Geology of Cordy's Flat, Malvern Hills, Canterbury.

By G. Jobberns, M.A., B.Sc., Christchurch Training College.

[*Read before the Philosophical Institute of Canterbury, 24th August, 1921; received by Editor, 31st December, 1924; issued separately, 13th March, 1926.*]

Contents.

1. Introduction.

This paper is a summary made from a thesis presented in 1920 for the M.A. degree of the New Zealand University. As a description of the Cordy's Flat area it follows to a considerable extent the published work of Haast, Hector, and Cox, all of whom were attracted to the locality in the early days by the discovery of brown coal. The area described is situated just beyond the Whitecliffs Railway-station, forty-two miles west of Christchurch, and forms a part of the Malvern Hills.

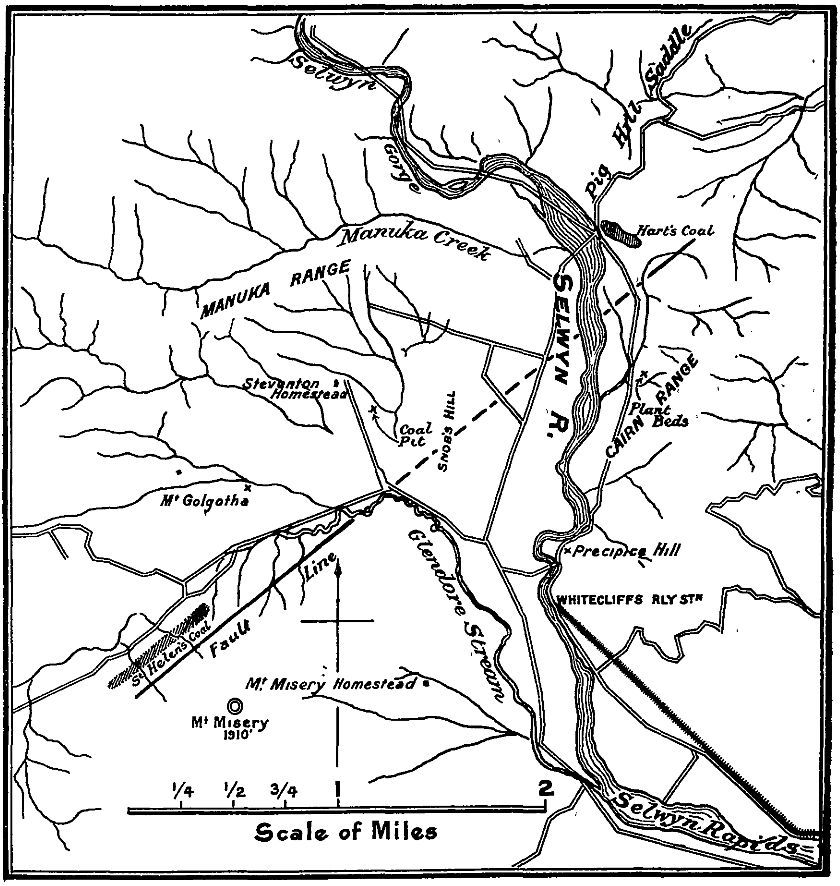
2. Physiography.

Cordy's Flat is a fairly large depression partly infilled by coarse alluvial gravels. Surrounded on all sides by older rocks, it contains isolated coal-bearing remnants of a former more widespread "Cretaceo-Tertiary" mantle (17, p. 345), which have in some places been completely removed and in others obscured by the thick alluvial deposits of the Selwyn River and its tributaries, Glendore and Manuka Creeks. The depression itself has been determined by a powerful dislocation, the Cordy's Flat fault, which runs across the flat in a north-east and south-west direction, and has a considerable downthrow to the north-west. This is No. 1 of the series of subparallel faults described in Professor Speight's recent paper on the Benmore coal area (19, map, p. 620). The higher ridge of the Flagpole Hill range has been deeply cut to form the narrow gorge through which the Selwyn debouches into the north-west corner of the flat. Park (15, p. 239) states that a branch of the Rakaia Glacier reached the Canterbury Plains via the Selwyn Valley, but in this area there seems to be no definite evidence of glacial action, and no need to invoke its agency for a satisfactory explanation of the surface features. Cordy's Flat may therefore best be described as an intermontane basin arising from the faulting which accompanied the elevation and folding of a pre-Pliocene peneplain.

