Transactions of the Royal Society of New Zealand 291
Vol. 77, Part 2, pp. 291–305, 2 Text Figures, Plate 35.

The Geology of the Wairaki Survey District, Southland

By M. V. Rout and R. W. Willett, N.Z. Geological Survey.

[*Read before the Southland Branch, July 24, 1946; received by the Editor, July 8, 1947; issued separately, February, 1949.*]

Abstract.

A preliminary account of the geology of the Wairaki Survey District, in the eastern foothills of the Takitimo Mountains, Southland, New Zealand, is presented. The northern part of the area is made up of parallel tilted fault blocks that control the drainage, and moderately high rolling downs country makes up the southern part of the area. The rocks consist largely of greywackes, argillites with interbedded tuffs, with a huge thickness of massive tuffs in the south-west. Igneous intrusions both concordant and discordant are present. Formations Carnic and Ladino-Carnic in age, fossiliferous at various localities, occupy the north-east part of the area, and along the western boundary of these beds is a narrow two-mile strip of Upper Palaeozoic beds (? Te Anau), rich in Zaphrentoid corals and Productus. The southern margin is marked by infaulted Tertiary (Coal Measures) strips. This account is illustrated by geological map, sections, and photographs.

Introduction.

The area mapped and discussed in this paper occupies Wairaki Survey District, Southland, covering an area of about 160 square miles, and lies on the south-east side of the Takitimo Mountains, a massive and rugged range between the Aparima and Waiau Rivers. It is bounded on the north and east by the Aparima River and on the west by the Wairaki River, that flows south-west along the base of the Takitimo Mountains. To the south the area is bounded by the edge of the Ohai Depression. The greater part of Wairaki Survey District is accessible only on foot or on horse, the roads being confined to the settled valleys of the Aparima and Morley Rivers. The country is, however, fairly open, and the musterers' huts over the area are served by good tracks.

Most of the area is tussock country with here and there patches of beech forest except where infaulted Tertiary strips occur, on which the growth is notably manuka scrub.

The provisional one-mile Morley sheet, S.159, was used as a base map and the detailed topography and abundant spot heights considerably facilitated the field work, which was entirely carried out by one of the writers (M. V. R.). Both writers spent several days in the area with Dr. J. Marwick, collecting from the Permian localities and examining the general geology. Appreciation is expressed of the benefit of Dr. Marwick's visit and helpful discussion in the field.

Shortly after the completion of the field work, Mr. Rout resigned from the Geological Survey, and the text of this paper was prepared by co-author (R. W. W.) from Mr. Rout's field sheets, notes, and discussion.

Previous Geological Work.

Hector (1869), in a progress report of the Geological Survey, gave the first geological account of the area, in which he described the Triassic sandstones, shales of the Coal Measures, and the clay marls and limestones of Sharpridge. From the Triassic beds, Hector noted that they had a good fauna and collected *Trigonia, Mytilus, Ammonites,* and *Pholadomya.*

Hutton (1872) followed Hector and reported on the geology of Southland as a whole, and indicated on his geological map the greater part of the Takitimo area as far south as the Wairaki, as Upper Palaeozoic (Te Anau Series of Hector). To the south, the Wairaki Downs area and the basement rocks around the Ohai coal field were considered to be lower secondary formation (Kaihiku Series of Hector). His sections show a fault contact between the Palaeozoic of the Takitimo area, and the lower secondary rocks to the east, and he placed an erosion contact between Mount Beaumont and Etal.

Hutton discussed the geological structure of Southland and each formation in some detail. The Takitimos were regarded as being composed of phyllite, similar to that seen at Athol, and dipping to the east-south-east and west-north-west alternately. The Kaihiku Series of Hector represented by the rocks of the Wairaki Hills were described as being less metamorphosed than those of the Te Anau Series, and with more abundant fossils. Hutton (p. 104) stated that at Morley Creek, on the south side of the Wairaki Hills, he got *Halobia* and casts of *Isocardia, Trochus,* etc., and thus he placed the beds as Triassic.

Hutton and Ulrich (1875) mapped the geology of the Wairaki area as belonging to the Maitai Formation, the base of their Mesozoic rocks. The remainder of the Takitimo Mountains were considered to belong to the Kaikoura Formation, the upper part of the Palaeozoic. Hutton (p. 39) described fossils found in Morley Creek, *Halobia, Isocardia,* and *Trochus* in addition to the *Inoceramus* and *Trigonia* reported by Hector from the same locality.

Cox (1878), in a report on the Geology of Te Anau District, mapped the geology of the north end of the Takitimo Mountains as far south as the Aparima. The rocks forming the main Takitimo Mountains he termed the Takitimo Series, placing them in the Maitai Formation. The Mount Hamilton-Centre Hill area lying between the Aparima and Mararoa Rivers was considered to belong to the Kaihiku Series of Cox and McKay.

Marshall (1912) in his geological map indicates the northern part of the Wairaki and Takitimo areas as belonging to the Maitai or Triassic and the southern part of the area as Hokonui or Jurassic.

Benson (1935), discussing the land forms of southern New Zealand, indicated a continuation of the late Tertiary peneplain over Fiordland and across the Takitimo Mountains.

Benson and Holloway (1940) illustrated a generalized geological map of south-western New Zealand showing the Takitimo and Wairaki areas belonging to the Te Anau Series, correlating them with rocks of the Livingstone and Longwood Ranges.

Park (1921) discussed and mapped the general geology of Western Southland and placed the Takitimo Mountains and the Wairaki district in the Maitai Series as Permo-Carboniferous. He correlated the rocks with those of the Livingstone Mountains to the north and the Longwoods to the south. Park (p. 39) considered the Takitimo Mountains to be made up of argillite and greywackes with associated bands of red argillite, green aphantic sandstones and breccias, and folded into a series of anticlines and synclines striking N.W.–S.E. Park (p. 40) mentioned the occurrence of *Productus, Spirifer, Spiriferina,* a *Turbo*-like gastropod, and two corals in a band of gritty limestone at the north end of the Livingstone Range. The presence of augite-porphyrite intrusions at the south end of the Takitimo Mountains was noted, particularly at Malakoff Hill.

