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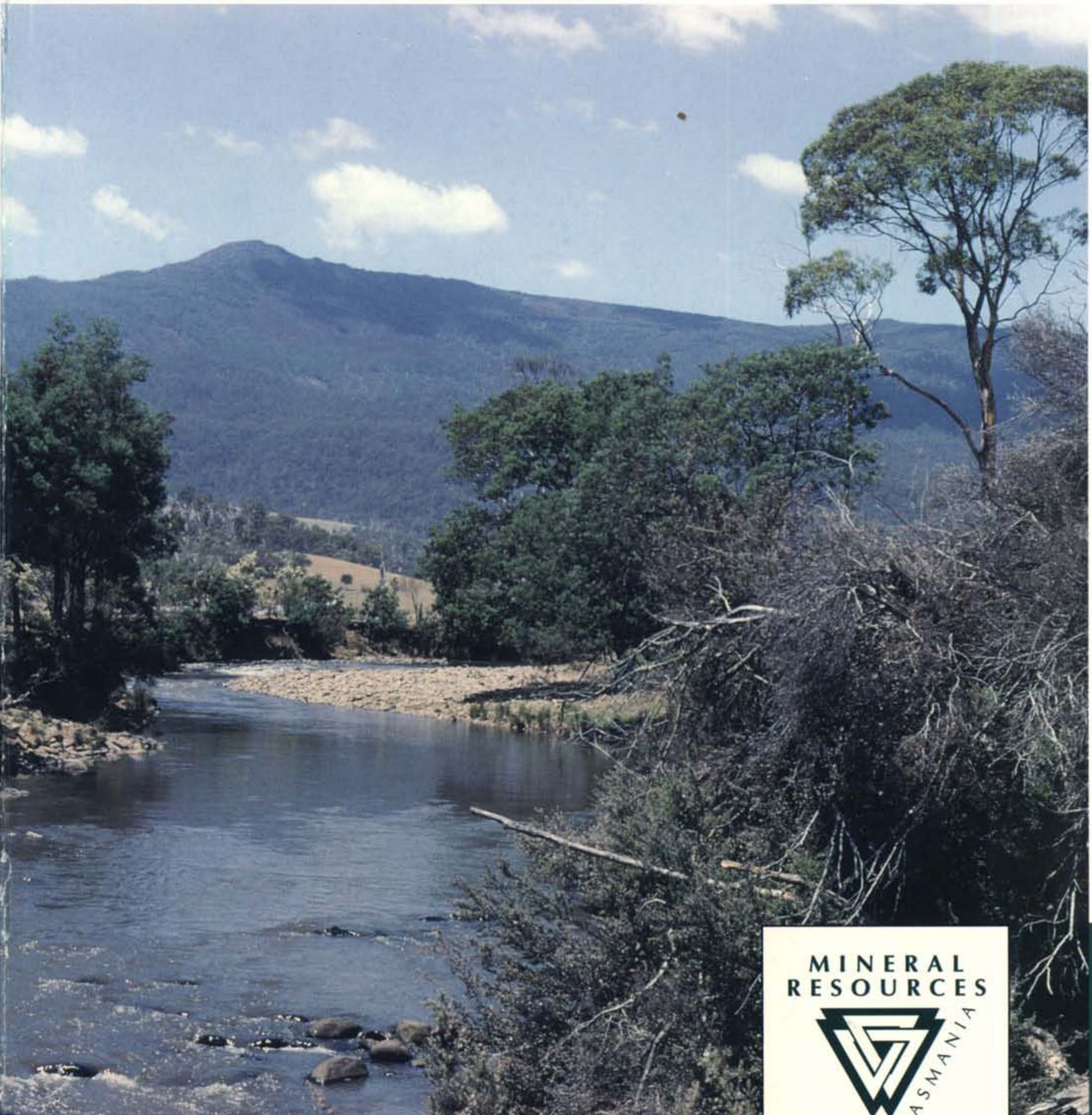
LAKE RIVER

Geological Survey Explanatory Report



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1996

GEOLOGICAL SURVEY EXPLANATORY REPORT

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LAKE RIVER

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Cover: *The Lake River flowing through Bluff Bottom, south of O'Connors Sugarloaf, with Millers Bluff in the background.*

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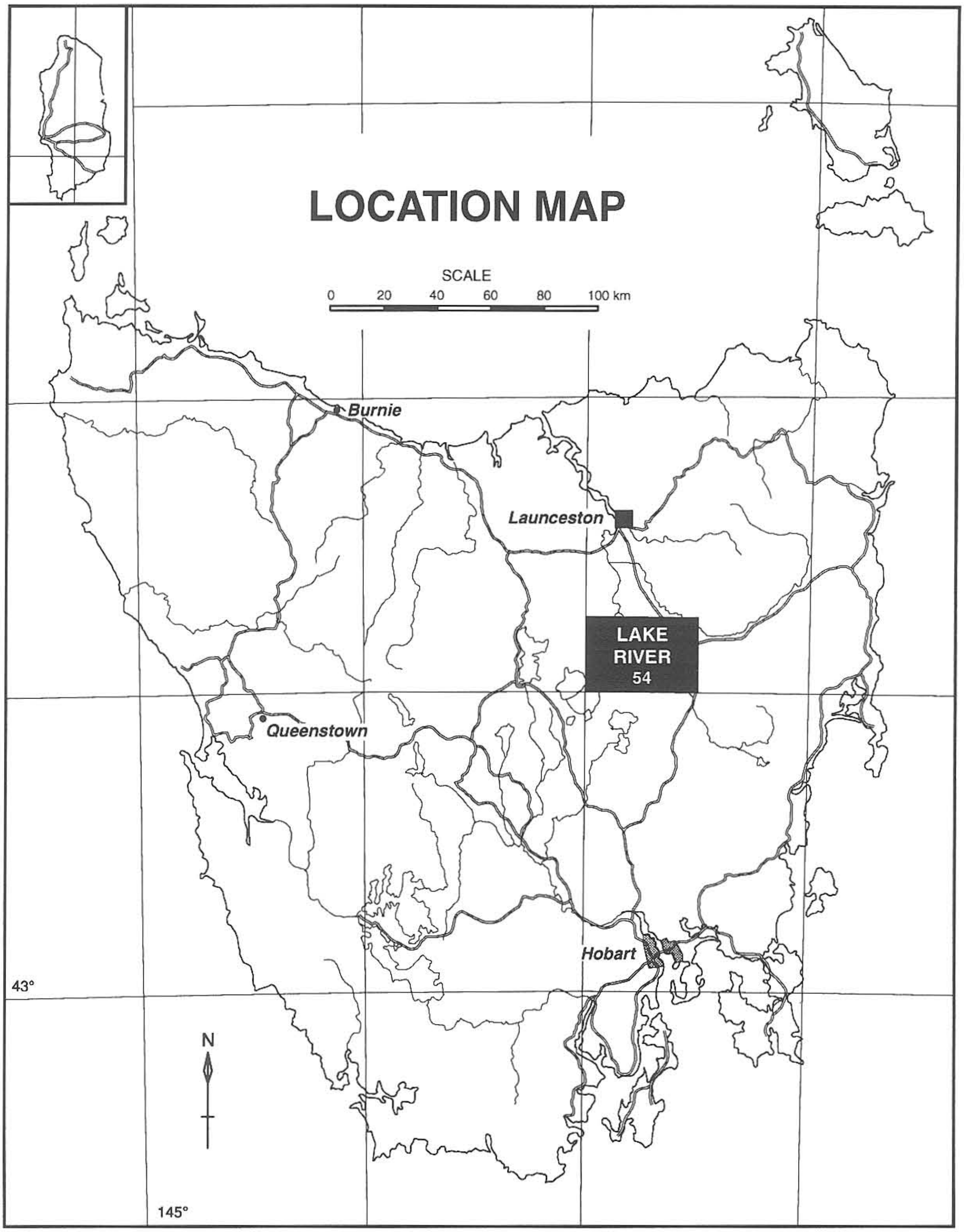


Figure 1

Location of Lake River Quadrangle

INTRODUCTION

The Lake River Quadrangle (fig. 1) was mapped as part of a study into groundwater resources in the major part of the Launceston Tertiary Basin centred around Longford. Detailed geological mapping was not available for a considerable part of the margin of the basin, and information on the geology was required so that structural influences on the formation of the basin could be examined. Completion of the mapping of the marginal areas of the basin left only a relatively small part of the Lake River Quadrangle to be mapped.

The quadrangle covers the area bounded by 41°45' to the north and 42°00' to the south, and 147°00' to the west and 147°30' to the east. This area includes the southern part of the Launceston Tertiary Basin, and extends from Campbell Town to Epping Forest on the eastern side to south of Cressy and the upper Lake River on the western side.

It should be noted that grid line 500 000 mE is incorrectly shown on the printed colour geological map, and in fact coincides with longitude 147°E, the western margin of the sheet. All grid references used in this report lie in the 100 000 metre grid square EP.

Acknowledgements

The advice of Dr E. Williams in the field and during map production is gratefully acknowledged.

LAND USE

The economic pursuits within the quadrangle are dominantly agricultural. The largest town is Campbell Town in the southeast corner, with the only other centres of population being the small towns of Conara, Cleveland and Epping Forest to the north along the Midland Highway. The remainder of the population is situated on individual rural properties.

About one-third of the quadrangle consists of relatively flat to slightly undulating low-lying land, which is used mainly for sheep and cattle grazing. Cropping takes place on a minor scale (e.g. potatoes). Much of the remainder of the quadrangle has a markedly variable relief and is only used for grazing. The southwest corner, comprising about 20% of the total area, is elevated and forms part of the Great Western Tiers, and has little agricultural use.

Timber harvesting takes place on the slopes to the Great Western Tiers. Recreational fishing is possible in many of the streams which traverse the quadrangle, particularly the Lake River.

Access

Access throughout the area is good except for the higher country in the southwest corner. The Midland Highway extends up the eastern side of the quadrangle, while an extensive network of secondary roads serves the agricultural areas. The elevated land, including that comprising the Great Western Tiers, has fewer roads. The main Hobart–Launceston railway line also traverses the eastern side of the quadrangle and is quite close to and parallels the Midland Highway. A small part of the Fingal Line crosses the eastern part of the quadrangle as it runs east from its junction with the South Line at Conara.

PHYSIOGRAPHY

The quadrangle contains a wide range of physical features, ranging from the elevated southwest part, which consists of the dissected edge of the Great Western Tiers, to the relatively flat lowlands of the Tertiary basin. Between these two extremes the land surface is undulating to steep, with some moderately high zones around the margin of the Tiers.

The two main peaks making up the Great Western Tiers portion are Millers Bluff [142572] (1210 m) and Parson and Clerk Mountain [040590], which has several peaks about 1200 m high. The Lake River has cut deeply into the land surface between these two mountains. Relatively small areas of plateau-like features occur further to the west and southwest. The steep slopes off the Great Western Tiers to the low-lying country extend down to about 250 m a.s.l. off Parson and Clerk Mountain (to the Lake River), and to about 200 m a.s.l. from Millers Bluff down to the Isis River. A low ridge interrupts the constant downward slope in the latter case.

These two mountains and the surrounding country are underlain by dolerite, a rock which is more resistant to erosion compared to most of the other rock types in the quadrangle. The dolerite is sill-like to slightly transgressive in the area of these mountains, and attains a thickness of up to 300–400 metres.

The development of the Great Western Tiers scarp is mainly due to faulting rather than erosion. A major northwest-trending fault system extends up the eastern side of Millers Bluff. At least some of the movement on this fault system is of Jurassic age or contemporaneous with the dolerite intrusion but some may be due to block faulting during the Tertiary, because of the large difference in the levels of dolerite occurring on the Tiers and that exposed to the east of the fault. The slopes are retreating scarps associated with this fault system.

The flat areas underlain by Tertiary sediments have been preserved because a zone of resistant dolerite is encountered by the South Esk River just before it enters the River Tamar at Launceston. This dolerite bar has retarded erosion, allowing the streams at higher levels to develop mature valleys and broad flood plains over the extensive parts of the hinterland underlain by softer rocks, mainly comprising the Tertiary sediments but also Triassic sediments.

This feature is repeated at a number of places in the quadrangle wherever streams flow through areas of dolerite and softer rocks occur upstream. The Lake River flows through a number of such zones, beginning with the Big Den area in the southwest corner of the quadrangle [040540]. Here the river flows through an area of dolerite about 1.5 km wide and separating Big Den from Little Den [080540]. Upstream from the dolerite the river has cut through to the basal part of the Permian sequence which the dolerite intrudes. The softer rocks have been eroded and a broad flat about two kilometres wide surrounds the river. Little Den is much smaller but has formed in the same way, while Boomers Bottom, 5 km downstream [080610], is another example. After the river passes through the zone of dolerite below Boomers Bottom it enters the area underlain by Tertiary sediments and passes through a more extensive flat area.

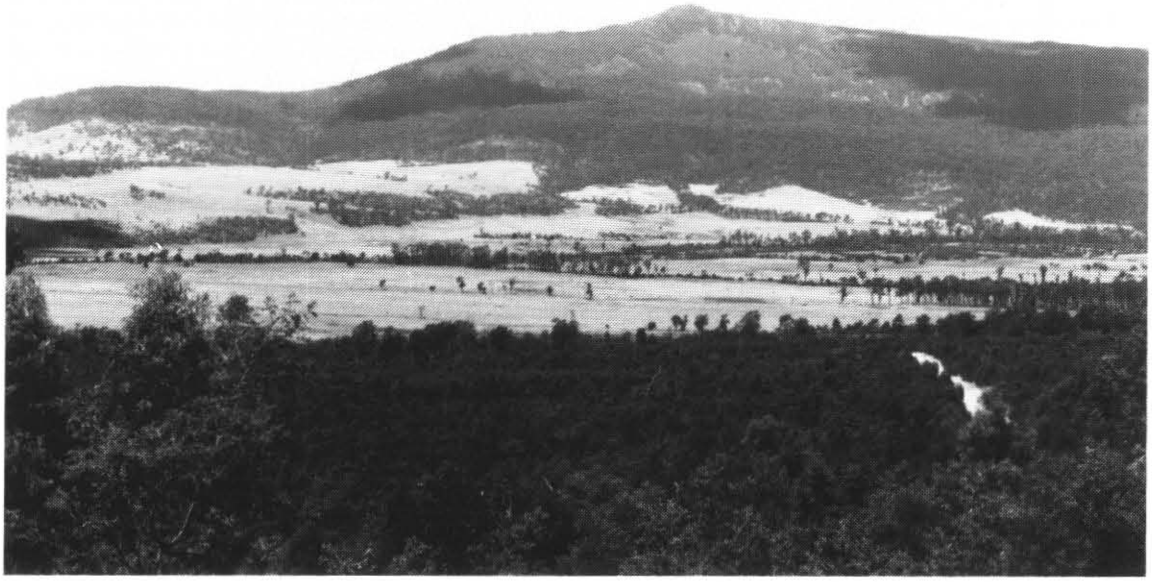


Plate 1

Plate 2

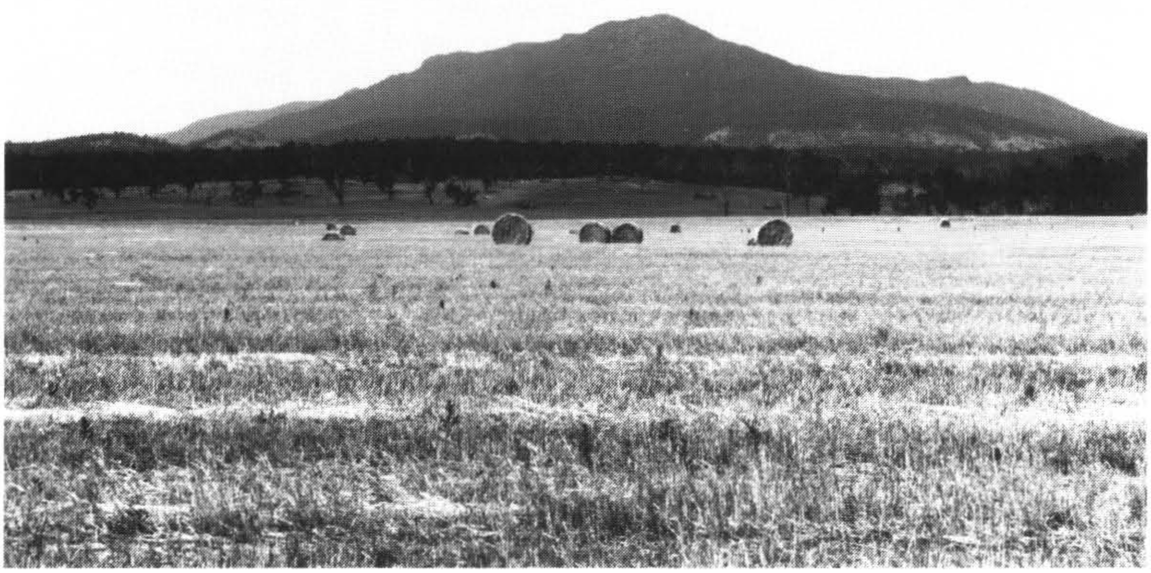


Plate 3

Terraces can be identified around the streams, and some of the upper terraces may represent flood plains as old as the Tertiary. The quartz gravel covering extensive areas of the Tertiary sediments is an example. The lateritic gravel and laterite which occur on the eastern side of the quadrangle (and which overlie the quartz gravel) again probably represent dissected terraces. The most extensive areas of quartz gravel occur marginal to the Lake River and South Esk River valleys, with only minor deposits around the Macquarie River. The most prominent and definite terraces surround the Isis River from the southern margin of the sheet [260502] to near *Barton* [200660]. These terraces are some 10–15 m above and slope gently towards the present flood plains.

Dolerite ridges have confined the streams to particular zones. The Macquarie River, in particular, has a northwest trend through most of the sheet. This is the major structural grain of the country. It is possible that the Macquarie, or an older major stream, flowed through the gap in the ridge southwest of Conara where Blanchards Creek now flows. This is a deep, relatively straight valley. Alternatively the South Esk River may have flowed through this valley. Both streams have no doubt been diverted in their flow direction by basalt flows, and one of them would have had to be responsible for the deposition of the quartz gravel beds which underlie the basalt in the Conara area and to the east.

Currently or recently-active landslides can be occasionally seen around the steeper slopes. The larger examples of these are in dolerite talus high on the side of the Tiers but the slip surfaces probably develop on the weathered portions of underlying sedimentary rocks. The shape of the land surface below outcropping dolerite and within the extensive talus areas suggests that this process has been going on for a considerable period, and may represent a major mechanism for the retreat of the dolerite scarp. These areas are hummocky and frequently have internal drainage, which are common features of landslide activity.

Plates 1 –3 (opposite)

These three views of the countryside surrounding Millers Bluff show the effect of the different rock types on the topography.

Plate 1, looking southeast from the foothills of the Great Western Tiers, shows the flat alluvial plains around the Lake River in the foreground, followed by a section through the Permian sequence from the Stockers Tillite to the Blackwood Conglomerate. Jurassic dolerite caps Millers Bluff, while talus fields are visible below the peak.

Plate 2, looking southeast from the foothills of O'Connors Sugarloaf, shows the more rolling topography of the Cambrian–Proterozoic sequence of rocks in the foreground, with the dolerite peak of Millers Bluff (1210 m) in the background.

Plate 3, looking south from the Macquarie Road near *Carnarvon*, shows the flat surface of the Tertiary sediments in the foreground, followed by low hills of dolerite. Permian sequences form the lower part of Millers Bluff, with dolerite capping the peak.

As well as slides in talus there is the prospect that some of the isolated bodies of dolerite, which have been mapped on the slopes below the Tiers summit, may be slipped or overturned blocks of dolerite. This applies particularly to the dolerite about two kilometres northwest of Parson and Clerk Mountain, and possibly to those outcrops downslope from Henrys Bluff [115565]. In the latter case the nearby dolerite is transgressive, and the outcrops may be the resistant remnants of a dyke.

Drainage

The quadrangle falls within the drainage basin of the South Esk River, although the South Esk River itself only crosses the northeast portion of the sheet. The major streams draining the area are the Lake and Macquarie Rivers and their tributaries, such as the Isis River and Brumby Creek. The Lake River flows into the Macquarie River two kilometres north of the quadrangle boundary, with the Macquarie flowing into the South Esk River at Longford, 18 km north of the quadrangle. Where the streams traverse the low-lying flat land, the broad flood plains are subject to widespread flooding during winter.

Soils and Vegetation

A 1:100 000 scale reconnaissance map of the soils and an accompanying report have been produced by R. B. Doyle (1993). Doyle found a strong relationship between parent rock material, topographic position, and the nature and age of particular landforms. On the older rocks (Proterozoic–Cambrian phyllite and volcanic rocks) Doyle described yellow and brown podzolic soils (Dermosols and Chromosols), and these soil types also occur on the Parmeener Supergroup sequence on the lower slopes and foothills of the Great Western Tiers.

Acid peats (Organosols) and red podzolics (stony Ferrosols) occur on dolerite on the plateau areas, while red podzolics-krasnozems (again stony Ferrosols) occur on the talus and dolerite on the slopes bordering the plateau. Krasnozems and brown soils (Ferrosols and Dermosols) have developed on the Tertiary basalt.

A range of lateritic podzolics and soloths, solodised solonetz, black earths and humic gleys (Kurosols and Sodosols, Vertosols and Hydrosols) have developed on the Tertiary to Recent sediments. Siliceous sand (Tenosols) occur on windblown sand areas and locally-derived sand deposits.

Much of the natural vegetation has been removed in the agricultural areas but dry schlerophyll grading into savannah forests extend over major parts of the quadrangle. Wet schlerophyll forest grows along the slopes of the Great Western Tiers, and these are the areas where most of the timber harvesting takes place, although some of the dry schlerophyll forest on the lower land has been used for the production of woodchips for export.

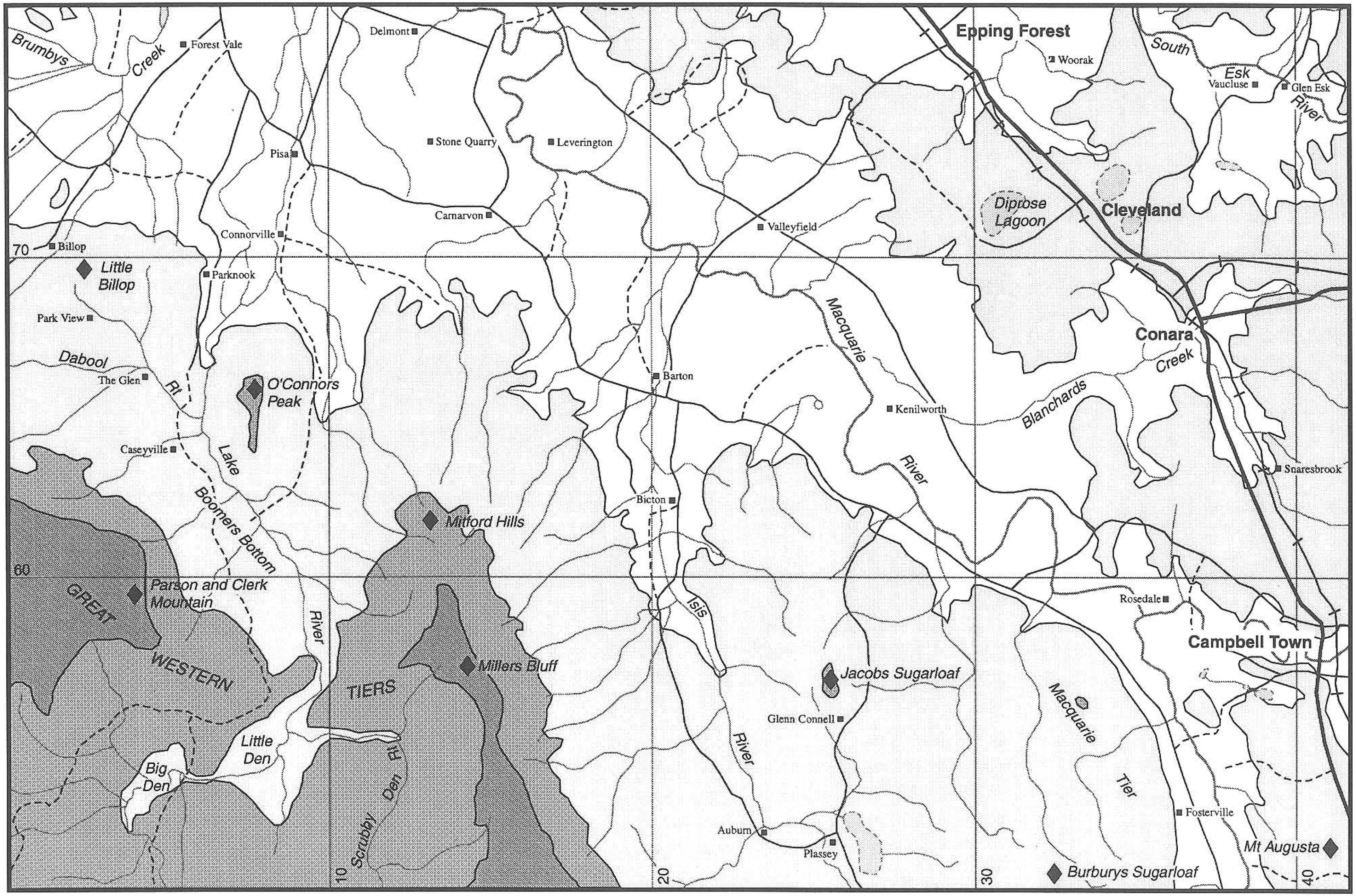


Figure 2. *Simplified relief and location of major drainage features. Topographic divisions are: land over 1000 m (dark fill); land 500–1000 m; land 200–500 m (light fill); and land less than 200 m (no fill).*

5 cm

STRATIGRAPHY

PROTEROZOIC (?) — CAMBRIAN (?)

The oldest exposed rocks in the district occur as a number of inliers in the west of the quadrangle, amongst the foothills of the Great Western Tiers. Their total exposed area, as mapped, is about 19 km^2, of which the largest inlier, north and east of O'Connors Peak, accounts for about 13 km^2. The other exposures occur around *The Glen* and *Caseyville* [055635], north of Little Billop, and at Little Den. There is also a small exposure of dolomite in the northwest of the quadrangle at 007769.

Previous Work

There is no indication of any of the inliers on the first geological map of Tasmania, which was produced in 1888 by R. M. Johnston. The inliers may have first been noted by C. G. Sara, who showed a belt of rocks assigned to the Silurian system around O'Connors Sugarloaf on a geological sketch of the northern Midlands dated 1913 (Mineral Resources Tasmania geological plans 305, 314).

The discovery of alluvial gold at Little Den was reported in the press in 1932, although it appears that intermittent prospecting had been previously carried out in the area for about 50 years. This led Scott (1932, 1935) to briefly visit and report on the workings, and Nye and Blake (1933) to produce a geological sketch map (MRT geological plan 623) of the country between Dabool Rivulet and Little Den, showing four pre-Carboniferous units, including Devonian dolerite and porphyry, Cambro-Ordovician slate, and Proterozoic schist. This work is now largely of historical interest only. Voisey (1949) also briefly discussed the regional geology, assigning a Cambrian age to some of the inliers. The gold prospects at Little Den are discussed by Threader (1963) and in the Economic Geology section of this report.

G. B. Everard (1968) studied twelve specimens of mafic tuff from the O'Connors Peak inlier. These specimens have been re-examined and are described in this report.

Recent mineral exploration in the area is reported by Zapata-Camus (1982), who supervised a programme including stream-sediment geochemistry, three petrographic descriptions, and four percussion drill holes on Connorville Estate; and Carter (1985), who described geochemical surveys in the Little Billop and *The Glen* areas. Results were discouraging, and these reports do not significantly add to the knowledge of the regional geology.

Overview

Two main associations have been recognised in the Proterozoic(?) – Cambrian(?) rocks:–

(a) a western, dominantly pelitic association of mainly phyllite, slate and cleaved siltstone (Ꞓsp), comprising the Little Billop inlier, those around *The Glen* and *Caseyville*, and probably the southeastern part of the Little Den inlier. Bedding is usually obliterated by a strongly developed foliation, which generally dips at low to moderate angles to the east or northeast. Some samples collected are best described as platy quartzite. Limestone (Ꞓsl) crops out on the banks of First Creek [near 023654], west of *The Glen*.

Within this dominantly pelitic association, small areas of metamorphosed basalt (lava?) have been mapped northeast of Little Billop [033708] and near the Lake River at *Caseyville* [around 059638]. Actinolite schist west of *The Glen* [025658] is probably also metabasalt.

(b) an eastern volcaniclastic association of mafic (pyroxene and plagioclase-bearing) crystal tuff, crystal-lithic tuff, volcanic breccia, tuffaceous conglomerate and very minor slate horizons (Ꞓsv). This association comprises the largest inlier, which extends from near *Parknook* homestead and runs east of O'Connors Peak to the Lake River at Bluff Bottom. It also forms the major part of the Little Den inlier, from which metabasalts (lava or intrusive?) have been collected. Generally the volcaniclastic rocks are strongly sheared, with moderate northeast or easterly dips, and unrecognised lavas may be present elsewhere.

A small outcrop of dolomite (Ꞓsld) occurs on the northern bank of Brumbys Creek [007769]. A possible interpretation of this outcrop as a very large erratic in Carboniferous tillite, which overlies it, has been suggested (M. C. Forster, pers. comm.) on the basis of unsuccessful attempts to prove extensions of it by drilling. However further drilling has proven that it is indeed basement (D. Hassel, pers. comm.; Appendix 1). The flat nature of the topography and the low stratigraphic level of the nearby Permo-Carboniferous strata (Blake *et al.*, 1956) suggest that the Cainozoic alluvium in this area, north and east of Poatina, may conceal more dolomite bedrock.

All these basement inliers are overlain by the Stockers Tillite with appreciable landscape unconformity, and most are intruded by dyke-like to irregular intrusions of Jurassic dolerite. Palynological evidence from the Stockers Tillite (see below) constrains the age of the basement rocks as pre-Late Carboniferous. However, as they are lithologically unlike the Ordovician–Devonian Mathinna Beds of northeastern Tasmania or the Late Cambrian–Devonian Wurawina Supergroup of western Tasmania, a pre-Late Cambrian age seems highly probable. As further discussed below, some of the metabasalts within the western pelitic association have geochemical characteristics similar to certain Eocambrian (probably latest Precambrian) basalts in western Tasmania.

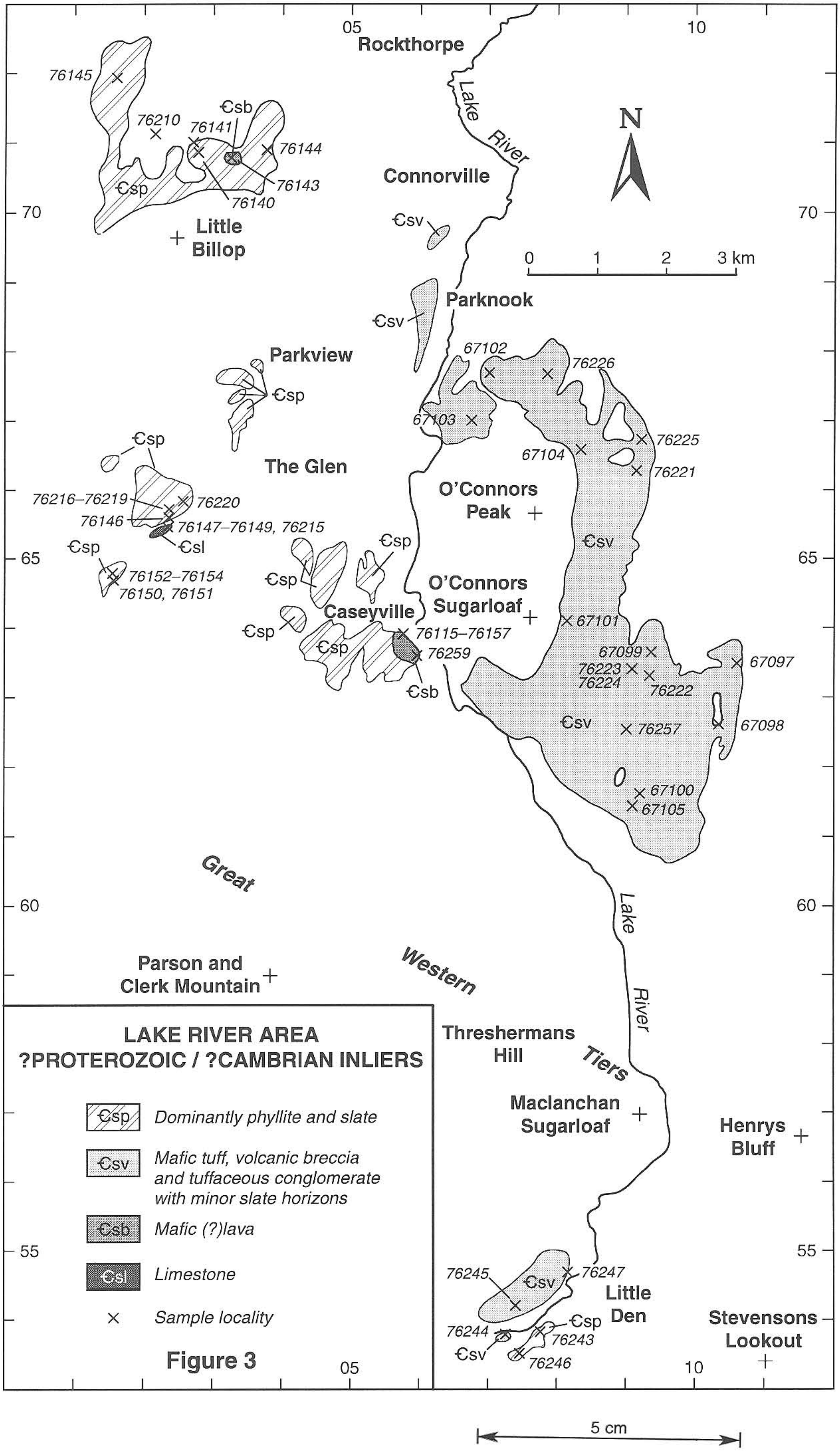
The relative age of the two associations is unknown. The few dips available suggest that, in the absence of major faulting or dislocation related to dolerite intrusion, the eastern volcaniclastic association may be younger than the western pelitic association. This would be in accord with an interpretation of the metabasalts as sources or feeders for the volcaniclastic rocks, but nevertheless must be regarded as conjecture.

Petrography

The following remarks and petrographic descriptions of the lithologies in the various inliers are based on specimens collected by W. L. Matthews during field mapping. X-ray diffraction of selected samples was undertaken by R. N. Woolley. Localities of samples are given in Table 1 and Figure 3.

Brumbys Creek inlier

This tiny inlier of dolomite occurs on the northern bank of Brumbys Creek [007769], on the *Creekton* property and



LAKE RIVER AREA ?PROTEROZOIC / ?CAMBRIAN INLIERS

Figure 3

about 6 km northeast of Poatina. The dolomite is overlain to the north and east by the Late Carboniferous Stockers Tillite, whilst to the south and west it disappears beneath Quaternary alluvium.

The outcropping dolomite has been worked as a source of burnt lime for mortar, and the remains of an old, apparently convict-built kiln, are located nearby. The dolomite has been investigated for possible industrial use by the Tasmanian Electro-Metallurgical Company (Temco), but silicified cap rock and difficulty of extraction has rendered this impractical. It may however be a useful source of agricultural dolomite (D. Hassel, pers. comm.).

Details of drilling in the vicinity by Temco are given in Appendix 1.

76134 (dolomite) (Plate 4)

The hand specimen is a tough massive dolomite; fresh surfaces are pale grey, but a cream to pale brown-coloured weathering rind 0.5–2 mm thick has developed. In thin section, the rock is seen to be a completely recrystallised, pure dolomite with a mean grain size of 10–30 µm. Ovoid to irregular-shaped domains, 500 µm–2 mm across, filled with much coarser-grained (100–500 µm) inward-grown carbonate, are common and are interpreted as cemented pores. Narrow (≤200 µm) sinuous veinlets of coarse-grained carbonate are associated with squarish euhedral and finely granular opaque minerals, probably pyrite, and very minor quartz. Traces (<<1%) of euhedral probable pyrite (5–20 µm) are disseminated throughout the rock, but tend to be associated with the coarser-grained pore-filling and veinlet carbonate.

A chemical analysis of this rock (Table 2) is consistent with a mineralogy of approximately 94.8% stoichiometric dolomite, 2.8% calcite, and 2.4% other minerals, principally quartz.

The rock has a strong lithological resemblance to the Smithton Dolomite of northwestern Tasmania, which is probably of Late Precambrian age. However correlation is unjustified on the available evidence.

Little Billop inlier

This inlier is exposed over an area of about 2.6 km^2 (as mapped) on the northern slopes of Little Billop. To the south it is overlain by tillite and intruded, partly transgressively, by Jurassic dolerite, whilst to the north and west it disappears beneath Cainozoic sediments. Outcrop is poor, but the dominant lithology is phyllite, with minor quartzite. Mafic volcanic rocks, including basalt, have been mapped in the eastern part of the inlier.

Carter (1985) reported traces of sulphide in chloritic tuff at 020706, associated with anomalously high copper values in stream sediment samples. W. L. Matthews collected samples of possible gossan developed on nearby laterite [027710].

76142 (phyllite)

The hand specimen is a soft, weathered, pale yellowish-orange (10YR8/6, Geological Society of America rock colour chart, 1991) fine-grained phyllite. In thin section it is very fine grained (≤10 µm) and contains abundant translucent orange-brown oxidised material, but appears to consist mainly of quartz and a strongly oriented length-slow phyllosilicate, probably sericite.

76143 (fine-grained metabasite)

This hard, tough, pale olive-coloured (10Y6/2) rock is well cleaved, but not fissile and lacks schistosity. In hand specimen it resembles a siltstone or platy quartzite. X-ray diffraction shows that the rock consists principally of amphibole, chlorite and plagioclase, with very minor muscovite and only a trace of quartz.

In thin section the rock is fine grained with a strong tectonic fabric, defined principally by orientation of splinters of colourless to very pale green tremolite or tremolite-actinolite (length slow, extinction angle up to about 25°), typically 20–100 µm long and 5–10 µm wide. A few splinters are oriented obliquely to the foliation. A colourless, low-birefringence phyllosilicate, probably chlorite, and traces of epidote are also present. Small (≤15 µm), angular, fuzzy grains of a high-birefringence mineral, probably sphene, are scattered throughout the rock. Much of the rock is too fine grained for definite optical identification, but low birefringence and X-ray diffraction indicate that chlorite and plagioclase (albite?) are major constituents. A few quartz veinlets are present, adjacent to which amphibole is pale brown-green in colour, and therefore probably more actinolitic.

The rock is derived from a mafic protolith and has been subjected to low-grade metamorphism, producing a mineral assemblage, tremolite/actinolite-chlorite-albite-epidote-sphene (?) characteristic of the greenschist facies.

Any original igneous texture has been completely destroyed, and it is impossible to say whether the rock was originally a volcaniclastic, a lava, or an intrusive.

76143a (metabasalt) (Plate 5)

In hand specimen the rock is a greyish-green (10G4/2) to slightly bluish, tough rock in which feldspar laths up to a few millimetres long are discernible. It is weakly magnetic ($\gamma > 0.48 \times 10^{-3}$ SI units). X-ray diffraction shows that the principal minerals present are chlorite, amphibole, plagioclase (probably albite) and sphene, with possible epidote, stilpnomelane and pyroxene.

A thin section shows the rock to be a rather coarse-grained metabasalt. Polygonal, subhedral to euhedral phenocrysts (500 µm–1 mm) of augite (biaxial positive, moderate 2V) are common, but partly replaced by well-crystallised epidote and pale green chlorite. Plagioclase occurs as large (≤3 mm) elongate to irregularly polygonal euhedra and subhedra, sometimes clumped into glomerocrysts. Although turbid, multiple twinning is often recognisable, and extinction angles and the positive optic sign indicate albite. Some composite glomerocrysts of plagioclase and pyroxene are present, suggesting a coarse-grained igneous texture.

The groundmass, which lacks any foliation, consists of numerous disoriented splinters (50–200 µm long) of colourless to pale yellow tremolite-actinolite, irregular patches of pale-green to colourless chlorite, numerous angular, turbid grains of sphene (50–400 µm), traces of probable epidote, and probably fine-grained, undeterminable feldspar. Small quantities of a poorly crystallised, strongly

TABLE 1
Sample localities, Proterozoic(?) – Cambrian(?) rocks, Lake River Quadrangle

Registered No.	*Field No.*	*Analysis No.*	*Co-ordinates*	*Rock Type*	*Preparation*
Brumbys Creek (Creekton)					
76-134	C1	901428	EP007769	Dolomite	TS, CA, PH
North of Little Billop					
76-141	C7	-	EP027710	Gossan(?) on laterite	-
76-142	C8	-	EP028709	Weathered sericitic phyllite	TS
76-143	C9	-	EP033708	Fine-grained metabasalt	TS, XRD
76-143A	C10	901430	EP033708	Metabasalt	TS, XRD, CA, PH
76-144	C11	-	EP038709	Sericitic phyllite (float)	TS, XRD
76-145	C12	-	EP016719	Quartz-sericitic phyllite	TS, XRD, PH
76-210	C80	-	EP022711	Platy quartzite	TS, XRD
First Creek/The Glen					
76220	C87	-	EP026658	Dark grey sericitic phyllite	TS, XRD, PH
76216	C86A	-	EP025658	Metabasalt from adit	TS
76217	C86B	-	EP025658	Metabasalt from adit	TS, XRD
76218	C86C	-	EP025658	Metabasalt from adit	-
76219	C86D	-	EP025658	Metabasalt from adit	-
76146	C13	-	EP024656	Dark grey sericitic phyllite	TS, XRD
76147	C14A	901429	EP024655	Limestone	TS, CA, PH
76148	C14B	-	EP024655	Limestone	TS, PH
76149	C14C	-	EP024655	Dark grey cleaved siltstone	TS
76215	C85	-	EP024655	Limestone with mineralisation	TS
76152	C16A	-	EP016648	Dark grey cleaved siltstone	TS, XRD
76153	C16B	-	EP016648	Dark grey cleaved siltstone	TS, XRD, PH
76154	C16C	-	EP016648	Dark grey cleaved siltstone	-
76150	C15A	-	EP016647	Weathered siltstone	TS, XRD
76151	C15B	-	EP016647	Weathered siltstone	-
Caseyville					
76155	C17A	901431	EP058639	Metabasalt	TS, XRD, CA, PH
76156	C17B	-	EP058639	Metabasalt	-
76157	C17C	-	EP058639	Metabasalt	-
76259	C118	-	EP060636	Metabasalt	XRD
O'Connors Peak/Sugarloaf area (Connorville)					
67103	-	-	EP068670	Lithic-crystal tuff	TS
67102A	-	-	EP070677	Lithic(?) tuff	TS,XRD
67102B	-	-	EP070677	Lithic(?) tuff	TS
76226	C92	-	EP079677	Crystal-lithic tuff	TS
67104	-	-	EP084666	Crystal-lithic(?) tuff	TS, XRD, PH
76225	C91	-	EP093667	Amphibolite pebble	TS, PH
76221	C88	-	EP092663	Phyllitic semi-schist	TS, XRD, PH
67101A	-	-	EP081641	Crystal-lithic tuff	TS, XRD, PH
67101B	-	-	EP081641	Crystal-lithic tuff	TS
67099	-	-	EP094636	Crystal-lithic tuff	TS
76223	C90A	-	EP091634	Crystal tuff	TS
76224	C90B	-	EP091634	Crystal tuff	TS, XRD
76222	C89	-	EP094633	Crystal-lithic tuff	TS, XRD
67097	-	-	EP107635	Crystal tuff	TS
67098	-	-	EP104626	Crystal-lithic tuff	TS, PH
76257	C116	-	EP090625	Tuffaceous mudstone	TS, XRD
67100	-	-	EP092616	Crystal tuff	TS, XRD
67105A	-	-	EP091614	Schistose lithic tuff	TS
67105B	-	-	EP091614	Mafic volcaniclastic conglomerate	TS
Little Den					
76243	C103	-	EP078538	Pale grey phyllitic slate	TS, XRD, PH
76244	C104	-	EP073538	Crystal tuff	TS
76245	C105	-	EP074542	Crystal tuff (?)	XRD
76246	C106	-	EP075535	Black pyritic slate	TS, XRD
76247	C107	901432	EP082547	Metabasalt	TS, XRD, CA, PH

* TS — thin section, XRD — X-ray diffraction, CA — chemical analysis, PH — photomicrograph

pleochroic (bright amber, deep brown) platy mineral may be stilpnomelane, as suggested by X-ray diffraction.

The rock is a clinopyroxene-feldspar phyric basalt, with a groundmass mineral assemblage indicating greenschist facies metamorphism.

76144 (phyllite)

In hand specimen the rock is a rather hard, fine-grained, cream-coloured (10YR8/2) cleaved rock. X-ray diffraction shows that mica, quartz and kaolinite are the only major minerals present. In thin section the rock consists of strongly oriented splinters of sericite (length slow, ≤20 μm), minor anhedral quartz, and scattered tiny (≤5 μm) opaque blebs around which a brownish stain has developed, mottling the specimen.

The rock is a sericite phyllite.

76145 (phyllite) (Plate 6)

The hand specimen is a rather hard but fissile, off-white to very pale grey-brown, strongly foliated phyllite. Quartz and minor sericite were the only minerals detected by X-ray diffraction.

In thin section, the rock consists dominantly of an interlocking mosaic of small equant quartz anhedra (10–20 μm across), and volumetrically subordinate, strongly oriented shreds of muscovite, 1–2 μm wide and up to 50 μm long. Accessory minerals include irregular aggregates of oxidised, brown iron oxides, possible sphene, and very rare tiny anhedra (≤40 μm long) of probable detrital zircon.

The rock is a quartz-muscovite phyllite.

76210 (platy quartzite)

This rock is a tough, fine-grained pale grey quartzite, consisting of quartz and minor mica (X-ray diffraction). In thin section, it resembles 76145 but is finer grained and less micaceous, consisting mainly of finely recrystallised quartz anhedra (≤5 μm), and inconspicuous, sparsely distributed, strongly oriented muscovite splinters (mostly ≤20 μm long). Sparsely distributed, equant opaque grains (5–40 μm) may be concentrated into trains parallel to the cleavage, or occasionally clumped into larger irregular aggregates. Several sinuous quartz veinlets, 100–500 μm long, traverse the slide. An anastomising, spaced cleavage is developed.

The Glen inliers

These occupy a total area of about 1 km^2. North of the Dabool Rivulet near *Park View* and *Cyda Park* an area of phyllite, partly concealed by alluvium, may be a window or roof pendant in Jurassic dolerite. About two kilometres west of *The Glen* a larger inlier of phyllite, within which a small dyke-like body of actinolite schist [026658] has been mapped, is overlain by Carboniferous tillite and intruded by dolerite. Nearby, on the banks of First Creek [024655], well bedded limestone with traces of sulphide minerals is exposed. Carter (1985) reported that the limestone contained traces of pyrrhotite and near-background levels of Cu, Pb and Zn. Further upstream in First Creek, another small inlier of cleaved siltstone is intruded by small dykes, and a larger dyke-like intrusion, of Jurassic dolerite.

76220 (phyllite) (Plate 7)

The hand specimen is a greyish-black fissile phyllite with a moderately developed sheen on cleavage surfaces and some suggestion of a lineation. It is essentially non-magnetic ($\gamma \approx 0.26 \times 10^{-3}$). X-ray diffraction shows that it consists mainly of quartz and mica, with minor potash feldspar, plagioclase and kaolinite.

In thin section the rock consists of strongly oriented strands of sericite and an anastomising, strongly oriented network of black carbonaceous material in a fine-grained (≤10 μm) quartzo-feldspathic matrix. The rock shows crude compositional layering with alternating zones or microlithons, 200–500 μm wide and more or less parallel to the cleavage, of dominantly quartzo-feldspathic and sericitic-carbonaceous material.

76216 (?metabasalt)

The hand specimen, collected from an old adit and described in the field as serpentine, is a tough fine-grained greenish-grey rock containing sinuous narrow veinlets a few millimetres wide, and irregular patches of off-white material, including carbonate. It is weakly magnetic ($\gamma > 1.20 \times 10^{-3}$).

