The Geology of View Hill and Neighbourhood.

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A. Introductory.

The neighbourhood of View Hill presents several points of geological interest. Within a radius of six miles from the hill itself, there are several inliers of Trias-Jura, Cretaceous, and Tertiary rocks, cropping up through the gravels of the plains, while lying on the western spurs of Mount Oxford occurs an interesting deposit of chalk with associated greensands and basic volcanics. Haast has made brief reference to View Hill and Burnt Hill (1879, p. 282). Hutton has referred to Gorge Hill on the Waimakariri (1877, pp. 56-7. and 1885, pp. 49-53), to View Hill and Burnt Hill (1877, p. 41); and McKay (1881, pp. 40-53) and Wilson (1888, pp. 274-276) have referred to the chalk deposit. I have found McKay's account exceptionally accurate considering the fact that the country was covered with bush when he reported on it. He had the advantage all the same of being able to see the chalk quarry when it had been opened out, whereas it is now difficult to find the exact spot where it was. McKay's statements are used as the basis of the account of the chalk deposit given in Bulletin No. 22 of the New Zealand Geological Survey (1919, p. 234). There is also a brief reference to the locality in Palaeontological Bulletin No. 11 (1926, p. 12) where Chapman gives a list of the foraminifera found in the chalk.

With this brief introduction I will proceed with the description of the geological features of the district, taking each particular locality in turn commencing with the name locality, View Hill.

B. VARIOUS OCCURRENCES.

1. *View Hill.*

This elevation lies about two miles due north of the Waimakariri Gorge Bridge and rises to a height of 1231ft. above sea-level, or about 250ft. above the general level of the plains in the neighbourhood, which average about 1000ft. The hill is a double one with two well-defined summits, separated by a low tract of country eroded on weakly-resistant rocks. The eastern hill is the higher of the two, and it takes the form of a ridge, steep on the north-west side but more gentle on the south-east. The western hill shows subdued landscape features, and its south-eastern slope is evidently part of a stripped surface of greywacke. On this rest unconformably sandy shales, well laminated, with thin layers of carbonaceous material, dipping south-east at angles of from 5° to 10°. Over these lie sands which have been indurated in places by the capping of dolerite,* but the actual contacts cannot be seen owing to the covering of soil and slip material. The dolerite is continuous along the top of the ridge, and the capping is formed of flows dipping south-east. Its texture is frequently coarse, and it is then singularly susceptible to weathering agents, so that fresh samples are difficult to obtain. At times it is markedly vesicular. The general circumstances of the rocks point to their being flows and not intrusions, and in all probability there are several flows present as in the case of the occurrences at Burnt Hill, to be described later—and along the Harper Hills and Homebush Ridge in the Malvern district; but in the absence of any clear exposures of the overlying beds this point cannot be settled for certain. Although chalk has been reported as coming from View Hill itself, I have seen no sign of it on the hill, so I think confusion has arisen between the name of the hill and the name of the district, which extends across the Eyre River to the north.

2. *Eagle Hill.*

The greywacke surface of View Hill no doubt extends towards the south-west under the gravels of the plains, for greywacke appears again on the banks of the Waimakariri in an eminence known as Eagle Hill, and on the flanks of the terraces extending south-west therefrom towards the bed of the river. The rock exposed is everywhere a hard greyish greywacke, and it has an apparent strike in a north-east direction. Like View Hill the steep slope of this hill faces north-west.

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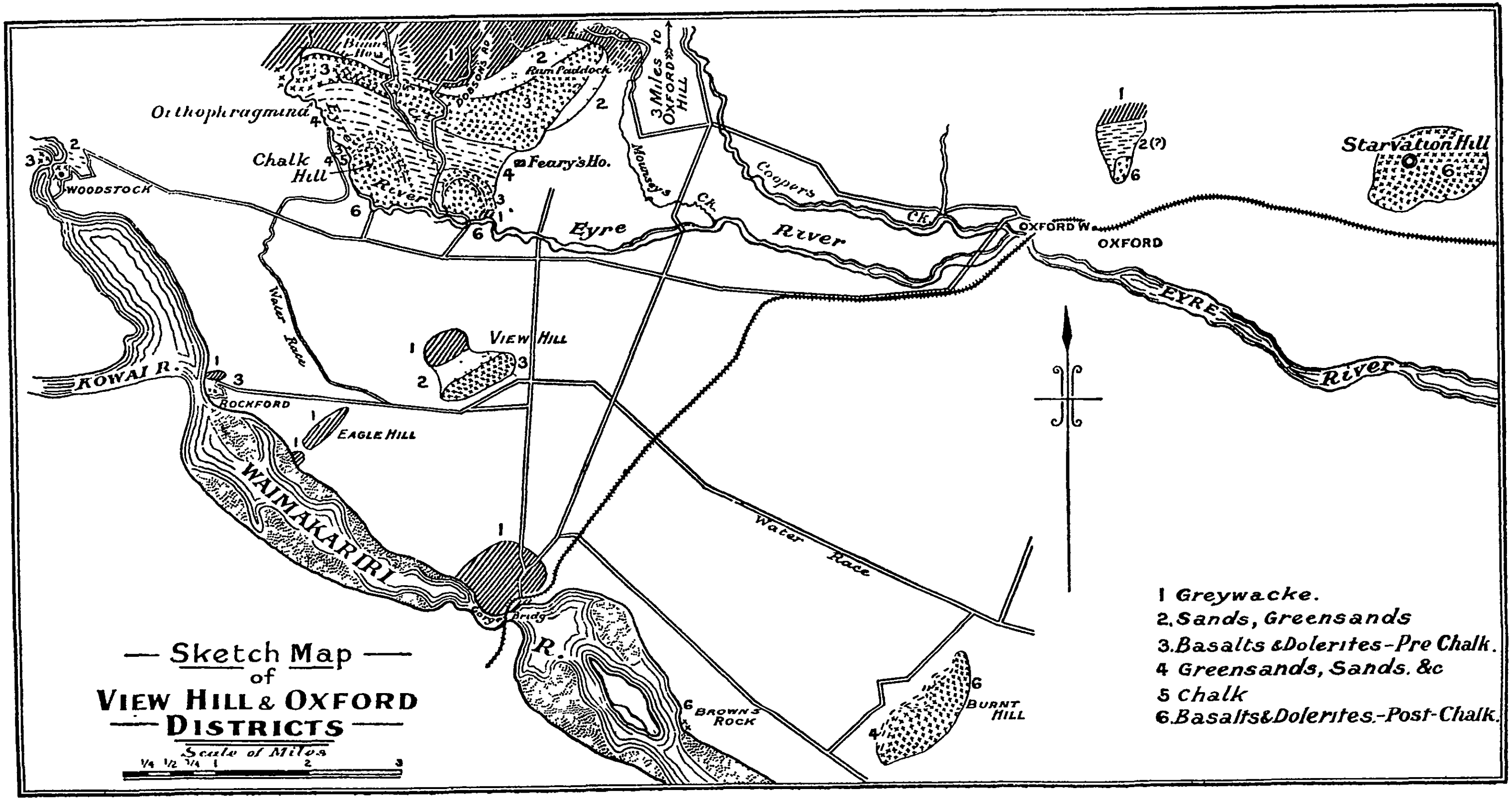
*The term "Dolerite" as used in this paper means a coarse-grained basalt.



Sketch Map of VIEW HILL & OXFORD DISTRICTS

3. *Rockford.*

About a mile further up stream, just below the junction of the Kowai with the Waimakariri, is a spot known as Rockford, from a crossing of the river near a greywacke rock standing up in the middle of the stream. A similar rock occurs on the floor of one of the lower terraces, and in close proximity to it is a small exposure of dolerite. The true extent of this cannot be determined owing to the mask of gravel, but it is similar in texture to that at View Hill.