Benson (1921) published a geological map prepared by P. G. Morgan which shows the entire Takitimo Mountains belonging to the Trias-Jura and grouped with the rocks of the Hokonui Hills through to the Catlins Coast.

Willett (1945) described a small patch of infaulted Tertiary coal measures in Coal Creek and the Waterloo Burn, tributaries of the Aparima in the north-east of the Takitimo Range.

Lillie (MS., 1945) mapped in detail the Ohai coal measures and noted the occurrence of fossils in the greywackes around the northern margin of the basin, particularly in Morley Creek.

Reed (1945), in a general geological map of Otago and Southland, showed the Takitimo and Longwood areas as being composed of greywackes, etc., probably late Palaeozoic in age.

TOPOGRAPHY.

Relief. The area contained within the Wairaki district forms the eastern foothills of the Takitimo Mountains. A series of ridges with steep west slopes and more gentle east slopes strike north and rise on an average to about 2,500 ft. above sea-level. Three main ridges mark out the topography of the northern and central part of the Wairaki district. In the east is the Saddle Hill-Chimney Ridge ranging from 2,000 to 2,400 ft.; it is separated from the Etal-Beaumont Ridge by the headwaters of the Etal Creek and a tributary of the Aparima. The Etal-Beaumont Ridge ranges from 2,700 to 3,000 ft. and is broken by an area of rolling country and a tributary of the Etal, which separates the Etal Block from the Beaumont Block. South of Beaumont, the eastern branch of the Beaumont Creek and Sheepwash Creek separate the Beaumont Ridge from a small 2,000 ft. block.

To the west of the Etal-Beaumont Block is the Letham Block which ranges from 2,300 to 3,100 ft. and is separated from the Etal-Beaumont Block in the east by the North Etal Stream and from the main Takitimo Range by Pleasant Creek and Letham Burn. Just south of this Letham Block, Morley Hill forms a small but prominent ridge. The eastern part of this area is made up of low rolling hills that slope gently to the wide alluviated valley of the Aparima. On the south side the hills break off sharply to the Ohai Depression, which separates the Takitimo Mountains from the Longwoods to the south, the higher ridges occupying the western part of the Wairaki area with here and there large areas of rolling upland country. The south-

west corner of the area, bounded by the Morley Stream in the east and the Wairaki River in the west, is made up of fairly high down country ranging in height from 1,500 to 2,200 ft., forming a more subdued topography than the rest of the area.

The main Takitimo Range itself rises abruptly at the western boundary, forming a striking topographic contrast with the Wairaki area.

Drainage. The drainage pattern parallels the ridge topography described above and is in the main a north-south drainage, forming with tributaries a rectangular pattern. In detail the pattern approaches a more dendritic type, but the main streams themselves emphasise the rectangular aspect. In the south-west corner of the area, where the fairly high rolling country forms the topography, the drainage pattern is radial around the highest point, Wether Hill, 2,208 ft.

The major streams that drain the area are the Aparima, the Wairaki, and the Morley in order of size. The northern and eastern parts are drained by tributaries falling into the Aparima, the western part, but actually a small part of the whole area, drained by the Wairaki, and the remainder by streams that form the Ohai or Morley River. The streams are at grade, and while the Aparima flows along a wide alluviated valley some of the smaller streams meander over the valley floors as underfit streams; others have entrenched themselves in the valley floor and some have cut deep narrow gorges through rock ridges that lie across their course. The headwaters of the streams are generally close and very little elevation separates them, giving the continuous north-south valley-ridge topography. The relation of the present drainage pattern to that of the past is discussed in later sections under physiography.

Physiography.

Fault blocks. Mention has already been made of the north-striking faults that block out the ridges and control the present drainage. The faults are indicated on the geological map (Fig. 1). The main ridges, the Letham, Etal, and to a lesser degree, the Chimney ridges, present along their western faces a steep fault scarp with the gentle back-slope toward the east. These folded fault blocks have been breached by water-gaps in the central and southern part of the Wairaki area at several points by the present drainage system. There is, however, some evidence to suggest another series of faults, trending east, causing the breaks in the north-trending scarps. It is impossible on the present evidence to place the faults into age groups, except that the youngest beds affected are the immediately pre-Whaingaroan coal measures.

The faults involving the coal measures in the southern part of the area, that is, the strip striking east, north of Trig. H, the strip striking north-west lying and between the Wairaki area and Mount Linton, and the Ohai Depression south of Mount Linton and Mount Franklin, may be older than those forming north-trending fault scarps. The north-trending fault scarps are, in the main, young in form and present a much less subdued appearance than the fault scarps associated with the Tertiary sediments.