In thin section most of the rock consists of fuzzy, turbid, fine-grained material. Under strong illumination particularly, narrow to acicular, unoriented laths up to 400 μm long but only 5–20 μm wide of probable plagioclase can be discerned. The fuzzy material is unresolvable. The rock may be an altered fine-grained, possibly glassy, basalt.

Numerous veins with a varied mineralogy transect the thin section. The main minerals present are coarsely crystalline carbonate (≤1 mm); fine-grained colourless, scaly, length-fast chlorite (≤50 μm); colourless, well crystallised tremolite; and minor albite. Tremolite appears to have been the first vein mineral to crystallise, as it forms columnar to comb-like aggregates growing inward from the metabasalt(?) host rock, whilst chlorite and albite appear to be late-stage minerals. This sequence is also suggested by the cross-cutting of veinlets of various mineralogy.

76217 (?metabasalt)

This is also a sample of 'serpentine' from the adit, similar to sample 76216. X-ray diffraction of this sample shows that plagioclase, chlorite, amphibole, possible clinopyroxene, and very minor calcite are present.

In thin section the rock is similar to sample 76216, consisting principally of fuzzy, turbid, fine-grained material in which lath-like to acicular crystals of probable plagioclase can be distinguished. The indeterminate surrounding material may include partially hydrated clinopyroxene and tremolite. The rock is interpreted as a metabasalt.

The veinlets are less abundant than in 76216 and consist mainly of fine-grained chlorite (anomalous dark blue-grey birefringence) and minor albite, with only a little tremolite lining the veinlet walls.

76146 (phyllite)

The rock is a dark grey, non-magnetic phyllite with a weakly developed sheen, and closely resembles sample 76220. X-ray diffraction shows that it also consists mainly of mica and quartz, with minor plagioclase, potash feldspar and kaolinite.

In thin section the rock is fine grained, with compositional banding defined by alternating sericitic, sericitic-carbonaceous, and quartzo-feldspathic zones. The banding may be relict bedding, as cleavage defined by orientation of sericite and carbonaceous material is up to 30° oblique to the banding.

76147 (limestone) (Plate 8)

The hand specimen is a pale grey to cream-coloured limestone, with thinly spaced, somewhat wavy darker laminae 0.5–2 mm wide, defining bedding.

A thin section shows the rock to be a fairly pure, finely recrystallised (10–100 μm) microsparite, interlaminated with wavy, somewhat anastomising discontinuous bands of carbonaceous mudstone. The limestone is often coarser grained within and adjacent to the carbonaceous bands. Very minor (<1%) anhedral quartz grains are also present.

An analysis of the limestone (Table 2) suggests that it contains about 70% calcium carbonate and about 30% impurities, principally quartz, with some silicates, sulphide and apatite. The thin section has probably intersected a relatively pure zone within the limestone (see samples 76148, 76215).

76148 (limestone) (Plate 9)

The hand specimen is a pale grey to cream coloured, diffusely banded (2–10 mm) limestone.

In thin section the rock consists of coarsely recrystallised calcite (mostly 50–500 μm) and about 10% anhedral polycrystalline detrital quartz (100–200 μm), probably of metamorphic provenance. Corroded grain boundaries of quartz suggest some silica mobilisation. The diffuse banding is defined by variations in calcite grain size and carbonaceous impurities. Some scaly, high-birefringence, length-fast material (prehnite?) is associated with the carbonaceous bands. Small equant polygonal opaque grains (≤40 μm), probably pyrite, are sparingly disseminated throughout the rock.

76215 (limestone)

The hand specimen is a pale to medium grey, thinly laminated (0.5–2 mm) limestone, closely resembling sample 76147.

In thin section it is seen to be a similar, but more coarsely recrystallised (40–400 μm) sparite, containing about 10% anhedral quartz grains (50–250 μm), interlaminated with darker carbonaceous mudstone. Deformation twinning in the larger calcite grains is due to post-recrystallisation, probably tectonic, deformation. Scattered equant polygonal grains of pyrite, 100–200 μm across, are present; sulphide was noted during field observation (WLM).

76149 (siltstone)

The hand specimen is a tough, dark grey streaky siltstone. A thin section shows the rock to be a poorly-sorted, fine-grained, slightly carbonaceous and micaceous silty mudstone. The grain size of quartz ranges from 5 to 100 μm, and there are many detrital muscovite flakes (≤100 μm). Cleavage is defined mainly by anastomising seams of carbonaceous material. There is a suggestion of compositional layering, possibly bedding, at about 45° to the cleavage.

The rock closely resembles sample 76152, but is a little less well cleaved.

76152 (siltstone)

The hand specimen is a rough, dark grey cleaved siltstone. X-ray diffraction shows that quartz, mica and minor potash feldspar and plagioclase are the main minerals present.

A thin section shows the rock to be a poorly-sorted, micaceous and carbonaceous siltstone with a typical grain size of 5–40 μm (quartz and subordinate feldspar). Elongate flakes of detrital muscovite are up to 300 μm long, but typically a few tens of micrometres, and poorly oriented. Cleavage is mainly defined by diffuse anastomising seams of carbonaceous material.

76153 (siltstone) (Plate 10)

This rock is a tough, medium to dark grey cleaved siltstone. X-ray diffraction shows that the main constituents are quartz, mica, minor kaolinite, and very minor potash feldspar.

In thin section the rock is a carbonaceous and micaceous, poorly-sorted siltstone similar to, but better cleaved than, sample 76152. Detrital muscovite is randomly oriented, but cleavage is defined by orientation of carbonaceous material and some sericite.

76150 (siltstone)

This is a pale grey-brown, poorly cleaved rock. X-ray diffraction shows that only quartz, mica and smectitic clays are present.

In thin section the rock is seen to be a poorly-sorted, somewhat oxidised micaceous quartz siltstone, consisting of subangular quartz grains (≤50 μm) and ragged fragments of oxidised mica (including some pleochroic brown biotite), grading down to a fine-grained quartz-sericite matrix. A poorly developed spaced cleavage is present.

Caseyville inlier

This inlier crops out over an area of about 1.5 km^2 west of the Lake River and south of *The Glen*. It too is overlain by tillite, intruded by irregular Jurassic dolerite bodies, and partly concealed by alluvium. Most of the inlier consists of phyllite, containing apparently barren quartz veins into which exploratory trenches and adits have been cut and driven in search for gold, without success (Nye and Blake, 1933). A small area of metabasalt has been mapped to the southeast; its petrography and geochemistry are described below. Nye and Blake reported small grains of pyrite and chalcopyrite within the rock, and described it as Devonian dolerite, as at the time this age was ascribed to similar rocks in western Tasmania.

76155 (metabasalt) (Plate 11)

The hand specimen is a weakly magnetic ($\gamma > 0.82 \times 10^{-3}$) tough, massive, dark grey-green aphanitic rock. X-ray diffraction shows that the main minerals present are plagioclase, chlorite, amphibole and sphene.

A thin section shows the rock to be an aphyric metabasalt in which no relict igneous minerals or texture are preserved, although cleavage is poorly developed.

Plagioclase occurs as ragged, subhedral, squat oblong grains (mostly 100–400 µm long) or as more equant, interlocking polygons. These are relatively clear, with multiple twinning well developed. Extinction angles and a positive optic sign indicate albite (An_{1-2}).

Amphibole is abundant, occurring as fibrous to lath-like, but unoriented, splinters and patches (≤150 µm long). The mineral is colourless to very pale yellow but without detectable pleochroism, length slow with extinction angles up to 20°, and is probably tremolite or fairly magnesium tremolite-actinolite.

Chlorite characteristically occurs as pale yellow, very finely granular (<10 µm) irregular patches, often associated with amphibole.

Sphene, turbid possibly due to partial alteration to anatase, is common as irregularly angular to polygonal grains, 100–500 µm across. Traces of epidote are also present.

A few veinlets of chlorite, often associated with fine-grained sphene, traverse the slide. Alteration is slight; secondary carbonate is rare, and only incipient alteration of albite and oxidation of chlorite has occurred.

The rock is a completely recrystallised aphyric metabasalt, with a greenschist facies metamorphic assemblage.

76259 (metabasalt)

The hand specimen is a dense, massive, dark grey aphanitic rock similar to 76155. The sample is fairly large and the moderately high magnetic susceptibility, measured in the laboratory, of up to 2.44×10^{-3} probably approximates the true value. Although a thin section is not available, X-ray diffraction indicates that the main minerals present are amphibole, chlorite, plagioclase, and possible minor pyroxene. Thus the rock is also a metabasalt, possibly with some relict igneous minerals.

O'Connors Peak inlier

This inlier extends from the vicinity of *Parknook* homestead, around the northern and eastern flanks of O'Connors Peak, to the Lake River at Bluff Bottom. It is overlain with landscape unconformity by Permo-Carboniferous rocks which are in turn intruded by Jurassic dolerite. Northwest and southwest of O'Connors Peak the dolerite transgresses stratigraphically downward to directly intrude the basement rocks. Carter (1985) was unable to verify the full extent of the 1.2 km long area of basement shown at *Parknook*.

Lithologically the rocks are mainly greenish-grey (5G5/2 to 5BG5/2) crystal and crystal-lithic tuff, volcanic breccia and volcaniclastic conglomerate of mafic composition. No definite lavas have been identified, but as the rocks are strongly sheared, unrecognised lavas may be present. Many of the rocks are clearly fragmental in hand specimen and thin section, apparently consisting of fused, tectonically flattened and drawn-out lithic clasts, but in others the deformation has obliterated any relict volcaniclastic texture.

In thin section most of the samples are mineralogically similar, but differ widely in grain size, crystal abundance and intensity of foliation. Most contain abundant, typically subhedral crystals of clinopyroxene (augite) and partly altered plagioclase (probably mainly albite, although probable oligoclase was noted in sample 76226). Sometimes brown to green pleochroic hornblende is also present, at least partly derived from alteration of clinopyroxene. In sample 67104, deep green uralitic hornblende is abundant. Quartz anhedra, where present (67105A, 76221), appear to be debris from the disaggregation of quartzite clasts.

Typically the matrix consists of fine-grained plagioclase feldspar, chlorite, tremolite-actinolite, sphene, and sometimes minor epidote (clinozoisite in sample 67100) and mica; biotite was noted in 67104. This assemblage is characteristic of mafic igneous rocks metamorphosed under greenschist facies conditions. X-ray diffraction shows that quartz (other than detrital quartz) and potash feldspar are absent, and thus the dominant volcanic component of the rocks is probably basaltic in composition.

Lithic clasts, where recognisable, are mostly mafic crystal tuffs and possible (sometimes andesitic?) lava fragments, distinguished from each other and the rest of the rock only by variations in texture and grain size. Some sedimentary clasts are present, including phyllite and fine-grained quartzite (67101A, 67105A) similar to some of the lithologies in the western inliers at Little Billop and elsewhere. Unusual amphibolite clasts, consisting largely of hornblende and tremolite, were noted in two samples (67105B, 76225).

Minor slate horizons within the volcaniclastic rocks were noted in the field, but a sample (76221) collected from east of O'Connors Peak is petrographically a strongly sheared, fine-grained phyllite of mixed mafic and quartzo-feldspathic provenance. A hard, fine-grained, diffusely-bedded sedimentary rock (76257) collected from within the volcaniclastic rocks is, in thin section, seen to consist entirely of very fine-grained mafic material.

Most of the samples collected are only weakly magnetic, with susceptibilities, as measured in the laboratory, of about 0.5×10^{-3} (SI). Sample 67103 gave a higher reading of about 1.5×10^{-3}.

76221 (phyllite semi-schist) (Plate 12)

In hand specimen, the rock is a greenish grey, fissile phyllite or semi-schist. Within the foliation, which dips at 60° towards 015°, a strong lineation plunging at about 48° towards 065° has developed.

In thin section the rock consists of anhedra (≤200 µm) of abundant quartz, subordinate hornblende and rare plagioclase and chlorite, which grade downward in size to a strongly sheared matrix. Many of the quartz anhedra are polycrystalline, and probably of metamorphic provenance. Hornblende is pleochroic (probably α colourless, β khaki-brown, γ sea green), optically negative with moderate to large 2V, and partially altered to paler tremolite-actinolite. The plagioclase is albite. Chlorite occurs as aggregates, possibly pseudomorphs (≤1 mm), typically drawn out in the direction of the foliation, to which direction the mineral cleavage may be quite oblique.

The matrix consists of anastomising strands and shreds, typically 50–100 µm wide, of colourless tremolite-actinolite and possibly a little primary muscovite which define the cleavage, between which is finely comminuted (5–20 µm) anhedral quartzo-feldspathic material. Beards of

5 cm

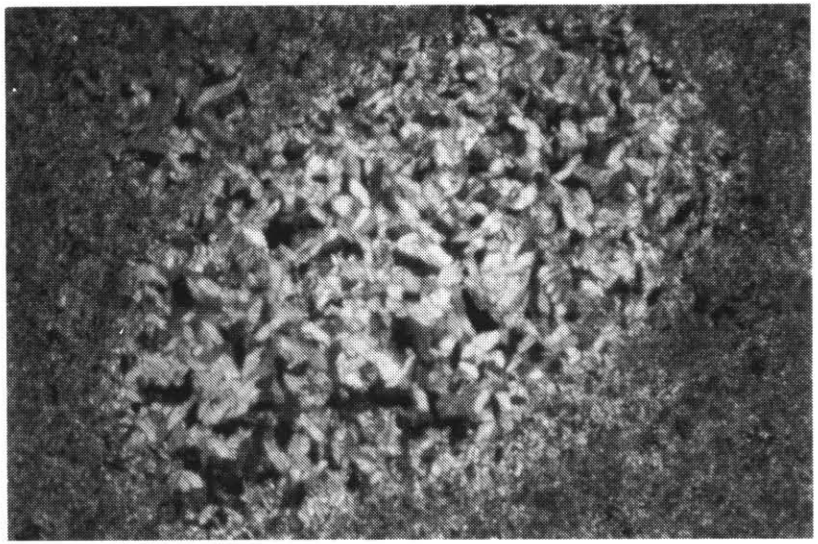


Plate 4. *Sample 76134, dolomite, Brumbys Creek. Pore in fine-grained dolomite, filled with a coarse-grained dolomite cement. Crossed nicols, field of view 4.4 × 2.9 mm.*

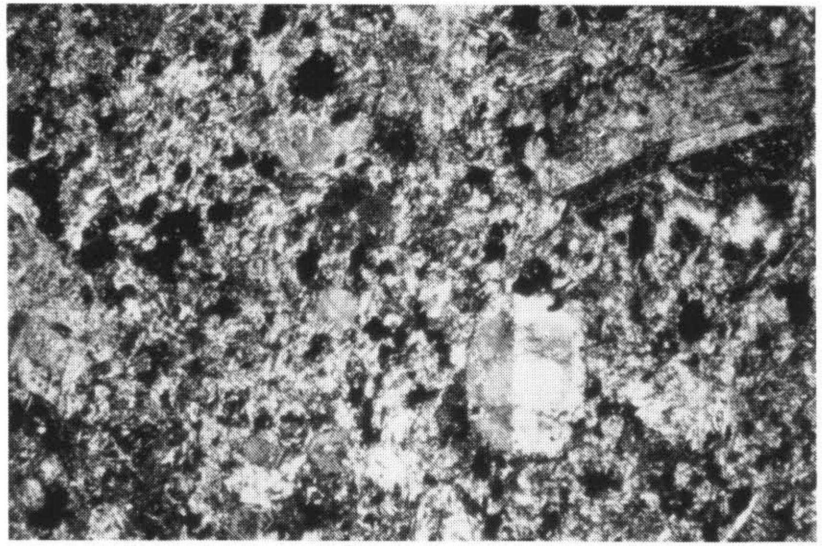


Plate 5. *Sample 76134A, metabasalt, Little Billop inlier. Phenocrysts of twinned augite (lower right) and multiply twinned plagioclase (upper right); dark grains in groundmass are mainly sphene. Crossed nicols, field of view 4.4 × 2.9 mm.*

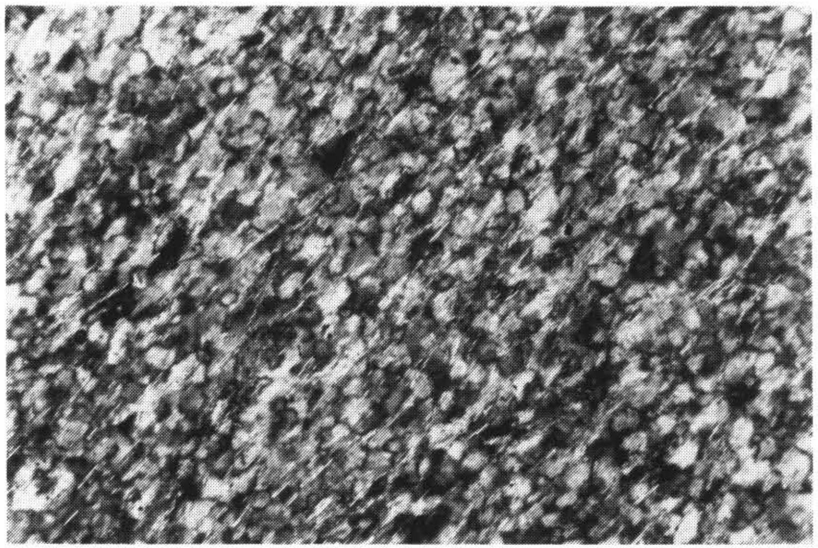


Plate 6. *Sample 76145, phyllite, Little Billop inlier. High magnification, showing quartz anhedra and aligned shreds of muscovite. Crossed nicols, field of view 0.69 × 0.46 mm.*

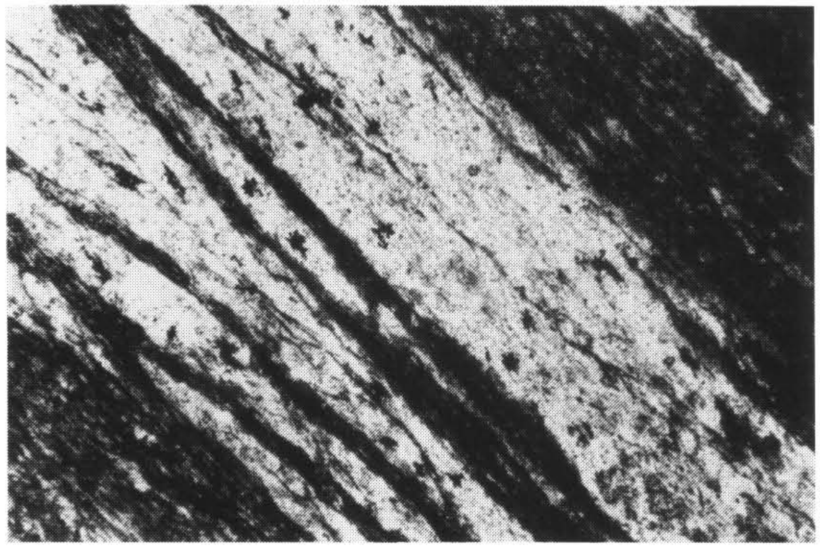


Plate 7. *Sample 76220, phyllite, The Glen inlier. Alternating microlithons of dominantly quartzofeldspathic (light) and sericitic/carbonaceous material (dark). Plane polarised light, field of view 1.8 × 1.2 mm.*

5 cm

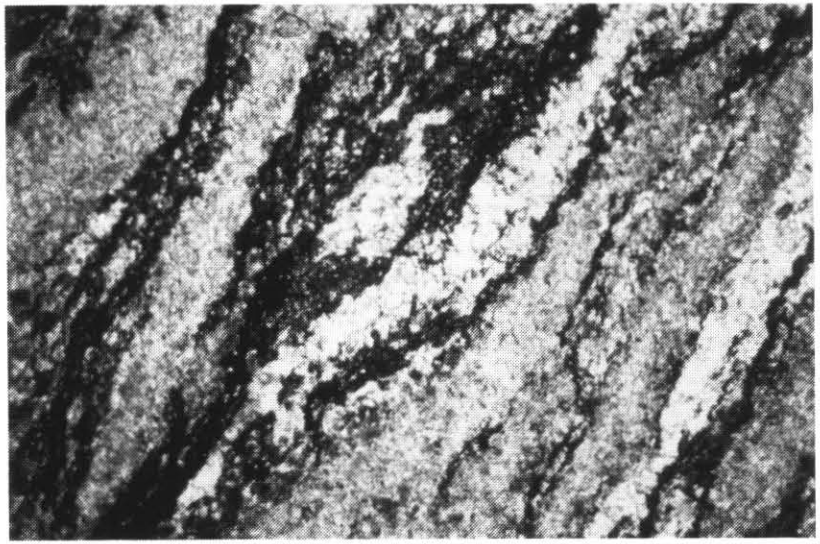


Plate 8. *Sample 76147, limestone, First Creek, The Glen inlier. Recrystallised microsparite interlaminated with carbonaceous mudstone (dark) and coarser-grained limestone (light). Plane polarised light, field of view 4.4 × 2.9 mm.*

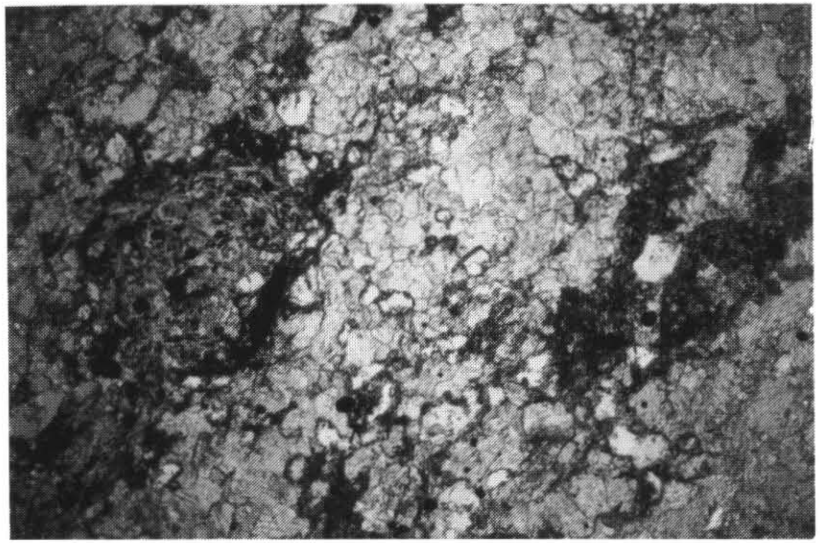


Plate 9. *Sample 76148, impure limestone, First Creek, The Glen inlier. Detrital quartz anhedra (white) and carbonaceous material (dark). Knot of unidentified scaly material (prehnite?) at left. Plane polarised light, field of view 4.4 × 2.9 mm.*

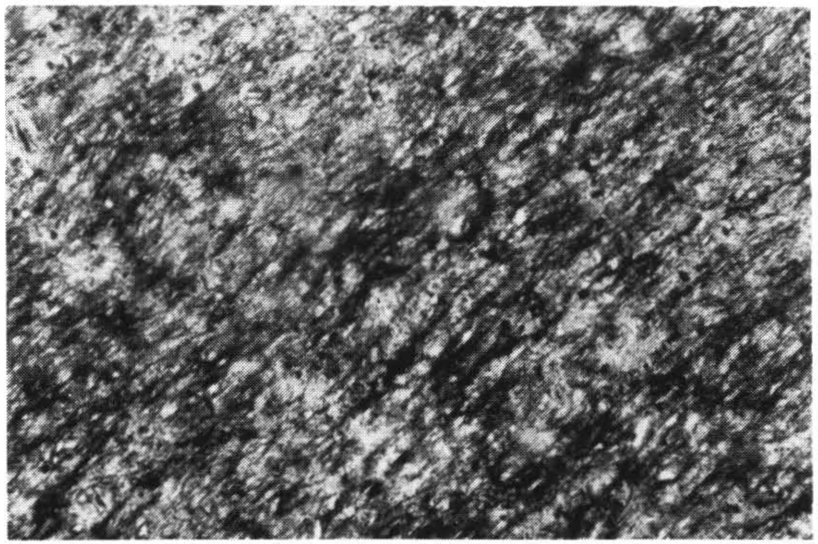


Plate 10. *Sample 76153, cleaved siltstone, First Creek, The Glen inlier. Cleavage defined by alignment of sericite and carbonaceous material. Plane polarised light, field of view 1.8 × 1.2 mm.*

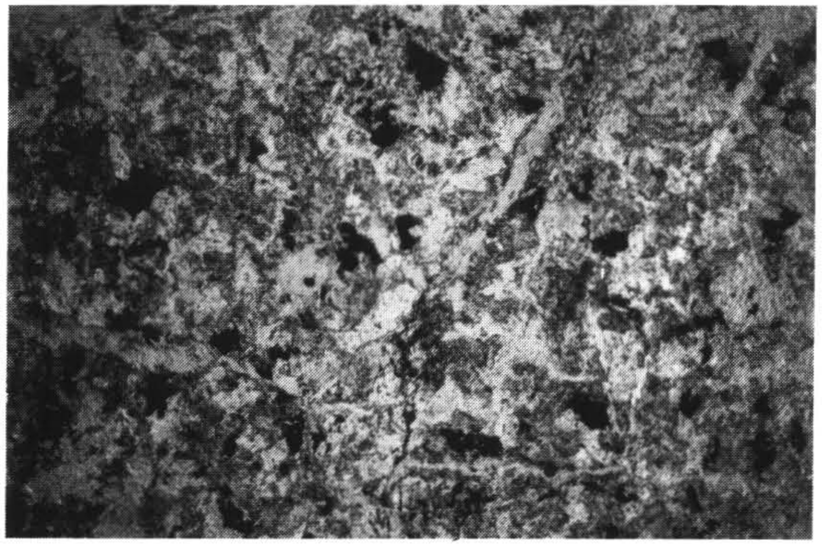


Plate 11. *Sample 76155, metabasalt, Caseyville. Mainly plagioclase (pale), chlorite and tremolite (grey), and sphene (dark). Plane polarised light, field of view 4.4 × 2.9 mm.*

tremolite-actinolite are developed leading from hornblende fragments.

Accessory minerals include a little turbid, nearly opaque sphene and traces of orange-brown pleochroic tourmaline and zircon. Some coarsely crystalline calcite patches are present and tend to be elongated parallel to the cleavage.

The rock is a phyllitic semi-schist of mixed mafic volcanic and metamorphic provenance.

76222 (crystal-lithic tuff)

This is a cleaved but not fissile, greenish-grey rock. In thin section it consists of abundant subhedral crystals, mainly of plagioclase and clinopyroxene, and scattered lithic fragments, grading down to a fine-grained matrix.

The clinopyroxene crystals are equant subhedra and anhedra, up to 3 mm across but commonly 200–500 µm. The mineral is colourless, commonly twinned, has low to moderate 2V with positive sign, and is therefore augite. Plagioclase subhedra and anhedra (≤500 µm) are turbid due to incipient alteration, but multiple twinning is often visible, and the mineral is albite. Scattered small fragments of pale brown to pale green hornblende are also present. Quartz is notably absent.

Rare fine-grained feldspathic or quartzo-feldspathic rock fragments are present; one fragment about 1.5 mm long contains part of a turbid feldspar phenocryst, and may be an intermediate or felsic volcanic rock.

The poorly-cleaved matrix is fine grained and turbid, but consists mainly of plagioclase, chlorite, splinters of tremolite-actinolite, and a few grains of epidote. X-ray diffraction confirms this mineralogy, and also shows that mica is present (as an alteration product of plagioclase?) and quartz absent. Altered sphene and finely acicular possible apatite are present as accessory minerals.

76223 (crystal tuff)

This is another greenish-grey tuff similar to 76222 but better cleaved, although not fissile.

In thin section, the rock consists of euhedral to subhedral crystals of pyroxene (≤3 mm), largely altered to tremolite-actinolite and pale green nearly isotropic chlorite; partly to completely altered elongate plagioclase crystals (≤800 µm); and a fine-grained altered matrix of strongly oriented tremolite-actinolite, subordinate chlorite and probably altered feldspar. Several amygdales, up to 5 mm long but commonly 1–2 mm, are elongate in the direction of the foliation. These amygdales are usually lined with polycrystalline (≤50 µm) quartz and often have a core of pale green chlorite.

76224 (crystal tuff)

The hand specimen is notably coarser-grained than most other samples from this inlier.

In thin section, the rock is very poorly sorted, and consists of abundant large (≤6 mm) anhedral to subhedral crystals of augite, and abundant but smaller (≤1 mm) turbid, multiply-twinned crystals of plagioclase (albite?), both of which grade down in size to a fine-grained matrix of feldspathic material, finely fibrous tremolite-actinolite, and yellow-green chlorite. Rare small grains of pleochroic khaki-brown hornblende and altered sphene are also present. The rock has a very uneven texture, and there are elongate to wispy zones in the matrix that are very fine grained, almost glassy and possibly pumiceous. The rock may have originally consisted of jumbled, lapilli-sized clasts of crystal tuff, but if so, the outlines of individual clasts are now difficult to recognise.

Mica, indicated by X-ray diffraction, is probably fine-grained sericite formed as an alteration product of plagioclase.

76225 (amphibolite pebble in tuffaceous conglomerate) (Plate 13)

The pebble is a dark grey to black, sparkling, foliated rock, which in thin section consists of hornblende porphyroblasts in a fine-grained groundmass.

The porphyroblasts, which comprise about 40% of the rock, are typically equant to elongate subhedra (200–500 µm), crudely aligned to define the foliation. The mineral is strongly pleochroic (α pale yellow, β khaki brown-green, γ olive-green to faintly bluish-green), optically negative with moderate 2V, and is probably common hornblende.

The groundmass is finely fibrous but poorly foliated, fine grained (10–20 µm), and may consist largely of tremolite and altered (sericitised?) feldspar. A little secondary carbonate is present.

76226 (crystal-lithic tuff)

In hand specimen the rock is a poorly foliated greenish-grey tuff in which equant white crystals (≤4 mm) and a crudely ellipsoidal lithic clast, measuring about 40 × 20 mm on the cut surface, are clearly visible.

In thin section, the crystals are seen to be elongate euhedra and subhedra (≤3 mm) of turbid plagioclase, and glomerocrysts of five or more plagioclase crystals. Low extinction angles and a negative optic sign suggest that at least some is oligoclase.

A few clinopyroxene (augite) crystals are present, including one euhedron 1.5 mm across, but most are much smaller and subhedral to anhedral.

The crystals grade down in size to a very poorly-sorted matrix of plagioclase, pale green chlorite, and minor clinopyroxene, epidote and sphene. Amygdales up to 3 mm long are filled with a mosaic of interlocking anhedra (100–200 µm) of clear albite, and may be lined with an identified, finely granular (25–50 µm), fairly high relief, isotropic mineral, possibly analcite.

The lithic clast consists of plagioclase crystals and glomerocrysts, similar to those described above, in a very fine-grained to cryptocrystalline matrix (altered glass?) in which small grains of chlorite and epidote(?) can be seen.

76257 (tuffaceous mudstone)

The rock, described in the field as a "hard sediment in volcanics", is a tough pale greenish-grey rock with faint but distinct bedding. X-ray diffraction shows that the main minerals are amphibole, plagioclase, epidote and minor mica.

In thin section, the rock is too fine grained for the confident identification of most minerals. Lath-like to splintery tremolite fragments up to 70 µm are present, but are commonly only 10–20 µm. Most of the rock is a fine-grained (5–10 µm) pale yellow-brown mosaic, presumably mainly of turbid plagioclase and epidote. Very little opaque mineral is present. Bedding is defined by subtle variations in grain size and mineralogy.

The rock is probably a tuffaceous mudstone derived from reworking of mafic volcanic rocks or ash.

67097 (crystal tuff)

In hand specimen, this is a hard, strongly foliated but not fissile, greyish-green rock, in which crystals 2–3 mm across are visible.

In thin section, the rock consists of scattered equant, mostly subhedral crystals and glomerocrysts of clinopyroxene up to 3 mm across, and more abundant but smaller (≤500 µm), crudely aligned, subhedra and anhedra of plagioclase, which grade down to a strongly foliated, fine-grained matrix. The clinopyroxene, which is augite, is commonly partly altered to chlorite and subordinate fibrous tremolite-actinolite, which in turn may be stained brown due to oxidation. Plagioclase is probably albite and is optically fairly clear.

The matrix probably largely consists of plagioclase, oriented laths and shreds (20–40 µm × 2–5 µm) of tremolite-actinolite (length slow), chlorite, small granules of sphene (5–10 µm), and a little epidote.

The rock is a crystal tuff, but is finer grained and less crystal rich than many others from this area.

67098 (crystal-lithic tuff) (Plate 14)

this is a poorly-foliated, dark greenish-grey rock in which pyroxene grains are clearly visible.

The thin section contains abundant, subhedral to typically anhedral crystals of clinopyroxene (≤2.5 mm) and turbid plagioclase (≤1 mm), which together comprise about 50% of the rock. The clinopyroxene crystals are augite (biaxial positive) and may be clumped into glomerocrysts, twinned, or rarely zoned. Plagioclase is probably albite.

The crystals grade downward in size to the matrix, which in addition contains abundant pale green chlorite, small grains of pale yellow epidote, and a little fibrous, weakly pleochroic tremolite-actinolite. Accessory minerals include rare sphene, traces of probable chromite (deep red-brown, isotropic) and a few small opaque grains.

Irregular to wispy patches of very fine-grained material in the matrix are aligned to define a crude foliation, and may be flattened vitric fragments. One unequivocal lithic clast, about 2 mm across and only slightly flattened, was noticed. This consists of a very fine-grained aggregate of tremolite, possibly epidote and other minerals, in which ovoid vesicles up to 400 µm long are filled with pale green chlorite, clear albite and minor epidote.

67099 (crystal-lithic tuff)

The hand specimen is a strongly foliated greenish-grey rock in which feldspar and pyroxene crystals, up to a few millimetres across, are visible.

In thin section, the rock contains abundant subhedral to anhedral crystals, mostly 200 µm–1 mm across, of clinopyroxene and turbid plagioclase, in a strongly foliated matrix. There are also a few fragments of green to brown pleochroic hornblende and rare grains of sphene and an opaque mineral. Irregular to wispy patches of very fine-grained, probably tremolitic material are elongated parallel to the foliation, and may be flattened lithic fragments of fine-grained, altered basalt or andesite.

The matrix consists of strongly aligned shreds and strands of chlorite, subordinate finely-fibrous tremolite, and probably fine-grained feldspathic material. Beards, particularly of tremolite on pyroxene, are developed on some of the crystals.

67100 (crystal tuff)

This is also a strongly foliated grey-green rock with visible porphyroblasts. X-ray diffraction indicates that the main minerals present are chlorite, amphibole, plagioclase and epidote.

In thin section, the rock consists of a few, typically subhedral clinopyroxene crystals (≤5 mm, but mostly 500 µm–2 mm), and more numerous but smaller (500 µm–1 mm) plagioclase anhedra and subhedra, in a fine-grained, strongly foliated matrix. The plagioclase crystals are turbid, but multiple twinning is recognisable, and on the basis of extinction angles and positive optic sign, are probably albite. Their long axes are strongly oriented parallel to the foliation, and some are strained.

The matrix consists mainly of anastomising strands of fine-grained chlorite and tremolite-actinolite, which form beards on the crystals, and fine-grained feldspar. Small (50–200 µm) crystals of clinozoisite (high relief, low to moderate birefringence with anomalous interference colours, optically positive) are also common, particularly associated with chlorite. No lithic fragments are recognised, and very little opaque material is present. There is a slight brown discoloration in the matrix due to oxidation.

67101A (crystal-lithic tuff) (Plate 15)

The hand specimen is a well-foliated, grey-green rock in which irregularly-shaped to elongate lithic fragments up to 20 mm long are recognisable.

Most of the thin section is a strongly foliated, poorly sorted, metamorphosed volcaniclastic rock, consisting of subhedral to anhedral crystals (≤1 mm) of plagioclase (albite), and generally smaller (200–500 µm) fragments of brown to green pleochroic hornblende, grading down to a matrix of pale green to colourless fibrous tremolite-actinolite, chlorite, feldspar, and minor epidote, sphene and secondary carbonate. No relict igneous pyroxene was seen.

At least four types of lithic clast are present:–

(a) feldspar porphyry, consisting mainly of crudely aligned plagioclase crystals (≤1 mm) in a fine-grained, strongly foliated sericitic(?) groundmass. A single crystal (phenocryst?) of colourless amphibole, and a flattened chlorite-filled amygdale, are also present.

(b) a feldspathic (meta-igneous?) rock, consisting of interlocking, ragged subhedra and anhedra (200–500 µm) of plagioclase and abundant fine-grained

5 cm

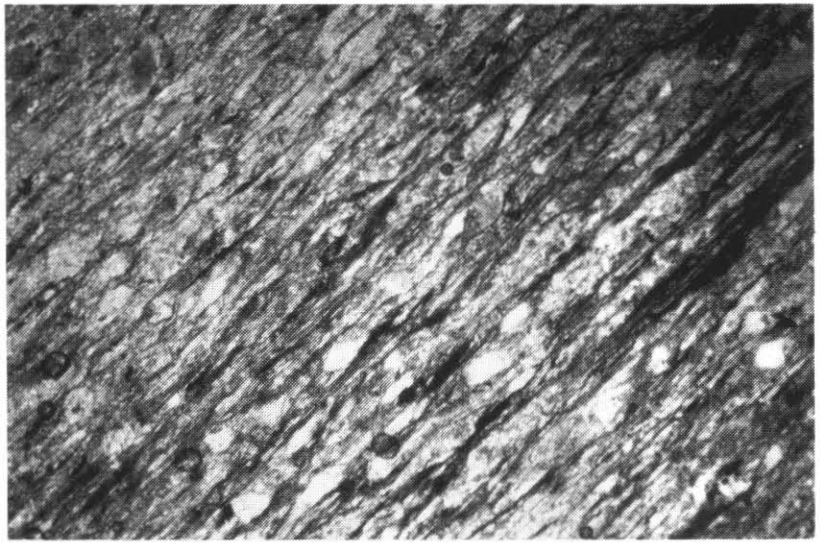


Plate 12. *Sample 76221, phyllitic semi-schist, O'Connors Peak inlier. Anhedra of mainly quartz and hornblende in a strongly sheared matrix. Plane polarised light, field of view 4.4 × 2.9 mm.*

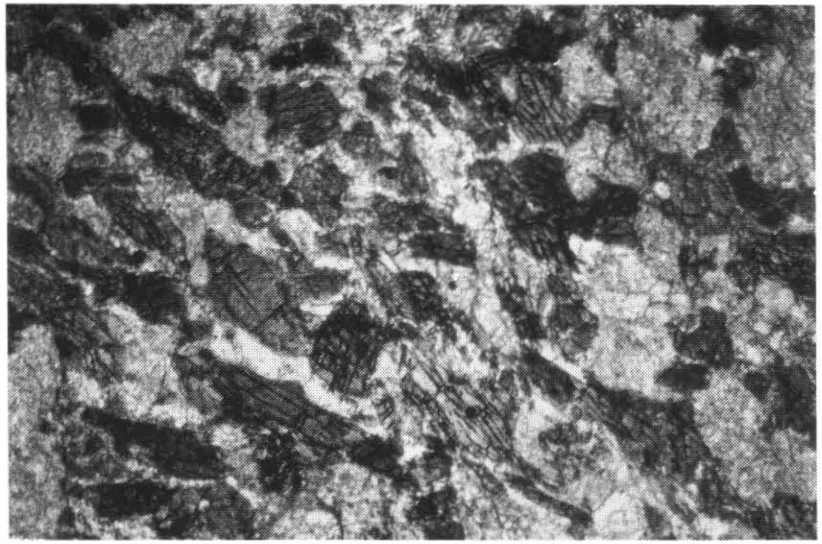


Plate 13. *Sample 76225, amphibolite pebble in tuffaceous conglomerate, O'Connors Peak inlier. Subhedral brown to green hornblende and a groundmass of probably mainly tremolite and altered plagioclase. Plane polarised lights, field of view 4.4 × 2.9 mm.*

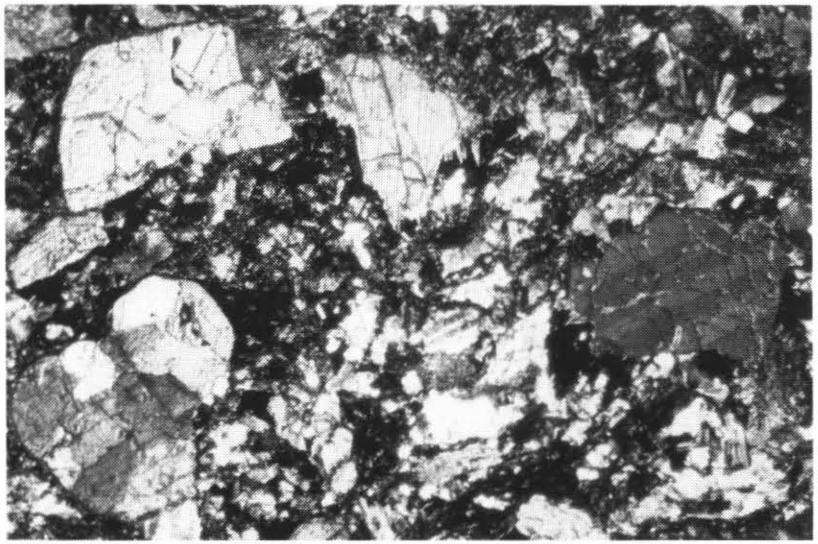


Plate 14. *Sample 67098, coarse-grained crystal-lithic tuff, O'Connors Peak inlier. Dominantly anhedral crystals of augite and plagioclase (smaller), grading down to the matrix. Crossed nicols, field of view 4.4 × 2.9 mm.*

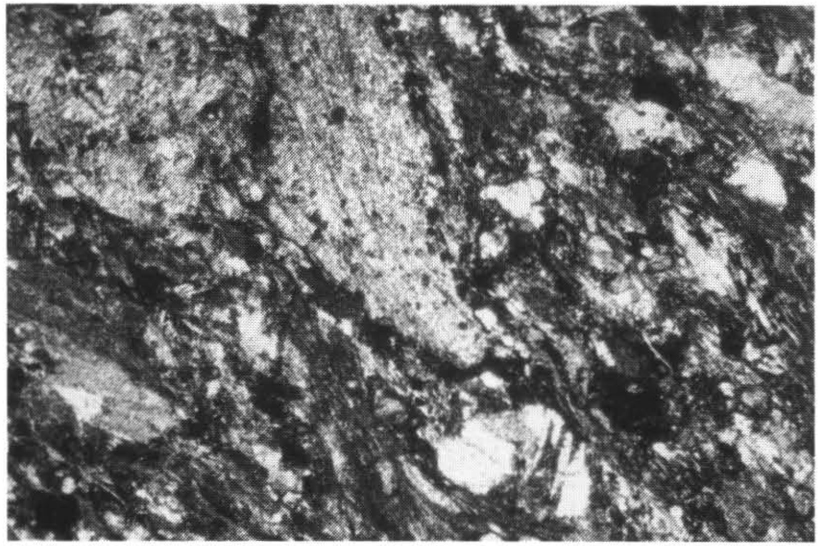


Plate 15. *Sample 67101A, foliated crystal-lithic tuff, O'Connors Peak inlier. Plagioclase and hornblende subhedra and anhedra, clast of phyllite (upper centre) and a foliated matrix. Crossed nicols, field of view 4.4 × 2.9 mm.*

5 cm

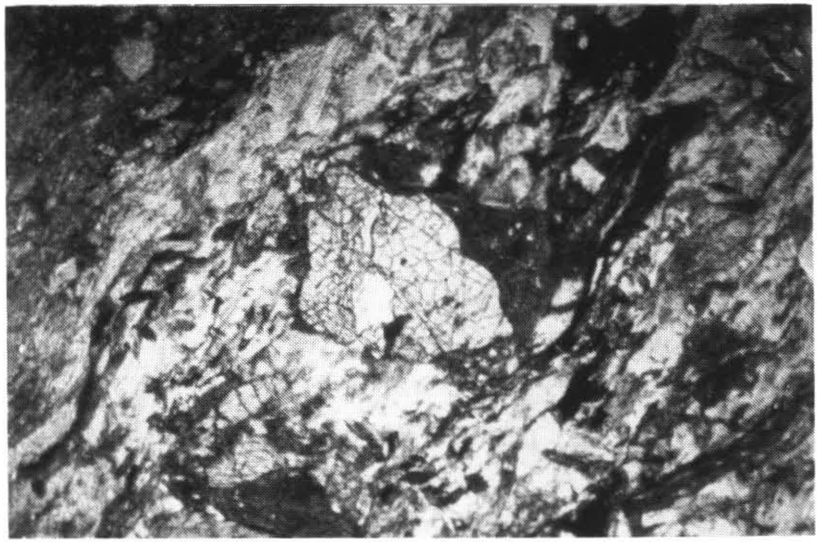


Plate 16. *Sample 67104, foliated crystal-lithic(?) tuff, O'Connors Peak inlier. Augite crystals (centre and bottom) with peripheral alteration to uralitic hornblende. Matrix mainly of feldspar and hornblende. Finer grained lithic clast(?) (top left). Plane polarised light, field of view 4.4 × 2.9*

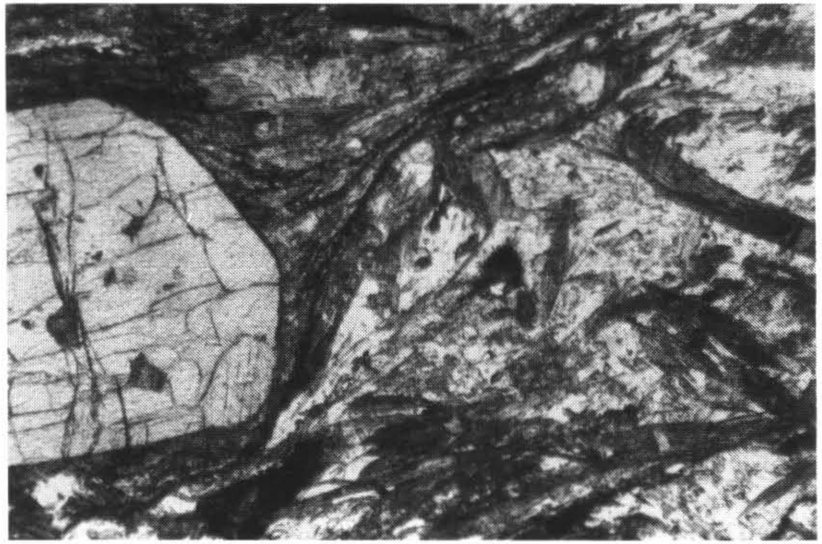


Plate 17. *Sample 67104. Close up, showing augite euhedron (left) and matrix of elongate uralitic hornblende and finely comminuted feldspar. Plane polarised light, field of view 1.8 × 1.2 mm.*

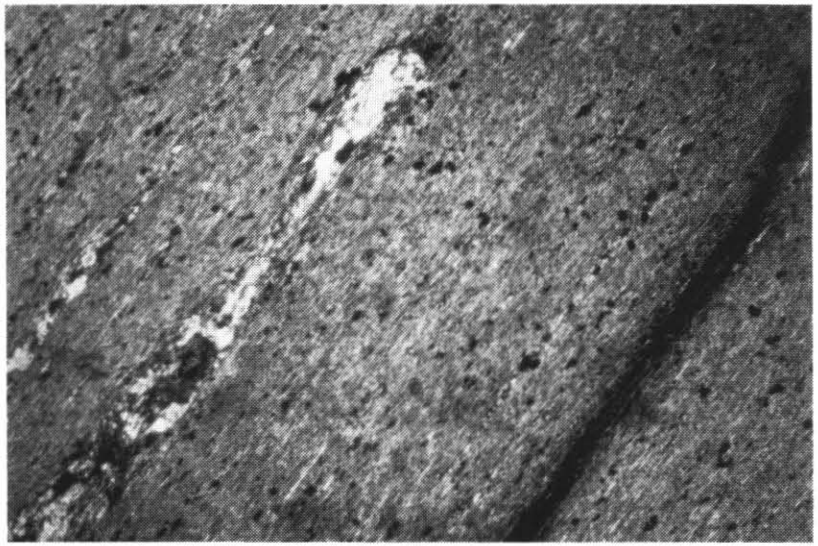


Plate 18. *Sample 76243, phyllite, Little Den inlier. Strongly aligned sericite and fine-grained quartz with coarser-grained quartz-rich microlithon (left) and carbonaceous band (right). Crossed nicols, field of view 4.4 × 2.9 mm.*

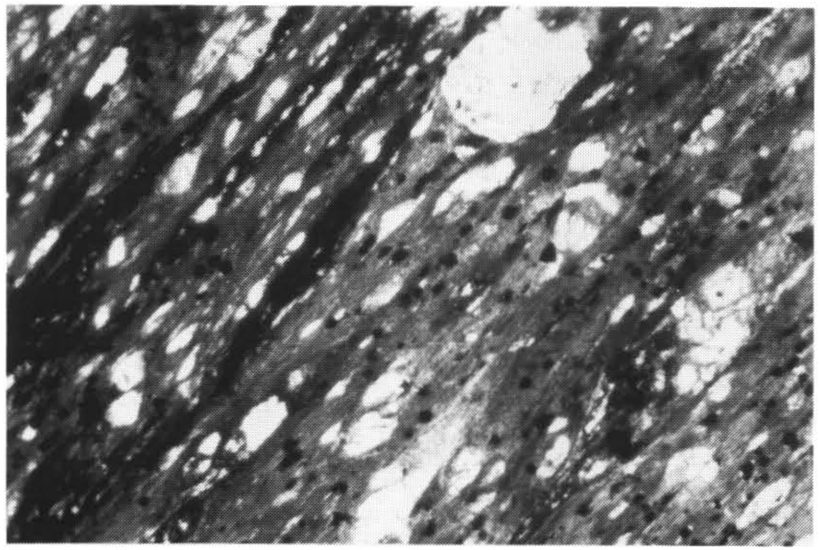


Plate 19. *Sample 76247, strongly-sheared metabasalt, Little Den inlier. Feldspar porphyroblasts, and granules of sphene and opaques (dark). Plane polarised light, field of view 4.4 × 2.9 mm.*

(20–50 µm) sphene, together with a little interstitial chlorite, tremolite-actinolite and fine-grained recrystallised feldspathic or quartzo-feldspathic anhedra.

