The Geology of the Northern Taringatura Hills, Southland

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Abstract

Unfossiliferous late Palaeozoic (?) beds on the south side of the Five Rivers Plain are separated by a fault contact from upthrust Triassic blocks to the south-west. Immediately south-west of the fault is a 10,600 ft. sequence designated the North Range beds. These are dominantly tuffaceous and include laumontite rock replacing vitric tuffs. In the absence of distinctive fossils, their age is believed to be Middle or Lower Triassic. The North Range beds are followed conformably to the south by approximately 20,000 ft. of fossiliferous late Middle to Upper Triassic strata in which tuffs are again widespread, dacitic types now predominating in place of the mildly altered andesitic tuffs which occur in the North Range beds. All these Triassic rocks occur on the steeply dipping north-east limb of a south-east plunging, asymmetric syncline, the axis of which lies towards the south of the area mapped. Three outliers of Tertiary sediments (Duntroonian to Altonian) are recorded. Late Tertiary earth movements and subsequent erosion have blocked out the present topography.

Contents

Introduction

The aim of this paper is to describe the stratigraphy and general geology of part of the Taringatura Survey District, in the province of Southland, lying immediately to the north-west of the Hokonui Hills mapped by Cox and McKay in 1878. Structurally, the present area is a continuation of the Hokonuis. It will be shown that pyroclastic material is present in the Taringatura Triassic in copious quantity. Determination of tuffs and tuffaceous greywackes is based on examination of thin sections. Albitisation and zeolitisation of these rocks are widespread, but petrographic discussion will be withheld until a later date.

Steeply dipping, block-faulted Mesozoic rocks form ranges of hills rising to a maximum height of 2,300 ft. The regional strike is N.W.–S.E. The tussock cover is often rather thin and although no extensive continuous sections are exposed, there is an abundance of outcrops over most of the area, enabling stratigraphy and structure of the Triassic rocks to be pieced together fairly satisfactorily. Strike faults, however, could have escaped attention. Richly fossiliferous bands are not particularly common, but scattered fossils are widespread. Collections of Triassic fossils were made from about 80 localities and are lodged at the Geology Department, University of Otago. Identifications of these are the work of the author and tables are given showing the position and content of selected collections.

The area mapped is bordered by alluvial plains on the north, west and east sides, although the alluviated valley of the Oreti River to the east and south-east is quite narrow. To the south lie the hills of the southern part of the Taringatura Survey District, at present being investigated by Mr. J. D. Campbell, B.Sc. The Triassic beds of the Wairaki Survey District, recently mapped by Rout and Willett (1949) lie on the opposite side of the Aparima River to the west and southwest.

A preliminary visit to the area was made in May 1945. The main field work was done during the following summer, but has been supplemented by a number of later visits Mapping was carried out at a scale of 20 chains to one inch on field sheets enlarged from topographic maps S.159 and S.160, Provisional One Mile Series, with minor corrections.

The writer wishes to express his gratitude to Professor W. N. Benson for his interest and helpful comments at all times, to Professors F. J. Turner and C. O. Hutton for stimulating discussion at successive stages of the work, to Drs. H. J. Finlay and J. Marwick for identifications of Tertiary foraminifera and mollusca respectively. and for discussion of palaeontological problems, to Mr. A. C. Haase, Chief Surveyor, Invercargill, for the assistance of his department, and to many friends in the district, especially Mr. and Mrs. C. D. Bourke, of Mossburn, and Mr. and Mrs. J. Reid, of Dipton West, for their most generous hospitality.

PREVIOUS GEOLOGICAL WORK

No systematic work has previously been attempted in the district, although it has been visited by a number of geologists.

Hutton (1872) and Hutton and Ulrich (1875) placed the rocks of the "Moonlight Ranges" (i e. Taringatura) in Hutton's Maitai formation in which Triassic and Jurassic beds were then included. Hutton recorded the *Monotis* and *Halobia* beds of Wether Hill (see Plate 54) and two outliers of Tertiary limestone which are shown on his map.

Cox (1878, p. 28) stated that his supposed anticline in the Triassic rocks at the north end of the Hokonuis may be seen continuing into the Moonlight Ranges. The existence of this anticline in the Taringatura area has been disproved.

Hamilton (1893 and 1894) described limestone caves at Castle Downs and avian remains collected therefrom.

Morgan (1919, pp. 279–280) referred to an investigation by Ongley of the Castle Downs (Castle Rock) limestone, and published analyses.

Cotton (1922 and 1942) discussed the course of the Oreti River, citing it as an example of diversion through alluviation, while Rout and Willett (1949) have given a more general discussion of the development of major features of the Southland drainage pattern.

STRATIGRAPHY

The following is the sequence of beds in the area mapped. Triassic correlations follow Trechmann (1918); Tertiary correlations follow Finlay and Marwick (1947). The thickness of some Triassic formations varies significantly along the strike, e.g. the Oreti Series at Wether Hill is about 5,300 ft. thick and contains no coarse conglomerate bands, but at the north-west end of White Hill, only seven miles away, the series appears to be over 7,000 ft. thick and contains massive conglomerates of which eight bands are shown on the map. In view of the rapid variations in lithology, especially in the Upper Triassic, and the lenticular nature of many of the beds, detailed stratigraphic columns have not been prepared. Igneous rocks were not found *in situ*.

		Estimated Thickness
IV. *Pleistocene and Recent*	Alluvium, peat bogs, and terrace gravels	—
III. *Tertiary*		
3. Altonian, i.e. Southland Series (Lower Miocene)	Infaulted patch of sandstone	50 ft.
2. Duntroonian to Otaian, i.e. Landon and Pareora Series (Oligocene)	Limestone with arenaceous bands	350 ft.
1. ?	Unexposed limestones, marls, and sandstones (bore hole data)	? 300 ft.
II. *Mesozoic*		
B Late Middle to Upper Triassic or Lower Jurassic	Conglomerates, feldspathic sandstones, indurated mudstones, and tuffaceous bands	
6 Uppermost Rhaetic or Lower Jurassic	No fossils	1,000 ft.
5. Otapiri Series (Rhaetic)	*Clavigera*, *Rastelligera*, etc.	4,700 ft.
4. Warepa Series (Noric)	*Monotis richmondiana*	1,300–2,000 ft.
3. Otamita Series (Carnic)	(ii) *Halobia*, *Athyris*, early *Rastelligera*, etc.	1,900 ft
	(i) *Mytilus problematicus*, etc.	1,000 ft.
2 Oreti Series (Carnic)	Fine-grained flinty greywackes conspicuous. Conglomerates copiously developed towards N.W., where the section thickens. *Halobia*, *Athyris* cf. *wreyi*, and other scattered fossils	5,300–7,000 ft.
1. Kaihiku Series (Ladino-Carnic)	Many fossils in upper parts. *Spiriferina kaihikuana*, etc. First local occurrence of plutonic pebbles in basal conglomerate	2,900–3,300 ft.
A. North Range Beds (? Lower-Middle Trias.)	Mildly altered andesitic tuffs sometimes zeolitised, tuffaceous greywackes, minor volcanic conglomerates and indurated mudstones, especially in upper parts. No plutonic pebbles. Fragmentary plant remains	10,600 ft.
I *Upper Palaeozoic* (?)		
Roe Burn Beds	Shales, greywackes, and minor conglomerate faulted against North Range beds. Unfossiliferous	2,500 ft.
Undifferentiated	Tuffaceous greywackes with pebble bands and fragmentary plant remains near Mossburn	1,200 ft.
	Poorly exposed greywackes at Castlerock Station	?

