STRATIGRAPHY AND STRUCTURE
IN THE NORTHERN PART OF THE AREA BETWEEN
THE GLENROY AND MATAKITAKI RIVERS,
SOUTH NELSON, NEW ZEALAND.

A thesis presented for the
degree of Master of Science with Honours in Geology
in the University of Canterbury,
Christchurch, New Zealand.

by
R. G. ADAMSON

FEBRUARY, 1966
# CONTENTS

**PART I - INTRODUCTION**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location, physiography and vegetation</td>
<td>1</td>
</tr>
<tr>
<td>Previous work</td>
<td>3</td>
</tr>
<tr>
<td>Scope of present work</td>
<td>5</td>
</tr>
<tr>
<td>Mapping</td>
<td>7</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>8</td>
</tr>
</tbody>
</table>

**PART II - SEDIMENTARY ROCKS**

**Pre-Permian rocks**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nardoo Formation</td>
<td>10</td>
</tr>
</tbody>
</table>

**Permian rocks**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>13</td>
</tr>
<tr>
<td>Potberry Formation</td>
<td>14</td>
</tr>
<tr>
<td>Matskitaki Limestone</td>
<td>21</td>
</tr>
<tr>
<td>Wheeler Formation (including Gorge Shale Member)</td>
<td>27</td>
</tr>
<tr>
<td>McNee Formation</td>
<td>33</td>
</tr>
<tr>
<td>Yorkey Formation (including Hut Flat Conglomerate Member and Branch Siltstone Member)</td>
<td>36</td>
</tr>
</tbody>
</table>

**Tertiary rocks**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>45</td>
</tr>
<tr>
<td>Double Creek Formation</td>
<td>46</td>
</tr>
<tr>
<td>Horse Terrace Formation</td>
<td>52</td>
</tr>
<tr>
<td>Foulsham Formation</td>
<td>56</td>
</tr>
<tr>
<td>Tertiary rocks Contd.</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Priestman Formation</td>
<td>59</td>
</tr>
<tr>
<td><strong>Longford Formation</strong></td>
<td>66</td>
</tr>
<tr>
<td>Water Race Formation</td>
<td>69</td>
</tr>
<tr>
<td>Quaternary deposits</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>75</td>
</tr>
<tr>
<td>Alluvium</td>
<td>75</td>
</tr>
<tr>
<td>Moraine</td>
<td>77</td>
</tr>
<tr>
<td>Cemented terrace gravel</td>
<td>77</td>
</tr>
<tr>
<td>Calc-tufa</td>
<td>78</td>
</tr>
</tbody>
</table>

**PART III - IGNEOUS AND METAMORPHIC ROCKS**

<table>
<thead>
<tr>
<th>Station Creek Formation (including Hunter Dunite Member)</th>
<th>79</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baldy Microgabbro</td>
<td>86</td>
</tr>
<tr>
<td>Woodham Granite</td>
<td>90</td>
</tr>
<tr>
<td>Blick Diatreme</td>
<td>104</td>
</tr>
<tr>
<td>Haast Schist Group</td>
<td>130</td>
</tr>
</tbody>
</table>

**Part IV - STRUCTURAL GEOLOGY**

<table>
<thead>
<tr>
<th>Introduction</th>
<th>134</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of the major faults</td>
<td></td>
</tr>
<tr>
<td>Alpine Fault</td>
<td>135</td>
</tr>
<tr>
<td>Glenroy Fault</td>
<td>136</td>
</tr>
<tr>
<td>Hunter and Potberry Faults</td>
<td>138</td>
</tr>
<tr>
<td>Branch and Thornton Faults</td>
<td>140</td>
</tr>
</tbody>
</table>
Structural Geology Contd.

Woodham Fault

Matakitaki Fault

The evidence for late Palaeozoic - early Mesozoic diastrophism in this area

Fault pattern

PART V GEOLOGICAL HISTORY

REFERENCES

APPENDICES

I  Mineralogy and classification of varicolitic basalt and obsidian from the Blick Diatreme.

II  Attitudes of fault-planes in the Glenroy - Matakitaki area.
# TABLE OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontispiece</td>
<td>Panorama of thesis area, photographed from Mount Woodham.</td>
</tr>
<tr>
<td>Table</td>
<td>Stratigraphic units in the Glenroy - Matakiki area.</td>
</tr>
<tr>
<td>1.</td>
<td>Location map of thesis area.</td>
</tr>
<tr>
<td>2.</td>
<td>Thin-bedded Matakiki Limestone, 100 yards north of the gorge in Wheeler Creek.</td>
</tr>
<tr>
<td>3.</td>
<td>Vertically-dipping contact of McNee Formation and Hut Flat Conglomerate Member.</td>
</tr>
<tr>
<td>4.</td>
<td>Bedded conglomerate of the Friestman Formation.</td>
</tr>
<tr>
<td>5.</td>
<td>Channel-filling structure in Friestman Formation conglomerate.</td>
</tr>
<tr>
<td>6.</td>
<td>Poorly-sorted breccia of the Water Race Formation.</td>
</tr>
<tr>
<td>7.</td>
<td>Photomicrograph of Woodham Granite.</td>
</tr>
<tr>
<td>8.</td>
<td>Photomicrograph of Woodham Granite showing myrmekitic texture.</td>
</tr>
<tr>
<td>9.</td>
<td>Head of Fuchsia Gully showing situation of the Blick Diatreme, as viewed from the west.</td>
</tr>
<tr>
<td>10.</td>
<td>Sketch-plan and cross-section of the Blick Diatreme.</td>
</tr>
<tr>
<td>11.</td>
<td>Type 'B' volcanic breccia at north end of Blick Diatreme.</td>
</tr>
<tr>
<td>12.</td>
<td>Pocket of type 'C' volcanic breccia on upper surface of type 'A' volcanic breccia, Blick Diatreme.</td>
</tr>
</tbody>
</table>
Figure

13. Cut and polished specimen of type 'C' volcanic breccia, Blick Diatreme. 113

14. Pahoehoe surface of variolitic basalt. 113

15. Photomicrograph of variolitic basalt. 114

16. Photomicrograph of tuffisite. 114

17. Ice-plucked Chlorite 2 schist in northern face of roche moutonee east of Nardoo Creek. 132

18. Rose diagram for the strikes of 21 faults in the Glenroy - Matakitaki area. 116

TABLE OF PLATES

(In pocket of back cover)

Plate

1. Geological map of the northern part of the area between the Glenroy and Matakitaki Rivers.

2. Cross-sections to accompany the geological map of the northern part of the area between the Glenroy and Matakitaki Rivers.

3. Stratigraphic columns and correlations of middle Tertiary sections.
Frontispiece:

Panorama of thesis area, photographed from Mount Woodham. At left, looking toward Murchison down the Matakitaki Valley; at right, the northern end of the Nardoo Range. The foreground is the valley of the East Branch Glenroy River.
<table>
<thead>
<tr>
<th>Map Name and Symbol</th>
<th>Lithology</th>
<th>Thickness (ft.)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvium</td>
<td>Fluvial terraces, lake deposits, glacial outwash.</td>
<td></td>
<td>Holocene and Upper Pleistocene</td>
</tr>
<tr>
<td>Moraine</td>
<td>Moraine</td>
<td></td>
<td>Middle Pleistocene</td>
</tr>
<tr>
<td>Black Bluff (intrusive into fo &amp; sc)</td>
<td>Tuffite, variolitic basalt, volcanic breccia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longford Formation</td>
<td>Massive silty sandstone, fissile carbonaceous siltstone.</td>
<td>500</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td>Water Race Formation</td>
<td>wri</td>
<td>Compacted breccia, sandstone lenses.</td>
<td>9%</td>
</tr>
<tr>
<td>Glenroy Fault</td>
<td>Angular unconformity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Priestman Formation</td>
<td>Massive round-stone conglomerate, sandstone beds, plant fragments.</td>
<td>2,500</td>
<td>Upper Oligocene</td>
</tr>
<tr>
<td>Double Creek Formation</td>
<td>Silty sandstone, fossiliferous limestone lenses</td>
<td>200</td>
<td>Middle Oligocene</td>
</tr>
<tr>
<td>Horse Terrace Formation</td>
<td>Grainy very coarse-grained sandstone, locally basal conglomerate and coal measures.</td>
<td>600</td>
<td>Lower Oligocene</td>
</tr>
<tr>
<td>Logan Granite</td>
<td>WUL</td>
<td>Bimodal-biota granule, serpentiferous crumolite, mafic rocks,</td>
<td>Lower Triassic</td>
</tr>
<tr>
<td>Redwall Formation</td>
<td>Intrusive contact</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yorkey Formation</td>
<td>Highly indurated sandstone (often massive), conglomerate lenses, argillite.</td>
<td>6,500</td>
<td>Upper Permian</td>
</tr>
<tr>
<td>Branch Siltstone Member</td>
<td>Evenly-beded purple and green siltstone.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rut Flat Conglomerate Member</td>
<td>Well-rounded boulder-chunk conglomerate</td>
<td>(250)</td>
<td></td>
</tr>
<tr>
<td>Holmes Formation</td>
<td>Micaceous sandstone and red and green siltstone and sandstone.</td>
<td>660</td>
<td></td>
</tr>
<tr>
<td>Wheeler Formation</td>
<td>Laminated, graded bedded sandstone and siltstone.</td>
<td>3,400</td>
<td>Middle Permian</td>
</tr>
<tr>
<td>Gorge Shale Member</td>
<td>Laminitated black shale.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matakitaki Limestone</td>
<td>Grey fine-grained crystalline limestone, thinly bedded with sand and clay laminations.</td>
<td>1,100</td>
<td>Middle Permian</td>
</tr>
<tr>
<td>Pottery Formation</td>
<td>Tuffaceous sandstone, hemaitic conglomerate, basic lava, laminated grey mudstone and siltstone.</td>
<td>7,100</td>
<td>Middle Permian</td>
</tr>
<tr>
<td>Intrinsic contact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waldy Microgabbro</td>
<td>Medium to fine-grained, partially serpentinized gabbro.</td>
<td>3,200</td>
<td>Lower Triassic</td>
</tr>
<tr>
<td>Station Creek Formation (intrusive into sc)</td>
<td>Serpentinite pods and dikes, rhodolite veins, hornblende, pyroxene, chlorite.</td>
<td>3,500</td>
<td>Middle Permian</td>
</tr>
<tr>
<td>Hunter Dunite Member</td>
<td>Dunite</td>
<td></td>
<td>3,600</td>
</tr>
<tr>
<td>Fault contact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warrego Formation</td>
<td>Green (often massive) sandstone, zones of quartz veinlets.</td>
<td>5,200</td>
<td>Lower Permian</td>
</tr>
<tr>
<td>Haast Schist Group</td>
<td>Unfluid II schist</td>
<td></td>
<td>Mesozoic</td>
</tr>
<tr>
<td></td>
<td>Chlorite III schist</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biotite schist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PART I - INTRODUCTION

LOCATION, PHYSIOGRAPHY AND VEGETATION

The area mapped for this thesis lies within the Matakitaki Survey District (Maruia Subdivision), in the south of the Nelson Province; see Fig 1.

It is bounded to east and north by the course of the Matakitaki River, a major north-flowing tributary of the Buller River; and in the west by the Glenroy River, itself a tributary of the Matakitaki River. The southern boundary is an arbitrary east-west line through the headwaters of the East Branch Glenroy River. These boundaries define an area of about forty square miles.

Road access from Christchurch, a distance of 15½ miles, is by the Lewis Pass Main Highway and the settlement of Maruia. From the township of Murchison, access is by road 17 miles up the Matakitaki Valley.

Topographically, the area is of high relief. Altitudes range from 1000 feet, near the Glenroy-Matakitaki confluence, to 5000 feet on the ridge south of Baldy Trig. The regional drainage is to the valleys of the Glenroy and Matakitaki Rivers. The Glenroy-Matakitaki area is divided into four main water-sheds by two northeasterly trending ranges in the central and eastern portions and a north-westerly trending ridge in the northwest.

The vegetative cover is primarily mountain beech forest up to 4,500 feet, with sub-alpine shrubs and alpine meadows above.
Figure 1. Location map of thesis area.
this height. On some of the lower slopes and the river terraces, forest has been cleared to make way for farmlands.

PREVIOUS WORK

An account of the first geological exploration of the area is given by Cox (1884) in a report on the district between the Buller and the Maruia Rivers. He was interested primarily in the Cretaceous-Tertiary coal measures of the area and did not concern himself with the structure of the older rocks.

In 1894 Alexander McKay visited the Matakitaki and Glenroy Valleys in the course of a journey to discover the source of the alluvial gold of the Buller and North Westland Rivers, McKay (1895). Both Cox and McKay mapped the Palaeozoic rocks of the area as Maitai and Te Anau Series of Carboniferous and Devonian age, respectively.

Fyfe (1929) gave an account of the physiography and geology of this area during the course of a geological survey of the Murchison and Maruia Subdivisions. A further account (Fyfe, 1930), is accompanied by a map showing an extension of the Wairau Fault crossing the Matakitaki River a mile south of Mole Stream. Fyfe correlated the Palaeozoic rocks with the Mount Arthur and Haupiri Series of North-west Nelson. He mapped the Tertiary conglomerate and sandstone of the Glenroy area as Longford Series, the uppermost of the four Tertiary formations which he recognised
in the Murchison region. The map of the Matakitaki Subdivision in Henderson and Fyfe (1935), the text of which has not been published, introduced the undefined term 'Rotoroa Igneous complex' for the acid plutonic igneous rocks of the area. For the schist, greywacke and argillite east of the Wairau Fault extension, these authors used a local term, 'Glenroy Series'.

The geological map of New Zealand (1948) shows the Palaeozoic rocks as Maitai and Te Anau Series, correlating them with the Upper Palaeozoic rocks of the East Nelson district. Wellman (1953) noted that this change in correlation was due to a later examination by Fyfe. This is supported by the finding of a single specimen of Orthoceras and numerous fragments of a prismatic shell, believed to be Atomodesma, in boulders of calcareous sandstone eroded from a high escarpment on the south bank of the Matakitaki River (Wellman, 1953).

Reed (1958) mapped the metamorphic zones in the schist east of the Alpine Fault. He found that the Biotite Zone is adjacent to the Alpine Fault in the Nardoo Ranges and that it terminates against the fault about two miles south of the Matakitaki River. Chlorite 3 Subzone schist occurring next to the fault north of this point. Grindley (Grindley et al., 1958) refers to the Rotoroa Igneous complex of Fyfe as 'Rotoroa Gneiss' and this unit is mapped over the major part of the area.
Waterhouse (1964) examined the area while preparing a bulletin on the Permian stratigraphy of New Zealand. He recognised all five formations of the Maitai Group as well as the Pelorous and Lee River Groups. This is the first publication to describe the stratigraphy of the upper Palaeozoic rocks of this area in any detail.

Bowen (1964) mapped the Maitai Group rocks of the Matakitaki Valley as a steeply dipping, partly overturned sequence. He considered them to be faulted against Rotoroa Igneous complex in the west, the eastern boundary being unaltered at its eastern contact with the Dun Mountain Formation.

SCOPE OF PRESENT WORK

The aim of this thesis has been to map the area defined above, and to describe its stratigraphy and structure.

The treatment of the Quaternary deposits has been limited to noting the existence of certain features which may be of interest to future workers in this area. This stems from a belief that the understanding of these deposits requires field-work over a much greater area than that undertaken by the writer. It is considered that the investigation of these deposits constitutes a comprehensive study in itself.

The upper Palaeozoic rocks of the Glenroy-Matakitaki area resemble, in lithology and succession, the Permian sequences in Nelson and Southland. Wellman (1953) and Waterhouse (1964)
have referred the Glenroy-Matakitaki rocks to the Maitai Group. The more detailed mapping carried out for this thesis shows that, in this area, the nature of some units differs from that in the standard sequence at Nelson. It has been deemed expedient, therefore, to erect a separate stratigraphic nomenclature for these rocks.

The nomenclature of Fyfe (1930) was found insufficient for the detailed mapping of the Tertiary rocks; thus new formations in the Tertiary rocks have been defined in this area. The Longford Formation (Fyfe, 1930) has, however, been retained.

The principle used in establishing type sections has been to select one which best demonstrates the rock types known to be typical of that formation, as well as, their stratigraphic relation to adjacent formations. In some cases no one section exhibits both the upper and lower contacts. Thus, when setting up formations in the Tertiary rocks, reference sections only have been named in these cases, in the belief that the formations are recognisable beyond the thesis area. Therefore at localities further removed there may be sections more suitable for establishing as type sections. Because the Permian formations are confined to this area, type sections are established even if contacts are not exposed therein.

The Glenroy-Matakitaki area lies within the Alpine Bend, as defined by Kupfer (1964, p. 688). For this reason, the elucidation and interpretation of its geological structure has considerable regional significance. However, the area forms
but a small part of the Alpine Bend region; the structure of the remainder being, as yet, poorly known. Thus little more than a description of the structure of the area mapped, is attempted. Relation of the structure of this limited area to the problems of Alpine Fault tectonics and to the structure of the Permian rocks of Nelson and Southland is considered to be beyond the scope of this thesis. It should too, await further investigation of the Alpine Bend region.

MAPPING

The geology of the larger streams was recorded by pace and compass traverses; the same method being used to locate features in densely forested country by means of traverses to known points. Aerial photographs and compass resection of trigonometrical stations were used for locating features in some cases. Magnetic compass error in Station Creek was checked by means of a sun compass. The maximum error observed was 5 degrees.

The information obtained in this manner was plotted onto a base map (scale 1:15840) prepared from NZMS 1 sheets and corrected from pace and compass data and aerial photographs.

A general lack of geographic names in this area has necessitated the use of the names of some settlers for rock-stratigraphic units.

In the text, petrological thin section numbers prefixed
by 'UC' are housed in the Geology Department, University of Canterbury. Microfossils have both N.Z. Fossil Record Form numbers and UCF numbers and are in the collections of the Geology Department, University of Canterbury. Macrofossils have N.Z. Fossil Record Form numbers and are in the collections of the N.Z. Geological Survey, Lower Hutt.

Mapping symbols appear in parentheses after the heading of each formation.

Grid references given in the text, are in terms of the national 1000 yard grid system.

ACKNOWLEDGMENTS

The writer wishes to thank the following persons:-

The teaching staff of the Geology Department, University of Canterbury, who have discussed various aspects of this thesis with the writer. In particular, Dr. M. Gage, Professor of Geology, for valuable discussion in the field and during writing; Dr. M. J. Frost, Senior Lecturer, for assistance with petrography and helpful discussion of the petrology.

Dr. W. D. Sevon and graduate students who accompanied the writer in the course of field work.

Mr. D. J. Jones, Senior Technician, for advice and assistance with photography.
Mr. N. deB. Hornibrook and Mr. P. A. Maxwell, N.Z.G.S., for determinations of microfossils and macrofossils respectively.


Mr. M.R.J. Ford, Surveyor, for the compilation of sun compass tables.

Mr. and Mrs. L. Foulsham, Glenroy; and the brothers Oxnam, Murchison; for the generous provision of accommodation during the field work.

Special thanks are due to all the residents of the Glenroy district for their friendly interest and for the kind hospitality extended to the writer.
PART II - SEDIMENTARY ROCKS

PRE-PERMIAN ROCKS

Nardoo Formation (n)

Definition and type section

The name Nardoo Formation is given to the beds of massive siltstone and sandstone which crop out on the western flanks of the Nardoo Range. The Nardoo Formation includes all the strata between the Station Creek Formation, against which it is faulted, and the Alpine Fault.

The type section is located in a north-westward flowing tributary of Station Creek, which joins the latter about 160 chains above the Matakitaki - Station Creek confluence.

Distribution and thickness

The formation crops out on the western slopes of the Nardoo Range west of the Alpine Fault trace, and in the headwaters of Station Creek.

The maximum thickness present is 5,200 feet but it is not known to what extent this figure is affected by intraformational deformation.

Lithology

In the type section the formation is seen as a sequence of massive and strongly-indurated siltstone and fine
to medium-grained sandstone. All the rocks have a distinctly green colour. Bedding is visible in some of the western outcrops and an incipient schistosity is apparent nearer to the Alpine Fault. Quartz-epidote veins are common and these occur as broad zones of closely spaced sub-parallel veinlets. Thicker veins cut across the veinlet zones and both become more common in the proximity of the Alpine Fault. The strike of the veinlet zones is generally parallel to that of the fault. Most of the rocks show some effects of shearing, the intensity of which increases toward the fault.

Isolated bands of grey low-rank schist are interbedded with less schistose green sandstone in the upper reaches of Station Creek.

**Relation to adjacent formations**

The western boundary of the formation is the Alpine Fault, where it is in contact with the Haast Schist Group. A zone of crushed and shattered rock extends westward from the contact for about 1,000 feet.

The contact with the Station Creek Formation is along a series of faults arranged in a zig-zag pattern. The faults have pugs up to 6 inches thick and dips of greater than 60 degrees.

The Nardoo Formation appears to be a block of north-
northeast striking sediments dipping steeply toward the Alpine Fault. Its structural attitude is consistent with it being the beds which may once have conformably underlain the Station Creek Formation. This implies that the beds of the Nardoo Formation are overturned.

Mode of formation

The lithology of the formation suggests that the beds are a geosynclinal deposit. Low-grade regional metamorphism aided perhaps, by minor cataclastic effects, has raised their metamorphic rank to the Chlorite 1 and Chlorite 2 Subzones of Turner (1935).

Age and correlation

The lithology and apparent stratigraphic position of the Nardoo Formation suggests a possible correlation with the upper part of the Pelorous Group of Nelson (Waterhouse, 1964). This may be extended to the Tuapeka Group of Southland (Wood, 1956). Waterhouse (1964) has provisionally assigned these groups a pre-Permian, possibly Carboniferous age, on the basis of their apparent position in sequence and their lack of Atomodesma.
PERMIAN ROCKS

Introduction

Rocks believed to be of Permian age crop out in the north and central parts of the Glenroy-Matakitaki area. The moderately to highly-indurated strata comprise a conformable sequence. The rock types and their relationships to one another, are indicative of essentially continuous deposition in a marine environment.

These rocks have been mapped as five formations; in two of these formations, members have been recognised.

The writer did not find fossils in these rocks, although previous workers, Wellman (1953) and Waterhouse (1961), have found fragments of the Permian pelecypod Atomodesma. With one exception, these occurrences were not in situ; however the lithologies of the rocks containing them, as described, are characteristic of these formations. Wellman also found a single specimen of Orthoceras and this demonstrates that the rocks are not younger than Triassic.

The lithology and stratigraphy of the sequence resembles the Maitai Group of Nelson and the Bryneira Group of the Hollyford-Eglinton area. Both these groups have long been recognised as being of upper Permian age; probably Kungurian and Tartarian (Waterhouse, 1963).
Structurally, the Permian rocks of the Glenroy-Matakaitaki area comprise an overturned block with generally steep dips to east-southeast and younging westward. In the west, subsidiary faulting has created smaller blocks, some of which are 'right way up', and has also infaulted middle-Tertiary sediments into the sequence.

Potberry Formation (po)

Definition and type section

The name Potberry Formation is applied to beds of tuffaceous sandstone, basic lava, hematitic conglomerate, and siltstone at the base of the Permian sequence. It includes all the strata between the lowest limestone bed of the overlying Matakaitaki Limestone and the microgabbro of the Baldy Microgabbro.

The formation is poorly exposed for it crops out in some of the steepest and most heavily forested country of the area. The type section is located on the ridge trending northeast from Baldy to the limestone bluffs (Grid. Ref. S32/684415) southwest of the mouth of Station Creek.

Distribution and thickness

The Potberry Formation forms a continuous belt lying to the east of the prominent outcrops of the Matakaitaki Limestone. It extends from Station Creek through the headwaters
of Potberry Creek to where it pinches out 20 to 30 chains south-southwest of Mount Gaultheria. The greatest thickness, approximately 1,100 feet, is at the type section. Southwestwards from the type section the formation gradually thins to less than 200 feet where it crosses the Mount Gaultheria-Sub Baldy ridge.