(c) a dark fine-grained rock containing small splinters of tremolite-actinolite, resembling sample 76257 and probably also a reworked mafic volcanic rock.

(d) quartz-muscovite phyllite, resembling sample 76145 from near Little Billop; fine-grained (10–30 µm).

67101B (crystal-lithic tuff)

The hand specimen is a grey-green, rather coarse-grained fragmental rock in which dark green pyroxene crystals (≤5 mm), pale green angular lithic fragments (≤20 mm), and patches of white secondary carbonate are clearly visible. Foliation is poorly developed.

In thin section, the rock consists of anhedral to subhedral crystals of clinopyroxene (augite) and lithic fragments, which grade down to a matrix principally of interlocking anhedral or finely-granulated, possibly recrystallised plagioclase (albite?, biaxial positive); pale green, nearly isotropic chlorite; and small (50–100 µm) grains of epidote (biaxial negative). A little tremolite-actinolite and patches of secondary carbonate are locally present.

The lithic fragments are flattened to wispy, and are probably compositionally similar to the rest of the rock. They contain corroded (resorbed?) phenocrysts of augite, in a very fine-grained foliated groundmass, probably once glass, in which numerous elongate vesicles are filled with albite, chlorite and epidote. The foliation in various individual clasts is roughly aligned, and therefore post dates incorporation of the clasts into the rock.

67102A (lithic tuff?)

The hand specimen is a weathered, pale grey-green well-foliated rock, containing numerous darker inclusions, a few millimetres long, roughly aligned in the foliation. X-ray diffraction shows that amphibole, plagioclase, chlorite and epidote are the main minerals present.

In thin section, the mineralogy and texture is variable, and the rock may well consist of fused lithic clasts of various, but mostly mafic, lithologies. Much of the thin section consists of a crudely foliated aggregate of plagioclase (≤400 µm, but commonly much smaller), finely fibrous to acicular, pale yellow-green tremolite-actinolite, and pale green, nearly isotropic chlorite. One distinct zone contains abundant subhedral to anhedral plagioclase crystals in a matrix of mainly finely granular epidote. In other distinct, sharply defined ovoid to irregularly-shaped zones, chlorite or tremolite-actinolite is dominant.

67102B (lithic tuff?)

The hand specimen is a blotchy, apparently fragmental rock composed of numerous angular dark grey-green clasts or pseudoclasts, typically 1–10 mm across, in a paler grass-green matrix.

The thin section consists of scattered, typically anhedral clinopyroxene crystals (500 µm–3 mm across), partly altered to chlorite and epidote, and numerous elongate (500 µm–1 mm) to anhedral, turbid plagioclase crystals, in a variable, fine-grained matrix. Much of the matrix consists of finely fibrous (typically 100 µm × 5 µm) to acicular tremolite-actinolite and feldspar, but there are discrete patches and veinlets consisting mainly of finely granular, yellowish epidote.

The epidote-rich and tremolite-actinolite–rich patches typically have sharp irregular boundaries, perhaps originally the margins of separate clasts. Another apparent clast consists mainly of coarsely anhedral plagioclase (≤1.5 mm) in a matrix of finely granular feldspar, chlorite and minor tremolite-actinolite.

Apparent rounded vesicles are also present in the rock, variously filled with granular albite, epidote or a mixture of chlorite and tremolite-actinolite.

67103 (lithic-crystal tuff)

The hand specimen is a moderately magnetic ($\gamma > 1.53 \times 10^{-3}$), dark grey-green, crudely foliated rock in which crystals of pyroxene and feldspar are clearly visible. The rock has a distinctly blotchy to streaky appearance, suggesting that it consists of fused lithic clasts, flattened to define the foliation.

In thin section, crystals of pyroxene (augite, biaxial positive, low to moderate 2V) are fairly abundant, typically anhedral to rarely subhedral, and up to 3 mm across, although typically 200 µm–1 mm. Occasionally they are twinned, or are clumped together in glomerocrysts. Plagioclase (albite) is also abundant as oblong subhedra (≤1 mm long) and equant euhedra; generally the plagioclase is clear and much fresher than in most samples from this inlier.

The matrix consists mainly of fine-grained feldspar, pale yellow-green splinters (≤100 µm long) of tremolite-actinolite, and patches of similar coloured chlorite.

Within the matrix, several elongate to irregularly-shaped, sharply bounded zones, several millimetres across, are defined mainly by variations in grain size, and are probably fused, tectonically flattened, original lithic clasts. All appear to be mafic to intermediate volcanic rocks, although there are also differences between individual clasts in the abundance and proportion of crystals. For example, one type of clast contains abundant plagioclase crystals but little or no pyroxene, whilst in another apparent clast there are numerous small (≤100 µm) grains of sphene.

67104 (crystal-lithic? tuff) (Plates 16, 17)

The hand specimen is a dark greenish-grey, strongly-foliated rock, in which pyroxene and feldspar crystals are clearly visible, and elongate, paler green irregular patches up to 15 mm long may represent tectonically flattened lithic clasts. Chlorite, plagioclase and amphibole were the only minerals detected by X-ray diffraction.

In thin section, the rock consists of scattered crystals (≤1 mm) of clinopyroxene and plagioclase in a sheared matrix of hornblende and comminuted feldspathic material of variable grain size.

The clinopyroxene (augite, biaxial positive, rather low 2V) crystals are typically euhedral to subhedral, and frequently show peripheral alteration to well crystallised hornblende similar to that in the matrix. Plagioclase crystals occur as oblong subhedra and anhedra, grading down in grain size to the matrix, and are probably albite. Hornblende occurs both as elongate to acicular laths up to 500 µm long and sometimes only 10 µm wide, and as a platy alteration rim to pyroxene crystals. It is strongly and strikingly pleochroic (α pale straw yellow, β deep yellow-green, γ deep blue-green) and optically negative. The pleochroism and paragenesis are characteristic of the variety uralite.

The feldspathic matrix has an overall streaky appearance, due to variations in grain size of the constituent anhedra from 100 µm or so, to almost cryptocrystalline material. There is some suggestion of discrete zones (former clasts?) but these have been severely disrupted by shearing. Traces of pale brown pleochroic biotite, sphene, and opaque minerals are also present.

67105A (schistose lithic tuff)

The hand specimen is a strongly foliated to schistose, pale grey-green rock, containing several fine-grained, dark grey, subangular lithic (phyllitic?) fragments up to 15 mm long, elongate in the direction of the foliation. As noted by G. B. Everard (1968), a knot of pale green, slightly coarser-grained material, about 20 mm across, and around which the foliation appears to part, is present in the centre of the cut face.

In thin section, the bulk of the rock consists of small (mostly 100–200 µm) anhedra of plagioclase (albite?) and quartz, and ragged fragments of tremolite-actinolite scattered in a strongly foliated matrix consisting mainly of finer-grained to fibrous tremolite-actinolite and chlorite. The tremolite-actinolite is nearly colourless and may be fairly magnesian (i.e. close to tremolite). However a few small anhedra of pleochroic, green to brown hornblende, are also present. No pyroxene is present.

One lithic fragment, about 5 mm long by 2 mm wide and aligned parallel to the foliation, consists of fine-grained quartzite. Individual, interlocking quartz grains (50–500 µm) tend to be elongate parallel to the foliation, appear strained, and are probably slightly mylonitised. The quartzite also contains a little muscovite. The anhedral quartz fragments may be largely derived from disaggregation of similar quartzite clasts.

Other clasts are much finer-grained (≤20 µm), more sericitic, and are perhaps best described as phyllite.

The knot visible in hand specimen consists almost entirely of relatively coarse-grained (100–400 µm), colourless tremolite, although radiating sheaves of clinozoisite (with low, anomalous blue birefringence) and a little chlorite are also present. The knot lacks foliation and therefore recrystallised later than the main deformation.

67105B (mafic volcaniclastic conglomerate)

The hand specimen is a strongly foliated and somewhat weathered grey-green schistose conglomerate, in which rounded pebble-sized clasts up to at least 20 mm across are clearly visible.

Within the area transected by the thin section, about 20 mm in diameter, four or five distinct, sharply-defined clasts of various lithologies can be recognised.

One clast consists of a crudely foliated aggregate with a mean grain size of about 500 µm, mainly of moderately pleochroic (α nearly colourless, β deep yellow-brown, γ khaki-brown; biaxial negative, moderate 2V) hornblende grading to colourless to pale green tremolite, subordinate incipiently altered plagioclase, and minor opaque minerals. Another clast consists mainly of interlocking subhedra (150–500 µm) of hornblende with different pleochroism (α very pale yellow, β pale yellow-green, γ pale green; biaxial negative, large 2V), together with irregular patches up to 1 mm across of very fine-grained sericite (or talc?), minor anhedral quartz, and a fine-grained, high relief, isotropic mineral, possibly perovskite. Both these clasts may be relatively high-grade metabasites (amphibolites).

Other more felsic lithologies are present, including one consisting of small oblong (≤500 µm) sericitised plagioclase subhedra, aligned in a very fine-grained sericitised matrix. Another rock type consists of scattered polycrystalline quartz anhedra in a matrix of fine-grained fibrous tremolite-actinolite, and probable clinozoisite.

Little Den inlier

This inlier occupies an area of about 0.7 km^2 in the floor of an amphitheatre-like depression in the Great Western Tiers, into which the Lake River enters and exits through small gorges. The basement rocks are intruded by dolerite to the north, and overlain by tillite to the west and south. Northwest of the river, the rocks are mainly feldspar-pyroxene bearing crystal tuffs similar to those around O'Connors Peak, although a sample of strongly sheared metabasalt has been collected and analysed. The main lithology southeast of the river is dark grey to black slate.

Gold was originally discovered and worked in alluvium on the left bank of the river, pieces "the size of the wheat" being reported (Scott, 1932, 1935; Nye and Blake, 1933). Quartz veins have been opened up by small adits, both in the slate (ibid.) and in the mafic tuff on the opposite bank (Threader, 1963).

76243 (phyllite) (Plate 18)

In hand specimen the rock is a fissile, very well cleaved, pale grey phyllite. A strong lineation is visible on cleavage surfaces. The rock is essentially non-magnetic, and X-ray diffraction shows that it consists of quartz, mica and very minor kaolinite.

In thin section, the rock consists mainly of very strongly oriented sericite, between which are narrow quartz-rich microlithons, typically 5–30 µm wide and traceable for several millimetres along the cleavage. Occasionally the microlithons grade into quartz stringers, rarely up to 500 µm wide, in which the constituent grains may be very elongated parallel or sub-parallel to the cleavage direction.

Irregular patches of an opaque mineral (≤200 µm across) are scattered throughout the rock. They do not appear to have deflected the cleavage, but may have a preferred orientation parallel to it. Rare dark patches within the sericite may be due to intergrown carbonaceous material.

76244 (mafic crystal tuff)

The hand specimen is a strongly magnetic ($\gamma > 9.04 \times 10^{-3}$), dense, tough, fine-grained, dark grey-green rock with a well-developed foliation.

In thin section, the rock is seen to be a strongly sheared, metamorphosed mafic volcanic, containing large crystals (≤2.5 mm) of relict igneous clinopyroxene, and smaller (mostly ≤500 µm) subhedral to anhedral, often slightly elongate fragments of partially sericitised albite, in a strongly cleaved, fine-grained groundmass.

The generally subhedral pyroxene crystals are probably sub-calcic augite (colourless, biaxial positive, rather low 2V), and are partly altered to fibrous tremolite-actinolite and epidote. Wispy beards of the former mineral occur adjacent to the pyroxene crystals and parallel to the foliation.

The matrix appears to consist largely of fine-grained chlorite, with subordinate tremolite-actinolite. The foliation parts to envelop the crystals, with pressure shadows of coarser-grained pale-green chlorite developed adjacent to albite crystals. Equant to angular grains (mostly ≤50 µm) of turbid altered sphene are abundant, and there is also a fine dissemination of fine-grained (5–10 µm) opaque blebs (magnetite?) throughout the matrix.

The rock is a pyroxene-feldspar crystal tuff, metamorphosed in the greenschist facies, and strongly resembles similar crystal tuffs in the O'Connors Peak inlier.

76245 (mafic? crystal tuff)

The rock is a dense, strongly foliated, strongly magnetic (γ >25.9×10^{-3}), tough, dark grey to black rock, resembling sample 76244 from nearby. Crystals of pyroxene(?) up to 5 mm across are visible in hand specimen. No thin section is available, but X-ray diffraction indicates that the main minerals present are plagioclase, chlorite, amphibole and quartz. Therefore the rock is probably also a metamorphosed mafic volcanic.

76246 (slate)

In hand specimen the rock is a dark grey to black pyritic slate with a strongly developed cleavage, along which it readily splits into sheets half a metre or more long and a few millimetres thick. The rock is essentially non-magnetic, and X-ray diffraction shows that quartz, minor potash feldspar and very minor mica and smectite are the main constituent minerals.

In thin section, the rock consists mainly of fine-grained (typically 5–10 µm) polycrystalline, recrystallised quartz, but the abundant black carbonaceous material obscures much of the fabric. Some elongate micro-boudins of coarser-grained (≤100 µm) quartz are aligned parallel to the cleavage, which is principally defined by elongation of the quartz (± feldspar grains), and very crude banding of the carbonaceous material.

The sample has a strong lithological resemblance to the Cowrie Siltstone from the Rocky Cape Group of northwestern Tasmania, but correlation is unjustified on the available information.

76247 (?metabasalt) (Plate 19)

The hand specimens are tough, strongly sheared, medium-grey rocks, in which feldspar porphyroblasts (1–2 mm) are strongly aligned parallel to the foliation. X-ray diffraction suggests that the main minerals present are potash feldspar, chlorite and mica The samples are moderately magnetic ($\gamma \approx 1.05 \times 10^{-3}$), and a chemical analysis (Table 2) indicates a basaltic composition.

The thin section consists of abundant, somewhat turbid, strongly-aligned feldspar porphyroblasts (≤1 mm but mostly 100–500 µm long) and scattered, small (50–200 µm) grains of altered sphene in a fine-grained, strongly foliated matrix. The feldspar porphyroblasts may include both sanidine (biaxial negative, low 2V) and multiply-twinned plagioclase (?albite; biaxial positive). The grains of sphene are partly altered to very fine-grained opaque dust, but equant grains (≤50 µm) of probable primary ilmenite and/or magnetite are also present. Some fine-grained opaque material forms stringers parallel to the cleavage. Rare small elongate grains of a high birefringence mineral (epidote or amphibole?) are present. The matrix is too fine grained to resolve optically, but X-ray diffraction results suggest that it is largely sericite and chlorite. Some carbonate veining is present.

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The rock may have originally been a basaltic lava or volcaniclastic (although the presence of potash feldspar is unusual), but original textures have been completely obliterated by recrystallisation and cleavage development.

Geochemistry of basaltic rocks

Only three chemical analyses (Table 2) are available of the volumetrically minor metabasalts occurring within the Proterozoic(?)–Cambrian(?) inliers. The samples were collected by W. L. Matthews, and major and trace elements determined in the former Department of Mines laboratories. Rare-earth elements (Table 3) were determined for one of the samples, courtesy of Dr A. J. Crawford, University of Tasmania.

Two of the analysed samples (76143, 76155), collected from within the western pelitic association near Little Billop [033708] and at *Caseyville* [058639], are essentially similar. A third sample (76247) from within the volcaniclastic sequence at Little Den is distinctly different, notably with lower TiO_2, total FeO, Zr, Nb and Y, and higher CaO.

All three samples are tholeiitic basalts, characterised by relatively low levels of alkalis and of incompatible elements such as P, Zr, Nb and the rare-earth elements (REE). Low Nb/Y ratios (<1) are also diagnostic (e.g. Winchester and Floyd, 1976). The low MgO (high FeO/MgO) values suggest that the rocks are relatively fractionated. The high Cu content of the sample from near Little Billop (76143) suggests trace mineralisation, possibly of chalcopyrite.

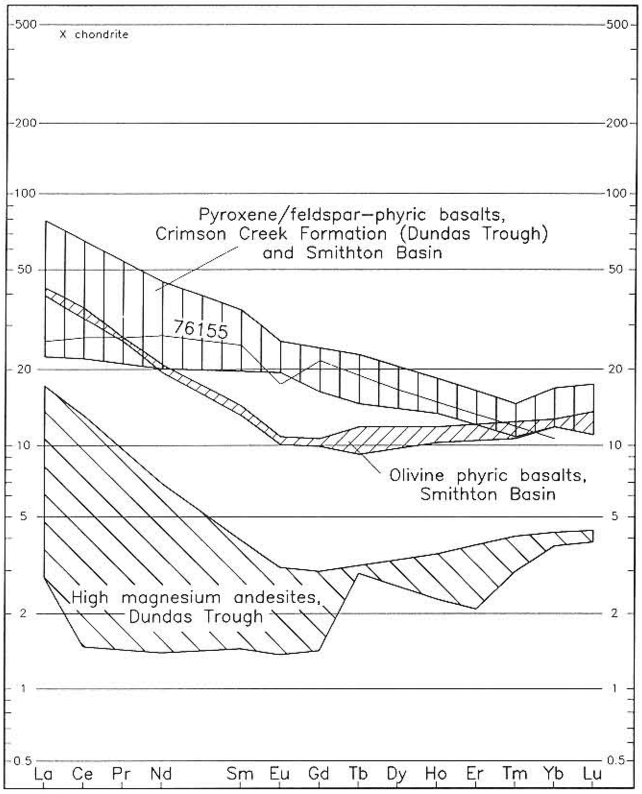
TABLE 2
Chemical analyses of Proterozoic(?) / Cambrian(?) samples, Lake River Quadrangle, and possible correlate in the Smithton Basin

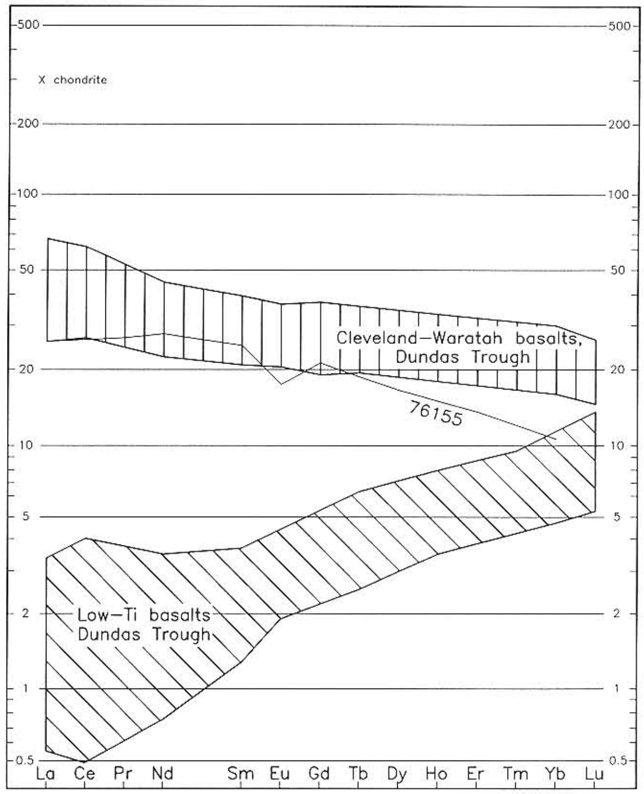
Registered No.	76134	76147	76143	76155	76247	*
Analysis No.	901428	901429	901430	901431	901432	814089-814093
Field No.	C1	C14A	C10	C17A	C107	ABS22-ABS26
Rock type	Dolomite	Limestone	Metabasalt	Metabasalt	Metabasalt	
SiO_2	1.64	20.02	47.61	46.87	49.94	48.36
TiO_2	0.02	0.15	2.30	2.36	0.58	2.34
Al_2O_3	0.15	2.49	14.56	14.23	15.91	13.45
Fe_2O_3	0.00	0.64	2.51	1.33	2.73	5.27
FeO	0.23	0.40	9.92	10.72	7.57	8.00
MnO	0.03	0.04	0.17	0.16	0.19	0.20
MgO	20.56	0.44	5.50	6.73	6.89	5.96
CaO	30.49	43.05	6.88	9.40	10.91	9.33
Na_2O	0.00	0.00	3.63	2.58	2.09	2.99
K_2O	0.01	0.86	0.39	0.83	0.65	0.30
P_2O_5	0.21	0.30	0.25	0.25	0.18	0.27
H_2O^+	na	na	4.10	2.96	2.06	2.82
CO_2	na	na	1.67	0.03	0.16	0.10
Sulphate as SO_3	0.13	1.41	0.07	0.06	0.06	na
Sulphide as SO_3	na	na	0.12	0.10	0.06	na
Loss on ignition	46.39	30.95	-	-	-	-
TOTAL	99.86	100.75	99.68	98.61	99.98	99.39
Trace elements (ppm)						
Sc	na	na	26	28	26	na
V	na	na	350	310	220	na
Cr	na	na	55	220	90	152
Co	na	na	56	59	52	na
Ni	na	na	61	115	37	83
Cu	na	na	890	250	210	na
Zn	na	na	91	84	77	na
Ga	na	na	16	17	12	na
As	na	na	<20	<20	<20	na
Sr	na	na	240	460	360	265
Y	na	na	30	27	12	23
Zr	na	na	145	135	37	145
Nb	na	na	11	8	<3	15
Mo	na	na	<5	<5	<5	na
Sn	na	na	<9	20	<9	na
Ba	na	na	460	350	190	na
La	na	na	<20	<20	<20	na
Ce	na	na	55	44	37	na
Nd	na	na	25	<20	<20	na
Pb	na	na	<10	13	<10	na
Bi	na	na	<5	6	5	na
Th	na	na	<10	<10	<10	na
U	na	na	<10	<10	<10	na

*Average of 5 similar analyses of basalts from Smithton and Montagu (from Brown, 1985).
Analyses 901428–901432 by W. Leong and L. Hay, Mineral Resources Tasmania.

Because many elements are mobile under conditions of low grade, greenschist facies metamorphism to which these rocks have been subjected, the analyses should be interpreted with caution; for this reason CIPW and Rittmann norms have not been calculated. However, the high field strength elements (HFSE), such as Ti, P, Y, Zr, Nb and the REE, which form relatively small, highly charged cations, are considered relatively immobile under such conditions (e.g. Pearce, 1975; Beswick, 1983), and therefore attention is focused on them.

The rare-earth data, although available from only the *Caseyville* sample (76155), are particularly interesting (fig. 4). The chondrite-normalised pattern is slightly light-rare-earth element (LREE) enriched (La*/Yb* = 2.43), with a moderate Eu anomaly, perhaps attributable to alteration or plagioclase fractionation. Compared to the Cambrian and Eocambrian mafic rocks of western Tasmania, the pattern is broadly similar to those from the pyroxene-feldspar-phyric basalts from the Smithton Basin and their correlates (Crimson Creek Formation) in the Dundas Trough. It also resembles data from basalts near Mt Ramsay, also in the Dundas Trough but assigned to the separate Cleveland–Waratah association by Brown (1989) (see discussion below). It is dissimilar to the basal olivine-phyric basalts in the Smithton Basin, and quite different from the other two main mafic suites in the Dundas Trough, the low-titanium basalts and the high-magnesium andesites (boninites) (Brown, 1986; Brown and Jenner, 1989).





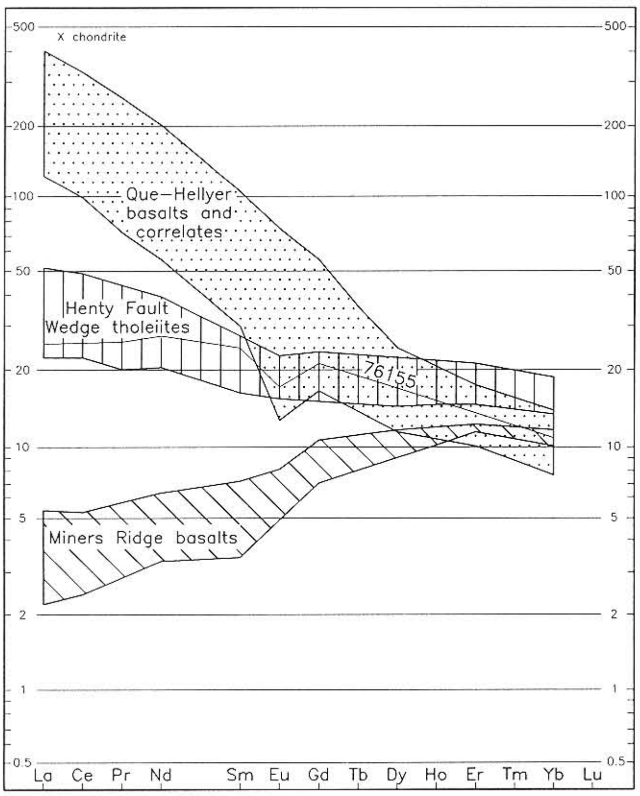


Figure 4

Chondrite-normalised rare-earth element plots for Eocambrian(?) metabasalt sample 76155 (heavy line), compared with fields for Cambrian/Eocambrian mafic units from the Dundas Trough, Smithton Basin and Mt Read Volcanics, western Tasmania (data from Brown, 1986; Waldron and Brown, 1985; Crawford et al., 1992; Chondrite normalisation factors from Taylor and Gorton, 1977).

5 cm

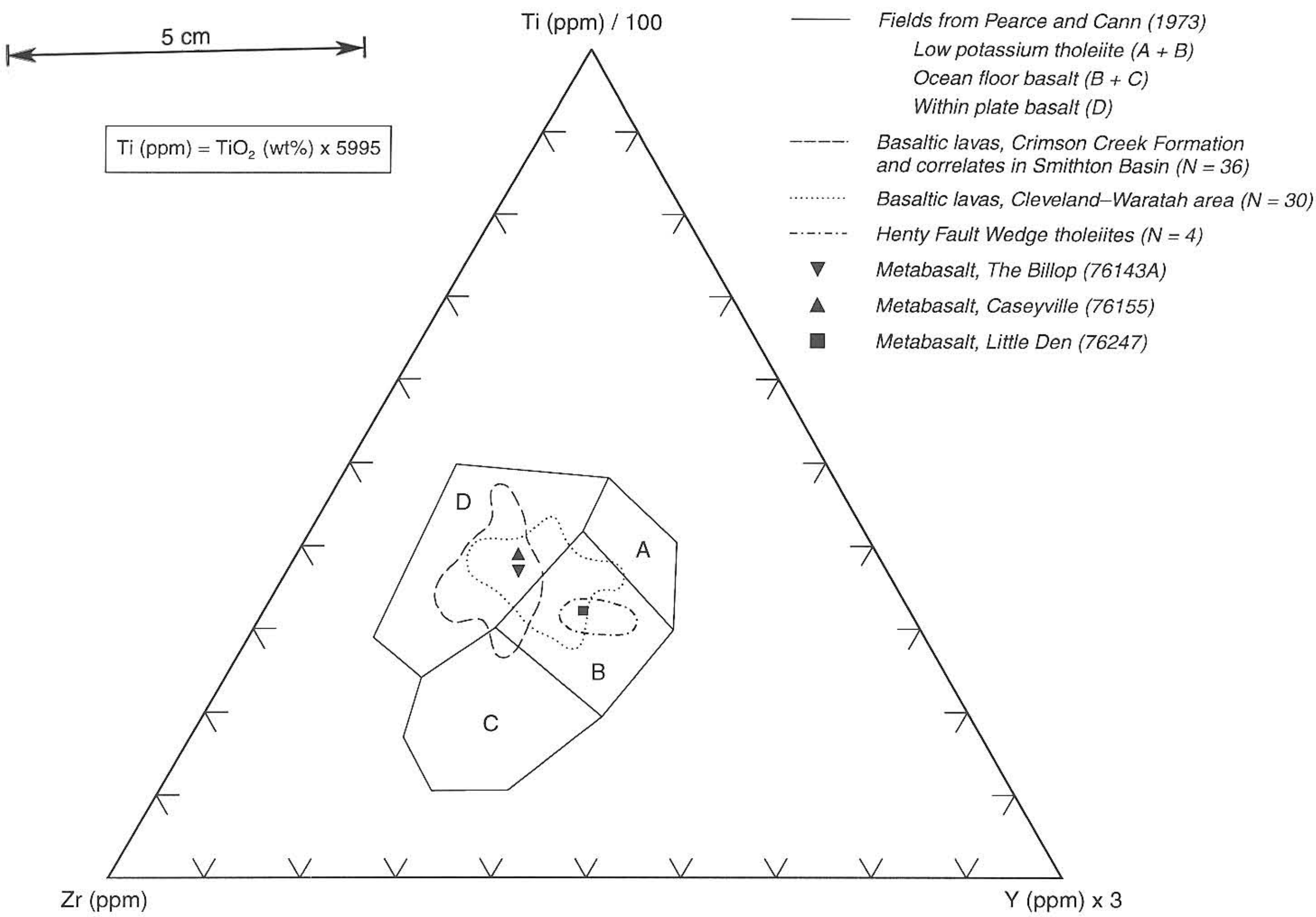


Figure 5. *Eocambrian(?) metabasalts from the Lake River Quadrangle, plotted on a Ti-Zr-Y diagram, with fields for basalts from various tectonic settings shown after Pearce and Cann (1973). Fields of Crimson Creek Formation and Smithton Basin basalts, Cleveland–Waratah association basalts, and Henty Fault Wedge tholeiites also shown (data from Brown, 1989, p. 64 and Crawford et al., 1992).*

TABLE 3

Rare-earth element analyses, Eocambrian(?) metabasalt, sample 76155, Caseyville

	A	B	C
La	8.18	0.315	26.0
Ce	21.7	0.813	26.7
Pr	3.22	0.116	26.8
Nd	16.6	0.597	27.8
Sm	4.78	0.192	24.9
Eu	1.25	0.0722	17.3
Gd	5.56	0.259	21.5
Dy	5.42	0.325	16.7
Er	2.91	0.213	13.7
Yb	2.23	0.208	10.7

A: Absolute values, sample 76155, parts per million (courtesy of A. J. Crawford)

B: Average chondrite normalisation values (Taylor and Gorton, 1977)

C: Chondrite normalised values, sample 76155

Of the three mafic suites identified by Crawford *et al.* (1992) in the dominantly felsic Mt Read Volcanics, which lie along the eastern margin of the Dundas Trough, two are eliminated as possible correlates of sample 76155 by the rare-earth data alone. The highly mineralised Que-Hellyer basalts and their correlates near Queenstown (Suite III of Crawford *et al.*, 1992) are much more LREE-enriched, whilst the Miners Ridge basalts (Suite V) are LREE depleted. Only the tholeiites occurring north of Queenstown, in a wedge between two branches of the Henty Fault, and possible feeder dykes within felsic volcanic rocks (Suite IV) emerge as potential correlates. An important feature of the Suite IV rocks is their low Nb (<3 ppm), suggesting a supra-subduction zone tectonic setting, such as a back-arc basin (Crawford *et al.*, 1992, pp. 610, 616). The higher Nb values in the Lake River Quadrangle samples 76143 and 76155 argue against correlation with the Henty Fault Wedge tholeiites, and are more consistent with a continental rift setting. TiO_2 and P_2O_5 values are also higher.

A triangular Ti-Zr-Y plot (fig. 5), of the form used by Pearce and Cann (1973) to discriminate between basalts erupted in various tectonic settings, shows that both the Little Billop (76143) and *Caseyville* (76155) metabasalts fall in the within-plate-basalt field. Correlation with either the Crimson Creek Formation tholeiites or the Cleveland–Waratah association basalts is possible on the basis of this data.

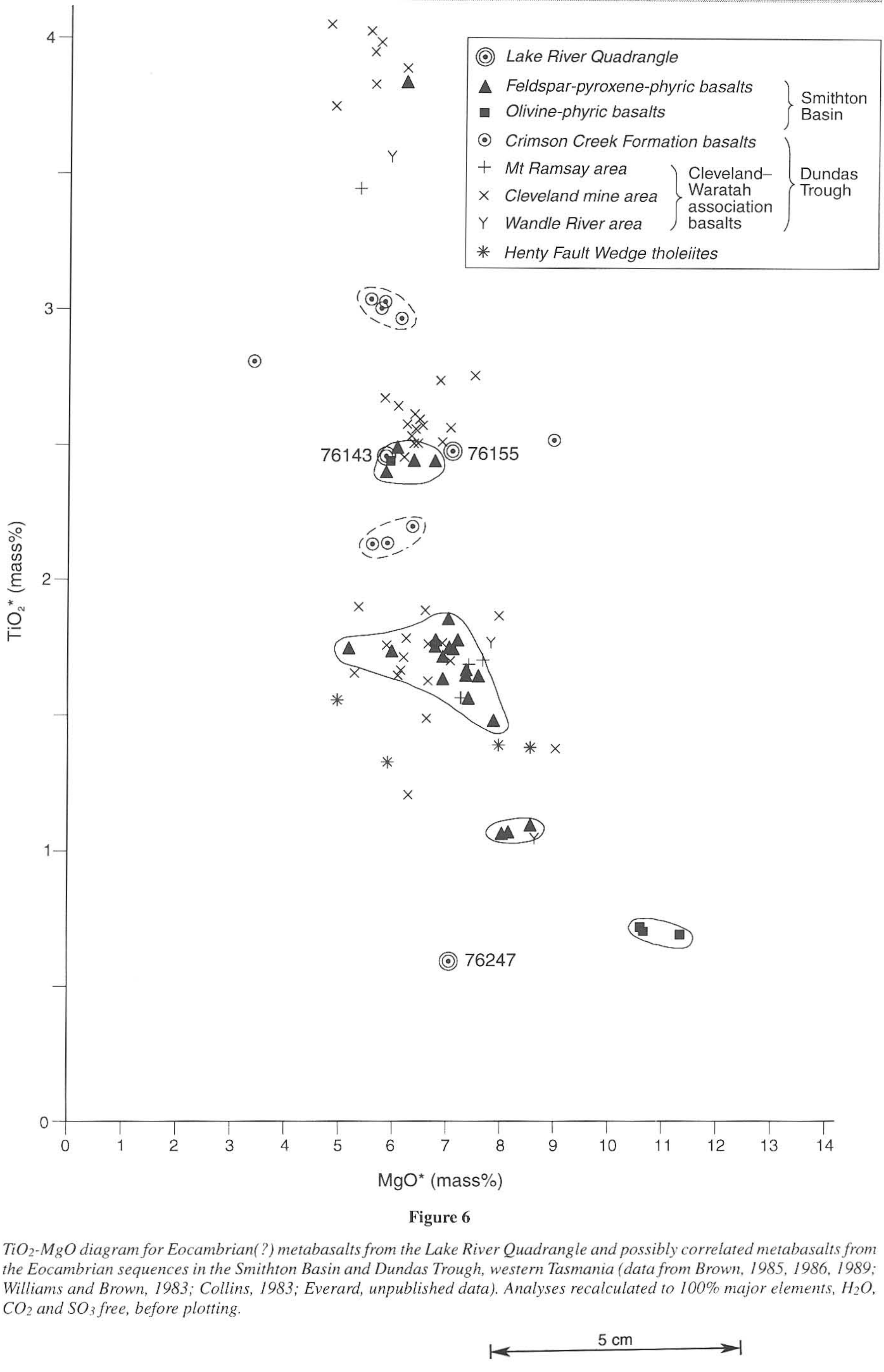


Figure 6

TiO_2-MgO diagram for Eocambrian(?) metabasalts from the Lake River Quadrangle and possibly correlated metabasalts from the Eocambrian sequences in the Smithton Basin and Dundas Trough, western Tasmania (data from Brown, 1985, 1986, 1989; Williams and Brown, 1983; Collins, 1983; Everard, unpublished data). Analyses recalculated to 100% major elements, H_2O, CO_2 and SO_3 free, before plotting.

The volcano-sedimentary Cleveland–Waratah association occurs in the Dundas Trough, and extends from east of the Huskisson Syncline and Meredith Granite, north to the Wandle River area (Williams and Brown, 1983). Brown (1989, p. 64) distinguished this association from the lithologically similar Crimson Creek Formation, lying generally west of the Huskisson syncline, principally on the basis of somewhat different trace element geochemistry (e.g. fig. 5) and unpublished Nd-Sm isotope data (with G. A. Jenner) from the intercalated basalts. It was suggested that the Cleveland–Waratah association basalts (notably the Deep Creek Volcanics, analysed by Collins, 1983) had ocean-floor-basalt affinities, in contrast to the continental, within-plate Crimson Creek Formation tholeiites. However on the basis of the published data it is difficult to clearly distinguish between the two basalt groups, which many authors had previously correlated (e.g. Groves and Solomon, 1964; Rubenach, 1973; Collins, 1983). Clearly a re-assessment of this question is needed; however it is outside the scope of this report.

A plot of TiO_2 against MgO (fig. 6) for these rocks shows that the Smithton Basin basalts, as noted by Brown (1989, p. 77), can be subdivided into a number of discrete groups, representing successive batches of magma. The available data suggest that at least four groups, with successively higher TiO_2 and lower MgO, are present. Correlates in the Crimson Creek Formation include at least a further two groups. Data from the Cleveland–Waratah association are more scattered, but there is also a suggestion of clustering into three or more groups, at least one of which may coincide with one of the groups from the Smithton Basin. Plots of TiO_2 against other elements, such as P_2O_5, Zr or FeO/MgO, also show this same clustering.

Two of the analyses from the Lake River Quadrangle (76143, Little Billop, and 76155, Caseyville) plot within or very close to a group defined by basalts from Copper Mine Point and near Montagu, in the Smithton Basin (Seymour and Baillie, 1992; Brown, 1985, 1989). Major elements (particularly if allowance is made for oxidation, hydration and carbonation of the samples) and available trace elements values are also similar (Table 2).

Attempts to find western Tasmanian equivalents to the relatively low TiO_2 Little Den sample (76247) are more difficult, particularly as no rare-earth data are available. The olivine-phyric basalts at the base of the Smithton Basin succession are eliminated on petrographic grounds, and their higher MgO, Ni, Cr, Nb and lower SiO_2 values (Brown, 1985, 1989). Correlates of the Smithton Basin basalts occur at Double Cove, south of Macquarie Harbour (Crawford and Berry, 1992), where highly depleted TiO_2 and Zr-poor basalts occur uppermost in the pile; however their high Ti/Zr (>160) is unlike sample 76247. Low-titanium basalts in the Dundas Trough at Black Hill and Heazlewood also generally have very low Zr and high Ti/Zr (Brown, 1986; Brown and Jenner, 1989), and differ in other respects. In contrast, the Henty Fault wedge tholeiites (Crawford *et al.*, 1992) have higher TiO_2 and Zr than 76247.

Conclusions

The identification of the basaltic rocks in the basement inliers of the Lake River Quadrangle as, at least partly, continental rift tholeiites, and their tentative correlation with the Eocambrian basalts of the Smithton Basin and Dundas Trough, has some tectonic implications. For example, if the radical allochthon model of Berry and Crawford (1988) for western Tasmania is accepted, the Lake River rocks are part of the continental basement which therefore extended at least this far east, and not part of the overthrust allochthonous fore-arc terrane which includes the low-Ti tholeiites, boninites and associated ultramafic complexes.

In terms of mineral exploration, it is significant that the Lake River inliers are not correlates of the Mt Read Volcanics. The most easterly exposures of Cambrian felsic volcanic rocks in Tasmania are quartz-feldspar porphyries south of Deloraine (Wells, 1957; Barton *et al.*, 1969; Pike 1973), although rocks correlated with the Mt Read Volcanics were intersected below a depth of 591 m in a drill hole at Glenorchy near Hobart (G. B. Everard, 1976).

The Mt Read Volcanic belt has been thought to continue east of the Tyennan region, beneath younger cover in the Midlands, but it does not crop out in the Lake River Quadrangle, and also does not occur in drill holes at Tunbridge Tier [245349] or southwest of Ross [363472], in which deformed carbonaceous quartz-mica rocks of probable Precambrian age were intersected at depth (E. Williams, quoted by Forsyth, 1989, pp. 14–15).

Possible additional work to aid the characterisation and correlation of these Proterozoic(?)–Cambrian(?) inliers could include further geochemical sampling, especially of the mafic rocks, rare-earth element and isotopic work, and electron microprobe studies, particularly of relict igneous phases such as pyroxene. Isotopic studies of the carbonates, and geochronology if suitable samples can be found, might also assist in correlation. More detailed study of the structural geology might also be warranted.

PERMIAN

At the time of mapping and compilation of the map sheet for publication, the Parmeener Supergroup, consisting of the rocks ranging in age from Upper Carboniferous to Triassic, had not been defined (Banks, 1973). The Lower Parmeener Supergroup in the Lake River Quadrangle comprises the rocks from the basal tillite to the top of the Bogan Gap Group, while the Upper Parmeener Supergroup consists of the top freshwater rocks in the Permian, and the Triassic sediments, also freshwater rocks. In these notes the rocks will be subdivided and described as on the map sheet, i.e. Permian and Triassic.

Exposures of Permian rocks are confined to the western one-third of the quadrangle, forming a wedge-shaped area with the broad base along the southern boundary and the narrow end in the northwest corner. All of the major rock units described in neighbouring quadrangles are represented, ranging from the basal tillite to the base of the freshwater Triassic sandstone which overlies the Permian rocks. The complete sequence is not represented in any one particular section. The most complete continuous section occurs on the northern face of Millers Bluff, where the section extends from basement rocks (Proterozoic–Cambrian) to the Blackwood Conglomerate near the top of the Bogan Gap Group. The total thickness of the Permian rocks in the quadrangle is of the order of 700–800 metres.

The Permian rocks consist of dominantly shallow water marine sediments deposited in cold water conditions. There is one relatively minor but very persistent interval of freshwater deposits near the middle of the sequence, and another at the top.

No borehole information is available to establish accurate thicknesses of the various units making up the Permian in the Lake River Quadrangle. Most large-scale measurements of thickness have been made using an aneroid barometer, and although the units have usually been measured more than once at different locations, the resulting thickness estimates cannot be regarded as highly accurate. Where there is no continuous outcrop, which is usually the situation, the occurrence of any small faults will also cause inaccuracies.

The Permian formations and groups have been defined and described by earlier workers in the general area surrounding the quadrangle; e.g. Wells (1957), McKellar (1957), Clarke (1968), Pike (1973), and Forsyth (1989).

STOCKERS TILLITE

The Stockers Tillite unconformably overlies the Proterozoic–Cambrian rocks in the area to the west and northwest of Millers Bluff. The tillite was deposited on a very irregular surface if present day basal positions are considered, with differences of up to about 200 m in the levels of the contacts between the tillite and the older rocks in the vicinity of O'Connors Peak. These base levels may have been modified by later unidentified faulting.

The Stockers Tillite probably attains a maximum thickness of about 150–180 m in the quadrangle, with the greatest continuous areas being to the west of *The Glen*, to the north of *Parknook*, and on the northwestern slopes of Millers Bluff. If there is no faulting between the isolated areas on O'Connors Peak, a total thickness of about 200 m is possible. This compares with 103 m+ at Poatina (McKellar, 1957) and 199 m at Tunbridge Tier (Forsyth, 1989).

In the Lake River Quadrangle the Stockers Tillite consists of tillite (tilloid?), sandstone, laminated mudstone or rhythmites, and minor limestone horizons. The tillite is poorly sorted, often with no obvious bedding at most locations. Pebbles or boulders making up the coarse fraction consist mainly of quartzite, although slate, granite (up to 0.5 m across) and conglomerate have been noted. Of particular interest is a concentration of ferruginous conglomerate boulders (which are probably Owen Conglomerate) on a low ridge to the north of *Parknook*.

Sandstone units of even, medium to coarse-grain size are exposed on a hill about one kilometre north of *Parknook* [063698], where the rock has been quarried on a small scale as a building stone. Similar sandstone occurs on undulating land east of O'Connors Peak, and is fairly extensively exposed in this area.

Thinly-banded rhythmites have only been noted in a few places because of their generally low resistance to weathering. The rhythmite tends only to be seen in man-made excavations, for example about 500 m north of *Parknook* homestead, although it is also exposed at two locations at Little Den. The rhythmites consist of dark grey silty-clay beds interbedded with lighter coloured material. The bands are only up to a few millimetres thick, and often are only 2–3 mm or less.

Dense blue-grey coloured limestone has been noted at a few locations within the Stokers Tillite. Areas include just north of *Parknook* and on the lower slopes to the northwest and northeast of the summit of Millers Bluff.

No macrofossils have been found in the Stockers Tillite but mixtite samples from the upper part of the sequence at 060695 have yielded poorly diversified Stage 2 microfloras (Truswell, 1978). On this basis this part of the sequence is of Late Carboniferous age (Balme, 1980).

QUAMBY MUDSTONE

The Quamby Mudstone consists dominantly of a dark grey, poorly-bedded mudstone to siltstone containing a few erratics. Limestone has been noted interbedded with the mudstone.

The formation is probably up to about 140 m thick in the Lake River Quadrangle, with exposures of this order occurring on the northern side of Millers Bluff and to the west of *The Glen*. At other locations in the quadrangle the Quamby Mudstone is either intruded by dolerite (e.g. Big Den) or faulting prevents the whole formation being exposed (e.g. along the eastern side of Millers Bluff). The thickness in the Lake River Quadrangle compares with thicknesses of 100 m at Great Lake (McKellar, 1957), 172 m at Quamby (Pike, 1973), and probably 232 m at Tunbridge Tier (Forsyth, 1984).

The mudstone is fairly uniform in appearance. It is a dark grey-blue rock with very occasional erratics which characteristically weather into small angular fragments up to about 5–10 mm diameter. The mudstone rarely crops out, and can usually only be seen in excavations and creek sections. However weathered fragments on the surface are often a good guide to its presence at depth. The mudstone tends not

Table 4
Analyses of limestone samples

Analysis	1	2	3	4	5
SiO_2	27.20	19.30	23.35	1.64	20.02
TiO_2	0.28	0.13	0.20	0.02	0.15
Al_2O_3	5.73	2.56	4.42	0.15	2.45
Fe_2O_3	0.73	0.31	0.18	0.00	0.64
FeO	1.88	1.14	1.47	0.23	0.40
MnO	1.10	0.36	0.98	0.03	0.04
MgO	1.06	1.66	0.74	20.56	0.44
CaO	31.98	39.26	36.40	30.49	43.05
Na_2O	0.67	0.29	0.97	0.00	0.00
K_2O	0.79	0.24	0.46	0.01	0.86
P_2O_5	0.94	0.44	0.65	0.21	0.30
H_2O					
CO_2					
SO_3	0.43	0.64	0.77	0.13	1.41
LOI	26.75	33.00	29.61	46.39	30.95
TOTAL	99.54	99.33	100.20	99.83	100.75

1. Limestone in Quamby Mudstone, north end of Millers Bluff [115617]
2. Limestone in Golden Valley Group, north end of Millers Bluff [125625]
3. Limestone in Quamby Mudstone, east side of Millers Bluff [168583]
4. Dolomite from northwest corner of sheet [998769]
5. Proterozoic–Cambrian limestone, southwest of *The Glen* homestead [015654]

to support the growth of a thick understory and in bushland, apart from *Eucalyptus* and *Acacia* species, often has grassland rather than small bushes. Oolitic mudstone occurs in a small quarry at 079596.