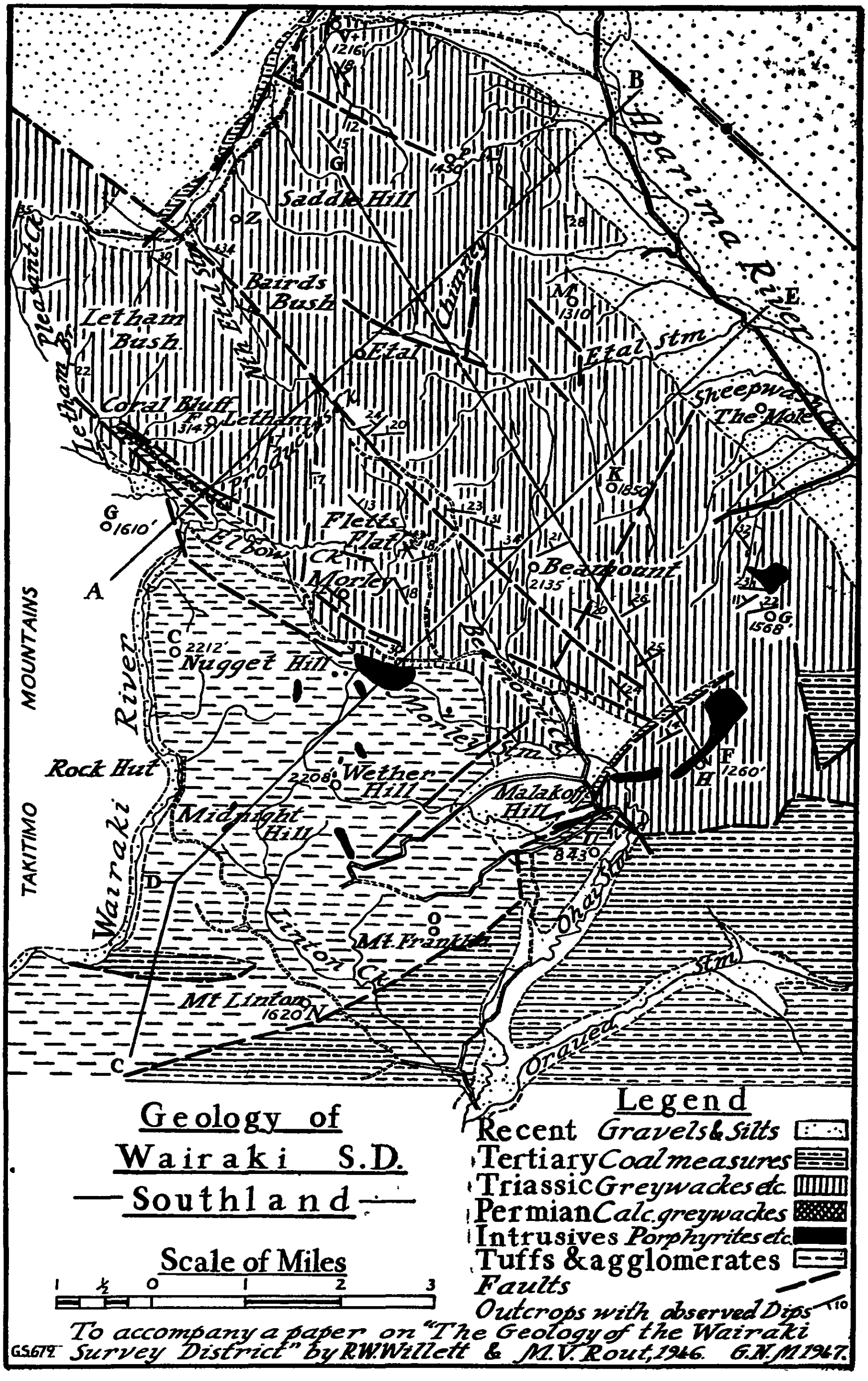
Geology of
Wairaki S.D.
Southland
Scale of Miles
1 ½ 0 1 2 3
Legend
Recent Gravels & Silts
Tertiary Coal measures
Triassic Greywackes etc.
Permian Calc. greywackes
Intrusives Porphyrites etc.
Tuffs & agglomerates
Faults
Outcrops with observed Dips
To accompany a paper on "The Geology of the Wairaki Survey District" by R.W. Willett & M.V. Rout, 1946. G.N./M.1947.
GS.679
TAKITIMO MOUNTAINS
Wairaki River
Aparima River
Saddle Hill
Bairds Bush
Letham Bush
Letham Br.
Pleasant Ck
Coral Bluff
Lethams Prospect
Chimney
Etal
Etal stm
Sheepwash Ck
The Mole
Fletts Flat
Elbow Ck
Morley
Beaumont
Nugget Hill
Morley Stm.
Wether Hill
Malakoff Hill
Midnight Hill
Mt Franklin
Linton Ck
Mt Linton
Ohai Stm
Orauea
Rock Hut
2212'
1610'
2135
2208
1850
1310
1260'
843
1620
1568
A
B
C
D
E
F
G
H
K
M
Z

FIGURE 1.

In addition to the faults that belong to either the north-trending group or the east-trending group, there are two smaller ones diagonal to these two groups, one trending north-west involving coal measures in the south-west and one controlling the valleys of the Beaumont Creek and Sheepwash Creek and trending north-east.

Drainage.

The present drainage pattern is largely controlled by fault valleys. In the south the Ohai trough has resulted from a series of east-trending faults, and to the north of the trough are several small east-trending fault valleys. Between the Ohai Depression and the east-trending fault of the Upper Aparima river valley, the pattern is predominantly influenced by north-trending fault valleys, though some minor faulting striking east appears to have modified the pattern. Lithology and stratification of the beds seems to have had little influence on the general pattern.

The drainage pattern of the immediate past appears to have been almost completely controlled by the north-south fault system. The main outlet from the area appears to have been near Ohai, into the ancient "Wallace" River (Lillie, personal communication) flowing east. This river was formed by the junction (in the vicinity of the Beaumont alluvium) of two large branches, the east branch appears to have flowed south along the course now occupied by Waterloo Burn, North Etal Stream, and Beaumont Creek; the west branch along a course now occupied by Pleasant Creek, Letham Stream, Elbow Creek, and Morley Stream. The pre-Aparima was probably connected with the river system draining the area of the present Mararoa and Oreti Rivers, and flowed from Burwood plateau through the Mount Hamilton-Centre Hill Gap towards the Southland Plains.