1. *Upper Palaeozoic*

The Roe Burn beds underlie a well-grassed strip of subdued topography at the foot of the North Range escarpment. Exposures consist of occasional outcrops of rather deeply weathered shales, tuffaceous greywackes and pebble beds, with the coarser members on the south side of the strip often standing out in relief. The lithology is different from that of adjacent North Range rocks which belong to the Triassic sequence. In hand specimen, Roe Burn rocks are rather soft and of weathered appearance. The coarser types contain numerous dull red or brown fragments and pebbles of fine-grained volcanic and sedimentary rocks, the colour being due to finely disseminated iron oxides. The shales often have a distinctly reddish brown tint and sometimes show a faint phyllitic sheen. Moreover, they show widespread slickensiding, a feature which is quite lacking in the adjacent North Range beds. The slickensided surfaces are approximately parallel to the bedding and the lineation to the dip. The exposed sequence is 1,100 ft. of shale (the lowest member), followed by 650 ft. of tuffaceous greywackes, pebble beds and conglomerate with some interbedded shales, 300 ft. of shales, and 350 ft. of pebble beds, greywacke, etc., making a total of about 2,400 ft. All these beds strike N.W.–S E. and dip fairly steeply ($60° \pm 10°$) to the south-west. An anticlinal axis is believed to lie at the base of the measured sequence. On the north limb the dip is 50° to 80° to the north, the lowest shale and pebble beds being exposed again before basement rock is concealed by the alluvium of the Five Rivers Plain

The change in lithology between the Roe Burn and North Range beds coincides with the foot of the steepest slopes of the north frontal escarpment of the North Range. Disregarding the narrow Oreti River gap, this escarpment is continuous with the fault scarp running the full length of the Hokonui Hills to the south-east, a lineament of great regularity with a slight concavity to the north-east. Dr. W. N. Benson (1935) illustrates this Hokonui fault line with down-thrown Tertiary limestone on the north side at Balfour. Both the North Range beds and the south limb of the Roe Burn beds have closely comparable N.W.–S.E. strikes and south-west dips, but there is indecisive evidence suggesting that both groups approach their line of contact at a small angle. The contact is interpreted as a fault contact, a steeply dipping bedding thrust. In the movements following the late Tertiary peneplanation a displacement of perhaps 500–1,000 ft. has occurred along what is probably a very old fault line.

Healy (1938, p. 29) has described rocks identical with the coarser members of the Roe Burn beds from Ram Hill,* a small ridge on the north flank of the Hokonuis on the opposite side of the Oreti River from Taringatura. He concluded that they could probably be correlated with the Permian(?) Clinton Series This may well be so, but in the absence of fossils the present writer prefers to leave the issue open. The Roe Burn–Ram Hill lithology is not quite identical with the typical Clinton rocks, and the plutonic igneous pebbles of the Clinton conglomerates (see Ongley, 1939, p. 32) are not present in the Roe

* As shown on older Survey Maps, not Prov. 1 ml. Sheet S.159.

Burn conglomerates, which consist almost entirely of fine-grained volcanic rocks of meta-andesitic aspect. Nevertheless, the Roe Burn beds are presumably older than the North Range beds and are very likely of late Palaeozoic age.

The same applies to small isolated masses exposed at Castlerock and Rocky Point, about one mile north-west of Mossburn. At Rocky Point there are about 1,200 ft. of bluish to greenish grey tuffaceous greywackes with occasional pebble bands and a thin bed containing finely comminuted plant remains. Pebbles of quartz-keratophyres are prominent in the conglomeratic bands. Relationships at Castlerock hillock are obscure. A high terrace alluvial remnant forms the northern slopes, while the southern slope appears to be underlain by blue-grey tuffaceous greywackes containing rather frequent quartz grains.

II. *Mesozoic*

Taringatura S.D. lies near the north-west end of a belt of Mesozoic rocks running north-westward from the sea at the Nuggets, about 90 miles away. The stratigraphy of certain other sections of this belt has been described by various authors, notably Cox and McKay (1878), who described the Hokonui Hills immediately south-east of Taringatura, Park (1904) and Mackie (1935), who described the coastal section in the Glenomaru Survey District, and Ongley (1939), who described the Kaihiku Ranges inland from Glenomaru. As a result of their investigations and the palaeontological work of Trechmann (1918) and Wilckens (1927) the general picture of Upper Triassic stratigraphy in Southland is fairly well known. For purposes of description the Mesozoic rocks of Taringatura may be conveniently divided into two groups.

A. *The North Range Beds*

Between the Taringatura end of the Hokonui fault and the main fossil beds of the Kaihiku series there are about 13,000 ft. of largely unfossiliferous strata, all essentially conformable. The lowest 10,600 ft. form a well-defined lithologic group named here the North Range beds. They make up the main mass of the North Range and its south-east continuation, Pig Range, while the upper members floor the Stag Stream lowland and the lower north-eastern slopes of White Hill and Wether Hill to the south. The strike is N.W.–S.E. and the dip is usually about 70° to the south-west, but local variations occur and occasionally the bedding may be vertical, or still more rarely overturned to give the appearance of a dip of about 80° to the north-east. The sequence is as follows:

NR_1. (900 ft. thick, immediately south-east of the Hokonui fault). Blue-grey lithic tuffs and tuffaceous greywackes with interbedded bands of mudstone and of fine-grained altered vitric tuff. The latter have undergone a variety of changes, replacement almost *in toto* by the zeolite laumonite being characteristic. Such bedded laumontite rocks from a few inches to twelve feet thick are a noteworthy feature of North Range geology. They are white, cream, or pale buff in colour, typically very well jointed, and are often traceable for several miles.

NR₂. (450 ft.) A massive bed of crystal-vitric tuffs. These are mostly rather soft and buff coloured as the result of much laumontite replacing glass, but they are studded with greenish flecks, and contain nodules, lenticles and larger masses of very hard green rock, the result of local quartz-albite metasomatism. These green rocks are the most resistant in the district and litter the northern slopes of the North Range. Interbedded are a few bands of fine volcanic conglomerate and layers bearing finely fragmented plant remains. The whole forms a distinctive mapping unit. The presence of the bands of fine conglomerate and the graded bedding of some of the tuffs show that subaqueous deposition or resorting has occurred.

NR_3. (1,000 ft.) Tuffaceous grits and fine volcanic conglomerate—the detritus derived from the degradation of a volcanic pile. The colour of fresh specimens is usually dark bluish grey, but weathering sometimes produces a reddish coloration. The grain-size varies considerably and lenticular pebble bands occur frequently. A massive volcanic conglomerate outcrops in a steep gully 124 chains at $127\frac{1}{2}°$ from Trig. G. The pebbles are generally less than 2 in. diameter and are rather crudely rounded. No granitic or other plutonic types were found.

NR_4. (650 ft.) Mudstone grading into fine-grained greywacke and containing a few minor tuffaceous bands which are sometimes altered to laumontite. A series of subsequent gullies cut in this bed divides the North Range and Pig Range into two parallel strike ridges.

NR_5. (2,700 ft.) Lithic tuffs, tuffaceous greywackes and numerous bands of white laumontite rock representing altered vitric tuffs. Two beds of the latter, each about 12 ft. thick, occur 250 and 500 ft. respectively above the top of the NR_4 mudstones. Both form prominent and persistent outcrops towards the Mossburn end of the North Range. Intraformational folding is often well developed, beautiful examples of tiny nappe-like folds being observed together with larger contortions. It is significant that the beds are regularly jointed and the joint planes are continuous right across the folds. Fragmentary plant remains are sometimes present.

NR_6. (750 ft.) Mudstone.

NR_7. (150 ft.) Interbedded tuffaceous greywacke, mudstone and subordinate laumontite rock.

NR_8. (4,000 ft.) Mudstone with occasional layers of tuff and of coarse-grained or even pebbly material.