4. *Woodstock.*

Close to Woodstock Homestead, in the precipitous banks of the Waimakariri, is an occurrence of greensand associated with basalt. This lies almost opposite to the occurrence of sands exposed on the right bank of the stream near Otarama containing *Conchothyra parasitica,* which is the place of origin of the specimens of this shell described by Hutton. The greensands probably belong to the same occurrence. They are deep green in tint, very glauconitic, somewhat coarse in texture with grains of quartz clearly visible to the eye. The sands contain small fragments of shells, but little can be said definitely about the whole occurrence because it cannot be properly examined owing to the dangerous nature of the banks of the river at the spot. The basalt with which the sands are associated is fine-grained amygdaloidal especially near the lower margin, with numerous veins of crystalline calcite, much jointed, dark in colour, and apparently resting on greensand, not intrusive into it. At the only contact visible it rests against a bank of greensand, which may be a fault-contact, though the probability is against such being the case. The basalt forms the projecting portion of the terrace, and protects the easily eroded greensand from the erosive action of the stream.

5. *Browns Rock.*

About two miles below the Gorge Bridge a point stretches out into the bed of the Waimakariri buttressed on the end by a mass of basic volcanic rock. The exposure is a very small one, extending for about a couple of chains in the north side of the point, and about a chain facing the direction of the main stream. It is covered by gravels and no exposures of associated sedimentaries other than the gravels are visible, so its relations cannot be determined. As will be pointed out later its lithological characters are those of the latest occurrences of volcanic rocks in the area.

It furnishes an excellent example of such a mass acting as a ledge defending terraces formed by re-excavation, according to the principles of Miller and W. M. Davis (see *Amer. Journ. Sci.* vol. 14, 1902. pp. 77-94). The same applies to the rocks, both greywacke and dolerite, at Rockford, although they do not act as perfectly in the manner indicated as those at Browns Rock.

6. *The Eyre River.*

a. *General Stratigraphy* (See Sections A, B, C).

This is the most important occurrence in the district, not only from its intrinsic interest but from the extent of the country covered by the beds. The area stretches in an easterly direction along the base of the southern and south-western slopes of Mount Oxford from the gorge of the Eyre River, a distance of nearly four miles. The western boundary follows along the main Eyre for about three miles, while the width narrows to practically a point on following the beds eastward.

The country for which these beds are the basis consists of downs which rise above the plains to a maximum of about 500 feet, and which have suffered dissection by the Eyre and its tributaries, the directions of the chief ridges being determined by the lines of outcrop of the igneous rocks. Wherever observed the beds have a dip to S.S.W. at low angles, so that the scarps as a rule trend approximately east and west.

The chief tributaries of the Eyre coming in from this area are Whites Creek, which runs across the strike in the western part and Mounseys Creek which runs east along the line of junction of the greywacke for a distance of two miles, on for a further distance of two miles in greywacke, and then turns at right angles and flows south to join the main Eyre River. The upper part of this creek is bounded on the north by a stripped surface of greywacke and on the south by a flattish area, known as the Ram Paddock, which stretches towards the south to an east and west scarp formed out of lava-flows with a gentle southerly dip. There is also a tendency to develop subsequent streams, other than these, in the soft beds between the lava-flows, and the low gap behind Mr. Feary's homestead may be attributed to this action.

Although the scarps are moderately well defined good exposures are rare, the best being found on the banks of the Eyre River and the hillsides adjacent thereto. These will be dealt with first.

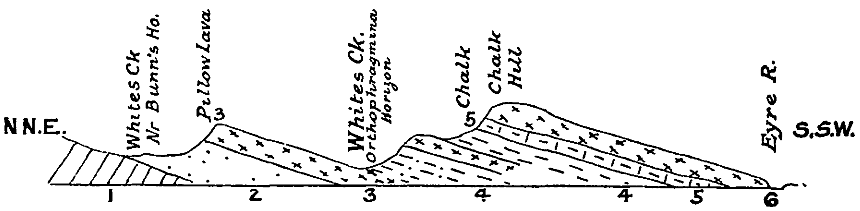
Following down this river from the greywacke gorge, the banks are obscured for nearly half a mile; then occurs a sheet of basalt about 25ft. thick lying over greensand, striking E. 25° S and dipping approximately S.S.W. at an angle of 10°. This basalt is amygdaloidal, and exhibits on the outcrop signs of pillow structure. It can be traced across the ridge between the Eyre and Whites Creek, the next tributary to the east, and on into the bed of this stream where it has been quarried for road metal. On the crest of the dividing ridge it separated by but a small distance from the outcrops of greywacke. I was not able to trace this basalt to the west of the Eyre although a well defined bush-clad ridge appeared in alignment with it, but no outcrops of basic rock or boulders of basic rock were seen, although greywacke boulders were plentiful.

Another ridge lying parallel to this and more to the south-west is composed entirely of greywacke, but lying on it occurs one of the cherty masses associated with the basalt in this area, to be referred to more particularly later, and this probably indicates an extension of the basic rocks to the west of the Eyre.

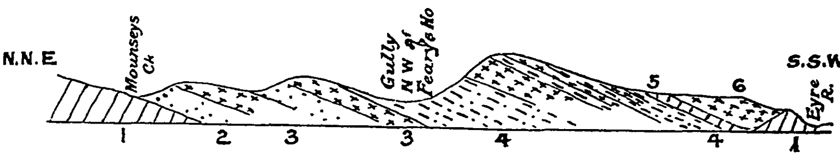
On the terrace just above the outcrop of basalt on the left bank of the stream, there are a fair number of these blocks lying on the surface, suggesting that the bed from which they have been derived was once in close proximity. These masses are similar to the quartzose blocks which lie on the surface of the schists of Central

Otago, formed by the cementation of quartz sands, and are locally known to the miners of that district as "chinamen."

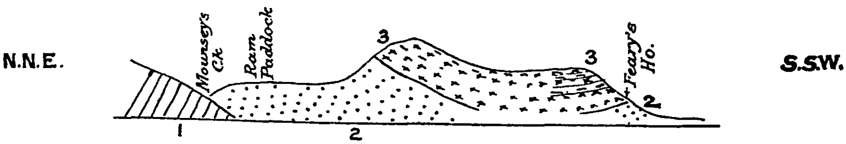
About 300 yards below the junction of the tributary of the Eyre coming in from the west, and just below the old ruined homestead and yards, the river is crossed diagonally by a sheet of pillow-lava; owing to the bending of the course of the river it is intersected twice. The lava rests on a greenish-grey, slightly glauconitic, non-calcareous sand, while overlying it are calcareous ash-beds containing *Orthophragmina*. The general strike of all these beds is approximately east and west, almost parallel to the general trend of the river in that part of its course. The outcrops occur here in places over a length of about 200 yards. The occurrence is important, as it clearly indicates the presence of pillow-lava at two levels in the greensand.



Section A. From S W slopes of Mt Oxford, near Dobson s Road, across Chalk Hill to Eyre River. Length—1½ mile



Section B. Across W side of Ram Paddock to Eyre River below junction with White's Creek. Length—1½ mile.



Section C. From lower slopes of Mt Oxford across Ram Paddock to East of Feary's Homestead. Length—1 mile.

1 Greywacke 2 Sands passing up into Greensands 3. Basalts—Pre-Chalk.
4. Greensands passing up into Sands, &c 5 Chalk. 6 Basalts—Post-Chalk.

SECTIONS ACROSS THE EYRE RIVER TERTIARY BEDS.

These sections are taken across the strike from the slopes of Mount Oxford towards the Eyre River, and give a diagrammatic representation of the lie of the beds. It is impossible to represent on such a small scale all the occurrences of basalt that occur in the sands below the chalk, and those that are given must be taken as representative merely.

Further down stream, about 200 yards above the intake of the water-race, is an occurrence of much decomposed ash on the right bank of the Eyre. This outcrops in places over a length of 100 yards.