The Quamby Mudstone in its lower parts is only rarely, if ever, fossiliferous, is pyritic and contains glendonites. Of particular note are the moulds of glendonite rosettes at Big Den and west of *The Glen*.

The limestone beds which have been noted within the formation are lenticular in nature and cannot be traced for long distances. The most prominent development of limestone noted was on the western slopes of Mitford Hills [around 115616], where it may be up to 15–20 m thick. The limestone has also been noted on the eastern slopes of Millers Bluff, where at one location it has been quarried for use in the production of mortar. Analyses of limestone samples from Millers Bluff are given in Table 4.

The limestone is dark blue-grey in colour, is massive in nature, and contains abundant fossils at some locations. Fossils found at 115618 include well preserved *Schizodus australis* (Runnegar), *Trigonotreta stokesi* Koenig, and the important species *Grumantia costellata* Clarke and *Phestia darwini* (de Koninck). All four species are confined to the Tamarian Stage, and the latter two species are diagnostic of the Early Tamarian (Faunizone 1) Stage (Clarke and Farmer, 1976; Clarke, 1990).

On the northern side of Millers Bluff, Quamby-like mudstone contains abundant fossils, mainly bryozoans, for a thickness of at least 12 m below a prominent pebbly limestone horizon which extends around the slope. The boundary of the Quamby Mudstone and the overlying Golden Valley Group has been mapped as the base of the pebbly limestone bed. The bryozoan-rich bed and the lower limestone beds may have been mapped as Golden Valley Group in neighbouring quadrangles but at the time of mapping this area McKellar's boundaries (where he defined the *Eurydesma*-rich limestone as the base of the Golden Valley Group) were used.

GOLDEN VALLEY GROUP

The Golden Valley Group consists of mudstone, siltstone, pebbly sandstone and pebbly limestone and, as with the Quamby Mudstone (which it conformably overlies), occurs around the flanks of Millers Bluff and Parson and Clerk Mountain.

The basal limestone varies in thickness at Millers Bluff from about 1.5–3 metres, and contains abundant fossils including *Eurydesma* and abundant pebbles often up to about 50 mm diameter. The limestone crops out prominently at some locations, while at others it does not and may lens laterally into a different lithology. An analysis of a limestone sample from Millers Bluff is given in Table 4.

On the lower slopes of Millers Bluff at 128625, impure limestone and calcareous siltstone are richly fossiliferous. The fauna includes abundant *Eurydesma* spp. (including *E. cordatum* Morris and *E. hobartensis hobartensis* (Johnston)), coarsely-ribbed *Deltopecten illawarensis* (Morris), *Etheripecten tenuicollis* (Dana), *Keeneia platyschismoides* (Morris), *Stenopora tasmaniensis* Lonsdale, and the brachiopods *Trigonotreta stokesi* Koenig, *Tomiopsis konincki* (Etheridge) and *Strophalosia subcircularis* Clarke, the latter in growth position and in great abundance. This fauna is indicative of a Middle Tamarian (Faunizone 2) age.

Overlying the limestone is a richly fossiliferous siltstone and dirty pebbly, richly-fossiliferous sandstone (Billop Sandstone). This characteristic sandstone has been mapped at various locations from Barra Barra [198525], near the southern margin of the quadrangle, to the eastern side of Mitford Hills, and has been noted in isolated areas downslope from Parson and Clerk Mountain.

At 176560, coarse-grained arkosic sandstone and conglomerate yield a surprisingly varied and well-preserved fauna. Forms recorded include *Deltopecten illawarensis, Eurydesma, Etheripecten tenuicollis, Keeneia platyschismoides, Myonia morrisi* (Etheridge), *Myonia elongata* Dana, *Gilledia, Fletcherithyris, Strophalosia subcircularis, Trigonotreta stokesi, Sulciplica crassa* Clarke, *Tomiopsis konincki* and *Tomiopsis* cf. *branxtonensis* (Etheridge). The occurrence of *Sulciplica crassa* and *Tomiopsis* cf. *branxtonensis* indicates a Late Tamarian (Faunizone 3) age. This is also the type locality of the unusual crinoid *Neocamptocrinus millerensis* Willink, 1980.

Above the sandstone horizon are beds of a dark grey-blue siltstone/mudstone very similar in nature and appearance to the Quamby Mudstone except that it has a few bryozoan fossils.

The Golden Valley Group in the Lake River Quadrangle has a thickness of about 60 m, which compares with reported thicknesses of 52 m at Great Lake (McKellar, 1957), 83 m at Quamby (Pike, 1973), and about 80 m at Tunbridge Tier (Forsyth, 1984).

LIFFEY GROUP

The Liffey Group is a freshwater-deposited group of strata consisting of micaceous sandstone, carbonaceous mudstone and massive quartz sandstone beds. Minor micaceous coaly or richly-carbonaceous beds occur.

Only the topmost beds of the group usually crop out, as they consist of massive sandstone or quartz sandstone beds which are particularly resistant to erosion and form benches around the slopes. These beds produce a consistent marker horizon for mapping. Sometimes the sandstone occurs as cliffs up to about 5 m high, while at other locations it is only represented by a line of boulders around the contour.

The lower parts of the group are not well exposed except in excavations or in streams. Thinly-bedded micaceous sandstone and carbonaceous shale are occasionally seen. An apparently almost complete section of the Liffey Group has been recently exposed in a road cutting at about 056612, where a section some 36 m thick occurs. A brief description, with very approximate thicknesses, is as follows:

Thickness (m)	*Lithology*
Top	
3	Massive quartz sandstone (mainly boulders) showing some worm casts.
6	No outcrop, clayey soil
5	Brown siltstone and fine-grained sandstone
7	Sandy micaceous shale
2	Thinly bedded quartz sandstone
2	Carbonaceous shale
4	Thinly bedded quartz sandstone
0.5	Micaceous coaly bed
6	Thinly bedded carbonaceous and micaceous sandstone interbedded with clean sandstone
0.3	Very hard quartz sandstone (single bed)
Base	
1.5	Purplish coloured siltstone
0.4	Pebbly dirty sandstone bed

The thickness of about 36 m compares with 27 m at Great Lake (McKellar, 1957), 33–35 m at Quamby (Pike, 1973), and about 38 m for the correlate at Tunbridge Tier (Forsyth, 1984).

At Golden Valley the Liffey Sandstone yields a Substage 3b microflora (Truswell, 1978) and is Early Bernacchian in age.

POATINA GROUP

The Poatina Group occurs extensively on the higher levels of the slopes to the top of the Great Western Tiers and also in downfaulted parts of the lowlands east of Millers Bluff. The Group has a generally poor outcrop in the higher country, and contacts with other units of the Permian sequence are not commonly observed. In the lowlands the Group often occurs on relatively flat country, so the sequence cannot be observed in detail.

In general the Poatina Group unit consists of mudstone, sandy siltstone, sandstone and pebbly sandstone. It is variably fossiliferous. The subdivisions, as defined by Pike (1973), have not been definitely recognised at all points. A mudstone, which probably represents the Weston Mudstone, has been noted near the western margin of the quadrangle, while the probable Dabool Sandstone equivalent has been noted over much of the quadrangle.

The lower part of the Group consists of pebbly mudstone and sandstone. Tough, highly resistant clayey sandstone occurs on very distinct benches around the slopes. There have been two or three such horizons noted in some locations. The probable Dabool Sandstone equivalent is a pebbly, richly fossiliferous sandstone which again is a little resistant to weathering and occurs on benches but not often as prominent as the lower hard sandstone. The Weston Mudstone, where it has been recognised, is a richly-fossiliferous mudstone, the main fossils being bryozoans.

The Garcia Sandstone has not been regularly recognised as such throughout much of the quadrangle, although it may be present in a slightly different form to that described by Bravo and Pike (1969) over at least some of the quadrangle. As it has been defined as marking the boundary between the Poatina and Bogan Gap Groups, it is a relatively important unit. However, the two groups were generally differentiated on lithology (little or no sandstone at the base of the Bogan Gap Group) and the abundance of fossils (the very base of the Bogan Gap Group does not appear to be fossiliferous).

The thickness of the Poatina Group is about 80–90 m in the Lake River Quadrangle; in other quadrangles it is 90 m thick in Quamby and Great Lake, and up to 105.5 m in Interlaken.

The correlate of the Dabool Sandstone is richly fossiliferous at all localities. Characteristic species diagnostic of a Middle Lymingtonian (Faunizone 8) age include *Deltopecten multicostatus* (Fletcher), *Astartila intrepida* (Dana), *Tomiopsis brevis* (M'Clung and Armstrong), *Tomiopsis undulosa* (Campbell), *Sulciplica transversa* Waterhouse, *Trigonotreta wairakiensis* (Waterhouse), *Wyndhamia dalwoodensis* Bookes and large *Gilledia cymbaeformis* (Morris).

BOGAN GAP GROUP

The Bogan Gap Group, as with the Poatina Group which it conformably overlies, occurs high on the slopes of the Great Western Tiers as well as in down-faulted sections east of Millers Bluff.

The Bogan Gap Group consists mainly of blue-grey and grey mudstone, siltstone and sandy siltstone beds with relatively sparse pebbles or dropstones. It is more thickly bedded than most other parts of the Permian sequence. Two coarser-grained beds are prominent around the slopes and form benches, the upper one being the more prominent.

The equivalent of the Palmer Sandstone produces a small but persistent bench around slopes where the group frequently occurs. This unit is a dirty, fairly even-grained sandstone, sometimes with grit-size fragments and occasional pebbles. Where there is no outcrop the unit can usually be traced by the presence of boulders on a subdued bench. Boulders downslope also clearly indicate the presence of the unit, as they tend to extend over wide areas.

No obvious sandstone beds occur within the Group before the Palmer Sandstone is reached, although there are silt-rich beds. This lithology differentiates the Palmer Sandstone from the underlying Poatina Group.

The Blackwood Conglomerate forms a very distinct bench even though it does not crop out as commonly. Because it mainly occurs high on the slopes the conglomerate is often covered by dolerite talus. Boulders sometimes occur below the bench, while in other locations the conglomerate crops out in stream valleys and on ridges. The rock is hard and quartz-particle rich, and varies in grain size from medium sand, to coarse sand with quartz pebbles, to a conglomerate. On the northern end of Millers Bluff the conglomerate appears to attain a greater thickness (up to about 4.0 m) than in adjoining quadrangles (2.4 m at Tunbridge Tier and one metre at Poatina). Exposures up to 3.0 m thick have been noted in other parts of the quadrangle but the complete thickness may not be represented.

The thickness of mudstone and siltstone between the Blackwood Conglomerate and Palmer Sandstone is consistently about 125 m, as measured by aneroid barometer. This compares with about 100 m in the Quamby Quadrangle where measured, and about 133 m in the Interlaken Quadrangle. The section between the Blackwood Conglomerate and Triassic has only been seen at one location, where somewhat less than 10 m of greenish mudstone overlies the Blackwood Conglomerate before carbonaceous shale and sandstone occur.

Limestone horizons have been shown on the map within the Bogan Gap Group. It is now not certain whether such beds occur, as a thin section of a 'limestone' sample from near the western margin of the quadrangle, examined after the map was produced, showed the rock to be fine-grained dolerite. In outcrop the rock is dark blue and weathers with a dimpled pattern on the surface, similar to limestone. Only one other 'limestone' location has been marked on the map, but this has not been revisited.

The Bogan Gap Group is largely unfossiliferous, although sparse fossil zones have been noted near the road to Big Den on the northern end of Millers Bluff, and near the southern margin of the quadrangle. At 072579, an important fauna close to the Palmer Sandstone includes *Astartila intrepida, Merismopteria macroptera* (Morris), *Vacunella curvata* (Morris), abundant worm and molluscan burrows, and the trace fossil *Phycosiphon, Megadesmus grandis* (Dana), and the very large and alate spiriferids *Sulciplica transversa* and *Fusispirifer avicula* (Morris). These fossils demonstrate a Late Lymingtonian (Faunizone 10) age, and represent the northwestern-most extent of a brief, more open marine incursion into the essentially brackish estuarine embayment which occupied most of Tasmania during Late Lymingtonian times. Associated palynomorphs include *Didecitriletes ericianus*, which indicates an age no older than Stage 5b of the eastern Australian palynological zonal scheme.

The thickness of the Group in the Lake River Quadrangle is about 190 m, which compares with 200 m at Great Lake, about 180 m at Quamby, and about 248 m at Tunbridge Tier in the Interlaken Quadrangle.

JACKEY FORMATION

This formation has only been noted occasionally in the Lake River Quadrangle, and only incomplete sections and exposures are present. Dolerite either intrudes below the level of the formation, or dolerite talus covers it high on the slopes.

A smaller thickness is probably present in this quadrangle than in neighbouring quadrangles, although a section with overlying Triassic sandstone has only been found at one location north of Threshermans Hill [055580].

Near the western margin of the quadrangle, a small section mapped as Jackey Formation consists of sandstone and shale beds. These are usually micaceous and sometimes carbonaceous. Khaki-coloured shale makes up part of the sequence.

A little further to the east, feldspathic sandstone and massively and thinly bedded shale underlies dolerite.

North of Threshermans Hill feldspathic sandstone (medium, even grained), carbonaceous and micaceous shale, and sandy shale are exposed in a track cutting. A lenticular bed of pebble conglomerate up to about 0.3 m thick is interbedded with these sediments. The difference in level between the Blackwood Conglomerate and the base of the massive quartz sandstone is about 24 metres. Some nine metres of greenish siltstone (outcrop and fragments in soil) overlying the Blackwood Conglomerate has been included in the Bogan Gap Group, making a maximum thickness of about 15 m for the Jackey Formation in this area. However as a fault passes through the area, as shown by the steep dips, no definite figure can be given for the thickness. The formation is about 43 m thick in the Great Lake–Quamby area.

TRIASSIC

Triassic sediments occur mainly in a northwest-trending broad band through the central part of the quadrangle, where the rocks generally occur as isolated small areas interspersed with areas of dolerite. These areas all occur on the eastern side of the Tiers Fault.

Small areas of Triassic rocks have also been mapped high up on the Great Western Tiers. These occurrences are fairly rare when compared to other areas around the Great Western Tiers to the north, as in this area the dolerite intrudes the Permian rocks or is at least low in the Triassic sequence, and the Triassic is usually covered by dolerite talus near the contact.

Only small sections of Triassic sediments have thus been seen in outcrop. The section on the Great Western Tiers is limited, and the areas on the flatter land often consist only of the most resistant rocks (sandstone).

The largest section on the Tiers occurs to the north of Threshermans Hill, where massive beds of quartz sandstone crop out. Here there is an almost continuous section with the Upper Permian. A small area of Triassic rocks also occurs just to the north. The only other occurrence of probable Triassic rocks mapped at high altitude is on the east-facing slope to the southeast of Millers Bluff [158542].

The isolated areas of Triassic rocks in the central band are almost always of sandstone, except for the areas immediately south of Hummocky Hills. The sandstone, being more resistant to weathering, forms small positive topographic features. Mudstone areas may be present locally, and if no drill hole information was available some of these could have been mapped as Tertiary or Quaternary in small areas. At some locations the sandstone has been indurated by dolerite to form a hard flinty rock which was used as tool-making material by Aboriginals.

The area to the south of Hummocky Hills contains considerable amounts of shale in the sequence with sandstone beds. Again the shale shows induration. At *Stone Quarry*, just to the east [130733], drill holes have encountered carbonaceous shale horizons. These areas are likely to represent the upper part of the Triassic sequence, although this is by no means definite because of the lack of a significant sequence above or below the shale.

TERTIARY

The Lake River Quadrangle covers most of the southern part of the Launceston Tertiary Basin, although the basin is still open to the southeast and extends into the neighbouring quadrangles of Interlaken to the south and Snow Hill to the east. The southern part of the basin comprises two sub-basins separated by a discontinuous ridge composed dominantly of dolerite but partly of Triassic sediments. Both of these sub-basins occur within the quadrangle.

The bulk of the Tertiary sedimentation comprises deposits of clay, sandy clay and sand beds with some gravel horizons. These sediments were laid down under lacustrine and fluvial conditions, and reach known thicknesses of up to 195 m within the quadrangle. To the north they are known to be up to 790 m thick in the deeper parts of the basin.

Other Tertiary deposits within the quadrangle include ferricrete, younger gravel, and silica stone.

Detailed descriptions of the Tertiary sediments within the Launceston Tertiary Basin can be found in Matthews (1983); a much briefer coverage will be given here.

TERTIARY SEDIMENTS

The main sequence of Tertiary sediments consists of clay, sandy clay, sand and gravel beds. These sediments are partly lacustrine and partly fluvial. Although carbonaceous clay occurs, there does not appear to be much in the way of lignite in this part of the Tertiary Basin (except around Belmont in the Longford Quadrangle), a feature of the northern parts to the basin. This may be another sign that perhaps there has been more fluviatile influence in this part of the basin than in the northern part. Palynological examination of sediments in one hole in each sub-basin indicates a middle to late Eocene age for the later period of sedimentation.

The Tertiary sediments are poorly exposed, and the only significant information on the stratigraphy is from borehole intersections in various parts of the basin. These holes include groundwater investigation holes, contract waterbores, shallow auger drilling, and mineral prospecting holes.

Coarse-grained sediments

Gravel beds occur in the Epping Forest to Conara area of the eastern sub-basin, where they are usually less than 40 m below the surface. These beds underlie basalt and are probably related to the ancestral South Esk River, as they occur near where the South Esk enters the basin from the Avoca region. The river has probably occupied its present course east of the basin since at least before the basalt volcanism, as basalt extends up the floor of the valley towards Avoca.

There are at least two such gravel beds in some boreholes. One bed may persist over large areas, or the beds may lens out with others taking their place at different locations. The gravel beds underlie middle to upper Eocene clay in one borehole, and are therefore at least of similar age to the clay, and may also be of similar age but slightly older than the basalt.

The gravel beds consist of clear and milky quartz with occasional agate and quartzite fragments. The clear fragments, and probably the remainder, are largely derived from the granite areas upstream in the South Esk catchment areas. This is supported by the identification of small amounts of zircon, topaz and tourmaline. Ilmenite, rutile and garnet fragments have also been recognised. It is possible that some or all of these accessory minerals are recycled from the weathering of Triassic rocks but the association with granite-like quartz would be coincidental, as beds with this kind of quartz are unknown within the Triassic sequence in the general region.

Conglomerate

Zones of conglomerate are interbedded with other sediments in the western sub-basin. Two holes had thin layers of very hard siliceous conglomerate resembling greybilly. In other areas of the western sub-basin, where it is quite narrow between two dolerite ridges, conglomerate containing rounded dolerite, quartz and basalt has been drilled. Carbonate minerals are often associated with the conglomerate beds. The conglomerate is obviously derived from the erosion of nearby rocks, and may attain thicknesses of several metres.

Sand beds

The fine sand beds are probably derived from the weathering of the Triassic sandstone which surrounds the basin. The thick sand beds (up to 15 m) which occur in the main part of the Tertiary basin north of the quadrangle are not common in boreholes in the Lake River Quadrangle. Fine even-grained sand was struck in boreholes in the Belmont area at Longford, where the basin is still a few kilometres wide. One bore in this area had a slightly coarser sand bed with an average grain size of about 0.9 mm, but in general the sand has an average grain size in the 0.2–0.3 mm range.

Fine-grained sediments

Clay and sandy-clay deposits make up the bulk of the sediments comprising the Tertiary sequence. These deposits probably represent lacustrine deposition in much of the sequence. The fine-grained sediments, although visually appearing to be dominantly clay, contain appreciable quantities of sand and silt-size fragments.

The clay mineralogy of a sample from a borehole at Cleveland indicated that the main mineral present is kaolinite, as in most other parts of the basin, although small amounts of montmorillonite occur. Quartz makes up a significant proportion of these sediments.

The clay-rich sediments are mainly derived from the weathering of dolerite, Triassic shale beds and Permian rocks in the surrounding areas of the basin. Some of the sediment has probably come downstream from the granite areas of the northeast in the same way that some of the material deposited in gravel beds was also derived from that area.

SILICA STONE

Hard siliceous sandstone and conglomerate occur at a few locations in the quadrangle. The main occurrence is in the Forest Vale–Connorville area in the northwest corner of the quadrangle, with small areas occurring to the northwest of Campbell Town and another area near the South Esk River to the northeast of Conara.

Table 5
Analyses of laterite samples

Analysis No.	1	2	3	4	5	6	7
SiO_2	43.37	28.06	27.56	33.00	26.16	23.79	39.03
TiO_2	1.27	1.36	0.55	0.64	0.70	2.36	1.04
Al_2O_3	5.30	8.50	3.77	5.59	4.78	8.52	5.45
Fe_2O_3	42.56	56.38	60.66	50.61	55.08	53.08	49.80
FeO	0.60	2.95	0.94	0.33	0.51	0.74	1.41
MnO	0.04	0.05	0.04	0.03	0.04	0.03	0.03
MgO	0.29	0.31	0.23	0.16	0.23	0.18	0.19
CaO	0.06	0.05	0.13	0.02	0.05	0.03	0.03
Na_2O	0.28	0.35	0.05	0.31	0.10	0.00	0.00
K_2O	0.06	0.09	0.08	0.07	0.08	0.03	0.09
P_2O_5	0.02	0.05	0.01	0.06	0.12	0.06	0.08
H_2O^+	6.01	1.64	4.20	7.82	0.32	9.04	1.19
CO_2	1.26	1.72	0.70	0.90	3.14	1.02	1.12
SO_3	0.05	0.03	0.07	0.05	0.06	0.04	0.05
LOI	7.20	3.03	4.80	8.68	2.52	9.98	2.15
TOTAL	101.17	101.54	99.08	99.59	99.37	98.92	99.51

1. East of homestead, Connorville [123688]
2. South of Epping Forest [299756]
3. North of Conara (near Nile Road) [352709]
4. Northwest of Epping Forest (sheet edge) [235800]
5. Northwest of Epping Forest (lag gravel) [235800]
6. South of Macquarie River [259625]
7. North of Conara (surface lag) [357694]

The areas of silica stone in the eastern part of the quadrangle occur close to basalt. It is thought, by some authors, that there is a close association between basalt and silica stone, with the siliceous-bearing solutions which occur with volcanism producing the cementing material for the sand and gravel.

No basalt occurs close to areas of silica stone in the western part of the quadrangle, although it is possible that basalt may have been present at one time and has since been eroded. In these areas the silica stone overlies quartz gravel, and the cementation and degree of compactness of the rock is progressive upwards. It is possible that solutions may have passed up a nearby major fault and caused cementation of the gravel in this area.

Thin sections of samples from the northwestern part of the quadrangle, examined by G. B. Everard, showed that the silica stone consisted of angular grains of quartz without any special matrix. Magnetite crystals and occasional rutile grains were identified.

A sample from northwest of Campbell Town consisted of angular to subrounded quartz grains in a matrix of finer quartz with a gradation between the grain and matrix. Magnetite grains (altered to limonite) are present.

UPPER QUARTZ GRAVEL

Poorly consolidated and unconsolidated siliceous gravel occurs over widespread areas across the northern part of the quadrangle between Conara and Forest Vale. The gravel consists of rounded fragments of quartzite and quartz in a matrix of sand, silt and sandy clay, and probably represents flood-plain or braided stream deposits. The gravel may have been deposited as a result of a northward diversion of the South Esk River by basalt flows. This diversion caused a slowing of erosion rates, and the movement of stream beds across broad flood plains.

The gravel appears to be older than the ferricrete or lateritic deposits. Drill holes north of Epping Forest have shown that the quartz gravel occurs under the ferruginous lag gravel deposits, but does not attain great thicknesses and in most areas only reaches a maximum of 2–3 m thick, and may be much thinner over most of its extent. The gravel at some locations develops circular areas of iron oxide staining.

FERRICRETE

Ferricrete of probable Tertiary age has developed on most materials, including Tertiary sediments, basalt and dolerite, within the flatter part of the basin. The most notable areas are the exposures around Campbell Town, where the ferricrete or laterite on basalt has become enriched in aluminium oxide and has been identified as bauxite. Analyses of some samples from the Lake River Quadrangle are given in Table 5.

Although the resource of aluminium-rich material is now small, it probably once extended over much wider areas but has been subsequently eroded, resulting in exposure of the underlying basalt. Some dolerite marginal to the lateritised basalt in the Campbell Town area also shows signs of being lateritised.

Other areas of ferricrete occur on the slopes to the Macquarie River valley south of *Kenilworth*, close to the contact between Tertiary sediments and dolerite, and on the *Connorville* property, some 4–5 km southeast of the homestead.

The ferricrete's resistance to erosion has also resulted in the preservation of Tertiary sediments at elevations of up to about 200 m above sea level within the basin. Where erosion has

Plate 20

Bench formed by a thick surface layer of ferricrete on the eastern side of Connorville property.

cut through the ferricrete, deposits 1–2 m thick of cemented pisolitic iron oxide are exposed. Bright red soils have developed on the lateritised areas around Campbell Town, while in other areas the soils are gravelly, iron-oxide rich, and are dull brown in colour.

QUATERNARY

Quaternary sediments are represented by alluvium around existing streams, deposits on older terraces, windblown sand, talus, and pisolitic ironstone lag deposits.

The flood-plain deposits consist dominantly of gravel, clay and sandy clay. The gravel has been differentiated according to boulder composition in some areas, e.g. rounded-dolerite boulder beds in the northeast corner of the quadrangle.

Rounded-dolerite boulder deposits occur over extensive areas to the north of the quadrangle. The material in these beds is obviously derived from the weathering of nearby dolerite bodies, and has been transported by streams in Recent times. The boulder deposits tend to be more extensive than the present-day size of the streams would suggest, and they may be related to the probable greater runoff which resulted from ice melt during the Pleistocene. Similar rounded-dolerite boulders also occur around Scrubby Den Rivulet on the southern margin of the quadrangle, and around the Lake River in Little Den and a little further downstream at Boomers Bottom.

Quartz gravel has been differentiated from alluvium in a few areas. These deposits have probably been derived from the reworking of Tertiary quartz gravel and from the weathering-out of erratics in the Permian rocks. Neither the quartz gravel nor the dolerite gravel attain significant thicknesses, and in most cases will only be a metre or so thick.

The alluvium around the streams is largely fine-grained material, a direct result of the general low energy of the streams which traverse the area, particularly once they reach the lowlands. The areas through which these streams flow are largely underlain by fine-grained sediments such as clay, sandy clay and sand in the Tertiary, and sandstone and siltstone which comprise the Triassic and Permian rocks. The other main rock types (basalt and dolerite) weather to a clay, which again provides a source for fine-grained deposits.

SWAMP AND LAGOON DEPOSITS

Swamp and lagoon deposits occur at various localities throughout the quadrangle. Some are present on the plateau top and are composed largely of clay, although windblown sand and/or remnants of Triassic rocks can provide a source for sand. The other main areas are in the lagoons around Cleveland. In this area the swamp and lagoon deposits have been deposited on Tertiary sediments and are derived from materials found locally. The lagoons near Cleveland tend to be elongated in a SW–NE direction, and may have formed as a result of blowouts, the direction of elongation indicating the prevailing wind direction.

WINDBLOWN AND LOCALLY-DERIVED SAND

This material occurs over widespread areas in the northeastern part of the quadrangle, with only small occurrences found outside this area. Dune-like features are rounded and obviously mature, and are stabilised at most locations. The sand is likely to be mainly derived from the weathering of Triassic sandstone but exposed sand beds within the Tertiary sequence would also be a possible source. The windblown sand deposits are not likely to be thicker than one to five metres.

Sand deposits in the Cleveland area occur in valleys where streams have cut through the laterite and pisolitic ironstone gravel deposits. These deposits are likely to be remobilised sand from the Tertiary sediments and are unlikely to be greater than a metre or so thick.

BASALT TALUS

Small areas of talus have been mapped in the northeastern section of the quadrangle, where *in situ* basalt has also been mapped. It is possible that *in situ* basalt underlies these talus areas but only boulders are indicated on the surface.

PERMIAN TALUS

Permian talus has been mapped in localised areas. One such area to the north of Millers Bluff is within an area of Stockers Tillite but the talus consists of hard siltstone and sandstone boulders of probable Poatina Group origin. An area to the northwest of this is on the line of a major fault between Stockers Tillite and Triassic rocks, with dolerite within the fault plane. The boulders making up the talus are not tillite-type material and are not otherwise recognisable. They may be boulders in the crush zone around the fault, and may represent non-fossiliferous parts of the Permian sequence above the tillite. The other major area of Permian talus occurs northwest of *Connorville*, and again is on the alignment of a major fault. The boulders are unrecognisable as far as position in the Permian sequence is concerned.

DOLERITE TALUS AND SCREE

Dolerite talus and scree are present in wide areas around the plateau edge of the Great Western Tiers, and if similar to the material around Poatina could attain considerable thicknesses [McKellar (1957) reported depths of more than 150 m from drill hole information]. Near the contact with the *in situ* dolerite capping the Tiers, the deposits consist largely of piles of loose rock with little soil and vegetation. Both vegetation and soil content increase lower down the slopes.

Where Permian rocks crop out on east-facing slopes of the Tiers, mixtures of dolerite and Permian boulders are found in gullies extending down the slope. These valleys probably formed during the Pleistocene, when ice-melt provided larger amounts of surface water than at present. The distribution of the talus may have been partly due to landslide action as well as stream flow. The valleys have cut through a lower zone of dolerite which forms a discontinuous ridge to the east of the Tiers.

OLDER TERRACE DEPOSITS

Terrace deposits, composed dominantly of Permian boulders, occur around the Isis River at the foot of the Great Western Tiers. The material is almost certainly sourced from the valleys extending up the side of Millers Bluff but the dolerite, which may have been in the source area, has either been reduced to clay by weathering or attrition. The terrace is some 10–15 m above the present flood plain level.

LAG DEPOSITS

Lag deposits of pisolitic iron oxide, formed as a result of lateritisation, are fairly extensive in the Conara–Epping Forest area, with other smaller areas around and to the west of the Macquarie River. Some deposits are cemented to form a compact rock while others comprise loose rounded fragments with a silt matrix.

The deposits tend to occur on relatively flat surfaces, and where excavated are usually only about one metre or less in thickness in concentrated form, although where cemented material occurs, the deposits can occasionally be up to two metres thick. The underlying sediments (Tertiary) have pisoliths widely scattered through the clay.

IGNEOUS ROCKS

JURASSIC DOLERITE

Dolerite is probably the most widespread rock type within the quadrangle, with only the area underlain by Tertiary sediments rivalling it in areal extent. The dolerite is in contact with and intrudes all of the rocks older than Jurassic within the area of the quadrangle.

In *The Glen* area dolerite dykes intrude the Cambrian rocks. Other bodies form sloping dykes which gradually intrude to higher levels in the stratigraphic sequence. A dyke on O'Connors Peak is in contact with Cambrian rocks around the Lake River but on its eastern margin it reaches as high as the Quamby Mudstone. Similarly the dolerite rises up the sequence to the north towards *Connorville* homestead. At Little Den the dolerite is again in contact with the Cambrian rocks and the Lower Permian, while to the west around Big Den it is a little further up the sequence and is in contact with the Quamby Mudstone.

To the north of Little Den a dolerite body forming a steep, high hill (between Threshermans Hill and Henrys Bluff) is in contact with the Golden Valley Group at the base and rises to be in contact with the Bogan Gap Group to the southwest.

The area around *The Glen* and Little Den are centres of intrusion, with the dolerite away from these areas reaching higher up in the Permian and Triassic sequences. The dolerite extends up into the Triassic sediments to the east and west of the Little Den centre but does not reach as high stratigraphically as it does near Poatina and on the Great Western Tiers to the north. The dolerite on the Tiers appears to reach a thickness of at least 300 metres.

Dolerite has intruded along faulted areas low down on the slopes of the Tiers in the general region of the Tiers Fault. Small isolated hills of dolerite occur to the east of Millers Bluff where dolerite has intruded Permian rocks. To the north of Millers Bluff dolerite occupies a narrow zone separating Stockers Tillite and Triassic sandstone. This is also the situation in the northwest corner of the quadrangle.

In other parts of the quadrangle (east of the Tiers Fault) dolerite intrudes Triassic sediments. The form of the dolerite is often largely unknown but at least some is probably sill-like, for example the large body forming Macquarie Tier. Dolerite intrudes high up in the Triassic on the south side of Hummocky Hills and in this area, and perhaps in other areas, forms two sill-like bodies connected by dykes.

In other parts of the quadrangle dolerite forms isolated bodies or monadnocks surrounded by Tertiary sediments or basalt.

A small area mapped as Tertiary basalt on the southern bank of the South Esk River, 1.5 km northwest of *Vaucluse* [around 369761] is, in fact, fine-grained dolerite. In hand specimen (samples 004557, 004558, Tables 7, 8) the rock is very fresh, rough, massive and dark grey with a conchoidal fracture, and is quite distinct from the surrounding coarser-grained dolerite. The body probably represents a minor late-stage intrusion. As discussed below, typical Tertiary basalts in the region are usually more-or-less vesicular, with at least incipient alteration.

In thin section, sample 004558 consists mainly of an intergranular/subophitic groundmass of randomly-oriented plagioclase laths (typically 100–20 μm × 10–30 μm) and equant to irregularly shaped clinopyroxene granules (50–200 μm). The plagioclase is fairly calcic (up to An_{78}), and the pyroxene is mainly augite, with subordinate pigeonite. There are also minor intersertal patches of a grey to brownish, glassy mesostasis, which under strong illumination are seen to contain numerous exsolved dust-sized opaque blobs, and scarcely birefringent to isotropic trichites of other minerals. Euhedral, broadly oblong to polygonal microphenocrysts of orthopyroxene (≤500 μm), some with narrow discontinuous reaction rims of clinopyroxene, are scattered throughout this groundmass. There are also rare, more narrowly oblong microphenocrysts of augite (≤1 mm × 50–150 μm), plagioclase (≤500 μm), and partially resorbed pigeonite (≤800 μm), all of which grade downward in grain size to the groundmass.

Another sample (004557; Plate 21) from the same area is a similar, but slightly coarser-grained rock with slightly more mesostasis. It consists of sparsely distributed microphenocrysts of orthopyroxene (≤1 μm) and plagioclase (about An_{78}) (≤600 μm) in a dominantly subophitic/intergranular groundmass consisting of plagioclase laths (typically An_{63}) (≤200 μm), augite and subordinate pigeonite, and black glassy intersertal mesostasis.

Petrographically these samples are typical fine-grained Jurassic dolerites, found in both the marginal zones of major intrusions and in some minor late-stage dykes. However some of the tholeiitic Tertiary basalts of this region are mineralogically similar, in that they contain pigeonite and orthopyroxene, and lack olivine.

A chemical analysis of sample 004557 (Tables 7, 8) shows that the rock is a quartz-normative tholeiite, closely resembling the average chilled margin composition of Tasmanian Jurassic dolerite (Hergt *et al.*, 1989), which represents the initial undifferentiated magma composition.

Both differ markedly from the quartz to olivine-normative tholeiitic Tertiary basalt of this region, notably in lower TiO_2, P_2O_5, Cr, Ni, Zn and Sr, and higher CaO, Sc, V and Cu. The higher magnetic susceptibility of the dolerite, compared to the tholeiitic Tertiary basalt (Table 6), is also notable.

A few other dolerite specimens (004554, 004555, 004556) were collected during sampling of the Tertiary basalts. All are floaters of coarse-grained (≤5 μm) dolerite, petrographically characteristic of the middle and upper parts of major sills.

TERTIARY BASALT

Distribution and Age

All the Tertiary basalt known from the quadrangle occurs within 14 km of the eastern margin of the sheet, in the Campbell Town, Conara and Epping Forest areas. Three distinct petrological types have been identified:–

(a) nepheline hawaiite and nepheline mugearite, which occur as a probable plug at Burburys Sugarloaf, near the southern margin of the sheet, and a few nearby probable flow remnants or subsidiary plugs.

(b) probable alkali olivine basalt, known only from a single sample from a drill hole near Epping Forest.

(c) quartz-normative and olivine-normative tholeiite, and rare transitional olivine basalt, extensive flows of which occur on the basalt plains between Campbell Town and Epping Forest. This association extends beyond the quadrangle, south through Ross and Tunbridge (Sutherland, 1989*b*) and in the upper Macquarie River valley; east in the South Esk valley to beyond Avoca and in the St Pauls valley to near Royal George (Everard, unpublished data); and northeast to the southeastern corner of the Longford Quadrangle.

The relative and absolute ages of these three associations are not firmly established. Johnston (1888, p. 215–218, 249) regarded all the Tasmanian Tertiary basalts as upper Palaeogene (meaning Miocene?). Nye (1926) regarded the basalt between Ross and Cleveland as overlying Lower Tertiary sediments, and partly overlain by Upper Tertiary sediments, and therefore "closing the Lower Tertiary era". Nye and Blake (1938) and Edwards (1939, 1950) correlated the sub-basaltic sediments in the valleys of the South Esk, St Pauls and Macquarie Rivers with Tertiary beds in the Launceston area, then erroneously regarded as Lower to Middle Pliocene (David, 1932). This led them to suggest an Upper Pliocene or even possibly Pleistocene age for the basalts. Edwards (1939) thought that a young age was also indicated by physiographic considerations and, supported by petrographic and chemical similarities, made a tentative correlation with the Pliocene to Pleistocene Newer Volcanics of Victoria. On the legend of the 1:63,360 scale Longford geological map sheet, Blake (1959) also showed a Pliocene age for the basalt.

There is still little evidence within the quadrangle to indicate the age of any of the three basalt associations. No radiometric dates are available, and during sampling the only rocks found that would be marginally suitable are the nepheline hawaiites and mugearites at and near Burburys Sugarloaf, particularly those with well crystallised anorthoclase (F. L. Sutherland, pers. comm.). The only palynological data available from the area was obtained from Tertiary clay and sand found beneath basalt in a percussion hole (IH59) drilled about 3 km east of Conara [396668] (Matthews, 1983). In this hole, S. M. Forsyth (pers. comm.) obtained spores assigned to the Lower to Middle *Nothofagidites asperus* Zone (together with much reworked Triassic material), corresponding roughly to a middle to late Eocene age (perhaps 36 to 45 Ma). This places a maximum limit on the age of the tholeiitic basalt at this locality.

North of the quadrangle, in drill hole IH44 about 5 km south of Evandale, both Esso Australia Ltd and S. M. Forsyth (quoted in Matthews, 1983, p. 57) obtained spores of middle to late Eocene age in samples of sediment both above and below a 3 m thick interval of basalt. The basalt in this area is alkali olivine basalt (Sutherland, 1971), and the tholeiites in the Lake River Quadrangle may be of a different age. The probable alkali olivine basalt known from a drill hole (IH63) near Epping Forest [275757] may belong to this association, but correlation is tenuous. At the latter locality, a few large boulders of quartz tholeiite occur on the surface, suggesting that the tholeiitic association may be younger than the alkali olivine basalt.

The nearest tholeiite that has been radiometrically dated is an unusual lherzolite-bearing flow 9 km ESE of Andover, and more than 35 km SSE of the Lake River Quadrangle. This rock gave a latest Oligocene age of 25.6 ± 0.2 Ma (Sutherland and Wellman, 1986). Perhaps influenced by this date, these authors suggested a relatively young (early to middle Miocene) age for the tholeiites in the Macquarie and South Esk River valleys.

Four radiometric dates, ranging in age from 24.1 ± 0.2 to 25.0 ± 0.3 Ma, are available for hawaiites, nepheline hawaiites and olivine nephelinites from the Interlaken Quadrangle (Sutherland, 1989*a*) and Oatlands area (Sutherland and Wellman, 1986). The nepheline hawaiite at Burburys Sugarloaf probably represents the northern limit of this association, and may be of a similar (latest Oligocene/earliest Miocene) age.

The Pliocene age suggested by Nye, Edwards and Blake for the tholeiitic association is almost certainly too young. About twenty radiometric age determinations for Tasmanian Tertiary basalts are available, ranging in age from 58.5 ± 0.7 Ma (Palaeocene) at Bream Creek (Baillie, 1987) to 8.5 ± 0.1 Ma (late Miocene) at Green Hills, near Stanley (Baillie, 1986); most other data are tabulated by Sutherland and Wellman (1986) and Sutherland (1989*a*).

The author (JLE) favours a middle to late Eocene age, close to the maximum age permitted by the palynological data, for the tholeiitic basalts in the Lake River Quadrangle, for the following reasons:

(a) except for a few Palaeocene ages obtained from the deeper parts of the basin, all dated sediments from the Longford Sub-basin, including those closely associated with basalt, give early or middle–late Eocene ages (Matthews, 1983, p. 53, 57; Matthews, 1989, p. 371). In particular, no Oligocene or younger flora is known.

(b) extensive laterite (Matthews, 1974) and local bauxite (Blake, 1959) have developed on the tholeiites (Woodstock Surface of Nicolls, 1960). These processes do not appear to have affected the 25 Ma hawaiites and olivine nephelinites to the south and west, which therefore may be younger than the tholeiites (*contra* Sutherland and Wellman, 1986).

The distribution of the three basalt associations in the region was probably partly controlled by Late Cretaceous or Early Tertiary epeirogenic rifting, which in turn may reflect major structures in the pre-Carboniferous basement. The voluminous tholeiitic association occurs in lowlands corresponding to the southern continuation of the Tamar graben, in which extensional tectonics has permitted large volumes of magma to rise to the surface. Sutherland (1989*b*, p. 148) considered that "the lavas centred on Campbell Town mark a change in the trend of the Tamar rift structure, where the main downthrows are taken up on other fault trends", and suggested that the rift structure marked the site of the major basement fault between the pre-Carboniferous rocks of eastern and western Tasmania. In contrast, the nepheline hawaiites and nepheline mugearites occur in the relatively uplifted region extending west to the Central Plateau. They represent small volumes of magma generated at greater depths and/or by smaller degrees of partial melting than the tholeiites, which have managed to penetrate through the crust and reach the surface in only a few places. However, the tectonic significance of other features of the basalt distribution, such as the change to alkali olivine basalt around Epping Forest and the absence of any basalt in the west of the quadrangle, remains obscure.

Approximately fifty samples of Tertiary basalt were collected for petrographic study from all major mapped areas in the quadrangle, and from adjoining areas in the Longford Quadrangle immediately to the north (Table 6, fig. 7). Chemical analyses (Table 7) were obtained for a subset of 15 samples, chosen to be representative of the petrographic variety and geographic distribution of the basalts. CIPW and Rittmann norms are given in Table 8.

The field relationships, petrography and geochemistry of the three petrological associations of Tertiary basalt identified within the quadrangle are discussed below.

Nepheline Hawaiite and Nepheline Mugearite

These rock types are restricted to the vicinity of Macquarie Tier in the southeast of the quadrangle. The main area of nepheline hawaiite is at Burburys Sugarloaf [325505], a small but prominent hill rising to an altitude of 498 m above sea level. This probably represents a small plug piercing Triassic sandstone. A small area of rubbly sub-outcrop, 900 m to the NNW, is probably an eroded flow remnant. A larger area of outcrop, 4 km to the northeast at *Fosterville*, is more problematic. It lacks any strong topographic expression, with its elevation of about 220 m being just above the general level of the basalt plains in the Campbell Town–Conara area. Petrographically and geochemically this rock, although a nepheline mugearite, resembles the rock at Burburys Sugarloaf. It may also be a flow remnant originating from there, or alternatively a separate, although possibly related, small plug.

Forsyth (1986) mapped, and Sutherland (1989*a*) described a small outcrop of "lherzolite-bearing nepheline hawaiite" in the Interlaken Quadrangle about 500 m south of Burburys Sugarloaf, as possibly "a small flow remnant or related intrusion of the main plug". A brief petrographic description (Sutherland, 1989*a*, p. 58) indeed closely tallies with the rock at Burburys Sugarloaf (see below), but chemical data (Sutherland, 1989*a*, p. 59–60), although not explicitly quoted, suggest significant differences.

PETROGRAPHY

Burburys Sugarloaf (004501–004503) (Plate 22)

In hand specimen the rock is a massive, dark grey, fine-grained basalt with an irregular, hackly fracture, containing numerous equidimensional to ellipsoidal lherzolite nodules, typically about 10 mm long. Narrow

TABLE 6
Sample localities, Tertiary basalt and miscellaneous samples

Registered No.	Plot No.	Field No.	Analysis No.	Co-ordinates	Locality	Rock Type	Susceptibility*
004501	1	LSB24	910352	EP325505	Burburys Sugarloaf	Tb–massive, with nodules	>21.9
004502	2	LSB24A	–	EP325505	Burburys Sugarloaf	Tb–massive, with nodules	>28.0
004503	3	LSB24B	–	EP325505	Burburys Sugarloaf	Tb–massive, with nodules	44.8
004504	4	LSB25	–	EP321513	0.9 km NNW of Burburys Sugarloaf	Tb–massive, with nodules	34.1
004505	5	LSB25A	–	EP321513	0.9 km NNW of Burburys Sugarloaf	Tb–massive, with nodules	31.7
004506	6	LSB25B	–	EP321513	0.9 km NNW of Burburys Sugarloaf	Tb–massive	
004507	7	LSB23	910351	EP356538	Residence of H. Foster (*Fosterville*)	Tb–massive	22.7
004508	8	LSB14	910347	EP413489	2 km north of Ross	Tb–massive	2.04
004509	9	LSB1	–	EP412540	2 km south of Campbell Town	Tb–vesicular	>1.09
004510	10	LSB20	910349	EP409567	Forster Street, Campbell Town	Tb–nearly massive	1.44
004511	11	LSB3	–	EP405584	Old quarry (Gatty Park), Campbell Town	Tb–finely vesicular	1.24
004512	12	LSB44	–	EP396605	3 km north of Campbell Town	Tb–finely vesicular	1.14
004513	13	LSB19	–	EP377559	Small hill, Hoggs Ford Road	Tb–nearly massive	1.61
004514	14	LSB18	910348	EP361562	Macquarie R., 5 km SW of Campbell Town	Tb–finely vesicular	0.98
004515	15	LSB16	–	EP375580	Elizabeth River, 3 km west of Campbell Town	Tb–vesicular, weathered	1.36
004516	16	LSB15	–	EP369584	Elizabeth River, Merton Vale	Tb–vesicular	>2.03
004517	17	LSB17	–	EP368585	Elizabeth River, Merton Vale	Tb–vesicular	1.38
004518	18	LSB2	910346	EP365611	Macquarie Rd, 5 km NW of Campbell Town	Tb–vesicular	>3.00
004519	19	LSB21	910350	EP382645	Small hill, 1 km north of Snaresbrook	Tb– finely vesicular	3.48
004520	20	LSB30	–	EP401689	Blanchards Creek, 0.5 km W of bridge	Tb– finely vesicular	1.92
004521	21	LSB42	–	EP385688	Blanchards Creek, 2.3 km E of Conara	Tb–vesicular, weathered	1.79
004522	22	LSB22	–	EP363676	1 km south of Conara	Tb–nearly massive	>1.41
004523	23	LSB43	–	EP343688	1.8 km west of Conara	Tb–finely vesicular, bleached	0.36
004524	24	LSB38	–	EP293667	2.5 km NE of Kenilworth	Tb–vesicular	>0.80
004525	25	LSB39	910355	EP290687	3 km ENE of Stockwell	Tb–nearly massive	>0.76
004526	26	LSB40	–	EP289689	3 km ENE of Stockwell	Tb–finely vesicular, bleached	1.06
004527	27	LSB41	–	EP292692	3.3 km ENE of Stockwell	Tb–finely vesicular, bleached	0.92
004528	28	LSB29	910353	EP315720	Northeast shore, Diprose Lagoon	Tb–vesicular	>0.81
004529	29	LSB26	–	EP337721	West shore, Cleveland Lagoon	Tb–finely vesicular	0.59
004530	30	LSB27	–	EP346726	North shore, Cleveland Lagoon	Tb–vesicular, oxidised	0.66
004531	31	LSB36	–	EP319749	1.2 km SSE of Woorak	Tb–finely vesicular	0.65
004532	32	LSB34	–	EP334752	1 km ESE of Woorak	Tb–finely vesicular	3.04
004533	33	LSB33	–	EP337773	1.7 km northeast of Woorak outstation	Tb–nearly massive, weathered	>0.54
004534	34	LSB32	910354	EP325760	Woorak outstation	Tb–massive	1.88
004535	35	LSB37	–	EP304756	1.8 km south of Epping Forest	Tb–vesicular	>2.56
004536	36	LSB78	910761	EP276756	Barton Road, 1.8 km from Epping Forest	Tb–nearly massive	0.96
004537	37	LSB77A	–	EP273756	Knoll north of Barton Road	Tb–vesicular, very weathered	>0.82
004538	38	LSB47	910356	EP302780	Belle Vue Road	Tb–very finely vesicular	1.40
004539	39	LSB45	–	EP316788	0.5 km east of Midwood	Tb–vesicular, bleached	>0.38
004540	40	LSB46	–	EP341787	Clyne Vale	Tb–slightly vesicular, bleached	2.05
004541	41	LSB51	–	EP343813	Kallatie Road	Tb–vesicular	2.54
004542	42	LSB50	–	EP347813	Vineys Sugarloaf	Tb–vesicular	1.79
004543	43	LSB53	910358	EP381797	Shooters Hill	Tb–vesicular	1.07
004544	44	LSB54	–	EP391790	1 km east of Shooters Hill	Tb–finely vesicular, bleached	0.90
004545	45	LSB48	910357	EP397747	0.5 km south of Glen Esk	Tb–finely vesicular	0.87
004546	46	LSB49	–	EP413726	3 km siouthеast of Glen Esk	Tb–vesicular	0.79
004547	47	LSB60	910360	EP387722	3 km south of Glen Esk	Tb–nearly massive	>0.98
004548	48	LSB59	–	EP372727	West end of Vaucluse Reservoir	Tb–nearly massive	2.49
004549	49	LSB58	–	EP372734	2 km SSW of Vaucluse	Tb– slightly vesicular	0.85
004550	50	LSB57	–	EP363753	1.5 km west of Vaucluse	Tb–vesicular	0.66
Miscellaneous samples							
004551	–	LSB52	–	EP349815	250 m east of Vineys Sugarloaf	Pisolitic ironstone	76.4
004552	–	LSB50B	–	EP347813	Vineys Sugarloaf	Bauxite	>0.06
004553	–	LSB77C	–	EP275757	Track north of Barton Rd	Silcrete(?)	>0.20
004554	–	LSB77B	–	EP273756	Knoll north of Barton Rd	Jdl–coarse grained, weathered	10.1
004455	–	LSB28	–	EP315721	NE shore, Diprose Lagoon	Jdl–coarse grained	>8.64
004556	–	LSB35	–	EP320745	1.6 km SSE of Woorak	Jdl–coarse grained, weathered	17.5
004557	57	LSB55	910359	EP368763	South Esk River near Vaucluse	Jdl–fine grained, weathered	7.51
004558	–	LSB56	–	EP368762	South Esk River near Vaucluse	Jdl—fine grained, weathered	>7.11
–	63	IH63/10 m	–	EP275757	Barton Road, 2 km from Epping Forest	Tb	
72304	304	–	–	EP410570	Campbell Town	Tb	
72306	306	–	–	EP383570	2.5 km west of Campbell Town	Tb	

* Magnetic susceptibility, units of 10^{-3} SI, measured on hand specimen. Minimum values (>) given for specimens considered too small to give a reliable measurement.