The North Range beds suggest a scene of repeated volcanic activity with many explosive eruptions and ash showers. Local patches of almost unaltered tuff show that the ejected material was, generally speaking, andesitic in nature. Some of the ash may have fallen directly into water, some fell on the land, but much of this was washed off again before consolidation could occur and became mixed with finely comminuted plant remains. It is rather remarkable that no massive volcanic rocks have been found *in situ* in Taringatura. The land mass providing detritus was almost entirely covered with volcanic material. No recognisable fragments of plutonic igneous rock have been found in the North Range beds and even allogenic quartz and micas are never common. It is worthy of note, however, that in some micro-slides small fragments of fine-grained hornfelsic metamorphic rock are not infrequent, and one quartzose fragment contained numerous prisms of greyish-blue tourmaline. Erosion of this volcanic pile produced the volcanic conglomerates and tuffaceous greywackes—often with a directly pyroclastic admixture—and in periods of quiescence and slower deposition the mudstones were accumulated.

Correlation

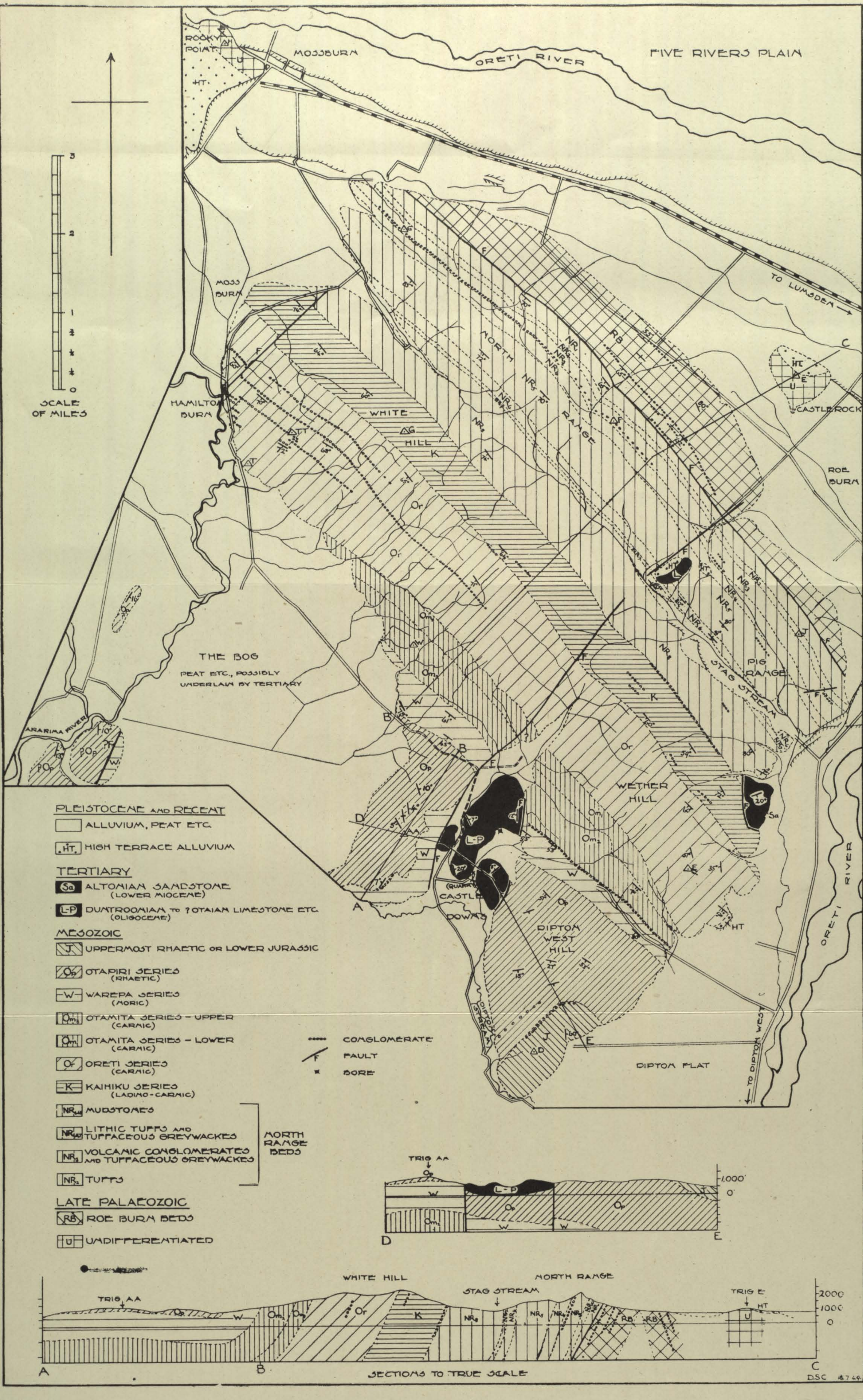
Apart from the fragmentary plant remains the whole of the sequence is extraordinarily poor in fossils. Two quite indeterminate shell casts were found in bed NR_4 and fucoid markings occur in some of the higher mudstones. About 18 chains south-east of a musterer's hut near the head of Stag Stream and about 1,000 ft. below the arbitrary base of the Kaihiku Series the following fossils were collected:

Daonella sp. (Fragments).
?*Isocrinus* sp. (Columnal plates).

Also Annelid tubes and some small, poorly preserved pelecypods. *Daonella* fragments and a solitary *Lima* were collected about 1,000 ft. higher up the same gully, near the North Range-Kaihiku contact. Annelid tubes and crinoid columnal plates very similar or identical to the above were found at points 2,500 and 1,100 ft. respectively above the base of the Kaihiku Series. The North Range beds are conformably below the fossiliferous late Middle to Upper Triassic and it seems likely that they were deposited during Middle and perhaps Lower Triassic times.

Cox (1878, pp. 27–28) and McKay (1878, p. 74) postulate an anticline in the northern part of the Hokonuis with its axis along the "black marls" of the Okaiterua Stream. These "black marls" are without doubt the mudstones of the upper part of the North Range beds which outcrop over most of the Stag Stream lowland, and Cox and McKay's anticline must not be confused with that in the Roe Burn beds. Cox states that his anticline can be seen to continue into the "Moonlight Range" with the beds "dipping away to the north and south respectively on either side of (Stag Stream)." The North Range beds are quite dissimilar from the fossiliferous Upper Triassic rocks on the south side of Stag Stream, and, moreover, apart from local overturning, the dip of the North Range beds is to the south-west, not to the north. The writer can only conclude that the "anticline" does not exist in Taringatura, and his own observations as well as those of I. C. McKellar (unpublished thesis, University of Otago) show that it does not exist at the north-west end of the Hokonuis. This fact has already been suggested on general grounds by Ongley (1939, p. 24). It follows that Cox's figure of 21,000 ft. for the total thickness of the Hokonui rocks is an underestimate to the extent of all the rocks to the north of his anticlinal axis.

Plate 54



Geological map and sections, northern part of the Taringatura district, Southland.

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The North Range beds undoubtedly continue at least into the north-west end of the Hokonui Hills. Early or pre-Kaihiku plant beds are known to occur at Kuriwao Gorge in the Kaihiku area and in the Nuggets section, but from the published reports the lithology does not appear to be quite comparable with that of the dominantly tuffaceous North Range beds. Rout and Willett (1949) have described a 9,000 ft. sequence of Triassic rocks containing fossils of the Kaihiku to Warepa (i.e. Upper Wairoa) Series from the Wairaki area some dozen miles south-west of the area considered in this paper. That is approximately the thickness of the same beds in Taringatura, and it is clear that North Range correlatives, if present, must be in much smaller amount than in Taringatura. Extensive tuffs (and massive volcanic rocks) certainly occur in the south-west of the Wairaki area, but Rout and Willett show that in all probability the age of these is late Palaeozoic.