Then comes the ridge which I have called Chalk Hill for convenience of reference. The rocks outcropping on the extreme north-western end of this ridge are doleritic in character, and form a well-defined shelf which can be traced down on the eastern flank of the ridge towards Whites Creek. The summit of the ridge consists of dolerite, and beneath it lies the chalk, which can be seen in very few places owing to the covering of soil, but it can be traced down into the bed of the Eyre, where there is an exposure of the beds over a length of about two chains. The sequence from below upwards is as follows:—

1. *Basalt and ash-beds,* of uncertain thickness.
2. *Sands,* bluish-grey in colour, non-calcareous, with yellow powdery efflorescence, (? sulphur), and smelling of sulphur; 12 to 15 ft. thick.
3. *Greensand,* markedly glauconitic, 12 to 15 ft. thick.
4. *Chalk,* somewhat marly in character, flaky in texture, 15 to 17ft. thick.
5. *Dolerite,* following on apparently conformably, but the actual contact is obscured, and for 6in. the underlying bed could not be seen, and the junction was filled with clay. There is no sign of alteration in the chalk beyond this obscurity.

On the hillside above the stream flints appear plentifully, and in some cases they form well -defined layers in the chalk extending on the surface of the ground for over 2 chains. Just above the exposure in the Eyre the dolerite has been quarried to make room for a bush road, and some of the stone has been used for metalling. In the quarry columnar structure is well developed, and the columns show well marked constrictions across their length, producing an appearance which may be called a "concertina" effect. The ribs so formed appear to be associated with cross cracks due to shrinkage in length, for the rock in their immediate vicinity is closer grained and more resistant to weathering.

Basalt occurs all along the slope of the ridge facing the Eyre River and probably indicates flows at various levels, separated by layers of ash or of fragmentary material, although the latter are not apparent. The river follows round the base of the ridge, and there are signs of the development of valleys in the softer beds and the cutting through of the harder capping in places, so that the underlying weaker beds are attacked. Owing to the absence of clear sections it is difficult to say whether or not this is actually the case, or whether the hollows are partly due to synclinal folding of the lava-flows. Such modification of the beds occurs lower down the Eyre, and perhaps sympathetic structures occur on the western and southern facing of the hill above the junction of Whites Creek.

Whites Creek runs more directly across the strike of the beds, and the banks on either side furnish the most complete record of events that have occurred in the area. The greywackes form the basement beds, and are well exposed in the upper part of the creek. They are of the slightly-coarser definitely grey type, and I could not find any trace of the diabase ash recorded by McKay (1881 p. 53.) as occurring near the chalk deposit, although it occurs more to the eastward on the slopes of Mount Oxford in the vicinity of Coopers Creek. It is thus midway between the occurrences in the Ashley Gorge and those on the southern side of the valley of the Hawkins River in the Malvern area.

Pillow lava, Whites Creek. Showing ovoid masses, with glassy selvages and cuboidal and prismatic jointing.

The clearly exposed covering-beds are greensands, which are followed somewhat closely by pillow-lava. The former are exposed in the bed of the creek just below Mr. Bunn's homestead, and the latter close alongside in a quarry used for procuring road-metal, the structure of the rock being clearly seen in the workings. (Plate 38), Ovoid masses up to 3 feet in diameter, characteristic of pillow-structure, are well developed, and the spaces between them are filled by smaller spheroids. They break up into more or less cuboidal or prismatic blocks of small size, up to about 6 inches in length. The outside of each pillow is formed of a thin selvage of glassy material as if the rock had been suddenly chilled. The general mass of the rock is close grained but is in places full of small steam-holes and then again of larger ones several inches in length. The latter are usually filled with amygdules of calcite, but in some of them chalcedony is the filling material. In the spaces between the pillows occur masses of chalcedonic quartz, which gives a feeble reaction to acid, showing that carbonates are also present.

In places, too, there are radiating masses of chalcedony, stained with iron oxide, with fibres or rods occasionally three inches in length and varying in thickness from one sixteenth of an inch up to nearly half an inch.

The pillow-lava and the underlying greensands strike E.S.E.-W.N.W., and have a southerly dip at moderate angles. The lava forms a well-defined scarp extending for at least half a mile in either direction, and on the northern face in several places the "pillows" lie weathered out on the surface of the ground. About a quarter of a mile to the east the decomposed material is exposed in a shallow cutting where the Dobson Road crosses the ridge.

The next exposure higher in the sequence is about three hundred yards further down the creek. Here the following beds occur:—

1. *Calcareous greyish sands.*
2. *Ash-beds* with a greyish matrix, containing angular pieces of volcanic material.
3. *Finer grained ash-beds* with cuboidal fracture, calcareous.
4. *Calcareous sands*, greyish in colour.
5. *Calcareous ash-beds,* with many fragments of fossil shells the fragments of such small size as to be undistinguishable; markedly cross bedded.
6. *Glauconitic sands,* distinctly calcareous.

These are capped with recent river gravels. The total length of this exposure does not exceed one chain, and the strike of the beds is towards the gap in the ridge behind Mr. Feary's house, where similar beds occur, as will be recorded later.

Further down stream there are occurrences of greensand, and then the beds developed in Chalk Hill. The first bed exposed overlying the greensand is a flow of lava which rises towards the north-west end of the hill and forms a definite shelf which marks the north-east facing of the ridge. Over this, perhaps, not directly, lies the chalk, fairly high up and close under the dolerite which caps the ridge. The chalk was formerly worked in two places, one near the point of the spur near the junction of Whites Creek with the Eyre, about 100 feet above the level of the valley, and the other near the northern end of the ridge about 270 feet above that level. At present the workings are almost obliterated. The chalk is white or greyish white in colour; in places soft and earthy, but in others hard like limestone. This latter facies should on drying crush into powder tolerably well. Masses and fragments of flint occur freely in it. It is followed closely by a basic flow, and in parallel sequence, as far as can be judged though there is no evidence that the flow is submarine. If this is not the case, and the flow is subaerial, then it implies an erosion period between the deposit of the chalk and the extrusion of the volcanic rocks.

The thickness of the chalk is probably about 50 ft., but cannot be determined in any place with exactness. The strike is E.S.E.-W.N.W. as calculated from the heights and positions of three outcrops. This differs from the determination made by McKay.

On the eastern side of the creek the chalk does not appear at the surface, although I am told by Mr. Feary that it was seen in post-holes when fences were being run along the top of the ridge west of his house between Whites Creek and the Eyre River. However, in a slip there is a good exposure of yellowish-white quartz sand, slightly calcareous, which probably lies at lower stratigraphical horizon than the chalk, and there is at this horizon and at lower ones a great development of cherty masses, apparently interstratified with the basalt at various levels. There are no clear exposures, so that the problem of their precise relationship to the basalts must be left unsolved for the present.

The uppermost bed on the eastern side of Whites Creek near its junction with the Eyre is a coarse basalt or dolerite which covers ash. This has the usual dip, but round the corner in a downstream direction the beds are apparently bent up into a syncline with an axis extending a short distance in a north-easterly direction, and with its south-eastern limb resting on greywacke. This last is exposed in the bed and steep banks of the Eyre for a few chains, and it forms a small rounded hill acting as a buttress to the basalts and their associated beds at their most southerly extension towards the plains. This inlier of greywacke is close to that of View Hill, and in alignment with it and the outcrops of greywacke at Eagle Hill and its extensions towards the Waimakariri below Rockford.

The total thickness of the sands, greensands, chalk, and volcanics as developed in this section approximates 1200 feet.

The next section will be taken running approximately south across the area from the Ram Paddock to the Valley behind Mr. Feary's house. In Mounseys Creek the greywacke is exposed striking E.N.E. and with a northerly dip at high angles. It forms a stripped surface extending up the slope to the north. On this, as far as can be seen, rests unconformably the following sequence, from below upwards:—

1. *Sandy Clays* with *impure shale*, striking along the creek, that is, E.N.E. and with a southerly dip at low angles.
2. *Sands*, yellowish-white in colour and weathering brown.
3. *Sands*, greenish-grey in colour, in places definitely green.
4. *Basalt*, probably dipping S.S.W.

For some distance there are no exposures, and then the sequence is resumed with

5. *Ash-beds.*
6. *Basalt,* capping the ash, and exhibiting pillow structure, probably connected with the pillow-lava in Whites Creek.
7. *Greensands,* exposed in the creek behind Mr. Feary's house.
8. *Calcareous Tuffs,* current-bedded, with a southerly dip, like those in Whites Creek.