3. Detailed Stratigraphy.

A. *Maitai Rocks.*

Rocks assigned to the Maitai series as defined by Cox (3, p. 24) form the greater part of the north-west boundary of Cordy's Flat from Mount Golgotha to the Pig Hill saddle, across which they probably continue beneath the recent accumulation of swampy alluvium, silt, and gravels until at the Cordy's Flat fault they butt against the Jurassic sandstones of the Cairn Range. The Maitai rocks consist of greywackes and sandstones which in many places have been rendered slaty by the pressure of sharp folding. They are everywhere steeply inclined, and in the bed of the Selwyn about a quarter of a mile above the Springfield road-crossing they strike N. 40° W., with an easterly dip of 65°, while the same general direction of strike is to be found in the rocks to the south-west of the Manuka Range. The greywacke, as shown by thin sections of samples from various points, is of a very uniform type, containing a considerable amount of calcium carbonate. The rock seems everywhere considerably



MAP OF PART OF MALVERN HILLS DISTRICT.

altered, the sections showing abundant epidote, together with much kaolin, presumably produced by the weathering of potash feldspar. The evidence available does not assist in assigning a definite age to the greywackes, but their unconformable relationship to the Jurassic rocks of the Cairn Range is discussed in a subsequent section.

B. *Jurassic Rocks.*

Rocks of Jurassic age constitute the northern part of the Cairn Range from the neighbourhood of Precipice Hill to the Cretaceous outlier near Hart's coal-pit. They are again exposed on the north-western side of

Cordy's Flat, where they form Manuka Range, the series of ridges lying at the eastern base of Flagpole Hill. Erosion, followed by deposition of river-gravels in the intervening valley, has made impossible any definite statement of the exact stratigraphical relationship between the beds in the two areas, but they are lithologically similar, and in all probability are continuous under the gravels of the flat at no great depth.

Extensive surface slumping, due to the steepness of the slopes and the incoherent nature of the strata, the masking of the base by accumulated talus, and the thick mantle of vegetation, render the accurate observation of the structure of the Cairn Range difficult. In their brief references to this locality both Haast and Hector seem to have overlooked the structural importance of the Cordy's Flat fault, the scarp of which is preserved in the northern extremity of the range. Here the greensand strata of the "Cretaceo-Tertiary" outlier may be traced for some distance up a ravine-like gully, the course of which seems to have been determined by the infold of a local syncline. The south-easterly dip of the greensands is somewhat flattened until they disappear beneath an accumulation of talus material just below the sharply-defined shoulder of the fault-scarp. Immediately above this are extremely brecciated argillites and decomposed greywacke, with a thin coaly band showing distortion of dip, the whole resting against the slickensided surface of sandstones with plant-remains similar to those exposed a little farther south at the summit of the range. Though considerable movement has occurred here, it is evidently not in the plane of the major fault, which, some few yards farther down, is completely obscured by slip-debris.

The strata exposed here strike east and west, with a southerly dip; the fault runs north-east and south-west (magnetic), with downthrow to the north-west; while the sandstone bands of the southern side of the gully are inclined north-north-west. Thus the general structure here is characterized by synclinal folding with faulting.

From the summit of the ridge above the fault-scarp to the foot of the range below the plant-beds the downward succession of strata is as follows:—

(6.) (*a.*) Soft friable sandstone, or "freestone," light-coloured, composed of loosely-cemented quartz-grains with occasional irregular secretions of iron oxide.

(*b.*) Similar rock to above, but with a fine lamellar banding, due to deposition of reddish ferruginous material in alternating layers.

(5.) Bands of earthy and coaly shales varying in thickness from a few inches to several feet. These occur at more or less regular intervals, and interstratified with them are—

(4.) Fine-grained sandy conglomerates, passing down into thick beds of coarse incoherent conglomerates composed of rounded pebbles of greywacke and sandstone.

(3.) Massive bands of compact hard deep-brown sandstone which in many places has a thin platy horizontal parting as well as vertical jointing.

(2.) Dull-brownish earthy sandstones in relatively thin bands, containing plentiful fragmentary plant-remains in a remarkably good state of preservation.

(1.) Thin bands of a particularly hard compact sandstone, so calcareous as to show abundant white calcite on cross-fracturing.

The highest portion of this northern range is the denuded crest of an anticline, the beds observed dipping north-north-west at an angle of 10° to 15°. The numerous alternations of sandstones, conglomerates, and shales, with great variation in thickness, indicate long-continued oscillation of base-level.