**Lithology**

The formation consists of massive, medium to coarse-grained tuffaceous sandstone; lenses of hematitic conglomerate and beds of laminated, slightly calcareous siltstone and mudstone Basic lava is interbedded with the tuffaceous sandstone and conglomerate. In the poorly exposed type section the following sequence was recorded.

<table>
<thead>
<tr>
<th>Matakitaki Limestone</th>
<th>Approximate Thickness (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey, finely-laminated siltstone and</td>
<td>100</td>
</tr>
<tr>
<td>mudstone, calcareous near the top</td>
<td></td>
</tr>
<tr>
<td>Grey and green tuffaceous greywacke</td>
<td>400</td>
</tr>
<tr>
<td>and sandstone</td>
<td></td>
</tr>
<tr>
<td>Red, highly-indurated, hematitic</td>
<td>200</td>
</tr>
<tr>
<td>conglomerate</td>
<td></td>
</tr>
<tr>
<td>Basic lava, grey and green tuffaceous</td>
<td>300</td>
</tr>
<tr>
<td>sandstone</td>
<td></td>
</tr>
</tbody>
</table>

Baldy Microgabbro
(underlies)
The most distinctive rock type of the Potberry Formation is the hematitic conglomerate which is conspicuous in the alluvium of Potberry and Station Creeks. This highly-indurated conglomerate consists of poorly-sorted, sub-angular rock fragments ranging in size from 0.5 to 10 cm., the majority lying within the 2 to 6 cm. range. Volcanic rocks are the predominant constituents, greywacke and jaspillite are present in minor amount only; no plutonic rock fragments have been observed. In hand specimen, most of the volcanic rock fragments appear to be dark, basic, porphyritic and amygdaloidal lavas. Less abundant fragments of a green, extremely fine-grained rock are also present and these are possibly acidic lavas. No microscopic examination of these rocks was undertaken and in hand specimen the fragments appear to be little weathered. The matrix is finely-divided hematite which has penetrated some of the rock fragments along fractures. Rock fragments of 1 mm. diameter and less are distributed through the matrix. The conglomerate is not obviously bedded and appears to occur as lenticular bodies at several horizons in the lower and middle parts of the formation. It is not seen in the Mount Gaultheria-Sub Baldy ridge section.

The basic lava is more widespread than the conglomerate although occurring at similar places in the sequence. It crops
out interbedded with tuffaceous sandstone 80 feet below the top of the formation near Station Creek; near the base of the type section; in the middle of the formation in the headwaters of Potberry Creek and at the base of the Mount Gaultheria-Sub Baldy ridge section. The lava is typically basaltic in hand-specimen, some specimens show amygdaloidal texture. It appears similar to the fragments of basic volcanic material in the hematitic conglomerate. No obvious pillow forms were found but its occurrence, interbedded with marine sediment, suggests that the basic lava is probably spilitic in character.

The youngest beds of the formation are moderately-to strongly-indurated fissile grey siltstone and mudstone. They are finely laminated and become progressively calcareous toward the base of the overlying limestone. These beds are best exposed in bluffs near Station Creek where siltstone and mudstone overlie tuffaceous sandstone and basic lava. These strata everywhere form the top of the formation and are of almost constant thickness.

Relation to underlying beds

No clear exposure of the contact of the Potberry Formation with the Baldy Microgabbro was seen. The base of the formation was mapped as the most western exposure of
microgabbro. The contact is nonconformable and, as stated elsewhere, is considered to be intrusive.

Mode of formation

For reasons which follow, this formation is believed to be the result of progressive marine transgression onto a shallow shelf-area prior to the deposition of the overlying deep-water limestone.

Early in the history of deposition, basic lava was emplaced on and in the sediments of the sea floor. Although the field relations of conglomerate and lava are obscured, they are closely associated and probably of contemporaneous origin. The sub-angular shape and volcanic origin of the conglomerate pebbles suggests that they were derived locally by submarine erosion. Wave action may have partially rounded the debris eroded from lava masses extruded on areas of the sea-floor above wave-base. Deposition of this material was probably around the base of the lava masses. The introduction of large amounts of hematite into the conglomerate matrix may have resulted from volcanic activity continuing after deposition. Although no volcanic rocks similar to the green fine-grained fragments in the conglomerate were found associated with the sediments, the low rounding of these fragments suggests that they have been derived in a similar manner.
These are essentially intraformational conglomerates, the formation of which did not necessarily require either variation in sea-level or major tectonic activity at the time of deposition. Grindley (1958) has suggested a similar origin of the red and green conglomerates in the Livingstone Volcanics.

Typical marine-shelf sedimentation followed deposition of the conglomerate bodies. Immediately above them the sediments are tuffaceous and coarse-grained, indicating a near source of clastic and pyroclastic materials. Higher in the sequence, the transition to a deeper-water environment is indicated by the presence of argillaceous sediments which become calcareous toward the top of the formation.

**Age and correlation**

Hematitic conglomerate and breccia are known from below the base of the Wooded Peak Limestone in Nelson (Waterhouse, 1964) and from the top of the Livingstone Volcanics in the Eglinton Valley (Grindley, 1958). The Livingstone Volcanics underlie the Howden (limestone) Formation at the base of the Bryneira Group. Lauder (1965a) has mapped the Nelson breccias as the Rangitoto Volcanic Breccia Member of his Rangitoto Formation. On grounds of lithology and of stratigraphic sequence, the red conglomerates of the Potberry Formation are correlated with those in the upper part of the
Livingston Volcanics and with the Rangitoto Volcanic Breccia Member of the Dun Mountain area. The lower 300 feet of the Potberry Formation, containing tuffaceous sandstone and basic lava, is tentatively correlated with the Little Twin Member of Lauder (1965). If these correlations are correct, the formation is of Hungurian age (Waterhouse, 1963 (Table 2)).

It is noteworthy that the upper 100 feet of grey siltstone of the Potberry Formation is not known in either the Nelson or the Southland sequences. In both areas the red breccias, where present, are overlain directly by limestone formations. Lauder considers the Rangitoto Volcanic Breccia to be a basal conglomerate of the Maitai Group, indicating erosion and disconformity between the Maitai and Te Anau Groups. In the Eglinton Valley however, Grindley (1958) states "there is little evidence for a break in sedimentation at the base of the (Howden) formation". The Potberry Formation grades upward into the Matakitaki Limestone with no indication of a sedimentary break. Consequently, if the spilitic volcanism of the three areas were contemporaneous, the base of the Matakitaki Limestone would perhaps be younger than the base of the Wooded Peak Limestone. The upper 100 feet of the Potberry Formation may thus represent some of the time missing from the Nelson succession, in which case the disconformity noted by Lauder (1965a) would have only local significance.
Matakiki Limestone (ma)

Definition and type section

The name Matakiki Limestone is given to thinly-bedded limestone which overlies the Potberry Formation in the northeast and central portions of the area. It includes all the strata between the lowest non-calcareous beds of the overlying Wheeler Formation (or the Gorge Shale Member, where present) and the lowest occurrence of thinly-bedded limestone overlying the Potberry Formation.

The type section is in the bluffs (Grid Reference S32/88h15) southwest of the mouth of Station Creek. The base of the formation is well shown at this locality; the contact with the Wheeler Formation is best seen in the head of Potberry Creek.

Distribution and thickness

The Matakiki Limestone crops out in prominent bluffs which are actively shedding talus, and as hog-back ridges on the south bank of the Matakiki River and north of the gorge in Wheeler Creek. Its outcrop pattern is a sinuous belt extending from near the mouth of Station Creek, through the headwaters of Potberry and Wheeler Creeks and into the northern slopes of the East Branch Glenroy Valley where it terminates.
against the Branch Fault. The curvature in outcrop is believed due to apparent dextral transcurrent offset on the Hunter and Baldy Faults.

The formation is of almost uniform thickness (1,100 feet) except at the type section where it is only 600 feet thick.

The Matakitaki Limestone also crops out as a low hill on the north bank of the Matakitaki River, a quarter of a mile east of Mole Stream.

**Lithology**

The Matakitaki Limestone has a distinctive and generally uniform lithology. Thin beds of fine-grained limestone, usually 1 to 2 cm. thick, alternate with non-calcareous argillaceous laminae which rarely exceed 1 cm. in thickness, (Fig. 2).

The limestone beds are uniformly fine-grained and vary in colour from cream to grey, green and, rarely, pink. In thin section (UC 5262) the limestone is comprised of fine-grained calcite with rare minute grains of quartz. No fossils have been found and there are no features to suggest that the limestone is other than a well-cemented lime-mud deposit.

The argillaceous laminae are green in colour, display a bedding schistosity and show a micaceous sheen on the schistosity planes. In the northern outcrops of the Matakitaki Limestone,
Figure 2. Thin-bedded Matakitaki Limestone, 100 yards north of the gorge in Wheeler Creek. The small-scale folds are confined to this locality.
these laminae carry parallel joints perpendicular to the
bedding planes. The joints are filled with cross-fibre calcite
veins up to 2 mm. wide. They are confined to the argillaceous
laminae and are interpreted as pull-apart or tension gashes
related to folding of the limestone.

In weathered outcrop, the limestone beds are seen to
be very finely laminated in thicknesses of $\frac{3}{4}$ to 1 mm.;
differential weathering etching out the more calcareous laminae.
This fine lamination imparts a rough fissility to the limestone
beds.

In outcrop, the bedding and lamination of the lime-
stone is more or less continuous and varies little in thickness.
Gentle crenulations in the bedding of some outcrops near the
Wheeler Creek Gorge are probably of tectonic origin.

**Relation to underlying beds**

The base of the Matakitaki Limestone, within six feet
of Baldy Microgabbro, is exposed at the head of Wheeler Creek.
Details of the contact, which is thought to be intrusive, are
described elsewhere. North of Wheeler Gorge the limestone is
conformably underlain by the Potberry Formation. The silt-
stone and mudstone of the Potberry Formation become calcareous
in the upper six feet and grade rapidly into the Matakitaki
Limestone.
Mode of formation

The rhythmic deposition of the Matakitaki Limestone is well shown by the regular thin bedding. Macro-organisms appear to have contributed little, if any, material to the beds. It is likely that burrowing organisms were entirely absent, for the fine-scale laminations would have been reworked.

The presence of argillaceous sediments above and below the limestone and its gradation into them, suggests that carbonate deposition was a process introduced into a sedimentary environment which normally favoured the deposition of muddy and clayey sediments. The continuation of this 'normal' type of deposition, between episodes of carbonate deposition, is shown by the presence of the argillaceous laminae. The conditions leading to the rhythmic deposition of lime-mud are not well understood.

The limestone appears to have been deposited as a continuous veneer during each episode and was not reworked by wave, current or organic agencies. This indicates deposition in generally deep-water conditions, probably near the edge of a continental shelf.

Age and correlation

By reason of its calcareous nature and its position in the sequence, the Matakitaki Limestone may be correlated with the Wooded Peak Limestone (Waterhouse, 1964) and with the
Howden Formation (Grindley, 1958).

In some respects however, the lithology of the Matakitaki Limestone is similar to that of the Malita Limestone in Nelson. This is described (Waterhouse, 1959) as "alternating thin pink and thicker green limestone in layers \(\frac{1}{2}\) in. thick". The stratigraphic relationship of the Malita Limestone is uncertain. In Waterhouse (1959) the Malita Limestone is mapped higher in the sequence than the Wooded Peak Limestone and everywhere separated from it by the Roding Green Sandstone. Later (Waterhouse, 1961h) he extended the usage of 'Wooded Peak Limestone' to include all the strata between the base of the Tranway Sandstone and the ultrabasic rocks in the Nelson area. He noted the occurrence of the Malita Limestone lithology but did not comment on its position in the sequence; or describe its relationship to the major rock type of the Wooded Peak Limestone, the massive grey foetid limestone, a lithology not seen in the Matakitaki Valley. The Matakitaki Limestone and the Wooded Peak Limestone may perhaps be related by facies.

Lauder (1965a) describes and figures a lithology similar to the Matakitaki Limestone as the Rangitoto Marble Member. These two units are therefore correlated on lithologic grounds.

Waterhouse (1963, 1964) has assigned the Wooded Peak Limestone an early Kazanian age by correlation with dated Arthurton beds in Southland and the Waipapa Limestone of North-
land. If correlation with the Wooded Peak Limestone is correct, then the Matakitaki Limestone may represent some part of Kazanian time.

Wheeler Formation (w)

Including Gorge Shale Member (w.e.)

Definition and type section

The name Wheeler Formation is applied to the sequence of interbedded sandstone and siltstone which overlies the Matakitaki limestone. It includes all the strata lying between the lowest non-calcareous argillite and the lowest maroon and green siltstone bed of the overlying McNee Formation. The type section is in Wheeler Creek; from 100 chains above its mouth, thence upstream to the Wheeler Gorge.

The Gorge Shale Member includes the beds of dark-coloured shale at the base of the Wheeler Formation. The type section for this member is the upper 50 chains of the type section for the Wheeler Formation.

That part of the Wheeler Formation exclusive of the Gorge Shale Member will be referred to as the 'undifferentiated beds' of the formation.
Distribution and thickness

The Wheeler Formation is exposed on the south bank of the Matakitaki River for about 30 chains east of Trig FS; in Potherry Creek; and the greater part of the watershed of Wheeler Creek. It ranges in thickness from 2,300 feet in the area of Trig FS to a maximum of 3,400 feet near the head of Wheeler Creek.

The Gorge Shale Member of the Wheeler Formation has its greatest thickness (2,800 feet) in Wheeler Creek; is not present in Potherry Creek but is exposed on the south bank of the Matakitaki River where it is 800 feet thick.

Lithology

The rocks comprising the undifferentiated beds of the Wheeler Formation are, in general, composed of well-bedded fine-grained clastic material. The dominant rock type is a rhythmic succession of thinly-bedded grey siltstone and fine-grained sandstone, the beds often being separated by thin laminae of black argillite. In the higher part of the formation, massive beds of grey-green sandstone occur between sequences of bedded siltstone and sandstone. All rocks are strongly indurated.

Graded bedding is often prominent in the thin-bedded sandstone and siltstone, current bedding is relatively uncommon.
Mud balls and mud-flake breccias occur at the base of some massive sandstone beds. The 'mud' is a grey argillite similar to that of the interbedded siltstone strata.

The thickness of beds and laminae varies throughout the formation, although individual beds maintain constant thickness along their observable length. Graded beds range between $\frac{1}{2}$ and 10 cms. in thickness; those of more uniform size grades tend to be the thicker strata. Argillaceous laminae seldom exceed 1 mm. in thickness.

In thin section (UC 5263) the thin-bedded sandstone is seen to be poorly sorted and composed of nearly equal amounts of quartz, plagioclase feldspar, and argillite fragments. The clayey matrix contains sparse flakes of biotite. Some recrystallisation of the matrix is indicated by the textural relationships of chloritic matter and sericite to the clastic components. The siltstone portion visible in the thin section contains much angular quartz. Carbonaceous material is common in the thin argillaceous laminae between the siltstone and sandstone beds.

The Gorge Shale Member is lithologically uniform; the rock type is a dark-grey to black, finely laminated mudstone. It has a prominent fissility parallel to the bedding and its induration approaches that of argillite. The laminae are generally thicker than 2 mm.; and on fresh bedding planes
a phyllitic sheen is often conspicuous when weathering has not produced a dark-brown coating, probably of limonite.

Relation to underlying beds

Near the head of Wheeler Creek, fissile mudstone of the Gorge Shale Member grades down into thin-bedded Matakitaki Limestone over a distance of 20 to 30 feet - the argillaceous laminae gradually become thicker and more calcareous until they disappear.

In Potberry Creek, the Gorge Shale Member is not present but the gradation from Wheeler Formation into Matakitaki Limestone is pronounced - the sandstones become progressively more calcareous until they are sandy limestones; finally only pure limestone is present. Argillaceous laminae characteristic of the Matakitaki Limestone closely resemble laminae in the Wheeler Formation.

Mode of formation

The Gorge Shale Member appears characteristic of the black shale facies (Fettijohn, 1957). Although pyrite crystals are not visible, limonite weathering products indicate a significant iron content. Hence the unit was most probably deposited under anaerobic conditions. The thickness and restricted areal extent of the Gorge Shale Member suggests that deposition occurred in a deep local basin; but whether this basin was barred from the
sea by a rising barrier or created by uneven subsidence of a
continental shelf, is in some doubt.

The undifferentiated beds of the Wheeler Formation
show rhythmic deposition of 'greywacke and argillite' similar
to the turbidity current deposits described by Kuenen and
Migliorini (1950). It has been suggested (Waterhouse, 1964)
that a pulsating type of turbidity current deposited the
Greville Formation, a correlative of the Wheeler Formation.
The present author finds that, apart from the graded nature of
the sandstones and their rhythmic succession, there is little
evidence to prove whether or not turbidity currents were active
during the deposition of the Wheeler Formation. It may be that
the hypothesis of an intermittently subsiding basin and bar
(Kingma, 1958) actually applies. Rhythmic deposition also
appears to have prevailed during the deposition of the under-
lying limestone and this might be interpreted as evidence
against a turbidity current origin.

Wellman (1952), Grindley (1958) and Waterhouse (1964)
have commented on the resemblance of laminations, in correlatives
of the Wheeler Formation, to glacial varves. The two latter
authors find no evidence for this mode of origin in the Tapara
and Greville Formations; nor does the present author in the
Wheeler Formation.
Age and Correlation

Owing to variations in the interpretation, by different workers, of the Nelson and Hollyford-Eglinton Permian sequences, correlation of the Wheeler Formation is not entirely clear. Simply on the basis of lithology the undifferentiated beds of the Wheeler Formation may be correlated with the Tapara Formation of the Eglinton Valley (Grindley, 1958) and with the Greville Formation of the Nelson district (Waterhouse, 1964). However, in the Nelson sequence a 'Tramway Sandstone' occurs between the Greville Formation and the underlying Wooded Peak Limestone. In the Eglinton Valley, Waterhouse (1964) described an 'Annear Sandstone' unit from between the Tapara Formation and the underlying Howden Formation which is a correlative of the Matakitaki Limestone; he correlated the Annear Sandstone with the Tramway Sandstone. Beck (1964) mapped the Tramway Sandstone with the Wooded Peak Limestone and correlated both units with the Howden Formation.

The rock types of the Tramway Sandstone include dark-grey laminated siltstone which may be represented by the Gorge Shale Member in the Matakitaki area. Thus it is proposed that the Gorge Shale Member is simply a facies variant of the Tramway and/or Annear Sandstone units.

Lauder (1965a) has mapped the Greville Argillite in the Dun Mountain area and the Gorge Shale Member may be correlated with part of that formation.
Tentative lithologic correlation with the Permian sequences of Nelson and of Southland suggest that the Wheeler Formation is upper Kazanian in age.

**McNee Formation (mn)**

**Definition and type section**

The name McNee Formation is given to the laminated maroon and green siltstone and sandstone overlying the Wheeler Formation. It includes all the strata lying between the lowest maroon and green siltstone bed and the lowest conglomerate or coarse-grained sandstone bed of the overlying Yorkey Formation.

The type section is at Trig FS on the south bank of the Matakitaki River, a mile west of Station Creek.

**Distribution and thickness**

At the type locality, the formation is 600 feet thick and crops out on the eastern slopes of the south-trending ridge on which Trig FS is situated. The McNee Formation extends southward from the river for about 40 chains and is believed to terminate against the Hunter Fault. Apart from an outcrop, 15 feet thick, in the bed of Wheeler Creek, the formation is not known at any other locality. It is probable that the beds of the McNee Formation are not laterally continuous.
Lithology

The rock type of the McNee Formation is distinctive and uniform. It consists of strongly-indurated and interlaminated maroon siltstone and green fine-grained sandstone and siltstone.

The laminae are thin (1 to 5 mm thick) and even in handspecimen they are quite discontinuous. They are grouped into beds of 3 to 4 cms., thickness. This gives the rocks a prominent bedding-plane fissility. The beds are not fissile within themselves due to the interfingerering of the constituent laminae.

Relation to underlying beds

No contact with the Wheeler Formation was observed owing to soil and vegetation cover. The similar attitude of the beds of the McNee Formation to nearby strata of the Wheeler Formation, suggests that the contact is conformable.

Mode of formation

The origin of these rocks in other areas of Permian outcrop has been much discussed; even so it is still in some doubt. While little new data is presented, the current study suggests a possible reinterpretation of that already available.

Grindley (1958) and Waterhouse (1964) have favoured deposition associated with volcanism. Other than not requiring direct deposition from ash-showers, these authors do not state the relationship between the sediments and their hypothetical volcanic source. Reed (1957) concluded that the red and green argillites in the Lower Mesozoic rocks of Wellington were
affected by volcanic solutions apparently derived from submarine lava. In none of the three areas of upper Permian sediments is there any evidence of submarine volcanism at or after the time of deposition of the maroon and green laminated argillite sequences.

Reed (1957) quotes analyses of red and green argillites from the Waiua Formation (Maitai Group) of Nelson. Both the red and green beds have a similar total iron content of about 7%. It is the FeO/Fe₂O₃ ratio which varies with colour; 1:2 in the red beds, 3:1 in the green beds. Thus colour is dependent upon the prevailing oxidation state of the iron content in the laminae. With regard to mode of formation, this may be interpreted in at least two ways:—

1) The sediments were deposited at a site which alternately favoured oxidising and then reducing conditions, but to which the supply of iron remained constant.

2) A variation in the amount of oxidation suffered by ferriferous detritus during transport.

The second interpretation is favoured, for the following reason. The green laminae are generally of coarser grain than the maroon; hence this may indicate a greater rate of erosion and transportation of the clastic material comprising the green laminae, with consequently less opportunity for oxidation, compared with the finer grained maroon laminae. This implies that the source rocks had a high initial FeO/Fe₂O₃ ratio; this condition could be fulfilled by the basic volcanic rocks of the Brook Street Volcanic
Group which crop out on the western margin of the Permian rocks of the Nelson district.

The site of deposition was probably close to wave base and subject to currents of varying strength and direction, thus favouring deposition of irregular laminae. The $E_h$ of such an environment of deposition is likely to have been sufficient to maintain the oxidation state of ferric iron supplied to it, without causing substantial oxidation of ferrous iron.

**Age and correlation**

On the basis of stratigraphic position and of lithology, the McNee Formation is correlated with the Waiua and Winton Formations of the Nelson and the Hollyford - Eglinton Permian sequences, respectively. The distinctive lithology of these formations renders them useful stratigraphic marker-beds in those areas. The probably lenticular nature of the McNee Formation makes this aspect less reliable in the Matakitaki - Glenroy area.

**Yorkey Formation (y)**

*Including Hut Flat Conglomerate Member (y,h)*

*and Branch Siltstone Member (y,b)*

**Definition and type section**

The name Yorkey Formation is given to the sequence of conglomerate, coarse and fine-grained massive sandstone, red and green bedded siltstone, pebbly sandstone and sandstone with argillite laminae which overlies the McNee Formation. Its overall
lithology is dominated by an abundance of coarse-grained clastic material, deposited in thick and discontinuous beds and lenses. This feature has been used to distinguish it during mapping, as the underlying formations are predominantly fine-grained and well-bedded.

The base of the Yorkey Formation is defined as the top of the highest maroon and green bed of the MoNee Formation or, where this is not present, the highest thin-bedded siltstone and sandstone beds of the Wheeler Formation. The top of the Yorkey Formation cannot be stratigraphically delineated for the upper beds have been intruded by the Woodham Granite.

The type section is in the valley of the East Branch Glenroy River, from 100 to 220 chains upstream of the bridge. This section is approximately parallel to the regional dip direction.

The Yorkey Formation includes two members; the remainder of the formation being referred to as the 'undifferentiated beds'.

