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PROVINCE OF CANTERBURY.

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By His Honor's Command,

THOMAS WILLIAM MAUDE,
Provincial Secretary.

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NOTES ON THE GEOLOGY OF THE PROVINCE OF CANTERBURY, N.Z.

To His Honor the Superintendent.

Sir,—In accordance with the wish expressed in your letter, I now beg to forward you the following interim report of my recent geological investigations in this Province.

Before entering, however, into the main object of my Report, I shall briefly state in what directions my Geological Surveys have been made, so as to enable you to see what has been accomplished during a period of nineteen months, thirteen of which I passed in the field.

From February, 1861, to June of the same year, I surveyed the rivers Ashburton and Rangitata and their different branches to their very sources, fixing on the unsurveyed ground all the principal topographical features. Returning thence towards the middle of June, I started for the Malvern Hills, where I was occupied for six weeks in provisionally examining this most important zone, until heavy falls of snow drove me back to lower regions.

At the end of October I visited the Kowai Coal-fields (Malvern Hills) superintending the drive excavated on behalf of the Provincial Government, in order to test the extent of the valuable coal measures in that district. During a stay of about eleven weeks I accomplished this task, surveying carefully at the same time the whole neighbourhood, including Mount Torlesse and the Thirteen Mile Bush Range.

At the end of January I proceeded to the Mount Cook district, with a view to ascertain if any auriferous rocks occurred in that region, at the same time continuing my regular geological survey. During a lapse of over four months I accomplished, with the active and hearty co-operation of Mr. Arthur Dobson, my assistant in the topographical work, chaining about 130 miles, the survey of the extensive river system which forms Lakes Tekapo, Pukaki, and Ohou.

This brought me into the very heart of the Southern Alps of New Zealand, which, in grandeur and beauty, are worthy rivals of their European namesakes. The ground travelled over has been so extensive, and the collected geological details are so varied, that at present it will be impossible to offer more than a summary outline of the geological structure of that part of the Province.

Before any fuller account can be given, it will be necessary to have some data from the West Coast, and I propose to go thither as soon as possible, to collect the necessary information.

After my return I shall prepare a more detailed report, together with geological and topographical maps, sections, &c., so as to give a general outline of the structure of this highly interesting country. But in order to give you an idea of the work which has already been accomplished, I refer you to the accompanying maps and sections, of which I shall speak more fully when treating of the formations of which they are intended to give you an insight.*

The western part of the Province of Canterbury consists mainly of a high mountain chain — the Southern Alps—which begins at the saddle of the Hurunui and Taramakau rivers, and continues without interruption to the southern boundary of the Province.

Covered with perpetual snow, from which numerous glaciers descend—twenty-four of which, of the first order I have already visited and observed—this magnificent chain gives rise to all the principal rivers of the Province, which are all true glacial streams.

This main range is the back-bone of the island, stretching through the Nelson Province north of the Hurunui Pass, and thence under different names to Cape Campbell.

This principal chain again commences at Wellington, and continues to the East Cape, attaining its highest elevation in the Ruahine range. This chain consists of sedimentary rocks, sandstones, slates, shales, flagstones, pebble beds, conglomerates, alumschists, &c. These rocks are of very high and as yet undetermined age, no characteristic fossils having as yet been found in them; but from the few fragmentary exuviæ of their fauna, and their lithological character, it is evident that they belong to a distant palæozoic period.

In order to shew why no gold bearing rocks have been met with on the eastern side of the Province, I refer you to No. 1 geological sketch map of New Zealand, showing, in broad outline, the different parallel zones.

Gold, as is well-known, is generally confined to metamorphic rocks of silurian age, associated with plutonic and eruptive rocks, granites, syenites, diorites, and hornblende rocks, &c. It will be evident, therefore, even to those unacquainted with geology, that this broad zone of sedimentary rocks of which the Southern Alps are composed, cannot, at least in its northern and middle portions, contain payable gold-fields.

In the south-western part of the Alps, however, in the Moorhouse range as well as along the banks of the rivers forming Lake Ohou, the rocks assume a somewhat metamorphic character, the slates becoming foliated and interstratified with quartz; it is therefore very possible that we may here meet with gold-bearing deposits

When I was in that district last autumn the season was far advanced, and the snow lying on the ground prevented a search being made. It is my intention, however, in a few weeks to continue my researches in that part of the country, and it is to be hoped that we shall not long remain behind our more fortunate southern neighbours.

I may here add, that gold is generally diffused through many formations, but in such minute quantities that it will not pay the expenses of working.

Therefore, if now and then a few minute specks of the precious metal should be found, we must not hastily come to the conclusion that a gold-field has been discovered.

Several instances have come before me in this Province where a few specks of gold were said to have been found, but on examining carefully the spots where the discoveries were alleged to have been made, I have in no case been able to perceive any traces of it, probably either yellow sand or minute scales of mica having caused the mistake.

The metamorphic and plutonic series, painted pink on the map No. 1, are true gold-bearing rocks, and are confined in our Province to the West Coast, although judging from the richness of the Otago gold-fields the semi-metamorphic rocks seem to vie in richness with those of the more truly metamorphic type in the Nelson Province.

The geological map of the Province, No. 2 of the accompanying series, and of which I am preparing one on a larger scale with all details, will show you that in the Alps, sedimentary rocks of at least two distinct periods occur, although both series agree in lithological character, joints, &c. The relations between these two palæozoic formations of which the one overlies the other unconformably, are extremely difficult to decipher, and I hesitate to give a decided opinion before I have made some special surveys along the lines of contact. Concerning the formation of the central chain, it is evident that the strata have not only been upheaved, but have also been folded in the most remarkable manner.