The present pattern has developed by back cutting, resulting from lowering of base level, of the lower Aparima and Wairaki Rivers which captured the upper reaches of the east and west branches respectively, and by the reversal of flow in parts of the old valleys caused either by very extensive back and down-cutting of the old Aparima and Wairaki Rivers or by gentle warping. Thus we now have Waterloo Burn, a captured tributary of the Aparima River; the underfit Pleasant Creek meandering through the swamps and bogs of the wide valley floor, a reversed stream flowing into the Aparima; North Etal Stream flowing north in the valley of the old East branch, with its lower reaches deeply entrenched in a wide, hanging-valley floor; in its upper reaches the entrenchment increases and becomes a deep V-shaped gorge. The Letham Burn, an underfit stream, resembling Pleasant Creek, flows down its wide valley and joins the Wairaki River just north of the junction with Elbow Creek. Elbow Creek is a deeply entrenched, reversed stream flowing through a wide, strongly dissected valley floor. The beheaded Morley Stream, the tributaries of which have suffered many captures by those of the increasingly vigorous Wairaki River, is now reduced to a small stream flowing in a wide valley. Similarly, the beheaded Beaumont Creek flows for part of its course along a wide flat valley floor. Other features of this drainage transition are: the Elbow Creek capture in which Beaumont Creek was further beheaded by the more vigorous Wairaki

River tributary; the continuous high upland surface which extends over the lower part of the Elbow Creek valley, and over a large area of the Wairaki valley from one mile down the river from the junction of the Elbow Creek, northwards up the Wairaki and Letham valleys; the steep-sided deep gorge which the Wairaki River enters at the southern end of the upland surface; and the hummocky area with peat bogs of Flett's Flat, where possibly ponding was a stage in the transformation of the old east branch. The deep gorges through which Coal and Morley Streams leave the Beaumont alluvium are the result of superposition. The alluvium covers an area practically stripped of Tertiary beds, the hills through which the gorges are cut being upfaulted blocks.

The eastern foothills lying toward Aparima valley are drained by insequent streams (the chief of which is Etal Stream) with fairly mature valleys. It is considered that the pattern here has changed very little during the transition from the early drainage pattern to the present.

The south-west part of the area shows a radial drainage pattern of streams deeply entrenched on an old upland surface. The valley cross-sections are frequently shouldered and terraced. It appears that with only slight changes the old drainage pattern has here entrenched itself as a result of the lowering of base level.

GENERAL DEVELOPMENT OF PRESENT DRAINAGE PATTERN.

Although at present little can be said beyond a few general remarks, it may be appropriate here to give some notes on the presumed general development of the present Southland drainage, of which that of the Wairaki area is a part.

At the close of the Pleistocene when the valley glaciers had retreated well towards the heads of the valleys, the Te Anau-Waiau-Mararoa Depression was filled with a huge thickness of outwash material. The main drainage is considered to have flowed toward the south-east, with the drainage of the present Mararoa area flowing down the Waimea Valley and reaching the sea near the present Molyneux outlet. The gravel-covered Burwood Plateau, 1,500 ft. above sea-level, is regarded as approximately representing the original level of the outwash deposits which must have filled the present Waiau Depression. The Ohai terrace, 650 ft. high, marks the level of another eastward-flowing river draining part of the Waiau Valley and having as tributaries the south-west-flowing rivers of the Takitimos.

Changes in base level, indicated by the succession of terraces in the Waiau Valley, on the coast west of the Waiau and in the Mataura Valley, caused the drainage to assume initial southward courses beginning the present pattern. The "Burwood" River then flowed between Mount Hamilton and Centre Hill and formed the Pre-Aparima; and the main Waiau had developed and was working headwards toward the Te Anau Basin.

The next stage was the diversion of the "Burwood" River headwaters toward the Waiau Valley with the beginnings of the present Waiau and Mararoa Rivers. As a result of this change the beheaded "Burwood" began to break up into the Aparima and Oreti, with the latter continuing to flow over the Waimea Plain and probably joining the Mataura, becoming fixed at the Gore gap.

The final stage is the development through minor changes of the present pattern, the Oreti becoming fixed in the Caroline gap, the Mataura flowing down the Waimea Plains to the Gore gap, and the Mossburn located in an air gap. During this stage and the previous stage most of the changes noted in the Wairaki area took place.

Stratigraphy.

The greater part of the Wairakei area, the eastern part, is made up of Triassic greywackes, argillites, and conglomerates, the remainder being made up of massive and bedded tuffs whose age is not certain. Striking north and dipping steeply to the east, the Upper Palaeozoic (Permian ?) calcareous rocks form a narrow strip five miles long. To the south the Tertiary coal measures occur as infaulted strips and those of the Ohai Depression form the southern boundary of the area.

The following is the sequence of beds in Wairaki Survey District.

			Thickness
Sedimentary.			
(1)	Recent and Pleistocene:	Alluvium, flood-plain gravels, and high-level terrace (Pleistocene?) gravels.	10–50 ft.
(2)	Tertiary:	Coal measures with coal thin except in the Ohai basin (Pre-Whaingaroan) Upper Eocene or Lower Oligocene.	600 ft.
(3)	Triassic:	Bedded greywackes and argillites with conglomerate bands. Fossiliferous Wairoa and Kaihiku.	9,000 ft.
(4)	Permian (?):	Fossiliferous greywacke with coral and *Productus* limestone.	200 ft.
Igneous.			
(1)	Porphyrites:	Intruded into the Triassic rocks and tuffs.	
(2)	Tuffs:	Massive and bedded tuffs. Some interbedded with Triassic rocks, the greater mass to the west of uncertain age.	10,000 ft.

Sedimentary.

(1) *Recent.* Recent alluvium is confined to the Aparima Valley, the lower Morley Valley, the Ohai Depression, and the lower Wairaki. Of these the old flood plain of the Aparima represents by far the greatest area.

Some higher-level terraces are composed of heavy, well-rounded alluvial gravels, coarser than those of the present flood plains that may be remnants of the Pleistocene outwash gravels. These older gravels cover the country in the vicinity of the junction of the Beaumont and Morley Creeks, and layers several feet in thickness are exposed by the entrenched streams. Likewise the terraces in the Letham valley, on the west side, between Letham and Elbow Creeks, too are covered with heavy coarse gravels. The heavy gravels are at present considered to have been deposited by the old north-south river system once a part of an earlier drainage system of Western Southland.