5 cm

feldspar laths, a few millimetres long, are also visible to the naked eye, but otherwise the rock is aphanitic.

The thin sections consist of scattered anhedral olivine phenocrysts and augite microphenocrysts in a fine-grained groundmass consisting of augite, olivine, opaque minerals, minor biotite and nepheline (confirmed by X-ray diffraction), and a low birefringence mesostasis. The latter may largely consist of sodic plagioclase and anorthoclase, as large elongate lath-like plates (≤5 mm long) have in places crystallised, poikilitically enclosing the other groundmass phases.

The olivine phenocrysts are typically equant, anhedral but not strongly embayed, and range in size from 2 mm to a few hundred micrometres. They are biaxial positive with a large 2V, and are therefore highly magnesian ($Fo_{>87}$). Undoubtedly most, if not all, are derived from disaggregation of lherzolite nodules, or are related mantle-derived xenocrysts. Rare anhedral xenocrysts of finely granular (?)olivine may result from the reaction of lherzolite-derived orthopyroxene with the liquid. Very rare spinel xenocrysts are also present.

The sparsely distributed, subhedral to euhedral clinopyroxene microphenocrysts range in grain size from a few hundred micrometres down to the groundmass. The mineral is very pale yellow-grey, biaxial positive with moderate 2V, and is probably slightly titaniferous augite. A few crystals are apparently zoned with a deeper yellowish, probably more titaniferous rim.

The groundmass consists mainly of equant granules (typically 50–150 μm across) of both augite and olivine, as well as very abundant tiny augite laths (typically 30–60 μm × 5–10 μm) and abundant equidimensional, polygonal opaque minerals (typically 10–30 μm), probably titanomagnetite, together with an indeterminable low birefringence mesostasis. The groundmass olivine is optically negative and, in contrast to the phenocrysts, is therefore a relatively iron-rich variety, probably in equilibrium with the magma. Scattered rounded opaque patches up to 200 μm across appear to be aggregrates of smaller grains. The groundmass also contains occasional small (50–100 μm) ragged grains of biotite, pleochroic from deep red-brown to pale yellow-brown. Accessory apatite is also present.

In some thin sections, 40–50% of this groundmass has been poikilitically enclosed, with olivine, augite and opaque granules riddling elongate feldspar laths up to 5 mm long. Although the coarse nature of their twinning makes the Michel-Levy method difficult to apply, the low extinction angles and positive optic sign suggest that the majority are sodic plagioclase (albite or sodic oligoclase). However a few sections exhibit finely cross-hatched twinning and give an optically negative figure with moderate 2V, indicating anorthoclase.

Equidimensional patches, mostly 100–150 μm across, containing usually polycrystalline aggregrates of colourless mineral grains with low relief and birefringence, are scattered throughout the slides. The majority are probably small amygdales, but a few have a crudely polygonal outline suggesting crystal faces. Most are filled with an undetermined, biaxial negative zeolite, but a few give

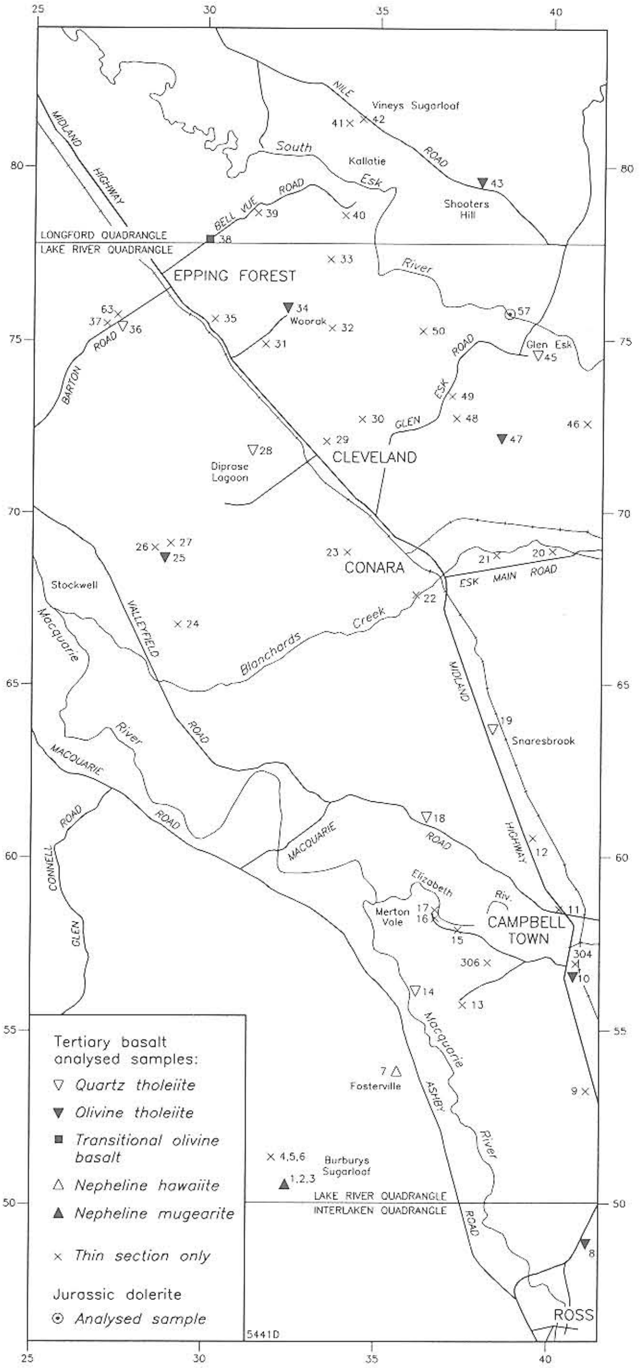


Figure 7

Localities of Tertiary basalt and Jurassic dolerite samples.

uniaxial negative figures and may be small grains of primary nepheline.

In most thin sections alteration is confined to incipient orange-brown iddingsitisation of olivine.

900 m NNW of Burburys Sugarloaf (004504–004506)

Hand specimens of this small outlier are identical to those collected from the Sugarloaf itself. In thin section the rock is also very similar, except that the groundmass is generally finer grained and more altered. Poikilitically riddled plagioclase and anorthoclase laths have developed in only one (004506) of the three thin sections cut.

Spinel lherzolite nodules are also present at this locality.

TABLE 7
Chemical analyses of Tertiary basalts and Jurassic dolerite

Registered No. Analysis No. Field No.	004501 910352 LSB24	004507 910351 LSB23	004508 910347 LSB14	004510 910349 LSB20	004514 910348 LSB18	004518 910346 LSB2	004519 910350 LSB21	004525 910355 LSB39	004528 910353 LSB29
SiO_2	43.77	42.77	49.56	49.61	51.38	53.04	52.56	50.99	53.47
TiO_2	2.39	2.69	1.47	1.79	1.40	1.32	1.45	1.36	1.48
Al_2O_3	11.92	11.40	12.88	14.14	13.80	14.02	14.12	14.24	14.61
Fe_2O_3	5.96	4.90	1.44	3.51	2.46	2.09	1.91	1.16	1.18
FeO	7.30	8.64	9.92	8.44	8.11	8.17	8.58	9.38	6.77
MnO	0.22	0.23	0.18	0.16	0.17	0.16	0.16	0.16	0.15
MgO	8.57	9.21	8.44	7.50	7.58	7.98	7.73	8.14	7.66
CaO	8.46	9.06	9.06	9.29	9.10	9.28	9.12	9.18	8.43
Na_2O	3.36	4.77	2.87	3.04	2.84	2.68	2.60	3.01	2.53
K_2O	2.81	1.60	0.70	0.61	0.56	0.40	0.38	0.59	0.45
P_2O_5	1.72	1.81	0.29	0.29	0.22	0.19	0.22	0.18	0.22
H_2O^+	2.89	2.00	1.37	1.28	1.25	0.83	0.92	0.96	1.56
CO_2	0.11	0.14	1.03	0.05	0.14	0.07	0.07	0.06	0.17
Sulphate as SO_3	0.00	0.01	0.01	0.00	0.03	0.00	0.01	0.06	0.00
Sulphide as SO_3	0.03	0.18	0.15	0.02	0.00	0.02	0.02	0.07	0.07
TOTAL	99.51	99.41	99.37	99.73	99.04	100.25	99.85	99.54	98.75
100Mg/Mg + Fe (a)	57.8	58.8	60.4	56.7	59.8	61.6	60.3	61.2	66.4
Trace elements (ppm)									
Sc	17	14	30	25	26	26	28	24	29
V	62	85	135	125	125	110	120	110	125
Cr	240	220	280	190	250	250	250	195	250
Co	46	41	45	46	46	43	46	45	48
Ni	190	180	155	135	135	120	125	125	120
Cu	22	25	35	41	42	36	32	35	42
Zn	190	200	93	110	96	90	96	92	98
Ga	28	28	18	20	19	17	18	17	20
As	<20	<20	<20	<20	<20	<20	<20	<20	<20
Rb	61	55	22	20	20	14	22	17	14
Sr	1650	1700	260	330	250	200	230	240	210
Y	47	61	16	24	31	15	24	17	27
Zr	680	710	95	115	115	75	85	83	85
Nb	100	120	11	11	11	5	7	6	3
Mo	5	11	<5	<5	<5	<5	<5	<5	<5
Sn	<9	<9	<9	<9	<9	<9	<9	<9	<9
Ba	910	890	150	155	155	100	100	130	360
La	160	170	<20	<20	<20	<20	<20	<20	<20
Ce	270	280	35	29	30	<28	<28	31	<28
Nd	100	100	<20	<20	<20	<20	<20	<20	<20
W	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pb	<10	<10	<10	<10	<10	<10	<10	<10	<10
Bi	<5	<5	<5	<5	<5	<5	<5	<5	<5
Th	<10	11	<10	10	<10	<10	<10	<10	<10
U	<10	<10	<10	<10	<10	<10	<10	<10	<10

(a) calculated at $Fe_2O_3/FeO = 0.15$

TABLE 7

Chemical analyses of Tertiary basalts and Jurassic dolerite *(continued)*

							Jurassic dolerite	
Registered No.	004534	004536	004538	004543	004545	004547	004557	Average Tasmanian
Analysis No.	910354	910761	910356	910358	910357	910360	910359	chilled margin
Field No.	LSB32	LSB78	LSB47	LSB53	LSB48	LSB60	LSB55	(Hergt *et al.*, 1988)
SiO_2	49.97	51.08	49.85	50.45	51.30	50.63	53.83	54.98 ± 0.49
TiO_2	1.66	1.50	1.65	1.34	1.59	1.73	0.63	0.65 ± 0.02
Al_2O_3	13.34	14.06	12.98	13.89	13.82	13.44	14.20	14.84 ± 0.12
Fe_2O_3	0.84	0.73	1.70	1.54	2.75	1.28	0.88	8.91 ± 0.13(b)
FeO	9.58	10.47	9.51	9.45	8.91	10.05	8.44	
MnO	0.17	0.17	0.18	0.18	0.17	0.18	0.18	0.18 ± 0.01
MgO	7.58	7.24	9.57	9.32	6.95	8.04	6.68	6.72 ± 0.22
CaO	9.58	9.25	9.04	9.37	9.45	9.24	11.03	10.69 ± 0.42
Na_2O	3.19	2.79	3.09	2.75	2.96	2.75	2.10	2.00 ± 0.19
K_2O	0.71	0.60	0.81	0.37	0.45	0.62	0.69	0.89 ± 0.12
P_2O_5	0.27	0.20	0.25	0.21	0.21	0.28	0.12	0.09 ± 0.01
H_2O^+	1.11	0.68	0.64	0.87	1.04	0.95	1.19	-
CO_2	1.18	0.61	0.39	0.17	0.31	0.18	0.11	-
Sulphate as SO_3	0.16	0.07	0.07	0.00	0.02	0.04	0.03	0.05 ± 0.02(c)
Sulphide as SO_3	0.03	0.11	0.09	0.04	0.07	0.09	0.12	
TOTAL	99.37	99.56	99.82	99.95	100.00	99.50	100.23	100.00
100Mg/Mg + Fe	59.7	56.8	63.7	63.5	55.3	59.2	59.4	60.4
Trace elements (ppm)								
Sc	25	13	28	28	29	29	46	41.3 ± 0.9
V	125	175	130	125	140	135	200	225 ± 6.5
Cr	240	200	260	240	230	240	86	108 ± 13
Co	48	70	51	53	44	46	40	49 ± 1.2
Ni	150	234	180	170	125	135	64	78 ± 3.8
Cu	44	69	37	37	40	45	60	74 ± 1.6
Zn	100	128	100	94	97	105	68	79 ± 3.7
Ga	20	20	19	19	19	18	16	16.4 ± 0.6
As	<20	<20	<20	<20	<20	23	<20	nd
Rb	24	18	21	12	15	19	21	33 ± 5.1
Sr	280	266	310	260	230	310	120	135 ± 21
Y	22	22	18	17	20	22	20	20 ± 0.5
Zr	110	104	105	79	91	84	89	95 ± 3.1
Nb	11	7	12	<3	8	7	<3	4.5 ± 0.4
Mo	<5	5	<5	<5	<5	<5	<3	nd
Sn	<9	<9	<9	<9	<9	<9	<9	nd
Ba	120	na	160	115	105	145	190	217 ± 33
La	<20	na	<20	<20	<20	<20	<20	10.9 ± 0.3
Ce	<28	na	39	<28	<28	41	35	24.4 ± 1.0
Nd	<20	na	<20	<20	<20	<20	<20	12.4 ± 0.7
W	<10	<10	<10	<10	<10	<10	<10	nd
Pb	<10	<10	<10	<10	<10	12	<10	6 ± 0.7
Bi	<5	<5	<5	<5	<5	<5	<5	nd
Th	<10	<10	<10	<10	<10	<10	<10	3.5 ± 0.12
U	<10	<10	<10	<10	<10	<10	<10	11 ± 0.2

(b) – total iron as FeO
(c) – total sulphur as S

5 cm

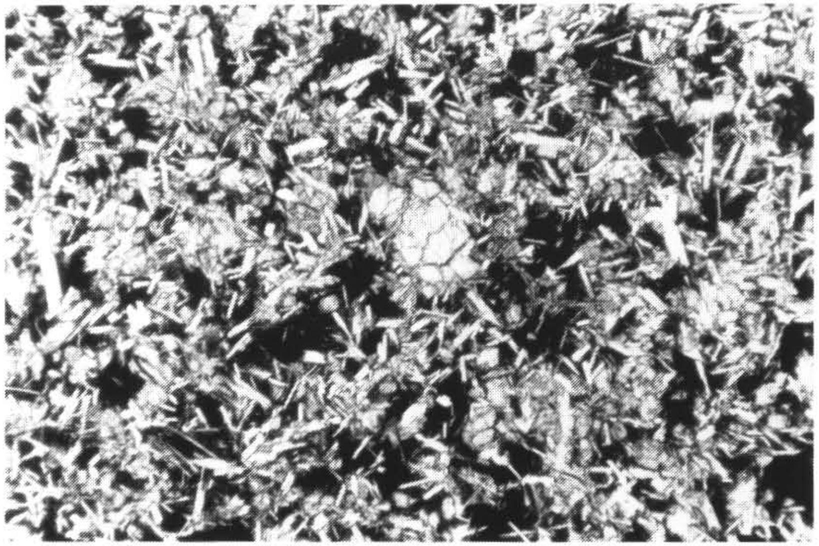


Plate 21. *Sample 004557, Jurassic dolerite, South Esk River near Vaucluse. Orthopyroxene microphenocryst (centre) and fine-grained dominantly subophitic groundmass with intersertal glassy mesostasis (dark). Plane polarised light, field of view 4.4 × 2.9 mm.*

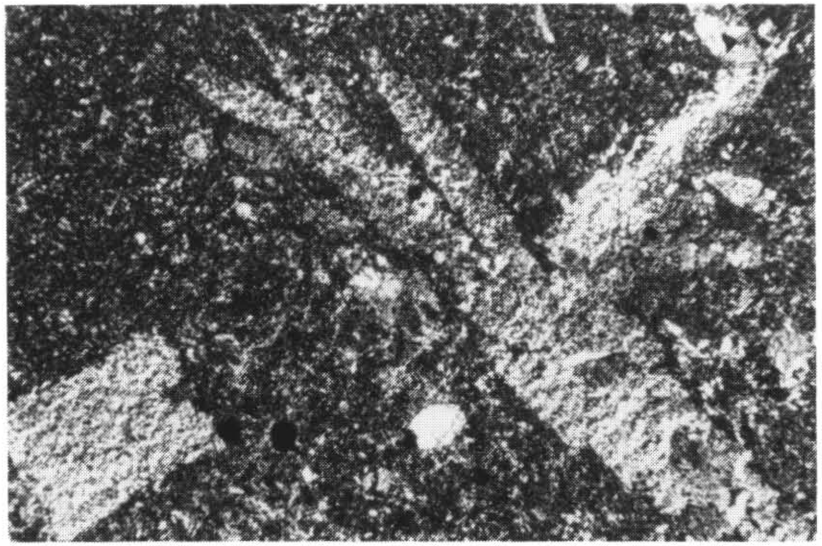


Plate 22. *Sample 004502, Tertiary basalt (nepheline hawaiite), Burburys Sugarloaf. Poikilitically riddled laths and platelets of sodic plagioclase, partially enclosing a very fine-grained groundmass. Crossed nicols, field of view 11.1 × 7.4 mm.*

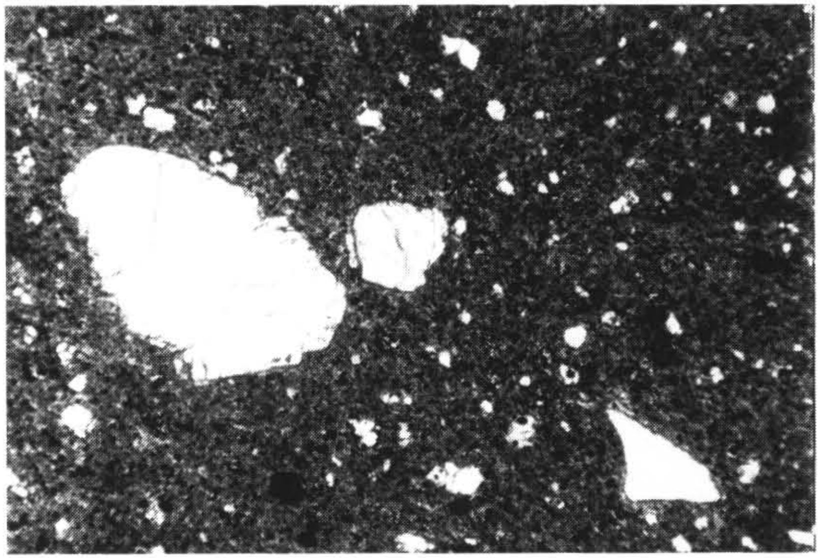


Plate 23. *Sample 004507, Tertiary basalt (nepheline mugearite), Fosterville. Anhedral olivine xenocrysts in a very fine-grained groundmass. Plane polarised light, field of view 4.4 × 2.9 mm.*

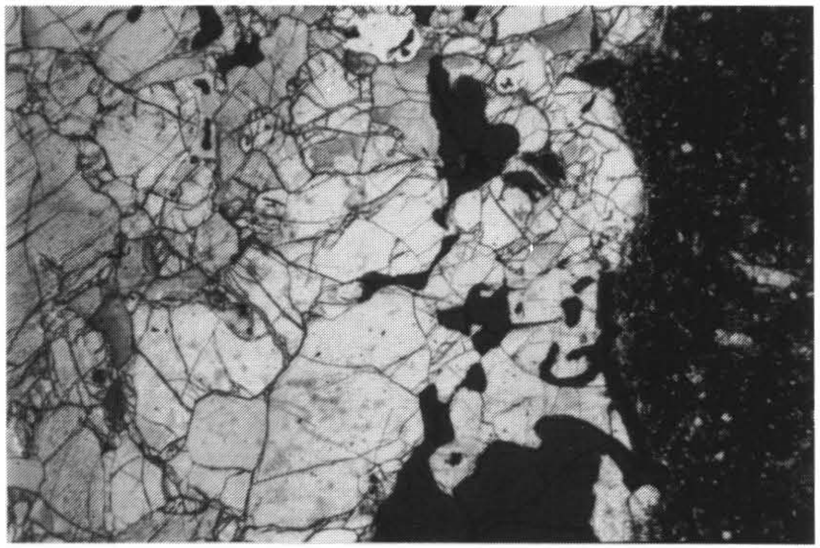


Plate 24. *Sample 004505, Tertiary basalt, near Burburys Sugarloaf. Part of a spinel lherzolite nodule, showing vermiform brown spinel (dark) and clinopyroxene (pale grey, left). Other grains are mostly olivine; groundmass of host rock at right. Plane polarised light, field of view 11.1 × 7.4 mm.*

TABLE 8
CIPW and Rittmann norms, Tertiary basalts and Jurassic dolerite

	Tertiary basalt															*Jdl*
Regist. No.	004501	004507	004508	004510	004514	004518	004519	004525	004528	004534	004536	004538	004543	004545	004547	004557
Analysi No.	910352	910351	910347	910349	910348	910346	910350	910355	910353	910354	910761	910356	910358	910357	910360	910359
Field No.	LSB24	LSB23	LSB14	LSB20	LSB18	LSB2	LSB21	LSB39	LSB29	LSB32	LSB78	LSB47	LSB53	LSB48	LSB60	LSB55
CIPW Norms (mass %)																
Q	-	-	-	-	0.78	2.95	3.31	-	6.86	-	0.26	-	-	0.44	-	5.49
or	17.28	9.78	4.25	3.65	3.42	2.36	2.31	3.55	2.72	4.30	3.60	4.84	2.19	2.72	3.71	4.13
ab	12.77	12.78	25.09	26.19	24.67	22.81	22.30	25.85	22.05	27.88	24.07	26.53	23.57	25.43	23.65	17.99
an	9.54	5.12	20.86	23.57	23.81	25.26	26.01	24.00	28.08	20.61	24.50	19.42	24.74	23.46	22.93	27.60
ne	9.09	15.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-
di	18.38	23.80	19.30	17.60	17.19	16.24	15.03	17.24	11.01	21.76	17.22	19.88	17.03	18.74	17.88	22.18
hy	-	-	16.87	14.59	24.83	25.46	25.74	19.22	24.29	11.63	24.79	8.65	20.61	23.42	23.93	19.30
ol	21.49	20.62	7.82	7.97	-	-	-	5.07	-	7.88	-	14.77	6.69	-	1.69	-
mt	2.53	2.59	2.22	2.26	2.03	1.94	2.00	2.03	1.55	2.04	2.17	2.15	2.10	2.22	2.19	1.80
il	4.72	5.27	2.89	3.47	2.73	2.53	2.79	2.62	2.91	3.24	2.91	3.19	2.58	3.08	3.33	1.22
ap	4.21	4.40	0.71	0.71	0.54	0.45	0.52	0.42	0.54	0.66	0.47	0.59	0.50	0.50	0.68	0.28
Total	100.01	100.02	100.01	100.01	100.00	100.00	100.01	100.00	100.01	100.00	99.99	100.02	100.01	100.01	99.99	99.99
mol % an (plagioclase)	41.3	27.4	43.9	45.9	47.6	50.1	52.4	46.7	54.6	41.1	49.0	40.8	49.7	46.5	47.7	59.1
D.I.†	39.14	38.22	29.34	29.84	28.87	28.12	27.92	29.40	31.63	32.18	27.93	31.37	25.76	28.59	27.36	27.61
Rittmann norms (vol. %)																
Quartz	-	-	-	-	2.1	4.4	4.7	-	8.3	-	1.5	-	-	1.8	0.5	7.9
Sanidine	27.7	15.2	0.5	-	-	-	-	-	-	0.2	-	1.5	-	-	-	0.3
Plagioclase	19.1	18.1	54.2	58.3	56.4	54.7	55.0	57.9	56.7	56.8	56.9	53.5	54.9	56.3	55.0	52.7
Nepheline	8.2	14.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clinopyroxene*	21.3(T)	29.1(T)	38.4(S)	34.1(S)	38.2(P)	38.0(P)	37.1(P)	37.5(P)	32.0(P)	36.4(S)	38.1(P)	32.8(S)	38.9(P)	38.3(S)	40.7(P)	36.7(S)
Olivine	16.2	15.9	3.3	3.6	-	-	-	1.4	-	3.1	-	8.7	3.0	-	-	-
Magnetite	2.4	2.6	1.7	1.7	1.5	1.3	1.4	1.5	1.0	1.6	1.6	1.7	1.5	1.6	1.6	1.6
Ilmenite	1.3	-	1.3	1.7	1.3	1.3	1.4	1.3	1.5	1.4	1.4	1.4	1.3	1.5	1.6	0.6
Apatite	3.9	4.2	0.7	0.6	0.5	0.4	0.5	0.4	0.5	0.6	0.4	0.5	0.5	0.5	0.6	0.3
Total	100.1	100.0	100.1	100.0	100.0	100.1	100.1	100.0	100.0	100.1	99.9	100.1	100.1	100.0	100.0	100.1

*T – titanaugite, S – sub-calcic augite, P – pigeonite

† Differentiation index (ΣQ + or + ab + ne)

All norms calculated at $FE_2O_3/FeO = 0.15$, from major elements recalculated to 100% anhydrous.

'Fosterville' (004507) (Plate 23)

The hand specimen, obtained from scattered cobble and small-boulder sized float in the vicinity, is a massive, dark grey, fine-grained basalt with an irregular to subconchoidal fracture, and closely resembles the rock at Burburys Sugarloaf. Sparse discoidal to ellipsoidal lherzolite nodules, with long axes up to 15 mm long, and lherzolitic debris, are present in the rock.

The thin section consists of abundant phenocrysts, mainly of olivine, in a fine-grained groundmass of olivine, clinopyroxene, opaque minerals and mesostasis.

The olivine phenocrysts range in size from 2 mm down to the groundmass. The larger phenocrysts are typically anhedral with large 2V, and are probably derived from disaggregation of lherzolite nodules. However some grains, particularly the smaller ones, have well-developed crystal faces and are probably cognate. Negative interference figures, implying a relatively iron-rich composition, were obtained from some. Thus there are probably two generations of olivine present.

One anhedral phenocryst of (?)enstatitic orthopyroxene (biaxial positive, very large 2V, low birefringence, straight extinction), measuring about 1.5 × 1 mm, is surrounded by a reaction rim about 500 µm wide of finely granular, high birefringence olivine and/or clinopyroxene. This grain is probably also a lherzolite-derived xenocryst. A few small patches (≤500 µm) of finely granular olivine or clinopyroxene are scattered throughout the rock, and may also be derived from the reaction of orthopyroxene with its host melt.

Rare equant to elongate microphenocrysts (≤200 µm) of augite (biaxial positive, moderate 2V) are also present.

The groundmass consists of sparse olivine granules; abundant laths of clinopyroxene (≤50 µm long and 5–10 µm across); abundant, equant, squarish to polygonal opaque minerals (10–50 µm); and an indeterminate, low birefringence mesostasis. No plagioclase, alkali feldspar or nepheline is visible, but X-ray diffraction indicates that nepheline, magnetite and apatite are also present.

Scattered equidimensional patches, up to 200 µm across, filled with a pale yellow-brown to yellow-green, very fine-grained, low birefringence alteration product occur throughout the slide. Most of these patches are probably amygdales, but some have a crudely polygonal outline and may be pseudomorphs, probably after olivine. Rare carbonate-filled amygdales are also present.

The rock is similar to the outcrops at and near Burburys Sugarloaf (samples 004501–004506), but differs mainly in having a finer grained groundmass in which poikilitic anorthoclase and sodic plagioclase phases have not developed and biotite is absent.

SPINEL LHERZOLITE NODULES

Thin sections of samples 004502, 004505 (Plate 24) and 004506 intersect nodules. These nodules are unfoliated and consist of interlocking granoblastic anhedra of widely variable grain size (most 500 µm–5 mm), often with irregular or curved grain boundaries. This is considered characteristic of the protogranular type of lherzolite texture (Mercier and Nicolas, 1975), which is the most common type in nodules from Tasmanian Tertiary basalts (Varne, 1977).

The mineralogy of the nodules is olivine, orthopyroxene and clinopyroxene and minor, sometimes vermiform, brown spinel. Some of the olivine and orthopyroxene grains give optically negative figures, suggesting relatively iron-rich compositions ($Fo_{<87}$ and $En_{<88}$), atypical of mantle olivine and orthopyroxene. No electron microprobe data have been obtained.

CLASSIFICATION, GEOCHEMISTRY AND PETROGENESIS

In the CIPW-normative based classification outlined by Johnson (1989), a modification of the system of Coombs and Wilkinson (1969) which has been widely applied to Tasmanian Tertiary basalts, the rock from Burburys Sugarloaf (004501) is a potassic nepheline hawaiite (*ne*>5%, *ab*>5%, andesine-normative plagioclase, $K_2O/Na_2O>1$). The rock from *Fosterville* (004507), which has very similar abundances of most elements but significantly higher Na_2O and lower K_2O, has oligoclase-normative plagioclase ($An_{27.4}$) and is thus classified as a nepheline mugearite. On the less widely accepted total alkali-silica classification of Le Maitre (1984), both rocks fall in the basanite field.

Because of the presence of abundant lherzolite nodules and derived debris in both rocks, the whole-rock compositions (Table 7) probably do not exactly represent the true composition of the host magma. In particular, MgO (and 100Mg/Mg + Fe), Ni and Cr are probably slightly exaggerated. On the other hand, the abundance of opaque iron oxides, seen in thin section, and the lack of petrographic evidence for strong oxidation, suggests that the high Fe_2O_3 content of the analysis is a primary feature. Thus the assumed ratio of Fe_2O_3/FeO of 0.15, used to calculate the CIPW norms, may be unrealistically low. A higher ratio would not only increase *mt* but decrease the degree of silica undersaturation in the norm (decrease *ne* and therefore increase *ab*).

The higher K_2O content of the Burburys Sugarloaf rock (004501) is consistent with the petrographic presence of groundmass biotite. However it is unclear whether the lower K_2O and higher Na_2O of the *Fosterville* rock (004507) are primary features, perhaps due to biotite rather than amphibole fractionation at high pressures (see below), or are due to late-stage metasomatism, perhaps on an outcrop scale due to the crystallisation of poikilitic plates of anorthoclase and sodic plagioclase. Thus the question as to whether the *Fosterville* rock is a flow remnant or a separate plug remains unresolved without further study.

Although the presence of spinel lherzolite nodules, at both Burburys Sugarloaf and *Fosterville*, implies that the magma rose rapidly from the mantle, without fractionating at crystal levels, the 100Mg/Mg + Fe values are far below those (68–72) expected of undifferentiated primitive magmas (Frey *et al.*, 1978), as are the Ni values. Substantial crystal fractionation at mantle levels, prior to entrainment of the lherzolite xenoliths, is required. At these depths, phases additional to olivine would be involved. For a chemically similar nepheline hawaiite at The Nipples, near Antill Ponds (and about 25 km south of Burburys Sugarloaf), Sutherland (1985, 1989*a*) postulated derivation from a primitive basanite by about 25% fractionation of olivine, aluminous augite, and subordinate ulvospinel and magnetite. On the other hand, Green *et al.* (1974) showed that a basanite-nepheline hawaiite-nepheline mugearite lineage could be produced by fractionation of kaersutitic amphibole ± clinopyroxene ± olivine from a magma containing 2–6% H_2O at 10–20 kb. Fractionation of amphibole would tend to increase K/Na (see Green, 1989, p. 324–325) and could also account for the potassic nature of the Burburys Sugarloaf rock.

The comments of Sutherland (1989*a*) about "the lherzolite-bearing nepheline hawaiite from north-east Interlaken", apparently referring to unpublished data on the "South Burburys Sugarloaf" outcrop, are not applicable to the present data (004501, 004507), and thus that outcrop may represent a separate plug from Burburys Sugarloaf.

The postulated parental basanites, on the model of Frey *et al.* (1978), would be derived from 5–7% partial melting of mantle.

Critical element abundances (fig. 8) in both rocks (004501, 004507) are broadly similar to those from Tertiary nepheline hawaiites elsewhere in eastern Australia (Ewart and Chappell, 1989). Somewhat higher values for the incompatible elements Nb, Ce, P_2O_5 and Zr may reflect the relatively fractionated nature of these rocks, a slightly lower degree of partial melting, or mantle heterogeneity. Higher values for Y may indicate the absence of garnet from the residue after partial melting.

Alkali Olivine Basalt(?)

Barton Road, Epping Forest (IH63/10 m)

The only known possible alkali olivine basalt from the Lake River Quadrangle was found at a depth of 10 m in a percussion hole (IH63) drilled in Tertiary clay and sand, north of Barton Road and 1.9 km southwest of Epping Forest [275757] (Matthews, 1983). The basalt is not actually mentioned on Matthew's log, but occurs within an interval (6.1–15.2 m) described as "grey and brown even-grained clayey sand"; thus it may be a clast or perhaps a very thin rubbly flow.

A thin section, which has since (recently) been lost, was described by G. B. Everard (*in* Matthews, 1983):

"The specimen is a fine-grained black rock with visible sparkling prismatic crystals and some granular honey-coloured masses.

5 cm

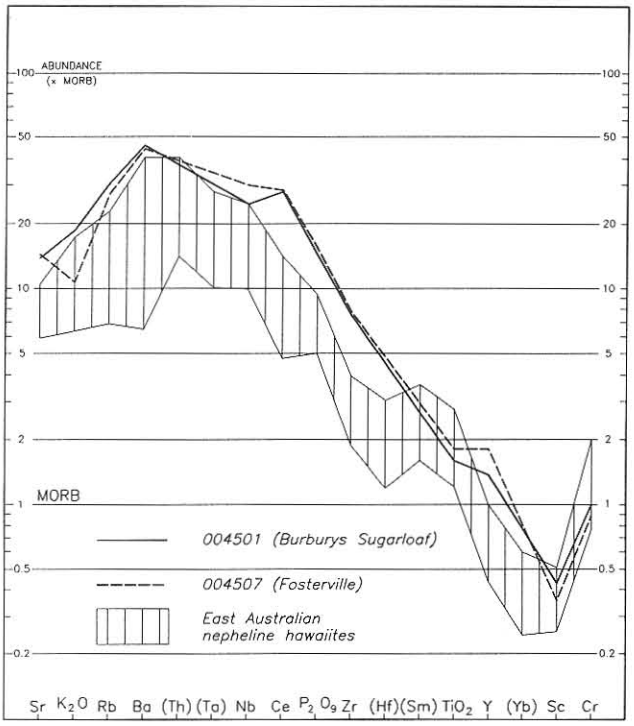


Figure 8. *MORB-normalised element abundances for nepheline hawaiite and nepheline mugearite, Lake River Quadrangle. Mid-ocean ridge basalt normalisation factors (Sr = 120 ppm,* K_2O *= 0.15%, Rb = 2 ppm, Ba = 20 ppm, Ce = 10 ppm,* P_2O_5 *= 0.12%, Zr = 90 ppm,* TiO_2 *= 1.5%, Y = 30 ppm, Sc = 40 ppm, Cr = 250 ppm) from Pearce (1980). Range of East Australian nepheline hawaiites (Ewart and Chappell, 1989) also shown.*

"In thin section, the texture is intersertal, consisting of laths of labradorite up to 1 mm long and prisms of titanaugite with interstitial black glass and a little granular olivine. Olivine is also present as occasional larger euhedral crystals, about 1 mm long showing alteration along irregular cracks. The titanaugite and labradorite tend to be in ophitic relationship. A little brownish carbonate is also present."

The presence of titanaugite, and also interstitial granular olivine, strongly suggests that the rock is an alkali olivine basalt, or perhaps a basanite. Less undersaturated basalts, such as transitional olivine basalt and tholeiite, typically contain colourless, non-titaniferous augite, whilst more undersaturated basalts such as olivine nephelinite typically lack plagioclase.

Tertiary basalt cropping out east and south of this locality, as well as boulder-sized basalt float on the surface in the immediate vicinity, are quartz-tholeiite to olivine-tholeiite, or rarely transitional olivine basalt (see below).

The nearest known titanaugite-bearing alkali olivine basalt, comparable to this specimen, occurs 20 to 25 km to the NNW in the vicinity of Longford, Perth and Western Junction (Edwards, 1950; Sutherland, 1971; Matthews, 1974, 1983). This locality may therefore represent the southern limit of an association of dominantly alkali olivine basalt found in the northern Longford Basin and Tamar Trough. However no outcropping or sub-surface basalt is known in the intervening area around Powranna.

Quartz and Olivine Tholeiites

Considered areally or volumetrically, nearly all the Tertiary basalt within the quadrangle is assigned to this association. As mapped it occupies an area of about 44 km^2, but this includes many small probable flow remnants, and much basalt is probably concealed beneath younger sediments. Thus before erosion or cover, the initial extent may have been three or four times greater than present. This tholeiitic association extends beyond the confines of the quadrangle to the SSE, east and northeast. Within the quadrangle these rocks form extensive flows on plains from south of Campbell Town to Epping Forest and *Glen Esk*, through which, in places, the more resistant Jurassic dolerite projects as small hills. Less commonly the basalt rests on Triassic sandstone. Sub-basalt Tertiary sediments are rarely exposed.

The subdued topography makes the thickness of the basalt difficult to estimate in many places. North of Hoggs Ford [near 361561], where the Macquarie River has cut through to dolerite, the basalt is, after an unknown amount of erosion, about 45 m thick. Likewise 2 km west of Campbell Town [at 384586] its present thickness may be about 30 metres. However at both these localities the underlying dolerite basement appears to be irregular. More reliable estimates can be obtained from drill holes further to the north. The present thickness near *Snaresbrook* (IH60, EP394636) is 19.8 m; east of Conara (IH59, EP396668) it is 21.3 m; but south of *Glen Esk* (IH61, EP393723) it is only 1.5 metres.

An initial volume of basalt, within the quadrangle, of the order of 2–5 km^3 seems likely.

In most cases feeders for the flows have not been located. Near *Truelands*, about 10 km ENE of Campbell Town in the Snow Hill Quadrangle, a prominent ridge of tholeiitic basalt rises to over 460 m at EP502615 (Gulline *et al.*, 1991). As is long known (Nye, 1926) this almost certainly represents the site of a major vent, from which flows up to 100 m thick moved down the ancestral Elizabeth River valley, contributing to the basalt plains around Campbell Town. The Elizabeth River was probably thus diverted from its original course, which may have lain well to the north of the present river. Edwards (1950) described Vineys Sugarloaf [347814], a small hill in the Longford Quadrangle, as a "distinctive small point of eruption". Small hillocks east of the Midland Highway, between Campbell Town and Conara [at 385634 and 382644], may be small vents, or perhaps merely residuals. Other vents or fissures have probably fed the flows, but are now concealed. Magnetic methods would probably not as readily identify the feeders as elsewhere in Tasmania, as the dominant basement rock (dolerite) has a higher magnetic susceptibility than the basalt (Table 6).

In addition to the probable diversion of the Elizabeth River mentioned above, the tholeiite flows probably diverted the Macquarie River westward from an original course east of Mt Augusta (Nye, 1926, p. 18; Matthews, 1983, p. 55) and may have diverted the South Esk River near *Glen Esk* [395755] from an earlier, more westward course through Cleveland and Epping Forest (Matthews, 1983).

In hand specimen, most of the basalts are vesicular and many appear quite weathered; however they often appear surprisingly fresh in thin section. Typically they are dark to medium grey, usually with a slight greenish or olive tint. Most common colours (Geological Society of America rock colour chart, 1991) are medium-dark grey (N4), greenish-grey (5GY6/1), dark greenish-grey (5GY4/1) and light olive-grey (5Y6/1). The two dark grey (N3) specimens contain a substantial amount of glass in thin section (004525, 004536). Unusually pale (004523, Conara; light greenish-grey, 5GY8/1) or greenish (004529, Cleveland Lagoon; greyish yellow-green, 5GY7/2) colours seem to be correlated with large amounts of poorly crystalline alteration products in thin section.

Vesicles range from scattered, sub-spherical to elongate voids 5–10 mm across, to more frequently small (<1 mm), inconspicuous, irregularly-shaped voids, sometimes with amygdaloidal clayey fillings. The smaller vesicles may be very abundant. Few specimens are completely massive (004508, 004525, 004534).

The basalt weathers variably but has not produced the deep soils which occur on basalt along the North West Coast. In general, the Lake River Quadrangle basalts form sandy soils, perhaps due to the drier climate and/or the relatively siliceous, tholeiitic composition of the basalt. Where the basalt has been lateritised, particularly around Campbell Town, iron-rich soils occur. There is also some massive laterite, and low grade bauxite, overlying the basalt (WLM).

Laterite and bauxite also occur around Vineys Sugarloaf in the southeast corner of the adjoining Longford Quadrangle (Blake, 1959). During examination of the basalts for these Explanatory Notes, a visually striking orange-brown pisolitic ironstone (004551) was collected from the Vineys Sugarloaf area [349815]. This rock consists of black to orange-brown, well-rounded to subrounded pisolites 1–4 mm across, tightly cemented by a more pale orange-brown matrix with a few irregular to narrowly elongate voids. A sample (004552) of pale orange-brown, earthy bauxite from the Sugarloaf itself contains dominantly gibbsite, minor kaolinite, and very minor goethite (R. N. Woolley, X-ray diffraction). The bauxite is discussed in the Economic Geology section.

PETROGRAPHY

Summary

Detailed petrographic descriptions of selected samples, including all those analysed, are given below. Comparative notes are given for most others. The petrography of all samples is summarised in Table 9.

About 60% of the basalts, as sampled, contain olivine phenocrysts, including both olivine-normative and quartz-normative types. In the latter case the olivine, as indicated by embayment, is a quenched liquidus phase which would have been resorbed had perfect equilibrium crystallisation taken place.

About 10% of the samples contain orthopyroxene phenocrysts. All the samples analysed are quartz-normative tholeiites, and it is very likely that the remainder are also. They may have inverted from pigeonite, or crystallised directly, during slow cooling in a crustal magma chamber.

Plagioclase and clinopyroxene microphenocrysts are rare and probably merely represent slightly coarser, earlier crystallised groundmass phases.

Pigeonite and augite, distinguished by their optic angles, are both present in the groundmass of many samples, but others appear to contain only one or the other. This does not seem to correlate in any obvious way with whole-rock chemistry or texture. However this method of determination may be too crude, as a continuous compositional range of sub-calcic pyroxene is doubtless present.

The basalts vary widely in grain size, texture (ophitic to intergranular/intersertal), and abundance of glass (although most are holocrystalline or nearly so). Edwards (1950) and McDougall (1959) classified similar tholeiitic "basalts with black glass" into five textural types: Ouse type (glassy); Bridgewater type (intersertal to intergranular); Pontville type (intersertal to ophitic); Jordan type (more or less holocrystalline, intergranular); and Midlands type (more or less holocrystalline, ophitic). On this basis, most of these basalts would be assigned to the Jordan or Midlands type, a few to the Bridgewater type, and at least two (004516, 004536) to the Ouse type. However this classification is of limited petrological significance.

2 km north of Ross (sample 004508) (Plate 25)

In hand specimen the rock is medium to dark grey (N4), massive and fairly fresh. In thin section it consists of rather sparsely distributed olivine phenocrysts in a fine-grained intergranular groundmass.

The olivine phenocrysts (≤2 mm but typically 300 µm–1 mm across) are subrounded subhedra and anhedra, partially embayed by the groundmass. They occur as isolated grains or are clumped together in small glomerocrysts. Around their margins and internal cracks they may be altered to very fine-grained, nearly opaque cryptocrystalline material, but are otherwise fairly fresh.

The groundmass contains stubby to narrowly elongate, unorientated plagioclase laths typically 100–200 µm long, with intergranular pale grey angular clinopyroxene granules (mostly ≤50 µm); small, elongate to irregularly angular opaque grains; minor interstitial khaki brown-green glass; and common but inconspicuous secondary carbonate.

The plagioclase is labradorite (about An_{65}) as determined by the Michel-Levy method, and the clinopyroxene granules include both augite (biaxial positive) and pigeonite (nearly uniaxial, positive).

2 km south of Campbell Town (004509)

This rock is greenish-grey (5GYG/1) and vesicular, containing numerous very small (≤0.5 mm) and scattered subspherical larger vesicles (≤2 mm). In thin section the rock contains scattered orthopyroxene phenocrysts in a fine-grained intergranular groundmass.

The orthopyroxene phenocrysts are elongate to equant subhedra and euhedra, typically 500 µm–1.5 mm long, and sometimes slightly resorbed by the groundmass with thin discontinuous reaction rims. Occasionally they are clumped together in interlocking glomerocrysts of two to eight grains.

The groundmass consists of unorientated plagioclase laths (typically 100–200 × 20–50 µm), intergranular clinopyroxene granules (30–150 µm), and irregularly angular (50 mm) to elongate or acicular (up to 350 × 10 µm) opaque minerals. Small amounts of a turbid mesostasis contain pale purple-brown glass, opaque dust and possible alkali feldspar. About 20% of the rock is void.