The Hut Flat Conglomerate Member (y.b) is the massive conglomerate which overlies the MoNee Formation near Trig FS. The type section is from Trig FS westward for 12 chains. At this locality it is the basal strata of the Yorkey Formation.

The Branch Siltstone Member (y.b) is the sequence of well-bedded red and green siltstone which crops out in the East Branch Glenroy River. The type section is in the bed of the East Branch Glenroy River, between 20 and 30 chains downstream from the Woodham Fault.
Distribution and thickness

The Yorkey Formation has the greatest extent of any of the Permian formations in the Glenroy-Matakiteki area. It crops out over much of the area between Wheeler Creek and the East Branch Glenroy River and extends southwest to the watershed of Double Creek where it terminates against the Woodham Fault in the south, and the Woodham Granite to the west. A small outcrop area is present on the south bank of the Matakiteki River, north of the Hunter Fault. A maximum thickness of 6,500 feet is estimated in the type section; this may be an excessive value due to repetition by complex faulting.

The Hut Flat Conglomerate Member has been recognised only at its type section where it is 700 feet thick. It is believed to extend southwest to the Hunter Fault.

The Branch Siltstone Member occurs discontinuously within the formation and may also be of variable stratigraphic position. At its type section the member is 250 feet thick. It is also known to crop out on the ridge between Wheeler Creek and the East Branch Glenroy River, where it is 50 to 100 feet thick; and in the north branch of Double Creek immediately west of the Woodham Fault, where it is 50 feet thick.

Lithology

The Yorkey Formation is the most diverse unit of the Permian rocks. It is characterised by an abundance of coarse-grained clastic material which generally appears to be lenticularly bedded; similar rock types are repeated throughout the formation. Finer-grained strata are interbedded with those of coarser grain;
the most conspicuous being the Branch Siltstone Member. The
difficulty of determining the sequence is increased by local
faulting which has rotated some blocks to a 'right way up'
position in a generally overturned sequence. Exposures are not
continuous and sections in different creeks cannot be correlated
on account of the lenticular nature of the strata.

The Hut Flat Conglomerate Member is a massive body of
round-stone conglomerate. The constituent pebbles, cobbles and
boulders are of greywacke, quartz and fine-grained volcanic rocks.
They are tightly packed in a highly-indurated sandy matrix.
The deposit is not well-sorted, the smaller pebbles and cobbles
usually occurring as a matrix about the larger boulders. Minor
sandy lenses are present at the base.

The Branch Siltstone Member lithologically resembles the
McNee Formation for it too, is characterised by the presence of red
and green siltstone. The Branch Siltstone Member is distinguished
by its much thicker bedding and by the lack of lamination within
the beds; it is a more regularly stratified unit. Each bed is of
uniform colour; they range in thickness from 4 to 50 cms. and any
one bed is generally of constant thickness throughout its observable
length. In thin sections (UC 5264, UC 5265) the rock is seen to
be a siltstone comprised of very angular quartz grains set in a
clayey matrix. The green beds contain much chamosite in fine-
grained aggregates of oblate shape. Most chamosite shows partial
alteration to calcite. Scattered grains of magnetite and hematite
are present in the matrix of the green siltstone and these may be 
ferriferous products derived from the alteration of chamosite.

In the undifferentiated beds of the Yorkey Formation 
the rock types represented are: conglomerate, coarse-grained 
angular sandstone, pebbly sandstone, green massive fine - to 
medium-grained sandstone, laminated 'greywacke and argillite' and 
massive grey siltstone. All rocks are highly indurated.

Conglomerate bands up to 20 feet thick occur in many 
places. They are made up of well-rounded pebble-sized fragments 
of the same rock types as in the Hut Flat Conglomerate.

Green-grey coarse-grained sandstone, comprised of 
angular chips of quartz set in an argillaceous matrix, is 
common in the East Branch Glenroy River. Similar sandstone 
containing rounded pebbles of undetermined composition is also 
present.

One of the most common rock types is a blue-green 
massive fine to medium-grained sandstone having an uneven 
fracture. Breakage of this rock exposes small areas of brown 
(? limonite) stained surfaces, possibly resulting from the weather-
ing out of shell fragments.

Laminated greywacke and argillite sequences with inter-
bedded sandstone of coarser grain are locally present. Occasionally 
these rocks exhibit flame structures between argillite and overlying 
greywacke beds; this has been used to determine directions of
younging. Some of these beds show intraformational deformation.

Thick beds (order of 100 feet) of a massive dovegrey siltstone occur above and below the Branch Siltstone beds.

Thin section (UC 5266, UC 5267, UC 5268, UC 5269) examination of the undifferentiated beds indicates that the majority of the sandstones fall within the volcanic wacke class of Gilbert (1954). The rock fragments are predominantly rhyolite together with minor amounts of microgranite. Fragments of sodic plagioclase are common, quartz fragments being less abundant. The matrix is generally recrystallised and often contains a mineral having the following properties:

- Clusters of tabular grains
- Pleochroism, bright bluish-green to pale yellow-brown or colourless
- High relief
- Middle second order interference colours
- Parallel extinction

This is thought to be a variety of lawsonite or pumpellyite.

Relation to underlying beds

The contact of the Yorkey Formation with the underlying McNeel Formation was seen only at Trig FS. Here the Hut Flat Conglomerate Member rests directly upon laminated siltstone of the McNeel Formation. The contact is sharp and apparently conformable; it is illustrated by Fig. 3. The uppermost beds of the McNeel Formation are succeeded abruptly by conglomerate. The Hut Flat Conglomerate is overlain by a green coarse-grained massive sandstone which also has a sharp basal contact.
Figure 3. Vertically-dipping contact of McNee Formation (left) and Hut Flat Conglomerate Member (right), near Trig. FS on the south bank of the Matakitaki River.
At each of the outcrops of the Branch Siltstone Member, it is in conformable contact, both above and below, with a dove-grey siltstone which grades into the coarser-grained sediments more typical of the Yorkey Formation.

**Mode of formation**

It is evident that the Yorkey Formation records a considerable change in the manner of deposition of the Permian rocks. Deposition must have taken place in shallow water near to a source area that was rapidly supplying great quantities of poorly sorted sediment.

The sharply conformable contact of the Hut Flat Conglomerate and the McNeel Formation suggests that the change in sedimentation was quite abrupt. Rapid uplift in a source area that had long been stable may have caused sudden flooding of nearby sea-floor areas with well-rounded river and marine gravel derived from the foreland. Sub-aqueous slumping possibly contributed to the swift spreading of the gravels across the sea-floor.

During the deposition of the remainder of the formation, movements in the source area and in the geosyncline appear to have been quite irregular and perhaps subject to periods of quiescence. This is indicated by the occurrence of such diverse rock types as conglomerate and thick siltstone. A temporary return to conditions similar to those prevailing at the time of deposition.
of the McNee Formation, is suggested by the presence of the Branch Siltstone Member.

The sediments indicate that at the time of deposition of the Yorkey Formation, considerable tectonic activity was affecting both the source area and the geosyncline. It is probable that these were the initial movements of the orogeny which folded the sediments of the upper Permian geosyncline.

**Age and correlation**

The stratigraphic position of the Yorkey Formation indicates that it is probably a correlative of the Stephens Formation of Nelson and the Countess Formation in the Eglinton Valley. In both the correlative formations, conglomerate and coarse-grained sandstone are the typical rock types; it is thus likely that diastrophism affected the whole of the Permian geosynclinal system during the time of deposition of these formations. Red and green siltstone and argillite similar to the Branch Siltstone Member is known from both the Stephens and Countess Formations.

Waterhouse (1963, 1964) has tentatively assigned a Tartarian age to the Stephens Formation on palaeontological evidence; the Yorkey Formation is therefore probably of similar age.
TERTIARY ROCKS

Introduction

The rocks of Tertiary age in the Glenroy area have been subdivided into six formations, as follows:

Upper Tertiary
   Water Race Formation (35+ unconf.) Longford Formation (2000+ Glenroy Fault)

Middle Tertiary
   Priestman (2500)
   Foulsham (200)
   Horse Terrace (600)
   Double Creek (1,600)

Figures in parentheses are approximate stratigraphic thicknesses in feet.

Fyfe (1930) used the name 'Longford' to designate the youngest 'Series' in his four-fold classification of the Tertiary rocks in the Murchison Subdivision. He mapped most of the Tertiary rocks of the Glenroy area as Longford Series and assigned them an upper Tertiary age. Subsequently, Suggate (in Fleming, 1957) has referred to that unit as a 'Formation' and this usage has been adopted by Bowen (1964).

In this thesis, only the rocks west of the Glenroy Fault have been mapped as Longford Formation. Those to the east of the fault are almost entirely of lower or middle Oligocene age and may therefore be correlated with the Matiri Series (Fyfe, 1930). Four formations of this age have been mapped, two of them being lateral equivalents. A fanglomerate deposit (the Water Race Formation), which unconformably overlies the Oligocene strata, has not previously been mapped; it is of probable Pliocene age.
Double Creek Formation (dc)

Definition and reference section

The name Double Creek Formation is applied to massive silty sandstone and the enclosed lenticular fossiliferous limestone. It includes all the rocks of this lithology which lie immediately east of, and stratigraphically below, the lowest micaceous sandstone bed of the Foulsham Formation in the Fuchsia Gully–Double Creek area. The base of the formation is not defined for it is faulted out in all known cases. For that reason, a type section is not designated at present, but a convenient reference section is at the head of Fuchsia Gully and eastwards for 500 yards along the ridge to Trig LXI.

Distribution and thickness

The formation extends south–southeast from the reference section to the north branch of Double Creek and terminates several yards to the south against the Woodham Fault. Structure suggests that the formation extends north–northwest from the reference section, through an area of obscured outcrop, to near the Glenroy Valley road.

The formation also crops out as a separate structural unit in the East Branch Glenroy River, about 1½0 chains upstream from the bridge. Limestone strata are known only at the reference section.

Recognition of the Double Creek Formation beyond the reference section has been confirmed by the presence of Landon foraminifera in comparable rock types.
At the reference section, where the strata are vertical, the Double Creek Formation is 1,600 feet thick.

**Lithology**

The sequence at the reference section is illustrated in Chart 1. The dominant rock type is a brown moderately-indurated silty fine to medium-grained sandstone. The sandstone is massive and carries occasional shell fragments. Twenty feet east of the thinner limestone lens, several cobbles of grey moderately-indurated siltstone occur within the sandstone. Highly-weathered pebbles are present in silty sandstone in the easternmost part of the reference section.

In thin section (UC 5270) the sandstone is seen to be comprised of poorly-sorted angular grains with a size range of 0.10 to 0.25 mm., set in a clay matrix. Quartz is the predominant detrital component and plagioclase (An25-An28) is a minor constituent. Sparse grains of microcline, orthoclase and a microcrystalline quartz intergrowth (probably vein quartz) are also present. Fine flakes of detrital biotite, often altering to chlorite, occur interstitially. The rock is cemented by a thin coating of limonite on the sand-size grains.

The mode by point counter is:

- Quartz 31%
- Feldspar 10%
- Biotite 6%
- Matrix 53%

In the classification of Gilbert (1964) this rock is an arkosic wacke.
Two limestone lenses are interbedded with silty sandstone in the reference section. They have resisted weathering more than the surrounding sandstone and form prominent outcrops on the ridge. Shell fragments are abundant in some part of the limestone, in other parts it is quite crystalline. In thin section (UC 5061) the limestone is seen to contain algae, bryozoa and foraminifera in a fine-grained calcareous matrix with rare grains of quartz. Thin calcite veins are common.

The larger limestone lens is 70 feet thick and maintains this thickness for 100 yards along its strike before terminating quite abruptly. The smaller lens does not exceed 20 feet in thickness.

Fossils

Microfossils were extracted from the limestone by leaching in acetic acid, and from the sandstone by treatment with hypo and kerosene followed by crushing in a vice. They have been identified by Mr. N. de B. Hornibrook (N.Z.G.S.) and he has supplied the age determinations.

N.Z.F.R.F. S39/522 Limestone

Gaudryina convexa (Stache)

Uvigerina cf. canariensis (d'Orb.)

Gaudryina n.sp. elongate "Kaiataensis"

Semivulvulina capitata (Stache)

Lower Landon Series. The elongate Gaudryina is not known above Whaingaroan.

Dorothia minima (Karrer)
Semivulvulina capitata (Stache)
Arenodosaria antipoda (Stache)
Karreriella novozealandica Cushman

Landon Series.

N.Z.F.R.F. S39/524 Silty sandstone 150 feet east of limestone

Cyclammina cf. incisa (Stache)
Melonis maoricum (Stache)
Gyroidinoides cf. allani (Finlay)
Cibicides cf. thiara (Stache)
Cibicides perforatus (Karrer)
Quinqueloculina sp.
Arenodosaria antipoda (Stache)

Probably Landon Series.


Cyclammina cf. incisa (Stache)
Cassidulina cf. subglobosa (Brady)
Robulus loculosus (Stache)
Semivulvulina capitata (Stache)
Siphotextularia sp.
Nodosaria sp.
Gyroidinoides cf. allani (Finlay)

Probably Landon Series.
N.Z.F.R.F. S39/526  Siltstone in East Branch Glenroy River

Melonis doreeni (Hornibrook)

Semivulvulina capitata (Stache)

Gyroidinoides allani (Finlay)

? Cyclammina incisa

Landon Series

Fragments of a large thick-shelled oyster, Ostrea sp., also occur in the limestone. Similar oysters are common in some Landon limestones of Southland but their occurrence is probably so influenced by facies that they are of little stratigraphic value (Mr. P.A. Maxwell, written comm.).

Relation to adjacent formations

Except where it is conformably overlain by the Foulsham Formation in the west of reference section, the Double Creek Formation is faulted against the adjacent rocks. In the east of the reference section and in the East Branch Glenroy River, it is in fault contact with the Yorkey Formation of Upper Permian age.

Northwest of the reference section, beds of the Double Creek Formation are believed to be faulted against rocks of the younger Priestman Formation.

Mode of formation

The silty sandstone and the limestone of the Double Creek Formation both contain marine fossils. The formation is thought to have been deposited in a shallow sea which received sediment from a dominantly granitic landmass. The limestone lenses were probably shallow reef areas which favoured the growth of calcite-
secreting organisms in an environment comparatively free from detrital sedimentation.

It is probable that these rocks were deposited at the maximum of the Landon marine transgression.

**Age and correlation**

On the evidence of microfossils, a Landon age is adopted for this formation. The presence of an elongate *Jaudryina* in the limestone suggests an age not younger than Whaingaroan (Mr. N. de B. Hornibrook, written comm.) Other samples from the formation cannot be dated more precisely than Landon Series.

At the reference section there is no indication, by sedimentary structures, concerning the direction of face of the beds. The Double Creek Formation is believed, however, to be younging to the west; that is, it stratigraphically underlies the Foulsham Formation with which it is in conformable contact. This assumption is made on the evidence of a similar age for both the Double Creek and the Horse Terrace Formations, the latter being known to underlie the Foulsham Formation in the area of Sub B.

On grounds of lithology, the Double Creek Formation is tentatively correlated with that part of the Matiri Formation (Series) which contains limestone strata in other areas of the Murchison Subdivision (Fyfe, 1930; Bowen, 1964). These strata are also of probable Landon age (Bowen, 1964).

Within the thesis area, the Double Creek Formation is tentatively correlated in time with the Horse Terrace Formation; the two formations being believed to be related by facies.
Horse Terrace Formation (ht)

Definition and type section

The name Horse Terrace Formation is given to coarse-grained massive sandstone, basal conglomerate and coal measures at the base of the Tertiary sequence. It includes all strata having that lithology and lying between the nonconformable contact with the underlying Woodham Granite and the lowest bed of micaceous sandstone of the Foulsham Formation.

The type section is in the ridge at Sub B, and includes exposures in the bluffs immediately northeast of that point.

Distribution and thickness

The formation crops out as a continuous belt from the north bank of the Matakitaki River at the Horse Terrace Bridge, southward through Sub B, to the bed of the East Branch Glenroy River. Debris of the Horse Terrace Formation occurs in a stream bed 20 chains west of Sub V; the formation is therefore mapped southward into the thickly-bushed country between the East Branch Glenroy River and Fuchsia Gully.

A further outcrop, structurally separated from those referred to above, occurs in the valley of the upper East Branch Glenroy River, 2½ miles upstream from the bridge. The formation is the basal part of an infaulted Tertiary outlier bounded by the Woodham and Branch Faults, and nonconformably overlies Woodham Granite.

At Davis Creek, in the southwest of the thesis area, medium to coarse-grained sandstone and associated coal measures which
overlie Woodham Granite are mapped as Horse Terrace Formation.

The Horse Terrace Formation is 400 feet thick at the type section and thickens northward to 600 feet at the Horse Terrace Bridge. In the upper East Branch Glenroy River it is 300 feet thick and a similar thickness, of which the lower 200 feet are coal measures, is exposed at Davis Creek.

The basal conglomerate crops out in the section in the upper East Branch Glenroy River, at Sub V, and at a poorly exposed outcrop on the northern slopes of Fuchsia Gulley. In the upper East Branch Glenroy River it has a total stratigraphic thickness of 20 feet but this value may be exceeded in the vicinity of Sub V where the contacts are not exposed.

Lithology

The dominant rock type is a massive cream-coloured medium to very coarse-grained sandstone. It is moderately-sorted although the beds are pebbly in places. The sandstone is made up of quartz and feldspar granules and a lesser amount of greywacke rock fragments. The granules are sub-angular and closely packed in a matrix of fine-grained sand with rare flakes of biotite and muscovite. Induration varies from a poorly-consolidated and friable deposit to one that is well-indurated and compacted. The formation is typically massive, contains rare marine macrofossils and is considered to be a near-shore marine sandstone.

The coal measures at Davis Creek are a sequence of interbedded coal seams, the thickest being 2 feet, and dark-grey carbon-
aceous fine-grained sandstone. Thin carbonaceous streaks and laminae are present in the upper part of the formation in the lower East Branch Glenroy River.

The basal conglomerate consists wholly of Woodham Granite debris. The rock fragments are predominantly sub-angular and some are well-rounded; their maximum diameters range from 4 to 40 cms. The matrix is a very coarse-grained little-weathered granitic sand. It is indurated to such an extent that it can be distinguished only with difficulty from slightly weathered granite. The platy flow structure of some granite fragments is often the only means of determining their extent in outcrop surface.

Relation to underlying rocks

In three exposures of the base of the Horse Terrace Formation, it is seen to be overlying Woodham Granite. At two of these localities, i.e. at Sub V and in the Upper East Branch Glenroy River, the basal conglomerate is present and rests on a smooth surface cut in Woodham Granite.

At Sub B, the basal conglomerate is absent and coarse-grained sandstone has been deposited on a near-planar surface cut into the granite basement.

In Davis Creek, the coal measures are believed to be the basal strata of the formation in that locality. Their contact with the Woodham Granite is not exposed.

Fossils

The writer collected macrofossils from stream boulders of Horse Terrace Formation lithology in the upper East Branch Glenroy River.
They have been identified by Mr. P.A. Maxwell (N.Z.G.S.), as follows:

**N.Z.F.R.F. S39/521**

- Grandaxinea sp.
- Lima sp.
- ?Anomia sp.

Grandaxinea sp. resembles *Grandaxinea lorrensis* (Marwick) which has a known range of Kaiatan - Whaingaroan. The genus *Lima* is common in the Landon Series as *Lima colorata paleata* (Hutton) but may range down to the Kaiatan - Runangan (Mr. P.A. Maxwell, written comm.).

A previous collection from the section in the upper East Branch Glenroy River by Dr. D. Kear and Mr. J.C. Schofield yielded the following:

**N.Z.F.R.F. S39/50h**

- ?Serripecten
- *Isognomon fortissimum* (King)
  
**Age:** ? Landon.

### Mode of formation

The Horse Terrace Formation is believed to be the terrestrial and near-shore deposits laid down during a major transgression of the sea into this area in mid-Tertiary time.

The sea advanced onto a landmass of Woodham Granite which had an irregular topography. Erosional debris was probably swept off the 'highs' and deposited in the 'lows', thus forming the basal
conglomerate. Estuarine or paludal conditions prevailed at some localities, leading to the deposition of coal measures.

Continued advance of the sea deposited sub-littoral sediments conformably on the basal conglomerate and coal measures, and nonconformably on the cleanly-washed 'highs' of Woodham Granite.

**Age and correlation**

Fossils suggest that this formation is no younger than Landon and could conceivably be older. On the basis of evidence within the thesis area, a Landon age is adopted.

The position in sequence (illustrated in Chart 1) below the Foulsham Formation, which elsewhere overlies the Double Creek Formation of lower Landon age, is the major evidence for proposing the penecontemporaneous deposition of the Double Creek and Horse Terrace Formations.

The Horse Terrace Formation is therefore thought to be of similar age to the Double Creek Formation; hence these two formations are provisionally interpreted as being contemporaneous near-shore facies and shelf facies, respectively.

There is at present little basis for lithological correlation outside the Glenroy-Matakitaki region as the Tertiary rocks of the Murchison Subdivision have not yet been described in detail.

---

**Foulsham Formation (fo)**

**Definition and type section**

The name Foulsham Formation is applied to brown micaceous silty sandstone overlying the Double Creek and Horse Terrace Formations. It includes all the strata lying between the highest cream
coarse-grained sandstone of the Horse Terrace Formation and the lowest conglomerate band of the overlying Priestman Formation. The type section is on the west-facing slopes of Sub B, stratigraphically above that of the Horse Terrace Formation.

**Distribution and thickness**

From the type section at Sub B, the Foulsham Formation extends northward for 900 yards, pinching out just south of the Matakitaki School. Southwards, the formation is unconformably overlaid by the Water Race Formation and lenses out between Sub B and the lower East Branch Glenroy River. The formation crops out further south at the head of Fuchsia Gully where it is believed to conformably overlie the Double Creek Formation. Its western margin is in fault contact with the Yorkey Formation.

The thickness at the type section is 200 feet and at Fuchsia Gully it may exceed 300 feet.

**Lithology**

In hand specimen, the rock type of the Foulsham Formation is a well-indurated silty medium to coarse-grained sandstone containing conspicuous biotite flakes. No bedding is visible in outcrop and fossils are unknown.

In thin section (UC 5271) the rock is seen to be comprised of angular grains with a size range of 0.2 to 1 mm; the modal grain size being about 0.7 mm. The dominant constituent is quartz, as single grains and as anhedral intergrowths of two or more grains. Plagioclase feldspar is present in lesser amount, some grains being quite fresh while others are extensively sericitized. Microline
grains and possible rhyolite fragments are present in minor amount. Detrital biotite is abundant as flakes varying in length from 0.5 to 2mm. The flakes have been bent around larger clastic grains during compaction. The biotite shows a complete range of alteration to chloritic minerals; the alteration being accompanied by swelling of the original biotite. The detrital grains are closely packed in a clay matrix. A thin film of limonite cements the sandstone grains.

The mode (point counter) is:

- Quartz 36.5%
- Feldspar 17.5%
- Biotite 17.75%
- Matrix 27.75%

In the classification of Gilbert (1954) the rock is an arkosic wacke.

Relation to underlying beds

At the type section the Foulsham Formation conformably overlies the Horse Terrace Formation. The contact is gradational; the underlying very coarse-grained sandstone becoming finer-grained and micaceous as the base of the Foulsham Formation is approached. A similar contact exists in Fuchsia Gully: the sandstone of the Double Creek Formation becoming micaceous and coarser-grained as it passes into the Foulsham Formation.

Mode of formation

The discontinuous distribution of the Foulsham Formation, and its lesser thickness when compared with the other mid-Tertiary
formations, suggests that the deposition of these rocks was a relatively minor event in the sedimentary history of the basin. Because both the Foulsham Formation and the Horse Terrace Formation are overlain by the conglomeratic Priestman Formation in different localities, it is likely that the Foulsham Formation was deposited at much the same time as the lowest beds of the Priestman Formation. It is therefore suggested that the source of the Foulsham Formation was the finer-grained detrital material which by-passed the site of deposition of the first conglomerate beds of the Priestman Formation. The immature nature of the sandstone is considered to be indicative of rapid transport and deposition; conditions of sedimentation such as must have prevailed in a tectonic environment suitable for the deposition of thick conglomerate sequences.