Then follows a succession of basalt flows with cherty beds interstratified, at least three in number and perhaps more, the uppermost bed of chert lying in all probability close under the chalk. This is capped by lava-flows, whose ends are truncated by a steep slope facing south-east as if a fault ran along and determined the edge of the downs in that direction.

This area of associated volcanics and sedimentaries extends north-east and forms the ridge between Mounseys Creek and the plain. I did not see it across the creek, though it is possible that small isolated outliers may exist lying on the greywacke surface. In this portion of the area the exposures are not clear, but it is evident that there is the same succession of beds as elsewhere. Sands form the lowest member of the more recent sequence; sometimes these are concretionary in character, and interstratified with them are fine-grained basalts similar in external appearance to the pillow-lavas in Whites Creek; over the lavas lie sands which in many places are concretionary, and these are succeeded by greensands, which are best exposed in the gully behind Mr. Langer's house and in the bush lying south-west of it. To the north of the house concretionary sands are well developed, probably higher in the sequence than the greensands. On the western side of this bushclad gully there is a good exposure of concretionary greensand. I saw no fossils in this, and I could get no exposure which enabled the dip to be determined with accuracy, but it is probably towards the south-west in agreement with the slope of the basement surface of greywacke, although there are some indications that it may be bent up into a syncline with an axis running N.E.-S.W.

Over these sands there is a regular succession of basalts of coarser texture with interstratified masses of cherty rock. These are repeated several times as the beds are followed to higher levels, but no clear exposure showing the relations of the sedimentaries to the volcanics could be discovered, although the whole country was carefully examined.

A somewhat interesting occurrence was observed in the gully just east of Mr. Feary's house.

Here there are volcanic ash-beds interstratified with flows, the former striking N.E.-S.W. and dipping N.W. at an angle of 30°. The ash-beds are 50ft. thick and consist of fine material with angular volcanic fragments up to 2ft. in diameter, though they are mostly small, 2 to 3 inches in diameter. Some beds are slightly calcareous. On the ridge to the north-west are flows lying fairly flat or dipping slightly west, while there are cherty masses on the ridge to the north-east divided from the ash-beds by at least one flow of basalt.

The thickness of the volcanic rocks, and the number of flows existing, are apparently greater in this part of the area than in any other, but no actual centre has been located from which the flows might have come; and they resemble in that particular the other occurrences of Tertiary volcanics that fringe the base of the mountain area of Canterbury. Whether or not these represent some form of fissure eruption or whether the actual centres lie buried under the gravels of plains cannot be determined at present.

6. *The Chalk Deposit:* It is unfortunate that there are so few exposures of Chalk at the present time. When it was referred to by McKay and Wilson the pit was being worked, but now one can hardly see where it was located. The composition of the chalk is very variable from place to place. It is occasionally very argillaceous and again a fairly pure calcium carbonate. Wherever exposed it was found to contain nodules of flint, and at times layers of siliceous material.

Analyses made in the Dominion Laboratory are as follows;—

Matters insoluble in acid	15.69	32.10
Alumina		0.92
Iron Oxides	Traces	Traces
Calcium Carbonate	82.26	66.82
Magnesium Carbonate	1.84	
Water	0.21	0.16
	100.00	100.00

The matter insoluble in acid must be largely siliceous material.

The examination of the ckalk in a section under the microscope discloses that it is composed of an irresoluble base in which can be seen very clearly remains of the tests of foraminifera; sometimes these are almost perfect. There is as well a considerable amount of glauconite in grains, as well as very small fragments of quartz, distributed quite freely through it.

The flint presents certain features of interest. The fact that it occurs at times in definite layers rather supports the hypothesis that it may be the result of chemical precipitation and not an organic deposit.

The only signs of organisms are the remains of foraminifera, similar to those in the calcareous material, which have been silicified and retain their form in that state. Under the microscope there appears to be just about the same proportion of glauconite as appears in the chalk, and there are as well numerous grains of quartz, and occasional flecks of mica, distinguished from the glauconite by their stronger pleochroism and lower extinction angle. These minerals occur in a groundmass which is irresoluble, but which has a higher index of refraction than balsam. In the hand specimen the flint presents a smooth resinous appearance, a conchoidal fracture, and in some instances a colour which is brownish to honey-yellow, and where exposed to the atmosphere takes on the surface-appearances which may be called "desert varnish."

This deposit is referred to by Chapman in his report on the Foraminifers of New Zealand (1926, p. 12) where he gives the list of the forms occurring therein and classifies the age as Upper Cretaceous, i.e. Danian, the age being the same as that of the Amuri Limestone as it occurs in various parts of North Canterbury from Kaikoura, through Amuri Bluff, and Weka Pass to the Waipara. He states that the marls of the Broken River area which have sometimes been correlated with the Amuri Limestone belong to a slightly higher horizon, viz. Eocene.

Previous to the present examination of the country the only definite evidence of age was that based on Chapman's determination of the foraminifera. McKay records the reported discovery of a shell of *Conchothyra parasitica* in the bed of the Eyre River, and presumably it came from the strata underlying the chalk, a presumption strengthened by the association of beds containing *Conchothyra* with greensand in the Waimakariri, a comparatively small distance away, and striking in the same direction as the greensands in the Eyre.

Wilson (1888, p. 275) reports the occurrence of *Pecten williamsoni* and *P. fischeri* in the chalk, and a specimen of the former marked as coming from Oxford, and with a matrix similar to that of the chalk as found in the bed of the Eyre, occurs among the fossil shells of the Canterbury Museum. The discovery of these shells does not materially aid in the determination of the age of the beds, and as there was some doubt about their identification I submitted the specimen in the Museum to Dr. J. Marwick, Palaeontologist to the New Zealand Geological Survey, and he writes as follows:—"I have compared the Oxford *Pecten williamsoni* with topotypes of that species. The Canterbury shell has a similar number of ribs, but is considerably smaller. Also the apical angle is much less than in true *williamsoni* and the shape is different. Of course the Museum specimen may be a juvenile, but even granted that I do not think it should be classed as *Chlamys williamsoni.* As it is only an internal cast I doubt if it can be used for any reliable correlation, but the general appearance and preservation suggest a Tertiary age."

The discovery of *Orthophragmina* at a lower stratigraphical horizon than the chalk bed—approximately 600ft. below it—in a position where faulting on a major scale appears impossible, adds a new interest to the problem. Wherever *Orthophragmina* occurs in Europe or America it is regarded as an Eocene form, so a revision of the age of the chalk appears necessary. If the beds containing *Orthophragmina* be regarded as Eocene this would enable a correlation of these beds to be made with those in the Trelissick basin, classed by Chapman as Eocene (1926, pp. 14-15), and then the sequence of the beds near the Eyre would fit in with those of the Trelissick where the marls are underlain with sands, greensands, sands, beds containing *Conchothyra*, etc., and clays and shales with coal, in descending order, just as the chalk bed near the Eyre is underlain by a similar sequence, except that the *Conchothyra* is wanting, although it does occur at Woodstock apparently under greensand. I am sorry that the difficult nature of this locality renders it practically impossible at present to say what are the precise relations of the greensand near the Woodstock homestead to the shell bed a little higher upstream across the river. All the same, they may be conformable below the greensand just as they are in the Trelissick basin.

There is besides a difference in the general facies of the sedimentaries near the Eyre from that of the classic locality at the Waipara and at Malvern, which throws some doubt on the chalk being Cretaceous in age. The Saurian beds, the black-oyster bed, and the concretionary sands characteristic of these areas just mentioned, where the beds are definitely Cretaceous, are absent from the Eyre locality, and this absence requires some explanation if the occurrence there is considered to be Cretaceous. It seems therefore to be best to follow the conclusion based on the presence of *Orthophragmina,* that the beds are Lower Tertiary in age. However, if Chapman's correlation of the chalk at Oxford with the Amuri Limestone of North Canterbury be correct, then the record of the presence of *Orthophragmina* below the chalk has an important bearing on the accepted age of the various beds in the Cretaceous to Tertiary sequence of the North Canterbury area.