2. *Tertiary.* The Tertiary beds occurring within the Wairaki area consist of conglomerates, gritstones, sandstones, siltstones, and mudstones, with interbedded coal and carbonaceous shales. These beds belong to the pre-Whaingaroan coal measures of Western Southland; these attain economic importance in the Ohai area. The Tertiary beds occur as infaulted strips in the southern part of the area, one several chains wide, extends east along a fault for a distance of about four miles from Malakoff Hill, Morley Stream cuts across the Tertiary

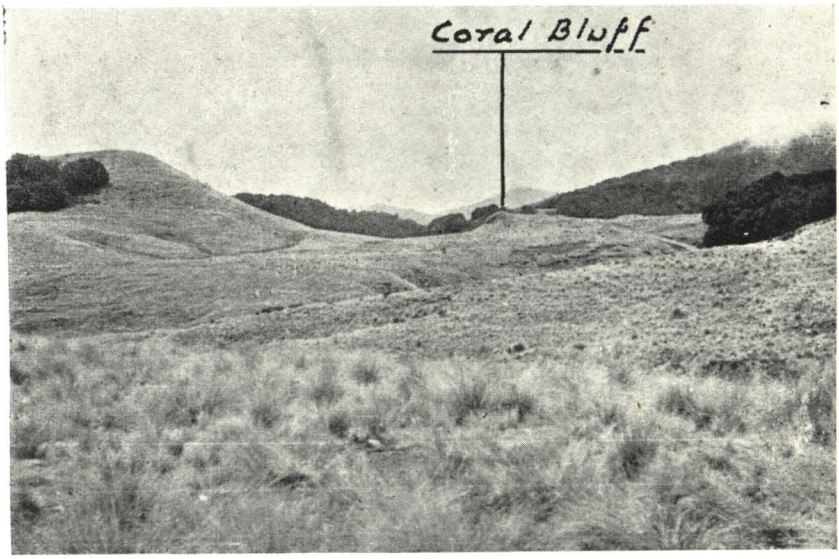

Photo. J. Marwick.

FIG. 1.

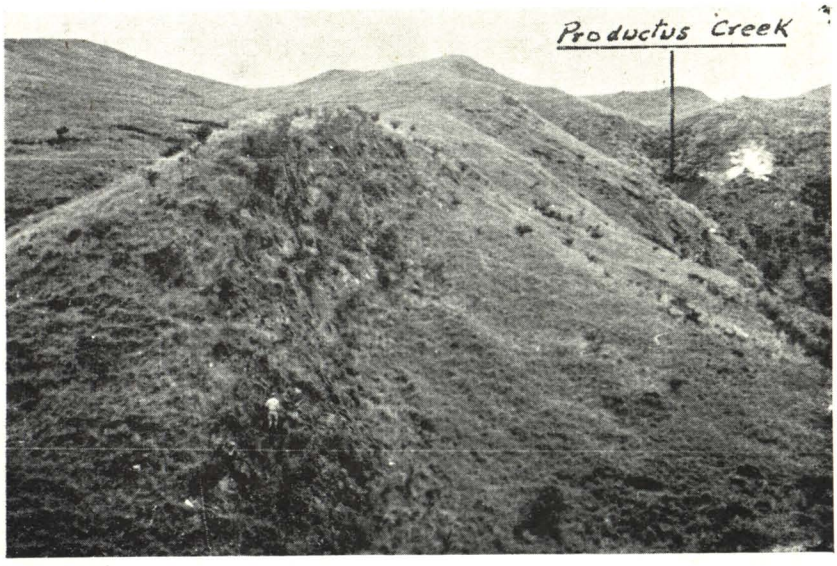

Photo. J. Marwick.

FIG. 2.

[*To face page* 298

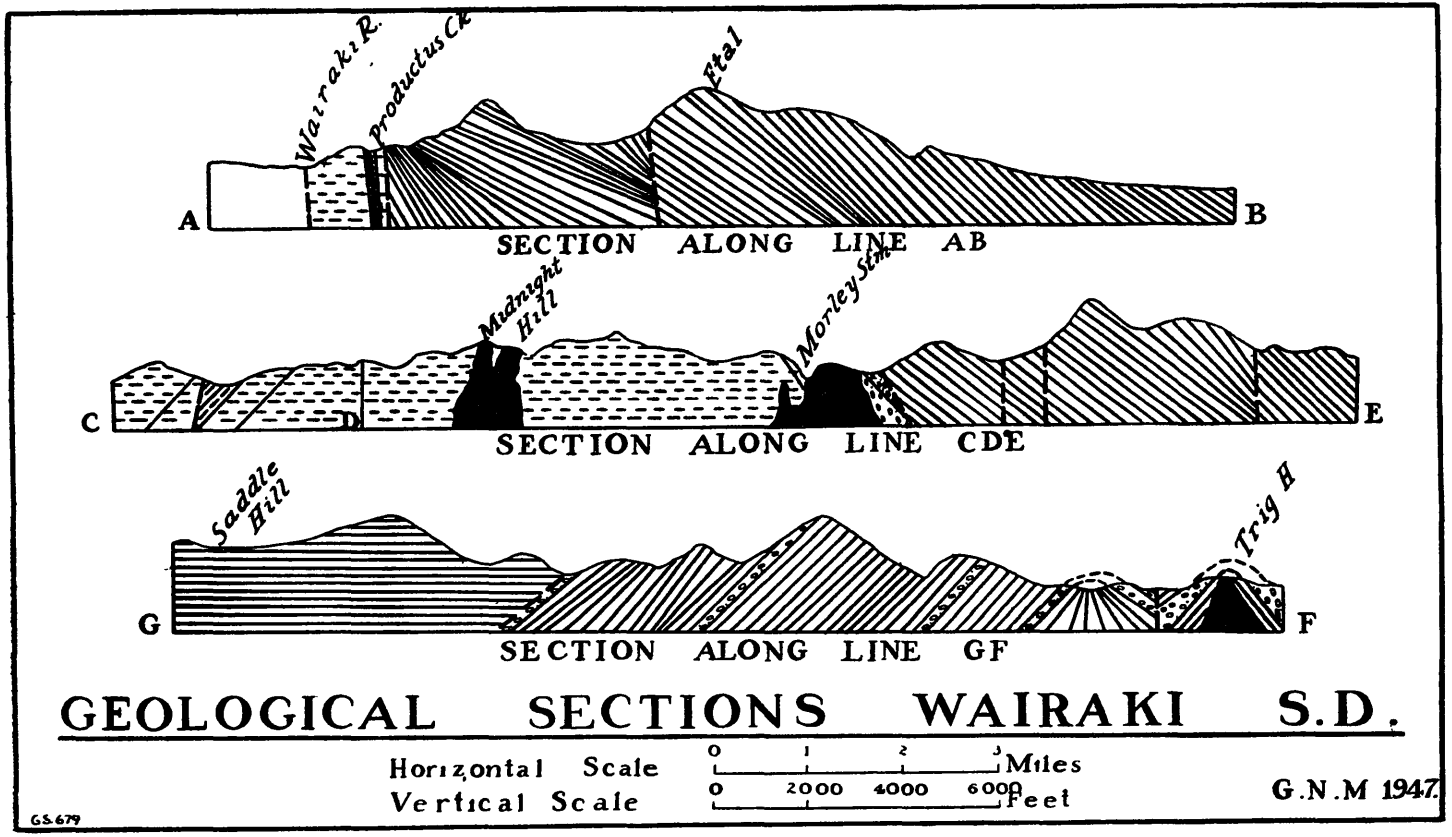
Wairaki R.
Productus Ck
Etal
A
B
SECTION ALONG LINE AB
Midnight Hill
Morley Stn.
C
D
E
SECTION ALONG LINE CDE
Saddle Hill
Trig H
G
F
SECTION ALONG LINE GF
GEOLOGICAL SECTIONS WAIRAKI S.D.
Horizontal Scale
Vertical Scale
0 1 2 3 Miles
0 2000 4000 6000 Feet
G.N.M 1947.
GS.679