Age and correlation

The Foulsham Formation is unfossiliferous but because it conformably overlies beds of probable lower Landon Age (the Double Creek Formation), it is considered to be middle or upper Landon.

Priestman Formation (pr)

Definition and reference section

The name Priestman Formation is applied to massive conglomerate and interbedded sandstone cropping out in the lower Glenroy Valley. The base of the Priestman Formation is the lowest conglomerate bed overlying the Foulsham and Horse Terrace Formations. The top of formation is not defined herein as the youngest beds are faulted out by the Glenroy Fault. For that reason no type section is
proposed. However, the base of the formation may be seen in the upper East Branch Glenroy River and on the western slopes of Sub B. The lower East Branch Glenroy River, downstream from the Priestman Water Race headworks, provides a suitable reference section.

Distribution and thickness

For the most part, the Priestman Formation crops out on the valley slopes of the Glenroy River where it forms the true right bank for four miles upstream from the Foulsham homestead. The western boundary of the formation, is the Glenroy Fault where it is in contact with the Longford Formation. The maximum thickness in the Glenroy area is estimated to be 2,500 feet.

The Priestman Formation also crops out in the upper East Branch Glenroy River where it overlies the Horse Terrace Formation. The outcrop area is a steeply-dipping west-southwest trending sliver, the north east margin being in contact with the Yorkey Formation along the Woodham Fault. The greatest thickness at this locality is approximately 1000 feet and the formation thins westward toward the northern flank of Mt. Woodham.

Lithology

The Priestman Formation consists primarily of thickly-beded to massive round-stone conglomerate. In the upper part, however, sandstone beds up to 1 foot thick are common and conglomeratic sandstone is present near the base of the formation.

The conglomerate has a generally uniform pebble size within any one bed, see Fig 4. Pebble diameters of 4 to 5 cms. are the most
Figure 1. Bedded conglomerate of the Priestman Formation. Low-sphericity pebbles in the upper bed show some imbrication.
common, but some thinner beds may be composed of pebbles no greater than 3 cms. in diameter. In the lower part, cobbles in conglomeratic sandstone have average diameters up to 20 cms. All pebbles and cobbles are of high sphericity (0.7 to 0.9; visual estimation) and are well-rounded (0.9; visual estimation). On account of the high induration of the matrix and the fractured nature of most pebbles, it was not possible to extract sufficient specimens for more precise determination of roundness and sphericity values.

The pebbles are almost entirely of blue-green and grey-green greywacke which, in hand specimen, can be matched with rock types of the Yorkey and Wheeler Formations. Occasional quartz pebbles occur throughout the formation and weathered pebbles of Woodham Granite are known only from the lower beds.

The pebbles are tightly packed in a matrix ranging from a silty fine-grained sandstone to a medium-grained sandstone. The matrix is well to highly-indurated, the induration often increasing toward fault planes. Fracturing of pebbles is common and some have been offset along internal shear planes; this effect too, is most common near faults.

Interbedded sandstone occurs as lenticular beds. In hand specimen the sandstone appears similar to that of the Foulsham Formation but is not micaceous. Usually the induration of the sandstone is a little less than that of the surrounding conglomerate. Plant fragments are present in some of the stratigraphically highest sandstone beds. One of the beds, without plant fragments, was
examined for microfauna but found to be barren.

In the upper East Branch Glenroy River the conglomerate is sparsely fossiliferous; several specimens of a nacreous thin-shelled Ostrea being found in conglomeratic stream boulders derived from that locality.

Relation to underlying beds

At the section in the lower East Branch Glenroy River, the coarse-grained sandstone of the Horse Terrace Formation grades upwards through conglomeratic sandstone and thin beds of conglomerate, into the massive conglomerate typical of the Priestman Formation. This gradation takes place over a stratigraphic interval of 200 feet. A cut-and fill structure (Fig 5) in conglomerate at this locality confirms that the direction of the face of the beds is as indicated by the stratigraphy.

The contact between the Horse Terrace Formation and the Priestman Formation in the upper East Branch Glenroy River is sharper than that described above. Over a distance of 10 feet, coarse-grained sandstone of the Horse Terrace Formation grades through conglomeratic sandstone into a conglomerate of small pebbles (average diameter of 2 to 3 cms.). This conglomerate is comprised of approximately equal amounts of granite and greywacke. Higher in this sequence, granite pebbles become less abundant and finally disappear completely.
Figure 5. Channel-filling structure in Priestman Formation conglomerate, lower East Branch Glenroy River. The beds "young" to the top of the photograph.
West of Sub B the surface of contact with the Foulsham Formation is obscured. Westward from the Foulsham Formation, the first conglomerate encountered is similar to that overlying the Horse Terrace Formation in the upper East Branch Glenroy River. Here, granite pebbles are not present and the conglomerate becomes coarser westwards.

Mode of formation

The presence of *Ostrea* sp. at the base of the Priestman Formation suggests that the earliest conglomerate beds were deposited under marine or estuarine conditions. A later transition to brackish or fresh-water conditions is indicated by the presence of plant fragments in the upper sandstone beds. The massive nature of the conglomerate is thought to indicate initially rapid deposition in a subsiding basin. The change to non-marine conditions probably occurred in response to a reduction, or even a cessation, in the rate of subsidence of the basin toward the end of its depositional history. The incoming of conglomerate in the upper part of the middle Tertiary sequence is believed to indicate extensive uplift and erosion of the Permian rocks at that time. The restriction of granitic detritus to the base of the formation may indicate that the Landon marine transgression had entirely covered the areas of Woodham Granite outcrop at the time of deposition of the Priestman Formation.

Age and correlation

The fossils so far found in the Priestman Formation (*Ostrea* sp. and unidentified plant fragments) are of little use
in dating the strata. Because it was rapidly deposited, and in some localities conformably overlies beds of probable Landon Age (the Horse Terrace Formation), the formation is provisionally assigned a middle or upper Landon age. Thus the Priestman Formation may be correlated, in a time-stratigraphic sense, with the Matiri Series (Henderson and Fyfe, 1935) or the Matiri Formation (Bowen, 1964).

The outcrops of Priestman Formation in the lower Glenroy Valley were mapped by Henderson and Fyfe, (1935) as Longford Series of probable upper Miocene age. Bowen (1964) mapped the same rocks as part of the Taranaki Series which he correlated with the Longford Formation in the Murchison district.

**Longford Formation** (lo)

**Introduction**

In the preceding section it has been shown that most of the Tertiary rocks, of the Glenroy area, are of Landon age and are correlated (on a time-stratigraphic basis) with the Matiri Series. The remainder of the Tertiary rocks are believed to be younger and because no direct age determination is available, it is proposed to follow Henderson and Fyfe (1935) and Bowen (1964) in mapping them as Longford Formation.

The name Longford Formation is applied, in this thesis, to a sequence of dark-coloured and dominantly carbonaceous sediments which are lithologically distinct from the previously described middle Tertiary formations.
The formation, which is of little more than informal status, is not defined herein because only a limited portion of the sequence is exposed in the area.

**Distribution and thickness**

The Longford Formation crops out at the gorge in the lower reaches of the Glenroy River and in the road cuttings about the Glenroy Bridge. The strata, which strike generally parallel to the river and dip to the west, probably extend westward into the area between the Glenroy and upper Maruia Rivers. Although only 500 feet are exposed within the thesis area, the total stratigraphic thickness is estimated to exceed 2000 feet in the country to the west.

Near the Glenroy Fault the beds have varying attitudes; apparently chaotically disrupted by minor faults associated with the Glenroy Fault.

**Lithology**

A massive dark-grey silty medium-grained sandstone is the dominant rock type. Beds (10 to 20 feet thick) of fissile carbonaceous siltstone, some bearing abundant and well-preserved plant impressions, occur throughout the sandstone. In some places, coarse-grained sandstone and conglomerate with small (\(\frac{1}{2}\) to 1 cm. diameter) pebbles, occur as lenticular beds with a maximum thickness of 10 feet. Pebbles in the conglomerate are of Permian greywacke and sandstone, granite and, rarely, green jaspillite. All the rocks are moderately to well-indurated, dark coloured and often contain streaks of carbonaceous material.
Plant impressions are abundant in fissile siltstone for several yards east of the Glenroy River Bridge, and on the west bank of the Glenroy River 3/4 of a mile upstream of the Glenroy Bridge. A vertical coal seam 18 inches thick is interbedded with carbonaceous fissile siltstone on the roadside 3 chains east of the bridge.

**Relation to adjacent beds.**

No contact of Longford Formation and Priestman Formation is exposed in the area. However, consideration of regional structure strongly suggests that they are in faulted contact along the Glenroy Fault.

The relationship of the Longford Formation to the rocks of the west is not certainly known as mapping was not extended west of the true left bank of the Glenroy River. The westerly dip of the strata does suggest that these rocks are part of the north-south trending syncline mapped by Bowen (1964) between the Glenroy and Maruia Rivers. If this is so, these beds underlie those of upper Taranakian and Wanganuian age in which the syncline has been mapped.

**Mode of formation**

Interbedding of conglomerate and siltstone within a sandstone sequence, indicates considerable variation in the rate of sedimentation of this part of the formation. This feature, together with the abundance of carbonaceous matter, is believed to indicate a shallow-water estuarine or lacustrine environment of deposition. It was probably subjected to intermittent flooding which supplied coarse detritus and much plant matter.
Age and correlation

Henderson and Fyfe (1935) mapped these beds as Longford Series, to which they assigned an Upper Miocene age. Suggrate (in Fleming, 1957) judged the Longford Formation (Series) to be no older than Lillburnian at its base and Bowen (1964) adopted a Taranakian age for the Longford Formation. No evidence as to age was found in this investigation, but spore and pollen data from the carbonaceous beds may give a direct age determination.

The writer examined Longford strata at the Longford Bridge (on the Buller River) and there is little doubt that the beds at the Glenroy Bridge are lithologically similar.

Water Race Formation (wr)

Definition and type section

The name Water Race Formation is given to a compacted breccia containing minor sandstone lenses which overlies, with marked angular unconformity, the Horse Terrace and Priestman Formations in the Glenroy area.

The type section is the north wall of the small gorge in the lower East Branch Glenroy River, 40 chains upstream from the bridge.

Distribution and thickness

The major outcrop of the Water Race Formation is the south-facing slope between the Sub B - McNee ridge and the gorge of the lower East Branch Glenroy River. The northern and
southern limits of the outcrop are seen on the ridge and in the
gorge, respectively. The exposures are poor in the intervening
area but the formation is mapped as extending throughout. About
30 chains of the north bank in the lower East Branch Glenroy River
is comprised of this formation.

A small outcrop of the Water Race Formation occurs on the
south bank of the East Branch Glenroy River. It is situated 200
yards south of, and 700 feet above, the outcrops in the gorge.

At the gorge section the formation is up to 35 feet thick;
on the Sub B - McNee ridge it is rarely more than 10 feet thick;
south of the river the thickness is unknown.

**Lithology**

The Water Race Formation is a generally massive breccia
of unsorted rock fragments and rare sandstone lenses; it is
illustrated in Figure 6.

The constituents are predominately highly-Indurated blue-
green sandstone and greywacke typical of the Yorkey Formation;
sparse fragments of Woodham Granite are also present. Commonly,
the longest axes of the rock fragments are within the range of
1 to 10 cms.; fragments of greater dimensions are rare. The
sphericity of all rock fragments is low (none exceed 0.3, visual
estimation) while in some cases the roundness, which is generally
low, appears to be as high as 0.7 (visual estimation). The breccia
matrix is a poorly-sorted mixture of granules, sand and silt-sized
particles; the coarser grades are principally rock fragments.
Figure 6. Poorly-sorted breccia of the Water Race Formation.
It varies considerably in degree of induration, being almost friable in some outcrops and well-indurated in others. In fresh outcrop the matrix is distinctly green in colour.

Occasional lenses of sandstone, 3 to 4 feet in length and 8 to 10 inches thick, are included within the breccia. It is a green poorly-sorted silty sandstone similar to the breccia matrix. Its induration conforms to that of the surrounding breccia.

The breccia is practically massive except for bedding shown by the presence of sandstone lenses. A channel-filling, in the most easternly outcrop in the East Branch Glenroy River, was the only other sedimentary structure observed.

Stratigraphic relationship and structure

In the middle of the gorge section, the Water Race Formation rests on a near-horizontal surface cut into unweathered and steeply-dipping strata of the Horse Terrace and Priestman Formations. At this locality the Water Race Formation dips 5 degrees to the west.

Further upstream in the East Branch Glenroy River, the formation dips to the east at 45 degrees.

In the downstream part of the gorge section, the bedding again becomes more steeply inclined with dips of up to 45 degrees to the south and southwest.

On the Sub B – McNee ridge, the Water Race Formation occupies channels cut into unweathered sandstone of the Horse Terrace Formation. The channels are up to 3 feet deep and 10 feet wide. The general surface of unconformity is estimated
to dip 10 degrees to the southwest, at this locality.

South of the East Branch Glenroy River, the Water Race Formation dips shallowly to the south; here the basal contact is obscured.

The most westerly outcrop, in the East Branch Glenroy River, is 100 feet vertically below the surface of the highest constructional terrace in that part of the valley. Hence it is assumed that these late Pleistocene deposits overlie the Water Race Formation, although no contact has been seen.

From aerial photographs, the trace of the Branch Fault is seen to cut the Water Race Formation; it is slightly upthrown to the southwest. The present dips within the formation are dominantly of tectonic origin, but in this type of deposit initial dips of high angle are to be expected. Hence it is not known to what extent other lesser faults penetrate the formation.

The relationship of the outcrops on either side of the East Branch Glenroy River is not entirely clear. The difference in elevation may be accounted for, either by faulting parallel to the Branch and Thornton Faults, for which independent evidence is lacking; or by postulating an initially much greater thickness which has been removed by downcutting of the East Branch Glenroy River. For the present, the latter alternative is accepted.

**Age**

As stated above, the Water Race Formation unconformably overlies strata of middle Oligocene age which were deformed during the late Oligocene or early Miocene. It is itself believed to be overlain by late Pleistocene river terraces. This generally
well-indurated deposit has been considerably eroded, hence it is probably not younger than early Pleistocene. As it was tilted by the last major movements in the Glenroy area, which were probably in the early Pleistocene, the formation is considered to be of late Miocene or Pliocene age.

**Mode of formation**

The lithology of the Water Race Formation is similar to that of the Hawks Crag Breccia and its correlative formations in the Westland region. Morgan and Bartram (1915) and Gage (1952) have discarded the hypothesis of a glacial origin for these formations. Although a deposit of near-Pleistocene age, a glacial origin for the Water Race Formation is rejected on similar grounds, and a fanglomerate origin is postulated.

In late Miocene or Pliocene time, rapid and local erosion and re-deposition of Permian sediments occurred. The source of the angular rock debris now comprising the Water Race Formation, may well have been crush-zones within the Permian rocks. The crush-zones being an effect of the late Oligocene diastrophism. Deposition took place after a very short interval of water transport, as shown by the angularity of the rock fragments and the present nearness of the source rocks. The depositing streams initially had strongly erosive properties for the surface of unconformity was swept clean of regolith and, in some places, extensive channels were cut. The result was a fanglomerate deposit in the area of what is now the lower reaches of the East Branch Glenroy River.
Subsequently, movement of the block between the Eranch and the
Thornton Faults, in early Pleistocene time, has tilted the formation
and allowed the East Branch Glenroy River to erode its present
course through the breccia.

QUATERNARY DEPOSITS

Introduction

A detailed treatment of the glacial deposits of the
Glenroy and Matakaitaki Valleys is considered to be beyond the
scope of this thesis. For mapping purposes these deposits
have been differentiated into:

Alluvium (river terrace and lake deposits)
Moraine

Additional late Pleistocene deposits too limited in extent to be
mapped but which will be briefly discussed are:

Cemented terrace gravel
Calc-tufa

Alluvium (al)

Herein, this term includes the terrace systems of the
Glenroy and Matakaitaki Valleys, and the lake deposits of the
Matakaitaki (or Oxnam) Plains.
A prominent flight of terraces is present in the area of the Glenroy - Matakikaki confluence. Their surfaces extend up the Matakikaki Valley to Wheeler Creek, and for a distance of 6 to 7 miles up the Glenroy Valley. Suggate (1965) traced the highest of these outwash surfaces downstream from Wheeler Creek to Murchison where it grades into the aggradation surface of the Speargrass Formation. He also correlated a terrace surface in the lower part of the Glenroy Valley with the Speargrass Formation.

In the lower half of the valley of the East Branch Glenroy River, there is a well-defined terrace surface 6 to 10 feet above present river level. It is a degradational terrace for it is cut into the country rock and carries only a thin veneer of alluvium. This feature indicates active downcutting by the East Branch Glenroy River in response to recent movements of the Branch and Thornton Faults.

In its upper part, the west-trending portion of the Matakikaki Valley is occupied by a broad and level surface, the Matakikaki Plains. Suggate (1965) has described this feature as a drained lake. Massive blue-grey silt, overlain by moraine and outwash gravel, is exposed in the south bank of the Matakikaki River half a mile east of the mouth of Station Creek. This is a lake-deposited silt which may have been laid down prior to the last glaciation. The lake, in which these sediments were deposited, resulted from damming of the Matakikaki River, near the Horse Terrace Bridge, by the terminal moraines of the Otira Glaciation (Suggate, 1965). The lake was drained by downcutting through
these deposits and the river is now incised into a gorge in
Woodham Granite between Potberry and Wheeler Creeks.

**Moraine** (mr)

On the south bank of the Matakitaki River, between the
mouths of Nardoo and Station Creeks, an extensive area of hummocky
ground is comprised of unsorted and angular blocks of Chlorite 2
Subzone schist. This is an ablation moraine, much of the detritus
having been derived from the roche-moutonée immediately southeast
of the mouth of Nardoo Creek. The schist of the roche-moutonée is
characteristically veined with quartz and this feature is typical
of the rocks of the moraine.

**Cemented terrace gravel**

A high terrace, 100 to 150 feet above the stream bed, has
been cut on the west bank of Station Creek. The surface is covered
by a veneer of gravel derived from local rocks. The matrix consists
of fine-grained rock fragments and calcareous cement. The degree
of induration is such that the gravel is eroded as conglomeratic
boulders which are present in the alluvium of Station Creek. The
Matakitaki Limestone is the source of the calcareous cement, whence
it has been derived by solution and re-precipitation.
Calc-tufa

Streams running down dip slopes of Matakitaki Limestone occur on the lower west bank of Station Creek. Several waterfalls are present and in some cases they are bordered by an abundant growth of moss. Calcareous stream waters precipitate a sinter of calcium carbonate over the moss and a porous spongy mass results. Locally, sheets of calc-tufa 12 to 18 inches thick, have been formed in this manner.
PART III - IGNEOUS AND METAMORPHIC ROCKS

Station Creek Formation (sc)

including the Hunter Dunite Member (HD)

Definition

The name Station Creek Formation is given to all the igneous rocks of dominantly ultramafic composition, and the associated metasediments, which lie between the steeply dipping contacts with the Baldy Microgabbro on the west and the Nardoo Formation to the east.

The name Hunter Dunite Member is given to the body of dunite which intrudes the Station Creek Formation.

Distribution and thickness

The rocks of the Station Creek Formation comprise the greater part of the western slopes of Station Creek. They are well exposed in many places along the banks of this creek. The formation crops out as a lenticular belt striking concordantly with the country rocks. At the northern end, the formation appears to pinch out between the Nardoo Formation and the Baldy Microgabbro. The formation thins rapidly to the south in the head of Station Creek and is believed to terminate against the Branch Fault. Mr A.C. Beck (pers. comm.) has found a thin and sheared belt of serpentinite against the Alpine Fault, 40 to 60 chains to the south of the Branch Fault.
The maximum thickness of the formation is 3,500 feet. This, however, may be an excessive value as the effect of intraformational deformation is unknown.

The Hunter Dunite Member is restricted to a relatively narrow belt parallel to the western margin of the formation; it crops out on the north-trending ridge at the head of Wheeler Creek. It is not more than 500 feet thick and occurs only in the southern part of the formation. A serpentinite belt of similar thickness separates it from the Baldy Microgabbro in the west. The fertility of the dunite is low and the normally prolific growth of beech forest terminates abruptly at the edge of the outcrop. This feature has proved useful in mapping the extent of the dunite outcrop.

Content

The Station Creek Formation, although of diverse lithology, is characterised by an abundance of ultramafic rocks and their serpentinitised equivalents.

Serpentinite constitutes the major rock type. It occurs as a belt along the western margin of the Hunter Dunite, as large pods with dimensions of several hundreds of yards within the body of the formation, and as dyke-like bodies striking across Station Creek. For the most part, the serpentinite is an extremely fine-grained and massive variety. However, in some outcrops in Station Creek, particularly near the headwaters, the grainsize is much coarser and bastite pseudomorphs (after pyroxene) with cleavage plates up to 1 cm. across are common.
In many of the Station Creek outcrops, serpentine is seen as dykes transecting bodies of pyroxenite and hornblendite. The form of these bodies is not clear but it is probable that they intrude the metasediment of the formation. The pyroxenite is massive and fine-grained; the hornblendite is generally of coarser grain and carries hornblende crystals up to 2 cm. long.

In the right bank of Station Creek, 1 1/2 miles upstream from the mouth, fine-grained serpentine contains xenoliths of light-coloured coarse-grained igneous rock which, in hand specimen, compares closely with saussuritised rocks seen in the Baldy Microgabbro.

Ptygmatic veins of light-green, semi-translucent rodingite are seen to invade bastite serpentine in the upper part of Station Creek. The veins are usually less than 2 cms. thick.

Metasediment is seen in many places in Station Creek and its adjoining tributaries from the west. It is comprised of dark-brown moderately-indurated baked sandstone and mudstone. These rocks occur between the bodies of ultramafic rocks and are often complexly folded and contorted. In some cases, thin bands of serpentine traverse the metasediment.

The Hunter Dunite Member consists entirely of dunite having variable grain-size. It has a sharp and mylonitised contact with baked sediment of the Station Creek Formation on its eastern margin. At the western margin, dunite grades into serpentine.
Relation to adjacent formations

At all exposures seen, the Station Creek and Nardoo Formations are in fault contact. An unconsolidated fault-pug, which is up to 6 inches thick, is always present between the formations.

In the west, the contact of serpentinite with Baldy Microgabbro is quite sharp. It is not faulted and has an attitude similar to that of the overlying Permian formations.

Correlation

On lithologic and stratigraphic grounds, the Station Creek Formation is correlated with the Dun Mountain Ultramafites of the Nelson district, and with the Red Mountain Ultramafics of the Livingstone Mountains.

Mode of formation

The ultramafic rocks of the Station Creek Formation, as do the Dun Mountain Ultramafites and the Red Mountain Ultramafics, conform to the definition of 'alpine-type' serpentinite bodies (Benson, 1926). Challis (1965) has provided a concise summary of the suggested modes of origin of these rocks. Two recent publications dealing with the ultramafic rocks of the Nelson Province have advanced hypotheses differing both with regard to mode of formation and to time of emplacement. Lauder (1965b) considers Dun Mountain to be the eroded neck of a Cretaceous volcano. Challis (1965) suggests, alternatively, that the Red Hills, Dun Mountain, Red Mountain and other large masses of ultramafic rock associated with the Permian sediments and volcanoes of New Zealand, represent the deep-level
magma chambers of a line of upper Palaeozoic volcanoes.