C. *Volcanic Rocks*: The most interesting stratigraphical feature of the occurrence is the presence of flows of basalt at different levels. The lowest occurs in sands which are no doubt of Lower Tertiary age, and then pillow-lavas occur freely interstratified with greensand throughout a considerable thickness of beds under conditions which certainly suggest that they were submarine in origin, and in many cases too these lavas are interstratified with cherty layers, as is the case with so many pillow-lavas. In the higher parts of the greensand the pillow-facies disappears, although the evidence here also points to submarine eruptions and the presence of cherty beds.

Then follow flows underlying the chalk, which were no doubt submarine in origin, though they do not exhibit pillow-structure, the fact that they are underlain by marine beds and overlain by marine beds in parallel sequence rendering this almost a certainty. The bed overlying the chalk, though also apparently parallel, is probably subaerial. It exhibits no pillow-facies, and is comparable in every way, both mineralogically and texturally with the basalt closing the sequence of Burnt Hill, which is definitely post-Awamoan in age. As will be mentioned subsequently, the latest flows observable in any of those localities are hypersthene-bearing basalts or dolerites, and this points to a similarity in age, although it is not positive evidence that it is so.

A most interesting feature of the volcanic rocks is their association with cherty masses, which are probably cemented from sands interstratified with the flows. The pillow-lavas, however, are chiefly associated with greensands, whereas the quartz sands either occur at lower horizons than the volcanics or much higher in the sequence and at a level where pillow-lavas do not occur as far as can be seen. If it be taken that the chalk represents a deposit in water deeper than that at which greensand forms, then there may be some connection between the depth of water and the development of pillow-structure, but after all this may be only a coincidence and have no real bearing on the occurrence of this much-debated feature. And then again the chalk may have been laid down in water shallower than that at which the greensand was deposited and so the pillow structure is conceivably due to deeper water conditions.

7. *Oxford.*

That this series of beds once extended round the base of the foot-hills of Mt. Oxford in an easterly direction is proved by the occurrence of a scoriaceous basalt, once used for road-metal, on the end of the spur immediately behind the West Oxford township. The rock is exposed in an old quarry and for a few chains on the eastern side of the ridge. There is no other outcrop of rock for about half a mile up the ridge, but the characteristic subdued topography, in contrast with that of the greywacke hills behind it, suggests that the end of the spur is formed of unresistant beds. This conclusion is supported by the evidence of Mr. Burrows, who owns the property and is an extremely old resident of the district, that fine white sand was met with in a shaft sunk to a depth of about 60 feet, four or five chains from the end of the spur, and also that a greensand was encountered in a well on the flat about three-quarters of a mile to the north-east and immediately alongside the ridge. Just behind this, greywacke is seen in position, forming an old stripped surface inclined to the south with the beds striking the N.E.-S.W. and dipping at high angles to the N.W. Mr. Burrows also states that scoriaceous beds were met with in sinking wells on the flat to the east of the end of the spur, in the direction of Starvation Hill, which lies about three miles further east. This occurrence near Oxford is thus a connecting link between the beds developed in the Eyre basin and the volcanics of Starvation Hill, to be referred to in the next section.

8. *Starvation Hill.*

This is a detached elevation lying about two miles east of the township of East Oxford, just north of the railway and rising about 250ft. above the level of the plain in its vicinity. The hill is almost completely grassed, or under cultivation, and the only exposures of rock occur on the southern face where, in the gullies, there are outcrops of basic rock separated in places by fragmentary material. As far as can be judged from the limited exposures, the flows dip north at very low angles. Finer grained facies predominate in the lower exposures and coarser in the upper, the latter being usually somewhat vesicular. There is a specimen in the Canterbury Museum from Starvation Hill labelled by Hutton as Tachylyte Tuff, which is composed of very fine-grained basalt fragments cemented by calcareous material. I have not seen this material in position, and I expect it was obtained in the early days by Haast, when perhaps excavations were made which are now filled up. In any case it shows the close proximity of calcareous beds, and indicates the probable extension eastwards either of the beds near Oxford or the upper beds of Burnt Hill, which certainly do strike in the direction of Starvation Hill.

9. *Burnt Hill.*

a. *General Stratigraphy*: Burnt Hill is a Tertiary inlier rising through the gravels of the plains, about 6 miles S.S.W. of Oxford and 4 miles down stream from the Lower Waimakariri Gorge Bridge. It is a mile from the banks of the river. The trig. pole on the top is 1210ft. above the sea, and the level of the plains at the base approximately 700ft., so that it rises about 500ft. above the general surface. The hill forms a ridge about 1½ miles in length, sinking down to plain level at either end. The beds which determine its shape are basaltic lava-flows with a dip of about 10° to the south-east, on which side the slopes are gentle and accordant with the dip, while on the north-west facing they are steep and in some places precipitous.

As far as could be judged from exposures there are at least three definite flows of volcanic rock, and there may be more; a fairly complete covering of rich soil masks the south-easterly face. The north-west side affords the main evidence on which the structure of the hill is based, but it too is obscured except in a few places where slips disclose the solid beds underneath. The following is the sequence of the beds, as far as can be judged, commencing from the bottom:—

1. *Yellowish sands,* of uncertain thickness, but probably very thick; they extend downwards till they are covered with surface debris and the gravels of the plains. The upper 12 inches contains inclusions of greensand, and these get more and more numerous as the junction with the overlying bed is approached. In the lower part of the layer they are very scarce.
2. *Greensand,* dark green in colour, 2 ft.; at the base there is a layer of phosphatic nodules, very numerous, up to 2 inches in diameter, and associated with many sharks' teeth.
3. *Clayey Beds,* at the base definitely sandy and glauconitic, but at the top more argillaceous, but still sandy and glauconitic, 6ft.
4. *Ash-bed,* well stratified, with coarser and finer layers, occasionally showing basic glass, 12 ft. This bed is about 300 ft. above the level of the plain, and can be traced round the hill-slopes for several hundred yards.
5. *Sands,* with irregular layers of fragmentary shells, 2 ft.

   For some distance above this bed, about 100 ft., the sequence is obscured, but it is probably sandy. Then the sequence is resumed with—
6. *White quartz sands.*
7. *Ash-bed,* weathering red, 6 ft.
8. *Fragmentary volcanic layer,* up to 2 ft. thick, probably passing up into No. 9.
9. *Basaltic lava flow,* 50 ft., scoriaceous in places, and in places containing inclusions of porcellanite.

There are exposures of these beds in a few places on the sides of two gullies to the north, but they are of very limited extent. Ash-beds resting on clayey beds passing down into greensand and passing up into fragmentary shell-beds occur for certain, and, as far as can be judged, with a dip to the east at the northern end of the hill, as if there was an apparent conformation to the quavquaversal dip characteristic of a volcanic cone, and suggesting that the centre lay to the west of the hill, between it and View Hill. Sands, yellowish in colour, appear in places, and a bore put down for water near the homestead at the northern end of the ridge passed through 260 ft. of them. I think that these must represent the lowest sands mentioned in the table, that is, No. 1 of the series. I did not see samples, but Mr. Bassett, the owner of the station, has informed me of the fact.

At the south-western end of the ridge the top beds exposed consist of lava-flows with intervening ash-beds, dipping south-east at an angle of about 10°. At least three flows are probably present in this section. They are very scoriaceous in places, and the lowest contains near the base a quantity of porcellaninte. Under the solid flow there is a layer of large angular fragments, then a reddish ash, while the lowest beds exposed are white quartz sands.

All round the base of the hill are the gravels of the Canterbury Plains, completely masking the beds lying below.

The occurrence at Burnt Hill is very interesting, since Tertiary fossils are found in beds interstratified with volcanic material. The layer where they occur is unfortunately somewhat narrow, being from 3 to 12 inches in thickness, and the shells are very badly preserved and difficult to obtain in good condition. The layer was excavated in several places, and it is possible that if the excavations were made deeper better results might be obtained. Then again other points where fossils occur may chance to give a better harvest when they are located. Collections were made on two occasions and the whole of them submitted to Dr. J. Marwick, of the N.Z. Geological Survey, and he has kindly furnished a report on them, the substance of which is as follows:—

b. List of Fossils.—The list of Burnt Hill fossils to date is now quite a respectable one with 42 species; but its exact correlation is still rather uncertain. From the assemblage of genera he would say that the age was certainly Miocene, for they are practically all common Awamoan ones; but there is a lack of characteristic Awamoan species and a surprising number are new. From the presence of *Struthiolaria praenuntia, Alcithoe* cf. *arabicula, Melatoma* aff. *wanganuiensis* and *Baryspira* cf. *subhebera* he would be inclined to place the age as slightly younger than the typical Awamoan.