Plant-beds.—The best exposure of the plant-bearing earthy sandstones occurs immediately below the point where the upturned edges of the conglomerates, sandstones, and shales of the northern part of the Cairn Range are exposed at its summit. The downward succession of strata here may be summarized as follows:—

(7.) Fossiliferous sandstone—a thin band containing very plentiful plant-remains.
(6.) Black earthy shales attaining a thickness of 25 ft., containing rapidly-alternating clayey streaks.
(5.) Hard calcareous sandstone—unfossiliferous thin band.
(4.) Black shales resembling (6)—10 ft.
(3.) Sandstone like (7), but plant-remains not abundant.
(2.) Coarse conglomerates—6 ft.
(1.) Sandstone. Plant-remains occur very sparingly.

Shales with interstratified sandstones and conglomerates continue to the foot of the range, but the richly fossiliferous bands are restricted to the upper horizon.

Below the plant-beds the face of the hill has been covered with slumped blocks from landslips. The presence of massive greywacke crags on the summit of the ridge behind an isolated farmhouse suggests that the central part of the Cairn Range consists of greywacke. The strike of the greywacke is approximately north and south (magnetic), and the beds are almost vertical. It appears, then, that the Jurassic rocks of the northern part of the Cairn Range form part of a large anticlinal fold over this greywacke core, with which they are sharply unconformable.

The Manuka Range, on the opposite (or western) side of the Selwyn, is so densely covered with stunted scrub that only one outcrop of the component rocks was found. A small landslip reveals the following ascending sequence of strata:—

(1.) Compact sandstone with plant-stems in position (in bed of small stream).
(2.) Much-weathered crumbly argillite.
(3.) Brown coaly shale in thin bands; dip, N.W. 30°.
(4.) Argillite with ferruginous concretions.

Some distance above are the following:—

(5.) Fine sandy conglomerate.
(6.) Coarse incoherent sandstone and greywacke conglomerate.

Thin sections of pebbles from the conglomerate (bed 6) show them to be largely greywackes identical in character with the Maitai greywacke described above, and with the pebbles of the Cairn Range conglomerates. The conglomerate may be traced along the summit of the Manuka Range, its general strike being E. 10° N. At the northern extremity of the range the Maitai greywacke is found *in situ*, but no contact is exposed.

Unconformity between the Maitai Greywackes and the Cairn Range Beds.—The nature of the Cairn Range conglomerates demands the existence of the greywackes prior to the deposition of the Cairn Range beds. Haast overlooked this point, and, regarding the latter beds as inferior in position to the greywackes of the Selwyn Gorge, stated that they were the oldest representatives of the Palaeozoic strata of the Malvern Hills (8, p. 63). At the same time he remarked that the particularly incoherent matrix of the conglomerates, and the general nature of their component pebbles, would almost suggest that they consisted of post-Pliocene alluvium. He noted, too, the occurrence of plant-beds in which he obtained species of *Taeniopteris* and *Pecopteris*; but, being unable to reconcile the presence of *Taeniopteris* with his classification of the Cairn Range beds as Upper Palaeozoic, he held that its occurrence did not outweigh the stratigraphical evidence (8, pp. 6–7).

There is, then, no doubt that there is an unconformity between the beds of the Cairn Range and the greywackes, and that the latter are the more ancient rocks. This is not merely a local break in the sequence, because the greywackes are found to lie unconformably below the conglomerates of the Cairn Range type in many places in this part of the Malvern Hills.

The fossil flora of the Cairn Range has been described by the late Dr. E. A. N. Arber from specimens collected from the plant-beds by Professor R. Speight (*N.Z. Geol. Surv. Pal. Bull. 6*, p. 11). Arber considered these beds to be Lower Jurassic, though, as he remarks, "were a more extensive flora known from them, this conclusion might well require revision."

C. *Mount Misery Rhyolites.*

Mount Misery (1,910 ft.) is a dome-shaped mass of rhyolite rendered somewhat irregular in outline by erosion. Its western slope is marked by the steep fault-scarp which has determined the position of the coal-measures at its foot. On the summit are massive projecting rocks which would almost suggest extensive dykes, but the general lithological resemblance of all the rocks renders this unlikely. Mount Misery was obviously not a volcano of the ordinary explosive type, but probably was formed by slow accretion of a viscous lava by endogenous growth. Hutton referred the lavas to the "massive accumulations of Richthofen" (11, p. 41). From the summit of the mountain an easy descent is made to two lower ridges of rhyolite containing well-preserved garnets. Lying against the south-eastern side of the mountain is a great sequence of coaly shales and rhyolitic conglomerates.

Examination of thin sections of the rock from several points shows some slight variations in type. Some are rich in garnets, which are absent in others. Many of the sections exhibit a glassy base in which flow-structure may or may not be apparent; others have a groundmass which is completely though minutely crystalline and shows no evidence of fluxion. Cox (3, pp. 107–9) describes several examples of rhyolite from various localities, and considers that some possess an isotropic vitreous groundmass, while in others he remarks on the "devitrification" of the groundmass and the absence of flow-structure.