B. *Late Middle to Upper Triassic or Lower Jurassic*

This group differs from the North Range beds in the abundance of pebbles of plutonic rocks in the conglomerates, acidic types being especially common. The greywackes are generally lighter in colour than those of the North Range, and on the whole contain more quartz and micas Potash feldspar also appears as a detrital mineral. Quartz is never the dominant constituent, however, and all the coarser-grained rocks are highly feldspathic greywackes or sometimes arkoses. Fragments of fine-grained volcanic rocks are ubiquitous. Marine fossils are often abundant.

It should be stressed that volcanic activity continued intermittently throughout the period. In fact, micro-sections show that a surprisingly large proportion of the "greywackes," especially those of the Kaihiku to Otamita Series, contain altered glass fragments which give rise to vitroclastic structure interstitially to detrital rock and mineral grains (cf. Pirsson, 1915). The same applies to some of the many striking beds of pink or green highly feldspathic rocks of arkosic aspect, and some of these may really be crystal tuffs. Numerous purely tuffaceous bands are present, a group of salmon-coloured dacite tuffs high in the Oreti Series affording notable examples. Certain conglomerate and breccia bands are made up almost entirely of fragments of a given type of volcanic rock—for example, a rather fine, almost black, fossiliferous conglomerate in the Kaihiku Series about 30 chains north-west from the highest point of White Hill is made up almost entirely of pebbles and fragments of quartz-keratophyre. Mixed plutonic detritus is temporarily excluded in such beds, which must indicate more or less contemporaneous volcanic activity. In one rather remarkable occurrence, a massive bouldery conglomerate occurring 2,800 ft. above the base of the Oreti Series at the north-west end of White Hill, has as matrix a moderately fine-grained dacite crystal-vitric tuff. Possibly ash fell on a bouldery beach and was washed down into the spaces between the boulders. Tuffs have been found associated with all the fossiliferous formations except the Warepa Series. In contrast to the mainly andesitic tuffs of the North Range beds those of the Upper Triassic are dominantly dacitic. Zeolitisation has occurred as in the North Range tuffs, but laumontite rock is not common.

Intraformational folding is not uncommon, especially in association with tuffaceous beds. In a belt of the Kaihiku Series one to three miles south-east of Trig. G, a number of discontinuous knobby outcrops of fine fossiliferous volcanic breccia were found, these and others nearby often showing chaotic bedding. Possibly they may be the result of submarine slumping. In the same area are outcrops of coarse intraformational breccias containing masses of angular fragments and boulders of mudstone in a matrix of similar or of coarser grain-size, both matrix and boulders containing similar fossils. Intraformational breccias consisting of angular pellets of mudstone in a coarser matrix are not uncommon throughout the Upper Triassic. The grain size of the sedimentary beds varies throughout the sequence from rare argillites and more common siltstones and greywackes to conglomerates which contain well-rounded boulders a foot or more across. Although many of the beds can be traced along the strike for considerable distances, many are clearly lenticular and either pinch out or grade laterally into other lithological types. The case of the Oreti Series conglomerates has already been described.

Marine fossils are scattered sparsely through rocks of all grain sizes and are occasionally concentrated into richly fossiliferous bands or pockets. "Fucoid" markings are common in the finer rock types. One rather widespread lithological type, however, has not yielded any fossils. This is greywacke sandstone of mottled colour, the mottlings being about $\frac{1}{8}$ to $\frac{1}{4}$ inch across, and pink, yellowish or blue-grey in colour, a combination of two colours being shown by any one specimen. The outcrops of these mottled sandstones are liable to be prominent and traceable for several miles. The remains of transported plant fragments occur at a number of horizons, perhaps most commonly in the coarser phases of the Warepa and Otapiri Series. In one case, near the base of the Otapiri Series, brachiopods occur together with plant fragments in the one hand specimen. Petrified logs of Triassic driftwood were found in the Oreti Series conglomerate already recorded as having a tuffaceous matrix. Microfossils are rare, but a number of radiolaria, possibly *Cenosphaera* sp., occur in a microslide (O.U.8990) cut from a tuffaceous greywacke from the Kaihiku Series and a solitary *?Stichocapsa* occurs in a fine greywacke (9063) from the Otapiri Series.

Subdivision has been carried out as follows, based on interpretations of the series set forth by Hector (1878, pp. x–xi) and modified by Ongley (1939, pp. 34–41). The boundaries coincide with the main faunal changes.

(1) **Kaihiku Series**. (Ladino-Carnic, 2,900 to 3,300 ft. thick.)

Rocks containing or associated with fossils of the well-known Kaihiku fauna, dominated by forms such as *Daonella indica* Bitt., *Spiriferina fragilis* (Schlotheim), *S. kaihikuana* Trech., *Mentzeliopsis spinosa* Trech., *Athyris kaihikuana* (Trech.), and Rhynchonellids such as *Halorella zealandica* Trech.

The lowest granite bearing conglomerate outcropping along the north-east foot of Wether Hill indicates the change from North Range to Upper Triassic lithology and makes a convenient arbitrary base for the series, which is thus interpreted in a more restricted sense than has usually been the case. It may prove preferable to draw the boundary so as to include the fossiliferous beds near the top of the North Range beds when the fauna of these is better known. Conglomerate has not been found at a corresponding horizon on White Hill, the boundary being drawn tentatively along a band of coarse greywacke just above some laumontite tuff of North Range type. Fossils are rare in the lower part of the series, and apart from Isocrinal columnals and a solitary *Pleurotomaria,* the first distinctive fossils were found at a number of localities about 1,350 ft. above the base of the series. The faunule is scanty and is dominated by small Rhynchonellids together with *Spiriferina fragilis*. Fossils are varied and abundant at numerous White Hill localities in indurated mudstone about 100–500 ft. below the horizon of a locally developed fine conglomerate which contains fossils considered to be characteristic of the Oreti Series, and which is taken as the base of that series. One of the best localities is at the head of the gully which runs past the musterer's hut at the head of Stag Stream. Fossils identified from the more important localities are listed in Table I. In the Kaihiku Series, as in the later series, a number of unidentified or poorly preserved forms have also been found, but these are not listed except in special cases.

TABLE I—TARINGATURA FOSSILS FROM KAIHIKU SERIES*

	WHITE HILL									WETHER HILL		
Grid Reference . ..	221849	238837	255821	255822	239838	219858	240844	230851	258826	318752	319753	322753
Sheet, One Mile Series . ..	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.160	S.160	S.160
Stratigraphic Height (feet) .	3150	3150	3100	2850	2500	2300	1350	1350	1100	2550	2250	1750
Pleurotomaria sp.							×		×			
Trochus ? aff. *marshalli* Trech		×	C									
? *Naticopsis* sp.				×								
Daonella indica Bitt	×	×	×	×	×						×	×
Myophoria sp.		×	×									
"*Rhynchonella*" *nuggetensis* Wilck.	×				×						C	
"*Rhynchonella*" sp.							×	C				
Halorella zealandica Trech.	×		×	×	×	×						
Dielasma zealandica Trech	×		×								×	
Dielasma cf. *himalayana* Bitt	×										×	
Spiriferina fragilis (Schloth.)		×	C	×				C				
Spiriferina kaihikuana Trech.	C	×	×							C	×	
"*Spiriferina*" spp.	×	×	C	×		×	×	×		×		
Mentzeliopsis spinosa Trech.		×	C	×	×		×				C	
Athyris kaihikuana (Trech.)		×	C	×				?				
Entrochus cf. *ternis* Bather		×	×									
? *Entrochus* sp.			×									
? *Isocrinus* sp.									×			

Of lithological interest is the occurrence in the Wether Hill section of a number of conglomerate bands which appear to be missing at the north-west end of White Hill. Nevertheless, the total thickness of sediments at White Hill is estimated to be perhaps 400 ft. thicker

* Commoner forms indicated by "C"

than at the south-east side of Wether Hill, where the lenticular nature of many beds is noticeable.