The following is the list as furnished:—

Acteon n. sp.
Alcithoe cf. *arabicula* Marw.
Austrofusus cf. *spinifera* (Fin.)
Austrofusus (*Neocola*) n. sp.
Austrofusus (*Nassicola*) cf. *nassa* Fin.
Austrosipho n. sp. aff. *adusta* (Philippi).
Austrotoma n. sp.
Baryspira robusta (Marw.).
Baryspira cf. *subhebera* (Marw.).
Corbula canaliculata Hutton.
Corbula cf. *kaiparaensis* Marsh.
Crepidula wilckensi Fin.
Crepidula sp. probably new.
Cryptomella n. sp.
Dentalium solidum Hutton.
Diplodonta (*Zempsia*) n. sp.
Dosinia (*Kereia*) n. sp.
Eucrassatella attenuata (Hutt.).

Eulimella n. sp.
Eumarcia (*Atamarcia*) n. sp. aff. *curta* (Hutt.).
Gari lineolata (Gray).
Gari n. sp. aff. *stangeri* (Gray).
Glycymeris n. sp. aff. *laticostata* (Q. and G.).
Glycymeris n. sp. aff. *shrimptoni* Marw.
Limatula cf. *maoria* Fin.
Marama (*Hina*) cf. *mackenziei* Marw.
Melatoma n. sp. aff. *wanganuiensis* (Hutt.)
Mesalia n. sp.
Mydora n. sp.
Panope worthingtoni Hutt.
Paradione (*Notocallista*) n. sp.
Polinices lobatus (Marw.).
Polinices mucronatus (Marw.)
Spinomelon sp.
Struthiolaria aff. *spinosa* Hector.
Struthiolaria praenuntia Marw.
Syrnola n. sp.
Thracia cf. *magna* Marsh. and Murdoch.
Turbo operculum.
Turritella n. sp.
Turbonilla n. sp
Typhis cf. *maccoyi* T.-Woods.
Venericardia n. sp. aff. *purpurata* (Desh.).
Venericardia aff. *zelandica* (Desh.)
Verconella n. sp.

C. Petrology.

1. *Chemical Analyses.*

The chemical composition of rocks representative of the area is given by the analyses in the accompanying table. For these I have to express my indebtedness to Mr. P. G. Morgan, Director of the Geological Survey, who arranged to have the rocks analyzed in the Dominion Laboratory; I have also to express my thanks to Dr. MacLaurin and to Mr. Seelye for the great care taken in making these analyses.

		1	1a	2	3	4	5	6	7
Silica	...SiO_2	50·91	53·42	52·02	50·28	52·83	52·23	65·77	70·90
Alumina ...	..Al_2O_3	14·28	14 98	13·61	13·36	13·70	14·27	15 03	14 33
Ferric Oxide ...	...Fe_2O_2	2·95	3·10	1·98	3·73	3 59	4·27	2·27	0·23
Fersous Oxide ..	...FeO	6 46	6·78	8·50	5·94	6·95	7·27	2 23	2·55
Magnesia ...	...MgO	5·27	5·53	5 99	6·59	8·10	6·67	1·87	1·11
Lime	...CaO	10·08	7·82	9·21	8·78	8·30	8·31	3 34	1·31
Soda	...Na_2O	2·81	2·95	2 62	2·65	2·40	2·62	3·31	3·56
Potash	...K_2O	0 53	0 56	0 59	0·72	0·47	0·42	2 25	2·73
Water lost above 105	H_2O+	0·60	0·63	1·24	1·53	0·63	0 75	2·25	1·75
Water lost below 105	H_2O-	1·93	2·02	1·70	3·88	1·23	0 89	0·29	0·36
Carbon di-Oxide	...CO_2	2·07	—	0·39	0·06	0 02	trace	0·03	0·20
Titanium di-Oxide	...TiO_2	1·67	1 75	1·76	2·05	1·02	1·65	0·70	0 50
Phosphorus pentonide	P_2O_5	0·20	0·21	0·28	0·35	0·18	0 24	0 23	0·12
Ziorconium di-Oxide ..	ZrO_2	—	—	—	—	—	—	—	0 03
Sulphur ...	... S	0·08	0·08	0·04	0·04	trace	trace	0·01	0·05
Chronic Oxide...	...Cr_2O_3	0 04	0·04	0·04	0·05	0 06	0·05	none	none
Nickel Oxide ...	...NiO	0 03	0·03	0 04	0·03	0·03	0 05	trace ?	trace
Mangenous Oxide	...MnO	0·14	0·15	0·15	0·12	0·22	0·14	0·07	0·06
Strontra ...	...SrO	0·02	0·02	0·02	0 03	0·02	0·03	0·04	0·02
Baryta... ...	...BaO	trace ?	—	0·02	0·02	0·02	0·02	0·08	0·06
		100 07	100·07	100·20	100·21	99·79	99 88	99 77	99·87

Norms.	1	1a	2	3	4	5
Q	8·70	8 64	6·66	6 72	6 90	8·04
or.	2 78	3 34	3·34	3·89	2·78	2·22
ab	23·58	25·15	22 01	22·53	20·44	22·01
an.	25·02	25·85	23 63	22·52	25·02	26·13
di	8·99	9·67	14 35	14·39	12·30	11·44
hy.	15·71	16·38	19·18	14·14	22·83	18·44
mt.	4·41	4 41	3·02	5·34	5·34	6·26
il.	3·19	3·34	3·34	3·95	1 98	3·19
ap.	0·34	0·34	0·67	1·01	0·34	0 34
cc.	(4·70)	—	(0 90)	(0·10)	—	—

Analyst, F. T. Seelye.

No. 1. Dolerite, View Hill, S.W. end.—(11)(111). 4(5). (3)4. (4)5. Bandose.
No. 1a Dolerite, View Hill, S.W. end. No. 1 re-calculated on the basis of the absence of calcite from the sample.—(11)(111). 4(5). (3)4. (4)5. Bandose.
No. 2. Basalt, "Pillow-Lava," Whites Creek.—"111. (4)5. (3)4. 4(5). Auvergnose.
No. 3. Dolerite, Eyre River, just over the Chalk.—"111. (4)5. 3(4). 4". Camptonose.
No. 4. Hypersthene Dolerite, Junction of Whites Creek and Eyre River.—"111. 4(5). "4. (4)5. Koghose.
No. 5. Hypersthene Dolerite, Burnt Hill, Oxford, S. side middle saddle.—(11) 111. 4(5). "4. "5. Koghose.
No. 6. Greywacke, Gorge Hill, Waimakariri, on rise N. side of the Bridge.
No. 7. Greywacke, Otira Tunnel, Arthurs Pass.

The analyst notes with regard to No. 7 that a very small amount of carbonaceous matter was detected in the sample, and that owing to its presence the percentage given for FeO may possibly be higher; and that for Fe_2O_3 slightly lower, than the true figures.

These analyses show that the rocks of the area have a somewhat striking uniformity in chemical composition and also that they fit in with somewhat rare types of basic rocks in the C.I.P.W. system, viz., koghose and bandose. A specially noticeable feature is the occurrence of weighable quantities of nickel, chromium, and strontium.

I will deal with the microscopical features of the rocks of each of the areas in turn.