The section No. 3, across the island from Banks' Peninsula over Mount Cook to the westward, will enable you to get a clear insight into the structure of the different mountain chains.

It will show you moreover, how enormous the lateral pressure on both sides has been; on the east side by a large volcanic and eruptive zone, and on the west side by an

*1. Geological sketch map of the islands of New Zealand, showing in broad outline the different parallel zones.
2. Geological map of the Province of Canterbury, according to present survey.
3. Geological sections through the middle island of New Zealand, Province of Canterbury, from Banks' Peninsula to the western slopes of Mount Cook.
4. and 4A. Geological map and section of the Kowai coal measures.
5. Vertical section from north 41 west to south 41 east, Kowai coal measures.
6. Plan of the drive in the Kowai coal measures.
7. Section parallel to the south bank of the River Selwyn, Malvern Hills.
8. Sections along the northern banks of the Hororata, Malvern Hills.
9. Sections through Canterbury Plains, on the Southern Railway line, from the 29th to the 55th mile, by H. Whitcombe, Esq.

enormous zone of plutonic rocks, which in our province are mostly concealed below the sea, but are highly developed towards the north.

The data in this section dip and strike are all from actual survey as far as to the central part of Mount Cook, and a collection of rocks made for me at the west coast, near the base of Mount Cook, by Mr. James Mackay, Assistant Native Secretary, has enabled me to supply the deficiency in the direct observations.

The rocks occupying the western side, are in fact true metamorphic rocks, gneiss, mica, chlorite, graphite slates, etc., together with some quartzites, semi-crystalline sand stones and foliated flagstones. No granite or other plutonic rocks seem to occur there, as Mr. Mackay, an acute observer, was not able to find a single specimen of them. We may therefore assume that the hypogene rocks by which the Alps have been upheaved to their present position, and which are found so extensively in the Nelson Province, have partly been denuded, or lie concealed under tertiary or secondary strata.

The rocks which form the central chain are of so varied a nature or character, that it is almost impossible to give a full description in a report of this nature. Clayslates, gray wacke slates, and shales, alternate sharply with sandstones, flagstones, conglomerates, or pebble beds, or they merge into each other, or die out. Generally the strata, the strike of which may be said to be from north-east to south-west, stand vertical or nearly so, a dip of 75 deg. to 80 deg. being the average.

Their strike is generally regular, and they show a continuity of huge and steep foldings. In few places only greater disturbances occur, where the strata have not only been bent, but also contorted, faulted, and thrown over in various directions.

Of this I observed some very interesting and instructive instances, particularly in the northern main branch of the Rangitata. Some continuous faults also occur, the principal ones which fell under my observation were near the source of the River Havelock, the southern main branch of the Rangitata, and in the valley of the River Tasman, forming Lake Pukaki, near Mount Cook, the latter being without doubt the continuation of the former. Without swelling this memoir with details, I may say that the Alps consist of 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, my observations showed the exact reverse.

The enormous mass of Mount Cook occupies a synclinal trough, whilst the broad valley of the Godley River runs along an anticlinal arch.

The occurrence of such tremendous changes by which the arches or mountains have been converted into deep valleys, and the troughs into high serrated mountains, will give us some 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. It may be very possible that the arches, having been shattered by the upheaval, gave way sooner to the united aqueous and atmospheric action than the troughs, which by their position were more sheltered.

It is certain, however, that at least the greater part of the original strata must have been removed, before our present Alps could have taken their present form.

In all these enormous chains, the absence of limestone is very striking, even rocks with a calcareous matrix are wanting; only small veins of calcareous spar occur in a few places, but when we take a nearer view of the nature of the sediments which form the Alps, this absence is explained.

It is evident that we see before us the deposits, in shallow water, of rivers resembling those which at present fall into the sea at the East Coast; that the sea bottom underwent alternate periods of elevation and depression, the periods of depression, however, preponderating in length.

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 bed and conglomerates representing the immediate neighbourhood of the rivers or the littoral zone, whilst the claystones and finely grained sandstones represent those regions where only fine muddy particles were deposited far in the palæozoic sea.

The constituents of the pebble beds and conglomerates give us a clear insight into the structure of the mountains from which they were derived, and the fact that these constituents are of the same nature as the rocks which at present compose our Alps, show us what an almost incalculable lapse of time was necessary for the formation of the stratified rocks which here form the upper part of the earth's crust.

These pebbles are principally clay slates, gray wacke slates, flagstones, sandstones in the so called gray wacke form, but sometimes more crystalline, quartz, quartzites, hornstones, &c.

Only in a few places was I able to discover amongst these pebbles any traces of hypogene or metamorphic rocks whilst in the unconformably overlying zone of lower carboniferous or upper devonian rocks, where large conglomerate beds also occur, granites, syenites, gneiss, and porphyries are very abundant.

From this we may draw the inference that the palæozoic rocks were, before the deposition of the carboniferous beds, broken through by hypogene rocks, without being at present able to say where these hypogene rocks were situated. Some of the pebbles of porphyry are of great beauty, but the rocks from whence they are derived have never been observed by me in situ, anywhere in New Zealand.

Returning from this digression to the older palæozoic rocks of our Alps, we find that they have been derived from the detritus of large mountain chains which had similar constituents, and formed probably a large continent, of which all traces have disappeared; the eruptive and plutonic rocks on the western side of the island and the volcanic rocks on the eastern side, having entirely changed the configuration of the ground.