FIGURE 2.

strip about a mile and a-quarter north-west of Trig. H. (See Section G. F., Text Fig. 2.) The other infaulted strip (see Section C. D. E., Text Fig. 2) extends from Wairaki River two and a-half miles to the south-east. The south-west margin is a fault boundary toward which the coal measures dip at 25°. These measures are well exposed on the bank of the Wairaki, where about 600 ft. of coal measures can be seen, consisting of brown and grey quartz sands containing several interbedded 1 ft. and 2 ft. seams of carbonaceous shale and dirty coal. Associated with the coal seams are calcareous concretionary beds with pyrite nodules, and sands that grade down into well-bedded, cemented, coarse quartz sandstones with some carbonaceous seams. Excellent leaf impressions were observed in the carbonaceous seams of the sandstone. The measures are sufficiently thin on the north margin to permit low mounds of basement rock to project through. An interesting point is the possibility of mapping the Tertiary strips by the type of vegetation, the Tertiary strips being covered with manuka scrub which is notably absent on the basement rocks.

Along the northern boundary of the area, Tertiary beds crop out in the terrace on the north bank of the Aparima. A fault brings the Tertiary beds on the north bank in contact with the Triassic to the south. The Tertiary beds here consist of blue-grey mudstone similar lithologically to the beds along Weydon Creek north of Centre Hill, of which they are probably the southward extension. Foraminiferal determinations by Dr. H. J. Finlay place the beds as Whaingaroan.

The coal measures in the Ohai basin have been examined and described in detail by Lillie (MS. report, 1945); and it is sufficient here to note that the northern boundary of the depression is a fault contact lying just south of Mount Linton and Mount Franklin.

3. *Triassic.* The Triassic beds make up the eastern part of Wairaki district, extending from Aparima River and Pleasant Creek in the north to Trig. H in the south, and westward from Aparima Valley to Letham Burn and Morley Stream. The strike of these beds swings from north-west in the south to north-east in the north, and they dip to the north-east and east. Irregular dips occur in faulted and disturbed areas, but the general picture is fairly regular.

The Triassic rocks consist of grey to grey-blue well-indurated mudstones, claystones, sandstones and conglomerates with here and there interbedded tuff beds similar to the greywackes and argillites of the other Mesozoic areas in Southland. The conglomerates are strongly cemented and consist of well-rounded cobbles and pebbles of the Fiordland complex, Te Anau Series, and the occasional porphyrite. The beds weather mechanically very rapidly, the fine-grained argillites frit into small angular fragments, a characteristic feature of the Mesozoic argillites in Southland, and many of the coarser greywackes break into flags. The mechanical weathering processes proceed much more rapidly than chemical weathering, with the result that the rock is usually well exposed and not obscured by clay. Talus slopes of angular scree material are a common feature, particularly below large bluffs.

The thickness represented by the Triassic beds (see Text Fig. 2) is 9,000 ft., but the repetition of beds by faulting may require this

amount to be reduced. In the absence of good indicator beds the extent of stratigraphic repetition cannot be gauged.

The conglomerate beds stand out strongly and are easily traced over long distances. Along the western margin of the Triassic rocks the conglomerate beds show the general trend of the strike swinging from west to north.

Fossils are found at many localities throughout the eastern part of the Wairaki area, being fairly plentiful at most points, and particularly so at some. Collections were made from the following localities and the specimens deposited in the Geological Survey collection. Dr. J. Marwick, of the Geological Survey, made the palaeontological determinations.

(a) On the slopes of a hill east of the North Etal Creek, near its junction with the Aparima, there is fossiliferous material in talus at the base of the bluffs of tuffs and tuffaceous sandstones. This collection has not yet been described.

(b) On side of Etal Ridge fossils occur in tuff beds about 1,000 ft. above the previous locality, 168 chains at 11° from Mount Etal. Not described.

