GEOLOGICAL SURVEY

BULLETIN 58

STRATIGRAPHY, CORRELATION AND EVOLUTION OF THE MT READ VOLCANICS IN THE QUEENSTOWN, JUKES-DARWIN AND MT SEDGWICK AREAS

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Stratigraphy, correlation and evolution of the Mt Read Volcanics in the Queenstown, Jukes – Darwin and Mt Sedgwick areas

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Plate 1. *View south over Mt Lyell workings towards Mt Jukes.*

PREFACE

The belt of Cambrian acid volcanic rocks in Western Tasmania, known as the Mt Read Volcanics, is of considerable economic significance to the State. The belt is host to the Zn - Ag - Pb orebodies at Rosebery, Hercules and Mt Farrell, and to the Cu orebodies at Mt Lyell. The recently discovered Que River deposit also lies within the belt, and there are numerous smaller prospects. There is considerable potential for the discovery of further massive sulphide bodies, and many companies are actively involved in exploration. Because of their complexity and alteration, however, the volcanics have received little detailed study, and the nature and significance of the various rock types present and the relationship between mineralisation and stratigraphy have until recently been very poorly known.

A special study of the volcanics was commenced by Dr Corbett in 1974, aimed at defining and mapping the various rock units and determining, if possible, the relationship between stratigraphy and mineralisation. This Bulletin represents the first major report arising from that work, and deals with that section of the belt between Mt Darwin and Mt Sedgwick, encompassing the Mt Lyell Mines.

The report demonstrates that virtually all the significant mineralisation in this area occurs within one sequence dominated by characteristic ash-flows and lavas. This sequence was probably deposited in a rift valley structure somewhat analogous to a large caldera, which appears to extend for much of the length of the belt. This represents a major advance in understanding of the volcanics, and provides a much improved geological basis for further mineral exploration.

J.G. SYMONS, Director of Mines

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ABSTRACT

Detailed mapping shows two major sequences to be present within the Mt Read Volcanics in the South Queenstown area. The western volcano-sedimentary sequence is dominantly marine, and contains greywacke, shale, vitric tuff, quartz-phyric crystal tuff, quartz-feldspar porphyry intrusives, and minor tholeiitic basalts (the oldest unit). The second (central) sequence is dominated by feldspar-phyric agglomerate, tuff, lava and intrusives, with some andesitic intrusives and pyroclastics. Ash-flow tuffs are abundant in the latter sequence, which appears to be largely subaerial. The contact between the two sequences is abrupt and partly discordant, and is interpreted as a caldera-type margin, with the central sequence being contained within a subsidence structure developed after formation of the western sequence.

The central sequence continues southwards as an elongate belt to South Darwin Peak, where it includes the Darwin Granite and is flanked to the west by quartz-phyric volcanics in the Clark Valley. It is overlapped unconformably to the east by a sequence rich in volcaniclastic conglomerate and quartz-phyric volcanic rocks which extends north to Mt Huxley. Correlates of the western, central and eastern sequences are recognisable in the complex Yolande River-Mt Lyell Mines area, where there is considerable disruption by cross-faults, and in the Mt Sedgwick-Lake Beatrice area. A non-volcanic conglomerate-sandstone-siltstone sequence which rests unconformably on Precambrian rocks near Lake Beatrice probably represents the basin-margin equivalent of the western sequence.

The evolution of the volcanic belt in this area appears to have involved an early marine basin in which a line or belt of isolated volcanoes subsequently subsided to form a linear rift valley-caldera structure in which the central belt rocks were erupted. Fossil evidence suggests the rift probably developed in the late Middle Cambrian. Erosion of the earlier volcanic rocks, together with eruptions of mainly quartz-phyric volcanics, produced the eastern sequence, probably in the early Late Cambrian. The latter appears to have been deposited mainly in secondary rifts or depressions within the earlier rift. The type Comstock Tuff is considered to be part of this later sequence. Virtually all the known sulphide mineralisation is related to the rift valley sequence, and much may have been removed during the erosional period represented by the eastern sequence. Deposition of the siliceous Owen Conglomerate in the mid to late Late Cambrian and Early Ordovician was partly controlled by intra-rift faults.