Field evidence from the Station Creek Formation, and the related Baldy Microgabbro, cannot be reconciled entirely with the hypotheses of either of these authors. The relationship of ultramafic rocks and metasediments of the Station Creek Formation suggest that it is a sedimentary sequence which has been complexly intruded by ultramafic rocks.

It may be reasonably assumed, on structural grounds, that the sediments of the Station Creek Formation conformably underlay the Potberry Formation until such time as they were separated by intrusion of the Baldy Microgabbro. Therefore feeding-pipes for the extrusion of spilitic lava into the Potberry Formation should be present in the rocks of the Station Creek Formation. The intrusive bodies of pyroxenite and hornblende may be the lower parts of these pipes. Their high concentration of mafic minerals being due to gravitative differentiation within the feeding-pipes. The pyroxenite and hornblende of the Station Creek Formation may be, therefore, of middle Permian age.

The presence of gabbroic rocks in serpentinite is evidence that the main ultramafic intrusions, and the associated serpentinisation, followed emplacement of the Baldy Microgabbro. As shown later, the Baldy Microgabbro was probably intruded after the Permian sedimentary rocks had been folded to near their present attitude. This suggests that dunite and serpentinite emplacement is a late-orogenic event in the Matakitaki area.

The problems concerning the origin and emplacement of ultramafic rocks are well known; much of the controversy arising
from the apparent confliction of field and experimental evidence. Turner and Verhoogen (1960), after assessing the evidence, favour a peridotite 'magma' composed of olivine and pyroxene crystals lubricated by interstitial magmatic liquid or water vapour. They further consider that serpentinisation approximates to an equal-volume replacement at temperatures between 200° and 400°C, in the presence of water containing silica and carbon dioxide. In the Station Creek Formation there is clear evidence of shearing, and therefore of solid intrusion, at the dunite-metasediment contact. However, there is also evidence of apparently more fluid intrusion; shown by the presence of serpentine dykes cutting pyroxenite, hornblendeite and baked sediments. As well, there are gabbroic xenoliths within serpentine bodies which exhibit little reaction phenomena with the enclosing serpentine.

The relationship of the Hunter Dunite to the surrounding rocks may be considered with respect to the problem of fluid or solid emplacement. Its western margin is gradational into serpentineite and these rocks, in turn, have a sharp but almost unsheared contact with the Baldy Microgabbro. It is postulated, therefore that the western side of the dunite intrusion was considerably more fluid than the eastern margin where dunite is in contact with mylonitised metasediment. The fluidity resulted from the lubricating effects of copious amounts of water vapour. As the temperature of the intrusion was lowered, the same water vapour proceeded to serpentinise a considerable portion of the Hunter Dunite.
Because the eastern contact was relatively dry, no serpentinisation occurred. By this argument, pods of serpentine to the north and east of the Hunter Dunite outcrop must, originally, have been dunite intrusions which achieved complete serpentinisation due to their smaller size. The uneven serpentinisation of the Hunter Dunite could have occurred only if the predominant source of water was external to the 'magma'. Turner and Verhoogen (1960) find that the large quantity of silica and carbon dioxide-bearing water required for serpentinisation is unlikely to be supplied by a purely magmatic source. Connate water of the intruded sediments is probably the major source.

The origin of serpentine dykes within pyroxenite may be accounted for by the extension of a suggestion made by Bowen and Tuttle (1949), concerning the mutual relationships of rock types within ultramafic complexes. These authors consider that pyroxenite could be locally converted to dunite under the agency of waters, undersaturated with silica and at temperatures above 650°C, streaming through a crack in pyroxenite. If conditions suitable for serpentinisation of the dunite followed, the result might be expected to be a serpentine 'dyke' intruding pyroxenite.

As stated earlier, the intrusion of ultramafic rocks in this area is believed to be a late-orogenic feature. In a later section it will be shown that a certain body of evidence points to
an early Mesozoic folding of the Permian sediments. It is likely, therefore, that emplacement of the ultramafic rocks of the Station Creek Formation occurred in early Triassic time. The sedimentary strata which they intrude are probably no later than middle Permian in age, and could possibly be older.

**Baldy Microgabbro (BM)**

**Definition**

The name Baldy Microgabbro is given to the belt of basic igneous rock having a uniform composition which lies between the Station Creek Formation and the lowermost Permian formations.

**Distribution**

The Baldy Microgabbro crops out in the high tussock-covered ridge between Wheeler and Station Creeks, and in the lower part of Station Creek. It comprises the peaks of Baldy, Mount Gaultheria and Hunter Peak. The greatest thickness, 3,200 feet, is in the Baldy - Mount Gaultheria area.

**Content**

In handspecimen, the Baldy Microgabbro is fine to medium-grained and contains abundant mafic minerals set in a fine-grained white groundmass. The colour index is 50 percent and occasionally greater.
In thin section (UC 5285) it is seen to be comprised of anhedral grains of clinopyroxene (probably diallage) and palely pleochroic hornblende, set in a highly-altered groundmass. The groundmass is composed of flaky antigorite showing a lattice texture pseudomorphic after clinopyroxene, and of calcic plagioclase which is generally altered to a mesh of finely-divided clinozoisite.

The rock is a hornblende microgabbro in which clinopyroxene has been partially serpentinised and plagioclase has been extensively saussuritised. The bleached nature of the hornblende is also attributed to alteration.

In Station Creek, north of the Hunter Fault, the microgabbro is more highly altered, almost all the pyroxene grains being completely serpentinised.

The microgabbro is quite homogenous throughout the extent of its outcrop, no mineral layering or foliation having been observed. Rare boulders of very coarse-grained gabbro, with partially-serpentinised pyroxene crystals up to 2 cms. long, were seen in the headwaters of Wheeler Creek. This lithology was not found in place.

Relation to country rocks

The near-vertical contact with serpentinite of the Station Creek Formation is sharp and easily traced. Microgabbro close to the serpentinite appears bleached; probably the result of extensive serpentinisation associated with intrusion of the Hunter Dunite.
Contacts with the Potberry Formation were not seen. Above the gorge in Wheeler Creek, Matakitaki Limestone crops out within four feet of microgabbro. The limestone has been altered to a marble in which the original laminae have been extensively flowfolded. Near the contact it is heavily veined with calcite. Irregular patches of pink and purple colouration are common within the marble. In thin section (UC 5262) the marble is seen to be comprised entirely of fine-grained calcite and exhibits a partly recrystallised cataclastic texture. Microgabbro near the contact is slightly serpentinised.

**Manner of emplacement**

The Baldy Microgabbro has the form of a steeply-dipping concordant intrusion between the Permian Formations and the Station Creek Formation.

The intrusion has resulted in predominantly physical alteration of the Matakitaki Limestone, calc-silicate contact metamorphic minerals being absent. This may be due to low temperature at the edges of the intrusion and the high purity of the limestone, or, as suggested by Challis (1965), the original high-temperature effects within the limestone are obscured by later calcium-metasomatism resulting from serpentinisation within the microgabbro.

The absence of compositional layering parallel to the contacts, in a basic igneous intrusion of this size, is unusual. It is believed, therefore, that the intrusion was emplaced after
the enclosing rocks had more or less attained their present attitude, and that horizontal layering may be present in depth. Alteration within the microgabbro is mainly of hydrothermal origin, possibly resulting from retention of volatiles due to the impervious nature of the intruded rocks. Further alteration probably resulted from serpentinisation of the adjacent Station Creek Formation.

Age and correlation

The strongly serpentinised nature of the microgabbro at its contact with the Station Creek Formation shows that it was emplaced prior to the serpentinisation of that formation. As stated above, the microgabbro is likely to have been intruded after the major deformation of the Permian rocks, but, as it has preceded the intrusion of the Hunter Dunite, the two igneous bodies are closely similar in age and may well be genetically related. Hence the Baldy Microgabbro is believed to have been emplaced in the early Triassic at a late stage in the folding of the Permian rocks.

The association of gabbro and ultramafic rocks is known in other areas of Permian outcrop, but neither in Nelson nor in the Eglinton Valley is gabbro present on the scale seen in the Matakitaki region. Challis (1965) noted the occurrence of anorthosite gabbro in the Red Hills district but did not discuss its relationship to the enclosing ultramafic rocks. The writer has seen small gabbroic bodies in the Red Hills area where they appear to be intrusive into the Dun Mountain Ultramafites. As this is not the case at Matakitaki,
it is probable that intrusion of gabbro and emplacement of ultramafic rocks into Permian sediments varied in relative age and magnitude along the length of the geosyncline.

Woodham Granite (WG)

Introduction

In the geological map of the Murchison Subdivision (Henderson and Fyfe, 1935) the rocks to which the name Woodham Granite is applied, were mapped as part of the Rotoroa Igneous complex. This body of acid igneous rocks, generally of dioritic composition, extends from Kawatiri in the north, southward through the Matakitaki district to Springs Junction (Bowen, 1964). Grindley (Grindley et al, 1959) has referred to these rocks as the Rotoroa Gneiss.

Within the thesis area, these rocks have a nearly uniform granitic composition and hence they are considered to be a mappable unit of the Rotoroa Igneous complex.

Definition

The name Woodham Granite is applied to coarse-grained biotite-borneblende granite, often showing platy-flow structure, which crops out in the Glenroy-Matakitaki area. Further, it is proposed as the name for the unit having this lithology within the Rotoroa Igneous complex.
Within the thesis area, this definition also includes a body of leucocratic rocks, belonging to the granulite facies, which crop out in Davis Creek. Because they occur within granite, have a limited outcrop and uncertain relationships, they are mapped with the Woodham Granite.

The Woodham Granite is typically exposed in high bluffs on the prominent peaks of Mount Woodham and McNee, in the Glenroy district.

**Distribution**

Outcrop of the Woodham Granite is controlled by the distribution of overlying sediments, and by block-faulting which has tilted granite blocks together with their covering strata. It occurs as two separate blocks. One; a southwest-trending belt from the gorge of the Matakitaki River, through McNee and Sub V, becoming narrower until it is faulted out immediately north of Fuchsia Gully. The other; a large block lying, in the main, to the south of the Woodham and Branch Faults and bounded to the east by the Alpine Fault.

**Content**

The typical rock type is a medium to coarse-grained biotite-hornblende granite. Macroscopically, the mafic minerals are seen to occur as discrete platy clots 1 to 2 mm. thick and 4 to 8 mm. broad. Often the plates exhibit a parallel orientation which gives the granite a structure resembling the foliation of gneiss. True gneissic foliation is not present however, as there is no segregation into distinct bands of mafic and felsic minerals. In thin section (UC 5282)
the granite is holocrystalline and allotriomorphic with grains ranging from 1 to 2 mm. in diameter. Most of the grains have partially sutured boundaries, see Fig. 7. Potash feldspar is abundant and its main occurrence is as subhedral microperthite and microcline; the microcline is often perthitic as well, see Fig 8. Orthoclase is less abundant. Plagioclase is rare and occurs as small euhedral crystals, having embayed outlines, included in larger grains of potash feldspar. A lesser amount of acid plagioclase occurs interstitially as well-cleaved anhedral grains. In some cases the sodic plagioclase has developed a myrmekitic texture (see Fig. 8) by encroaching on the surrounding potash feldspars as a botryoidal mass containing curved quartz rods. Biotite and hornblende, owing to their concentration in mafic clots, are probably more common than indicated by the mode. Biotite is subhedral and is often ophitically enclosed in hornblende. Small flakes of biotite also occur interstitially with the felsic components. Quartz is interstitial and anhedral, usually with undulatory extinction and, rarely, fracturing. Many quartz grains carry slender needles, tentatively identified as rutile. Accessory minerals are rare euhedral crystals of monazite and apatite; sparse rounded grains of magnetite are present as inclusions in hornblende.

The mode, from 415 points, is:

- Perthite 28.0%
- Microcline 19.8%
- Orthoclase 14.9%
- Plagioclase 4.1%
- Quartz 26.3%
- Biotite 4.1%
- Hornblende 2.2%
Figure 7. Photomicrograph of Woodham Granite, X 40, crossed Nichols. Perthite and microcline micoperthite (m), orthoclase (o), quartz (q), biotite (b).
Photo: D. J. Jones

Figure 8. Photomicrograph of Woodham Granite showing myrmekitic texture, X 100, crossed Nichols. Oligoclase (at extinction) containing quartz rods has encroached on perthitic microcline.
Photo: D. J. Jones
The abundance of mafic clots, and their degree of orientation, is somewhat variable. On the northeast ridge of McNeese, near the contact with the Yorkey Formation, the colour index of the granite is high (up to 50%). This is due to an abundance of biotite and hornblende clots. Because of their dominantly parallel orientation, the granite has a rough fissility in this locality. Commonly the colour index is much lower, as shown by the mode, and the mafic elements are less strongly aligned. On Sub V the granite shows no preferred orientation of mafic minerals although they still occur as macroscopic segregations.

A noteworthy variation in the lithology of the Woodham Granite is seen in Davis Creek. A hundred yards upstream from the coalmine, the first outcrops seen are distinctly leucocratic. Dark-coloured mafic pods several feet thick are included within this leucocratic portion. The felsic rocks crop out for 300 yards further upstream where the usual mafic clots start to appear and finally there is a gradation into the typical Woodham Granite lithology. Mafic pods are present only in the lower part of the section; in the higher part, thin trains of pink garnet crystals occur in one outcrop of the leucocratic material.

In thin section (UC 5283) the garnetiferous leucocratic rock from Davis Creek is seen to be holocrystalline and allotriomorphic. Most of the grain boundaries are extensively sutured. The rock is primarily comprised of orthoclase, sodic plagioclase and quartz; in that order of relative abundance. Orthoclase is perthitic in part and the fineness of the exsolution lamellae recalls
the cryptoperthite seen in the Blick Diatreme tuff. Garnet occurs as single anhedral grains interstitial to feldspar and quartz, and also as trains of anhedral grains which sometimes enclose prismatic crystals of sillimanite. The sillimanite is characterised by a single cleavage, parallel extinction, and birefringence of 0.022 to 0.025. It is optically positive but has an unusually low 2V of 12°. Sparse flakes of biotite occur subophitically enclosed by garnet. Besides its leucocratic nature and the presence of garnet and sillimanite, this rock differs from the typical Woodham Granite in its lack of microcline and the limited development of perthite. Suturing of grain boundaries is also much more noticeable in this rock. The texture and mineral assemblage suggest that this is a quartzofeldspathic rock which has attained the granulite facies of regional metamorphism.

Other granitic rocks containing garnet are common in the alluvium of Davis Creek; they were not found in place however. They differ from those described above, in that garnet occurs as polycrystalline aggregates up to 8 mm in diameter in otherwise typical Woodham Granite lithology.

Pegmatite is rare, being known only at two localities. Low on the northern slopes of McNeel, a 3 inch thick vein of quartzofeldspathic pegmatite cross-cuts the platy-flow structure of the granite. On the western ridge of Mount Woodham, several pods of a very coarse-grained pegmatite, up to 1 foot thick, are also discordant with the platy structure.
Petrogenesis

Tuttle and Bowen (1958) have subdivided granites into two broad groups; the hypersolvus granites and the subsolvus granites. The criterion of subdivision is the absence or presence, respectively, of plagioclase other than that occurring as a component of perthite. The subdivision has genetic implications as the authors consider that granitic rocks containing discrete plagioclase crystals (the subsolvus granites) have recrystallised subsequent to magmatic crystallisation. On the other hand, the survival of perthite in hypersolvus granite indicates both an initially high temperature of crystallisation (above 660°C.) and either, extremely rapid cooling or an absence of volatile fluxes such as water vapour.

The abundance of perthite and the very low modal plagioclase content of the typical Woodham Granite is, using the criteria of Tuttle and Bowen, indicative of a hypersolvus granite. Thus the Woodham Granite has crystallised under the conditions, outlined above, for a hypersolvus granite. The field occurrence data for hypersolvus granites, as found by Tuttle and Bowen, correspond closely with that of the Woodham Granite. They state that these granites are usually small intrusives and that their contacts indicate that little metamorphism has been produced, despite the high temperature of crystallisation required by the feldspars.

The presence of myrmekite furnishes little petrogenetic data; in the literature the ascribed origin of this texture varies from deuteritic alteration of feldspars (Grout, 1932; Williams, Turner and Gilbert, 1958) to thermal metamorphism under pressure (Tyrell, 1929).
It has been established, above, that the Woodham Granite has crystallised directly from a melt without later partial recrystallisation. Thus there is good reason to believe that the platy structure of the granite is the product of flow orientation of tabular mafic minerals, rather than a metamorphically imposed foliation.

The leucocratic rocks in Davis Creek display a quartz-feldspathic mineral assemblage typical of the granulite facies of regional metamorphism. This is the quartz-orthoclase-plagioclase-sillimanite-garnet assemblage of Fyfe, Turner and Verhoogen (1958). The subsolvus-granite association of the feldspars in this rock suggests that it is a recrystallised part of the Woodham Granite; the originally perthitic potash feldspars having been unmixed by a post-crystallisation rise of temperature. This has had the effect of reducing the amount of perthite and increasing the sodic plagioclase content, both relative to the Woodham Granite. The allotriomorphic texture and highly-sutured grain boundaries are similar to that in the granulites of Saxony (Williams, Turner and Gilbert, 1958; Fig 85). The presence of the alumina-bearing minerals, sillimanite and garnet, suggests that that component was introduced into the recrystallising granite at the time of metamorphism, possibly by assimilation of sedimentary xenoliths. The hornblende of the Woodham Granite would have been unstable in a silica-rich rock at the conditions of the granulite facies (Barth, 1952; p. 346) and therefore hypersthene, or some other pyroxene might be expected to be present. These minerals do not occur in the leucocratic rocks but they may well be concentrated in the associated mafic pods.
This suggests that considerable metamorphic differentiation occurred during the formation of the granulite.

The evidence of an apparent hypersolvus - subsolvus relationship between the granite and the granulite, and an observable transition from one rock to the other in the field, points to the granulite as being derived by recrystallisation of the Woodham Granite. It is admitted however, that the field relations could also be interpreted as evidence for metamorphism of deeply-buried country rock by intrusion of the Woodham Granite. For the present the petrographic data is taken to favour the former hypothesis. This conclusion is therefore provisional until further data comes to hand; the procurement of which may be a fruitful field for further research.

**Relationship to the Permian rocks**

The contact of Woodham Granite and Permian sediments has been examined at three localities and these are described in order from north to south. The sections are not well exposed as all occur in country which is thickly covered with beech forest or second-growth.

(a) Twenty chains east of McNee, an east-flowing tributary of Wheeler Creek has its head in a steep scree-filled gully which cuts across the contact of the Woodham Granite and the Yorkey Formation. Here, massive sandstone shows extensive schlickensiding with little brecciation. The sandstone appears to grade west into 20 feet of mortared and highly-felsic granite which passes finally into typical Woodham Granite lithology. No definable granite-sediment interface is visible, but as the granite is approached the sandstone becomes extensively veined with quartz and epidote. The
width of the contact-zone is approximately 150 feet.

(b) In the lower valley of the East Branch Glenroy River, isolated and apparently in situ, outcrops of granite and Permian sandstone alternate along 200 yards of the river banks. This appears to show an inter-tonguing relationship of granite and sediment.

In a single outcrop on the north bank of the river, granite and sandstone occur together. It is covered with a heavy growth of moss and the detail of the contacts is not discernable. The distribution of granite and sediment within the outcrop suggests that granite encloses fragments of sandstone. Even here, the sediment appears to be little altered.

Further downstream, an outcrop of granite contains thin dark-coloured fine-grained streaks which may be xenoliths of hornfelsic country rock.

(c) This locality is the highest part of the ridge between Fuchsia Gully and Double Creek. Woodham Granite, having a well-defined platy-flow structure, is succeeded eastward by 600 feet of altered rocks containing mixed sedimentary and granitic material. These rocks terminate eastward at the head of Fuchsia Gully where they are faulted against the Foulsham Formation. Alteration in this part of the contact-zone is more extensive than that caused by the normal weathering of this region.

Granitic rocks are irregularly distributed throughout the zone and are dominantly of highly-felsic composition, similar to those at locality (a). Occasional masses of typical Woodham Granite are also present and both types show some alteration.
The sedimentary material is light to dark-brown in colour and is well-inedurated. It contains sparse rounded pebbles set in a partly clayey and partly crystalline matrix containing scattered pink grains thought to be decomposing potash feldspar. In thin section (UC 5284) the matrix is seen to contain grains of very dusty orthoclase and sodic plagioclase set in a felted mass of clay minerals and minute euhedral quartz and feldspar crystals. Minor amounts of chlorite are also present. Numerous small veins of zeolite, in which laumontite and scolecite have been identified, occur throughout the slide. The rock has the aspect of an arkosic sandstone which has been extensively altered by hydrothermal agencies. The effects of alteration are: kaolinisation and sericitisation of feldspars, recrystallisation of some groundmass minerals, and introduction of zeolite minerals.

Mode of emplacement of the Woodham Granite

The absence of granitic debris from Permian conglomerate indicates that if the Woodham Granite had crystallised prior to Permian time, it was certainly not exposed in the provenance area of those sediments. Also, because the Permian sequence is now overturned and faces toward the granite, it is unlikely that the sediments were deposited on a basement of Woodham Granite. This suggests that the two rock masses did not come into contact until post-Permian time.

Henderson and Fyfe (1935) and Bowen (1964) have mapped the Woodham Granite (Rotoroa Igneous complex) as being faulted against the Permian rocks. The present attitude of the Permian
strata suggests that a fault having a throw of at least 15,000 feet, the observed thickness of the Permian sediments, would be required to bring these rocks together. A fault of this magnitude might be expected to generate a conspicuous zone of cataclasis. Cataclastic effects have indeed been observed but their relatively small scale and their observed nature and relationships are more typical of autoclasis at the margin of a near-crystalline intrusion. It must, therefore, be concluded that the Woodham Granite has intruded the Permian rocks after their initial deformation, and to have been intimately involved with their subsequent deformation. The features of the contact-zone are more readily interpreted in the light of this hypothesis.

The previous acceptance of a fault-contact hypothesis has, no doubt, been based on the lack of conspicuous thermal metamorphism in the country rocks. Tuttle and Bowen (1958) have noted, however, that hypersolvus granites show little contact metamorphic phenomena. The presence of highly-felsic granite in the contact-zone is believed to indicate that some assimilation of quartzo-feldspathic sedimentary material occurred at depths below that which is now exposed. The observed mortarisation is likely to have occurred as the contaminated granite was intruded, along with the main body of granite, into higher parts of the crust. Where it is now seen, it has shielded the country rocks from all but incipient contact metamorphism. A low volatile content of the magma (as indicated by the prevalence of perthitic potash feldspar) would also be expected to limit the amount of contact metamorphism.
Crystallisation of the mafic constituents in the granitic magma must nearly have been complete at the time of intrusion. This is demonstrated by the presence of platy-flow structures; the orientation of which is concordant with the contact, as would be expected of a partially fluid intrusion. The margins of the intrusion were, as suggested above, zones of autobrecciation of granite and cataclasis of the country rocks. This has had differing effects in each the three localities described. At locality (a) the country rocks have been highly sheared but confining pressure has been sufficient to restrict the amount of brecciation. At locality (b) granitic material, probably near-crystalline at the time of intrusion, has actively invaded brecciated country rocks. The broad contact-zone at locality (c) has had a more complex history. Repeated injections of granite have probably lead to the development of a wide zone of autoclasis involving intimate intermixing of sedimentary and granitic material. The major part of the granitic material being derived from brecciation of the highly-felsic marginal facies; some injection of more typical Woodham Granite has also taken place. The extensive hydrothermal alteration of the sedimentary rocks is considered to be due to volatile constituents, emanating from later granitic injections, rising through the zone of autoclasis.

The variation of contact effects is attributable to their places of formation being at differing depths and positions on the edge of the pluton.
The Woodham Granite is therefore visualised as a plutonic mass injected into folded Permian sediments. That part which is now exposed, is considered to be the upper portions of the body. Further injection late in its igneous history has recrystallised part of the granite; leading to the development of the granulite rocks of Davis Creek; it has also been the agent for hydrothermal alteration of part of the marginal zone of autoclasis.