Judging from the observed effects we may safely conclude that a continent or large island, with huge mountain chains formerly existed in the neighbourhood of the spot, now occupied by these islands. These mountains were gradually worn down and their detritus carried into the sea, until the whole, assisted by a downward motion, disappeared below the waves, and whilst these older regions remained deep below the sea, the newer deposits derived from their destruction were brought up by plutonic and volcanic action during the secondary and tertiary periods.

As before stated, the general strike of the rocks forming the main range is nearly from N.E. to S.W., and no cleavage or even foliation is visible, except in the most westerly parts, of which I have hereafter to speak more fully, but the rocks are jointed in a most remarkable manner.

I have not yet been able to find a general law applying to the joints, and I shall leave this difficult subject to my more extended report, in which I shall discuss the matter. There are often three or four joints intersecting each other, generally with slicken-sides, coated with a green or white silicious glaze. Some of these are very smooth, and show clearly that the two sides of the joints have undergone several convulsive frictions, and that their faces no longer coincide, a throw upwards or downwards having taken place. This is very well shown by the older quartz veins, which intersect some of the thick-bedded sandstones in all directions, and which, at the joints, no longer preseve their continuity. The joints pass sharply not only through fine-grained rocks, but also through the hard conglomerates, the pebbles being cut through in the most defined manner.

One highly striking observation which thrusts itself upon the explorer, is the enormous waste which goes on amongst the rocks.

I have seen mountains rising from 5000 to 6000 feet above the valleys, everywhere covered with rubbish. They were in fact one continuous talus of detritus from sumnit to foot with hardly any rocks visible in situ, but the reason is obvious, when we consider the frequent thunderstorms with lightning by which the rocks must be riven, the heavy falls of rain by which the loose pieces are washed down, and the great difference between the diurnal and nocturnal temperatures. From observations which I made in this region, at an altitude of more than 3000 feet, I ascertained that the temperature for at least six months in the year falls generally during the night below freezing point, whilst generally by day the sun is so powerful that even in the middle of winter, in the shade, the temperature is much above freezing point, and in the sun is really warm, the days being generally very fine and the sky cloudless during that season. If we further consider the continual changes between the hot north-west and the cold south-east winds by which the mountains are alternately swept, it is evident that by the condensation of the clouds (forming ice in the fissures), another and powerful agency for the destruction of the rocks must be furnished. All these causes, however, would not produce such results, if the rocks themselves, in their lithological character, and in their vertical or nearly vertical positions did not offer the greatest facilities for their disintegration.

In the Alps proper no signs of ores were observed by me, and only a few veins of calcareous spur, without doubt of younger date than the quartz veins, were detected. I found also in some of the rivers heavy spar, but without meeting it in situ. The carboniferous rocks near their contact with the large volcanic zone, broken through as they are by dioritic rocks, by melaphyres and amygdaloids offer us better prospect of ores. A piece of grey copper ore, mixed with malachite, found in one of the streams joining the Ashburton, and the existence of various carbonates in the Mount Torlesse range lead us fairly to expect that workable mines may be discovered.

On the Moorhouse range where we meet with rocks having a somewhat metamorphic character, in some of the quartz veins small crystals or concretions of iron, copper, and arsenical pyrites occur, several of the sandstones being at the same time highly feruginous. My endeavours to find characteristic fossils have not met with success. Although I devoted many hours to the search, the only traces of animal or vegetable life that I was able to discover were a fossil, in a very fragmentary state, without doubt belonging to the serpulidæ, in a fine bluish clayslate from Mount Forbes, near the sources of the Rangitata, and the tracks of annelids in a carbonaceous slaty shale from the summit of Mount Observation, between the junction of the rivers Godley and Macaulay. Although in the Moorhouse range, south-west of Mount Cook, no direct evidence can be detected of a contact with hypogene rocks, the strata begin to be more or less altered, the clayslates become foliated, and have a silky lustre, the sand stones quartzitic, and hornstones and cherts are abundant.

Great quantities of quartz partly in veins feather-edging or inter-stratified amongst the fine silky schists, make their appearance, and as the gold-fields of Otago are situated in rocks of the same character, it is to be hoped that in this south-western corner of our Alps, from which I was driven by the inclemency of the weather, I shall be able to discover gold in more or less payable quantities.

The carboniferous rocks in our Province are of very considerable extent, but here also a great obscurity prevails which can only be cleared up by repeated and careful researches. As far as my own observations went, it is certain that they overlie unconformably the older palæozoic rocks, but regarding the age of the strata themselves great difficulties occur, which have for some time given rise to discussions in the scientific world, whch will probably be brought to an end by my discoveries in New Zealand.

These carboniferous rocks, where first observed, occur in a basin, which begins near Mount Rowley, where they clearly overlie older palæozoic rocks.

They consist of grits, and argillaceous shales, with a few thin layers of black band, and very small seams of coal. Some of these shaly beds consist almost entirely of impressions of plants, for the greatest part ferns, of which as far as I could judge, some are identical with, and others nearly related to the fossil plants of the Newcastle coal measures of Australia, which the researches of the eminent palæontologist, Professor Frederick McCoy have shown to belong to the oolite period. In these sandstones large trees lie imbedded, without doubt belonging to the group of acrogens, and whilst their hollow stems have been filled up by sand and clay, their more solid bark has been changed into shiny black coal.