INTRODUCTION

GEOLOGICAL SETTING

The Cambrian Mt Read Volcanics form a complex north-south belt, 10-20 km wide, of dominantly acid to intermediate volcanic rocks extending through western Tasmania. The belt is flanked to the east by Precambrian rocks of the Tyennan region, and to the west by Cambrian sedimentary sequences containing ultramafic-mafic complexes and mafic volcanics. The southern part of the volcanic belt is extensively overlapped by siliceous Precambrian-derived conglomerate and sandstone of the Owen Conglomerate formation, ranging in age from middle Late Cambrian to Early Ordovician, and by younger Ordovician limestone and Siluro-Devonian clastic sediments. Over much of the belt the Owen Conglomerate forms a broad, north-south trending, fault-bounded anticlinal structure, which at Mt Lyell is disrupted and twisted into an almost east-west orientation by a major system of Devonian cross-faults. A strong Devonian cleavage of northwesterly to north-north-westerly trend affects the Cambrian rocks, which show regional lower greenschist metamorphism and locally intense hydrothermal alteration.

The volcanic belt is host to the massive and disseminated base metal sulphide deposits at Mt Lyell, Hercules, Rosebery, Mt Farrell, Chester-Pinnacles and Que River, and constitutes one of the most heavily mineralised units in Australia. However, little detailed mapping of the sequence has been attempted because of the complexity of rock types involved and the difficulties caused by alteration, tectonism, weathering, dense forest cover and poor exposure.

The age of the volcanic rocks has long been a problem. The sequence is clearly older than the base of the Owen Conglomerate, dated as middle Late Cambrian at the Tyndall Range (Corbett, 1975*b*), although minor local volcanism and intrusion may have continued beyond this. A fossiliferous limestone occurs within the volcanic sequence at Mt Lyell, and indicates a late Middle or early Late Cambrian age (Jago, *et al.*, 1972), and a fossiliferous shale within the sequence at the Que River has a late Middle Cambrian age (Gee, Jago and Quilty, 1970). However, much of the volcanic sequence lies below these units, and a lower age limit is difficult to establish. Attempts to date the volcanics radiometrically have not yet been successful.

A study of acid-insoluble microfossils (acritarchs) from shale units within the volcanics was carried out by Dr Gonzalo Vidal in 1976-77, and originally suggested the possibility of a Late Precambrian age for some units. However, the stratigraphic value of the acritarchs, (particularly *Bavlinella faveolata* (Shepeleva) and *Chuaria circularis* Walcott, which were recovered from most of the samples) has been strongly questioned (*e.g.* Muir, 1977), and a Precambrian age for the volcanics seems highly unlikely. Results presented in this report, and recent work by the author in the Mt Read area, strongly suggest that the bulk of the volcanics are Middle to Late Cambrian.

SCOPE OF STUDY

A special field project on the volcanics, aimed at identifying and mapping the major rock types and establishing a workable stratigraphy, was undertaken by the author in 1974 in the Economic Geology Section of the Geological Survey of Tasmania. It was hoped that the stratigraphy could be related to the mineralisation, and hence provide a guide for further exploration. Areas of good exposure in which significant relationships could be determined were selected to begin the study, and most work to date has been on the southern part of the belt between South Darwin Peak and Mt Read. This report represents the first major publication arising from the project, although some progress reports and general reviews have been presented elsewhere.

The Queenstown area has particularly good exposure of the volcanics, mainly because of the lack of the usual rainforest vegetation, a feature initiated by early smelting techniques at Mt Lyell and perpetuated by frequent bushfires. The area is also one of the most complex in the belt, however, with numerous rock types in complex associations, considerable tectonic and metamorphic overprinting, and complications due to deep weathering, leaching and bleaching of outcrops. A relatively small area (about 32 km^2) between South Queenstown and Whip Spur has been mapped in considerable detail as a pilot study to identify and describe the major rock types, to determine their relationships to one another, and to establish a stratigraphy for correlation with other areas. The first part of this Bulletin deals with that area. Areas bordering this to the north and south are described in less detail in the second part of the Bulletin, based mainly on reconnaissance and detailed mapping by the author, and correlations to the South Queenstown area are discussed. The latter sections of the Bulletin deal with the interpretation of the various sequences and relationships, and a model for the evolution of the volcanic belt is presented.

A geochemical study of the volcanics is presently being undertaken by the author, but many of the data were unavailable at the time of writing and a more detailed account will be published elsewhere. All rock analyses obtained by the author for the Queenstown area, including trace element contents, are given in the Appendices, and some discrimination diagrams for the basaltic rocks are included in the text.

PREVIOUS WORK

The early literature on the Mt Lyell mines is summarised by Wade (1958) and Wade and Solomon (1958), and a recent account of the geology of the mine area is given by Reid (1976). Generalised sketch maps and brief descriptions of some of the volcanic rocks in the South Queenstown area have been given by Solomon (1960) and Bradley (1954). A general description of the volcanic sequence in the Queenstown area, and a discussion of the relationships with the overlying rocks, has been given by Corbett *et al.* (1974), and a review of the stratigraphic setting of the mineralisation between Mt Darwin and Red Hills by Corbett (1975*a*). A review of the geology of western Tasmania, with an account of the Mt Read Volcanics, is given by Corbett, Green and Williams (1977). The only major published work of value on the Jukes-Darwin area is that of Hills (1914). Unpublished reports dealing with the King River Gorge, Mt Jukes and South Darwin Peak areas are available at the Department of Mines (Corbett, 1976*a*, *b*,*c*).

