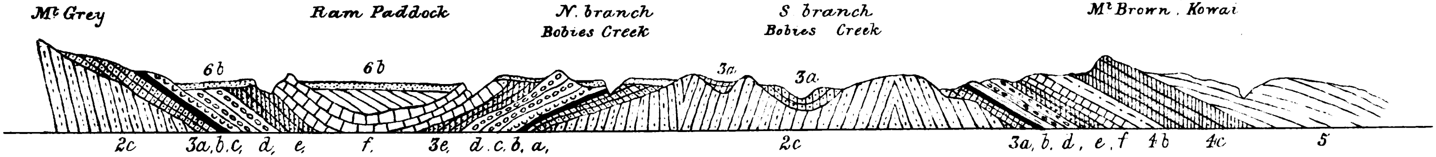
N° 10, Section of Coalcreek,
Ashburton.

Lyttelton Times, steam lith.

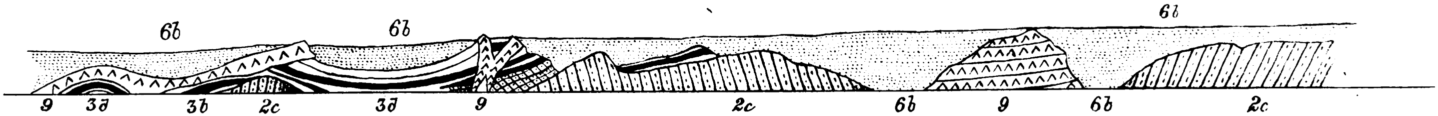
No. 4 Sections



No. 1 From slopes of Mt. Arden to mouth of Motanau River, 28 Miles.



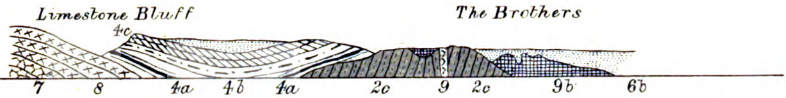
No. 2 From slopes of Mt. Grey to upper course of Kowai R, 7 Miles



No. 3 Along western bank of River Acheron 2 Miles.

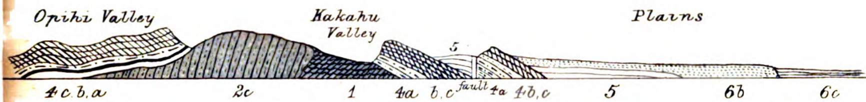
Lyttelton Times, steam lith

No. 5 Sections

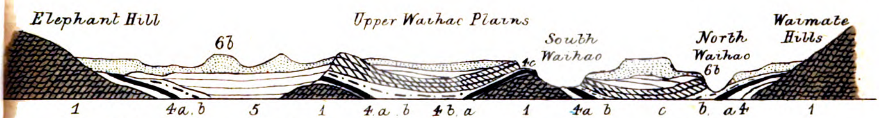


No. 1. From Limestone Bluff, Ashburton, to Two Brother's, 5 Miles.

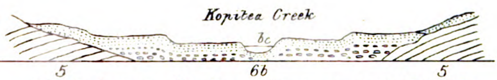
No. 2 From Upper Pareora, to East coast near mouth of Otaio, 21 Miles.



No. 3 From Upper Kakahu to Canterbury Plains, 9 Miles.



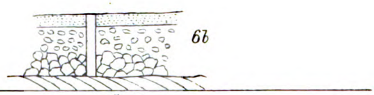
No. 4 From N. E. slopes of Elephant Hill to S.W slopes of Waimate Hills, 9 Miles.



No. 5 Waimea Lower No. 6 Waimea Upper. No. 7. Lower Kopitea, Westcoast Goldfields.

Westcoast Goldfields

No. 8 Kanieri Bluff, Westcoast Goldfields.

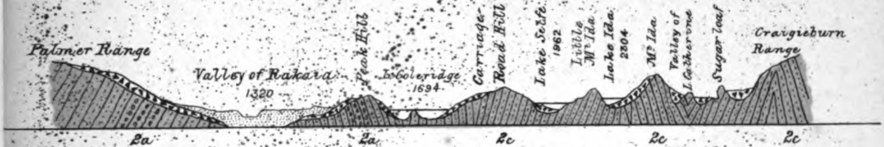


No. 9. Shaft on Kanieri Flat, *James & Party 1865.* Westcoast Goldfields.

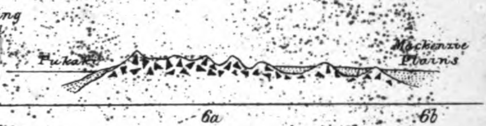
Lyttelton Times, steam lith

N° 7 Sections

N° 1 Ideal Section of Westland & Canterbury at the beginning of the Great Glacier Period, with outlines of present configuration.