2. *Microscopical Description of Rocks.*

a. *View Hill.*—The rock analyzed came from the S.W. end of the ridge. It is dark grey in colour, rough to the feel and vesicular. Under the microscope it appears to be composed of felspar (basic-labradorite) in broad laths up to 2mm. in length; the majority about half that length; augite, grey in colour, occasionally purplish; olivine in large grains up to 0.75mm. in length, altered along cracks to yellowish secondary products; ilmenite in irregular, occasional skeletal forms; also chlorite giving a greenish stain to portions of the rock. As far as could be seen from the hand specimen, this sample of the rock was fresh and unaltered, but other facies show considerable variation from this; notably is this the case when the rocks are coarser and more decomposed.

One of these coarser varieties exhibits the following characters. The felspars and augites average about 2mm. in length, the former typically a medium-labradorite, the latter greyish-green with a more pronounced greenish border; there is some olivine; calcite filling cavities either in grains or forming aggregations of radiating fibres; very occasional epidote; titaniferous magnetite or ilmenite, brownish black in colour and partly altered to leucoxene; occasional apatite; and flecks of mica frequently associated with magnetite and forming a border to it. The structure is at times most beautifully ophitic. The felspars exhibit some peculiarities. The usual type is labradorite, but it is often bordered by an untwinned felspar with lower index than balsam; there are as well grains of orthoclase apparently unconnected with original labradorite. Zeolites are also present in fair amount. One of these is fibrous, with higher polarization colours than quartz, straight extinction and low index of refraction, which corresponds to natrolite. This has been derived from the felspar, since grains of felspar can be seen passing into it or partly replaced by it. There is also another derived mineral in sheaves of radiating fibres, with low polarization colours, and refractive index about that of balsam; this probably corresponds to phillipsite. Both of these zeolites are associated with grains and needles of aegerine-aguite, the needles often arranged in radiating groups like the stellate forms of schorl. These occurrences show a decidedly alkaline relationship, and the decomposed facies of the rock is thus easily accounted for. In some slides there is a little of the zeolitic material and its associated minerals. Also, the augite is occasionally diallagic. This feature is strongly reminiscent of the coarser types of the dolerite at the Acheron River, especially the more gabbroid portions, which are also noteworthy since they contain fairly numerous inclusions of natrolite. I saw no nepheline or other felspathoid in the View Hill rocks to account for the presence of the zeolites, and therefore conclude that they have been derived from the felspar originally present.

The indurated sandstones occurring under these rocks are composed of quartz grains of an average diameter of 0.2 to 0.3mm. with extensive outgrowths of mossy quartz which no doubt acts as a cementing agent.

b. *Eyre River.*—Three rocks from this area were analysed. The first of these to consider is the pillow-lava from Whites Creek. In the hand specimen this is a dark-coloured rock, smooth and compact in appearance, with small steam-vesicles of which some are filled with amygdaloids. In some cases the vesicles are large and elongated. The analysis shows that the rock is a somewhat acid basalt, with no suggestion of the albitization characteristic of some of the pillow-lavas. Under the microscope the rock appears to be finely even-grained and non porphyritic. There is much felspar (labradorite) in stumpy laths 0.1 to 0.25mm. in length, frequently with forked ends. Augite occurs freely in grains and laths; olivine in very small grains; and patches of glass obscured with dust of magnetite and needles of ilmenite. Calcite occurs in quantity, either as isolated patches and aggregations or as amygdaloids. There are also amygdaloids of chalcedony up to 1.5mm. in diameter, stained greenish-yellow with alteration products.

Some specimens are coarser in texture and show augite as grains packed between felspar laths or at times intergrown sub-ophitically. The augites are up to 1mm. in length and the felspars 0.75mm. The former in places occur in aggregations of crystals. The felspar is labradorite.

A fair number of specimens from about this horizon were examined microscopically and all proved to be basic in character. Some contain abundant olivine, as for example the dolerite exposed in the bed of the Eyre, near the old farm-house.

A most interesting occurrence of a basalt of limburgite facies was noted in the slides obtained from chips of an outcrop about three-quarters of a mile east of the pillow-lava quarry. Under the microscope the rock appears to be even grained in texture, with a few phenocrysts of augite and of olivine, the latter represented in places by alteration products. I saw no phenocrysts of felspar in the slides, but a re-examination of the lòcality disclosed the fact that felspar phenocrysts, some up to 2cm. in length, do occur. It is possible that the exact spot where the specimens were obtained was not located. The groundmass appears to be composed of much augite, a base of glass about the same index of refraction as balsam, and patches of an isotropic substance with refractive index definitely lower than balsam, with a rough surface, which may be analcite. There were also very occasional laths with low polarization colours and straight extinction, which looked like nepheline but did not show its usual habit. They might after all be felspar, and if so this was the only occurrence of felspar in the slide. The description thus answers to that of a limburgite. This is one of the oldest occurrences of igneous rocks in the locality, since it lies almost down on the greywacke, with but a very small thickness of sands intervening.

At the eastern end of this area there are several occurrences of very fine-grained compact basalt. Under the microscope the only phenocrysts appear to be olivine, which occurs freely in grains up to 0.8mm. in length. The groundmass is composed of felspar laths about 0.1mm. in length. Small grains of augite, skeletal forms of magnetite, amygdaloids of calcite, and colourless isotropic mineral of higher index of refraction than balsam, occur in the spaces between the felspar laths, the last being no doubt a glass. These rocks are comparable as regards their basicity with the limburgitic facies of the basalt further west, which like them lies down near the base of the series just above the greywacke substratum on which these Tertiary beds lie.

A rock occurring at an intermediate horizon is that on the shelf north-west of Chalk Hill. This is a basalt with holocrystalline groundmass composed of augite grains and felspar laths. The phenocrysts are augite, often in aggregations of grains up to 1mm. in length, and abundant olivine in clear and colourless crystals, 1mm. in length, occasionally altered to greenish-yellow secondary products; there are micro-phenocrysts of plagioclase, ilmenite in many needle-shaped and skeletal forms, and occasional calcite. This rock is intermediate in texture between the pillow-lavas and the dolerites which are found higher in the series.

The second analysis from the Eyre River area, the third in the table, is that of the rock which immediately overlies the chalk in the bed of the river. This is a dolerite of fairly even grain. The felspar, a basic labradorite, forms crystals up to 1.25mm. in length with an average of about 0.5mm. The augite is faint purplish in colour, slightly pleochroic, and often in nests of crystals. Olivine occurs sparingly. Ilmenite forms broken-comb shapes and skeletal crystals, and also occurs as a fine dust clouding patches of glass. Chalcedony occurs in amygdules composed of radiating fibres stained green with alteration products.

Analysis No. 4 is of a specimen from the junction of Whites Creek and the Eyre River, and represents what is practically the most recent flow belonging to this area. The rock is grey in the hand specimen, rough to the feel, and somewhat vesicular, the vesicles being lined inside with yellowish alteration products. The texture of this rock is somewhat fine for a typical dolerite. The phenocrysts are of hypersthene, up to 1.5mm. in length, slightly pleochroic, usually in long quadrangular forms with longitudinal and cross-cleavages well developed, slightly pleochroic, and bordered and also intergrown with augite, often occurring in nests of crystals; augite also occurs, as well as occasional olivine stained with iron oxide. The groundmass is composed of felspar (labradorite); augite generally in equidimensional forms about 0.25mm. in length; and magnetite or ilmenite in grains and skeletal laths. The rock is thus a fine grained hypersthene dolerite.

On the western and southern slopes of Chalk Hill dolerites similar in features to this rock occur freely. They contain little olivine but considerable amounts of hypersthene, as is generally the case with the latest flows throughout the district.

Micro-sections were made of some of the siliceous masses i.e., "chinamen," associated with these basic rocks. They proved to be formed almost wholly of quartz grains of two sizes. The larger are subangular, occasionally well rounded, and with a diameter ranging from 2 to 4mm., and averaging 3mm., while packed in between them are numerous smaller grains averaging from one-fifth to one-tenth the diameter of the larger grains. These in a few places appear to be definitely attached to the larger grains as outgrowths, but are generally quite separate from them. Occasional grains of zircon also occur.

c. *Starvation Hill.*—Four samples were selected from this locality, all coming from the big gully that has cut back into the hill on the south-eastern face. The specimens were selected so as to give some idea of the variation between the earlier flows and the latest. All the specimens taken were basalts or dolerites.