Continuing across this basin towards the Rangitata we meet with sandstones and slaty shales, some of them entirely filled with the exuviæ of mollusca, which again are identified with or nearly resemble those found in the coal measures above mentioned, and the age of which is (according to Professor McCoy) lower carboniferous or upper devonian. Although the localities in which I discovered these fossils, Fossil Creek, near the Rangitata, and Fern Gully in Mount Rowley, are about 15 miles distant from each other, I hope, notwithstanding, to be able to show that the plant bearing beds not only overlie conformably the shell bearing deposits, but also that they follow each other in true sequence

The character of the rocks is similar, they are jointed in the same way, and this alone might lead us to the conclusion that they do not belong to such distant periods as the lower oolite and the upper devonian or lower carboniferous ; but we have a better test in the Waipara beds which contain saurians of an oolitic or liassic character, and which as I hope to be able to show, overlie the strata which contain the oolitic flora.

Far be it from me to contend with such an eminent palæontologist as Professor McCoy, as to the character of this flora, but is it not possible, when we observe still greater anomalies in the European Alps, to suppose that whilst our fauna is of a carboniferous character, our flora resembles that of the oolite of Europe.

This question, which, for many years, has given rise to vehement discussions amongst palæontologists and geologists in both hemispheres would be set at rest, could I prove that the saurian beds of the Waipara, which have not only been less disturbed, but have quite a modern aspect, overlie the strata with the oolitic flora.

Professor Frederick McCoy, at my request, has kindly undertaken the task of describing the fossils of our survey, and as soon as I receive his valuable communications, I shall presént them to you.

No coal seams of any consequence were met with either in Fern Gully or in Mount Harper, near the Rangitata, although small ones are very abundant, but not having finished my survey in that interesting part of the Province, it is very probable, that by more extended researches payable and workable seams may be found. Carboniferous rocks with small seams of coal were also met with by me at the Opihi near Mr. Maude's station, but as the snow was lying on the ground, I was unable to pursue my researches.

Although I had the honor of presenting to the Provincial Government a report on the Kowai coal field to which the maps and sections No. IV, IVA and V and VI belong, I shall offer a few more remarks on this subject, which is of so much importance to the future welfare of the Province.

The Kowai coal fields are only a small portion of large coal measures which will be found at the base of the mountain chains near Oxford, as well as in the Rakaia, near Lake Coleridge. The coal measures in the Selwyn, to the examination of which I devoted several days, lie detached amongst older palæozoic rocks. As I examined them only near this river, I am not able to state how far they will extend in a northerly direction, but from the nature of the rocks in the neighbourhood I think the basin will prove to be of small extent only.

There is not the least doubt that these coal measures are only a very small portion of those belonging to the Province, to the examination of which more time has to be devoted.

Although so far as I observed there appears to be a large gap between the palæozoic and tertiary rocks, yet it is clear that secondary rocks do exist, in which the remains of the Plesiosaurus Australis of Owen were obtained, thus pointing towards an age of oolite or lias. I have not yet been able to go to the Waipara, where the remains of these huge marine saurians were obtained.

If we ask ourselves, when the eastern side of our alps was upheaved to its present configuration, the beds at the foot of the large volcanic zone offer us an answer. This large longitudinal volcanic zone, which stretches with very little interruption from Timaru to the Kaikoras bounding the Canterbury plains to the west, shows us by the fossils imbedded in the tufaceous and calcareous beds at its base, that it has a tertiary age

These exuviæ, belonging to Pecten, Terebratula, Lima, Ostrea, Venus, Natica, Tellina, Nucula, Astarte, Cardium, Lucina, Fusus Voluta, Schizaster, Spatangus, are probably miocene, as we meet with beds of tertiarie of both a younger and an older period in other places in New Zealand

In this zone are found volcanic rocks of a very interesting character of great variety and of different ages.

The older rocks, by which the high chains to the west of this extensive volcanic zone have without doubt been brought to their present almost vertical position, are trachytic.

When this eruption took place large masses probably were in a pastelike semi-fluid state, ascending through huge fissures. Not the least sign of craters or scoriacious lava streams are to be observed. The mountains formed by these rocks are from 3000 to 5000 feet high and have generally soft rounded outlines, the highest points only having a tendency to assume a dome-like form.

The principal mountains consist mainly, as observed by me at the base of Mount Somers, on Snowy Peak, and Mount Misery in the Malvern hills, of a peculiar kind of trachytes, which, from their lighter specific gravity, their felsitic matrix, and the great amount of silica, sometimes amounting to three-fourths of their constituents, distinguish them not only from the heavier basic volcanic rocks, but also from the trachytes properly so called.

Their resemblance to certain granites is often so great, and their analysis so nearly identical, that there is no doubt, they have been derived from the same abyssological sources. Baron Richthofen has given to them the name of rhyolites, and I shall, in future, use this appropriate name to distinguish them from the other trachytic rocks abundant in the Province

Quartz in small crystals or grains and even in larger concretions is very abundant, and may, as a rule, be considered to be their distinguishing feature, although sanidin (glassy felspar) also occurs. In colour they are generally white or pale green, but they also present many varieties of lighter shade.

Their lithological character changes constantly, sometimes becoming pearlites or obsidians, the latter with a sphœrulitic structure without doubt the result of slower or quicker cooling of the erupted masses. They seem partly to have filled fissures formed in the main mass, and then present a more felsitic structure or to have flown from openings at their sides, in which case they generally present a pearlitic structure.