**Time of emplacement**

The preceding discussion has brought forward evidence of a post-Upper Permian time of emplacement for the Woodham Granite. The only upper age limit afforded by stratigraphy is that it is overlain by middle Tertiary strata.

The likelihood of a late Palaeozoic - early Mesozoic folding of the Permian sedimentary sequence is suggested in the section dealing with the structural geology of this area. It is probable, therefore that the Woodham Granite was associated with this orogenic period and is of early Mesozoic age.

Aronson (1965) has radiogenically dated a pegmatite from the Separation Point Granite; this has given a Lower-Middle Cretaceous age for that unit. Geographically the Separation Point Granite is the northern continuation of the Rotoroa Igneous complex and geologically they are very likely to be related in origin. If emplacement of the Woodham Granite is accepted as being related to deformation of the Permian rocks, the dated portion of the Separation Point Granite is certainly younger than the Woodham Granite.

As previously noted, the hypersolvus Woodham Granite is
thought not to have been recrystallised in its present geological situation; it may therefore be a very suitable rock for reliable radiogenic age determination.

**Blick Diatreme (BD)**

**Introduction**

Evidence of small-scale volcanic activity of Early Pleistocene age is present in the southwest corner of the thesis area. A volcanic neck containing tuffisite, volcanic breccia, variolitic basalt and obsidian crops out at the head of Fuchsia Gully. The name Blick Diatreme is applied to this association of volcanically derived rocks.

The diatreme is situated at the top of the steep slopes forming the head of the gully (Grid Ref. 539/762365). A general view of the locality is presented in Figure 9. Rocks of volcanic origin form a north-trending elongate mass about 450 feet long and having a maximum width of 150 feet. These are the vent-filling materials and they form a low mound which rises to about 50 feet above the vent-margins. Soil and vegetation obscures much of the outcrop but a good section is visible above a small slip in the head of Fuchsia Gully, on the northwestern side of the vent.

The geological setting of the Blick Diatreme is approximately a mile east-northeast of the junction of the Woodham and Glenroy Faults. This is an area of complex structure; fault-bounded slivers of middle Tertiary sediments are infaulted into Permian strata adjacent to their contact with the Woodham Granite. The vent is
Figure 9. Head of Fuchsia Gully showing situation of the Blick Diatreme, as viewed from the west. Tuffisite (t), volcanic breccia (vb), contact with country rocks (dashed line).
located on a north-trending fault within the Double Creek and Foulsham Formations.

As volcanic rocks of this age and occurrence have not hitherto been recorded in this region, the Blick Diatreme is described in some detail. Mineralogical work carried out during the investigation of the Blick Diatreme is described and discussed in an appendix to this thesis.

General description

The relationships of the rock units comprising the Blick Diatreme are shown in the sketch plan and section in Figure 10. The following paragraph names of rock units are underlined; these names are used to refer to these units in the remainder of the text.

The country rock marginal to the vent is baked hematitic sandstone of the Foulsham Formation. The northern part of the vent-margin is marked by a thin layer of red sheared clay, the sheared basal layer. It is overlain by a mass of volcanic breccia 30 feet thick. This unit has been subdivided into three subunits (types) on the basis of texture and origin. A small body of variolitic basalt is included within the volcanic breccia; this rock type also forms the matrix of the breccias. The most abundant rock type of the diatreme is the quartzo-feldspathic tuffisite. It comprises the bulk of the vent-filling material, being the only rock type seen in the middle and southern parts of the outcrop. It rests directly upon the baked hematitic sandstone. Loose blocks of obsidian occur on the outcrops at the northern end of the diatreme.
Petrography and petrology

Baked hematitic sandstone

This is the altered country rock surrounding the vent. The zone of alteration is at least 6 feet thick. In hand specimen, the rock is a grey-black medium-grained sandstone of moderate to high induration. Bedding, dipping into the vent, is visible in outcrop.

In thin section (UC 5273) it is seen to be a moderately-sorted feldspathic sandstone comprised of about equal amounts of angular quartz and basic oligoclase grains. The grains are loosely packed in a very fine-grained and dark-coloured matrix which has, in part, the appearance of a devitrified glass. The matrix comprises about half the rock and groups of minute quartz grains are scattered throughout it. Wollastonite occurs as small patches of parallel fibres. Rare grains of microcline are also present. Occasional shreds of muscovite appear in the matrix but it is more common as a sericitic alteration of some feldspar grains. The entire section is dominated by the presence of abundant hematite and magnetite, in the matrix and in veinlets up to 1 mm. thick.

The sandstone shows the effects of thermal metamorphism and metasomatism such as might be expected in the presence of high-temperature ferriferous solutions. Its detrital minerals are similar to the sandstone of the Double Creek Formation (which it is presumed to be). The presence of wollastonite indicates that temperatures of the pyroxene-hornfels facies were attained but this must have been for a very short period as the rock has not attained a hornfelsic texture.
Figure 10. Sketch-plan and cross-section of the Blick Diatreme.
Sheared basal layer

This occurs as a 6 to 8 inch thick layer between the baked hematitic sandstone and the volcanic breccia in the northern part of the vent. It is a moderately-indurated rust-red clay-like material which carries an abundance of strongly schlackensided shear planes. Both the sheared basal layer and the internal shear planes dip into the vent at about 40 degrees.

In thin section (UC 5272) it has the appearance of a sheared earth or mudstone. Very fine-grained angular quartz and a little feldspar is set in a streaked-out clay-like matrix. The matrix contains minute flakes of golden biotite and is thoroughly stained by large amounts of finely-divided hematite.

Occurring as stringers and pods within the sheared basal layer, is a grey moderately-indurated sandstone, the quartz grains of which are well-fractured and stained with hematite and magnetite. Minor amounts of white clay occur as thin sheared blebs between the sandstone bodies and the red clay of the sheared basal layer.

Volcanic breccias

These rocks comprise most of the northern part of the vent-filling materials. All are composed of sandstone fragments set in a matrix of variolitic basalt. Variation in the relationship of fragments and matrix allows subdivision of the breccias into three types, herein designated 'A', 'B' and 'C'. These textural differences reflect the modes of formation of the breccias.

The type 'A' volcanic breccia is the most abundant. It is 30 feet thick and comprises a continuous body resting on the sheared
basal layer and extending to the upper surface of the volcanic pile. It is composed of sandstone fragments 'floating' in a matrix of variolitic basalt. The fragments are angular to subangular and most are equidimensional, the longest axis ranging from $\frac{1}{2}$ to 3 inches. Few of the fragments are in contact, the matrix forming about two thirds of the total volume of the rock.

In thin section (UC 5274) the sandstone is seen to be medium-grained and composed of angular and heavily-fractured quartz grains set in a glassy groundmass containing patches of hematite. Veins of microlite-bearing glass, up to 1 mm thick, traverse the section.

The basaltic breccia-matrix is highly-vesicular throughout. The vesicles are somewhat flattened and near the base of the outcrop the flattening is parallel to the sheared basal layer. The stretching of the vesicles is due either to flowage of the breccia or to the weight of the overlying material.

The base of the breccia rests directly on the sheared basal layer, with which it has not intermingled. In the upper parts, the type 'A' volcanic breccia contains the type 'C' breccia and laterally it grades into the massive variolitic basalt associated with the type 'B' breccia.

The type 'A' breccia is considered to be the major product of the second eruptive episode of the diatreme. An ascending body of gas-laden basaltic magma picked up country rock from the sides of the vent and from material dropping down the vent during emplacement of the tuffisite. The fragmented material was carried within
the body of the magma and both were extruded at the surface as a viscous and spongy mass.

The type 'B' volcanic breccia is exposed at the north end of the diatreme, 25 feet above the sheared basal layer. It is of more massive appearance than the type 'A' breccia. The component fragments range in size from 3/4 to 6 inches across, are highly-angular and are very closely packed. In some cases it appears that large sandstone blocks have been brecciated in place, the magma fracturing and penetrating the rock without much relative displacement of the fragments. Its overall appearance is that of a sandstone body which has been veined by basaltic magma. This is illustrated by Figure 11. On the southern side it grades into massive and slightly vesicular variolitic basalt.

The type 'B' breccia appears to be enclosed in the type 'A', the large sandstone blocks have probably been transported from lower levels by ascending magma. The final brecciation must have occurred immediately prior to coming to rest for the fragments of the blocks have been little displaced. It is considered to have been emplaced in the second eruptive episode, along with the variolitic basalt and the type 'A' volcanic breccia.

The type 'C' volcanic breccia is an open stockwork of basalt-coated sandstone fragments situated on the upper surface of the type 'A' breccia. It is illustrated in Figure 12. The fragments are similar in size to those of the type 'A' breccia and the basalt coating is usually less than 1/8 inch thick (Figure 13). The open spaces within the stockwork are similar in size to the component
Figure 11. Type 'B' volcanic breccia at north end of Blick Diatreme. Angular sandstone fragments are enclosed by variolitic basalt.

Figure 12. Pocket of type 'C' volcanic breccia on upper surface of type 'A' volcanic breccia, Blick Diatreme.
Figure 13. Cut and polished specimen of type 'C' volcanic breccia, Blick Diatreme; X 1\(\frac{1}{2}\). The sandstone fragment at right is covered by a thin skin of vesicular basalt having an air-cooled surface.

Figure 14. Pahoehoe surface of variolitic basalt associated with types 'A' and 'C' volcanic breccias, Blick Diatreme; 1\(\frac{1}{2}\).
Figure 15. Photomicrograph of variolitic basalt, X 400, crossed Nichols. Varioles (at maximum illumination) surrounded by glassy margins and set in a groundmass of skeletal augite. Variole at lower left has a core of fractured and partially embayed quartz.

Photo: D. J. Jones

Figure 16. Photomicrograph of tuffisite, Elick Diatreme; X 400, crossed Nichols. Note clastic-type texture and rounding and distortion of grains. Quartz (q), crypto-perthite (c), plagioclase (p).

Photo: D. J. Jones
fragments; the basaltic-coating appearing to cement the fragments in place. The basalt has a smooth to slightly ropy surface and weathers a purplish-brown colour. In parts of the stockwork where the coating is thicker, it has a typically 'pahoehoe' textured surface (Fig. 1b), which in some cases is broken by vesicles. The direction of flow of the lava, as indicated by the flowed surfaces, suggests that the rocks are in essentially the same attitude as at the time of flow and cooling. It also demonstrates that this part of the volcanic breccia flowed and cooled in contact with the atmosphere.

The type 'C' volcanic breccia appears to be nested within the upper surface of the type 'A' breccia. It is thought to be derived from the type 'A' breccia by tumbling of sandstone fragments, previously coated with basalt, from an over-steepened face of type 'A' breccia immediately prior to its solidification. Solidification of the basalt coating must have occurred almost simultaneously with the fragments coming into contact with one another, hence preserving the open structure of the tumbled breccia. The type 'C' breccia is thus of very local significance; it is the result of a minor process occurring at the unstable face of a viscous and inhomogenous body.

The definition and classification of volcanic breccia has been the subject of considerable debate in recent literature. Fisher (1958) defines 'volcanic breccia' as:

".... a rock composed predominantly of angular volcanic fragments greater than 2 mm, in size set in a subordinate matrix of any composition and texture, or with no matrix: or of fragments other than volcanic set in a volcanic matrix."
It is clear that this definition carries no genetic significance, and as a field term may embrace a wide variety of rocks of diverse origin; it includes the breccias of the Blick Diatreme. However, in a comprehensive classification of "volcaniclastic" sediments and rocks (Fisher, 1961) no suitable subdivision incorporating the volcanic breccias of the Blick Diatreme is made. Wright and Bowes (1963) reject both the definition and classification of Fisher on the grounds that a volcanic breccia must be formed entirely by volcanic agencies, but they do not formally re-define the term. Wright and Bowes subdivide volcanic breccias into three groups: autoclastic, alloclastic and pyroclastic. They have stated that alloclastic volcanic breccia is formed:

"... by the fragmentation of any rock by any form of volcanic activity beneath the surface of the earth."

These authors subdivide alloclastic volcanic breccia into:

- **Intrusion breccia** - formed by the forcible intrusion of magma into country rock.
- **Intrusive breccia** - formed by the fragmentation of a rock and its mobilisation by magma or gases and intrusion with or without an igneous matrix.
- **Explosion breccia** - formed by gas explosions in confined places beneath the surface. This may be followed by gas-streaming and the formation of rounded boulders leading to the development of intrusive breccia.

Although this classification, with its genetic implications, may at times be difficult to use in the field, it is relatively satisfactory when discussing the volcanic breccias of the Blick Diatreme because their origin is quite obvious. Furthermore this classification does
embrace these breccias. Thus the classification of Wright and Bowes is to be preferred in this case.

The volcanic breccias of the Blick Diatreme are clearly alloclastic volcanic breccias for the majority of fragmentation has been caused by volcanic action. All are intrusive breccias with respect to the country rocks. The type 'B' breccia is an intrusive intrusion breccia. The type 'C' breccia is a surface modification of the type 'A' intrusive breccia. The type 'A' intrusive breccia may, in part, have had its origin as an explosion breccia as well as an intrusion breccia.

**Variolitic basalt**

In handspecimen, the rock is fine-grained, hard and dark-grey with light-grey spherical patches of about 1 mm, diameter abundantly distributed throughout the darker matrix. Vesicles are common and vary in size from 1 to 10 mm, the larger ones are often somewhat flattened. On surfaces exposed to air at the time of cooling, i.e. the pahoehoe surfaces, the rock weatheres to a dull brownish-purple, on other surfaces (fractures etc.) which have been cleared of debris by subaerial erosion the rock appears to be quite fresh, a slight lightening in colour being the only evidence of weathering.

In thin section (UC 5280) the rock is mesocrystalline and variolitic; sub-spherical varioles (0.8-1.0mm diameter) being set in a fibrous and partially glassy dark-coloured groundmass, see Figure 15. The varioles consist of sub-radiating and interlocking acicular labradorite crystals and microlites averaging 0.1mm in
length, with rare minute grains of augite and much interstitial magnetite. Some varioles have a single quartz grain in the core. These grains are well fractured and have rounded and partially eroded outlines; they are probably quartz xenocrysts derived from sandstone wall rock. Varioles without cores have a microcrystalline centre surrounded by a darker peripheral zone, parts of which appear glassy. The outer part of this zone is in contact with the groundmass which has a thin dark glassy selvedge against the variole. In grain size the groundmass is similar to the varioles, but its texture and composition differs in that it contains gently curved bundles of skeletal augite fibres which carry aligned magnetite grains. The bundles are randomly arranged and are interspersed with small augite grains (0.015-0.02mm diam.), occasional acicular plagioclase and patches of brown dusty glass. The habit of the groundmass augite is similar to the cervicorn structure described from the Talaidh Cone-Sheets of Mull by Thomas and Bailey (1924). They state that the structure does not appear to be that of an ophitic individual with simultaneous extinction of its component parts, but that each stock has its own orientation, the extension of each branch being in the general direction of the prismatic zone-axis. As the bundles described above are in optical continuity, each may be considered as being a cervicorn stock, although there is no recognisable stellate grouping of the bundles as typifies this structure in the quartz dolerites of central Mull.

Within the section an area of brown glass, containing
rare cracks and abundant crystallites, grades laterally into the
dark fibrous groundmass. Included in the glass are fractured and
partially eroded quartz grains and globules of a grey glass with dark
edges. Some of the crystallites are radially arranged about the
globules. This feature is believed to represent an incipient but
supercooled phase of the texture exhibited in the more crystalline
portion of the rock.

As the fine grained nature of the rock would render normal
point counting techniques difficult and inaccurate, a visual
estimation of the mode was carried out. This indicated:

| Augite     | 40% |
| Labradorite| 40% |
| Magnetite  | 10% |
| Glass      | 10% |
| Quartz xenocrysts | 1-2% |

The criteria for classifying this rock as basalt are
discussed in the appendix.

There is, in the literature, little uniformity in the use
of the terms "variolite" and "variolitic", although there is agree-
ment that varioles are the basic counterparts of the spherulites of
acid volcanic rocks. Some authors e.g. Daly (1914), Johannsen (1937)
and Tyrrell (1929) use the term "variolite" to name a rock having a
basaltic or diabasic composition and showing variolitic texture.
Hatch, Wells and Wells (1948), Harker (1909) and Williams, Turner
and Gilbert (1958) on the contrary, do not use "variolite" as a
rock classificatory name. These authors refer to "variolitic"
basalt or "variolitic" diabase, thus restricting usage to the
adjectival form. In view of the generally accepted need to reduce
the number of petrographic names to a practicable minimum, it seems wiser to use only the adjectival form; that is, as a textural term in conjunction with a normally recognised rock name. This is the usage as adopted herein; i.e. variolitic basalt.

**Quartz-feldspathic tuffisite**

This rock type is the most abundant constituent of the diatreme association. It comprises the central and southern parts where a maximum thickness of 50 feet is exposed above the vent-margins. It is believed that this rock type also extends to some depth within the volcanic neck.

Macroscopically, the tuffisite is fine-grained and minutely scoriaceous with occasional clusters of larger gas bubbles. Its induration varies from poor to moderate and it is predominantly red and black in colour. The colouration is distributed irregularly through the rock in streaks and patches of varying size and shape. Minor streaks of yellow-brown limonite are also present. No layering of stratification was observed.

Five thin sections (UC 5275, 5276, 5277, 5278, 5279) have been examined and the following description is compounded from them. Texturally the tuffisite has a decidedly clastic aspect. Angular grains of quartz and feldspar, in equal quantity, are evenly distributed throughout a dark groundmass which may constitute up to 75% of the rock. Hence the larger grains appear to be 'floating' in the fine-grained groundmass. Grain size of the larger fragments is extremely variable and ranges from 0.05 to 0.20 mm. Quartz grains comprise up to 15% of the rock, and are usually fractured but do not
show strain-shadowing. In one section where fractured quartz is common, the fractures are filled with a clear isotropic substance having a refractive index much below that of quartz; this may be groundmass glass which has not devitrified. Some quartz grains show irregular and partly embayed outlines which are probably due to partial melting.

Both plagioclase and potash feldspars are present. The plagioclase appears quite fresh and some grains have subhedral outlines, its composition is predominantly acid andesine (An30 - An40).

The potash feldspar has a 'crackle-finish' type of texture in individual grains, which are usually subhedral with parallel sides and corroded ends. It is slightly brown in plane-polarised light at low magnifications, has refractive index less than balsam and is biaxial negative with a 2V of 20-30 degrees. Minute discontinuous exsolution laminae were noted in some specimens. In optical properties and general appearance, this feldspar is similar to microperthite in the granulite rocks of Davis Creek. It is considered to be a sanidine-cryptoperthite or microperthite comparable with those studied by MacKenzie and Smith (1956). Reference to their Fig. 1 suggests (optic axial angle data) an orthoclase-molecule content of 70 to 80% by weight.

The groundmass is light coloured and almost isotropic. It is predominantly a devitrified glass which contains minute feldspar microlites and tiny grains of quartz. Minor shards of quartz and feldspar are scattered throughout the matrix which, on the average,
comprises 70-80% of the rock. Small vesicles (up to 0.5 mm diameter) are common throughout all the sections.

Rare and altered microcline was observed in most sections and single occurrences of zircon and alunite are noted. Small patches of calcite are also present. In one section a group of vesicles are lined with pale-yellow chalcedony.

The most conspicuous feature of the red tuffisite is its high content of iron oxides. Clumps of magnetite grains are scattered through all the sections but on the whole they are not very abundant. In the red tuffisite, however, there is 50 to 60% of finely divided, translucent bright-red hematite. It is most commonly seen on the borders of vesicles and has a patchy distribution in the matrix of the rock. In the black tuffisite, hematite is rare or absent and the colour is due to the fine grain size of the groundmass.

The average of the modes of four slides is:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>13.3%</td>
</tr>
<tr>
<td>Feldspar</td>
<td>12.5%</td>
</tr>
<tr>
<td>Matrix (incl. Fe oxides)</td>
<td>74.2%</td>
</tr>
</tbody>
</table>

The nature of the quartz and feldspar grains in this rock, indicates that they are derived from the country rocks. The highly-fractured quartz grains are likely to have been the components of sheared country rocks, the absence of strain-shadowing being due to the release of tectonic strain by heating. Crypto and microperthitic potash feldspar are the expected result of high temperatures (promoting exsolution) alteration of the perthite in the Woodham Granite. Microcline occurs in both the granitic and the sandstone
country rocks. On account of its high proportion of fine-grained country rock material, this rock is classified as tuffisite (Cloos, 1941). The texture is illustrated in Figure 16.

**Obsidian**

Loose blocks of highly-vesicular obsidian are found scattered about the northern end of the outcrop. It is a dark-grey to black glass exhibiting pronounced flow structures. This is shown by flattening and elongation of vesicles in a common direction and by bands of light-grey within the darker coloured variety. A block of sandstone, about 3 inches across, was found included in glass; the flow layering diverged and converged about it.

As discussed in the appendix, the obsidian is believed to have a silica content greater than that of the basalt from which it is presumed to be derived. The inclusion of country rocks suggests that this higher value may be due to assimilation of quartzose material. Alternatively it may have been completely-molten tuffisite.

Since no glass was found in place, its spatial relationship to the other rock types may only be surmised. Possibly it was associated with the initial episode of volcanicity and has been broken up and dispersed by the second episode.

**General features of diatremes and their formation**

The Blick Diatreme bears an overall similarity to the large number of worldwide occurrences of this form of volcanic activity. The marked preponderance of tuffaceous rock over crystalline
rock and the presence of abundant country rock debris within the vent-material, may be regarded as typical of diatremes in general. In addition, the absence of lava flows and the virtual restriction of ejected material to the confines of the vent-opening, are common features. The presence of an outwardly-flared neck (as indicated by the inward dip of the sheared basal layer and the baked hematitic sandstone) is characteristic. Daubree (1891), first to use the term 'diatreme', produced artificial explosion pipes which were funnel-shaped at each end. Hack (1942) has suggested that the origin of the flare is due partly to unconsolidated surface sediments and partly to the decrease in static pressure at the pipe opening. The magmatic rocks associated with diatreme formation are almost always of near-basaltic composition.

Diatremes are generally considered to be the product of explosive penetration of country rock; this being initiated by gaseous or phreatic explosions ahead of an ascending body of magma. The magma does not reach the surface in all cases and the complete volcanic episode is considered to be extremely short lived.

Daly (1914) included diatremes in his 'subordinate' class of central eruptions and considered that each vent originated over a magmatic body satellitic with respect to a main abyssal injection. Bradley (1965) proposed a mechanism for the production of small explosive volcanoes by localisation of steam pressure in the roof of a sill.
In some instances, the manner in which country rocks have been brecciated, and then intruded into volcanic necks, is not clear. Gates (1959) has reviewed the theories of brecciation of country rock by volcanic agencies. A wide range of mechanisms have been proposed. In general they vary with regard to the composition of the country rock and the intensity, and in some cases the absence, of explosive phenomena. However, one mechanism, that of 'fluidization' (Reynolds, 1954), appears, in recent literature, to have been more widely accepted than most. The application of the concept of this industrial process has enabled the satisfactory interpretation of many of the recorded features of diatremes. Thus, effects such as the comminution of country rock to fragments, the intrusion of breccia and the production of authigenic explosion breccias, can be interpreted as the results of a single mechanism.