NOMENCLATURE

General terms such as rhyolite, andesite etc. used in this Bulletin are based on silica percentages according to the scheme of Blissett (1975) and Branch (1978): basalt <53% SiO_2, andesite 53-63%, dacite 63-69%, rhyodacite 69-73%, rhyolite >73%. The general term 'tuff' is used for any pyroclastic rock (ash-fall or ash-flow) composed dominantly of fragments less than 4 mm diameter, and 'agglomerate' is used for rocks containing greater than 30% of fragments greater than 4 mm diameter. The terms 'ash-flow tuff' and 'ignimbrite' are used for tuffs or agglomerates showing evidence of deposition from hot ash-flows, *i.e.* compacted pumice fragments, fiamme, welding of shards, etc.

THE SOUTH QUEENSTOWN AREA

INTRODUCTION

Mapping of this area (fig. 1) was done mainly in the winter of 1975 and the summer of 1975-76, at a scale of 1:15 840 using a contoured base map and colour air photographs. Thin sections of over 200 samples from the area have been examined, and brief descriptions of some 140 are included. An exhaustive petrological study has not been attempted, however, and many of the mineral identifications are tentative. Localities for petrological and geochemical samples are shown on a separate map (fig. 2).

GENERAL GEOLOGY

The volcanic sequence south of Queenstown occupies a wedge-shaped area between a large syncline of Ordovician and Siluro-Devonian rocks to the west and the belt of Owen Conglomerate to the east. The latter formation, which includes boulder grade conglomerates, is of the order of 1000 m thick (Wade and Solomon, 1957). Its contact with the volcanics is discordant and appears to be faulted in most areas. The contact is flat-lying in places and may be a folded thrust fault in part. The Owen Formation is largely unfossiliferous except for a few trace fossil horizons, but is overlain by fossiliferous Gordon Limestone of Ordovician age. The sandy upper 10 m or so of the formation rests unconformably on the underlying part near Gormanston, and is known as the Pioneer Beds. A correlate of these beds, comprising some 10-20 m of siliceous sandstone and granule-pebble conglomerate, with minor calcareous siltstone, unconformably overlies the volcanic sequence along the western margin of the area, where it is succeeded conformably by Gordon Limestone. The absence of the bulk of the Owen Conglomerate in the western part appears to be a primary depositional feature reflecting control of sedimentation by the Great Lyell Fault (Corbett *et al.*, 1974). South of the mapped area at Mt Huxley, however, a significant thickness of pebble-cobble conglomerate occurs west of the continuation of the Great Lyell Fault System, and the locus of sedimentation appears to lie west of the fault in the Jukes-Darwin area (fig. 3).

The volcanic units trend generally N-S to NNW-SSE through the area, swinging to WNW-ESE at the northern margin near the main zone of Devonian cross-faulting. The rocks are mainly steeply-dipping, with slight overturning in some areas, and have a strong NW-trending steeply-dipping Devonian cleavage. This cleavage, which is also recognisable in the Owen Conglomerate, appears to be related to NW-trending cross-folds in the overlying rocks, but these folds are difficult to recognise in the volcanic sequence. The cleavage cross-cuts two large N-S trending folds in the Cambrian rocks - an anticline in the Miners Ridge area, and a syncline in the Little Owen area. There is no obvious cleavage associated with these early folds, but a detailed study of the structural elements has not been attempted. A NW-trending cross-fault dextrally offsets the Miners Ridge anticline by about 300 m, and brings a sandstone unit on the east limb south of the fault into juxtaposition with the same unit on the west limb north of the fault.

The volcanic sequence is very complex, with an almost complete spectrum of compositional types from acid to basic, and a wide range of intrusive, extrusive, pyroclastic and epiclastic lithologies. Considerable problems have been encountered in correlating sequences even over short distances, despite the good exposure. Such problems include rapid facies variations, wedging out of units, variable degrees of alteration and weathering, lack of marker horizons, lack of facing evidence in many units, difficulties in determining whether massive units are intrusive or extrusive, and lack of exposure of critical contacts. The stratigraphic relationships of a number of units remain doubtful.