(c) On the slopes between Etal and the Aparima a few fossils occur in indurated sandstone, 109 chains at 34° from Trig. M, G.S.3591.

Hokonuia rotundata Trech.

Mytilus problematicus Zitt.

Age: Wairoa Series; Carnic.

(d) About 60 chains north of the last locality is a similar occurrence of fossils. 107 chains at 135° from Trig. P, G.S.3586.

Halobia sp.

Dielasma cf. *zelandica* Trech.

Age: Wairoa Series: Carnic.

(e) On the south side of the Etal Valley fossils were found in indurated sandstone, 114 chains at 7° from Trig. K, G.S.3589.

Dielasma cf. *zelandica* Trech.

Age: Kaihiku Series; Ladino-Carnic.

(f) Same area as (e) about 40 chains to west, fossils occur in tuffs, 128 chains at 41° from Trig. D, G.S.3588.

Myophoria nuggettensis Trech.

Halobia sp.

Crinoid joints.

Age: Wairoa Series; Carnic.

(g) In the upper reaches of Beaumont Creek fossils are found in a conglomerate bed, 148 chains at 349 from Trig. H. G.S.3590.

(?) *Pleurophorous*

Age: Wairoa Series; Carnic.

(h) Near the headwaters of Kenny Creek fossils occur in tuffs on the margin of a porphyrite intrusion, 39 chains at 63° from Trig. P, G.S.3594.

Bryozoan

(i) On the west slope of Beaumont, fossils found in an indurated tuff, 64 chains at 255° from Trig. D, G.S.3587.

Pleurotomaria cf. *hokonuiensis* Trech.

? *Astarte*

Age: Wairoa Series: Carnic.

(j) In the same area as (h), but 20 chains to west, ammonites in tuffs. G.S.3593.

Pleurotomaria aff. *hokonuiensis* Trech.

Age: Wairoa Series; Carnic.

(k) In Beaumont Creek, about a mile downstream from (j), ammonites are found in tuffaceous material, 132 chains at 235° from Trig. D. G.S.3592.

Ammonites

Worm tube

(l) On the banks of the Morley Stream near the bridge at entrance to Beaumont Station, abundant ammonites occur in mudstone, 145 chains at 309° from Trig. H.

From all the above localities except k and l collections have been made by one of the writers (M. V. R.) and lodged in the Geological Survey collection, and are at present being examined in detail. Locality l was collected by Mr. R. A. S. Browne, and locality k by Messrs. Fraser Brothers, of Beaumont Station. All ammonite collections are being examined and described by Mr. R. A. S. Browne. Locality l had previously been collected by Dr. A. R. Lillie and Mr. M. Te Punga when working in the Ohai area.

The beds that make up the eastern part of the area, that is, lying to the east of Beaumont-Etal Ridge, are regarded as Carnic in age; to the west the narrow area of beds between the Carnic and the tuffs is Ladino-Carnic or older. Some of the ammonites are regarded as representing the upper part of the lower Triassic (personal communication, Mr. R. A. S. Browne).

4. (?)*Permian.* The Upper Palaeozoic (? Permian) beds are confined to a narrow strip ten chains wide and three miles long on the western scarp of the Letham Ridge. They crop out on the south in Productus Creek, a small tributary stream of Elbow Creek and end in the north at Coral Bluff near the headwaters of Letham Burn (Text Fig. 1).

The beds consist of a hard, fine-grained calcareous greywacke, almost black in colour. In places it is highly fossiliferous, particularly at Coral Bluff and Productus Creek. Between these two extreme points is a smaller fossiliferous outcrop; and detailed examination of the strip will probably reveal additional localities.

The Palaeozoic beds dip steeply to the east (Text Fig. 2) and are immediately overlain by a thin, steeply dipping band of conglomerates and tuffaceous rocks. All these beds appear to be faulted against the conglomerates, greywackes, and tuffs of the Triassic. The fault immediately east of the Permian rocks is regarded as being responsible for the exposure of these beds. The Permian beds appear to be dragged up along the east of the fault and are a part of the upthrow block as opposed to the greywacke and tuffs of the downthrow to the east.

The following are the most important fossiliferous localities.

(a) Coral Bluff. Here a calcareous greywacke contains abundant well-preserved corals of the zaphretoid type, 100 chains at 311° from Letham Hill (Plate 35, Fig. 1).

(b) Productus Creek, a small tributary of Elbow Creek 50 chains east of Elbow Creek-Wairaki River junction. The hard calcareous greywacke ridge west of the creek contains abundant *Productus* and a few other fossils (Plate 35, Fig. 2). 118 chains at 220° from Letham Hill.

Localities a and b were collected by Dr. J. Marwick and the writers, and specimens are housed in the Geological Survey Office awaiting detailed description.

Dr. J. Marwick tentatively regards the beds as Permian in age.

Igneous.

(1) *Porphyrites.* The sedimentary Triassic beds in the south-east part of the area are intruded by several large boss-like masses of a coarse-grained porphyrite.

Immediately north-east of Trig. G (1568 ft.) is a small porphyritic intrusion, and along the east-west ridge of Trig. H is a similar intrusive mass. The latter mass does, however, appear to be concordant as its line of outcrop parallels the strike of the Triassic beds. At Malakoff Hill a similar porphyrite may be a continuation of the Trig. H. intrusive mass separated from it by Quested's fault. Park (1921) mapped the Malakoff Hill as a dyke of augite-porphyrite.

In the south-west part of the area several igneous masses intrude the tuffs. One mile south-south-west of Wether Hill, a dyke of coarse pink porphyrite forms a sharp razor-back ridge. Half a mile south-south-west of Morley Hill is a large igneous boss-like mass, around which the Morley Stream swings. This lies on the west side of the boundary between tuffs and sedimentaries. Here and there, adjacent to this large igneous boss at Morley Stream are small igneous intrusions that generally form the resistant features of the landscape. Over the south-west area of tuffs all the igneous intrusions are marked by hills and sharp narrow ridges.