In some sections the groundmass consists of a micro-crystalline complex of quartz and feldspar too minute for individual identification, while in others it is almost completely isotropic with a dull felsitic appearance. In several the larger particles of the groundmass give a somewhat tufaceous appearance. The phenocrysts include quartz of very variable sizes, often showing considerable corrosion at the edges and somethmes a distinct brecciation, suggesting movement while cooling. Orthoclase is an abundant constituent, with rare plagioclase. Garnets, if present, are clear and well preserved, or completely weathered to a deep-brown ferrous substance like haematite. Biotite in scattered flakes may show alteration to magnetite, which seems always present in scattered grains or secondary patches.

The age of the rhyolites seems definitely fixed as Cretaceous, since, as Cox observed (3, p. 39), rhyolite tuffs and conglomerates occur interstratified with Cretaceous coals. But Marshall (14, p. 21) refers all this series of acid and intermediate rocks to his Trias-Jura system, while Park considers that the date of their eruption lies between the close of the Jurassic and the commencement of the Eocene (15, p. 83).

D. *Coal-measures.*

Discontinuous fragments of the "Cretaceo-Tertiary" coal-bearing series occur in many places in the neighbourhood, but in Cordy's Flat workable coal is found at—

(*a.*) Hart's Coal-pit—situated on the northern (or left) bank of the Selwyn River, just below the entrance to the gorge.

(*b.*) Hill's Coal-pit—on the Steventon Estate, in the central portion of the flat.

(*c.*) St. Helens Coal-pit—locally variously known as Wilson's, Levick's, or Sutherland's—at the north-western base of Mount Misery, in the valley of Glendore Stream.

These occurrences obviously represent remnants of a former more widespread field of a somewhat lenticular shape. That they now occupy the floor of the basin must be ascribed to the Cordy's Flat fault, on the downthrow side of which they lie. The comparatively elevated St. Helens seams, in close proximity to the fault, and the lower, more distant beds at Hill's coal-pit point to differential downthrow, which, greatest in the centre, probably determined the rudely semicircular form of the field. Hart's coal is quite isolated from the rest, the Selwyn River and the Manuka Creek having removed any pre-existing connecting beds and deposited a great depth of alluvial gravel. If coal-measures yet exist beneath these gravels, the remnants will be so small and will cut out so quickly against the fault as to make them not worth practical consideration. Snob's Hill, in the centre of the flat, has been prospected for coal, but has been found everywhere to consist of gravel.

Remnants of the "Cretaceo-Tertiary" sediments lie to the south-east of Mount Misery, stretch across the Selwyn River at the rapids, and bend south-eastward, again to become coal-bearing in Surveyor's Gully, behind Glentunnel Township. Hector (10, p. 53) thought there were two distinct and separate coal-bearing formations in the Malvern Hills, while Haast consistently refers to the Cordy's Flat coal-measures as an outlier of the main measures of the district. The weight of evidence is in support of Haast's view. The coal-bearing beds are everywhere of a remarkably uniform fineness of grain, suggesting deposition in shallow estuarine waters of sediments derived from a land of low relief.

Hart's Coal-mine.—An outcrop of the coal-measures is visible in the bend of the Selwyn River near the Springfield road-crossing at the north-east end of Cordy's Flat. Here an intrusion of dolerite has lent protection from erosion. The sequence at this place is somewhat obscured by debris from the old mining drives, and the dip of the strata has been much disturbed by the intrusive rock. The beds exposed are as follows, in ascending order:—

1. (1.) (Lower) Sandy shales, 8 ft. Baked white or greyish-white along whole length of exposure.
   (2.) Carbonaceous shales, 8 ft. Less metamorphosed than preceding.
   (3.) Sand and sandy shales, 20 ft. Contain bands of impure lignite. These strike north and south (magnetic), and dip E. 5°. Farther up the river the strike is north-north-east, and dip E.S.E. 20°.
   (4.) Surface gravels, 8 ft.

From here to the base of the Cairn Range the following sequence is encountered:—

2. White quartz sands, streaked and stained by iron oxide, which strike north-east, and dip uniformly S.E. 30°. These sands are used to some extent for moulding purposes. Together with the underlying shales they have a total thickness of 300 ft.
3. Calcareous sandstone, slightly glauconitic. Strike, N. 40° E.; dip, E. 30°. These cap the ridge above the sand.
4. Sands, 200 ft.
5. Calcareous sandstone, passing down into a band consisting almost entirely of remains of *Conchothyra parasitica* Hutton, exposed in the gully at the foot of the Cairn Range.