**Mode of emplacement of the Blick Diatreme**

The emplacement of the Blick Diatreme can be visualised as proceeding in two episodes. The first being perforation of the country rocks and the almost simultaneous filling of the vent by a large body of iron-rich quartzo-feldspathic tuffisite. In the second episode, a lesser amount of volcanic breccia and basaltic magma were intruded into the tuffisite body. The occurrence of the sheared basal layer, only at the volcanic breccia - country rock contact, is evidence for this sequence of events. The lithology of the sheared basal layer suggests that it is a part of the iron-rich tuffisite of the first episode which has been caught between the vent-wall and an upward-moving mass of viscous volcanic breccia.
This has resulted in the complete oxidation of iron oxides to hematite by steam lost from the magma, and in the finely-communited nature of the quartz and feldspar grains. The absence of shearing effects at the tuffisite-country rock interface is interpreted as evidence of the fluidized nature of the tuffisite at the time of its emplacement. The attainment of the fluidized state requires a high velocity of the supporting gaseous phase. This, in turn, suggests that the first episode in the emplacement of the Blick Diatreme was indeed of explosive character.

The glassy groundmass of the tuffisite demonstrates that the rock contained a high proportion of silicate-melt phase at the time of its emplacement. The major part of this is believed to have been molten fine-grained country rock debris with a high water content. The iron-oxide content of the rock is most likely to have come from iron-bearing aqueous solutions emanating from the basaltic magma. The variation, from angular to embayed outlines, of quartz grains in the tuffisite is probably due to the length of time they were exposed to the high-temperature conditions of the rock; some grains having entered the tuffisite later than others. It is considered that the tuffisite must have been heated as quickly as it appears to have cooled; there being only sufficient time for the complete melting of the finest-grained country rock debris. The production of obsidian may be an exception. The presence of wollastonite, indicating pyroxene hornfels facies conditions, in country rock without major textural changes, further suggests that high temperatures were attained for a very limited time only. This
supports the contention that the tuffisite has been explosively emplaced.

There is much evidence demonstrating that the Blick Diatreme has resulted from explosive activity associated with a basaltic intrusion. Initiation of the explosive activity is considered to have occurred as follows: because the diatreme is located in a fault-zone, it is probable that phreatonic waters penetrated to considerable depth within this zone of brecciated rock; basaltic magma also entering the same fault-zone and coming into contact with these waters could be expected to explosively liberate superheated steam and magmatic gases. If the resultant gaseous phase had a high temperature and pressure, it would have been capable of fluidizing the fault-breccia as it rose to the surface up the fault-zone. Once a fluidized state was achieved, considerable attrition of country rocks could occur, the finer-grained products of which must have been carried to the surface in a partially-molten state. Solidification of this material yielded the tuffisite rocks of the vent, these being the products of the first episode of emplacement.

The rise of basaltic magma in the pipe, probably closely following the fluidized phase, lead to the second episode of emplacement. In its upward course, the magma picked up much country rock debris, derived both from the sides of the pipe and from fragments too heavy to be supported by the fluidized stream. This material was intruded at the northern end of the vent to form the volcanic breccias and the associated massive variolitic basalt.
Age and geological implications

There is no evidence to suggest that the Blick Diatreme was emplaced in an attitude differing from that of the present time. The inferred direction of flow of the pahoeohoe lava in the type 'C' volcanic breccia is consistent with it having flowed under the influence of gravity in its present position. Therefore the diatreme must have been emplaced after the last tectonic events in this area. The Glenroy Fault and other faults in this area are believed to have been active in early Pleistocene time. The Branch and Thornton faults have moved slightly since then, but they are not known to have affected the Fuchsia Gully area. The early Pleistocene movements were probably the climax of the Kaikoura Orogeny in this region. Because active faulting and basaltic volcanism are generally held to be compatible events, it is suggested that the Blick Diatreme was emplaced immediately following the cessation of early Pleistocene diastrophism in the Glenroy-Matakitaki area. This age is believed to be supported by the geomorphology of the Fuchsia Gully area. A system of three gullies is radially arranged with respect to the diatreme outcrop, this suggests that it is sufficiently old to have had some influence on the development of the recenttopography.

In the majority of recorded cases, diatremes have been found to occur as swarms. Until detailed field examination of the surrounding region is undertaken, it will not be certainly known that the Blick Diatreme is an isolated feature. Until this is established, or otherwise, the geological significance will remain
obscure.

Many diatreme swarms have been shown to be related to the intrusion of basic igneous rocks on a regional scale. In most cases in the literature, areas with diatreme swarms show little tectonic disturbance. As the Blick Diatreme is set in an area of complex faulting, it may well be an unusual case. It provides evidence that, during the Kaikoura Orogeny, basaltic magma rose to the upper parts of the crust in this area. Geophysical investigation may indicate the extent of near-surface basaltic rocks and thus assist the interpretation of this effect.
Haast Schist Group (II, III)

Introduction

Suggate (1961) defined the Haast Schist Group to include all the schists produced by metamorphism of the rocks of the late Palaeozoic-Mesozoic geosyncline in New Zealand. In the Matakitaki region the schistose rocks east of the Alpine Fault are mapped within this group. Henderson and Fyfe (1935) applied the local name, Glenroy Series, to these rocks and mapped them as schists and sub-schists. Reed (1958) has mapped three metamorphic zones in these rocks; the zones are based on the appearance of index minerals. He subdivided the Chlorite Zone into three sub-zones. (Chlorite 1 to 3) corresponding to three (of four) subzones established by Hutton and Turner (1936) in the chlorite zone schists of Otago. Bowen (1964) has extended the mapping of these rocks, using the same terminology. Reed (1958) noted megascopic differences between rocks of the same subzone in Otago and in South-East Nelson; notably, the poorer development of schistosity in schists of the latter region.

Distribution

The rocks of the Haast Schist Group comprise that part of the thesis area east of the Alpine Fault, approximately a quarter of the area mapped. They form the major portion of the Nardoo Range and the divide between Nardoo Stream and the Matakitaki River.

Mapping of the Haast Schist Group

The criteria of Reed (1958, Table 15) have been used in classifying the schists in handspecimen and the subzone boundaries
have been mapped on this basis. Only the Chlorite 2 and Chlorite 3 Subzones were seen in the field.

**Lithology**

In hand specimen, the schists of Chlorite 2 Subzone differ little from the highly indurated sandstone of the Torlesse Group (Suggate, 1961). An incipient schistosity is present and the rock is moderately fissile. No foliation is present, most of the rocks being of massive appearance. A faint lineation is sometimes visible. Throughout most of their outcrop in this area, the rocks of the Chlorite 2 Subzone are heavily veined by quartz along sets of joint planes cross-cutting the schistosity, Fig.(17).

The schist of the Chlorite 3 Subzone has a prominent schistosity and foliation; the latter is stated by Reed (1958) to be a relict bedding with preservation of carbonaceous layers. The schistosity parallels the foliation. Lineation is more conspicuous than in Chlorite 2 Subzone rocks and some drag folding is present. Quartz veins are not as common as in the schist of the lower subzone.

**Distribution of the Subzones**

The Chlorite 3 Subzone occurs adjacent to the Alpine Fault for at least 3 miles southward from the mouth of the Nardoo Stream. Reed (1958) mapped the Chlorite 2-3 boundary as crossing the Matakitaki Valley at the north end of Windfall Flat. The writer, however, found Chlorite 3 schist in outcrops up to two miles south of this point, thus indicating that the chlorite 3 Subzone is more
Figure 17. Ice-plucked Chlorite 2 schist in northern face of roche moutonée east of Nardoo Creek. The heavy quartz veination is also seen in the Chlorite 2 schist of the moraine near Station Creek.
extensive. The southern boundary with Chlorite 2 schist was not seen.

Schist of Chlorite 2 Subzone crops out in the roche moutonée at the north end of Windfall Flat. From there it extends south-westward into the Nardoo Range. The outcrop is believed to be a north-east trending belt of Chlorite 2 schist which has been faulted into Chlorite 3 schist. The schistosity of the Chlorite 2 rocks strikes 20 to 30 degrees east of that of the surrounding Chlorite 3 rock; the lineation plunges about 10 degrees shallower, and in the same direction. The Chlorite 2 rocks are bounded by faults sub-parallel to the Alpine Fault; the shear-zone of the more southerly fault being exposed in the east face of the roche moutonée. The roche moutonée has remained as a resistant band of poorly schistose Chlorite 2 rocks while the surrounding Chlorite 3 rocks have been selectively abraded and plucked by ice, owing to their more schistose character.

The Biotite Zone was not seen in situ in the field, although stream boulders in the East Branch Glenroy River confirm that this zone is present in the Nardoo Range, as shown on the map of Reed (1958).

Schists of the Garnet Zone are not known to crop out in this area.
PART IV - STRUCTURAL GEOLOGY

Introduction

The rocks of the Glenroy-Matakitaki area have been deformed almost entirely by faulting. Apart from an inferred large-scale recumbent anticline, postulated to account for the overturned attitude of the Permian formations, no folding, either macroscopic or mesoscopic, is present. The rocks west of the Alpine Fault have been subjected to extensive block-faulting, and tilting of the blocks so formed.

So far as is known, all faults are steeply dipping, the minimum dip measured on a fault-plane being 45°. In general, these faults have created blocks and slivers, the majority of which show rotation about near-horizontal north and north-west trending axes; the rotation effecting a tilting to the west and northeast. The sense of displacement of most faults is reverse; most small-scale transcurrent components are believed to be apparent only. The Glenroy Fault exhibits considerable reversal of vertical displacement; the Woodham Fault may also show some reversal of movement.

The frequency of faults appears to increase in the west and southwest of the area. This may be due partly to the better exposures of that area, and partly to its position near to the intersection of the Glenroy and Woodham Faults.
The Yorkey Formation exhibits a considerable range of attitudes in the middle East Branch Glenroy River and much small-scale faulting is inferred to be present in this part. Directions of younging suggest that several of the fault blocks are 'right way up' in a sequence which is generally overturned; this is the most complexly deformed area of the Permian rocks.

Several faults transect the Woodham Granite and this may imply that they extend to considerable depth and are thus of importance with respect to regional tectonics.

**Description of the major faults**

**Alpine Fault**

A seven-mile sector of this major tectonic feature crosses the eastern part of the thesis area. The Alpine Fault trace is marked by a definite physiographic and lithologic break.

The physiographic break is a conspicuous trench which obliquely crosses the ridge between Station and Nardoo Creeks and continues southward along the eastern slopes of the Nardoo Range and into the headwaters of the East Branch Glenroy River. It is visible both on the ground and from aerial photographs. The trench is in the order of 100 feet deep and has a maximum width of 600 feet. Streams which cross it have parts of their courses adjusted along its strike and other streams have their heads within the trench. The rocks in the floor and sides are extensively crushed; well-jointed
Chlorite III schist forms the eastern wall and the west wall is of highly-crushed green sandstone of the Nardoo Formation. No actual contact of the two rock types has been seen. The origin of the physiographic break is not certainly known for it may be due, either to preferential erosion of crushed rocks, or to a small amount of recent relative upthrow of the western rocks.

This part of the Alpine Fault has not moved in post-glacial times. A fault-trace is not visible in the outwash surfaces and alluvium of the Matakitaki Valley, where the fault is presumed to cross it. The unconsolidated nature of the crushed rocks within the Alpine Fault trench suggests that the last movement of the fault may have been as recent as immediately pre-last glaciation.

**Glenroy Fault**

The north-south trending Glenroy Fault forms the western boundary of the area mapped. It is also believed to control the present course of the Glenroy River and that of the Matakitaki River below its junction with the Glenroy River.

The Glenroy Fault is inferred to form the contact between the formations of middle Tertiary age and the younger Longford Formation. It is also the eastern boundary of the syncline (hereafter, the upper Maruia syncline) in the upper Tertiary-lower Pleistocene rocks lying between the Maruia and Glenroy Rivers.

The present distribution of middle Tertiary and Longford Formation sediments can be interpreted only by postulating a reversal of vertical movement during the history of this fault.
During the diastrophic movements following the deposition of beds of Landon age, the area west of the fault must have been downthrown in order to allow accumulation of the Longford Formation in late Tertiary-early Pleistocene time. As no Longford strata have been recognised east of the fault, the Glenroy-Matakite area was probably a structural high at that time, material being eroded from it and transported across the fault to the present site of the syncline. The upper Maruia syncline is now, topographically, as high as the Glenroy-Matakite area, thus uplift west of the Glenroy Fault (reversing the earlier displacement) must have accompanied folding of the Longford beds in early or middle Pleistocene time. The same thrust regime which folded the syncline was undoubtedly responsible for uplifting the folded block; hence it is likely that the fault-plane dips to the west. Consequently it would appear that the first post-Landon movement of the fault must have had a normal component. In terms of principle horizontal stress, this is consistent with that indicated by the reverse nature of the east-west trending Woodham Fault, which was also active at that time. This aspect is further discussed in a later section.

The Glenroy Fault is thought to be the southern extension of a fault mapped in the lower Matakite Valley (Bowen, 1964). It may extend further to the south as the fault between Mount Arthur Group beds and Rotcrao Igneous complex west of Mount Cann (Bowen, 1964). Fyfe (1930), in a small sketch map accompanying a report, shows a fault parallel to the course of the Matakite River and extending from the Longford Bridge on the Buller River south to
Mount Cann. This is close to the presumed trace of the Glenroy Fault. It is not, however, shown on the maps of Henderson and Fyfe (1935).

It should be noted that no fault-plane has been seen in the Glenroy area, the fault being predicted from the evidence of structure and stratigraphy. There are too, locally disturbed attitudes in the Longford Formation close to the Glenroy Bridge. The thickness of the strata in the upper Maruia syncline suggests that the early-Pleistocene displacement involved a throw of at least 2000 feet. The amount of horizontal movement, if any, is unknown. The repeated movements of the Glenroy Fault have probably contributed to the prevalence of minor faults in the area between Fuchsia Gully and the East Branch Glenroy River.

Hunter and Potberry Faults

The Hunter and Potberry Faults are both northwest-trending fractures which appear to offset the Matakitaki Limestone and the formations which stratigraphically overlie it. A zone of crushed rocks within the Wheeler Formation in Potberry Creek, and a marked change of strike on either side, is the major evidence for the Potberry Fault. Brecciation of the Matakitaki Limestone south of Hut Flat and the presence of vertical beds of Wheeler, McNee and Yorkey Formation rocks east of this locality provide evidence of the Hunter Fault.

As there is no clear evidence that the Hunter and Potberry Faults penetrate the Station Creek and Nardoo Formations it is unlikely that simple dextral displacement along these faults will
account for the observed offsetting of the Permian strata. In both
cases, bedding immediately to the north of both fault-planes is
vertical or dipping steeply to the east, while that to the south is
overturned and dipping west. It is postulated, therefore, that the
blocks between the faults have undergone considerable northeastward
tilting and that this has exposed the steeply-dipping and non-
overturned beds of the recumbent anticline in the Permian rocks.
The apparent dextral offset is merely a result of the original
difference in depth, within the overturned limb, of strata now
adjacent.

Uplift immediately north of the Hunter Fault must have been
considerably more rapid than erosion. A large limestone flap has
slumped northwestward onto the younger Permian formations. This is
the origin of the shallow dips in the Matakitaki Limestone 1 2
miles northeast of Baldy and for its discordant contact with the McNee and
Yorkey Formations in that area.

Youthfulness of the topography and the survival of a
gravity flap of Matakitaki Limestone suggests that the last, and
possibly the major, movement on these faults occurred in geologically
recent time. It is likely, therefore, that the northeast tilting
of the blocks bounded by the Hunter and Potberry Faults is an effect
of the early Pleistocene diastrophism in this area. As these faults
do not appear to offset the Baldy Microgabbro, it may be that they
were initiated during the folding of the Permian formations, but
prior to emplacement of the Baldy Microgabbro later in the same early
Mesozoic diastrophism. Subsequent movements have taken place on
these pre-existing fractures.
Branch and Thornton Faults

The Branch Fault is considered to be the more important of these two faults, both of which are parallel to the Hunter and Potberry Faults. This is because of its greater extent and of the more pronounced physiographic and lithologic breaks which are attributable to it. It is probable that both faults have influenced the course of the East Branch Glenroy River.

The Branch Fault occurs as a conspicuous lineament (visible on aerial photographs) north of, and approximately parallel to, the East Branch Glenroy River. In the field, several streams which cross its trace are slightly offset (in a sinistral sense) in a zone of crushed rocks and discordant strikes. The southern face of the granite pinnacle of McNee is thought to be a retreating scarp of the Branch Fault and here the Woodham Granite-Yorkey Formation contact shows apparent dextral transcurrent offset.

At the southeastern end of the Branch Fault it has elevated Woodham Granite on the southwest side and brought it against the Matakitaki Limestone, the Baldy Microgabbro and the Station Creek Formation, all of which lie to the north of the fault. This has been accomplished by some pivotal movement, the pivotal axis lying in the upper East Branch Glenroy River. The consequence of this has been the downfaulting of the Horse Terrace and Priestman Formations, on the southwestern side of the fault, against the Wheeler Formation on the northeast side. The Branch Fault bifurcates at a point 2 miles west of the Alpine Fault; a more southerly-trending fault-trace crosses the head of the East Branch Glenroy River, and the extension of the main fault is considered
to terminate the southern end of the Matakitaki Limestone.

In the Glenroy area, the northern side of the Branch Fault is upthrown, thus elevating the prominent massif of McNee and Sub B, Westward tilting of the blocks on both sides is indicated by the attitude of the Horse Terrace Formation—Woodham Granite non-conformity in this area. The block to the north has been tilted through nearly 70 degrees while the southern block has been rotated further for both of these formations have a vertical attitude in the lower East Branch Glenroy River.

The hanging-wall of the Thornton Fault is seen where the fault-trace crosses the East Branch Glenroy River. A 6 inch fault pug is present, and the hanging-wall dips to the south at 45 degrees. Aerial photographs show a lineament extending northwestward from this point and passing to the north of Sub V. The steep northern escarpment of Sub V is considered to be an eroded fault-scarp on the southern and upthrown side. The Thornton Fault is thus reverse in character and the lower valley of the East Branch Glenroy River is therefore a depressed block.

The first movements of these faults are believed to have occurred in the Rangitata Orogeny. This would allow of the uplift and erosion of Permian strata, sufficient to expose the Woodham Granite so that it formed a surface of deposition by middle Tertiary time. The Branch and Thornton faults were again active in the Miocene, together with the Glenroy Fault; the consequence was the tilting of Landon strata and the underlying granite. Differential movement on the faults at this time, created cross-faulting which in-faulted the block of Double Creek Formation strata in the East
Branch Glenroy River. Further movements early in the Pleistocene are suggested by the youthfulness of the topography and the presence of a lineament cutting the Water Race Formation. It is likely that these last movements of the Branch and Thornton Faults were sympathetic to that of the Glenroy Fault at this time.

Woodham Fault

The Woodham Fault is a gently curving fracture which is concave to the north. In the south of the thesis area it forms the contact between the long west-trending sliver of Priestman Formation conglomerate and the Yorkey Formation. The fault-plane dips north and northwest, as does the nonconformable surface between Woodham Granite and the Horse Terrace Formation.

As the fault-plane dips more steeply than the surface of nonconformity, they are believed to intersect at depth, see cross-section B-B'. The Woodham Fault also, appears to have had a history of repeated and reversed movements. The latest displacement has been to thrust the Yorkey Formation southward over the Priestman Formation, together with tilting of the underlying Woodham Granite basement. However, the granite has earlier been elevated with respect to the Yorkey Formation, as shown in the discussion of the Branch Fault. Thus, if that movement occurred on the same fault-plane as is now visible, the Woodham Fault must once have had normal character. This is considered to have occurred during the Rangitata Orogeny which is the most probable time that Woodham Granite was elevated in this area.
Matakikaki Fault

This is an inferred fault lying just to the north of the area mapped. As it is believed to cause the northerly termination of the Permian formations, its probable character is discussed. Its trend is probably a little south of west, extending from north of the Matakitaki Limestone outcrop near Mole Stream to near the Warbeck Stream-Matakitaki River confluence. No fault-trace or crush-zone has been seen, these may lie beneath the gravels on the north side of the Matakitaki River. The fault is inferred on account of the considerable lithologic and physiographic breaks to north and south of the Matakitaki River. Displacement along the fault is probably complex because the block to the south has been both elevated and tilted in conjunction with movement on the Hunter Fault. Dextral transcurrent movement may also have occurred, as is suggested by the apparent displacement of the Rotcroa Igneous complex to the north and south of the Matakitaki River.

Henderson and Fyfe (1935) and Bowen (1964) have previously indicated the probable existence of such a fault.

The evidence for late Palaeozoic-early Mesozoic diastrophism in this area

Consideration of the structure of the Permian formations and their relationship to the Woodham Granite suggests that the Permian strata were folded in late Permian or early Triassic time, and that the Woodham Granite was intruded into them immediately after the folding.
The evidence for this is the overturned attitude of the Permian formations and the intrusion of the Woodham Granite against the youngest of these formations. From this relationship it is inferred that the Permian rocks were overturned prior to their intrusion by granite. As the granite was sufficiently exposed to form a surface of deposition in middle Tertiary time, erosion must have operated over a prolonged period in order to remove the Permian covering strata. The time required for the erosion of a considerable thickness of sedimentary rocks is difficult to assess, but it may have occupied the greater part of Mesozoic time.

The absence, elsewhere in New Zealand, of granitic intrusions associated with the Rangitata Orogeny, supports a time not later than early Triassic for intrusion of the granite. As noted previously, there is no evidence to suggest that the Woodham Granite was being eroded in Permian times.

Support for postulating diastrophism at the close of the Palaeozoic Era and early in the Mesozoic comes from the sediments of the Yorkey Formation. It has been suggested earlier in this thesis that the lithology of the formation, in common with its correlatives in Nelson and Southland, indicates the onset of relative movements between the Permian geosyncline and its provenance area. It is probable that the Yorkey Formation was being deposited as the geosyncline began to be everted and folded.

The structure of the Permian formations as exposed, is consistent with their being the overturned limb of a major anticline having an axial-plane dipping to the east. The vertical attitude of the Permian strata in tilted blocks north of the Potberry
and Hunter Faults has been earlier interpreted as demonstrating a transition from overturned to upright beds in depth. This indicates the likely existence of a synclinal axis to the west of the recumbent anticline. This proposed structure is illustrated in cross-section A-A'.

Emplacement of the Baldy Microgabbro and the Hunter Dunite probably preceded or accompanied that of the granite. These igneous bodies are considered to have been intruded parallel to the near-vertical bedding in the core of the anticline. These rocks, too, have been exposed only after considerable erosion of the folded Permian sediments.

Fault pattern

All faults west of the Alpine Fault, both known and inferred, have been plotted on a rose diagram, Figure 18. This method of presentation has been used because only the strike is known for many of the fault-planes. The data from which this diagram has been prepared are presented in an appendix to this thesis. Figure 18 shows that the faults of the Glenroy-Matakitaki area comprise three distinct sets with respect to their strikes.

An analysis of the faults falling within the three sets shows that each set is characterised by one of the major faults of the area. These are: the Glenroy Fault, the Alpine Fault, and the Branch Fault. The median strike of the sectors containing these faults is: 010°, 060°, 140°, respectively. All known faults within this area have strikes within 10 degrees of these values.

The existence of parallel shears suggests that at the
Figure 18. Rose diagram for the strikes of 21 faults in the Glenroy - Matakitaki area; all are west of the Alpine Fault.

Strikes in 20° sectors. Centimeters of radius equals number of faults.

The actual strikes of the major faults (from which the fault-sets have been named) appear outside the diagram.
time of application of regional stresses having a particular orientation, a set of parallel, and possibly en echelon, faults was developed. Evidence of reversal of displacement on several of these faults is interpreted as movement on pre-existing fractures in a stress-regime differing from that which caused the initial shear.

The Glenroy Fault set is, with the exception of a small fault in Station Creek, restricted to the west of the area. The minor faults are considered to be the result of some measure of antithetic faulting related to uplift along the Glenroy Fault.

The Alpine Fault set includes faults having a wider range of strikes and varying considerably in degree of importance. Apart from the Alpine Fault and the Woodham Fault, the faults of this set are generally minor faults of limited length and displacement; most appear to have originated no earlier than the Miocene. It is probable that they are the effects of highly-localised stress orientations resulting from movements on older and better developed faults in the area.