A general two-fold stratigraphic subdivision is possible into a western volcano-sedimentary sequence, best exposed in the Miners Ridge-Lynch Creek area, and a more complex volcanic-intrusive sequence in the Little Owen-Whip Spur area. The latter is referred to as the central sequence ('central lava belt' of Corbett *et al.*, 1974) because a third sequence, referred to as the eastern sequence, is developed just outside the mapped area to the south-east. The western sequence is rich in greywacke, shale, vitric tuff and quartz-phyric crystal tuff, and is intruded by a major quartz-feldspar porphyry body. The central sequence is dominated by feldspar-phyric acid volcanic rocks, including various agglomerates, tuffs, lavas and intrusives, but also includes andesitic intrusives and pyroclastics. The contact between the western and central sequences appears to represent a major break in the stratigraphy across which there is little or no correlation.

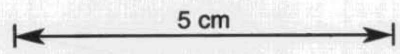
A major unit of intermediate tuff and agglomerate occurs at the top of the western sequence in the Lynchford area. This unit overlaps a lens of porphyritic basalts surrounded by greywackes in Lynch Creek, and containes identical basaltic detritus. The unit is lithologically very similar to the Comstock Tuff, an important fossiliferous unit near Mt Lyell which contains late Middle Cambrian or early Late Cambrian fossils (Corbett *et al.*, 1974). The Comstock Tuff overlies, possibly unconformably, schistose volcanics which appear to have been altered and mineralised prior to its deposition (Jago *et al.*, 1972). The Lynchford unit, however, is conformable with the underlying rocks, and its relationship with the western sequence and with the Comstock Tuff remains a problem. A large lens of agglomerate and tuff somewhat similar to the Lynchford unit occurs within the central sequence on Whip Spur, where it is surrounded and intruded by a large feldspar-porphyry mass. The age and original position of this lens are also problematical.

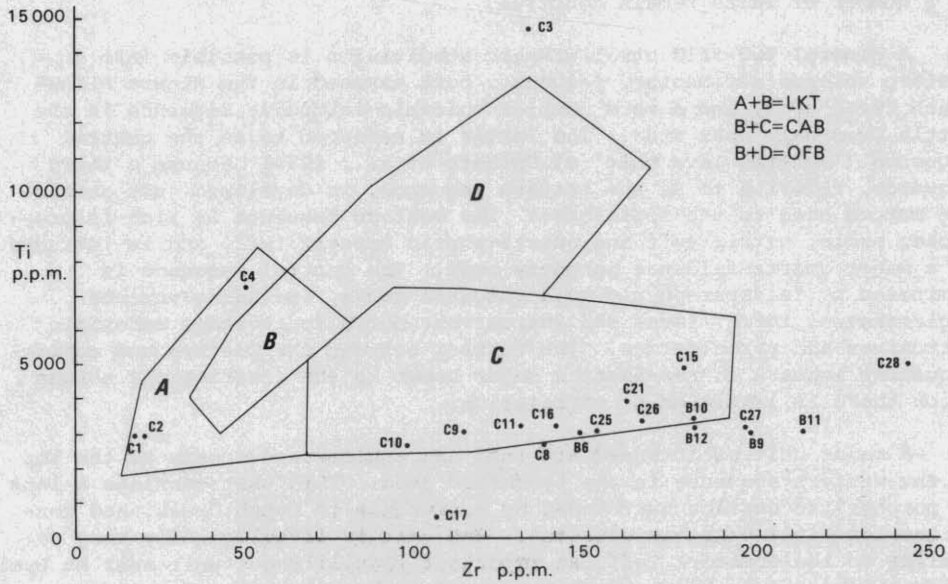
WESTERN VOLCANO - SEDIMENTARY SEQUENCE

General description

A thick sequence of greywacke, shale, sandstone, tuff and agglomerate, with intercalated basic lavas, is exposed in the vicinity of Miners Ridge and Lynch Creek. The sequence appears on either limb of the Miners Ridge anticline, but there is considerable asymmetry in the occurrence of various lithologies, *e.g.* the basic volcanic units and the major greywacke sequence occur mainly on the western flank. An elongate sub-conformable quartz-feldspar porphyry body, similar in composition to some of the quartz-rich tuffs, intrudes the sequence.