Hart's coal-mine has long been abandoned, though it attracted the attention of the early geologists on account of the semi-anthracitic nature of the coal altered by the dolerite sill. This coal was soon worked out, but the reports mention the discovery of a thick seam of good brown coal, which was not mined on account of the water encountered.

Hill's Coal-mine.—A long ridge not rising more than 150 ft. above the flat, and extending from the front of the Steventon Homestead to the present workings, is composed for the greater part of its length of the basal beds of the Cretaceous series, but no actual contact with the greywackes is visible. A small exposure in a little gully opposite the wool-shed shows the following beds, in ascending order:—

(1.) Sandstone—thick, red, highly ferruginous.
(2.) Clays.
(3.) Black shales 1 ft. 6 in. thick, containing compressed shiny plant-remains, and having conchoidal fracture.
(4.) Fireclay, typically hard, with concretions of ferruginous sandstone.

These strata dip S.E. 30°, and have a total thickness of about 60 ft. No further outcrop is seen for a long distance, but the beds exposed in prospecting-shafts sunk in various places by the present owner of Steventon have uniformly a dip of 30° S.E., and a total thickness of at least 760 ft.

As a result of this prospecting a permanent drive dipping south-east at 20° was opened. It passed through an irregularly vertical wall of dolerite, 8 ft. thick, at 17 ft. from the entrance. This is probably an upward extension of a sill, and it turns over near the roof, apparently to continue as a sill on an upper level. Immediately beyond the dolerite is a 3 ft. 6 in. seam of brecciated altered coal, increasing in thickness to 3 ft. 9 in. This drive opened up a good seam of a very fair quality brown coal, which has since been worked extensively.

At the foot of the ridge is the entrance to a drive excavated in 1871, and described by Haast in his report of that year (8, pp. 51–52). Though about 400 tons of coal was mined from a shaft near this point, the field seems to have been abandoned early, for no mention of it is made in Lindop's reports of 1885. The present owner of the property had the drive reopened, thus providing a good opportunity for re-examination of the relations between the coal-bearing beds and the intrusive igneous rock, by which they have been much altered. Haast concluded that, contemporaneous with the deposition of the coal-beds, there were flows of basic lava, above which shales and coal-seams were subsequently deposited. Though a detailed description of the drive is rendered unnecessary by that of Haast, examination shows that the dolerite is not the remnant of successive lava-flows, but represents a single large intrusion. The following observations made in the old drive support this view :—

(*a.*) Though the intrusion conforms generally to the bedding-planes of the strata, in several places it breaks across them vertically, to continue on a higher level.

(*b.*) Numerous projecting veins and tongues of igneous rock pass both upwards and downwards into the neighbouring beds. The intrusive rock itself shows a rude polyhedral parting on both upper and lower surfaces.

(*c.*) The underlying and overlying beds are equally altered by heat and pressure. Coal in contact with the intrusion has a highly developed columnar structure, and is semi-anthracitic above and below.

(*d.*) Where the intrusive rock has passed through beds of coal or carbonaceous shale it is itself completely altered to a dull-green earthy mass. The dip of the beds is very irregular at many points.

(*e.*) Many of the marginal columns of coal and indurated shale show a bending towards the inner end of the tunnel. If this be taken as indicative of direction of flow, the rock must be regarded as intrusive.

St. Helens Coal-mine.—This mine is not mentioned in Haast's reports on the Malvern Hills, nor did Cox refer to it in his reports of 1877–78, though he then inspected all the mines in the neighbourhood. In 1883, however, Cox mentions it as "Wilson's mine," giving a section showing what he thought to be a north-easterly extension of the Brockley dyke, which he expected to have a metamorphic effect on the brown coals (3, p. 34). A. N. Lindop gives a brief account of workings here (13, p. 17). There seems to be no evidence whatever of a continuation of the Brockley dyke as suggested by Cox.

The whole area has been prospected in recent years, and many old workings have been reopened. Data obtained from these explorations correspond roughly with Lindop's description. He, however, had taken no account of an 8 ft. seam some 40 ft. below the level of those previously worked. The seam recently worked here, known locally as "Wilson's seam," is 5 ft. to 6 ft. thick. An old dip drive following the seam was reopened and then continued, levels in the coal being set off at 124 ft., 160 ft., and 200 ft. from the surface. Overlying this seam there is about 15 in. of a poor fireclay, followed by 15 in. of coal, and a little above this there is a further 3 ft. to 4 ft. of coal with a band of ironstone 6 in. from the roof. There is a coal-seam 4 ft. to 5 ft. thick a little below Wilson's seam, with an 8 ft. seam about 40 ft. lower. The coal-seams here dip uniformly at 30° to the south-east, but terminate in that direction at the Cordy's Flat fault, which brings the coal-measures against the Mount Misery rhyolite.