TABLE 9
Summary of petrography, Tertiary tholeiitic basalts

Registered number	Chemical type (1)	Phenocrysts (2)	Groundmass Grain Size (3)	Groundmass Texture	Groundmass Mineralogy (4)	Comments
004508*	T	olivine common, ≤2 mm	f	intergranular	pigeonite, augite	secondary carbonate present
004509*		opx sparse, ≤1 mm	f	intergranular	pigeonite, augite	
004510*	T	olivine common, ≤1 mm	f	intergranular	augite	flow lamination present
004511		olivine sparse, ≤2 mm	m	ophitic/subophitic	augite	
004512		(?)olivine sparse, ≤1 mm (?)opx sparse, ≤1 mm	f	intergranular	pigeonite	rare quartz xenocrysts present
004513		olivine sparse, ≤500 μm, altered	f	intergranular	augite	olivine replaced by carbonate, iddingsite
004514*	Q	olivine sparse, ≤1 mm	m	ophitic	pigeonite>augite	olivine mostly iddingsitised
004515		olivine sparse, ≤1 mm	m-c	intersertal/intergranular	augite	
004516*		olivine common, ≤2 mm	f-m	glassy	olivine	
004517		olivine sparse, ≤1 mm	f-m	ophitic	augite	
004518*	Q	opx common, ≤1 mm	m	intergranular/subophitic	augite>pigeonite	
004519*	Q	-	m	intergranular	augite >pigeonite	
004520*		opx sparse, ≤3 mm cpx rare ≤500 μm plagioclase rare, ≤500 μm	f	intergranular	augite	secondary hematite present
004521		(?)olivine rare, ≤1 mm, altered	f-m	intergranular	augite, pigeonite	olivine replaced by clay minerals
004522		-	m-c	intergranular	augite	secondary hematite abundant
004523		opx sparse, ≤500 μm cpx sparse, ≤500 μm	f-m	intergranular/intersertal	augite	
004524		-	c	intergranular/intersertal	augite, pigeonite	secondary hematite present
004525*	T	-	c	glassy	olivine, augite	nearly fresh
004526		-	c	intergranular/subophitic	pigeonite>augite	secondary hematite abundant
004527*		-	c	intergranular	pigeonite, augite	
004528*	Q	opx common, ≤1.5 mm	m	intergranular/intersertal	augite>pigeonite, opx	
004529		-	f-m	intergranular	pigeonite	
004530*		-	m	intergranular	pigeonite	
004531		olivine rare, ≤500 μm, altered	f-m	intergranular/subophitic	augite>pigeonite	olivine iddingsitised
004532		olivine rare, ≤2 mm, altered	f-m	subophitic	augite	olivine iddingsitised
004533		olivine sparse, ≤1 mm, altered	f-m	intergranular	augite (>>pigeonite?)	olivine replaced by clay minerals
004534*	T	olivine sparse, ≤1 mm	m	subophitic/ophitic	augite>pigeonite	
004535		(?) olivine sparse, ≤500 μm, altered plagioclase (xenocrysts?) rare	m	subophitic	augite	olivine replaced by clay minerals
004536*	Q	-	c	glassy	olivine	minor secondary carbonate present
004538*	R	olivine abundant, ≤2.5 mm	m	intersertal	olivine, augite	pigeonite (?) xenocryst present
004539		-	m	subophitic	augite (>>>pigeonite?)	
004540		(?) olivine sparse, ≤1 mm, altered	f	intergranular	augite	olivine replaced by clay minerals
004541*		olivine rare, ≤500 μm	f	ophitic	augite	
004542		-	f	intergranular/subophitic	augite	secondary hematite abundant
004543*	T	olivine sparse, ≤800 μm	m-c	subophitic	augite, pigeonite	minor secondary carbonate present
004544		olivine rare, ≤500 μm	c	subophitic/ophitic	augite, pigeonite	secondary hematite abundant
004545*	Q	opx sparse, ≤1 mm	m	subophitic	augite, pigeonite, opx	secondary hematite present
004546		(?) olivine sparse, ≤1 mm altered	f-m	intergranular	pigeonite	olivine replaced by clay minerals
004547*	T	olivine common, ≤1 mm	f	intergranular	augite, pigeonite	minor secondary hematite present
004548		olivine common, ≤1 mm	f-m	intergranular/intersertal	augite, pigeonite	yellowish clay mineral in amygdales
004549		-	f-m	intergranular	augite, pigeonite	secondary hematite and minor carbonate present
004550		(?)olivine sparse, ≤1 mm, altered	f-m	intergranular/intersertal	pigeonite>augite	olivine replaced by iddingsite, clay minerals.

* See detailed description

(1) Q = quartz tholeiite, T = olivine tholeiite, R = transitional olivine basalt

(2) opx = orthopyroxene; cpx = clinopyroxene

(3) f = fine grained, plagioclase laths generally ≤200 μm long; m = medium grained, 200–500 μm; c = coarse-grained, ≥500 mm

(4) all samples contain plagioclase, all except glassy ones (004516, 004525, 004536) contain well crystallised, ilmenite and/or magnetite.

The groundmass clinopyroxene includes both pigeonite and augite.

A similar intergranular, orthopyroxene-phyric basalt (72-306), collected from 2.5 km west of Campbell Town, was described by G. B. Everard (*in* Matthews, 1983, p. 58). The orthopyroxene was described as enstatite but, as the thin section has been lost, it is not possible to compare the two rocks.

Forster Street, Campbell Town (sample 004510)

The hand specimen is a relatively fresh, dark greenish-grey (5GY4/1) basalt with a few irregular to flattened elongate vesicles up to 5 mm long. In thin section, the rock consists of numerous olivine phenocrysts in a fine-grained intergranular groundmass, in which alignment of plagioclase laths defines a strong flow lamination.

The olivine phenocrysts, which show incipient to partial alteration to brown iddingsite, are equant to somewhat elongate, sometimes strongly embayed subhedra and euhedra, up to 1 mm across but commonly about 500 µm or less, grading downward to the groundmass.

The groundmass consists of aligned small plagioclase laths (typically 100–200 × 10–20 µm), equant anhedral granules of colourless clinopyroxene (typically 50–100 µm), olivine (typically 50 mm, grading upward in size to phenocrysts), and numerous, irregularly polygonal to very elongate opaque minerals. Some interstitial alkali feldspar may be present. A pale yellow-brown, poorly crystalline alteration product is common in the mesostasis, and as a lining of vesicles.

The groundmass clinopyroxene is largely or wholly augite.

A specimen (004513) collected about 3.5 km west of this locality is a similar but more altered, fine-grained intergranular basalt in which the olivine phenocrysts have been replaced by carbonate and minor iddingsite.

G. B. Everard (*in* Matthews, 1983, p. 57–58) described a similar olivine-phyric intergranular-textured specimen (72-304) collected nearby. He described the plagioclase as andesine.

Macquarie River, 5 km SW of Campbell Town (004514)

The hand specimen is a dark greenish-grey (5GY4/1) basalt, containing very abundant but small (≤1 mm) vesicles. In thin section, the rock contains very sparsely distributed olivine phenocrysts in an ophitic groundmass of plagioclase, clinopyroxene, opaque materials and much void.

The olivine phenocrysts, which comprise less than 1% of the rock, are typically equant to slightly elongate, sometimes embayed, polygonal euhedra and subhedra, 500 µm–1 mm across. They are largely replaced by dark brown iddingsite, but a few remnant cores are present.

The groundmass consists of unorientated plagioclase laths (typically 150–400 × 30–60 µm), frequently enclosed by platelets of clinopyroxene (500 µm–1 mm) and irregularly angular to elongate opaque grains, some several hundred micrometres long. A few poorly crystalline interstitial patches, containing densely disseminated opaque dust, may be incipiently crystallised glass. Pale yellow-brown, fine-grained, low birefringence alteration products are found as a lining to the numerous subspherical to irregularly-shaped voids.

The groundmass clinopyroxene is dominantly pigeonite, but with subordinate augite, and the plagioclase is probably mainly sodic labradorite. However some untwinned, optically positive interstitial feldspar may be a more sodic plagioclase.

Samples 004511 and 004517, also from the Campbell Town area, are similarly sparsely olivine-phyric, ophitic to subophitic-textured basalts. However in these specimens the clinopyroxene is largely or wholly augite.

Merton Vale (004516)

This is a rather weathered, medium to dark grey (N4) basalt with numerous irregular vesicles up to 10 mm or more long, lined and sometimes filled with earthy yellow-green alteration products. In thin section the rock consists of abundant, euhedral to subhedral, sometimes embayed olivine phenocrysts (≤2 mm), which grade in size downward to a groundmass of olivine granules, plagioclase laths (100–400 µm long) and abundant black glass. Under high magnification and strong illumination the glass is resolvable into numerous acicular microlites and opaque dust. Yellow-orange to orange-red alteration is associated with the glass and the numerous vesicles, but olivine is quite fresh.

Another sample (004515), collected from a few hundred metres away, is the less quenched equivalent of 004516. It consists of olivine phenocrysts in an intersertal to intergranular groundmass of plagioclase, clinopyroxene (augite), opaque material and only minor interstitial black glass.

Macquarie Road (sample 004518)

The hand specimen is a somewhat weathered, greenish-grey (5GY6/1) basalt, containing very abundant, small (<0.5 mm) vesicles, sometimes lined with an earthy, pale yellow-green alteration product. In thin section, the rock consists of abundant (about 5% by volume) orthopyroxene phenocrysts in a medium-grained, intergranular to subophitic groundmass. Olivine is absent.

The orthopyroxene phenocrysts are typically polygonal to elongate subhedra, 500 µm–1 mm × 200–400 µm. The mineral is biaxial negative with a moderate 2V and birefringence, and is probably bronzite or hypersthene, rather than enstatite. A few phenocrysts are mantled with a discontinuous reaction rim, possibly of pigeonite.

The groundmass contains unorientated plagioclase laths (typically 150–400 µm long), partly surrounded subophitically by irregularly-shaped granules of clinopyroxene (100–300 µm), together with both irregularly angular equant and very elongate to acicular (to 400 × 5 µm) opaque minerals (?ilmenite and ?magnetite). Poorly crystalline cloudy patches with disseminated opaque dust may be incipiently crystallised glass. Numerous voids are present.

The groundmass pyroxenes are dominantly augite with subordinate pigeonite, and the plagioclase is labradorite (about An_{60}).

Hill near Snaresbrook (sample 004519)

The hand specimen is a dark greenish-grey (5GY4/1), slightly and very finely vesicular (<0.5 mm) basalt.

In thin section the rock is aphyric, and consists of an intergranular meshwork of plagioclase laths (200–400 μm), frequently elongate clinopyroxene grains, and equant to narrowly elongate (e.g. 100–200 × 10–30 μm) opaque minerals. Smaller, more equant grains of the same minerals occupy the interstices. Numerous voids are present.

The clinopyroxene, which is often turbid because of incipient alteration, is mainly augite with subordinate pigeonite. Plagioclase laths are labradorite (about An_{60}), but some of the interstitial material may be more sodic.

A specimen (004522) collected from south of Conara, about 3.5 km NNW of this locality, is very similar, but contains abundant interstitial and amygdaloidal hematite, readily visible in hand specimen, indicating the onset of lateritisation.

4 km east of Conara (004520)

The hand specimen is light olive-grey (5YG/1) and finely vesicular (mostly <0.5 mm but ≤2 mm). In thin section it consists of sparse orthopyroxene phenocrysts and rare microphenocrysts of plagioclase and clinopyroxene, in a fine-grained, flow-laminated intergranular groundmass.

The orthopyroxene phenocrysts, 500 μm–3 mm long, are commonly elongate, but are anhedral due to resorption by the groundmass, which is locally enriched in clinopyroxene adjacent to the phenocrysts. Sometimes they are clumped together in interlocking glomerocrystal aggregates.

The plagioclase and clinopyroxene microphenocrysts are up to a few hundred micrometres long, and grade down in size to the groundmass, which consists of plagioclase laths (typically 100–200 × 20–40 μm), augite granules (mostly ≤100 μm), generally narrowly-elongate opaque grains (≤300 μm long) and minor patches of a turbid mesostasis. About 20–25% of the rock is void. Interstitial and amygdaloidal fillings of deep-red hematite indicate incipient lateritisation. The orthopyroxene phenocrysts are optically negative, and probably are ferroan bronzite or hypersthene, whilst the groundmass pyroxene is largely or wholly augite.

A similar, but more weathered specimen (004523), was collected about 6 km to the west, near Conara.

3 km ENE of Stockwell (004525) (Plate 26)

The hand specimen is a massive, dark grey (N3) basalt in which plagioclase laths are clearly visible to the naked eye. In thin section the rock consists of large, oblong to very elongate plagioclase laths (500 μm–2.5 mm × 100–300 μm); much smaller, equant olivine euhedra and subhedra (50–200 μm); and a groundmass of black glass which comprises 40–50% of the rock.

Under strong illumination, the glass can be resolved into randomly oriented, very narrow to acicular, birefringent microlites of plagioclase and augite, and very fine-grained opaque dust. Except for occasional orange-brown to yellow-brown iddingsite developed from olivine granules, the rock is quite fresh.

Plagioclase is labradorite (An_{65-70}), and the negative optic sign of olivine indicates that it is relatively iron rich ($Fo_{<87}$).

Stockwell (004527)

The hand specimen is a light olive grey (5YG/1) rock with numerous small (<1 mm) vesicles and plagioclase laths clearly visible to the naked eye. In thin section, the rock is a coarse-grained, aphyric basalt with a dominantly intergranular texture. It consists of unorientated laths of plagioclase (typically 500 μm–2 mm long by 150–500 μm across), irregularly anhedral clinopyroxene granules (100–500 μm), irregular to commonly narrowly elongate opaque grains (≤500 μm long), and a little interstitial clear pink to brown glass. Minute acicular crystallites, too narrow to show birefringence, are present within the glass. About 15% of the rock is void.

The plagioclase is labradorite (An_{65-70}), and the clinopyroxene comprises pigeonite and augite in about equal proportions.

A patchy brownish alteration of pyroxene, and less commonly glass, pervades the slide.

Samples 004526 and 004524 (Plate 27), also from this area, are similar aphyric coarse-grained basalts. The former is slightly finer grained with some development of subophitic texture, whilst the latter has an intersertal texture, with substantial amounts of interstitial turbid black glass. Both contain botryoidal masses of dark red hematite, suggesting incipient lateritisation.

Diprose Lagoon (004528) (Plate 28)

In hand specimen the rock is greenish-grey (5GY6/1) with numerous, very small (<0.5 mm) vesicles. In thin section it contains numerous orthopyroxene microphenocrysts, which are only slightly larger than the intergranular/intersertal groundmass.

The orthopyroxene microphenocrysts are typically oblong subhedra, 500 μm–1.5 mm long and up to 500 μm wide, grading down in size to the groundmass. The negative optic sign, and low to moderate birefringence, suggest a relatively iron-rich composition, probably ferroan bronzite or hypersthene. A few microphenocrysts are partly mantled by a very narrow, discontinuous reaction rim, probably clinopyroxene.

The groundmass consists of unorientated plagioclase laths (typically 200–400 × 20–50 μm), angular pyroxene granules (100–400 μm), mostly very elongate to acicular opaque grains (several hundred micrometres long and ≤10 μm wide), and interstitial patches of poorly crystalline turbid mesostasis containing much opaque dust. Numerous irregularly-shaped voids comprise about 25% of the section.

The groundmass pyroxene is mainly augite, but subordinate orthopyroxene and minor pigeonite are present. Plagioclase is probably mainly labradorite (about An_{70}).

Cleveland Lagoon (004530)

The hand specimen is a light olive grey (5Y6/1), densely and finely (≤0.5 mm) vesicular rock, which shows signs of oxidation and incipient lateritisation. In thin section it is aphyric and intergranular, consisting of unorientated

5 cm

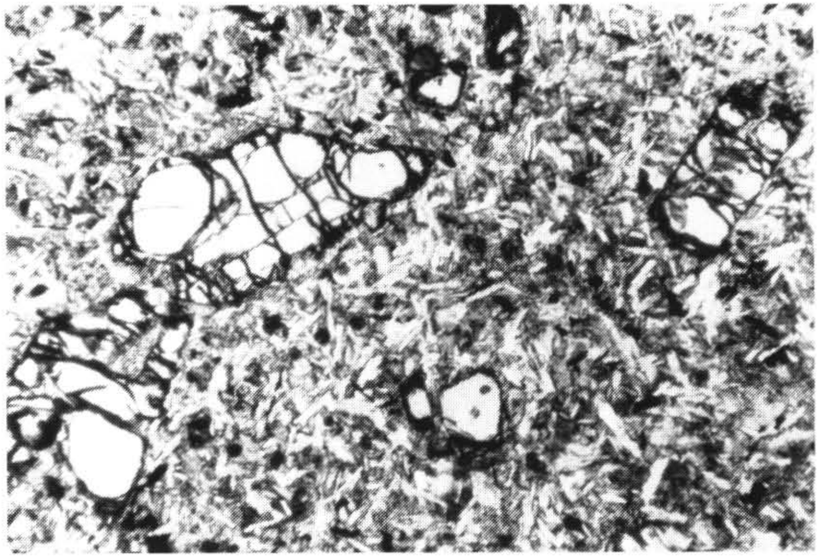


Plate 25. *Sample 004508, Tertiary basalt (olivine tholeiite), 2 km north of Ross. Partly resorbed olivine phenocrysts in a fine-grained intergranular groundmass. Plane polarised light, field of view 4.4 × 2.9 mm.*

Plate 26. *Sample 004525, Tertiary basalt (olivine tholeiite), near Stockwell. Coarse-grained intersertal basalt consisting of plagioclase laths and black glass containing small augite grains. Plane polarised light, field of view 4.4 × 2.9 mm.*

Plate 27. *Sample 004524, Tertiary basalt, near Kenilworth. Coarse-grained intergranular/intersertal basalt consisting of plagioclase laths (light), clinopyroxene (grey) and interstitial black glass. Plane polarised light, field of view 4.4 × 2.9 mm.*

Plate 28. *Sample 004528, Tertiary basalt (quartz tholeiite), Diprose Lagoon. Orthopyroxene phenocryst (centre) in a medium-grained, intergranular/intersertal groundmass, with minor black glass. Plane polarised light, field of view 4.4 × 2.9 mm.*

5 cm

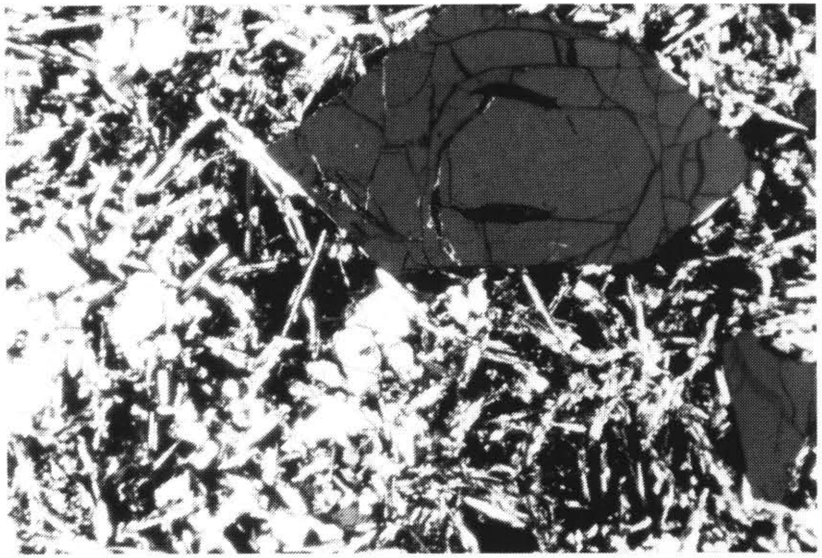


Plate 29. *Sample 004538, Tertiary basalt (transitional olivine basalt), Belle Vue Road. Euhedral olivine phenocrysts in a medium-grained intersertal groundmass with interstitial black glass. Crossed nicols, field of view 4.4 × 2.9 mm.*

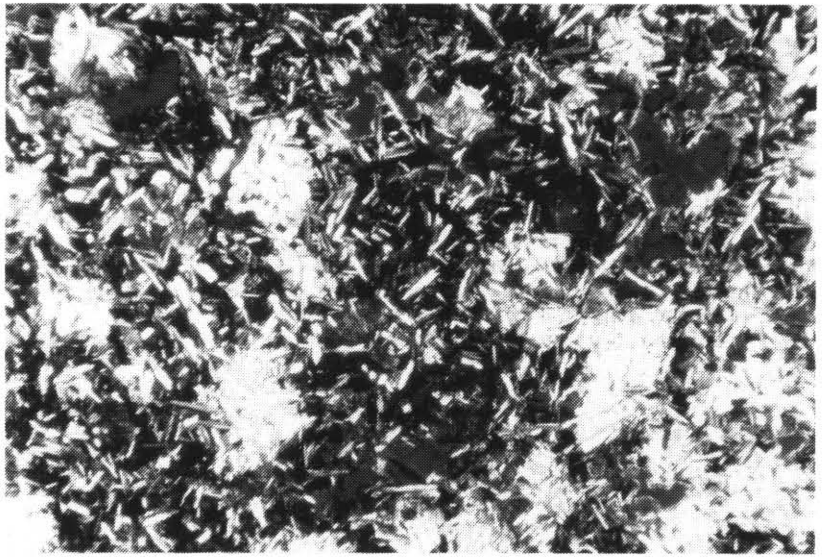


Plate 30. *Sample 004541, Tertiary basalt, Kallatie Road. Ophitic intergrowth of augite and small plagioclase laths. Crossed nicols, field of view 4.4 × 2.9 mm.*

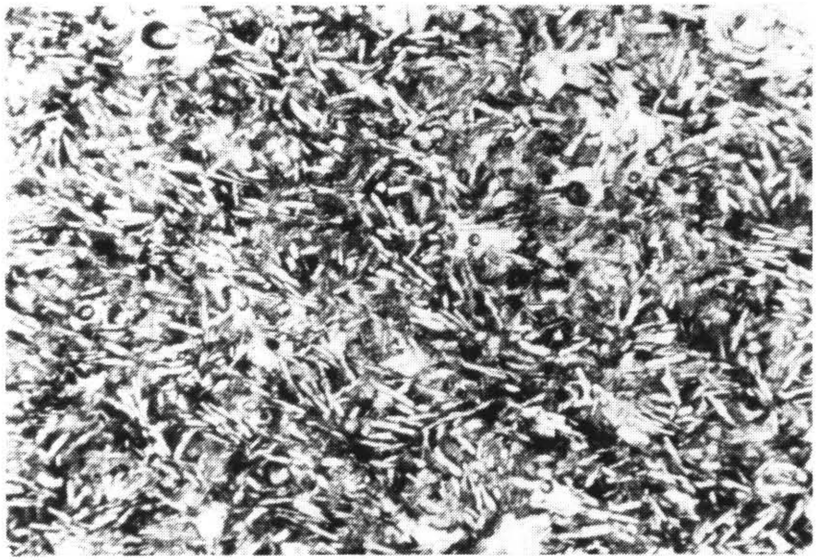


Plate 31. *Sample 004542, Tertiary basalt, Vineys Sugarloaf. Aphyric, fine-grained, intergranular to subophitic basalt. Plane polarised light, field of view 4.4 × 2.9 mm.*

Plate 32. *Sample 004543, Tertiary basalt (olivine tholeiite), Shooters Hill. Sparsely distributed olivine phenocrysts (left, pale) in a medium to coarse-grained subophitic groundmass of mainly plagioclase and clinopyroxene (grey). Plane polarised light, field of view 4.4 × 2.9 mm.*

plagioclase laths (200–500 × 20–70 μm), subhedral to anhedral clinopyroxene granules (50–200 μm), and scattered, angular and equant or more typically narrowly elongate opaque grains (50–200 μm long). The clinopyroxene appears to be entirely pigeonite, and the plagioclase mostly labradorite (about An_{55}). About 20–25% of the rock is void. Deep red to almost opaque hematite is commonly associated with the vesicles.

Sample 004529 from this area is very similar. Its greyish yellow-green (5GY7/2) colour is attributed to a very fine-grained, low birefringence clayey filling of vesicles apparent in thin section.

Woorak (sample 004534)

In hand specimen the rock is rough, massive, medium to dark grey (N4) and fairly fresh. In thin section it consists of rather sparsely distributed olivine phenocrysts in a subophitic to ophitic groundmass of clinopyroxene, plagioclase and some fine-grained interstitial alteration products.

The olivine phenocrysts are generally equant subhedra, not strongly embayed, and not much larger (≤1.5 mm, but usually ≤500 μm) than the groundmass. The mineral has an optic angle near 90°, and is probably fairly magnesian.

Plagioclase laths are unorientated, typically 200–400 μm long and 30–80 μm across, and are often partly (subophitically) or wholly (ophitically) surrounded by irregularly equidimensional platelets of clinopyroxene, typically about 500 μm across. Scattered irregular, angular to elongate opaque grains (100–300 μm) are present.

The clinopyroxene is mainly augite, but with subordinate pigeonite, and the plagioclase is probably mainly labradorite.

A turbid, fine-grained mesostasis, containing densely disseminated opaque blebs (a few micrometres) and dust, very finely acicular apatite, and colourless to pale purplish glass, is present in interstices. Alteration is largely confined to the mesostasis, and includes irregular patches of fine-grained, brown-stained carbonate, sometimes rimmed by isotropic yellow to yellow-brown palagonite.

Several samples from this area are essentially similar, but are more altered (004532, 004535) and/or apparently contain fewer olivine phenocrysts and a less well developed subophitic texture (004531, 004539). Samples 004533 and 004540 are mineralogically similar, with sparsely distributed and completely altered olivine phenocrysts, but have an intergranular groundmass texture. In all these samples, pyroxene is dominantly augite, with little or no pigeonite.

Barton Road (004536)

The rock is a massive, dark grey (N3) fresh basalt in which plagioclase laths are clearly visible in hand specimen. In thin section it consists of large laths of plagioclase (labradorite/bytownite, about An_{70}) typically 500 μm–1.5 mm long and 50–250 μm wide; much smaller equant, subhedral to euhedral olivine granules (25–100 μm) and black glass, which comprises about 40% of the thin section. Acicular to skeletal terminations of plagioclase laths within glass are common. Under strong illumination and high power, the glass is seen to be a turbid mass of elongate, incipiently birefringent plagioclase and (?)olivine or pyroxene microlites, and densely disseminated opaque dust. Within the glass there are a few irregular small amygdales (50–100 μm) across filled with botryoidal, brown-stained carbonate.

The rock is very similar to another glassy tholeiite (004525) from near *Stockwell* (see above).

Belle Vue Road (004538) (Plate 29)

The hand specimen is a fairly fresh, medium to dark grey (N4), nearly massive basalt, containing a few scattered, small (<0.5 mm) vesicles, and olivine phenocrysts (≤2.5 mm) visible to the naked eye. In thin section the rock consists of abundant olivine phenocrysts in a dominantly intersertal groundmass of plagioclase, clinopyroxene, olivine and about 15% black glass.

The olivine phenocrysts, which comprise about 15% of the rock, are typically equant euhedra or embayed to rarely almost skeletal subhedra, mostly 500 μm–1 mm across but up to 2.5 mm. They are frequently clumped into glomerocrysts. Some of the phenocrysts have a positive optic sign, so they are probably fairly magnesian (Fo_{87}). They are fresh, or have very slight iddingsitisation developed along fractures.

A single elongate, ragged anhedral phenocryst (5 × 1.5 mm) of clinopyroxene (probably pigeonite) is corroded by the glassy groundmass, with some development of sieve texture. It is probably a xenocryst of crustal origin.

The groundmass consists of unorientated plagioclase laths, typically 150–400 × 20–50 μm, small granules of clinopyroxene (10–20 μm), granules of olivine grading upward in size to phenocrysts, and intersertal turbid black glass. The plagioclase is labradorite (about An_{55}), and the groundmass clinopyroxene is largely or wholly colourless augite. Opaque minerals occur as small acicular to bleb or dust-sized grains, densely disseminated throughout the glass. Small amounts of finely crystalline, sometimes colloform, yellow-brown to red-brown alteration products are associated with the glass.

Kallatie Road (004541) (Plate 30)

The hand specimen is medium grey (N5) and contains numerous small vesicles (<0.5 mm) and a few larger, subspherical vesicles to 10 mm across. In thin section it contains rare, small, deeply embayed and partly iddingsitised olivine phenocrysts (≤500 μm) in an ophitic-textured groundmass, consisting dominantly of unorientated plagioclase laths (100–200 × 20–50 μm), and clinopyroxene platelets (300–500 μm across). Scattered, mostly narrowly elongate opaque grains (≤150 μm long) and a little dark, turbid to almost glassy, poorly crystalline mesostasis are also present. The clinopyroxene appears to be entirely augite.

A nearby sample (004542, Plate 31) from Vineys Sugarloaf (Longford Quadrangle) is similar, but olivine phenocrysts are completely absent and the groundmass texture is intergranular to subophitic. Abundant deep red, interstitial to amygdaloidal hematite indicates the onset of lateritisation.

Edwards (1950) described a specimen from this locality and quoted a quartz-normative chemical analysis.

Shooters Hill (004543) (Plate 32)

The hand specimen is an olive-grey (5Y4/1) rock containing very abundant small vesicles (≤1 mm) and a few larger subspherical vesicles 5–10 mm across. In thin section the rock contains rather sparsely distributed, fresh olivine subhedra (≤800 μm but mostly 200–400 μm), unorientated plagioclase laths (typically 200–600 × 50–150 μm) and more equant irregular polygons, subophitically intergrown with irregular polygonal clinopyroxene platelets (≤500 μm), and minor narrowly elongate (≤400 μm) to equant angular (50–200 μm) opaque grains. Some dark, turbid, finely crystalline mesostasis containing much fine-grained opaque dust is present interstitially.

The plagioclase is intermediate labradorite, and the clinopyroxene comprises both augite and pigeonite. Olivine is biaxial negative and is therefore relatively iron rich ($Fo_{<87}$).

About 20% of the rock is void. Alteration is largely confined to the mesostasis and the margins of the vesicles. The vesicles are locally filled with secondary carbonate.

Sample 004544, collected from about one kilometre to the southeast, is a similar but slightly coarser grained basalt. Its paler colour (light olive-grey, 5GY6/1) and the presence of deep red hematite in vesicles and amygdales suggests a greater degree of weathering and incipient lateritisation.

Glen Esk (004545)

This is a medium to dark grey (N4), finely vesicular (≤0.5 mm) basalt, with a few zones of coarser vesicles, 2–5 mm or more across, some with black hematitic or powdery white fillings.

In thin section the rock is more or less aphyric, with a subophitic texture, and consists of plagioclase, three types of pyroxene, opaque minerals and a little mesostasis.

Orthopyroxene is less common and slightly coarser grained than the clinopyroxenes, occurring as oblong, almost microphenocrystal subhedra up to 1 mm long. It is biaxial negative and thus is probably ferroan bronzite or hypersthene. It may have narrow reaction rims of clinopyroxene, and generally does not have a subophitic texture with plagioclase; it thus probably crystallised slightly earlier than the other minerals.

Plagioclase occurs as disoriented laths, typically 150–400 × 20–50 μm. It is labradorite (about An_{65}).

The other pyroxenes comprise about equal proportions of augite and pigeonite. They occur as very irregular, equant or sometimes elongate, subhedral to anhedral platelets 200–500 μm across.

Irregularly angular, equant to narrowly elongate opaque minerals are also present. Minor patches of fine-grained interstitial mesostasis contain much opaque dust.

Voids comprise about 25% of the thin section. Deep red-brown to almost opaque hematitic material, probably indicative of incipient lateritisation, is associated with these voids.

3 km south of Glen Esk (004547)

In hand specimen the rock is medium grey (N4) and nearly massive, with scattered, very small vesicles, and rare, subspherical or ellipsoidal larger vesicles up to 5 mm across. Some vesicles are filled with an earthy pale brown-orange material. Small olivine phenocrysts are visible to the naked eye.

In thin section the rock contains about 5% olivine phenocrysts in a fine-grained intergranular groundmass.

The olivine phenocrysts are typically equant, often embayed subhedra and euhedra, 200 μm–1 mm across. They occur as isolated grains, or are occasionally clumped together in glomerocrysts.

The groundmass consists of unorientated plagioclase laths (typically 100–250 μm), intergranular clinopyroxene granules (25–100 μm), and angular, equant to elongate opaque minerals. An interstitial, fine-grained opaque-rich mesostasis is also present.

The plagioclase is labradorite (about An_{60}) and the clinopyroxene includes both augite and pigeonite.

Deep red to almost opaque hematite, suggesting incipient lateritisation, is locally present in interstices and as an amygdaloidal filling.

Several other samples (004521, 004548, 004549, 004550) from this area northeast of Conara are essentially similar, differing in minor details such as the abundance of olivine, amount of mesostasis, grain size and degree of alteration. In sample 004546, which has less abundant olivine, clinopyroxene appears to be entirely pigeonite.

CLASSIFICATION, GEOCHEMISTRY AND PETROGENESIS

The thirteen analysed tholeiites (004508–004547, Table 7) are essentially similar and form a coherent group. Six with normative *Q* are classified as quartz-tholeiites, whilst the six with normative *ol* and more than 10% normative *hy* are classified as olivine-tholeiites. One sample (004538) from Belle Vue Road has less than 10% *hy* and is marginally classified as a transitional olivine basalt, although undoubtedly it has tholeiitic affinities. All the quartz tholeiites have greater than 52% SiO_2 after recalculation of major elements to 100% anhydrous (fig. 9) and therefore, in the classification of Le Maitre (1984), would be termed basaltic andesites.

Two samples are somewhat anomalous with respect to certain elements. The quartz tholeiite from Diprose Lagoon (004528) has significantly higher SiO_2 and Al_2O_3, and lower CaO and FeO, than the other samples. This appears to be one of the most felsic rocks yet analysed from the Tasmanian Tertiary volcanics. However, except for much higher Ba, its trace element chemistry is similar to the other samples. The pale colour and vesicularity in hand specimen might lead one to suspect alteration, but in thin section the rock is relatively fresh (see above). Another quartz tholeiite, from Barton Road (004536), has low Sc and high V, Co, Ni and Cu, significantly outside the range of the other samples, although major elements are similar.

Abundances of various critical elements are broadly similar to those in other East Australian Tertiary tholeiites (fig. 10; Ewart and Chappell, 1989). However in detail there may be subtle characteristic differences. For example, the element ratio K/Rb is lower, and the ratios Rb/Sr, Rb/Zr, Rb/Ba, Zr/Nb and Ba/Nb higher, than the ranges quoted by Ewart and Chappell (1989). This reflects the relatively high Rb and low Nb abundances of these rocks. Comparison with a large data set of quartz to olivine-normative tholeiites from the Guildford–Hampshire area of northwest Tasmania (Everard, 1989) suggests that the basalts from the Lake River Quadrangle have higher Sc and Rb, and lower V, Cr, Cu, Zn, Sr and Nb (Table 10). These differences are probably inherited from the source, implying mantle heterogeneity, or are perhaps attributable to contamination or wall-rock interaction.

All the analysed tholeiites lack the attributes used by Frey *et al.* (1978) for identifying primary basaltic magmas, such as 100Mg / MgO + FeO (Mg number) between 68 and 72, Ni >300 ppm, high values of other compatible trace elements such as Sc, Cr and Co, and the presence of lherzolite xenoliths. None is likely to directly represent an unmodified partial melt of mantle peridotite, and all have undergone crystal fractionation. The least fractionated samples are the Belle Vue Road transitional olivine basalt (004538) and the Shooters Hill olivine tholeiite (004543), as these samples have the higher Mg numbers (apart from the anomalous, low FeO sample 004528) and highest Ni contents. On the same criteria, the most fractionated sample is probably a quartz tholeiite from *Glen Esk* (004545).

In terms of the major elements, the main differences between olivine and quartz-tholeiites are the higher SiO_2 and slightly lower total alkalis in the former; this is readily seen in the total alkali silica plot (fig. 9, Table 10). Both K_2O and Na_2O are, independently, lower in the quartz tholeiites. This also applies to P_2O_5 and TiO_2. The other major elements including, significantly, MgO and Mg number, show no consistent differences between the two groups.

Similarly, of the trace elements (Table 10), Sr, Nb, Ce and possibly Rb and Zr have different levels in the two groups. All are slightly less abundant in the quartz tholeiites.

The data for seventeen elements (TiO_2, MgO, K_2O, P_2O_5, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr and Nb) were analysed statistically. For each possible pair of elements, correlation coefficients were calculated using the data for the thirteen analyses of tholeiites (Table 7), except for element pairs including Sc, V, Co, Ni and Cu, for which the anomalous data from sample 004536 were excluded. A matrix of the 153 coefficient correlations was constructed.

The results showed strong positive correlation, in most cases at least the 95% confidence level and commonly much greater, between pairs of any of the seven elements TiO_2, K_2O, P_2O_5, Rb, Sr, Zr and Nb. This is illustrated graphically for three examples, K_2O–Rb (fig. 11), TiO_2–P_2O_5 (fig. 12) and Sr–Zr (fig. 13). Although the X-ray fluorescence technique used is insufficiently sensitive, Ce could probably also be included in this group. These are incompatible elements which do not enter the lattice of early-forming minerals such as olivine and pyroxenes, and are also the same elements which tend to be slightly less abundant in the quartz tholeiites. The presence of Sr and TiO_2 in this group suggests that plagioclase and iron-titanium oxides were not significant fractionating phases.

The elements MgO, Ni and Co are also mutually covariant, correlating with each other at greater than the 99% confidence level (see fig. 14). This undoubtedly is due to

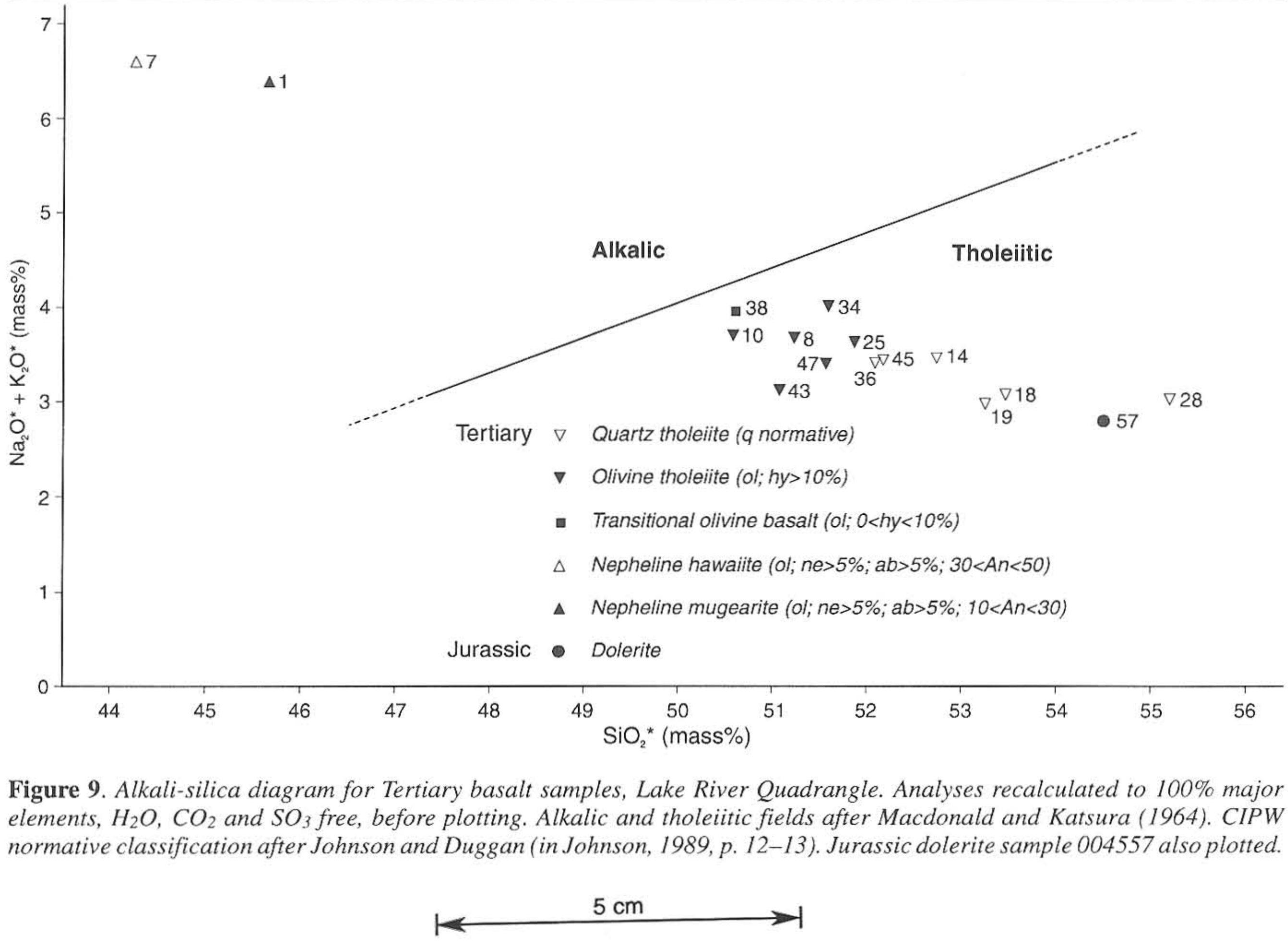


Figure 9. *Alkali-silica diagram for Tertiary basalt samples, Lake River Quadrangle. Analyses recalculated to 100% major elements, H_2O, CO_2 and SO_3 free, before plotting. Alkalic and tholeiitic fields after Macdonald and Katsura (1964). CIPW normative classification after Johnson and Duggan (in Johnson, 1989, p. 12–13). Jurassic dolerite sample 004557 also plotted.*

5 cm

TABLE 10
Average element abundances, Tertiary tholeiitic basalts

	Olivine tholeiites		Quartz tholeiites	
	LR(1)	SV(2)	LR(3)	SV(4)
Element (%)				
TiO_2	1.57	1.67	1.46	1.51
Na_2O	2.96	2.90	2.73	2.28
K_2O	0.63	0.75	0.47	0.48
P_2O_5	0.25	0.28	0.21	0.24
Mg No*	60.6	61.0	60.0	60.1
Trace elements (ppm)				
Sc	27.0	19.3	(27.6)	18.1
V	126	171	(124)	139
Cr	235	306	(246)	257
Co	48	49	(45)	47
Ni	150	164	(125)	157
Cu	39	54	(38)	45
Zn	99	115	(95)	112
Ga	19	18.3	19	18
Rb	19	16.8	17	13
Sr	284	337	224	277
Y	19	21	23	19
Zr	96	116	93	89
Nb	8.6	15.7	6.8	9.8
Ba	125	118	164	84
Ce	32(?)	63	<28	44

(1) Lake River Quadrangle, N = 7. Includes transitional olivine basalt 004538.

(2) St Valentines Quadrangle (Everard, 1989). N = 49

(3) Lake River Quadrangle, N = 6. Figures in parentheses exclude data for sample 004536.

(4) St Valentines Quadrangle (Everard, 1989). N = 18.

* 100 MgO/MgO + FeO, calculated at $Fe_2O_3/FeO = 0.15$.

olivine fractionation. As this group does not include Cr, it is likely that pyroxene, and especially clinopyroxene, is relatively unimportant as a fractionating phase.

The three elements Cu, Zn and Gn are also mutually covariant at the 95% confidence level, but the explanation is not so obvious. The pairs Sc–V, Sc–Cr (but not V–Cr), Ga–Zr and TiO_2–Cu also have large positive correlation coefficients (98% confidence level) but again the reasons are obscure.

These results indicate that:

(a) olivine was likely to have been the principal fractionating phase for most, or all, of the analysed tholeiites. However some of the quartz tholeiites may also have fractionated orthopyroxene. This is supported by the petrographic observation that olivine and, less commonly, orthopyroxene are virtually the only phenocryst phases.

(b) the quartz tholeiites are not the direct products, via olivine fractionation, of the analysed olivine tholeiites. If this were so they would be expected to have consistently lower MgO and Ni contents and Mg numbers, and higher, not lower, levels of incompatible elements, compared to the olivine tholeiites.

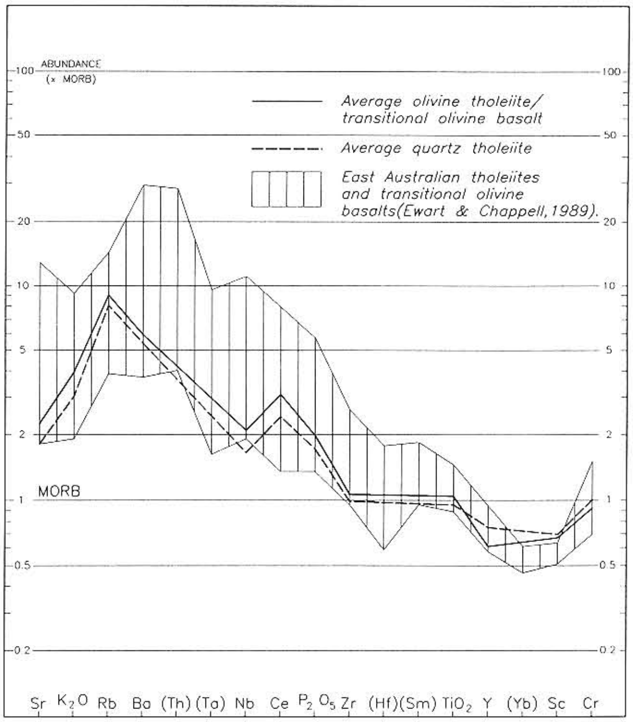


Figure 10. *MORB-normalised element abundances for average olivine- and quartz-tholeiites, Lake River Quadrangle. MORB normalisation factors as for Figure B, from Pearce (1980). Range of East Australian Tertiary tholeiites and transitional olivine basalts (Ewart and Chappell, 1989) also shown.*

Using the simplest model of fractional crystallisation of olivine alone, it is possible to estimate the composition of the parental primary magma, and the amount of olivine fractionated, for each analysed sample. Assumptions made are the same as Everard (1989) and include:

(a) a liquid-olivine, FeO-MgO partition constant of 0.3 (Roeder and Emslie, 1970);

(b) parental primary magmas with Mg numbers of 69–73 in equilibrium with mantle olivine of composition Fo_{88-90} (Ringwood, 1966);

(c) constant oxygen fugacity maintaining a Fe_2O_3/FeO ratio of 0.15 during fractionation.

This model is illustrated graphically in Figure 15, a MgO–total Fe as FeO diagram, on to which the values for each tholeiite analysis (recalculated to 100% major elements, anhydrous) are plotted. This shows that most of the samples, according to this simple model, could have been derived from primary magmas by 10 to 20% olivine fractionation. The graphically estimated amount for each sample can be added to the CIPW-normative olivine (Table 8) (in the case of the quartz tholeiites it must be noted that one part by weight quartz is resorbed by about 2½ parts by weight olivine, if composition Fo_{86}), and the total recalculated to 100%, to estimate the composition of the parental primary magmas (Table 11).