The oldest part of the sequence, exposed in the core of the anticline, is a unit of ophitic-textured basic lava and breccia. A sequence of greywacke, shale and tuff overlies the lavas, and is overlain by the Miners Ridge Sandstone, a distinctive non-volcanic quartzwacke unit which is an excellent marker horizon. Overlying the sandstone is a mixed sequence of vitric tuff, tuffaceous shale, siltstone, greywacke and





C1	Miners Ridge basalt	**C21**	Basic dyke in Whip Spur agglomerates
C2	Miners Ridge basalt	**C25**	Reservoir andesite body
C3	Miners Ridge basalt	**C26**	Reservoir andesite body
C4	Miners Ridge basalt -eastern lens	**C27**	Little Owen andesite body
C8	Lynch Creek basalt	**C28**	Andesite lens, NW flank of Little Owen
C9	Lynch Creek basalt		
C10	Lynch Creek basalt	**B6**	'Horse paddock andesite', Lake Margaret Road
C11	Lynch Creek basalt	**B9**	Crown Hill andesite, pylon locality
C15	Basic agglomerate, Reservoir Creek	**B10**	Crown Hill andesite, old house site
C16	Intermediate dyke, west of Little Owen	**B11**	Hornblende andesite, Bradshaws Road, Tyndall area
C17	Dyke or lava, lower Conglomerate Creek	**B12**	Hornblende andesite, Tyndall Drill Hole 1

Figure 4. *Discrimination diagram using Ti and Zr, after Pearce and Cann (1973). Fields A + B = low potassium tholeiites (LKT), B + C = calc-alkali basalts (CAB) and B + D = ocean-floor basalts (OFB). Sample numbers refer to Appendices A and B. Note that some altered samples (particularly B6, B12, C15, C17, C21, C28) do not comply with the compositional criterion of Pearce and Cann (20% >CaO + MgO >12%), but these are included to indicate the effects of alteration.*

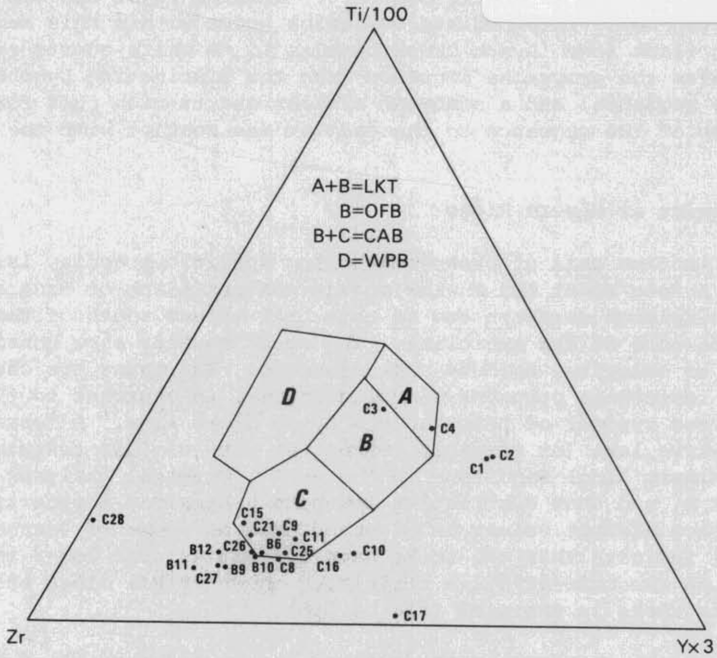


Figure 5. *Discrimination diagram using Ti, Zr and Y, after Pearce and Cann (1973). See Figure 4 for explanation.*

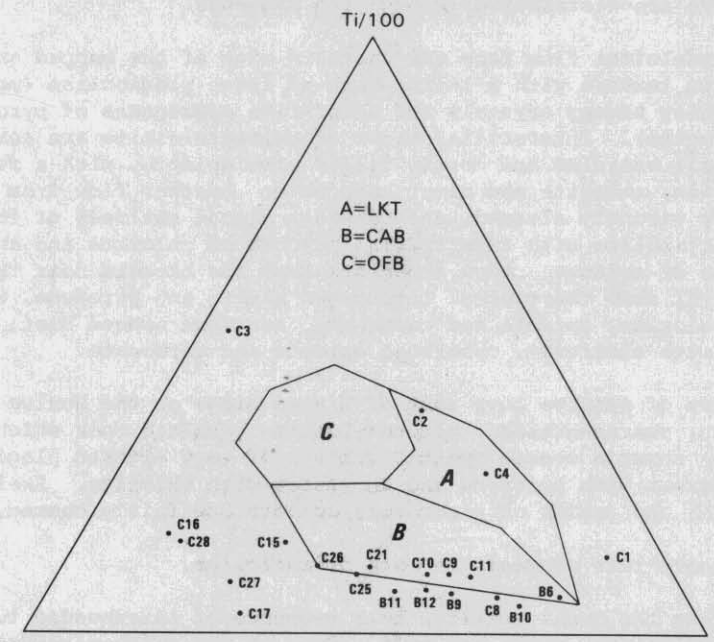


Figure 6. *Discrimination diagram using Ti, Zr and Sr, after Pearce and Cann (1973). See Figure 4 for explanation.*

crystal tuff, which on the western flank of the anticline passes gradationally into a greywacke-dominated sequence. Several major and minor units of porphyritic basic-intermediate volcanics occur within this sequence on the western flank (the 'Lynch Creek basalts'). A white quartz-rich tuff unit separates the greywacke sequence from the distinctive Lynchford tuff-agglomerate sequence, and a somewhat similar quartz-rich tuff forms the apparent top of the sequence to the east at the contact with the central sequence.