Intrusive Igneous Rocks in Coal-measures.—These are exposed at the workings of both Hart's and Hill's coal-pits, and have been referred to previously as doleritic intrusions penetrating the coal. Haast mentions the association of coal with igneous rock at Hart's mine in his report of 1871 (8, p. 52). He gives (8, p, 16) a plan and a section indicating that he considered the intrusion which has caused the alteration of the coal to be a large vertical dyke striking S. 15° E. to N. 15° W. (magnetic), with a thickness of some 18 ft. Examination of the locality on several occasions has failed to reveal any evidence in support of this description, and the direction of strike given by Haast cannot be inferred from the only outcrop now visible. He may have observed the loose weathered and rounded dolerite boulders which occur for a hundred yards along the river-bank, thereby arriving at an approximate north-and-south direction, but these boulders are obviously not *in situ* and their presence here is quite fortuitous.

The one outcrop of igneous rock as seen at the bend on the river-bank is so small that no definite statement as to the size and extent of the intrusion can be made. The underlying strata cannot be seen, but the upper surface of the dolerite is in contact with a clay bed dipping S.E. 30° and showing every indicarion of having been baked. Also, just round the point, a sandy shale is found to lie almost flat, and to be considerably baked and hardened. Comparison with the dolerite at Hill's mine, and the absence of any other igneous rock except the boulders previously mentioned, indicate that the intrusive is not a dyke, but a sill lying between the bedding-planes of the strata and dipping with them S.E. 30°. There seems no reason to doubt that the dolerites of Hart's and Hill's mines belong to the same sill, their extension across Cordy's Flat being obscured by river-erosion and gravel-deposition. Haast (8, p. 51) states that the " dyke " of dolerite (also described elsewhere as " interbedded sheets ") exposed in Hill's mine forms also the eastern corner of Mount Golgotha. This seems very probable, for, though the outcrop observed by Haast has since been obscured by cultivation, isolated small blocks of dolerite have been found here. The occurrence of basic sills in New Zealand is not common, and the only reference to them so far as the Malvern Hills district is concerned is that made by Park regarding their effect on coal (16, p. 50).

Examination of thin sections of the igneous rocks from Hart's and Hill's mines show that they are holocystalline dolerites of medium basicity. Hutton (12, p. 130) describes the rock from Hart's as an augite porphyrite. But the igneous rocks are distinctly not porphytitic in structure, and the occurrence of olivine and labradorite, the holocrystalline even-grained structure, and the doleritic relations of the augite and feldspar leave no doubt as to their proper classification as dolerites. The rock from Hill's shows labradorite in laths and small crystals of uniform size, ragged crystals and grains of augite sometimes completely enclosed by feldspar laths, olivine, magnetite, and various alteration products. That fron Hart's is remarkable for abundant calcite, the highly altered nature of the rock suggesting this to be secondary, as much of it occurs in veinlets due to infilling of cracks.

Effect of Igneous Intrusions on Coal.—At Hart's mine the high-grade coal due to the intrusion of dolerite into the coal-measures has been entirely mined, but at Hill's mine a bright semi-anthracitic coal is still observable. Where in contact with the dolerite sill it is generally characterized by brecciation and columnar jointing, and by being bright, hard, and clean to the touch. But within a comparatively short distance from the sill which has been responsible for the alteration it approaches more and more to the original type of brown coal. A good many analyses of samples of the altered coal are available. These show the general nature of the alteration, with a gradation from anthracitic coal to altered brown coal to normal hydrous brown coal (10, p. 54; 7, p. 140; 9, p. 19; 6, p. 565). The alteration of the Cordy's Flat coals is not such as to produce the property of coking, and they merely approximate to the anthracitic type. They are simply brown coals modified only in close contact with intrusive rocks by the loss of water, or volatile hydrocarbons, or both. The extreme product of alteration in contact with the neighbouring Brockley dyke is a natural coke.

Age of Dolerites.—The date at which the dolerites were intruded into the coal-measures cannot be definitely stated. They are certainly very deeply weathered, but this may be no indication whatever of an early Tertiary or a pre-Tertiary age. No assistance is to be obtained from correlation with the basaltic flows of the neighbourhood, for the age of these is equally uncertain. Although the only definite statement which may be made is that they are post-Cretaceous, they are probably to be associated with the earth-movements of the Pliocene, and therefore in the absence of evidence to the contrary they are here assigned to the later Tertiary.