The intrusions that occur in both the tuffs and sedimentaries are confined to the south part of the Wairaki area, and appear to have taken place in Triassic times or later; at least they probably post-date the large mass of tuffs. The intrusions in the Triassic are for the most part concordant, but it is not suggested that they are contemporaneous; they are considered to be intrusive into and younger than the interbedded tuffs of the Triassic rocks. A similar porphyrite sill

has been found by one of the writers (R. W. W.) in the Jurassic rocks at Glenham, south of Wyndham, in Eastern Southland, which suggests that igneous activity persisted at least to mid-Jurassic times.

2. *Tuffs.* The entire south-west part of the Wairaki area is made up of massive and bedded tuffs. They occupy a triangular area bounded by Wairaki River in the west, the Morley in the east, and a fault contact with the Tertiary coal-measures in the south. The tuffs occur to the west of Wairaki, and probably made up much of the main Takitimo Range. Throughout the south-west mass the tuffs are unfossiliferous.

Here and there the Triassic greywackes contain interbedded tuffs, which at several points are fossiliferous. The tuffs vary over a wide range which includes a coarse aggregation of volcanic fragments, indurated fine-grained material and ash, zeolitic rocks, and porphyrite-like rocks. Some of the tuffs are so well indurated that they are recognisable as such only from their weathering products.

The large area of tuffs lies west of the exposed strip of Permian rocks. Immediately east of the Permian strip and having the same steep dip is a narrow strip of tuffaceous rocks faulted against the Triassic beds. It is suggested that these tuffs are Upper Palaeozoic in age and that the fossiliferous beds represent a marine phase at the close of the period of volcanic activity, the beds being laid down in large lensoid masses. This would mean that tuffs of two ages are represented in the Wairaki area, the large area of Permian tuffs in the south-west and those of known Triassic age and interbedded with Triassic sediments. This suggests correlating the large area with those of known Upper Palaeozoic age (Maitai) of Riverton-Colac Bay area and the Greenhills area. The alternative is that all the tuffs of the Wairaki area are more or less of the same age, but at present there is less evidence to support this alternative and so the tuffs covering the south-west part of the Wairaki area are tentatively regarded as Upper Palaeozoic.

Collections of the intruded rocks and tuffs have been made and are deposited in the Geological Survey, but no detailed petrography has yet been carried out.

Structure.

The Wairaki area is too small to discuss in detail the geological structure. It is merely a part of the Mesozoic and Palaeozoic rocks of Southland, and the full structural picture cannot be presented until the geology of the adjacent areas, particularly to the north, has been worked out.

Essentially the area is made up of a series of tilted fault blocks, marked out by north-trending faults which have largely controlled the drainage. There are several faults, normal and oblique to the north-south direction, that have also exercised considerable control of the present topography and drainage pattern. These faults have resulted in the preservation of much of the Tertiary cover, represented by the Ohai Depression and the infaulted strips of coal measures at several points to the north. The Tertiary beds of the Mount Hamilton-Centre Hill area have been faulted against the Triassic rocks along the east-west course of the Aparima.

The Triassic rocks are well-bedded and strikes indicate a swing from north-west in the south to north-north-east in the northern part of the area with regional dip to the east, suggesting that the Triassic beds are a part of the nose of the pitching syncline indicated in the Mesozoic rocks of the Hokonui Hills to the east.

The tuffs are in places fairly well bedded, but any bedding that was observed is insufficient to indicate the structure.

Considerable faulting has marked off the boundary of the Tertiary coal measures, particularly along the southern margin of the area. The other Tertiary occurrences are represented by infaulted strips.

The north-striking faults that separate the faulted blocks are regarded as reverse faults; and in Letham Burn a fault has caused the exposure of the underlying Permian beds. These faults are the main faults of the area and are a part of the general fault-structure of Western Southland. The faults normal and oblique to their direction are subsidiary.

These faults as a rule have strong topographic expression, but are not usually associated with wide pug or crush zones. Noticeable crushing does occur on the bank of the Wairaki, just south of its junction with Letham Burn, where the rock is shattered and in places pugged for over half a mile.

This shattering is associated with the faults that extend up the Letham valley and down to the head of the Morley. Some minor faults in the Etal and Elbow valleys show little pug, and shatter zones, if present, are not exposed, and the faulting is expressed by the physiographic evidence.

LITERATURE.

BENSON, W. N., 1921. Recent Advances in New Zealand Geology. *Rept. Aust. Ass. Adv. Sci.*, Sect. C, pp. 56–58.

BENSON, W. N., and HOLLOWAY, J. T., 1940. Notes on the Geography and Rocks of the Ranges between the Pyke and Matukituki Rivers. *Trans. Roy. Soc. N.Z.*, vol. 70, pp. 1–24.

COX, S. H., 1878. Report on the Geology of the Te Anau District. *Rept. Geol. Expl. for 1877–78*, no. 11, pp. 110–118.

HUTTON, F. W., 1872. Report on the Geology of Southland. *Rept. Geol. Expl. for 1871–72*, pp. 89–112.

HUTTON, F. W., and ULRICH, G. H. F., 1875. *Geology of Otago.* Mills, Dick & Co., Dunedin.

MARSHALL, P., 1912. *Geology of New Zealand.* Government Printer, Wellington

PARK, J., 1921. The Geology and Mineral Resources of Western Southland. *Bull. N.Z. Geol. Surv.* (*N.Z.*), no. 23.

REED, J. J., 1945. The Scheelite Deposits at Glenorchy, New Zealand. *Trans. Roy. Soc. N.Z.*, vol. 75, pp. 371–393.

WILLETT, R. W., 1945. Coal at Coal Creek, Centre Hill S.D., Southland. *N.Z. Jour. Sci. and Tech.*, vol. 26, sec. B, pp. 214–218.