The first to be considered comes from the lowest beds exposed near the mouth of the gully. This is a dark-grey rock, usually compact, but with steam-holes sporadically distributed through it; phenocrysts of felspar, augite, and olivine are plainly visible in the hand-specimen. Under the microscope the phenocrysts appear to be of labradorite up to 2.5mm. in length and of augite up to 1mm., the latter frequently surrounded with a border of granular augite; and very occasional grains of olivine. The groundmass is holocrystalline and composed of laths of felspar, grains of augite and skeletal forms of magnetite, the average length of the felspars of the base being 0.25mm.

The next specimen is a moderately close-grained, non-vesicular, dark-coloured rock in the hand specimen. Under the microscope it is a fine grained dolerite or coarse basalt, composed of felspar laths up to 0.5mm. in length; augite in grains and short stumpy laths up to 0.5mm. in length; olivine in grains; quadrangular and skeletal forms of titaniferous magnetite; and phenocrysts of hypersthene in long quadrangular forms up to 1.5mm. in length, definitely pleochroic, and bordered with monoclinic augite.

Above this is found a grey, vesicular rock, which also proves to be a hypersthene-basalt. The hypersthene is in short stumpy forms as well as in long quadrangular laths, up to 1.5mm. in length, definitely pleochroic, and bordered with augite.

Olivine occurs in reddish-brown forms (iddingsite). I noticed no augite phenocrysts. The base consists of felspar laths, augite grains, and black iron ores.

The specimen from the topmost flow is very similar to this last but slightly more vesicular. The hypersthene occurs in forms characteristic of the area, the olivine is unaltered, but there are large grains of magnetite up to 2mm. in diameter in addition to the smaller quadrangular and skeletal forms.

As in other parts of the district the later appearances of volcanic rocks are characterized by the presence of hypersthene, and this may serve to indicate that they are all of about the same age.

d. *Burnt Hill.*—The specimen analyzed came from the southern side of the saddle which divides the Burnt Hill ridge into two almost equal parts. Microscopically the rock is dark-grey in colour, somewhat vesicular, and rough to the feel. It has in the field in some cases a distinctly reddish or pinkish tint which is probably due to the oxidation of the olivine it contains. Microscopically it is an even-grained rock, composed of felspar (labradorite) laths with an average length of 0.5mm.; a rhombic pyroxene with faint pleochroism, straight extinction, and negative character, therefore no doubt hypersthene; augite in smaller amount frequently twinned and also as a border to and intergrown with hypersthene; olivine stained brown with oxide of iron and forming iddingsite; much brownish-black titaniferous magnetite in grains of primary origin, as well as secondary ilmenite in broken-comb forms, both stained with whitish leucoxene; also apatite in stumpy needles. This rock may therefore be called a hypersthene-augite dolerite.

Other rocks from this locality show a similar composition, hypersthene occurring in all that were sectioned. Iddingsite is fairly common, but in some cases the larger olivines, really phenocrysts, show no alteration in that direction and are virtually fresh, whereas the micro-phenocrysts of olivine are stained with iron oxide. In some cases the augite is slightly purplish in colour. The texture varies, some specimens being sufficiently coarse for dolerites, while others are typical basalts.

The ash-bed under the fossil layer was also examined microscopically and showed the following composition. The field was composed mainly of a mosaic of calcite, fragments of volcanic glass, some dark in colour and other yellowish in tint (palagonite) containing bubbles filled in some cases with calcite and in others with chalcedony as well as numerous grains of magnetite. There were in addition fragments of augite, some blue-green in colour, hypersthene, olivine, felspar, flakes of mica, needles of apatite, and fairly numerous grains of glauconite. Most of these materials are similar to those occurring in the subsequent flows, but, as far as I know, the greenish augite does not occur as a constituent of these.

e. *Occurrences in the Waimakariri.* — As recorded previously volcanic rocks outcrop in three places close to the bed of the Waimakariri within the district under consideration. These are at Browns Rock, Rock Ford, and Woodstock.

(1) *Browns Rock.*

This rock is a rather fine-grained dolerite, somewhat vesicular in texture. It is porphyritic with phenocrysts of hypersthene up to 2mm. in length in rectangular forms about three times as long as broad, and with outgrowths of augite; olivine also occurs occasionally in grains which are usually clear and colourless and up to 1mm. in diameter. The groundmass is holocrystalline with the elements of sub-equal size, and consisting of felspar (labradorite), averaging about 0.25mm. in length; augite, in stumpy laths and grains sometimes ophitically intergrown with the felspar; grains of fresh and clear olivine; and grains and skeletal forms of brownish-black iron ore, altering to leucoxene and margined with hematite therefore in all probability, ilmenite. The last-named does not occur in such large amount as in the other rocks of the area.

(2) *Rockford.*

The occurrence here is a dolerite, somewhat coarse grained in texture, and composed of augite and felspar (labradorite) in sub-ophitic relationship; occasional hypersthene with a border of augite and very slightly pleochroic up to 2mm. in length; olivine in occasional grains; titaniferous-magnetite; and needles of apatite. The presence of hypersthene suggests a connection with the more recent flows in other parts of the district and with the occurrence at Browns Rock, but the texture belongs to an intrusive rather than to an effusive rock.

(3) *Woodstock.*

This in the hand specimen is a fine-grained rock, dark in colour, vesicular in places but generally compact with small amygdaloids plainly showing here and there. Under the microscope it shows an even-grained texture, the constituent minerals being felspar laths and augite, in places ophitically intergrown, the former are labradorite and have an average length of about 0.1mm. There are numerous small amygdaloids of chalcedony, and occasional larger ones up to 1mm. in diameter, all stained slightly green, but with the polarization colours and index of refraction and occasional fibrous structure of that mineral. There is also much ilmenite of secondary origin, in characteristic forms, sometimes forming aggregations round the amygdaloids. This is the most acidic rock encountered in the area.

f. *Greywackes.*—The last two analyses are those of two typical samples of greywacke, one from near the Waimakariri Gorge Railway Bridge and the other from Arthurs Pass. There are five inliers of greywacke in the area under consideration, and it was considered an advantage if representative samples could be submitted for analysis, especially as so few analyses of greywacke are available, in spite of the rock being the most important in the fabric of New Zealand as a whole.

The greywacke inliers are situated as folows: (1) near the junction of the Eyre and Whites Creek, (2) the north-western part of View Hill, (3) Eagle Hill and its extensions towards the Waimakariri, (4) Rockford, where there are at least two exposures, one forming the rock in the river near the old crossing, and the other forming a projecting mass on one of the lower terraces of the river, (5) at the Lower Gorge, where it forms for some distance the high banks on both sides of the river. In the last-named locality the greywacke is associated with well-bedded slaty shales, striking N.N.W. and dipping at high angles—much crushed in places with irregular dip and affected by small faults. Alongside this is a typical greywacke, forming a small hill to the north of the bridge. Analysis No. 6 is of a piece taken from here. In the hand specimen this shows the coarse grey facies of greywacke, very hard and tough. Under the microscope it appears to be composed mainly of quartz, and there are notable quantities of the felspars, both orthoclase and plagioclase, as well as subordinate amounts of both micas, augite, epidote, titanite, zircon, and calcite.

The most striking feature of the analysis is the relatively high value of the fraction $\frac{Na_2O}{K_2O}$—a feature of the No. 7 analysis as well—which may be taken to indicate that the greywackes were the debris of a granite land, but not subjected to much decomposition. If this had taken place to any extent then the fraction should have been smaller since soda-bearing minerals, especially felspars, are in general more susceptible to decomposing agents than those bearing potash. All the same the composition of the parent rock must exert some influence on the ratio, for a rock in which there is a relative excess of soda to start with, will produce with a small amount of decomposition a rock in which the fraction is greater than unity, while one with a small amount of soda will have a low fraction in any case, no matter whether the resulting detrital matter has been produced by decomposition or disintegration as the dominant destructive process.

In this case the low quantity of combined water supports the inference deduced from the high soda to potash ratio that disintegration and not decomposition was the dominant factor in producing the materials of greywacke from the parent rock.

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