The results suggest that most of the quartz tholeiites were derived from primitive olivine tholeiites with 4–15% normative *ol*, whilst the analysed olivine tholeiites were derived from primitive olivine tholeiites with 15–23% normative *ol*. Only the anomalous, high-SiO_2 sample 004528

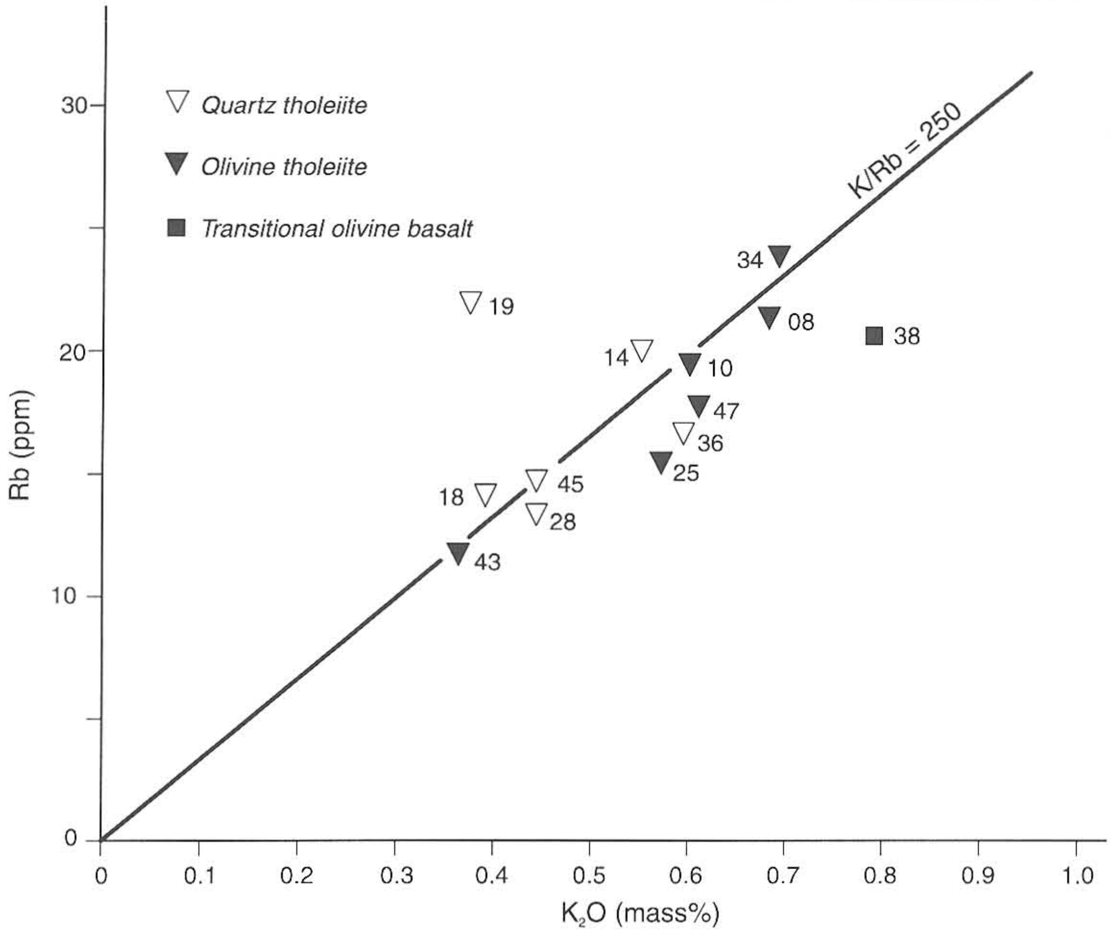


Figure 11. *Rb-K_2O plot for Tertiary tholeiitic basalts, Lake River Quadrangle*

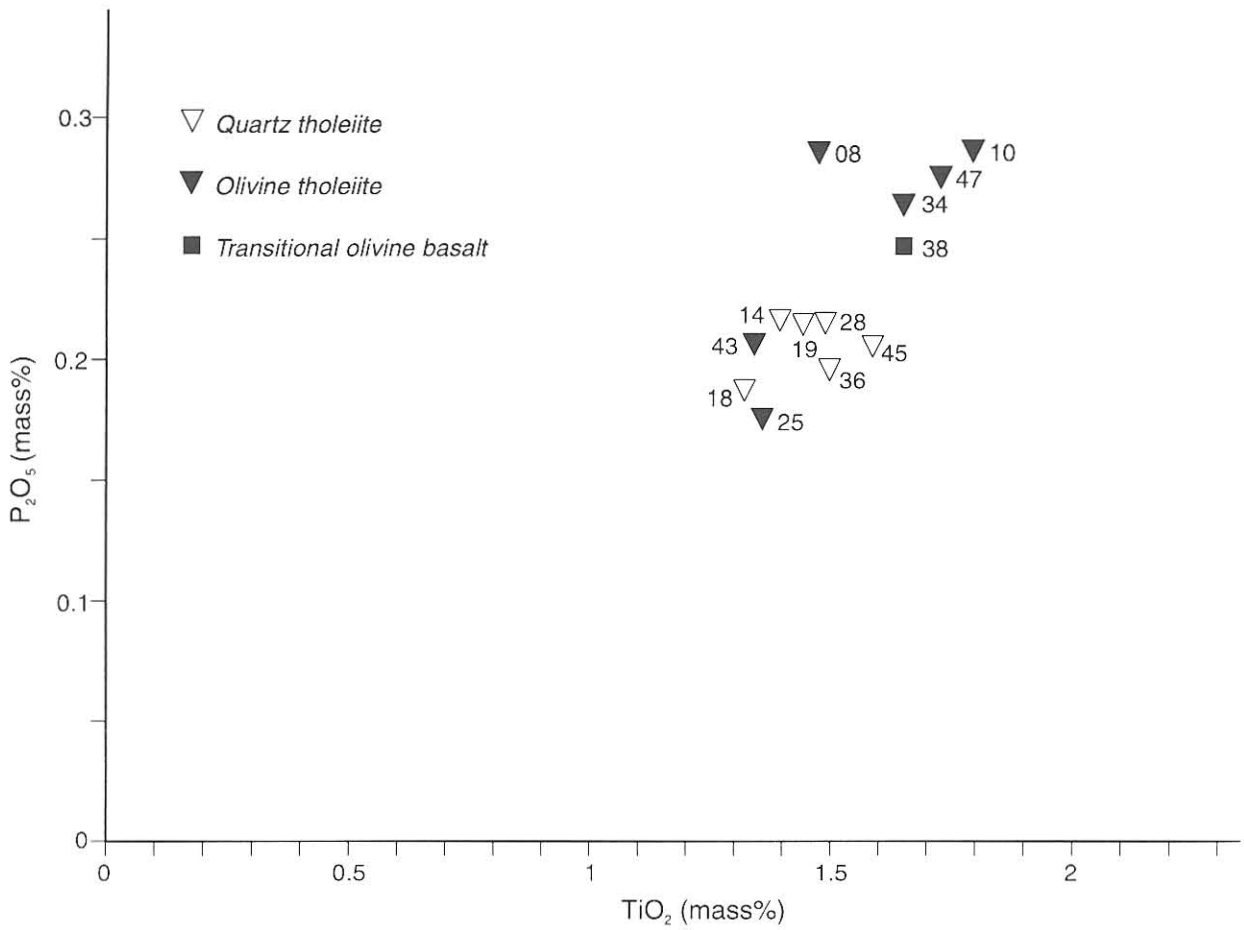


Figure 12. *P_2O_5-TiO_2 plot for Tertiary tholeiitic basalts, Lake River Quadrangle*

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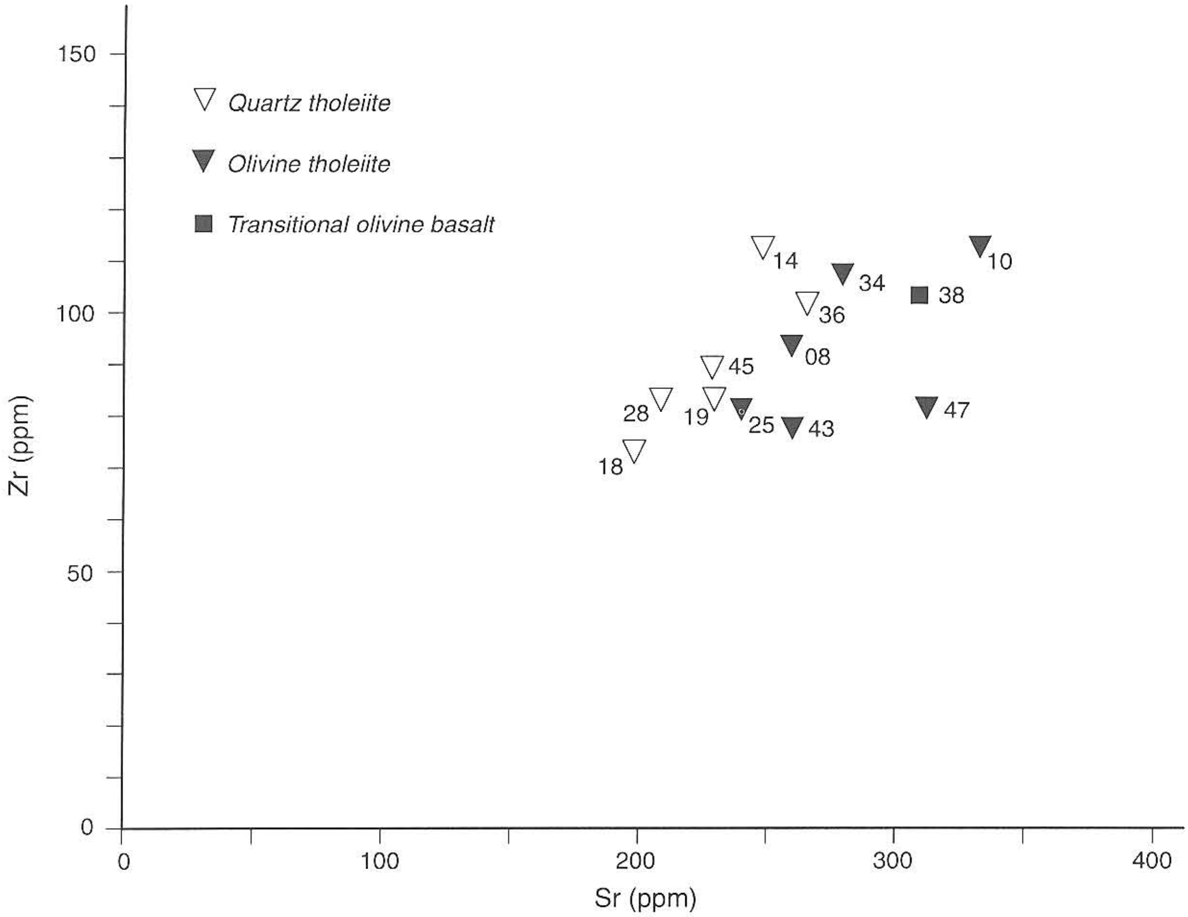

Figure 13. *Zr-Sr plot for Tertiary tholeiitic basalts, Lake River Quadrangle*

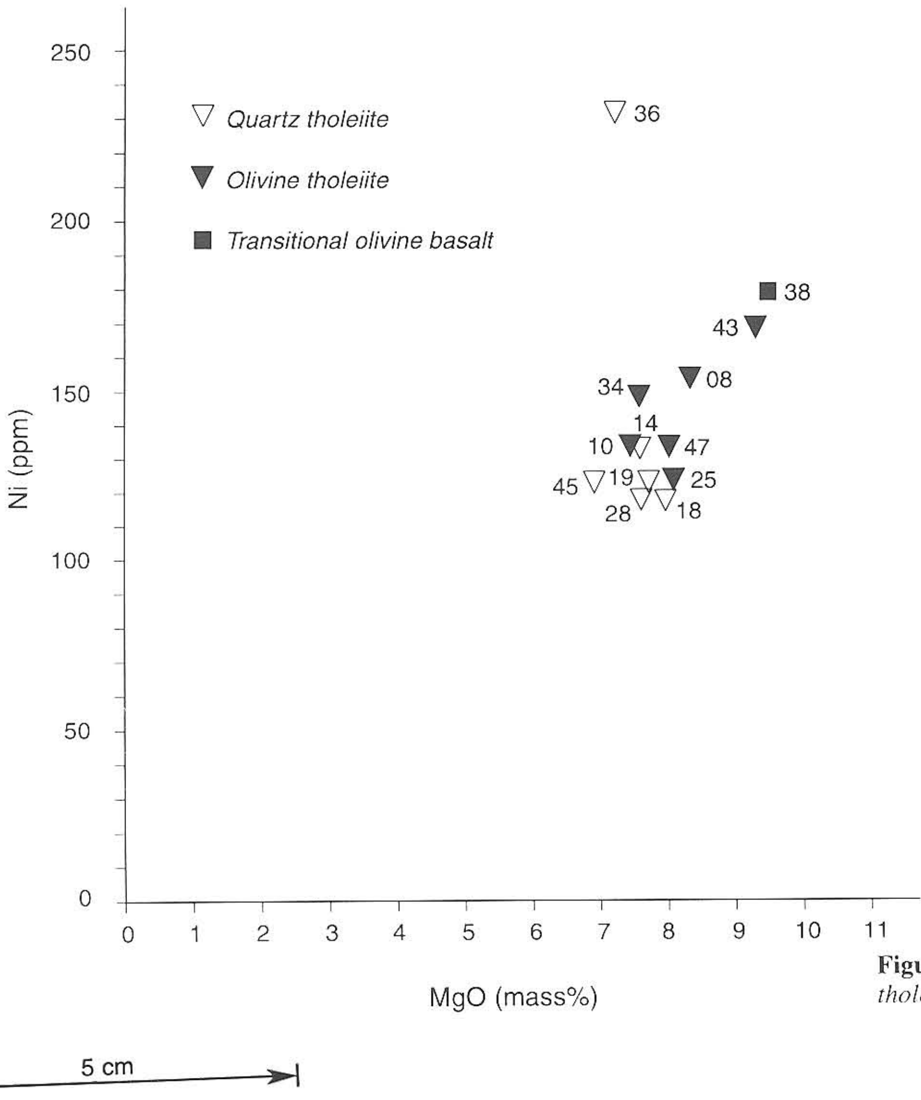

Figure 14. *Ni-MgO plot for Tertiary tholeiitic basalts, Lake River Quadrangle*

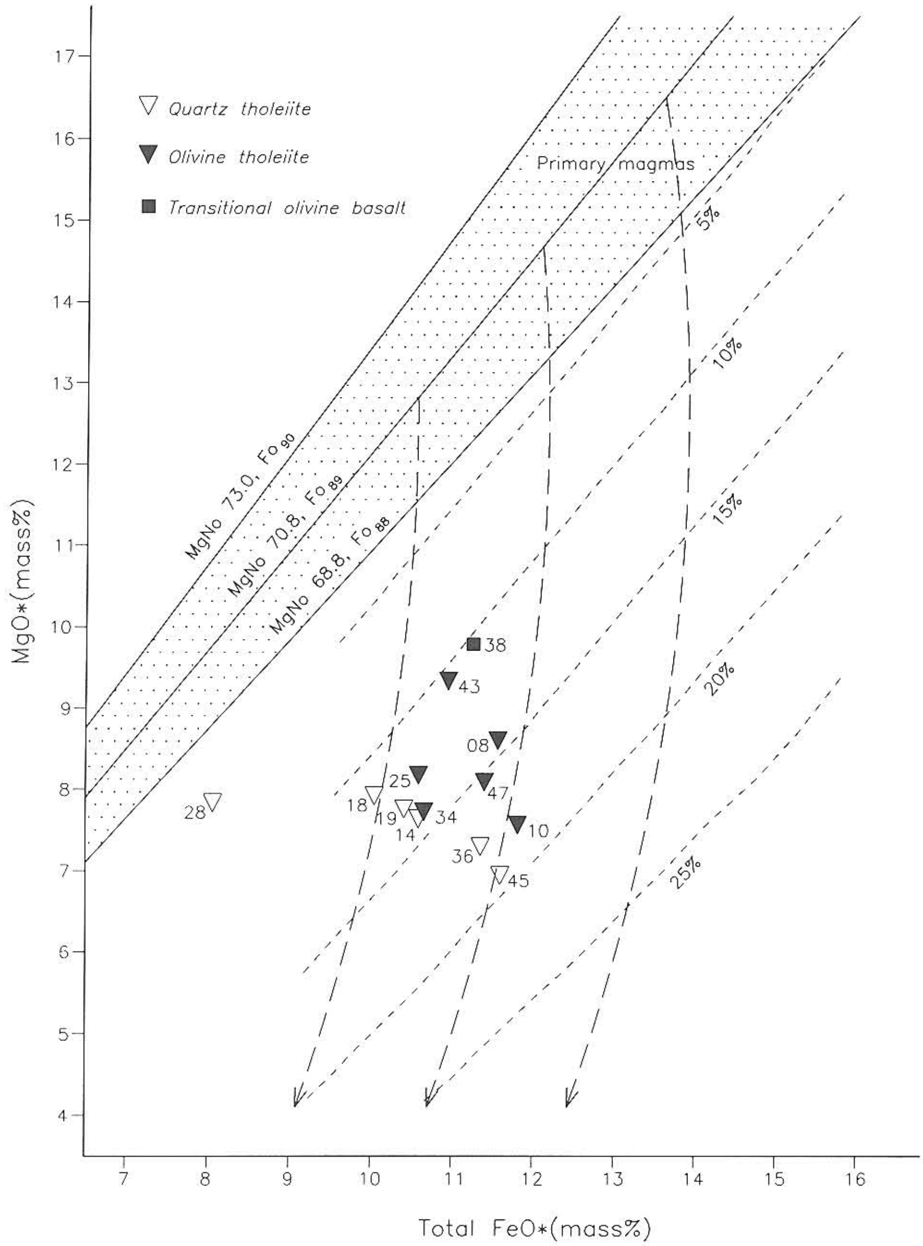

Figure 15

MgO-total Fe as FeO plot for Tertiary tholeiitic basalts, Lake River Quadrangle. Analyses recalculated to 100% major elements as before. Also shown are the field of primary magmas in equilibrium with mantle olivine of Fo_{88-90} (stippled), calculated trends for olivine fractionation and isopleths corresponding to 5, 10, 15, 20 and 25 mass percent olivine fractionation (dashed). See text for discussion.

5 cm

TABLE 11

Model for petrogenesis of tholeiites, by partial melting of pyrolite and olivine fractionation

Analysed sample			Estimated %	Estimated parental primary magma								Estimated %	
Sample No	Normative Q	Normative ol	olivine fractionation (1)	Normative Q	Normative ol	SiO_2 %	ΣFeO %	MgO %	K_2O %	P_2O_5 %	partial melting (2)	(3)
004508	-	7.82	14.5	-	19.5	49.7	11.7	14.2	0.63	0.26	20.7	22.9
004510	-	7.97	18.0	-	22.0	48.7	12.1	14.7	0.53	0.25	24.7	23.6
004514	0.78	-	14.0	-	10.8	50.7	10.9	13.2	0.51	0.20	25.6	29.7
004518	2.95	-	11.5	-	4.0	52.0	10.4	12.6	0.36	0.17	36.2	35.2
004519	3.31	-	13.0	-	4.5	51.6	10.6	12.9	0.35	0.19	37.7	30.8
004525	-	5.07	12.5	-	15.6	50.4	10.8	13.1	0.53	0.16	24.4	37.5
004528	6.86	-	5.0	4.9	-	54.5	8.4	10.2	0.44	0.22	29.7	27.4
004534	-	7.88	14.0	-	19.2	50.0	10.9	13.2	0.64	0.25	20.3	24.4
004536	0.26	-	17.0	-	14.1	50.1	11.7	14.2	0.52	0.17	24.9	35.1
004538	-	14.77	10.5	-	22.9	49.5	11.6	13.7	0.74	0.23	17.5	26.5
004543	-	6.69	10.5	-	15.6	50.0	11.2	13.5	0.33	0.19	38.8	31.6
004545	0.44	-	19.0	-	15.2	49.9	12.0	14.5	0.39	0.18	33.6	34.0
004547	-	1.69	15.5	-	14.9	49.8	11.6	14.1	0.52	0.25	25.0	23.9

(1) From Figure 15

(2) Based on K_2O, assuming 0.13% in pyrolite source (Ringwood, 1966)

(3) Based on P_2O_5, assuming 0.06% in pyrolite source (Ringwood, 1966)

cannot be derived from an olivine-normative parental primary magma by olivine fractionation.

The slightly lower levels of incompatible elements (TiO_2, K_2O, P_2O_5, Rb, Sr, Zr, Nb and Ce) in the quartz tholeiites are probably features inherited from their relatively olivine-poor parental magmas, suggesting that the latter were generated by larger degrees of partial melting than the more olivine-rich magmas parental to the analysed olivine tholeiites. There is too much scatter in the incompatible element data, and the model is probably too simplistic to confidently quantify the degree of partial melting required to generate the parental magmas (e.g. see Table 11). However, in a petrogenetic study of Tertiary basalts from Victoria and Tasmania, Frey *et al.* (1978) concluded that olivine tholeiites could have been generated by 20–25% partial melting of a mantle of pyrolite composition (Ringwood, 1966), provided that it was enriched, relative to chondrites, in incompatible elements. Slightly greater degrees of partial melting, perhaps up to 35%, may have generated the relatively olivine-poor tholeiites inferred as the parents of the quartz tholeiites. However potential complications, such as the possibility of mantle heterogeneity, crustal contamination, and the fractionation of orthopyroxene and other phases, make a more sophisticated model difficult to constrain with the present data.

Detailed discussion of the depths and physical conditions at which the parental magmas were generated is outside the scope of this report. However a relatively shallow source region above the low velocity zone and within lithosphere, perhaps at 12–15 kb (40–50 km), seems likely, with lower pressure and/or the presence of small amounts of water favouring greater degrees of partial melting and less olivine-rich (or even quartz-normative) partial melts (e.g. see reviews by Green, 1976, 1989).

STRUCTURE

The older Proterozoic to Cambrian rocks in the quadrangle have, in general, developed a strong consistent northeast to east-facing cleavage at most locations. Bedding is generally difficult to establish with any certainty but where it has been this is also northeast-facing with an angle to the main foliation. These directions are consistent with the foliation and bedding in the older rocks in neighbouring quadrangles to the northwest (namely Sheffield and Quamby), where the general trends are slightly more northerly. Taken as a whole, the trends indicate a continuation of the wrap-around feature of a central older block.

Because of the sparse bedding readings it is not possible to indicate folding in these older rocks other than to say that they appear to represent a limb of a major fold. Faulting in these rocks has not been identified, although it no doubt exists.

The Permian and Triassic sequences show no obvious folding, although occasionally in other parts of the State there is some evidence of very gentle folding. There may be such occurrences in the quadrangle but no favourable exposures demonstrating any folding have been seen. The strata are relatively flat bedded with some tilting related to faulting. Bedding near the faults can be quite steeply dipping.

The major structural feature identified is faulting within the Permian and Triassic rocks. The dominant direction of this faulting is northwesterly. The general direction or 'grain' of the rocks over the whole quadrangle is also northwesterly.

The largest fault (or set of faults) identified extends along the eastern side of Millers Bluff and to the northwest corner of the quadrangle. Over much of the distance the fault(s) is obscured by overlying younger rocks (Tertiary and Quaternary). In some locations it has also been intruded by dolerite, which again obscures it, but the nearby rock distribution shows that a considerable movement is involved, and is probably of the order of 700–1000 metres.

In the northwest corner of the quadrangle dolerite occupies a narrow region between outcropping Stockers Tillite, overlying Proterozoic–Cambrian dolomite, and quartz sandstone of Triassic age. The complete sequence of Permian rocks has been displaced by the movement between these points. A similar situation occurs some 4 km southeast of Connorville [around 110675] and for a further 4–5 km southeast from this point, where Permian tillite and Triassic sandstone are in close proximity. At this most southerly point there are indications that the total movement is distributed over a number of faults (it may also be to the northwest but the width of dolerite between the outcrops is relatively small). Along the eastern side of Millers Bluff the Permian rocks have been faulted into a series of down-faulted blocks over a width of a few kilometres.

Dolerite appears to have been intruded along the fault in the northwestern part of the fault line, and further to the south a series of small dolerite bodies have intruded on or near some of the fault. A line of hills trending in a northwest direction occurs near the foot of the main slope of the Tiers edge. A further line of northwest-trending dolerite bodies occurs to the east of this line of hills, again suggesting that the dolerite occupies faults between Upper Permian and Triassic sandstone.

The main Tertiary basins and the ridge of dolerite extending from near Campbell Town to the southern part of Hummocky Hills on the central northern margin of the quadrangle also have a northwest trend. Areas of dolerite in the northeastern part of the quadrangle also have this trend, indicating that the influence extends over most of the quadrangle and that the structural trend has had a major influence on drainage directions.

A ridge of dolerite on the slope of the Tiers and near the central western margin of the quadrangle (just north of The Glen) has an almost east-west direction. This dolerite occupies a fault which uplifts tillite on the north side, while further to the west a north-trending fault occurs.

The age of the faulting appears to be largely Jurassic, as dolerite occupies the faulted zones in many cases. However Tertiary faulting may also be present. Faults within Permian rocks, and which do not contain dolerite, could be either age.

The dolerite surrounding The Glen has been described as a cone sheet (Carey, 1958). Mapping supports this idea to some extent, but the dolerite body is very irregular. The dolerite intruding the basement rocks extends into the Permian rocks in most directions. A sloping dyke rises stratigraphically towards the summit of O'Connors Peak, and a similar dyke occurs to the north of Parknook.

To the north of Little Billop the dolerite is in contact with rocks lower in the sequence, and there is a fault between the basement rocks and the Permian rocks on the margins of the quadrangle. The dolerite dyke on the southern margin of the possible cone sheet appears almost vertical. Dolerite dykes extend through the middle of the structure and the dyke to the west of The Glen homestead occupies the fault indicated above, and is northwest trending.

ECONOMIC GEOLOGY

The economic mineral resources of the quadrangle are limited, and gravel has been the most significant resource so far exploited. The presence of small areas of Proterozoic to Cambrian-age rocks within the quadrangle has encouraged some exploration for metallic minerals but a little gold in the upper Lake River valley has been the only reported discovery.

Gold

Alluvial gold has been located in Little Den, a local flat area in the upper Lake River. It was first reported in the literature by Scott in 1932, and again by him in 1935. Nye and Blake also visited the area in 1933. Interest in the area again developed in the early 1960s and Threader (1963) visited the prospect to advise the mining tenement holder at that time.

Foliated igneous rocks (tuff and tuffaceous breccia) and slate of Proterozoic to Cambrian age occur in the area. These rocks are overlain by tillite of Permian age, and Jurassic dolerite intrudes rocks of both ages.

Gold has been found at shallow depth in the alluvial deposits around the river. The gold is reported to have been quite coarse and is not likely to have travelled far from its source. Quartz veins with low gold values have been reported but the coarser gold has not been located *in situ*. Although the older rocks have previously been regarded as the source of the gold, its derivation from the Permian tillite should not be discounted.

Most of the exploration effort in the area has involved working the alluvial material but adits have also been driven. Threader (1963) examined an adit east of the Lake River, while another adit occurs west of the river near the contact with dolerite. Strong quartz veining is present in the latter area.

Other Metallic Mineral Deposits

Prospecting using adits has been undertaken in The Glen area, again in Proterozoic to Cambrian rocks. Limestone in this area has signs of sulphide minerals and the adits were apparently driven at about the same time as the early work was being undertaken at Little Den (early 1930s). Permian tillite overlies the older rocks in the area of the adits.

Bauxite

Small areas of bauxite (or laterite with high aluminium values) developed on Tertiary basalt have been located near Campbell Town. They have been reported on by Williams (1942, 1943), Dickenson (1943) and Owen (1950). Extensive test pitting found no significant economic reserves, the material overall being high in iron and titanium. Reported analyses show the Al_2O_3 content to range from 34.6–51.3%, with the higher grade material being only in small lenses. The titanium oxide content is recorded as being up to 5%.

Limestone

Minor use has been made of limestone and dolomite in various parts of the quadrangle. These rocks have been quarried for the production of burnt lime for mortar production.

Lower Permian limestone occurs near Bicton [168584], in the southwest part of the quadrangle. The rock, which consists of a dark grey limestone with occasional fossils, was quarried and burnt in a kiln built on the site. Numerous other small areas of lower Permian limestone crop out but most of these have not been used for any purpose.

At Brumbys Creek [008769], in the northwest corner of the quadrangle, a small area of dolomite was quarried to produce burnt lime in a locally constructed kiln. Exposure of the deposit is limited, as it occurs towards the base of a valley and is overlain by Permian tillite.

Building Stone

Small quarries have been developed in sandstone and basalt specifically to construct particular buildings. For example a church and some houses have been built at Campbell Town from basalt mined from small quarries, while Triassic sandstone has been quarried northwest of Bicton and at Jacobs Sugarloaf. Minor use has been made of sandstone beds within the tillite sequence at Parknook as a building stone.

Other minor uses have been made of the local stone including a cider press at Auburn, where a vat has been cut out of sandstone (Plates 34, 35).

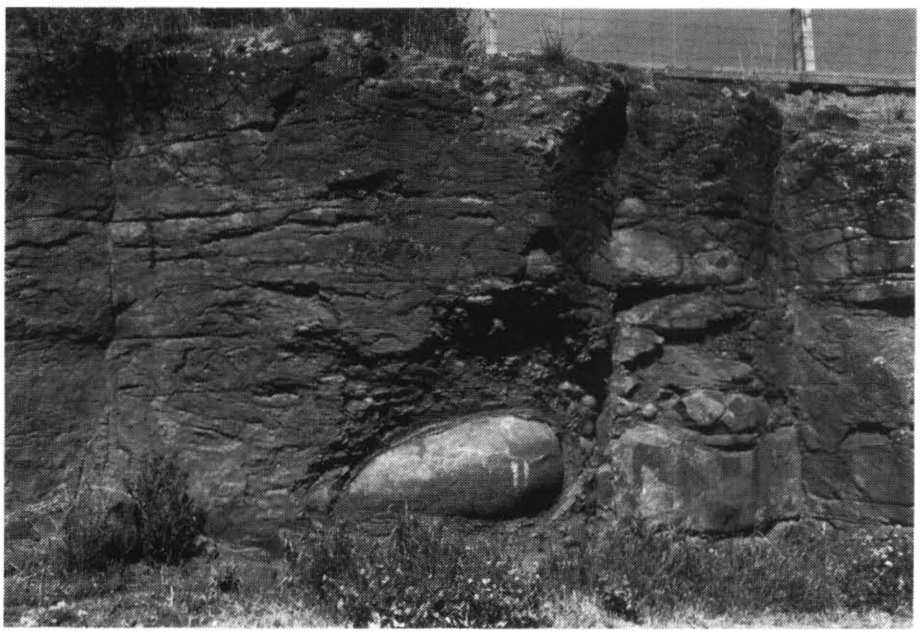

Plate 33

Quarry in Tertiary basalt at Campbell Town, used as a source of building stone.

Plate 34

A cider press, cut from Triassic sandstone, survives at Auburn homestead, 19 km southwest of Campbell Town.

Plate 35

The cider press was excavated from sandstone on the Downwood property on Glen Connell Road, 3 km northeast of Auburn. The excavation is still clearly visible.

Gravel Resources

Extensive use has been made of the gravel occurring within the quadrangle, and in particular of the pisolitic iron oxide deposits. These have been quarried at numerous locations in the northeast part of the quadrangle, particularly in the Epping Forest– Cleveland–Conara area but also in a zone to the southeast of Barton and south to the southern margin of the quadrangle (fig. 16). The gravel occurs mainly as thin lag deposits, up to about one metre thick, but which cover widespread areas. The gravel has been used in road construction and in extensions to the Launceston airport.

Siliceous gravel has been quarried south of Vaucluse, southwest of Epping Forest, and south of Delmont. In general these deposits are relatively restricted in extent and have been mainly used in road making.

Other rock types have also been used in road building, mainly because of the remoteness of other suitable materials in most cases. Triassic sandstone has been used near Jacobs Sugarloaf, northwest of Campbell Town, and southwest of Cleveland.

Permian mudstone and siltstone have been used extensively around Big Den and the upper Lake River. Further to the north, in The Glen area, Proterozoic–Cambrian phyllite has been quarried.

Dolerite has been little used but quarries in this rock exist at Cleveland and Big Den.

Minor amounts of sand and quartz grit have been excavated for addition to crushed aggregate around the margin of Diprose Lagoon and to the west of Cleveland.

Details of gravel extraction locations, taken from the CONMAT database, are given in Table 12.

Table 12
Details of construction materials, Lake River Quadrangle

Ref. No.	AMG Co-ordinates	Locality	Tenure	Reserves	Land Operations	Extractability	USCS	Uses	Quality	Laboratory Analysis
1	525253505	Auburn	Freehold	Small	Occasional	Dozer	GP-GM	RB,RU	Satisfactory	Yes
2	527553777	Epping Forest	Freehold	Small	Abandoned	Dozer	SW-SM	RB,RU	Satisfactory	Yes
3	528553738	Epping Forest	Freehold	Medium	Occasional	Dozer	SM	RB,RU	Satisfactory	Yes
4	526653621	Macquarie Road	Freehold	Small	Abandoned	Dozer	GP-GC	RB,RU	Satisfactory	Yes
5	527353556	Glen Connell	Freehold	Small	Abandoned	Dozer	SM-SC	RB,RU	Marginal	Yes
6	526653558	Glen Connell	Other	ND	Abandoned	Dozer	SM-SC	RB,RU	Satisfactory	Yes
7	520953616	Isis Road	Freehold	Nil	Abandoned	Dozer	SC	RB,RU	Marginal	Yes
8	503553678	Little Billop	Freehold	Medium	Occasional		GC	RS		Yes
9	531153737	Cleveland	Freehold	Medium	Occasional	Dozer	GW-GM	RB,RU	Satisfactory	Yes
10	539453677	Conara	Freehold	Medium	Occasional	Dozer	SM	RB,RU	Satisfactory	Yes
11	540853691	Blanchards Creek	Freehold	Medium	Operational	Dozer	SW-SM	RB,RW	Satisfactory	Yes
12	526753768	Epping Forest	Freehold	Medium	Abandoned	Dozer	GP-GM	RB,RU	Satisfactory	Yes
13	527553753	Epping Forest	Freehold	Medium	Abandoned	Dozer	GP-GM	RB,RU	Satisfactory	Yes
14	522653767	Hummocky Hills	Freehold	Medium	Abandoned	Dozer	GM	RB,RU	Satisfactory	Yes
15	526653745	Barton Road	Freehold	Medium	Abandoned	Dozer	SW	RB,RW	Satisfactory	Yes
16	522653638	Macquarie Road	Freehold	Medium	Abandoned	Dozer	SW-SM	RB,RU	Satisfactory	Yes
17	523753668	Rokeby Road	Freehold	Small	Occasional	Dozer	GM-GC	RB,RU	Satisfactory	Yes
18	522753643	Macquarie Road	Freehold		Abandoned	Dozer	GP-GM	RB,RU	Satisfactory	Yes
19	536353724	Glen Esk Road	Freehold	Medium	Abandoned	Dozer	SM-SC	RB,RU	Satisfactory	Yes
20	537453724	Glen Esk Road	Freehold	Medium	Abandoned	Dozer	SW-SM	RB,RW	Satisfactory	Yes
21	521753650	Macquarie Road	Freehold	Small	Occasional	Dozer	GM-GC	RB,RU	Satisfactory	Yes
22	514353747	Delmont Road	Crown Land	Small	Occasional	Dozer	SW-SM	RB,RW	Satisfactory	Yes
23	534553609	Macquarie Road	Freehold	Small	Occasional	Dozer	SM-SC	RB,RU	Satisfactory	Yes
24	506553607	River Road	Freehold	Medium	Occasional		GW-GM	RB,RU	Marginal	Yes
25	507553737	Lake River Road	Freehold	Small	Abandoned	Dozer	SM	RB,RW	Satisfactory	Yes
26	511153720	Macquarie Road	Freehold	Medium	Abandoned	Dozer	SM	RB,RW	Satisfactory	Yes
27	510553725	Macquarie Road	Freehold	Medium	Operational	Dozer	SM	RB,RW	Satisfactory	Yes
28	524053726	Barton Road	Freehold	Medium	Abandoned	Dozer	SP	RB,RU	Satisfactory	Yes
29	526853569	Jacobs SL	Crown Land	Small	Occasional	Dozer	GP-SP	RB,RU	Satisfactory	Yes
30	520653572	Isis Road	Freehold	Small	Occasional	Dozer	GW-SW	RB,RW	Satisfactory	Yes
31	523153638	Macquarie Road	Freehold	Medium	Operational	Dozer	SP	RB,RU	Satisfactory	Yes
32	522453635	Macquarie Road	Freehold	Small	Abandoned	Dozer	GP	RB,RU	Satisfactory	Yes
33	540153682	Esk Main Road	Freehold	Medium	Abandoned	Dozer	GW-GC	RB,RU	Satisfactory	Yes
34	532553733	Cleveland	Crown Land	Medium	Abandoned	Dozer	CA			No
35	539853731	Glen Esk Road	Freehold	Medium	Occasional	Dozer	RB,RU			No
36	532353730	Cleveland	Freehold	Nil	Abandoned	Dozer	SW-SC	RB,RU	Satisfactory	Yes
37	528953739	Epping Forest	Freehold	Medium	Occasional	Dozer	GP	RB,RU	Satisfactory	Yes
38	528253742	Epping Forest	Freehold	Medium	Abandoned	Dozer	GP	RB,RU	Satisfactory	Yes
39	527753743	Epping Forest	Freehold	Medium	Abandoned	Dozer	GW-GP	RB,RU	Satisfactory	Yes
40	526053764	Epping Forest	Freehold	Medium	Operational	Dozer	GW-SW	RB,RW	Satisfactory	Yes
41	505653539	Lake River Road	Freehold	Small	Occasional	Dozer	GC	RB,RU		Yes
42	502453548	Big Den	State Forest	Small	Abandoned	Dozer	GC	RB,RU		Yes
43	504653560	Big Den	State Forest	Medium	Occasional	Dozer	GC	RB,RU		Yes
44	508653546	Little Den	Freehold	Medium	Occasional	Dozer	GW-GP	RB,RU		Yes
45	508053567	Lake River Road	State Forest	Small	Abandoned	Dozer	GW-GC	RB,RU		Yes
46	507953570	Lake River Road	Freehold	Small	Abandoned	Dozer	GW-GC	RB,RU		Yes
47	507353579	Lake River Road	Freehold	Medium	Occasional	Dozer	GW	RB,RU		Yes

Table 12
Details of construction materials, Lake River Quadrangle *(continued)*

Ref. No.	*AMG Co-ordinates*	*Locality*	*Land Tenure*	*Reserves*	*Operations*	*Extractability*	*USCS*	*Uses*	*Quality*	*Laboratory Analysis*
48	507453581	Lake River Road	Freehold	Nil	Abandoned	Dozer	SW	RB,RU		Yes
49	507553599	Lake River Road	Freehold	Nil	Occasional	Dozer	GW-GC	RB,RU		Yes
50	505853634	Lake River Road	Freehold	Small	Occasional	Dozer	GW-GP	RB,RU		Yes
51	504853651	Lake River Road	Freehold	Small	Occasional	Dozer	GW-SW	RB,RU		Yes
52	526353756	Epping Forest	Freehold	Small	Abandoned	Dozer	SP	RB,RU		Yes
53	526353751	Epping Forest	Freehold	Medium	Abandoned	Dozer	GP	RB,RU		Yes
54	525553726	Barton Road	Freehold	Medium	Abandoned	Dozer	SW	RB,RU		Yes
55	527253747	Epping Forest	Freehold	Medium	Abandoned	Dozer	SW-SP	RB,RU		Yes
56	527253741	Epping Forest	Freehold	Medium	Abandoned	Dozer	SW-SP	RB,RU		Yes
57	527453756	Epping Forest	Freehold	Medium	Abandoned	Dozer	SW-SP	RB,RU		Yes
58	529953754	Epping Forest	Crown Land	Medium	Abandoned	Dozer	SW-SP	RB,RU		Yes
59	530353694	Cleveland	Freehold	Medium	Occasional	Dozer		RB,RU		No
60	529453690	Cleveland	Freehold	Small	Abandoned	Dozer	GP	RB		No
61	502153701	Little Billop	Freehold	Small	Occasional	Dozer	SW-SP	RB,RU		Yes
62	516053704	Macquarie Road	Freehold	Medium	Occasional	Dozer	SP	RB,RU		Yes
63	513353737	Macquarie Road	Freehold	Medium	Occasional	Dozer	SW	RB,RW		No
64	524553634	Macquarie Road	Freehold	Small	Abandoned	Dozer		RB,RU		No
65	530553728	Cleveland	Freehold	Medium	Occasional	Dozer	GW-GM	RB,RU	Satisfactory	Yes
66	508353596	Lake River Road	Freehold	Small	Abandoned	Dozer	GW-GM	RB,RU	Marginal	No
67	512753734	Carnarvon	Freehold	Medium	Abandoned	Dozer	SW	RB,RU		No
68	532353708	Cleveland	Freehold	Medium	Operational	Excavator	SP	SG		Yes
69	523853751	Epping Forest	Freehold	Medium	Abandoned	Excavator	SP	SG		No
70	530353705	Cleveland	Freehold	Medium	New area		SP	SG		No
71	534053740	Bostock Hill	Freehold			Dozer		RB,RU		No
72	523453761	Lincoln Lagoon								No
73	517253572	Big Sugarloaf	Freehold							No
74	523653635	Macquarie Road	Freehold			Dozer		RB,RU		No

Locations are shown on Figure 16. Data are taken from the CONMAT database.

Reserves: ND = Not Determined; Nil = <1000 t; Small = 1000–10 000 t; Medium = 10 000–1 000 000 t

Use: RS = Road sub-base; RB = Road base course; RW = Road wearing (sealed); RU = Road unsealed; SG = Sand, glass;
CA = Crushed aggregate

USCS = Unified Soil Classification System:
SW = Well-graded sands, gravelly sands, little or no fines;
GW = Well-graded gravels, gravel-sand mixtures, little or no fines;
SP = Poorly-graded sands, gravelly sands, little or no fines;
GP = Poorly-graded gravels, gravel-sand mixtures, little or no fines;
SM = Silty sands, sand-silt mixtures
GM = Silty gravels, gravel-sand-silt mixtures
SC = Clayey sands, sand-clay mixtures
GC = Clayey gravels, gravel-sand-clay mixtures

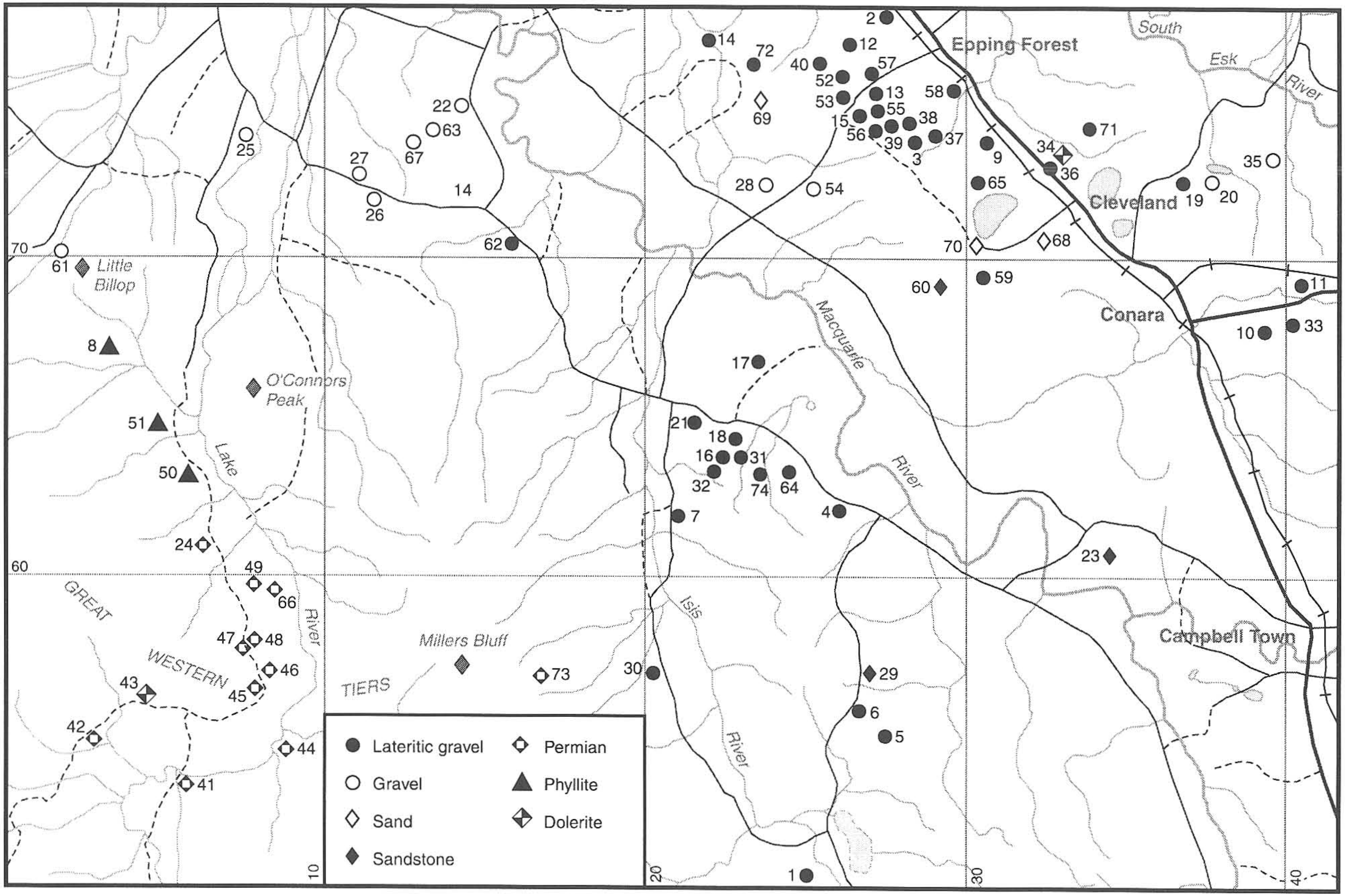

Figure 16. *Location of construction material extraction sites (see Table 12 for details)*

5 cm

GROUNDWATER RESOURCES

The Lake River Quadrangle incorporates the southern part of the Launceston Tertiary Basin; groundwater resources of this larger region are described in Matthews (1983).

All rock types within the quadrangle are capable of yielding groundwater, although the Proterozoic–Cambrian rock units are likely to be the least prospective. Jurassic dolerite also has a lower potential to produce groundwater. This is reflected in the lower success rate of water bores than most of the other rock types in the State, even in favourable topographic situations. Because of its greater resistance to weathering, dolerite occurs on elevated areas and this will also have an influence on groundwater occurrences. The most prospective rock types in the quadrangle are the Tertiary sediments, the Tertiary basalt, and the Upper and Lower Parmeener Supergroup rocks.

Records of 57 bores are held by the Tasmanian Geological Survey. Table 13 summarises the results of these bores according to rock type, while the approximate locations of these bores are shown on Figure 17. More detailed records of the known water bores are given in Table 14.

Unconsolidated sediments of mainly Tertiary age are extensive, the main areas being around the Midland Highway from Epping Forest to just south of Conara, and an area from Forest Vale–Delmont in the northwestern part of the quadrangle to Winton to the northwest of Campbell Town. In the former area the majority of the groundwater is found in coarse sand to fine gravel deposits which appear to be derived from the weathering of granite, and were probably transported by and deposited around the ancestral South Esk River. Where these deposits are relatively thick, yields from bores can be quite high — over 900 litres per minute (12,000+ gallons per hour). These gravels are within about 30–50 m of the surface. In the latter area fine sand aquifers occur from 50–150 m from the surface in the northern part, while in the southern part groundwater is obtained from conglomerate beds as well as fine sand deposits.

Bores have been drilled in basalt in the Campbell Town area with fairly regular success. Rates of up to 900 L/min (12,000 gallons per hour) have been reported.

A few bores have been drilled into Triassic sediments, with mixed success. Bores in areas where shale beds are common within the sequence appear to have a lower success rate than in areas where sandstone is dominant.

No water bores have been drilled in the Permian or older rocks. The Permian is regarded as prospective, and areas where bores are likely to be successful include the lower slopes on the eastern side of Millers Bluff, Big Den, the west side of Boomers Bottom, and the crest of Little Billop. Permian rocks may underlie some of the Quaternary and Tertiary sediments at shallow depth where outcropping Permian is nearby.

The quality of groundwater is variable within the region. In the Tertiary sediments most of the groundwater ranges from 700–2000 mg/L total dissolved solids (TDS), although some bores north of Campbell Town have between 3000 and 6000 mg/L TDS. Shallow bores (<10 m) to the south of Arlington Park had water with a total salinity of up to about 14 000 mg/L TDS. The basalt has water mainly with 1500–2000 mg/L TDS although one bore north of Campbell Town obtained water with about 5000 mg/L TDS. Analyses of water from three bores in dolerite indicate greater than 3800 mg/L TDS, while one sample had 1230 mg/L TDS. Water from two bores in Triassic rocks has been analysed, with total salinity in the range of 1100–1400 mg/L TDS.

Table 13
Summary of groundwater exploration in different rock types, Lake River Quadrangle.