Silica, in the forms of rock crystal, amethyst, calcedony, heliotrope, agate, cornelian, jasper, semi-opal, and chrysoprase are very abundant. They either line fissures or form godes or concretions (lythophyses) and such masses have been left exposed by the decomposition of the softer body of the rock, so that some mountains, as for instance Snowy Peak, are literally strewed with these siliceous minerals. Some rocks of an amydoloidal structure have their hollows filled up, partly with calcedony, partly with a siliceous green earthy substance (pimelite.)

Sometimes thin plates of calcedony are met with, having on both sides the impressions of crystals of calcareous spar. In rare instances I found pseudomorphic crystals of the calcareous spar, the carbonate of lime previously deposited in these fissures, having been decomposed by water surcharged with silica, which deposited the latter mineral without destroying the forms of the original crystals.

No sign of silica, in the form of quartzsinter or geyserite was met with, so as to indicate that boiling siliceous springs, such as still exist in great activity in similar volcanic zones in the Northern Island, have here been at work.

In other places true trachytes occur, often with tabular and other very interesting structures, but having only cursorily and during the middle of winter examined this district, I am not yet prepared to say in what relation they stand to the more extended rhyolites of this volcanic zone. At the base of the systems above described we meet with large beds of tufa, often so much resembling the rocks from which they have been derived, that they look more like decomposed volcanic rocks than mere aqueous deposits.

Some are well stratified, forming ribbon-tafas of great beauty and variety. In other places they become so coarse as to present the appearance of agglomerates.

It is evident, that during a long period these volcanic rocks remained deeply immersed in the sea, during which time the extensive tufa beds, several hundred feet in thickness, were formed. A change then took place however, oscilations occurred, which made the water shallower and deposits of another nature were formed, in which also the disintegration of the western palæozoic rocks participated. By these various processes, of deposition on the one hand and upheaval on the other, dry land made its appearance, whilst some of the strata thus formed consisted of loose ferruginous sandstone. A luxuriant vegetation then overspread it for a long period, until, by a fresh depression of the ground, it was again buried below the sea level, giving birth to the extensive lignite beds found all along the margin of the volcanic zone.

That in some places oscillation occurred by which the dry land alternately became sea bottom, is shown by the existence of small seams interstratified with marine deposits, whilst that other places were not affected by these changes is shown by the existence of one large seam of lignite.

The downward motion, however, was exceedingly slow, as is shown by the character of the numerous fossils imbedded in the strata, which all have a littoral character.

They are inclosed in limestome, sometimes very compact, sometimes of a more earthy nature, or consisting of a mass of broken and rolled shells, cemented by an argillaceous or calcareous matrix.

Above these large oyster beds occur, which, by their hardness have better resisted the destroying action of the atmosphere than those lying above them, which are of a much softer nature. Many evidences of this period of subsidence are met with far inland, behind the first system of palæozoic strata, as for instance, in the coal basin east of the Thirteen-Mile Bush Range, and the extensive basin of the Upper Waimakariri, where all the phenomena before described are exhibited, although on a much larger scale.

By the continued sinking of the land, the higher volcanic eminences were again brought in contact with the destroying waves, and enormous masses of sand, derived from the degradation of the volcanic rocks, were deposited.

After a considerable lapse of time, the volcanic force, which had slept for a long period, again began to operate at the eastern base of the trachytic and rhyolitic ranges. Rocks of much greater specific gravity made their appearance in the form of dolerites and basalts, partly as dykes, partly as lava streams breaking through and disturbing the strata at the foot of the older volcanic regions.

That some of these lava streams were subaerial is proved by the very interesting and instructive beds of palagonite tufas in Harper's hills, the enclosed leaves and twigs of dicotyedonous trees showing that before the eruption of these basic volcanic rocks, the country had again risen above the sea level and been covered with a luxuriant vegetation.

The sections No. 7 and No. 8, will give you a clear insight into the relations of the different volcanic rocks and the tertiary strata at their base. But I may add, that for the elucidation and study of this interesting zone more time has to be devoted, and that more space will be required for its description than I can fairly devote in this preliminary report.

In what relation the separate volcanic system of Banks' Peninsula stands to the eastern zone, which it surrounds like the segment of a circle, can only be determined by future careful examination.

To the more recent basic volcanic rocks belong the systems of the left bank of the Orari and of Timaru and its neighbourhood.

As in the course of my report I shall often have occasion to refer to definite positions, I here add a table of altitudes, classified according to the different river systems; those marked thus * being the result of barometical observations, combined with those of the boiling water apparatus, whilst those without the star were only taken by the Aneroid barometer. I have to thank Mr. J. Williams of the Land Office, for keeping, during my absence, a meterological register, which has enabled me to calculate with a fair degree of precision, the altitudes of the different stations of my journey.

TABLES OF ALTITUDES.

Calculated from the results obtained by the Aneroid Barometer.

RIVER RANGITATA.

	FEET.
* Terminal face of Havelock glacier, principal source of the River Havelock, from Mount Tyndall, southern branch of Rangitata ...	3909
* Junction of Havelock with two other glacial streams, from Mount Forbes	3212
* Terminal face of Forbes Glacier ...	3837
*Junction of the outlet of the Forbes glacier with Havelock (good camping ground)	2871
* Clyde glacier, terminal face, source of River Clyde	3762
Tyndall glacier, terminal face..........	3950
*Junction of the McCoy with the Clyde (good camping ground) ...	3269
*Lawrence glacier, source of River Lawrence, northern branch of Rangitata	4061
*Junction of River Lawrence with River Clyde	2284
*Junction of River Havelock with Clyde, forming the River Rangitata	2192
Highest terrace in Upper Rangitata, west of Mr. S. Butler's station...	3413
Mount Sinclair, between Rangitata, and Lake Tekapo	7022
Saddle between Coalcreek falling into the Rangitata and Canterbury plains	2208
Canterbury plains, at the base of the mountains, where the Rangitata leaves the mountains..........	1309

RIVER ASHBURTON.