Basic volcanics at Miners Ridge

A distinctive unit of brown-weathering spilitic breccia, lava and tuff forms a zone about 100 m wide on the western flank of Miners Ridge. The fault-displaced northern end of this unit occurs south of the Huxley Track in the core of the anticline. The rocks usually show considerable alteration to chlorite, epidote and carbonate. The lavas are characterised by ophitic texture in pyroxene and plagioclase, in contrast to the porphyritic textures typical of units in the Lynch Creek area. A lens-shaped body of massive lava (or possibly intrusive) with similar texture occurs above the Miners Ridge sandstone to the east. Chemical analyses are given in Appendix A, and show distinctive low-potash basaltic compositions. Plots of trace element values on diagrams such as those of Pearce and Cann (1973) indicate that the rocks have affinities with low-K tholeiites as opposed to the calc-alkaline affinities shown by all other basic-intermediate rocks in the area (fig. 4,5,6).

Breccias are abundant in the main sequence, and consist of blocks of greenish lava from a few centimetres to a metre or so long in a strongly cleaved purplish green matrix rich in epidote and hematite. Many of the lava fragments are amygdaloidal. Blocks and irregular masses of banded tuff occur in the breccias in places. Irregular flows of massive or amygdaloidal lava are distributed through the sequence.

An amygdaloidal flow from the southern edge of the mapped area (P1)* shows ophitic texture with a latticework of large plagioclase (mainly albite) laths enclosing stumpy crystals and sheaf-like aggregates of pyroxene (probably augite). Interstitial blebs of chlorite-albite are common. The abundant small vesicles are mostly filled with epidote, with a few containing albite, chlorite and minor carbonate. Another flow from this area (P2) is very strongly altered, and consists almost entirely of fibrous tremolite-actinolite with interstitial patches of chlorite and abundant large grains of epidote. Lava fragments from the breccia near the Huxley Track (P3, P4) show the typical intergrown albite and pyroxene, with secondary chlorite, epidote and carbonate, and fine opaque dust. Amygdales are filled with albite(?), chlorite, epidote and carbonate.

The lens of massive lava east of Miners Ridge on the Huxley Track is a dark green, coarse-grained, altered-looking basaltic rock which in thin section (P5) shows a coarse ophitic texture of very altered plagioclase laths intergrown with pyroxene and in places with chlorite. Skeletal opaque grains and grains of pleochroic epidote are fairly common.

Greywacke-shale-tuff sequence in core of anticline

Overlying the basal spilites is a sequence of interbedded tuffaceous sandstone, siltstone, shale and tuff. Many of the thicker sandstone beds

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* Sample localities and Department of Mines catalogue numbers are shown on a separate map (fig. 2) in pocket.

(up to 2 m) contain shale pellets and show grading, erosional bases and laminated tops typical of turbidites.

A unit of brown-weathering fine- to medium-grained chloritic tuff and tuffaceous sandstone immediately overlies the spilites. In thin section (P6) it consists mainly of quartz grains, chlorite grains and altered feldspar grains, with scattered rock fragments, altered biotite flakes, and opaque dust. The quartz includes both polycrystalline and embayed types, and is predominantly angular.

A thin section of typical greywacke sandstone in Lynch Creek (P7) shows it to be poorly sorted, with about 30% matrix, much of which appears to be secondary chlorite. Grains consist mostly of quartz, and include a high proportion of composite and polycrystalline grains probably of Precambrian derivation. Grains of altered feldspar, some showing albite twinning, also occur, and there are scattered small volcanic rock fragments. Other components include fairly common muscovite grains, tourmaline, and scattered opaques. The margins of most grains have been corroded by recrystallisation of the matrix components, but some appear to have been originally well rounded.

Miners Ridge Sandstone

This unit is sufficiently distinctive and mappable to warrant formal definition as a formation. It has been recognised in the King River Gorge, some 4 km to the south, and also near the West Queen River some 5 km to the north. It is the unit of well-bedded white quartzose sandstone and subordinate grey siltstone which outcrops on the crest of Miners Ridge [CP807353]. The unit is 50-60 m thick in Lynch Creek on the eastern limb of the anticline, but appears to be much less than this on the western flank, where outcrop is poor. A NW-trending dextral transcurrent fault brings the eastern limb on the south side into juxtaposition with the western limb on the north side. The western limb disappears just south of the fault, possibly because of strike faulting, but the eastern limb continues southwards as a prominent ridge to the King River. The two limbs join in a complex crestal zone to the north of Lynch Creek, beyond which the western limb can be traced to South Queenstown. Large xenoliths of the sandstone occur in the intrusive quartz-feldspar porphyry in Roaring Meg Creek.