(2) **Oreti Series.** (Carnic, 5,300 ft. thick at Wether Hill; over 7,000 ft. thick at the N.W. end of White Hill.)

These rocks extend from the appearance of the inadequately known post-Kaihiku fauna up to the first appearance of *Mytilus problematicus*. Fossils are sparse in Taringatura, but a prolonged search in almost any of the finer-grained beds is likely to yield some forms, especially *Halobia*. The most characteristic fossils found are *Halobia* (probably more than one species), *Athyris* cf. *wreyi* (Suess), and a small unidentified but distinctive brachiopod. This latter is almost circular in outline, the valves are but slightly inflated and are ornamented with faint concentric growth lines. The shell is distinctly sulcate. There is a large pedicle opening with considerable infilling of shell matter on either side, and a very heavy, broad and rounded dorsal median septum extending more than two-thirds the distance to the anterior margin. A typical specimen measures 14 mm. long x 13 mm. wide. *Halobia* spp. and *Athyris* cf *wreyi* similar or identical to the Oreti forms are also found throughout the succeeding Otamita Series, but the unidentified brachiopod has been found only in the lowest 1,500 ft. of the Oreti Series. A number of other fossils have been collected, as listed in Table II, some of them evidently undescribed from the New Zealand Triassic. For example, a pocket of unidentified pelecypods was found immediately below the massive White Hill conglomerate 2,700 ft. above the base of the series.

TABLE II—TARINGATURA FOSSILS FROM ORETI SERIES

	WHITE HILL							WETHER HILL		
Grid Reference ..	262787	220836	217840	265801	838222	248823	268807	313734	311749	313750
Sheet, One Mile Series ..	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.160	S.160	S.160
Stratigraphic Height (feet)	5000	2950	2700	2050	1800	750	0–50	3500	1950	1500
Pleurotomaria sp.								×		
Palaeoneilo sp.	×									
Halobia spp.	×		×		×	×	×		×	
Anodontophora cf. *angulata* Trech.										×
Lamellibranchia gen. et spp. indet.		×	×		×					
"*Rhynchonella*" sp.						×				
Dielasma sp.									×	
Spiriferina otamitensis Trech.				×						
Athyris cf *wreyi* (Suess)				×	×		×		×	
Brachiopoda gen. et sp. indet. (see text)						×	×			×

A gap of less than 200 ft. separates the highest Kaihiku fauna found from the locally developed fine fossiliferous conglomerate on White Hill which contains the first Oreti fossils as described above. It is difficult to say whether or not this is equivalent to the heavy conglomerate which Hector states is always present at the base of the series in the Hokonui district, but there are so many conglomerate bands in Taringatura that it is unsafe to correlate one band with another unless continuity be demonstrated in the field. On Wether Hill the contact horizon appears to be marked by a prominent outcrop of tuffaceous pink grits and breccia, but the gap between known occurrences of Kaihiku and Oreti fossils is here much larger

A feature of Oreti Series lithology is a plentiful development of rather fine, greenish, flinty greywackes (sparsely fossiliferous) interbedded with softer mudstones and prominent bands of mottled greywacke-sandstone. A number of bands of pink feldspathic grits are prominent in the higher levels on Wether Hill, some of them being tuffaceous A group of flesh-coloured dacite tuffs, often containing visible flakes of biotite, occur interbedded with normal sedimentary rocks in the top 300 ft. of the series. Numerous conglomerate bands, some very coarse and massive, appear at the north-west end of White Hill, where the section appears to thicken from 5,300 to about 7,000 ft.

(3) **Otamita Series.** (Carnic, 2,900 ft. thick.)

These rocks extend from the first appearance of a fauna dominated by *Mytilus problematicus* Zitt. to the first appearance of *Monotis richmondiana* (Zitt.). It seems likely that at least two stages are represented, a lower one about 1,000 ft. thick in which *Mytilus* itself occurs along with plentiful *?Gonodon mellingi* Hauer. and also *Halobia*, *Anodontophora*, *Athyris* and others. In an upper stage about 1,900 ft thick, *Mytilus* is absent, but species of *Halobia* and *Athyris* continue and are accompanied by *Rastelligera* (the first Taringatura appearance of this genus) and other forms including *Myophoria* cf. *otamitensis* Trech. and *Hokonuia limaeformis* Trech. (Table III).

TABLE III—TARINGATURA FOSSILS FROM OTAMITA SERIES*

	Upper					Lower				
Grid Reference	244787	291737	295740	303732	264777	304733	303738	259786	313721	267781
Sheet, One Mile Series .. .	S 159	S.159	S.159	S.160	S.159	S.160	S.160	S.159	S.160	S.159
Stratigraphic Height (feet) .	2800	2600	1300	1300	1200	900	300	100	100	50
Palaeoneilo sp.							×			
Halobia spp.	C	×	×	C		C	C			
Mytilus problematicus Zitt.						C	C	C	C	C
Hokonuia limaeformis Trech.			×							
Anodontophora angulata Trech							×	×		
Anodontophora ovalis Trech.							×		×	
Myophoria cf. *otamitensis* Trech.				×	×					
? *Gonodon mellingi* Hauer							×		×	C
Dielasma sp.				×						
Rastelligera sp.					×					
Athyris cf. *wreyi* (Suess)		×		×	×				×	

* Commoner forms indicated "C"

This latter fauna is much less prolific than that of Trechmann's beds *a* to *e* above the *Mytilus* beds at Otamita stream (1918, p. 178), but it is probably equivalent in part or in whole. Good specimens of *Rastelligera* were not collected, but it is of interest to note that the specimens found are not very alate, being almost semicircular, and although the areas show the characteristic "comb tooth" structure, the tips are longitudinally striate, a feature which persists in some of the smaller *Rastelligerae* of the lower part of the Otapiri Series. Further, dental plates, feeble or absent in specimens from the Otapiri Series, are distinctly developed.

In the lower beds especially the average grain-size is coarse, with abundant feldspathic grits and intraformational breccias. These coarse-grained beds are often fossiliferous, but the best fossils come from siltstones. Tuffs are present and include a thin band of salmon-coloured dacite tuff on White Hill and a greyish-white bed of hard analcite-bearing tuff which forms a conspicuous outcrop at the 670 ft. stratigraphic level on Wether Hill. Wedging of beds occurs, and at the south-east end of the outcrop area, the whole series narrows down to about 1,300 ft., both the upper and lower members becoming thinner.

(4) **Warepa Series**. (Noric, 1,300 ft. thick at Wether Hill, 2,000 ft. at White Hill.)

Rocks containing a fauna dominated by *Monotis richmondiana* (Zitt.) in its many forms, or their age equivalents. The base is well defined on Wether Hill by a granite-bearing, fossiliferous conglomerate. The highest *Halobia* and *Athyris* found were about 300 ft. below this. On White Hill the Otamita-Warepa contact has been drawn along a persistent band of sandstone, *Monotis* having been found 50 ft. above, and *Halobia* 100 ft. below it. The following is the complete list of fossils found:

Monotis richmondiana (Zitt.). Numerous varieties, many localities.

Pelecypoda gen. et sp. indet. Fragments, several localities.

Rastelligera sp. Fragments in basal conglomerate.

Clavigera sp. Fragments in basal conglomerate, and small specimens beside the creek at the edge of the map, S.E. of Trig. AA. (Sheet S.159/240.727.)

Pleurotomaria sp. Same locality.

Monotis mudstones are exposed along the road line which follows the strike of the Warepa Series at Wether Hill, and coarser greywackes and gritty shell beds occur nearer the top of the series on the south side. Only a few miles to the west greywacke sandstones, sometimes containing plant remains, are more prominent, and the section is estimated to thicken from 1,300 ft. to 2,000 ft. So far, tuffs have not been recognised in the Warepa Series

(5) **Otapiri Series**. (Rhaetic, 4,700 ft. or more thick.)