*Mount Rowley, Ashburton..........	4244
Ashburton glacier	4823
Ribbonwood range, between the Ashburton and the Lake Heron Country summit..........	5862
First terrace towards Lake Heron...	3607
Highest ditto	5160
*Lake Tripp (its outlet to Ashburton) the watershed between it and the Rangitata about 30 feet above the level of this lake	2318
Lake Acland	2303
Lake Heron (the outlet of which belongs to the Rakaia river system), between this lake and the waters of the Ashburton, the watershed is about 100 feet	2297

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† After correction of Index error.

It is evident that at the base of so huge a mountain system as the Southern Alps of New Zealand (in which, during geologically recent times, great oscillations have taken place) large deposits of boulders, sand, clay, &c. must occur, formed from the detritus of its component rocks when acted upon by ice, snow, rain and other atmospheric influences.

The Canterbury plains, formed by these deposits, are 112 miles long, and on an average about 24 miles broad and consist, for some miles inland along the coast line of alluvium, brought down by the rivers which intersect these plains, and which, for about ten miles from their mouths, flow above the general level of the plains, resembling in this respect the Adige and Po.

Other parts of the lower plains are formed by littoral deposits. The general fall of the rivers is about 30 feet in the mile, although to the eye the plains present an apparently dead level. In order to show how the river beds, in the lower parts of their courses, are shifting, filling up and changing their channels I would refer to No. 9 section taken on the southern railway line from the 29th to the 55th mile peg by Mr. H. Whitcombe, which instructive section I owe to the courtesy of our Provincial Engineer. No more beautiful illustration of the phenomena to which I have alluded could be met with.

About eight to ten miles from the mouths of the rivers a change occurs, and although the beds of the glacial streams are still broad, they begin to cut into the loose deposits of the plains. Terraces are formed, which on the eastern side of the plains, near the base of the mountains, are often 300 feet above the level of the rivers, and consist of from four to six distinct and perfect terraces rising one above the other. At sudden curves in the rivers (which shift their channels with almost every heavy fresh), these terraces are often destroyed and beautiful vertical sections are exposed, showing clearly the nature of the deposits by which they have been formed.

There is in the first place generally a capping of well stratified shingle and sand sloping insensibly towards the sea; below this we find different beds of boulders, for the greater part rounded, but sometimes angular, inter-stratified with sand, loam and clay, exactly resembling the boulder clays of Europe. These beds are generally quite horizontal, but are sometimes irregularly disturbed as if tilted up by the stranding of an iceberg. In the blueish clays, which sometimes thin out in a distance of fifty or sixty yards from three to four feet to a few inches, I observed the remains of some exuviæ and bivalve shells, but so rotten that it was not only impossible to remove them, but even to ascertain the species; although I believed one of them to resemble the Venus intermedia of our seas.

Amongst these boulder clays I observed several angular blocks, surrounded by clay, but very few of them were of sufficient dimensions to deserve the name of erratic blocks.

This, at first, seems rather astonishing, when we consider that these enormous deposits of the pleistocene period, which are only exposed in their upper parts, have, in great measure, been transported by icebergs to the locality in which we now find them, or at least to their close neighbourhood.

During a careful examination of the boulders forming these deposits, I was not able to detect any eruptive or volcanic rocks or debris of the tertiary deposits at the base of the latter, but only the different sandstones, slates, flagstones, pebble beds and conglomerates which form the Southern Alps, whilst the rivers flowing through these zones now bring down a great quantity of volcanic detritus, from which we may conclude, that when these deposits of the glacial period were formed, the volcanic mountains (never more than 5000 feet, and generally 3000 to 3550 feet high), were lying below the level of the sea.

In order better to understand what I have to say about deposits of a similar nature in the Alps, it will be necessary to offer a few remarks on their physical geography. The main chain of the Alps, as far I explored them, runs north-east and south-west, and projects several divergent chains, often very little inferior in size, in a north and south direction. The main glaciers run along the base of the Alps in a line parallel to the main chain, either in a southerly or northerly direction. From the spot, where the rivers leave their glacial cave, they are true shingle rivers, that is to say, they meander through a straight valley often three miles broad without any falls or even great rapids, although their general fall is from 40 to 50 feet in the mile. The valley generally opens until they reach the last boundary chain of the plains, through which the rivers have cut deep lateral gorges with nearly perpendicular rocky walls, through which they rush with great impetuosity. In these gorges we find only traces of the drift period.

By following attentively the rising deposits, I found invariably, that above the gorges they again recurred, and by calculating the distance and the average rate of rise, which is from 35 to 40 feet in the mile, I found they corresponded perfectly, so that, in fact, the deposits in the middle courses of the rivers form a continuation of those of the Canterbury plains, consisting of the same boulders, but larger and more angular.

Several eminent geologists have entertained an opinion, that deposits forming similar plains, could not be brought down by glacial action, because the boulders are for the greater part rounded, but I am induced to arrive at a different conclusion from the fact, that the old glaciers were of a much larger size than the present ones, and that where brought down by the latter, the debris very soon presents a simularly rounded appearance.