The sandstone is typically parallel-bedded, in units 100 mm to one metre thick, with thin intercalations of grey siltstone and mudstone. Grading from coarse to fine sand is evident in some of the thinner beds, but many consist entirely of medium to fine sand and are not obviously graded. Most beds have sharp tops and bases. Convolute lamination is common in the upper parts of beds, and soles may show load casts and flame structures. The sequence is interpreted as a quartzwacke turbidite deposit.

Thin sections (P8, P9) show fine-grained, fairly well sorted sandstone in which most grains are in contact and matrix is only about 5%. The rock consits mostly of sub-angular quartz grains and quartzose rock fragments, with fairly numerous mica flakes (mostly muscovite, with some biotite and chlorite), scattered tourmaline grains, minor zircon, and some carbonate as scattered grains and blebs. The mica flakes show a marked alignment parallel to bedding. Most of the larger quartzose grains are polycrystalline, and some are clearly quartz schist fragments with included flakes of muscovite or chlorite, indicating derivation from a Precambrian source. There is no obvious volcanic quartz, feldspar or volcanic rock fragments, and all the components appear to have been derived from a metamorphic terrain.

Tuff-shale sequence above Miners Ridge Sandstone

A sequence of interbedded vitric tuff, shale, siltstone and greywacke, with several units of coarse-grained crystal tuff and several lenses of basic-intermediate rocks, conformably overlies the Miners Ridge Sandstone. The sequence is gradational with the greywacke-tuff sequence which overlies it to the west, and the boundary shown on the map indicates only the approximate position at which greywacke becomes more abundant than tuff. The apparent absence of the greywacke sequence on the eastern flank of the anticline may be largely due to differences in the degree of leaching and weathering, making the greywacke more difficult to recognise. The basic-intermediate rocks are described in a later section.

A typical rock type is a pale, fine-grained glassy tuff which may be laminated or massive. It is commonly interbedded with grey tuffaceous siltstone and shale, but may occur as continuous units up to 20 m thick. Shard textures and possible pumice fragments are preserved in some of the tuffs, suggesting that most are glassy ash deposits. Coarser grained tuffs with quartz and feldspar crystals are also common, and one of these forms a major mapping unit on the east flank of the anticline. Such tuffs commonly contain contorted shale clasts.

The high proportion of sediments, the abundance of fine lamination in the tuffs, and the presence of shale clasts in many units, suggest that much of the sequence was deposited subaqueously. The gradational relationship with the greywacke sequence, which contains marine trace fossils and microfossils in one area, suggests a marine rather than lacustrine environment.

A thin section (P10) from a massive white glassy tuff unit near the top of the sequence in Roaring Meg Creek consists almost entirely of devitrified glass shards, the shapes of which are evident in plain light. The shards are completely altered to fine-grained quartz-feldspar-sericite. There are also scattered small grains of quartz and feldspar, and abundant secondary carbonate blebs. The fine sericite shreds outline a weak foliation parallel to bedding, and a stronger one at about 50°. A tuff from approximately the same stratigraphic position on the south bank of the lower Reservoir Creek dam is generally massive except for egg-shaped devitrification structures which weather out on some surfaces. In thin section (P11) it consists almost entirely of fine sericitic glassy material, with scattered small feldspar crystals and a few possible rock fragments of feldspar porphyry. There is some suggestion of elongate shard shapes and possible pumice fragments, but these have been largely obliterated by the secondary foliations.

A massive pale vitric-crystal tuff in Roaring Meg Creek (P12) consists of a mixture of small angular quartz grains with some feldspar and rock fragments, in an abundant matrix of fine sericitic material with some secondary carbonate. Two prominent foliations are apparent, and original textures have been destroyed. Another massive fine-grained tuff from beside the quartz-feldspar porphyry body south of Roaring Meg Creek (P13) consists of recrystallised cryptocrystalline sub-isotropic material with only a few small feldspar grains. There is a strong suggestion of shard texture in ordinary light.