Rhyolitic Conglomerates, and associated Sandstones and Shales.—Conglomerates formed largely of rhyolite pebbles, interstratified with more or less ferruginous sandstones and shales, some layers of which are highly carbonaceous, are exposed on the eastern and south-eastern slopes of Mount Misery, and at Precipice Hill, where the sequence attains a thickness of several hundred feet. These beds are well seen in the small creek which comes down to Glendore Stream past the old Mount Misery homestead-site. At the entrance to the gully sandstones with ferruginous concretions are overlain by shales dipping south-east at 5°–10°. At the first waterfall, a few chains above this, the sequence is exposed to a lower band of ferruginous shales with indistinct plant-remains, surmounted by a fine sandy conglomerate passing up into a hard compact sandstone. These beds dip S.E. 20°. Just below the old homestead-site is the horizon of the rhyolitic conglomerates. Cox (3, p. 30) described tufaceous beds resting against the flank of Mount Misery in this locality, but there is no reason to regard these beds as tuffs. The pebbles, thoroughly rounded by water, do not consist exclusively of rhyolite fragments, many of them being greywacke. Moreover, the uniformly fine-grained sandy matrix, the abundant lenticular inclusions of coaly substance, and the interstratification with shales and sandstones all suggest that they are ordinary conglomerates, the rhyolite pebbles of which may well have been derived from the rock forming Mount Misery. The conglomerate band at this point attains a thickness of 35 ft., and dips at 30° to the east-south-east, a dip which is maintained up the stream until rhyolite appears. Underlying this thick band is a bed of coaly shale containing a large lenticular mass of conglomerate. From here is a succession of hard conglomerate bands, alternating with soft shaly layers, giving rise to a series of steps, over which the stream flows. The actual contact of the sedimentary beds with the massive rhyolite is not distinguishable, but the latter is encountered just past the second ridge and continues to the head of the stream.

A magnificent exposure at the steep cliff of Precipice Hill facing the Selwyn River, north of Whitecliffs Railway-station, shows a great thickness of black coaly shales with intermittent thin bands of ferruginous and concretionary sandstones, passing up into a thick band of finer and coarser rhyolitic conglomerates, with a recurrence of the shales and sandstones above. The structure here is highly interesting and demands careful consideration. The strata seen in the cliff dip west towards the Selwyn and form the eastern limb of a large synclinal fold. Some 150 yards from the face of the precipice, sharply tilted beds of hard reddish sandstone—a sandstone generally occurring at the base of the local Cretaceous—are seen to strike north and south (magnetic) and to dip 40° E. Fifty yards nearer the precipice hard sandy shales and sandstones with a dip of 40° E. are exposed. Thirty yards nearer similar hard sandy shales are seen to lie almost horizontally. Beneath the Selwyn River Bridge the same bed dips 40° E., but the strike is now slightly west of north, owing to synclinal twisting. Fifty yards below the bridge the same beds show a north-west strike.

These observations, together with the westerly dip of the Precipice Hill beds, supply the key to the structure, and there seems no doubt that the Selwyn River here flows over another syncline. The half-mile stretch from Precipice Hill to the eastern slopes of Mount Misery is mantled with alluvial gravels, but, since the basal beds of the local Cretaceous are exposed in the river, these gravels are probably not very thick.

The Upper Senonian age of the local coal-measures has been fully discussed in connection with fossil remains from Cordy's Flat and the Selwyn Rapids (20, pp. 294–305, 337–42; 22; 21, pp. 260–65; 23, pp. 539–44).

E. *Post-Pliocene Gravels.*

The grading of the Selwyn River channel after the successive periods of uplift to which the country was subjected has left thick mantles of greywacke gravels in various elevated places in the neighbourhood. These, together with the very coarse gravels comprising Snob's Hill, in the centre of Cordy's Flat, must be assigned to the older (Kowai) series of gravels (19). The formation of Snob's Hill is to be attributed to a partial infilling of the depression by material brought down from the upper gorge by a river of much greater velocity than the Selwyn has at present. Subsequently much of the gravel was removed during a period of erosion, leaving Snob's Hill as an isolated elevation. Down-cutting, owing to decreased volume of the river and its reaching a base-level across the flat, has now practically ceased.

References.