Pre-Jurassic rocks which follow the first appearance of a fauna dominated by various species of *Rastelligera* and *Clavigera*. It should be emphasised that both these genera appear in earlier beds as recorded by Hector (1878, p. x), who states that in the Wairoa Series (i.e. Otamita plus Warepa Series) "Brachiopoda are represented by the earliest appearance of *Clavigera* and *Rastelligera*, but they are very rare." Trechmann (1918) records *C. bisulcata* doubtfully from the Carnic and Noric of Otamita Stream, and Wilckens (1927, p. 30) records fragmentary *C. bisulcata* from beds containing ***Mytilus problematicus*** at Nugget Point. Early Taringatura occurrences have already been listed above. However, in the Otapiri Series the two genera dominate the fauna and *Monotis richmondiana* has completely disappeared in Taringatura. In this connection it is interesting to note that Marwick (1946, pp. 29–30) has recently recorded an angular unconformity in the *Monotis* beds of the Te Kuiti Subdivision of the North Island with different faunules of *Monotis* above and below it, typical *M. richmondiana* apparently being confined to the lower beds. The unconformity was taken as the base of the Otapiri Series, but such conditions have not been observed in Taringatura.

True *Rastelligera elongata* Thom. has so far been found by the writer only near the top of the series, but future search may yield specimens from lower down as well. Less alate and generally smaller, undescribed species occur in the lower horizons. A large and handsome *Lima* is abundant in a narrow band 22 chains south-west of Trig. AA and the presence of a number of other brachiopods and mollusca, some too poor for identification, indicates a fairly large and varied, though scattered, fauna (Table IV). The early workers, Hector, Cox and McKay, were evidently aware that the Otapiri fauna was extensive, but so far only about six species have been described by a modern worker, namely Trechmann (1917). Further collecting and palaeontological study is required.

TABLE IV—TARINGATURA FOSSILS FROM OTAPIRI SERIES*

Grid Reference ..	283704	279704	290712	278725	181768	172760	259761	255758	733245	250733	305719
Sheet, One Mile Series ..	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.159	S.160
Stratigraphic Height (feet)	4650	4450	4050	1900	?	?	350	300	200	50	0–50
Lima sp.									C		
Myophoria sp.				×							
"*Rhynchonella*" sp.	C										
"*Terebratula*" sp	C								×		
Spiriferina sp.			C								
Rastelligera elongata J. A. Thomson		C									
†*Rastelligera* spp.			×			×	×	C	C	×	×
Clavigera tumida J. A. Thomson	×	×									
‡*C. cf bisulcata* J. A. Thomson	×		×		C		×				
Clavigera sp.	×										

* Commoner forms indicated "C."
† More than one species present.
‡ More than one form may be represented.

Along the north-east side of Dipton West Hill, the Warepa-Otapiri contact has been drawn along a sandstone bed with *Monotis* in the lower part and *Rastelligera* above, associated with very fragmentary plant remains and followed by *Clavigera*. Further to the west, south of Trig. AA, there is a local development of conglomerate with *Rastelligera* above, *Monotis* below. In both localities the two faunules have been found less than 100 ft. apart.

The grain-size of rocks in the Otapiri Series varies rapidly in the usual manner, but apart from the locally developed basal conglomerate there is a tendency for increase towards the top, the highest 700 ft. being predominantly coarse greywacke-sandstones and feldspathic grits with pebble bands. Dacite tuffs have been identified on Dipton West Hill at stratigraphic heights of 1,200 and 2,700 ft.

(6) Uppermost Rhaetic or Lowest Jurassic.

At 4,700 ft. above the base of the Otapiri Series is a massive conglomerate traceable along the outcrop for about three-quarters of a mile before it merges into grits and greywacke sandstones. Above this band are perhaps 1,000 ft. of poorly exposed strata at the south-east corner of Dipton West Hill. Judging from surface boulders, it would appear that the predominant rock type is a coarse feldspathic grit. No fossils were found and definite correlation is not possible

Source of the Upper Triassic Sediments, Their Deposition and Thickness.

It has been seen that the change from North Range to Upper Triassic conditions is marked by an influx of plutonic and other mixed debris in place of the almost purely volcanic, notably andesitic, detritus in the North Range beds. It would not be valid to use this as evidence for post North Range, pre-Upper Triassic plutonic intrusions, as Permian (?) conglomerates at Clinton contain a wide variety of plutonic pebbles (Ongley, 1939, p. 32), and furthermore there is no evidence of angular unconformity between the North Range and Upper Triassic beds which are in depositional contact. Perhaps, after prolonged erosion, the volcanic cover of the old land which had provided detritus during the formation of the North Range beds had been cut through, and a mixed basement rock had been exposed. Alternatively, changes in drainage patterns resulted in the arrival of material from a new source. Be that as it may, the Upper Triassic conglomerate pebbles were derived from a land mass on which were exposed large quantities of acid plutonic rocks as well as some intermediate types, greywackes (not common in Taringatura conglomerates) and fine-grained metamorphic rocks, probably mostly hornfelses. Small fragments of the latter are common in the greywackes, but are less noticeable in the conglomerates. Fine-grained volcanic rocks were abundant. It is known that volcanic breccias, tuffs and massive volcanic rocks are well developed in the Te Anau group of presumably late Palaeozoic age in Western Otago and Southland (e.g. see Turner, 1935; Service, 1937, pp. 206-207). Volcanic activity also occurred during the deposition of the *Maitaia*-bearing beds of Permian (?) age as is shown, for example, by the occurrence of tuffs interbedded with *Maitaia* beds near Otama, Southland (writer's observations). In view of this late Palaeozoic volcanism, as well as that shown to be so frequent in the Triassic itself, it is not surprising that pebbles of volcanic rocks—dacite, andesite, quartz-keratophyre, keratophyre, meta-basalt, are abundant constituents of the Triassic conglomerates. Small fragments are ubiquitous in the greywackes, as indeed they are in the Roe Burn beds and in sections of Clinton group greywackes inspected by the writer.

In this respect it is interesting to note that the late Palaeozoic and Mesozoic rocks south of the Central Otago schist belt, with their copious volcanic fragments, offer a contrast with at least some of the rocks of comparable age immediately to the north of the Central Otago area. Thus volcanic fragments appear to be rare or lacking in the Triassic conglomerates, greywackes and semi-schists described by Mackie (1936) from his Waitaki River-Dunstan Peak traverse, whereas fragments of greywacke and other sedimentary types are abundant, and clastic quartz is commoner than in the Taringatura area. Amies (1950) has recently recorded volcanic pebbles in conglomerates of rather doubtful age in South Canterbury, but they do not appear to be particularly common and are associated with numerous sedimentary pebbles as well as some plutonic ones. It seems likely that detritus for the Triassic and perhaps earlier beds of North Otago and South Canterbury came from an area distinct from that which supplied detritus to the Southland area.

Large collections of Taringatura conglomerate pebbles have been made, but detailed comparative study has not yet been carried out. However, in view of the occurrence of granitic and other plutonic rocks in the Stewart Island–Fiordland belt to the south and west of Taringatura and the absence of such rocks to the north and east, it seems inevitable that the Taringatura detritus and that of the Southland Mesozoic area in general, came from a terrain to the south-west, as concluded on petrographic grounds by Mackie (1935, p. 298). Amies (MS.) has reached rather similar conclusions for the Permian (?) conglomerates of Clinton.