N° 2 Section across Rakaia valley & parallel depressions 11 Miles



N° 3 Across Rakaia, near Fighting Hill (5 miles)

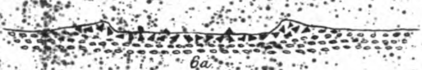
N° 4 Section of Frontal Moraine L. Pukaki (4 miles)

5 Section of lateral moraines L. Pukaki 10 miles

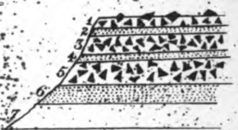
N° 6 Section of L. Tekapo & adjoining Ranges 9 Miles

Longitudinal Section of Railroad glacier Channel northern bank of Rakaia near gorge 3 Miles

N° 8 Frontal Moraine at A Section N° 7



N° 10 Section across Railway glacier Channel, Rakaia

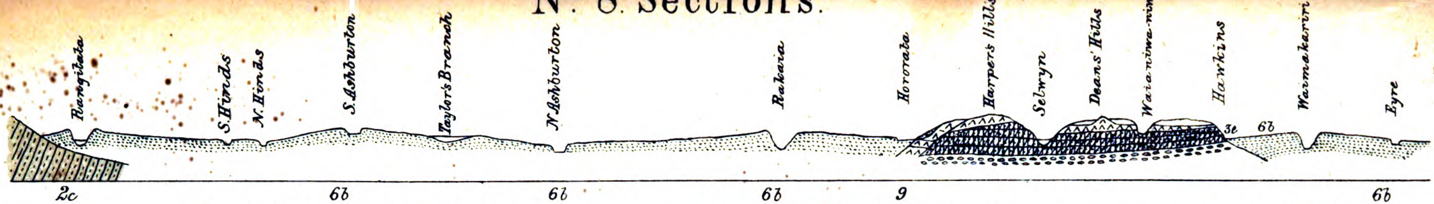


N° 11 Section left bank Potts River showing the arrangement of Glacier Deposits

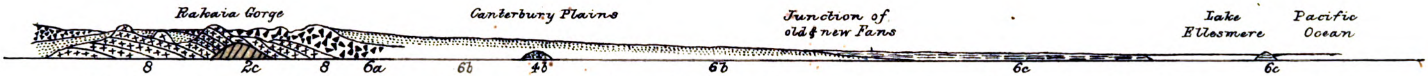
N° 9 Ground Plan Railroad Glacier Channel Rakaia

Lyttelton Times steam lith

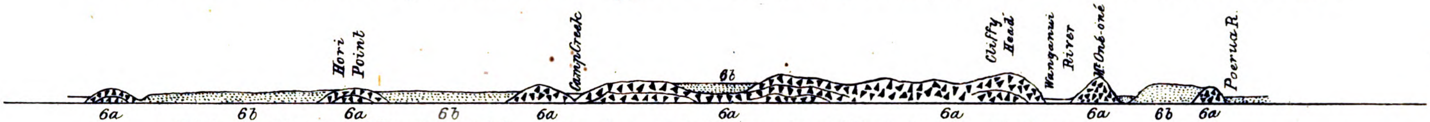
No. 8. Sections.



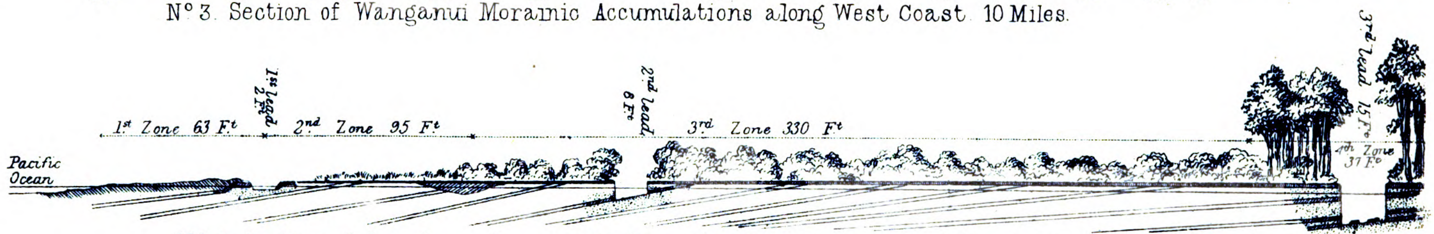
No. 1. Section of Canterbury Plains from N.E slopes of Mt Peel to River Eyre near Oxford 60 Miles



No. 2 Section of Canterbury Plains from Upper Rakaia Plains (northern side) to Pacific Ocean. 50 Miles



No. 3. Section of Wanganui Morainic Accumulations along West Coast 10 Miles.



No. 4. Section of Auriferous deposits, with Stone Implements, Bruce Bay, Westland

Position of Implements

Horizontal & Vertical Scale
80 Feet to 1 Inch

Shingle Beds
Auriferous Sands
Sands with drift wood
Vegetable soil

Lyttelton Times, steam lith