1. E. A. N. Arber. The Earlier Mesozoic Floras of New Zealand. *N.Z. Geol. Surv. Pal. Bull. 6.* 1917.
2. S. H. Cox. Report on the Geology of the Mount Somers District. *Rep. Geol. Explor., 1876–77,* pp. 1–10. 1877.
3. —— On Mount Somers and Malvern Hills District. *Ibid., 1883–84,* pp. 22–43. 1884.
4. —— On the Relations of the Quartz Porphyries and Pitchstones of Mount Somers and Malvern Hills. *Ibid.,* pp. 107–9.
5. W. P. Evans. Contact Metamorphism at the New Brockley Coal-mine (Malvern Hills). *Trans. N.Z. Inst.,* vol. 31, pp. 557–64. 1899.
6. —— Analyses (Technical) of New Zealand Coals. *Trans. N.Z. Inst.,* vol. 31, pp. 564–65. 1899.
7. J. von Haast. Preliminary Report on the Malvern Hills, Canterbury. *Rep. Geol. Explor., 1870–71,* pp. 135–46. 1871.
8. —— Report on the Geology of the Malvern Hills, Canterbury. *Ibid., 1871–72,* pp. 1–88. 1872.
9. —— On the so-called Hart's Coalfields in the Malvern Hills, Canterbury. *Ibid., 1883–84,* pp. 16–19. 1884.
10. J. Hector. On the Geological Structure of the Malvern Hills District, Canterbury. *Rep. Geol. Explor., 1870–71,* pp. 46–55. 1871.

11. F. W. HUTTON. Report on the Geology of the North-east Portion of the South Island from Cook Straits to the Rakaia. *Rep. Geol. Explor., 1873–74*, pp. 27–58. 1877.
12. —— The Eruptive Rocks of New Zealand. *Journ. and Proc. Roy. Soc. N.S.W.*, vol. 23, pp. 102–56. 1889.
13. A. B. LINDOP. On the Coal-mines in the Malvern District. *Rep. Geol. Explor., 1885*, pp. 15–21. 1886.
14. P. MARSHALL. *New Zealand and Adjacent Islands.* Heidelberg, 1912.
15. J. PARK. *Geology of New Zealand.* 1910.
16. —— *A Text-book of Mining Geology.* 3rd ed. 1911.
17. R. SPEIGHT. The Intermontane Basins of Canterbury. *Trans. N.Z. Inst.*, vol. 47, pp. 336–53. 1915.
18. —— The Older Gravels of North Canterbury. *Trans. N.Z. Inst.*, vol. 51, pp. 269–81. 1819.
19. —— The Benmore Coal Area of the Malvern Hills. *Trans. N.Z. Inst.*, vol. 55, pp. 619–26. 1924.
20. C. T. TRECHMANN. Cretaceous Mollusca from New Zealand. *Geol. Mag.*, dec. 6, vol. 4, pp. 294–305, 337–42. 1917.
21. OTTO WILCKENS. Die Bivalvenfauna des Obersenons von Neu-Seeland. *Centralblatt fuer Min.*, &c., 1920, pp. 260–65.
22. —— The Upper Cretaceous Gastropods of New Zealand. *N.Z. Geol. Surv. Pal. Bull. 9l* 1922.
23. —— *Lahillia* and some other Fossils from the Upper Senonian of New Zealand. *Trans. N.Z. Inst.*, vol. 55, pp. 539–44. 1924.

Raised Beaches in Teviotdale District, North Canterbury.

By G. JOBBERNS, M.A., B.Sc., Christchurch Training College.

[*Read before the Canterbury Philosophical Institute, 3rd December, 1924; received by Editor, 31st December, 1924; issued separately, 13th March, 1926.*]

IN view of Dr. Henderson's recent paper on the post-Tertiary coastal features of New Zealand (*Trans. N.Z. Inst.*, vol. 55, pp. 580–99, 1924), the following note on raised beaches is compiled from observations of the coast between the Motunau and Waipara Rivers. The terraces here are so well defined that they may often be seen distinctly from the Port Hills across Pegasus Bay, and they have previously been briefly described by Professor Speight in his paper on the Lower Waipara Gorge (*Trans. N.Z. Inst.*, vol. 44, pp. 221–33, 1912). Though intermittent uplift is clearly indicated along this coast, erosion has been so rapid as to cut away much of the original seaward extension of the lower terraces. For this reason it is very difficult to get any definite correlation between the river-terraces and the remnants of wave-levelled coastal platforms in the same district. The object of this paper is to record the heights and distribution of those platforms which are of marine origin.

THE DOVEDALE AREA.

The coastal marine terraces are divided into two groups by the Limestone Range, which reaches the coast about midway between the mouths of the Waipara and Motunau Rivers. This range, capped by a tilted and faulted block of Weka Pass limestone, extends from a point about three miles south-east of the Waipara Railway-station to the sea, through Montserrat, whence the limestone swings inland, continuing past Vulcan Hill to the north of the Motunau River.