This leads to the picture of a Mesozoic geosyncline with the present Southland area lying towards its south-western shore and receiving detritus from that direction as suggested by the maps of Benson (1921, Fig. 8) and Macpherson (1946, Map 3). Considerable relief must have been maintained on the old land throughout the period, as is indicated by the numerous conglomerates and the abundance of coarse-grained highly feldspathic greywacke. In terms of this concept detritus was not being received from the area north-east of Taringatura and the Hokonuis. Consequently, whether or not the Central Otago schists had been metamorphosed by this period, pebbles of these schists are hardly to be expected in any abundance in the Southland Lower Mesozoic conglomerates. Healy (1938) offered another explanation for the absence of Central Otago schists in the Hokonui conglomerates, namely, that the conglomerate pebbles are well rounded and of very resistant rock types, and that it was unlikely that Central Otago schist pebbles could survive in such an environment. On the other hand, quartz pebbles derived from the schist should survive, but even quartz pebbles are uncommon in Taringatura.

TABLE V—ESTIMATED THICKNESS OF LOWER MESOZOIC FORMATIONS

Locality		1 Glenomaru Coast	2 Kaihiku Ranges	3 Hokonui Hills	4 Wether Hill	5 White Hill	6 Te Kuiti Subdivn.
Distance N.W. from Coast		0 ml.	20 ml.	65 ml	85 ml.	95 ml.	—
JURASSIC		13,800 ft.	7,800 ft	6,550 ft	(1,000 ft.)	—	17,000 ft
TRIASSIC	Otapiri Series	∧	—	1,650	4,700	—	3,000
	Warepa Series	|	1,100	∧	1,300	2,000	1,000
	Otamita Series	2,950	2,500	3,000 ∨	2,900	3,000	700
	Oreti Series	∨	4,000	3,400	5,300	7,000	2,500
	Kaihiku & earlier	5,450	7,000	17,000?	13,500	13,900	4,000
TOTAL		22,200	22,400	31,600	28,700		28,200

1. Mackie (1935). Mackie's beds *a* and *b* are here included in the Kaihiku Series. It is possible that the total thickness of the lowest subdivision would be increased by mapping further to the north. The Warepa Series appears to be completely absent, and the Otapiri Series is very thin.
2. Ongley (1939). The thickness of Jurassic beds might well have been increased if mapping had been continued further south.
3. Cox and McKay (1878). These authors give 6,150 ft. for the Kaihiku Series, but this estimate must be increased to allow for all those beds north of the disproved anticlinal axis (see text). The above figure is an estimate based on their map and section through Flag Hill. The Jurassic total includes 3,500 ft. for the Mataura Series, which, strictly speaking, is not present in the Flag Hill section, being found further east, where, to judge from Cox and McKay's map, the thickness of the pre-Upper Triassic beds is less than it is near Flag Hill.
4. and 5. This paper. The beds ascribed tentatively to the Jurassic may belong to the Otapiri Series.
6. Williamson (1932) and Marwick (1946). In the nearby Huntley-Kawhia subdivision (Henderson and Grange, 1926), 22,000 ft. of Jurassic strata are exposed and 6,000 ft of Upper Triassic, a total of 28,000 ft.

In Table V are set forth estimated thicknesses of Lower Mesozoic sediments at various localities. The first five are along the same north-west trending belt running inland from the sea at Roaring Bay, while the sixth gives the figures for the Te Kuiti Subdivision of the North Island for comparison. It should be pointed out that no depositional base of the Triassic has yet been recognised in New Zealand, but that in Southland at least the lowest Triassic members usually appear to have a fault contact with Permian beds of closely similar dip and strike. It is clear that there is a definite tendency for the Triassic beds, especially the Upper Triassic, to thicken towards the north-west. This can perhaps be correlated in part with the abundance of pyroclastic material in the Taringatura area. On the other hand the exposed thickness of Jurassic sediments decreases in the same direction. This is partly due to the fact that any greater thickness of Jurassic beds which may have existed in the north-west has been removed by erosion or is buried beneath the Oreti River alluvium. However, Ongley gives 4,300 ft. as the thickness of the Bastion Series (i.e. lowest Jurassic) and 3,500 ft. for the succeeding Putataka Series in the Kaihiku Ranges, whereas Cox and McKay give the thickness of these two as 2,200 ft. and 850 ft. respectively with the 800 ft. Flag Hill Series between. Most of the 13,000 ft. Jurassic sequence at Glenomaru appears to belong to the same formations. This suggests that individual Jurassic formations may thin out between Glenomaru and the Hokonuis. The complementary manner in which the exposed thickness of the different Mesozoic groups varies is rather remarkable. The total thickness exposed at any one locality approaches 30,000 ft. Reliable figures for the adjacent late Palaeozoic beds will be awaited with interest.

III. *Tertiary*

Three outliers of Tertiary beds are shown on the map—a small cap of pebbly bryozoan limestone on a spur between North Range and Pig Range, the much larger Castle Downs (Castle Rock) limestone mass and an infaulted patch of sandstone on the north-east flank of Wether Hill at the edge of the valley of the Oreti River. Both the limestone areas were recorded and mapped by Hutton (1875). In addition, Tertiary sediments may underlie superficial deposits in part of the tectonic depression known as The Bog to the south-west of White Hill, and a veneer of terrace gravels south-west of Mossburn is in part underlain by Tertiary mudstone, a specimen of which was given to the writer but proved to be unfossiliferous.

As pointed out by Ongley (in Morgan, 1919, p. 279), the Castle Downs limestone occupies a structural basin and the beds dip inwards from all sides. Along the north-west side the limestone is let down against Noric beds by an important fault and, as will be seen later, there must be another fault along the east side. The Castle Downs basin has been formed where a transverse downwarp crosses the resulting N E.–S.W. tectonic depression, a depression which also contains the North Range limestone. About 400 ft. of limestone grading into marl and calcareous sandstone are exposed, and occasional pebble bands occur. Most beds are glauconitic. Macro-fossils include bryozoans, many Pectens and related forms, and occasional brachiopods. The writer is indebted to Dr H. J Finlay, who reports the presence of the following foraminifera:

From finely arenaceous layer in the creek bed at the south extremity of the largest Castle Downs limestone mass:

Alabamina tenuimarginata (C., P. & C.)
**Amphistegina lessoni* d'Orb.
Anomalinoides macraglabra (Fin.)
A. subnonionoides (Fin.)
Arenodosaria antipoda (Stache)
Discorbis concentricus (F. & M.)
D. scopus Fin.
Dyocibicides biserialis C. & V.
**Gaudryina crespinae* Cush.
Guttulina problema d'Orb
Gyroidina cf. *allani* Fin.
**Nonion maoricum* (Stache)

Bolivina aff. *tortuosa* Brady
**Calcarina mackayi* (Karr.)
Cancris lateralis Fin.
Cassidulina carinata Cush.
C. aff. *crassa* d'Orb.
C. subglobosa Brady
**Cibicides* cf. *maculatus* (Stache)
C. n.sp.
**Notorotalia spinosa* (Chap.) var. (as in Duntroonian)
**N.* n.sp.
Parrella balcombensis (C., P. & C.)
Semivulvulina capitata (Stache)
Siphotextularia heterostoma (Forn.)
Textularia n.sp. aff. *miozea* Fin.
Uvigerina dorreeni Fin.

Those marked with an asterisk together with *Eponides repandus* (F. & M.) also occur in a soft grey band near the base of the Dipton West lime works quarry face, stratigraphically about 90 ft. higher than the above locality. Dr Finlay reports that both samples are Duntroonian, of the *Calcarina mackayi* facies, which he says is well represented at Waimumu quarry and elsewhere in Southland

The lowest beds exposed at Castle Downs are probably those at the extreme north end of the mass, and in a calcareous sandstone from this locality Dr. Finlay reports another small Duntroonian fauna:

Amphistegina lessoni d'Orb., *Calcarina mackayi* (Karr.), *Nonion* aff. *pompilioides* (F. & M.), and *Notorotalia spinosa* (Chap.) var. as above.