For instance, on the great Tasman glacier, which, at its terminal face, has still a breadth of one mile and three quarters, we find that for at least three miles from its terminal face upwards, the debris is rounded and exhibits very few large blocks.

The surface of the glacier resembles the channel of a river bed, and, in fact, during the melting of the snow, and during and after heavy rains, the water rushes in streams over its surface, whilst below the centre of the glacier, at its end, a channel covered with shingle is formed, which is usually perfectly dry. Even at a few yards distance from the glacier, the debris carried down to its face when exposed to the action of the streams very soon looses the sharp angles and asumes the shape of the boulders which we find in the drift deposit. It is evident that the same agency which rounds the debris near the glacial caves and along the terminal face of the glaciers themselves, are also at work at the bottom of the sea.

Either currents rolled them, or when shallower water occurred so as to occasion the stranding of icebergs, the boulders were acted upon by the waves, which, from recent researches, have been found to act on substances deposited on the sea bottom at a depth of several hundred feet. Clay deposits (glacial mud, formed principally by attrition) mark those spots when the sea was undisturbed either by under currents or by the action of the waves, and the fact that amongst them I several times observed angular debris, deeply imbedded, affords an additional proof of the manner of their deposition.

But when we enter the Alps we soon find some very interesting phenomena which further explain the formation of drift deposits. The spurs which branch from the central chain, for many miles upwards, have been acted upon by two different agencies. The first and older of the two agencies was the sea, the effects of which are palpable from the fact that during the drift period the country was sunk at least 5200 feet below the sea level, above which it afterwards rose at several different periods so as to form ten distinct main terraces, which occur between the altitudes of 2500 and 5200 feet, giving to each terrace an average height of 290 feet, but these terraces are sometimes subdivided so as to present no less than 30 distinct smaller ones, as regular in appearance as fortifications.

They are only intact where we see no trace of glacial action after the period of their upheaval, as, for instance, in the Ashburton Plains on both sides of Lake Heron, but when we examine the main valleys at the head of which glaciers are still found, level terraces, when not destroyed by the atmospherilies, are only met with at the lower ends of the chain, soon disappearing below the lateral moraine lines, formed during the later glacial period.

Both terrace formations are easily recognisable, not only by the deposits of which they are composed, or by which they are covered, showing their littoral or moraine character, but also by their slopes. Whilst the marine terraces, as before stated, are quite horizontal, the moraine terraces slope downward at an angle varying from 2 to 5 deg., and are generally steepest in their upper parts.

Both these terraces form a most prominent feature in the landscape, because, to an altitude of about 5200, feet the mountains are generally smooth and covered with grass and subalpine vegetation, whilst above this we see the rugged and craggy summits of the Alps.

It would be impossible for me to point out all the indications of glacial action found in the valleys, the roches montonneés on both sides, and the sugar-loafs which exhibit the directions of the marine currents, and I must therefore leave these details to my future report, but I cannot omit noticing one of the most convincing proofs of the glacial period which perhaps is to be found on the globe.

The chain between the main rivers, which form Lake Pukaki and Tekapo, drops near the middle of the latter lake, whilst the former lies about ten miles distant from its terminating spurs, and a large flat, covered by drift formation, lies between and around the lakes.

This drift is cut through by streams flowing into the lakes. When first I reached these lakes I was not a little struck by the manner in which they had been formed, as they are bounded by lateral and terminal moraines of enormous glaciers, which, during the upheaval of the country in the glacial period, had extended to these points. These moraines not only encircle the lakes in a most remarkable manner on three sides, but their constituent debris is often of large size, and as angular and fresh as if freshly fallen from a glacier.

I followed these lateral moraines upwards for many miles, and found them, at about 16 miles above the outlet of Lake Pukaki, nearly 1200 feet above the level of the lake, lying on drift deposits, whilst twenty-four miles above the outlet, where the mountains rise steeply from the broad valley, they disappear and are replaced by sloping terraces, the highest of which I observed to be about 2500 feet above the valley, or 4800 above the level of the sea. Their glacial origin is not otherwise observable, the debris of the side moraines having been, in great measure, obliterated by avalanches and mountain torrents or been covered by shingle reaches, but the deep cutting in the mountain sides and the numerous roches montonneés offer convincing testimonials of their origin.

I shall now proceed to describe some of the physical phenomena which we meet around Lake Pukaki.

Ascending the outlet of this lake from the point at which it unites with that of Lake Tekapo, I found the river flowing over a broad shingly bed, the plains lying only a few feet above the level of the water. The plains here present a smooth surface, rising very gradually towards the lake, about 40 to 50 feet in the mile. Some distance up, the river forms terraces, which, about five miles from the outlet, stand nearly 100 feet above the level of the water.

Beyond this the level appearance of the plains is changed, exhibiting mounds like islands, consisting of large angular erratic blocks.

At first these island-like mounds are not numerous, but become more so as we approach the lakes, and ultimately encircle it like a wall only broken by the outlet. Amongst these elevations we met with numerous lagoons, covered with aquatic birds. These mounds are really ancient moraines, and indicate clearly, even to the unscientific observer who has once seen a glacier with moraine, their true origin. They are about two miles broad.

I may be permitted to offer a few remarks on the causes of the remarkable phenomena by which the formation of these lakes has been brought about, and which afford so convincing a proof of the great duration of the glacial period.