Rock units	No	Successful	Average depth (m)	Not successful	Average depth (m)	Maximum output (L/m)	Average output (L/m)
Tertiary/Quaternary	35	26	50.5	9	23	910+	136
Tertiary basalt	6	5	16.4	1	25.9	910	223
Jurassic dolerite	6	4	36	2	51.1	91	45
Triassic	10	6	31	4	32.9	151	86

Table 14
Details of groundwater bores, Lake River Quadrangle

Hole No.	*Location*	*AMG Co-ordinates*	*Date Drilled*	*Driller*	*Depth Water Struck (m)*	*Standing Water Level (m)*	*Total Depth (m)*	*Output (L/min)*	*Salinity (TDS)*	*Casing (m)*
1	Cleveland	336714	13/11/1963	MD		23.1	44.2	45.5	*1011	
2	Cleveland	335701	5/7/1968	MD			57.9	#108	*1830	
3	Conara	361686	June 1928	MD	30.5–33.5		36.6	15.2	*884	
4	Conara	359687	June 1928	MD	30.5–33.5		38.6	15.2	*884	
5	Epping Forest	322758	5/6/1967	Sides	10.7	8.5	16.2	45.5	*1805	16.2
6	Epping Forest		25/11/1980	GSD			19.8			
7	Epping Forest		26/11/1980	GSD	12.5–14.6		15.2			12.4
8	Epping Forest		3/4/1981	GSD			19.8			
9	Epping Forest		3/4/1981	GSD			15.2			
10	Epping Forest		3/4/1981	GSD			33.5			
11	Epping Forest		4/4/1981	GSD			15.2			
12	Epping Forest	322758	16/7/1981	MD	8.3	5.2	17.4	68.2		17.4
13	Campbell Town	387586	8/4/1973	Mono	4.9–9.5	4.6	14.6	#75.8	salty	
14	Cressy	130734	February 1973	Stacpoole			34.4			
15	Cressy	131728	February 1973	Stacpoole	3.1	1.8	15.9	7.2		
16	Campbell Town	207665	February 1973	Stacpoole	8.2–12.2		34.1	#7.6		
17	Cressy	066774	3/5/1968	MD		6.2	77.1	#303	*836	
18	Cressy	052765	13/5/1968	MD			25.6	#7.6	*3800	
19	Campbell Town	388657	9/11/1951	MD	20.7		22.9	22.7	*1480	
20	Campbell Town	391594	14/11/1951	MD	6.1		15.2	26.5		
21	Conara	395687	13/9/1968	MD	13.7–15.2, 35.1		36.6		*1815	
22	Epping Forest	178675	28/8/1967	MD			44.2			
23	Campbell Town	196670	3/12/1969	MD		8.5	83.8	83	*900	
24	Campbell Town	411560	19/11/1970	Mono	3.1	0	15.2	910	*1980	13.7
25	Cleveland	352707	12/6/1968	MD	22.9	22.3	61	26.5	*3485	33.5
26	Cleveland	351710		MD		23.4	35.1	910	*3340	39.1
27	Campbell Town	401634	4/5/1966	TD	9.1		12.2	53.1	*1985	
28	Campbell Town	394636	14/10/1968	MD	9.1–19.0	2.4	20.4	#53	*5120	
29	Campbell Town	385637	16/10/1968	MD			11.3	75.8		10.7
30	Cleveland	392723	30/10/1968	MD	22.4–30.5	6.1	53.3	#27	*1077	
31	Campbell Town	247661	12/12/1969			8.3	42.7	#265	*535	36.6
32	Cleveland	365718	1967	TD	22.9		28.7	227	*2370	
33	Epping Forest	307735	19/11/1968	MD	23.9–45.7	27.4	46.6	#364	*725	
34	Epping Forest	315742	22/11/1968	MD			13.7			
35	Epping Forest	315742	27/11/1968	MD	27.4–29.0	12.2	29.0	22.7	*2795	29.0
36	Cleveland	334715	January 1974	Stacpoole	22.9	22.9	32.3	37.9	*880	32.3
37	Delmont	123766	2/10/1969	MD		65.5				
38	Delmont	104767	9/2/1970	MD		artesian	153	#296	*730	61
39	Campbell Town	280670	19/3/63	MD	12.2		29.0	19.0	840	
40	Campbell Town	293671	21/3/1963	MD			8.2			
41	Campbell Town	291672	23/3/1963	MD			25.9			
42	Campbell Town	285658	27/3/1963	MD	36.6		39.0	22.7	1140	12.7
43	Campbell Town	285657	5/3/1965	MD	3.1, 38.1		42.7	22.7	1400	42.7
44	Campbell Town	307707	8/6/1967	TD	16.8, 22.9	5.2	22.9	190	*1480	22.9
45	Valleyfield	301708	8/6/1967	TD	13.4	4.6	18.3	227	*1035	18.3
46	Campbell Town	307675	25/5/1969	WWRD	19.8–67.1	15.2	80.8	91	*1230	6.4
47	Campbell Town	370651	25/5/1969	WWRD			74.7			19.8
48	Campbell Town	358642	28/5/1969	WWRD	6.7	5.2	22.9	5.3	*6990	7.0
49	Epping Forest	275757	14/12/1968	MD	15.2	22.9	53.3	#10	*580	
50	Delmont	153726	25/4/1969	MD		14.7	196.9	#235	*2500	111.3
51	Epping Forest	300780	23/1/1969	MD	21.3–30.5	4.2	53.3	#163	*5645	30.5
52	West Ross		March 1977	Mono			44.2			
53	West Ross		10/3/1977	Mono	13.7	10.7	29.0	34.1		2.4
54	'Plassy' Ross		1982	Victor			≈27.4			
55	'Plassy' Ross		1982	Victor			≈15.2			
56	'Plassy' Ross		1982	Victor			≈39.6			
57	'Preston' Ross		1982	Victor			≈30.5			

= hole abandoned; * = chemical analysis available

Drillers: MD = Department of Mines; TD = Tasmanian Drillers; Mono = Mono Pumps (Aust.) Pty Ltd; GSD = Gerald Spaulding Drillers; Sides = W. L. Sides & Co.; Victor = Victor Petroleum; WWRD = Waterland Well and Rock Drillers

Table 14
Details of groundwater bores, Lake River Quadrangle *(continued)*

Hole No.	*Drillers Log (depths in metres)*
1	0–18.3 clay and sand; 18.3–27.4 clay, bands of quartz gravel; 27.4–29.0 clay, wood fragments; 29.0–35.1 gravel; 35.1–44.2 sand, clay; 44.2 dolomite.
2	0–1.5 brown clay; 1.5–15.2 clay, sandy clay; 15.2–27.4 sand, fine gravel; 27.4–30.5 sandy clay; 30.5–38.1 grit, gravel; 38.1–45.7 grey sand; 45.7–47.2 grit with pyrite; 47.2–57.9 sandy clay.
3	0–14.6 surface soil, decomposed basalt; 14.6–20.1 hard basalt; 20.1–22.6 hard white sandstone; 22.6–36.5 fine sandy grit.
4	0–14.6 surface soil, decomposed basalt; 14.6–20.1 hard basalt; 20.1–22.6 hard white sandstone; 22.6–37.5 fine sandy grit; 32.5–39.6 mudstone.
5	0–4.0 firm clay; 4.0–7.3 fine yellow sand; 7.3–10.7 white sandy clay; 10.7–15.9 coarse sand, gravel fragments; 15.9–16.2 clay.
6	0–0.3 topsoil; 0.3–19.8 soft clay.
7	0–0.3 topsoil; 0.3–5.5 hard pan; 5.5–6.7 sand; 6.7–12.5 clay; 12.5–14.6 gravel; 14.6–15.2 brown clay.
8	0–0.3 topsoil; 0.3–9.1 clay; 9.1–19.8 sand.
9	0–0.3 topsoil; 0.3–9.1 clay; 9.1–15.2 sand.
10	0–0.3 topsoil; 0.3–9.1 dolerite; 9.1–15.2 sand; 15.2–29.0 brown clay; 29.0–33.5 wet sand.
11	0–0.3 topsoil; 0.3–9.1 clay; 9.1–15.2 sand.
12	0–3 soil, brown clay; 3–8.2 brown, grey clay; 8.2–15 fine, coarse sand (clayey gravel also?); 15–17.4 clay.
13	0–0.3 topsoil; 0.3–2.4 sand; 2.4–4.9 sandy clay; 4.9–8.2 decomposed material; 8.2–8.8 gravel; 8.8–14.6 dolerite.
14	0–0.6 soil; 0.6–6.7 soft clay, sandstone; 6.7–9.1 black clay; 9.1–24.4 brown clay; 24.4–34.4 grey mudstone.
15	0–0.3 soil; 0.3–3.1 clay; 3.1–15.9 mudstone.
16	0–0.3 soil; 0.3–4.9 clay and wash; 4.9–8.2 grey drift; 8.2–12.2 fine wet sand; 12.2–34.1 grey, black, brown drift.
17	0–1.5 clay, pebbles; 1.5–32 clay; 32–32.1 greybilly?; 32.1–76.2 sand, conglomerate, clay lenses; 76.2–77.1 dolerite.
18	0–3.1 sand, some clay; 3.1–16.8 clay; 16.8–16.9 greybilly; 16.9–24.4 dolerite, sand fragments; 24.4–26.6 dolerite.
19	0–0.6 surface soil; 0.6–7.6 clay; 7.6–15.2 soft sandstone; 15.2–16.8 dolerite or basalt?; 16.8–22.9 decomposed sandstone.
20	0–0.3 surface soil; 0.3–4.6 clay; 4.6–15.2 soft sandstone.
21	0–16.8 weathered basalt; 16.8–21.3 weathered vesicular basalt; 21.3–35.1 grey sandy clay, clayey sand; 35.1–36.6 coarse sand-grit.
22	0–0.3 topsoil; 0.3–44.2 sandy clay; 44.2 dolerite boulders.
23	0–18.3 mainly sand, clayey sand; 18.3–79.2 clay, a little sand; 79.2–83.8 conglomerate (dolerite fragments).
24	0–0.3 topsoil; 0.3–1.2 sandy clay; 1.2–15.2 basalt, vesicular bands.
25	0–4.6 brown sand, iron oxide modules; 4.6–6.1 clay; 6.1–22.9 clayey sand, sand, pebbles; 22.9–33.5 coarse sand, pebbles; 33.5–61 mainly clay, some sandy beds, a little gritty material.
26	0–1.5 brown sand; 1.5–11.3 laterite material, clay, sandy clay; 18.3–33.5 coarse pebbly sand, sand; 33.5–76.5 grey sandy clay.
27	0–0.6 sand; 0.6–5.5 clay; 5.5–12.2 basalt (honeycomb).
28	0–10.7 weathered basalt; 10.7–20.4 hard basalt.
29	0–4.6 brown topsoil, clay; 4.6–10.7 decomposed basalt; 10.7–11.3 basalt, unweathered at end.
30	0–1.5 basalt fragments; 1.5–27.4 clayey sand, clay; 27.4–30.5 grey sand, gravel; 30.5–53.3 grey and brown clay, some sand.
31	0–10.7 clayey sand, sand; 10.7–19.8 red clay, gravel fragments; 19.8–32 sandy clay; 32.0–42.7 conglomerate (dolerite mainly).
32	0–12.2 clay; 12.2–22.9 sand, gravel, some clay; 22.9–28.4 coarse sand, gravel; 28.4–28.7 clay.
33	0–16.8 clay, clayey sand; 16.8–22.9 sand, fine gravel; 22.9–25.9 sandy clay; 25.9–27.4 grit; 27.4–35.1 clayey sand, gravel; 35.1–45.7 grit, fine gravel; 45.7–46.6 sandy clay.
34	0–10.7 topsoil, clay, decomposed basalt, then gravel, sand.
35	0–15.2 topsoil, ironstone gravel, weathered basalt; 15.2–25.9 sand, small gravel; 25.9–29 gravel; 29+ clay.
36	0–18.9 clay; 18.9–24.4 clay, occasional pebble; 24.4–32.0 gravel and clay; 32.0–32.3 sandstone?
37	0–3.1 sand grit, gravel; 3.1–61.0 clay, some wood fragments; 61.0–65.5 dolerite fragments (conglomerate).
38	0–3.1 soil, clay; 3.1–4.6 gravel; 4.6–53.3 clay, clayey sand; 53.3–153 sand, clay, wood fragments – interbedded.
39	0–2.4 sand; 2.4–28.7 sandstone; 28.7–29.0 dolerite.
40	0–7.6 sand; 7.6–8.2 dolerite.
41	0–3.1 sand; 3.1–9.1 basalt; 9.1–18.3 sandstone; 18.3–25.6 basalt and mudstone; 25.6–25.9 dolerite.
42	0–6.1 sand, clay, gravel; 6.1–12.2 soft clay; 12.2–36.6 hard grey clay; 36.6–39.0 sandstone.
43	0–0.6 sand; 0.6–1.8 clay; 1.8–4.9 ironstone gravel; 4.9–18.3 grey clay, sand; 18.3–39.6 clay, ironstone gravel; 39.6–42.7 clayey sandstone, rounded pebbles.
44	0–0.6 topsoil; 0.6–16.8 clay; 16.8–22.9 coarse sand.
45	0–0.3 topsoil; 0.3–13.4 clay; 13.4–18.3 coarse sand.
46	0–0.6 topsoil; 0.6–2.4 clay; 2.4–5.2 sand; 5.2–6.1 ironstone; 6.1–7.6 decomposed dolerite; 7.6–80.8 dolerite.
47	0–1.2 topsoil; 1.2–4.9 basalt (honeycomb); 4.9–6.7 sandy clay; 6.7–74.7 mainly dolerite?, some weathered.
48	0–2.1 topsoil; 2.1–6.7 clayey weathered dolerite, sand; 6.7–8.5 soft sandstone, probably dolerite; 8.5–22.9 dolerite.
49	0–4.6 gravel, grit, clay; 4.6–15.2 sandy clay, clayey sand; 15.2–21.3 coarse sand, grit; 21.3–29.0 coarse clayey sand; 29.0–42.7 clayey sand; 42.7–45.7 coarse angular sand; 45.7–53.3 clayey sand, gritty clay.
50	0–1.5 fine brown sand; 1.5–59.4 clay, sandy clay; 59.4–128 sandy clay, sand; 128–192 clay, sandy clay, wood fragments; 192–196.9 dolerite.
51	0–13.7 clay; 13.7–15.2 clayey sand; 15.2–38.1 sand, coarse sand, some clay; 38.1–48.8 sandy clay; 48.8–53.3 fine sand.
52	0–3.1 boulders, clay; 3.1–38.1 sand, clay; 38.1–44.2 black clay (Triassic?)
53	0–2.1 boulders, clay; 2.1–29.0 sandstone.
54	Dolerite.
55	Triassic sandstone, shale, some baked.
56	Triassic sandstone and shale beds.
57	Triassic sediments.

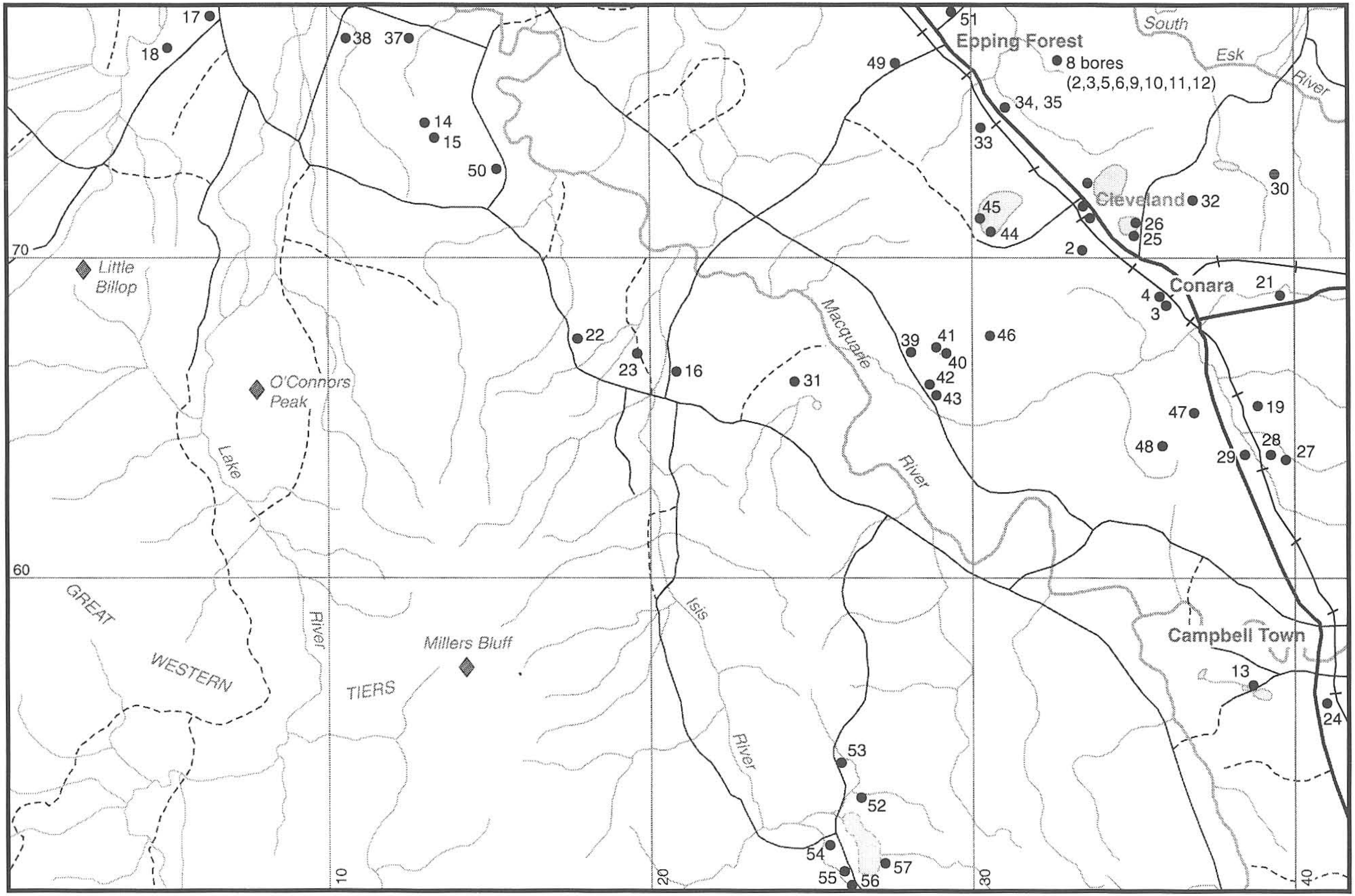

Figure 17. *Location of known groundwater bores (see Table 14 for details)*

5 cm

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APPENDIX 1

Percussion drilling for dolomite at McRaes Hills, August 1992

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PREVIOUS WORK

The known occurrence of dolomite at McRaes Hills, thought to be a large glacial erratic, was investigated by Mr M. Forster in February 1987 using an excavator to dig test pits in an effort to locate lateral extensions of the dolomite and thus prove the existence of a Precambrian dolomite horizon. This activity was partly instigated by TEMCO as part of its ongoing search for lower-priced raw materials.

The results of the work were reported to the Director of Mines in a letter from The Northwest Bay Co Pty Ltd on 20 February 1987.

It was concluded that the "deposit is a glacial boulder in Permian Tillite".

SUMMARY OF WORK CARRIED OUT

Subsequent to this activity, Beams Brothers, suppliers of limestone to TEMCO, had indicated an interest in developing a dolomite source in the northeastern Tasmania area for the agricultural industry and possibly for supply of dolomite to TEMCO.

It was decided to drill some scout bores with a Tamrock DHAT 400 rig owned by Beams Brothers in the immediate area of the old pit and kiln at the known deposit. This initial drilling, consisting of bores PP1 to PP9, proved the deposit to be more extensive and therefore **NOT** a glacial boulder.

Subsequent drilling by TEMCO to better evaluate the potential of the deposit was spaced on lines approximately 200 m apart running across strike and having bores 50 m apart along the lines (bores PP10 to PP21). These bores were positioned partly to test the theory that the topographic low to the southwest, once a shallow natural lake, may well be underlain by dolomite and if so, would provide a better quarry site from the point of view of overburden removal.

Bore PP22 was drilled approximately 500 m along strike to the northwest into a localised rise in the otherwise flat topography.

Further bores, designated 1A, 2A and 3A, were drilled by Beams Brothers to better evaluate the prime area of interest near the old workings. The rough layout of this work is shown in Figure 18. It must be stressed that the bore locations should be surveyed prior to any further work.

RESULTS

The results of drilling and analyses of samples are given in the tables. All bores were vertical.

DISCUSSION AND CONCLUSIONS

Generally the bores in close proximity to the old workings intersected outcropping or sub-outcropping dolomite. Away from the immediate old pit area it seems common for near-surface material to be siliceous. Below the tillite the material appears as a light grey shale which becomes less siliceous with depth, until it becomes dolomite. A good example of this is in hole PP8.

It was thought that this phenomenon may represent surface silicification of the dolomite but a study of all the bore results shows that some bores record siliceous material for their entire depth (e.g. Bores PP10, 12 and 13), while others show a fairly rapid transition to dolomite (e.g. Bore 3A).

In view of these observations, the local sequence is thought to be made up of interbedded dolomite and clastic sediments. Deeper bores drilled over a wider area would serve to better define the stratigraphy.

These bores results are considered to establish the presence of a Precambrian dolomite-rich sequence in the area.

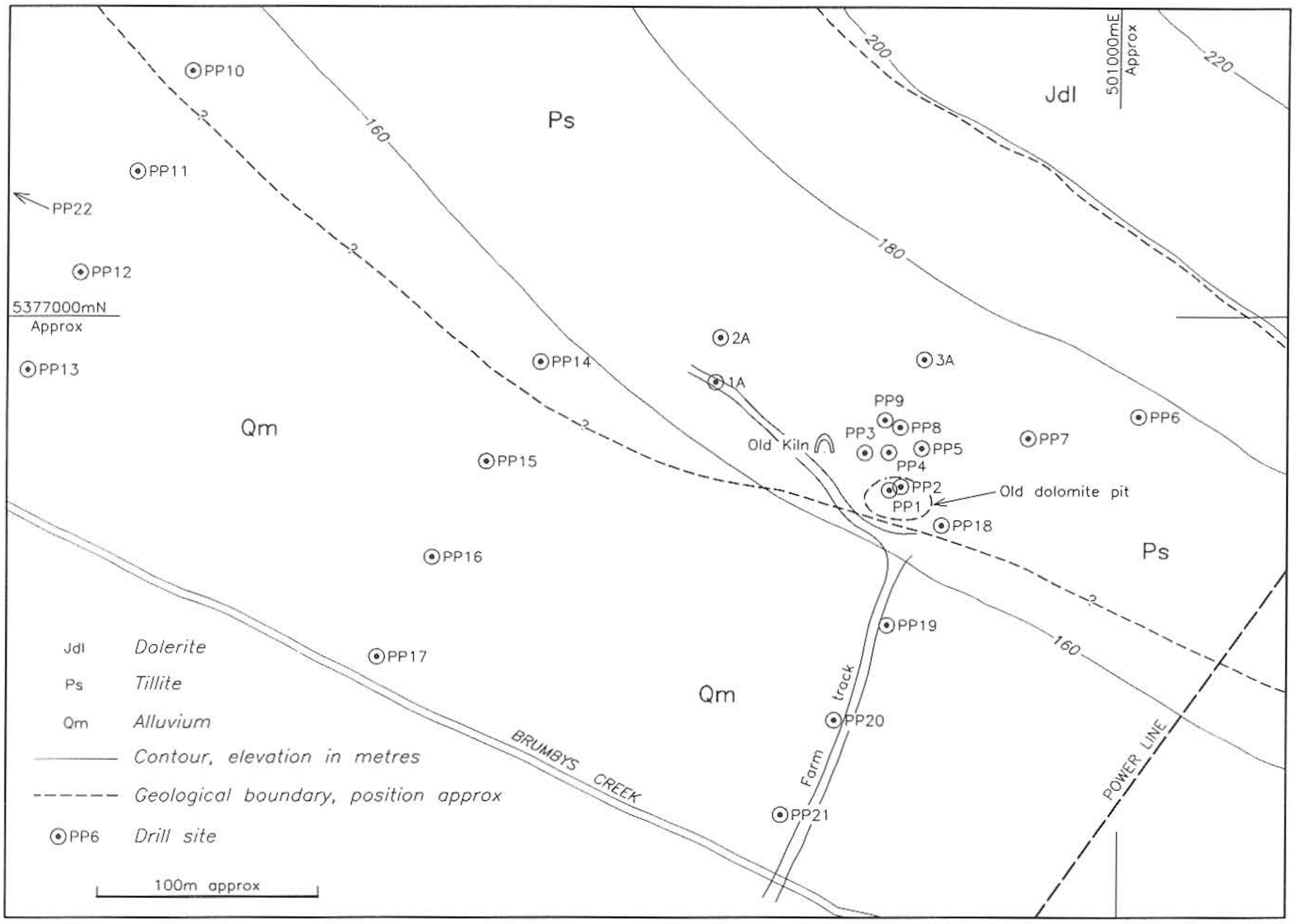

Figure 18. *Sketch plan of percussion drilling for dolomite at McRraes Hills*

RESULTS OF INITIAL DRILLING IN POATINA DOLOMITE
(Note: All holes vertical)

Hole No. PP1

Depth (m)	*CaO*	*MgO*	*SiO_2*	*Fe_2O_3*	*Analysis %* *Al_2O_3*	*TiO_2*	*MnO*	*P_2O_5*	*Na_2O*	*K_2O*
0 – 1.5	30.8	21.4	0.9	0.2	0.1	0.02	0.0	0.02	0.0	0.0
1.5 – 2.0	30.4	21.2	1.1	0.3	0.3	0.02	0.0	0.01	0.0	0.0
					Clay at 2.0 m (Hole abandoned)					

Hole PP2

Depth (m)	*CaO*	*MgO*	*SiO_2*	*Fe_2O_3*	*Analysis %* *Al_2O_3*	*TiO_2*	*MnO*	*P_2O_5*	*Na_2O*	*K_2O*
0 – 1.5					N/A (clay)					
1.5 – 3.0					N/A					
3.0 – 4.5	26.7	18.6	9.4	1.0	1.6	0.09	0.1	0.03	0.0	0.4
4.5 – 6.0	27.7	19.4	6.9	0.8	1.3	0.07	0.1	0.02	0.0	0.3
6.0 – 10.5					No sample taken (wet conditions)					
10.5 – 12.0	29.1	20.4	3.6	0.6	0.4	0.03	0.1	0.01	0.0	0.1
12.0 – 16.0	28.4	19.7	5.0	0.8	0.9	0.06	0.2	0.03	0.0	0.2

5 cm

Hole PP3

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 5.5				Clay (tillite)						
5 – 6.5	27.4	19.1	7.2	1.0	1.5	0.07	0.2	0.04	0.1	0.4
6.5 – 7.5	27.3	19.3	8.1	0.8	1.3	0.06	0.1	0.04	0.0	0.3
7.5 – 9.0	29.7	21.2	2.3	0.4	0.4	0.03	0.1	0.01	0.0	0.1
9.0 – 11.0	29.0	20.4	3.2	0.6	0.7	0.04	0.1	0.02	0.0	0.2
11.0 – 12.0	29.5	20.9	2.3	0.6	0.6	0.04	0.1	0.01	0.0	0.2

Hole PP4

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 5.0				Clay (tillite)						
	3.8	2.1	61.5	5.8	13.9	0.51	1.4	0.17	0.4	3.0
5.0 – 7.5	20.8	14.8	21.3	2.1	4.7	0.19	0.4	0.09	0.1	1.1
7.5 – 9.0	26.6	19.1	8.4	0.9	1.7	0.08	0.2	0.04	0.0	0.4
9.0 – 10.5	23.9	17.1	15.2	1.5	3.9	0.13	0.2	0.05	0.1	0.7
10.5 – 12.0	27.9	19.5	5.1	0.8	1.1	0.6	0.1	0.02	0.0	0.3

Hole PP5

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 5.0				Clay (tillite)						
5.0 – 6.0	3.3	2.1	63.8	5.5	14.6	0.56	0.1	0.17	0.4	3.0
6.0 – 7.5	5.2	3.0	60.0	5.1	13.1	0.51	0.3	0.17	0.3	2.7
7.5 – 9.0	17.5	12.1	29.3	2.8	6.7	0.28	0.2	0.08	0.1	1.6
9.0 – 10.5	23.8	16.6	15.4	1.6	3.3	0.14	0.1	0.05	0.0	0.8
10.5 – 12.0	26.1	18.3	9.9	1.1	2.1	0.09	0.1	0.03	0.0	0.5

Hole PP6

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 6.0				Clay (tillite)						
6.0 – 9.0	3.3	2.2	64.3	5.4	14.3	0.54	0.1	0.15	0.6	3.0
9.0 – 10.5	3.8	2.2	63.4	5.3	14.4	0.54	0.1	0.17	0.7	3.0
10.5 – 12.0	3.8	2.4	63.4	5.3	14.0	0.54	0.1	0.15	0.7	2.9

Hole PP7

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 3.0				Clay and topsoil						
3.0 – 6.0	3.3	2.2	64.6	5.6	14.3	0.57	0.1	0.16	0.6	2.9
6.0 – 9.0	3.5	2.2	63.7	5.7	14.7	0.56	0.1	0.15	0.5	3.0
9.0 – 10.5	3.7	2.5	63.3	5.4	14.2	0.55	0.1	0.16	0.5	3.0
10.5 – 12.0	3.5	2.3	64.5	5.6	14.3	0.55	0.2	0.14	0.5	3.0
12.0 – 13.5	3.4	2.3	63.7	5.4	14.4	0.55	0.2	0.15	0.5	3.0
13.5 – 15	3.2	2.4	64.6	5.3	14.7	0.55	0.1	0.14	0.5	3.0
15.0 – 16.5	4.4	2.7	61.6	5.1	12.7	0.48	1.8	0.16	0.4	2.7
16.5 – 18	6.9	4.1	57.3	5.0	11.3	0.49	0.7	0.24	0.3	2.4
18.0 – 19.5	3.7	2.7	57.9	6.9	15.3	0.7	0.1	0.11	0.1	4.1
19.5 – 21.0	3.4	2.4	58.3	6.7	15.3	0.69	0.1	0.11	0.0	4.2

Hole PP8

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 7.0				Clay (tillite)						
7.0 – 8.0	21.5	15.5	18.8	2.4	4.8	0.19	0.2	0.07	0.0	1.1
8.0 – 9.0	25.8	18.1	10.4	1.2	2.3	0.10	0.1	0.04	0.0	0.6
9.0 – 10.5	25.5	18.3	11.8	1.3	2.5	0.11	0.1	0.03	0.0	0.6
10.5 – 12.0	26.5	18.5	9.3	1.0	2.0	0.09	0.1	0.04	0.0	0.5
12.0 – 13.5	28.2	20.0	5.7	0.8	1.3	0.07	0.1	0.02	0.0	0.4
13.5 – 15.0	28.5	19.8	4.3	1.0	1.0	0.06	0.1	0.01	0.0	0.3
15.0 – 16.5	29.5	20.9	2.1	0.6	0.6	0.04	0.1	0.02	0.0	0.1
16.5 – 18.0	29.3	20.5	2.1	0.4	0.4	0.03	0.1	0.01	0.0	0.1
18.0 – 19.5	30.0	21.2	1.4	0.3	0.1	0.02	0.0	0.01	0.0	0.0
19.5 – 21.0	29.9	21.3	1.8	0.4	0.2	0.02	0.1	0.01	0.0	0.0

Analysis %

Hole PP9

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 6.0			Topsoil and clay (tillite)							
	5.9	3.1	58.8	5.2	13.2	0.53	0.1	0.14	0.4	2.8
6.0 – 7.5	26.5	18.6	8.8	1.1	2.0	0.09	0.1	0.03	0.0	0.5
7.5 – 9.0	23.2	16.4	16.3	1.8	3.6	0.16	0.1	0.04	0.0	0.9
9.0 – 10.5	27.7	19.0	6.3	1.4	1.3	0.07	0.1	0.03	0.0	0.3
10.5 – 12.0	31.0	21.6	3.5	1.2	0.7	0.04	0.1	0.02	0.0	0.2
12.5 – 13.5	29.3	20.6	2.3	0.7	0.6	0.04	0.1	0.01	0.0	0.2
13.5 – 15.0 (a)	28.0	19.7	5.8	0.8	1.2	0.06	0.1	0.02	0.0	0.3
13.5 – 15.0 (b)	28.3	20.0	4.9	0.9	1.1	0.05	0.1	0.02	0.0	0.3

Analysis %

Broken ground and water at 15 m (hole abandoned).

Hole PP10

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 2.0				No sample taken						
2.0 – 3.0	3.1	1.9	62.2	5.9	15.0	0.58	0.1	0.10	0.4	3.1
3.0 – 4.5	6.1	2.0	62.5	5.1	11.6	0.53	0.1	0.14	0.5	2.4
4.5 – 6.0	7.3	2.2	62.4	4.8	10.6	0.49	0.2	0.14	0.4	2.2
6.0 – 7.5	9.2	2.2	58.6	5.1	9.9	0.47	0.2	0.13	0.4	2.0
7.5 – 9.0	7.9	2.4	60.0	4.9	10.6	0.49	0.1	0.13	0.5	2.2
9.0 – 10.5	6.7	2.4	61.1	5.2	11.3	0.52	0.1	0.16	0.7	2.1
10.5 – 12.0	6.5	2.9	61.0	5.0	11.5	0.51	0.1	0.16	0.7	2.2
12.0 – 13.5	7.7	2.7	60.1	4.7	10.6	0.47	0.1	0.13	0.5	2.1
13.5 – 15.0	6.5	2.7	55.9	5.1	11.2	0.48	0.1	0.14	0.6	2.4
15.0 – 16.5	5.5	2.7	60.5	5.2	12.8	0.53	0.1	0.15	0.4	2.7
16.5 – 18.0	5.2	2.7	60.2	5.4	13.3	0.53	0.1	0.13	0.5	2.7
18.0 – 19.5	5.7	2.9	58.9	5.3	12.6	0.52	0.1	0.14	0.5	2.7
19.5 – 21.0	5.6	3.0	59.5	5.4	13.6	0.54	0.1	0.16	0.6	2.8
21.0 – 22.5	5.6	2.8	61.7	5.1	13.2	0.52	0.1	0.15	0.6	2.7
22.5 – 24.0	5.8	2.6	60.5	5.1	12.9	0.52	0.1	0.15	0.5	2.7
24.0 – 25.5	6.0	2.6	55.9	5.3	12.1	0.50	0.1	0.16	0.5	2.6
25.5 – 27.0	5.9	2.1	36.4	4.2	8.2	0.37	0.1	0.10	0.4	2.3

Analysis %

Hole PP11

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 4.0				No sample taken						
4.0 – 6.0	13.0	3.4	53.6	6.5	11.6	0.50	0.2	0.10	0.5	1.7
6.0 – 7.5	7.0	2.5	57.1	4.3	9.3	0.45	0.2	0.12	0.4	2.1
7.5 – 9.0	8.8	3.1	57.6	5.0	9.3	0.47	0.2	0.12	0.4	1.9
9.0 – 10.5	7.0	2.9	60.8	4.7	10.6	0.49	0.1	0.14	0.6	2.1
10.5 – 12.0	7.5	2.5	63.3	4.1	9.1	0.42	0.1	0.12	0.4	1.8
12.0 – 13.5	7.7	3.3	58.1	5.0	10.7	0.47	0.2	0.14	0.4	2.2
13.5 – 15.0	11.6	2.8	55.5	4.0	7.9	0.37	0.2	0.11	0.5	1.6
18.0	6.6	2.8	57.4	4.7	10.7	0.47	0.1	0.13	0.4	2.4

Hole PP12

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 5.0				No sample taken						
5.0 – 6.0	6.1	4.0	55.5	5.4	13.6	0.45	0.3	0.32	0.4	2.8
6.0 – 7.5	3.8	2.7	46.6	5.8	13.6	0.50	0.2	0.17	0.3	3.4
7.5 – 9.0	5.9	2.8	59.6	5.9	12.1	0.51	0.2	0.16	0.4	2.5
9.0 – 10.5	7.4	2.9	59.4	5.0	10.7	0.49	0.2	0.14	0.5	2.2
10.5 – 12.0	6.8	2.9	60.2	4.9	11.3	0.49	0.1	0.12	0.5	2.3
12.0 – 13.5	6.0	2.7	61.8	5.0	11.4	0.48	0.1	0.13	0.5	2.3
13.5 – 15.0	6.2	2.9	60.3	5.1	11.9	0.51	0.1	0.13	0.6	2.5
15.0 – 16.5	6.0	2.9	60.4	5.1	12.3	0.52	0.1	0.15	0.5	2.6
16.5 – 18.0	6.3	2.9	60.8	4.9	11.8	0.52	0.1	0.15	0.6	2.4
18.0 – 19.5	5.9	3.0	60.5	5.2	12.2	0.51	0.1	0.13	0.4	2.5
19.5 – 21.0	6.7	3.3	59.0	5.3	12.0	0.50	0.1	0.15	0.5	2.5
21.0 – 22.5	5.9	2.9	60.2	5.2	12.0	0.50	0.1	0.13	0.4	2.5
22.5 – 23.0	5.1	2.1	41.4	4.3	8.8	0.39	0.1	0.10	0.4	2.2

Hole PP13

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 4.0				No sample taken						
4.0 – 6.0	3.2	2.2	58.5	5.6	14.5	0.52	0.2	0.14	0.4	3.2
6.0 – 9.0	8.1	1.8	52.6	3.8	10.2	0.39	0.1	0.12	0.4	2.4
9.0 – 10.5	4.2	2.5	51.6	5.4	13.3	0.46	0.6	0.17	0.5	3.2
10.5 – 12.0	4.0	2.8	55.5	5.9	15.4	0.53	0.3	0.16	0.4	3.5
12.0 – 13.5	4.2	2.8	48.0	5.6	13.5	0.47	0.2	0.11	0.2	3.3
13.5 – 15.0	3.9	3.4	56.5	6.9	16.6	0.58	0.2	0.16	0.2	3.6
15.0 – 16.5	5.2	2.7	55.9	5.0	11.6	0.50	0.1	0.13	0.3	2.6
16.5 – 18.0	6.5	2.8	60.8	4.9	11.2	0.49	0.1	0.12	0.3	2.3
18.0 – 19.5	7.7	3.5	58.6	4.7	10.2	0.47	0.2	0.12	0.5	2.1

Hole PP14

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 4.0				No sample taken						
4.0 – 6.0	4.3	2.2	58.3	5.4	13.5	0.50	0.1	0.15	0.6	2.7
6.0 – 7.5	6.0	2.5	59.8	5.0	13.6	0.51	0.1	0.14	0.5	2.9
7.5 – 9.0	8.2	2.6	57.7	4.7	12.1	0.48	0.1	0.13	0.5	2.6
9.0 – 10.5	13.1	2.3	47.1	3.7	8.3	0.36	0.2	0.11	0.4	1.9
10.5 – 12.0	12.4	2.2	47.1	3.6	8.2	0.36	0.2	0.10	0.4	1.9

Hole PP15

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 6.0				No sample taken						
6.0 – 7.5	9.0	4.7	54.0	4.4	10.2	0.44	0.1	0.13	0.4	2.2
7.5 – 9.0	6.1	2.7	58.1	4.8	11.3	0.49	0.1	0.14	0.5	2.5
9.0 – 10.5	5.3	2.7	51.1	4.7	11.0	0.48	0.1	0.14	0.5	2.6
10.5 – 12.0	8.8	2.6	53.9	4.2	8.6	0.41	0.1	0.11	0.5	1.9
12.0 – 15.0	9.9	2.7	55.6	4.4	9.5	0.42	0.1	0.14	0.4	2.0
15.0 – 18.0	6.1	2.7	59.3	5.0	12.1	0.50	0.1	0.17	0.5	2.6

Hole PP16

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 4.0				No sample taken						
4.0 – 6.0	4.8	2.9	64.4	4.6	10.2	0.50	0.1	0.13	0.4	2.1
6.0 – 7.5	5.0	3.3	65.0	4.6	10.5	0.50	0.1	0.14	0.5	2.1
7.5 – 9.0	4.6	3.3	63.4	5.2	11.8	0.54	0.1	0.14	0.5	2.1
9.0 – 10.5	17.4	12.3	31.7	2.6	5.2	0.23	0.1	0.28	0.2	1.1
10.5 – 12.0	19.9	14.2	25.4	2.2	4.0	0.17	0.1	0.11	0.1	0.8
12.0 – 15.0	22.8	16.0	17.2	1.6	3.0	0.14	0.1	0.04	0.1	0.5
15.0 – 16.5	20.8	14.5	23.2	2.0	3.3	0.14	0.1	0.10	0.1	0.7

Hole PP17

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 6.0				No sample taken						
6.0 – 7.5	3.8	2.0	53.5	6.1	9.9	0.46	0.7	0.22	0.3	2.1
7.5 – 9.0	4.6	2.8	64.7	5.1	10.6	0.50	0.2	0.14	0.4	2.1
9.0 – 12.0	19.8	14.2	26.8	1.9	3.5	0.16	0.1	0.05	0.1	0.7
12.0 – 15.0	18.1	12.6	38.0	0.7	0.7	0.04	0.1	0.02	0.1	0.1

Hole PP18

Water and mud to eight metres then more solid, unable to take sample — running water

Hole PP19

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
				Rocks, mud and fine rock						
0 – 1.5	6.0	3.2	56.8	5.1	15.0	0.59	0.1	0.07	0.4	2.7
1.5 – 3.0	5.6	2.7	59.8	6.4	8.3	0.36	0.2	0.09	0.2	2.1

Hole PP20

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 6.0				No sample taken						
6.0 – 7.5	4.5	2.4	60.8	5.7	12.7	0.53	0.1	0.15	0.5	2.7
7.5 – 9.0	5.3	2.7	55.8	5.3	12.1	0.50	0.1	0.14	0.5	2.6
9.0 – 12.0	5.3	2.5	60.5	5.3	11.1	0.45	0.1	0.15	0.6	2.3

Hole PP21

Depth (m)	*CaO*	*MgO*	*SiO_2*	*Fe_2O_3*	*Analysis %* *Al_2O_3*	*TiO_2*	*MnO*	*P_2O_5*	*Na_2O*	*K_2O*
0 - 6.0				No sample taken						
6.0 - 7.5	6.1	3.2	56.6	4.9	9.1	0.44	0.2	0.11	0.4	2.0
7.5 - 9.0	6.1	3.3	57.2	4.9	9.4	0.45	0.2	0.12	0.4	2.0

Hole PP22

Depth (m)	*CaO*	*MgO*	*SiO_2*	*Fe_2O_3*	*Analysis %* *Al_2O_3*	*TiO_2*	*MnO*	*P_2O_5*	*Na_2O*	*K_2O*
0 - 6.0				No sample taken						
6.0 - 9.0	12.2	1.7	43.4	3.5	8.0	0.35	0.1	0.11	0.2	2.0
9.0 - 10.5	7.2	2.3	58.4	5.1	12.7	0.50	0.1	0.14	0.4	2.6
10.5 - 12.0	9.9	2.1	53.7	4.2	10.2	0.40	0.1	0.14	0.3	2.3
12.0 - 15.0	9.7	1.9	53.5	3.3	8.4	0.33	0.1	0.10	0.4	2.0
15.0 - 18.0	7.7	2.0	56.1	4.0	10.8	0.41	0.1	0.13	0.4	2.5
18.0 - 21.0	5.3	2.6	54.1	5.8	14.2	0.49	0.3	0.12	0.4	3.3
21.0 - 27.0	6.2	2.2	59.8	4.5	12.4	0.47	0.1	0.13	0.5	2.7

Hole 1A

Depth (m)	*CaO*	*MgO*	*SiO_2*	*Fe_2O_3*	*Analysis %* *Al_2O_3*	*TiO_2*	*MnO*	*P_2O_5*	*Na_2O*	*K_2O*
3.0 - 4.5	5.4	2.3	61.5	5.2	13.2	0.53	0.1	0.15	0.4	2.8
4.5 - 6.0	5.7	2.4	61.0	5.1	13.1	0.53	0.1	0.14	0.4	2.8
6.0 - 7.5	5.8	2.6	60.1	5.1	12.9	0.52	0.1	0.14	0.4	2.8
7.5 - 9.0	5.1	2.8	58.0	5.2	13.2	0.57	0.1	0.16	0.7	2.8
9.0 - 10.5	3.8	2.8	62.9	5.1	13.9	0.55	0.1	0.16	0.5	2.9
10.5 - 12.0	3.9	2.7	60.3	4.8	13.4	0.53	0.1	0.15	0.4	2.9
12.0 - 13.5	5.6	3.9	49.8	4.0	12.0	0.46	0.2	0.13	0.2	2.6

Hole 2A

Depth (m)	*CaO*	*MgO*	*SiO_2*	*Fe_2O_3*	*Analysis %* *Al_2O_3*	*TiO_2*	*MnO*	*P_2O_5*	*Na_2O*	*K_2O*
0 - 3.0	5.0	1.9	60.4	4.9	11.1	0.50	0.1	0.14	0.5	2.3
3.0 - 4.5	6.9	2.0	57.3	4.9	10.8	0.48	0.1	0.14	0.5	2.3
4.5 - 6.0	3.9	2.6	54.7	4.8	11.8	0.49	0.1	0.15	0.3	2.7
6.0 - 7.5	6.3	2.8	59.5	4.9	11.7	0.50	0.1	0.14	0.5	2.5
7.5 - 9.0	5.6	2.8	60.7	5.3	12.8	0.53	0.1	0.15	0.5	2.7
9.0 - 10.5	5.5	2.8	59.3	5.3	12.8	0.52	0.1	0.15	0.4	2.7
10.5 - 12.0	5.6	2.2	44.1	4.8	9.8	0.43	0.1	0.12	0.4	2.7
12.0 - 13.5	5.6	2.6	56.8	5.0	12.0	0.51	0.1	0.22	0.5	2.6
13.5 - 15.0	5.6	2.6	56.5	5.0	12.2	0.50	0.1	0.22	0.5	2.6
15.0 - 16.5	6.3	3.4	57.2	5.8	12.0	0.49	0.2	0.17	0.3	2.6
16.5 - 18.0	4.8	3.1	61.4	5.3	13.1	0.53	0.1	0.19	0.4	2.8
18.0 - 19.5	10.8	2.7	55.4	4.8	8.3	0.40	0.2	0.13	0.4	1.7
19.5 - 21.0	11.5	8.4	43.5	3.5	8.6	0.33	0.5	0.13	0.1	1.9
21.0 - 22.5	22.2	16.2	21.8	1.0	2.2	0.10	0.1	0.05	0.1	0.5
22.5 - 24.0	24.8	18.0	15.0	0.7	1.2	0.06	0.1	0.03	0.1	0.3
24.0 - 25.5	18.8	13.8	27.9	1.8	4.4	0.19	0.1	0.07	0.1	1.0

Hole 3A

Depth (m)	CaO	MgO	SiO_2	Fe_2O_3	Analysis % Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O
0 – 6.0	6.7	2.3	53.6	4.8	11.6	0.50	0.1	0.15	0.4	2.6
6.0 – 7.5	6.1	2.3	59.3	5.0	12.6	0.50	0.1	0.15	0.4	2.7
7.5 – 9.0	5.9	2.5	58.1	5.1	12.7	0.52	0.1	0.15	0.5	2.7
9.0 – 10.5	3.9	2.5	62.7	5.4	14.0	0.55	0.1	0.17	0.4	2.9
10.5 – 12.0	4.1	2.2	62.5	5.5	13.8	0.54	0.1	0.16	0.4	2.9
12.0 – 13.5	8.2	5.8	51.5	4.7	11.9	0.46	0.1	0.15	0.2	2.6
13.5 – 15.0	26.3	18.7	9.3	1.1	2.0	0.09	0.1	0.03	0.1	0.5
15.0 – 16.5	27.9	19.7	6.2	0.7	1.0	0.05	0.1	0.03	0.1	0.3
16.5 – 18.0	27.9	19.6	5.4	0.8	0.9	0.05	0.1	0.02	0.1	0.2
18.0 – 19.5	23.4	16.0	20.9	0.7	0.6	0.04	0.1	0.03	0.1	0.2
19.5 – 21.0	27.2	19.3	9.5	0.6	0.5	0.04	0.1	0.02	0.1	0.1
21.0 – 22.5	28.1	19.9	5.9	0.8	0.5	0.03	0.1	0.02	0.1	0.1
24.0 – 25.5	27.7	19.5	8.1	0.8	0.5	0.03	0.1	0.03	0.1	0.1
25.5 – 27.0	28.1	19.7	6.0	0.9	0.8	0.05	0.1	0.02	0.1	0.2

MINERAL RESOURCES
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