A small collection of brachiopods, *Pachymagas* cf. *cottoni* Thomson, was made about 150 ft. above the base of the quarry face mentioned above. This suggests the possibility of an Otaian age for this zone (Dr. Finlay, pers. comm.). Allan (1937) recorded *P. cottoni* as being abundant in the Lower Forest Hill limestone of Southland.

Through the courtesy of Mr. T. A. Gerrard, of Dipton West, the writer has inspected private reports by the late Professor Park (MS., 1924) concerning samples from a bore, sunk, it is said, to a depth of 360 ft. at the edge of the main limestone mass as shown on the map. The log records a series of Tertiary limestones, sandstones and marls for the full depth of the bore. Whether or not basement was reached is not clear. The presence of these buried sediments makes it necessary to postulate a fault along the eastern margin of the limestone. The throw may be of the order of 200 to 300 ft., or more if basement was not reached by the bore.

From the Wether Hill Tertiary sandstone Dr. J. Marwick has kindly determined the following mollusca:

Glycymeris (*Glycymerita*) cf. *thomsoni* Marw.
Limopsis aff. *zealandica* Hutton
Zemysia sp.
Zenatia aff. *acinaces* Q. & G.
Eumarcia cf. *thomsoni* Marw.
Zeacolpus n.sp.
Maoricolpus cf. *cavershamensis* Marw. (fragments)
Struthiolaria cf. *subspinosa* Marw. (fragments)
Taniella notocenica (Fin.)
Austrofusus (*Neocola*) *beta* Fin.
Baryspira herbera Hutton

He concludes, "I think the age is high in the Altonian, chiefly because of the *Neocola*, which is certainly intermediate between *alpha* and *gamma* and corresponds fairly well with *beta.*"

IV. *Pleistocene and Recent*

Extensive alluvial deposits mark the present flood plains of the Oreti and Aparima Rivers as well as the abandoned Mossburn-Aparima course of the Oreti River. Detritus derived from White Hill deeply litters the northern side of The Bog. Small high-level alluvial remnants were found on the north side of Castle Rock hillock and near the North Range limestone (300 ft. above the Five Rivers Plain) and on Wether Hill about 100 ft. above Dipton Flat. These remnants are considered to be of Pleistocene or perhaps earlier age.

Hamilton (1893, 1894) has described Pleistocene bird remains from caves in the Castle Downs limestone.

STRUCTURE OF THE OLDER ROCKS

A probable anticline in the Roe Burn beds has already been described.

Apart from a small area on the east side of Wether Hill, the dip and strike of most of the Triassic rocks is on the whole very regular, variations of more than 10° from the usual south-westerly dip of 60° to 70° being rare. Locally, on the south side of the North Range, the bedding may be vertical or even overturned to dip about 80° to the north-east. In the south, however, there is an abrupt change to lower and variable dips suggesting an asymmetric syncline pitching to the south-east. This is in accord with the major synclinal structure of the Hokonuis as described by Cox and McKay (1878), a structure brought about during the Hokonui orogeny of early Cretaceous times. The south-east pitch of the synclinal axis is not constant, being greatest towards the south-east of Dipton West Hill. Near Trig. AA there is a gentle anticlinal rise which may possibly be connected with the formation of The Bog tectonic depression on the west side of Trig. AA. Small outcropping masses on the west side of The Bog show easterly dips.

GEOMORPHOLOGY

The various hills in the district show a sufficient tendency towards flat tops to suggest that these tops are perhaps not far from the late Tertiary peneplain surface (cf. Benson, 1935). Dipton West Hill and Trig. AA hill are also flat topped and about 1,000 ft. below the summit levels to the north and south, suggesting a late Tertiary down-sag approximately along the axis of the Mesozoic syncline. This hypothesis is strengthened by the occurrence along the same axis of the inwardly dipping Castle Downs limestone and the alluviated tectonic depression of The Bog.

Faults have been recognised as follows:—

(a) The Taringatura continuation of the Hokonui fault already discussed. It forms the frontal escarpment of the North Range, and may be a steeply dipping bedding thrust.

(b) The Castle Downs fault on the west side of the Castle Downs and North Range limestones letting them down against the basement rocks. In the North Range section where the dip of the basement beds is very steep there is no obvious offset. In the trough between White and Wether Hills outcrops are indecisive. In the neighbourhood of the Castle Downs limestone interpretation is difficult owing to the presence of the Castle Downs Tertiary beds and of a second fault on the east side thereof. Nevertheless, a throw of the order of 1–2,000 ft. appears necessary to account for the relationships of the Triassic beds along the line of section DE (Plate 54), the upthrow being on the west. From consideration of summit levels it is unlikely that all of this movement occurred during the breaking up of the late Tertiary peneplain. It seems likely that movements occurring after Oligocene times, but before the late Tertiary peneplanation, resulted in preservation of the Castle Downs and North Range limestones during the peneplanation. Renewed movement occurred during the Kaikoura orogeny, when the present block structure was achieved. That the fault was recently active is shown by a feature interpreted as an earthquake scarplet which may be traced for several miles along the line of the fault on the south-east side of White Hill. Where it crosses the Dipton West–Mossburn surveyed roadline the scarplet is about four to five feet high, but a quarter of a mile to the north-north-east it rises to about 10 ft. before bifurcating. It is very clearly defined, even where it crosses alluvium in the bed of a small creek.

(c) The Mossburn fault. A north-east trending fault occurs at the north-west end of White Hill. The west side is the downthrow and marked offset of beds has occurred. A hypothetical fault on the south-east side of The Bog, possibly related to the "Mossburn" fault, appears to have let Otapiri Series beds down against inadequately exposed *Monotis* beds. This hypothetical fault is almost aligned with the Mossburn fault.

(d) The Oreti fault. The Oreti River gap is tentatively interpreted as a fault-angle depression with the western, i.e. Taringatura side upfaulted, and the north-west end of the Hokonui block tilted down towards it. The relationships of the Wether Hill Tertiary sandstone indicate that faulting may be complex.

Stag Stream Lowland and a Former Castle Downs Stream

One of the most striking topographic features in northern Taringatura is the broad Stag Stream lowland separating the North and Pig Ranges on the north from White Hill and Wether Hill on the south. The lowland is floored by closely jointed mudstones of the upper North Range beds, and it is largely of subsequent origin, though possibly earth movements may have contributed to its formation. A small, underfit tributary of the Moss Burn drains the north-west end of the depression and has an outlet at an altitude of about 1,000 ft. Stag Stream, on the other hand, has an outlet at only 500 ft. and is progressively capturing the headwaters of the Moss Burn tributary. As a result of invigoration consequent to this capture, the creeks draining the sides of North Range and White Hill have a much more rugged sculpture on the Stag Stream side of the creeping divide than is the case further to the north-west.

Near the North Range limestone are two patches of bouldery alluvium at an altitude of 1,000 ft., about 300 ft. above the present level of Stag Stream. The rock types represented can be matched with beds on White Hill and Wether Hill, and two boulders containing *Monotis* and another containing *Rastelligera* show that some of the detritus was derived from the *south* side of these hills. The boulders must have been deposited by a former Castle Downs Stream flowing north-east along the tectonic depression between White and Wether Hills, right across and above the present site of Stag Stream. This former stream would have reached the Five Rivers Plain at a level comparable to that of the terrace remnant on Castlerock hillock. The stream has been completely dismembered, Stag Stream having captured a part, while one of the headwater tributaries of Dipton Stream has reversed the drainage of the remainder.

The minor sculpture of the area consists of a series of subsequent divides and gullies with numerous transverse reaches.

ECONOMIC GEOLOGY

Limestone was once cut at Castle Downs for use as building stone and the stone is now quarried for use as agricultural lime. Attention may also be called to the extensive zeolite deposits in Taringatura, which may be worthy of investigation should a demand for such material arise. Laumontite occurs copiously in bedded masses in the North Range while analcite and other zeolites occur in lesser purity in tuffs of the Oreti and Otamita Series.

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