The upper sloping terraces show the different levels at which the glaciers, which then covering the Alps, reached the sea during the gradual upheaval of the land. Their terminal faces, washed by the waves, were broken off and carried away in the form of huge icebergs, as still occurs in the inhospitable polar regions, and even in Terra del Fuego.

By the melting and stranding of these icebergs, the detritus, with which they were charged filled the bottoms of the valleys, the deposits being generally assorted by submarine currents, and the action of the waves in the shallower places. As the country rose, the terminal faces of the glaciers were no longer subjected to marine action, and deposited their detritus load on dry land.

For a long time they seem to have maintained the same degree of magnitude, retreating very slowly, as we see by the different walls, several miles in breadth, which now enclose the lakes. After this, however, they must have retreated more rapidly, until they attained their present position, as in few places only did I see any remains of old moraines.

Not that such moraines do not exist, however, although without doubt the greater part of them are more covered by shingle and boulders, brought down by the rivers which supply the lakes.

These lakes, as is shown by the deltas at their upper end, are, geologically speaking, rapidly filling up. I am also led to believe, from their milky opaque colour, that the lakes themselves are shallow, though I had no opportunity of sounding. The waters of Lakes Pukaki and Tekapo have never been seen clear, which is the more surprising when we observe that the rivers which form them, become, after a continued period of fine weather comparatively clear, presenting the beautiful semi-opaque bluish colour, characteristic of glacial streams.

When surveying, this most interesting country, I was often struck by the violence of the wind, which so disturbed the waters of the lakes, as to form quite a surf on their shores, and it is evident, that the dull colour of their waters is in great measure due to the stirring up of the deposits of fine glacial sediment, brought down by the rivers.

This affords, moreover, additional evidence of the shallowness of these lakes. But if stronger proofs were wanting, it is to be found in the circumstance that after strong winds the water of their outlets becomes exceedingly white, from finely suspended matter different in appearance from that brought into them by the rivers, either after heavy rains or after the melting of the snows, which is thick and of a yellowish colour. The deposits round the lakes are equally instructive, and prove that their outlets each year cut deeper channels through the old moraines by which they are bounded, and thus lower the general level of their waters.

About 60 feet above the present level of the lakes we meet with shingle beds, which have evidently been assorted by the action of the waves. In other places to which the prevailing winds have had more access, the waves have eaten into the shores, and landslips have taken place, which present successive layers of fine flour-like whitish sediment, similar to that which is now deposited between the rocks in well sheltered places. Now and then small layers of a coarser nature and darker colour are met with, interstratified with these finer deposits. I also observed inclosed, in the first described sediment, large, well-rounded boulders, whilst the occurrence of a single large angular block, embedded in the glacial mud, was rather perplexing.

Further proof of the former higher level of the lakes is to be inferred from two breaks in the moraine wall, one 60 and the other 100 feet above the present level, through which the waters formerly flowed. Corresponding with these openings (called lake-passes by by the settlers) we find in the plains below them, small dry channels, evidently the former courses of the waters which flowed from these branch outlets.

Although at first sight we might suppose that only one subsidence of the land took place, by which it was sunk for many thousand feet below the sea level (followed as a consequence by the glacial period), yet, on closer examination, I was led to a different conclusion.

I observed, for example, in several places deposits of newer glacial drift, lying unconformably upon older deposits of a similar character, one mound (shewing these older deposits and rising above the level drift plains which stretch between the old moraine walls surrounding lakes Pukaki and Ohou), is so conspicuous, that I shall offer a short description of it. This mound lies on the edge of a small rivulet descending from the ranges between the two lakes. It is about one hundred feet high, and its base, on the side of the rivulet, is being gradually washed away. By the fall of the superincumbent mass, a nearly vertical bare cliff has been exhibited, of which the strata, for about 70 feet upwards, consist of many distinct layers of boulders; the interstices filled up alternately with whitish glacial mud or ferruginous sand and clay. These strata vary in thickness from four inches to five feet, and strike nearly north and south with a dip towards the west of 23 deg. These beds have been denuded for about 70 feet above the river, and are capped by 30 feet of boulder and boulder clays, having a rough horizontal stratification. I am not prepared to give a satisfactory explanation of this phenomenon, but may suggest, that although not many proofs are to be found of successive or regularly recurring changes in the level of the island during which the deposits of the great boulder formation have been formed, this one fact would point to the possibility of such an occurrence. And may we not assume, considering the loose character and great similarity of the deposits of the post-pliocene period, that it would be extremely difficult to determine, from their appearance alone, whether they had been formed during the period of a single or during those of several successive depressions.

The above described isolated mound clearly points to more than one period of subsidence, and I hope to be enabled, by further investigation, to bring forward additional evidence on this point.

Assuming that the rise of the country still continues, and that the lakes must ultimately be filled up, the rivers, which now supply them would flow through channels formed in their beds.

The further upheaval of the island would lead to the occurrence of similar phenomena to those observed in the valley of the Rangitata, where the more rapid fall of the water has partly removed similar lacastrine deposits, not only along the main channel, but also at various points at the bases of the neighbouring hills, where lateral deltas had been formed, which were afterwards, during a later period of subsidence, overlaid by boulders and boulder clays.

It is perhaps presumptuous to offer any remarks on this subject, before further study and investigation, but the wish to elucidate, and to suggest similar observations in the northern hemisphere, has led me to notice it.

I have the honor to be, Sir,
Your most obedient servant,
JULIUS HAAST

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