The Branch Fault set is the dominant one in the Glenroy-Matakiki area. It is considered that these faults are primarily reverse, as indicated by the Thornton Fault. They broadly divide the area into a series of northwest-trending slices which are nearly perpendicular to the Alpine Fault. The Branch Fault is the only fault which is known to extend close to that feature. The fault-bounded slices are tilted at generally high angles and the direction of tilt varies throughout the area. Transcurrent displacement is apparent on some faults but it varies with regard to both sense and amount; particularly so on the Branch Fault.
As the Branch Fault set is dominantly reverse in character, the direction of the principle horizontal stress at the time of its formation may have been northeast-southwest. The assumption is made that the entire Glenroy-Matakitaki block has not been rotated about a vertical axis. It has been suggested previously that these faults were initiated in the Rangitata Orogeny, or possibly earlier in the case of the Hunter and Potberry Faults. The Woodham Fault was probably a normal fault at this time. Because the Woodham Fault has a trend of approximately 45 degrees to that of the Branch Fault, it could therefore be argued that the principle horizontal stress was east-west at that time, not northeast-southwest. Thus the Branch Fault might be a sinistral transcurrent shear; this is true of its last movement, as indicated by stream offsets. However, the Woodham Granite appears to have been offset in a dextral sense. For the present, all that can be said regarding these conflicting interpretations, is that the situation is rather more complex and probably involves considerable amounts of oblique slip, and rotation of only parts of the slices between the faults at any one time. Until more is known about the net displacements and the relative ages of the faults, their further interpretation must remain in doubt.

There is clearer evidence for a north-south compression in Miocene time in this area. As the Glenroy Fault had normal character at that time, and the Woodham Fault was reverse, the Branch Fault might have moved in a dextral transcurrent manner, hence the offset of the Woodham Granite. In the early Pleistocene, the axis of compression in this region had shifted to an east-west orientation
and this was responsible for folding the beds of the Longford Formation, thus forming the upper Maruia syncline. It also uplifted this folded block along the Glenroy Fault, and its continued action has been the cause of the small amount of sinistral displacement now seen on the Branch Fault, the latter effect being more recent than movement on the Glenroy Fault.
PART V - GEOLOGICAL HISTORY

This part is an attempt to present in chronological sequence, the geological events described in the preceding parts of this thesis. In so doing, it has been necessary to date some events by what is known of the geological history of the surrounding region, where evidence is lacking within the thesis area. On the whole, however, the geological history presented herein is advanced as a sequence of events which are logically deduced from the rocks of this area. In dealing with the Permian rocks, it is assumed that they are now not far removed from their site of deposition; there being no local evidence to the contrary. The Alpine Fault is a regional feature of some complexity but is regarded, for the purposes of this discussion, as little more than an agency creating the juxtaposition of the Haast Schist Group and the Nardoo Formation.

The deposition of the Nardoo Formation in a geosynclinal environment, possibly in upper Carboniferous time, is the first geological event recognised within the area. Uplift and erosion of part of these rocks may have preceded the laying down of the sediments of the Station Creek Formation in lower Permian time. Little is known of the conditions of deposition of the Station Creek Formation, save that as it is considered to have conformably underlain the Potberry Formation until the intrusion of the Baldy Microgabbro, it was probably a continental-shelf deposit similar to the overlying Permian formations. Intrusion of basic igneous bodies may have been coeval with the sedi-
mentation of this formation. Alternatively, they may not have been emplaced until later when they were the feeding dykes of the submarine eruptions which provided the hematitic conglomerate of the lower Potberry Formation.

The Potberry Formation is believed to have conformably overlain the Station Creek Formation and its lower beds evidence considerable volcanicity. Submarine erosion of lava extruded above wave base, lead to the formation of bodies of intraformational hematitic conglomerate. The base of the Permian sequence in the Glenroy-Matakikaki area is typified by extensive syndepositional volcanic activity. Submarine volcanism ceased some time before the deposition of the Matakikaki Limestone and did not re-occur during the deposition of the remainder of the Permian sediments. Before the close of deposition of the Potberry Formation, the geosyncline began to subside at an increased rate; finely-laminated argillaceous sediments indicate the increased depth of deposition. The base of the Matakikaki Limestone marks the onset of a rhythmic type of deposition which persisted through this formation and into the two immediately overlying it. At the time of the Matakikaki Limestone, alternating rhythms of calcareous and argillaceous beds predominated. The incoming of sandy material, replacing calcareous laminae, marks the base of the Wheeler Formation. After the close of deposition of the Matakikaki Limestone, local basins developed on the sea floor and these became the sites of deposition of the Gorge Shale Member. As these basins were filled, the Wheeler Formation continued to be deposited as a typically rhythmic succession of siltstone and sandstone. The McNeal Formation, which preserved the rhythmic nature of deposition, marks a considerable change in the type
of sediment being supplied to the geosyncline. The origin of these maroon and green beds is not well understood; they perhaps record some extensive climatic change in the source area. The top of the McNee Formation marks the close of a period of uninterrupted rhythmic deposition which laid down over 5,000 feet of sediment, the rhythmic processes continuing to operate without regard to the change in composition of the sediments.

The sediments of the Yorkey Formation indicate the onset of tectonic activity toward the end of Permian time. Rapid uplift in the source area lead to the spread of aprons of conglomerate over parts of the shallowing sea floor. Superimposed on this general shallowing of the geosyncline were many local changes in the depth of deposition and the rate of supply of detritus. A short-lived return to conditions of sedimentation similar to those of the McNee Formation is shown by the Branch Siltstone Member. An increased rate of deposition in late Permian time is shown by the thickness of the Yorkey Formation relative to the underlying Permian formations. The Yorkey Formation is 6,000 feet or more thick, equal in thickness to the total of the four other formations, and probably deposited in a considerably shorter time.

At the close of the Permian Period, the diastrophic movements, which were foreshadowed by the sediments of the Yorkey Formation, reached a climax in the eversion of the shelf sediments, at least, of the Permian geosyncline. Diastrophism continued until the Permian sediments were folded into a major anticline recumbent to the west. This is believed to have effected the overturning of the Permian strata and may have initiated the Hunter and Potberry Faults. Towards the end of this diastrophic episode, after the formation of the recumbent
anticline, the Woodham Granite was emplaced. At about this time too, the Baldy Microgabbro was intruded, to be followed shortly afterwards by the Hunter Dunite and serpentinisation of the Station Creek Formation.

Throughout most of the Mesozoic Era, the folded Permian rocks were probably a foreland of the source area which supplied sediment to the New Zealand Geosyncline, thus depositing the Torlesse Group rocks. During this time, erosion of the Permian formations removed much of the strata covering the Woodham Granite and the Permian ultramafic rocks.

In late Jurassic–early Cretaceous time the Rangitata Orogeny elevated and folded the Torlesse Group rocks to the east. Within the area, the main diastrophic effects at this time are thought to have been the initiation of the Branch, Thornton, and Woodham Faults which elevated parts of the Woodham Granite.

Following the effects of the Rangitata Orogeny, the Glenroy-Matakitaki area resumed a state of tectonic calm throughout late Cretaceous and early Tertiary time. Stripping of the Sediments covering the Woodham Granite was accomplished during this period. The area appears to have been a structural high at this time and there is no evidence of sedimentation during the early Tertiary, although beds of Arnold age are known from adjoining basins (Fyfe, 1930; Bowen, 1964).

A transgression of the sea, in middle Tertiary time, lead to the deposition of beds containing marine faunas of Landon age. The Horse Terrace, Foulsham, Double Creek and Priestman Formations are the deposits of this time. The Horse Terrace Formation was laid down on a surface planed onto Woodham Granite; a basal conglomerate being
deposited in the lower parts of this surface. The Double Creek Formation is a deeper water deposit of the same time, the underlying beds having been faulted out since. Locally, as at Davis Creek, coal measures accumulated at the base of the Horse Terrace Formation. Deposition of the lenticularly-bedded Foulsham Formation was followed by the incoming of thick and widespread conglomerate of the Priestman Formation. The conglomerate resulted from the initial movements of the Kaikoura Orogeny which supplied vast quantities of greywacke debris to the Landon marine basins. Retreat of the sea from these basins accompanied their infilling with conglomerate, and a change to brackish or freshwater conditions is indicated by the presence of plant fossils in the upper beds of the Priestman Formation.

In common with other areas of lower and middle Tertiary deposition in Westland, the formations of Landon age in this area were elevated at the end of the Oligocene by the early phase of the Kaikoura Orogeny. This lead to the reactivation of the more southerly of the north-west trending faults and of the Woodham Fault. The Landon Formations were tilted and infaulted into Permian rocks and Woodham Granite, along these fractures. Uplift of the Glenroy-Matakitaki area, east of the Glenroy Fault, was perhaps the major effect of these movements.

From late Oligocene-early Miocene time onwards, the greater part of this area was free of sedimentation. Immediately to the west, however, a depression, the eastern edge of which was downfaulted along the Glenroy Fault, received dominantly terrestrial sediments of late Tertiary-early Pleistocene age. These deposits are the Longford Formation.
During the Pliocene, rapid deposition of a fanglomerate body in the Glenroy area, the Water Race Formation, may have resulted from minor movements preceding those of the early Pleistocene.

The last major diastrophic event in this area, occurred during Castlecliffian time in the main phase of the Kaikoura Orogeny. The late Oligocene-Miocene movement of the Glenroy Fault was reversed and the depression lying to the west of the fault was folded and uplifted to its present position as the upper Maruia syncline. This caused related movement on the Branch and Thornton Faults, which tilted and dislocated the Water Race Formation to its present attitude. These and faults further uplifted Woodham Granite and Permian strata, northeastward tilting along the Hunter and Potberry Faults occurred at this time. Movement on the faults of the Double Creek-Fuchsia Gully area was probably renewed and this is thought to have effected emplacement of the Blick Diatreme. Uplift east of the Alpine Fault probably began in the Pliocene and continued into the Early Pleistocene (Suggate, 1963), thus bringing the Haast Schist Group against the Nardoo Formation.

The late Pleistocene history is very sketchily known. Suggate (1965) has shown that the Matakitaki valley glacier, during the equivalent of the Kumara 2 advance, extended down-valley almost to the Horse Terrace Bridge. The lake beds of the Matakitaki Plains are thought to have been laid down in front of retreating ice of the equivalent of the Kumara 3 advance, which too, may have deposited the moraine east of the mouth of Station Creek.
REFERENCES


Kuenen, Ph.H.; Migliorini, C.I., 1950: Turbidity Currents as a Cause of Graded Bedding. J. Geol. 58: 91 - 127.


APPENDIX I

Mineralogy and classification of variolitic basalt and obsidian from the Blick Diatreme

Plagioclase feldspar

Optical data:

Occurs as acicular crystals or microlites with average dimensions of 0.1 x 0.008 mm.

n 1.54

Birefringence approximately 0.010 as determined from measured thickness of microlites having a maximum interference colour of first-order grey.

No visible twinning or cleavage.

Maximum extinction angle of 38° on elongation.

Assuming elongation parallel to a for microlites, Fig. 39 of Moorehouse (1959) indicates a composition of An58 for this plagioclase.

Due to the microcrystalline nature of the mineral it was deemed necessary to confirm identification by X-ray analysis.

A Frantz Isodynamic Magnetic Separator was used to concentrate the feldspar from a finely ground sample passing 300 mesh. A powder photograph was obtained using copper radiation with a nickel filter and exposing for fifty hours in a 114.4 mm diameter camera. The three main lines gave d spacing values of:

\[ 4.04 \text{ Å} \] (100)
\[ 3.21 \text{ Å} \] (80) Visually estimated intensities in parentheses.
\[ 2.51 \text{ Å} \] (80)
Comparison with the d values for plagioclases in the Index to X-ray Powder Data File (1961) confirmed the presence of plagioclase and suggested a composition within the andesine - labradorite range.

Smith and Gay (1956) have shown the limitations of X-ray methods of plagioclase determination; that is, that the effects of composition and of structural state (high-, intermediate-, low-temperature) are not always separable. They suggest that over the composition range An$_{20}$ to An$_{70}$, the function

$$\text{d} = 2 (131) + 2 (220) - 4 (131)$$

is the most useful for the determination of structural state if the composition is known. It is found that a smooth curve for variation of this function with composition is obtained from synthetic plagioclases, and a separate distinct and smooth curve for natural specimens from plutonic thick-layered intrusions. The curves are interpreted as defining high and low-temperature states respectively. Volcanic and hypabyssal specimens plot in intermediate positions with some tendencies for the hypabyssal values to plot between the plutonic and volcanic ones.

In the present study, use of data in Smith and Yoder (1956) enabled identification and measurement of the reflections for (131), (220), (131), and from these measurements a value of $d = 0.75$ for was determined. Plotting of this value on Fig. 1 of Smith and Gay (1956) shows that the plagioclase of the basalt, assuming crystallisation in a volcanic environment, has a probable composition within the range An$_{50}$ to An$_{60}$. Thus, both optical and X-ray data accord in suggesting a labradorite composition for this plagioclase.
Augite

Occurs as minute grains (0.015 - 0.02 mm in diameter) and as skeletal fibres arranged in bundles comprising cervicorn stocks. The fibrous variety carries prolific magnetite inclusions. \( n = 1.54 \). No visible cleavage. Birefringence is approximately 0.020 as judged by maximum interference colours of first order yellow and orange and allowing for the thickness of the grains. A refractive index determination on an augite concentrate obtained while separating for plagioclase, gave values of \( n \) between 1.67 and 1.70.

Classification of the variolitic basalt.

As a first approach to the classification of this rock, it was considered necessary to find some independent means of determining its silica percentage in the absence of a complete chemical analysis. Mathews (1951) has shown that for a given suite of volcanic rocks, the silica content of a rock within that suite is a function of the refractive index of the glass prepared by fusing the rock.

A powdered sample of the basalt was fused in a carbon arc and the resulting glass was crushed for a refractive index determination. The glass was inhomogenous with respect to refractive index (values of \( n \) ranged from 1.550 to 1.560), thus either fusion was incomplete or, more probably, there was insufficient mixing within the melt. Assuming that the true refractive index lies between the above two values, reference to Fig. 2 of Mathews (1951) indicates a silica percentage in the range 55 to 58. It must be noted that the curves given by Mathews are all for calcic suites of volcanic rocks. He states:
"Had alkaline suites been included in the studies we might expect to find other curves differing markedly from those already established, and in all probability lying on the opposite (left) side of the average curve prepared by George. Such variations show clearly how unsafe it is to assume that a composition-refractive index curve for one suite of rocks should necessarily apply for some other suite or age."

As the basalt shows rather more affinities with a calcic suite than with an alkaline one (lack of feldspathoids and potash feldspar) and furthermore, that it is only desired to find whether the rock is intermediate or basic, this range may be considered as a reasonable guide. Even if the rock is considered to be alkaline on the basis of possible feldspathoids in the mesostasis, the curve of George then gives a range in silica content of 52 to 54%. Subtracting 2% for xenocrystic quartz from both ranges of values, i.e., 53 to 56% and 50 to 52%, shows that the rock may be considered as lying on or just above the basic-intermediate boundary.

The difficulty in defining the limit between basalt and andesite is well known. Williams, Turner and Gilbert (1958) favour a silica percentage of 52 as their criterion, while Moorhouse (1959) prefers to distinguish these rocks on the basis of a plagioclase composition of Ab₁ An₁. In this case, because the determination of labradorite is considered to be more reliable than that of silica content, the definition of Moorhouse has been used in classifying this rock as basalt. Factors such as equal proportions of labradorite and augite, and the abundance of magnetite support this classification.
Obsidian

In thin section the glass is light-brown in colour, highly-vesicular and contains abundant crystallites.

A refractive index of 1.533 was found for a sample fused in platinum foil with an oxy-gas flame. From the curve of George (Mathews, 1951; Fig. 2), a silica content of 57% is indicated.

Determination of the water content of the glass was carried out using the method of Penfield. Duplicate runs gave identical results of 0.384% water by weight.

Lacy (1959) showed, in a study of the composition of hydrated glasses, that rhyolitic and rhyodacitic obsidians constitute a well-defined group in which the water content averages about 0.3% by weight, reaching a maximum of 1%. Other glasses of varying composition had water contents ranging from 2 to 10%.

From the data of Lacy, the silica content of the obsidian from the Elick Diatreme could be expected to be about 70%.

The difference in the values of silica percentage obtained by two separate methods can be variously interpreted. If the curve of George is not representative, then it is possible that the value determined by refractive index means is in error. On the other hand, if the water content of the obsidian is tightly bound by inter-molecular forces, then it is equally probable that this determination is in error owing to the failure of the experimental method to release all of the water.

The value based on water content is to be preferred for the following reasons. There is no field evidence which directly connects
the glass with the variolitic basalt; rather it is considered that it is part of the first episode of emplacement of the diatreme, that is, it may be completely-fused tuffisite. The tuffisite is a highly felsic rock derived principally from quartzo-feldspathic country rocks, the complete fusion of which might be expected to provide a glass having a rhyolitic or rhyodacitic composition.

It appears, therefore, that silica content determinations of obsidian, when based on refractive index values, require further analytical work in order that the curve of George may be corrected where necessary.
APPENDIX II

Attitudes of fault-planes in the Glenroy-Matakitaki area

The faults are grouped according to the set in which they lie in Figure 17; the attitude of the fault which gives its name to the set is the first quoted in each group.

Faults are identified by name; by the grid reference of the locality at which the attitude was observed; or by the name of the stream in which it was seen. All faults are shown on the geological map.

<table>
<thead>
<tr>
<th>Fault</th>
<th>Strike (° True)</th>
<th>Dip (° &amp; direction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenroy Fault</td>
<td>010</td>
<td>790</td>
</tr>
<tr>
<td>S39/753358</td>
<td>010</td>
<td>790</td>
</tr>
<tr>
<td>Double Creek (1st upstream)</td>
<td>023</td>
<td>55W</td>
</tr>
<tr>
<td>&quot; 3rd &quot;</td>
<td>010</td>
<td>70E</td>
</tr>
<tr>
<td>Station &quot; 2nd &quot;</td>
<td>012</td>
<td>60W</td>
</tr>
<tr>
<td>Alpine Fault</td>
<td>048</td>
<td>790</td>
</tr>
<tr>
<td>Station Creek (1st upstream)</td>
<td>070</td>
<td>80S</td>
</tr>
<tr>
<td>&quot; 3rd &quot;</td>
<td>045</td>
<td>790</td>
</tr>
<tr>
<td>Wheeler &quot; 1st &quot;</td>
<td>055</td>
<td>790</td>
</tr>
<tr>
<td>&quot; 2nd &quot;</td>
<td>050</td>
<td>790</td>
</tr>
<tr>
<td>Fault</td>
<td>Strike (°True)</td>
<td>Dip (° &amp; direction)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Woodham Fault</td>
<td>070</td>
<td>65N</td>
</tr>
<tr>
<td>S39/787364</td>
<td>043</td>
<td>55W</td>
</tr>
<tr>
<td>S39/774378</td>
<td>075</td>
<td>790</td>
</tr>
<tr>
<td>S39/774382</td>
<td>075</td>
<td>790</td>
</tr>
<tr>
<td>S39/768389</td>
<td>070</td>
<td>50°SE</td>
</tr>
<tr>
<td>Branch Fault</td>
<td>137</td>
<td>790</td>
</tr>
<tr>
<td>Hunter Fault</td>
<td>142</td>
<td>790</td>
</tr>
<tr>
<td>Potberry Fault</td>
<td>130</td>
<td>790</td>
</tr>
<tr>
<td>Thornton Fault</td>
<td>123</td>
<td>45°S</td>
</tr>
<tr>
<td>Double Creek (1st upstream)</td>
<td>155</td>
<td>70°E</td>
</tr>
<tr>
<td>&quot; &quot; (2nd &quot; )</td>
<td>155</td>
<td>790</td>
</tr>
<tr>
<td>&quot; &quot; (5th &quot; )</td>
<td>160</td>
<td>76°0E</td>
</tr>
</tbody>
</table>
Baldy Microgabbro

Haast Schist Group
- Chlorite II Subzone
- Chlorite III Subzone
- Biotite Zone

Mesozoic

Geological Symbols
- Inclined bedding
- Vertical "
- Observed direction of younging
- Inclined platy flow structures
- Vertical " "
- Attitude of pegmatite vein
- Inclined schistosity
- Vertical "
- Schistosity with trend and plunge of lineation

Formation boundary
- " " (position approximate)
- " " (concealed by overlying strata)
- " " (assumed extension of known contact)
- Fault (relative vertical displacement where known)
- " (dip of fault plane)
- " (assumed extension of known fault)
- " (existence inferred from stratigraphic and structural data)

Topographical Symbols
- Trigonometrical stations (names on geological map, heights on inset map)
- Spot heights

All heights are in feet above sea level.

Contours from NZMS1 sheets, extended by field sketching where necessary.

Contours at 1,000 intervals.
OLOGICAL MAP
OF THE NORTHERN PART OF THE AREA
BETWEEN THE AND MATAKITAKI RIVERS

One Inch to Twenty Chains = 1/15840
Inset Map showing topography of area covered by the geological map.

Scale: 1/63,360

1/2 0 1 mile
LEGEND

Sedimentary Rocks

al: Alluvium and glacial outwash
mo: Morainic deposits
wr: Water Race Formation
lo: Longford Formation
pr: Priestman Formation
fo: Foulsham Formation
dc: Double Creek Formation
ht: Horse Terrace Formation
y: Yorkey Formation
yb: Branch Slatestone Member
yn: Hut Flat Conglomerate Member
mn: Mcnee Formation
w: Wheeler Formation
wq: Gorge Shale Member

Holocene and Upper Pleistocene
Pliocene
Upper Miocene
Oligocene
Upper Permian
GEOLOGICAL
OF
NORTHERN
BETWEEN
GLENROY
AND
WERS
STRAITIGRAPHIC COLUMNS AND CORES OF MIDDLE TERTIARY IN THE GLENROY AREA

Lower East Branch Glenroy River

Well-rounded pebble conglomerate containing sandstone beds and plant fragments.
Well-rounded pebble conglomerate containing sandstone beds and plant fragments.

Cream-brown medium to coarse-grained sandstone.

Highly-indurated basal conglomerate of granite-derived pebbles and sand.

Woodham Granite

Well-rounded pebble-cobble conglomerate interbedded with sandstone. Some carbonaceous laminae.

Cream coarse to very coarse-grained sandstone.

Well-rounded pebble conglomerate and sandstone beds.

Woodham Granite
Well-rounded pebble conglomerate containing sandstone beds and plant fragments.

Grey medium to coarse-grained sandstone.
Coal measures. Thin coal interbedded with carbonaceous silty sandstone.

Woodham Granite
Massive well-rounded pebble conglomerate with thin sandstone lenses.

Fine to medium-grained micaceous sandstone.

Cream very coarse-grained sandstone.

Cream medium to coarse-grained sandstone.

Woodham Granite

<Diagram>

Middle East Branch Glenroy River

Yorkey Formation

Upper East Branch Glenroy River

Yorkey Formation
Brown medium-grained silty sandstone.

Massive well-rounded pebble conglomerate.

Cream coarse to very coarse-grained sandstone.

Highly-indurated basal conglomerate of granite-derived pebbles and sand.

Woodham Granite

---

**KEY**

- Conformable contact
- Nonconformable contact
- Faulted contact
- S 39/— N.Z. Fossil Record Form numbers
- ( ) N.Z. Tertiary stage as shown by fossils

Vertical scale: one inch to four hundred feet
CROSS-SECTIONS TO ACCOMPANY
OF THE NORTHERN PART OF THE GLENROY AND MATAK
To accompany thesis by R.C.
HE GEOLOGICAL MAP
AREA BETWEEN TAKI RIVERS

Scale: 1 inch to 1320 feet (4 inches to 1 mile) = 1/15840

Vertical scale is same as horizontal.
For symbols, refer to legend on Plate I.