A pyritised medium-grained crystal-vitric tuff from Lynch Creek west of Miners Ridge (P14) consists of a mixture of angular and broken quartz crystals, altered feldspar grains and chloritic rock fragments in a vitroclastic matrix now consisting mostly of sericite. A 10 m thick vitric-crystal tuff containing contorted blocks of black shale up to 1.5 m long occurs in Lynch Creek about 50 m upstream of the Huxley Track crossing. In thin section (P15) it contains volcanic quartz and feldspar phenocrysts and blebs of chlorite in an abundant matrix of recrystallised glassy material. The latter comprises masses and stringers of felted sericite separating areas of cryptocrystalline sericite, chlorite, feldspar and possibly quartz. Some of the sericite wisps wrap around the phenocrysts in a manner reminiscent of compacted pumice fragments.

A 100 m thick unit of massive, coarse-grained porphyry-like rock rich in quartz crystals occurs in the middle part of this sequence between Roaring Meg Creek and the foot of Whip Spur. The unit was originally mapped as quartz-feldspar porphyry, but thin section evidence, the abundance of shale clasts in places, and the apparently gradational eastern contact, suggest it is probably a crystal tuff (or series of tuffs). The unit is concordant and wedges out north of Roaring Meg Creek. It is generally deeply weathered, pale green to yellowish in colour, and strongly cleaved. Quartz phenocrysts up to 5 mm across are usually prominent, and are contained in a soft sericitic matrix. Contorted fragments of shale and fine-grained tuff up to 300 mm long occur abundantly within the unit in the northern part, where there are also large shale intercalations or rafts.

Thin sections (P16, P17) show scattered large embayed quartz phenocrysts, and abundant smaller angular quartz grains down to matrix size. There are also a number of aggregates of quartz fragments cemented with chert-like silica, possibly representing broken and re-annealed phenocrysts. There is no visible feldspar, but scattered tabular to irregular masses of felted sericite probably represent completely altered feldspar phenocrysts. Altered muscovite flakes are fairly common, many containing opaque dust and other inclusions and some intergrown with quartz. The matrix consists mostly of small rounded quartz grains, of fine sand grade, surrounded by scaly sericite and chlorite developed along two intersecting foliations. Accessories include epidote, zoisite(?), sphene and zircon.

The top of this sequence between Roaring Meg Creek and the lower part of Reservoir Creek is formed by a 20 m thick unit of laminated grey slate, tuffaceous siltstone and fine sandstone. The unit gradationally overlies a vitric tuff, and is overlain along an erosional contact by a coarse-grained quartz-rich tuff. The unit is intruded by a number of small feldspar-porphyry dykes and sills in the Reservoir Creek area. Structures such as pseudonodules, sole marks, grading and truncated cross-laminae indicate that the unit faces east. A finely laminated siltstone containing unusual small black glassy beads 1-2 mm across, around which the laminae are deformed, occurs within this unit on the north bank of Reservoir Creek. In thin section (P18) the rock consists of glassy ash recrystallised to fine-grained sericite-quartz-chlorite. The beads show slightly coarser recrystallisation, approaching granophyric texture in the cores of the larger ones, and appear to represent devitrification structures which formed soon after deposition and around which the laminae were compacted.

Greywacke-shale-tuff sequence in western part of area

Interbedded tuffaceous greywacke, siltstone, shale, slate and acid tuff occurs extensively in the western part of the area, surrounding several large lenses of basic-intermediate volcanics. Many of the sandstone beds show grading, erosional soles and laminated tops typical of turbidites, but sole marks are rarely observed. It is often difficult in the field to distinguish greywacke from crystal-lithic tuff, the distinction usually being made on the presence of detrital mica flakes and of bedding or lamination in the greywacke. The tuff units may be up to 10 m thick, and commonly contain contorted shale clasts, suggesting they represent large submarine flows. Sequences up to 10 m thick consisting of grey slate and siltstone, with only thin sandy intercalations, also occur, as do units of pale, fine-grained vitric tuff similar to that previously described.

Laminated grey siltstone 100 m west of the lower dam on Roaring Meg Creek contains abundant branching fucoidal structures which appear to represent compressed feeding burrows. The dark filaments are 2-5 mm across, and are referable to *Chondrites*, a marine trace fossil ranging from Cambrian to Tertiary (Häntzschel, 1962). Dr Gonzalo Vidal (pers. comm.) has also recovered the acritarchs *Bavlinella faveolata* (Shepeleva) and *Trachysphaeridium levis* (Lopukhin) from this locality. No other fossils are known from the western sequence.

A pale pink to grey, coarse-grained crystal-rich tuff containing abundant shale fragments forms a mappable unit in the middle reaches of Lynch Creek. It is possible that this tuff is equivalent to the unit previously described from east of Miners Ridge. In thin section (P19) it consists of volcanic quartz and feldspar grains, some Precambrian quartzite-type rock fragments, carbonate grains, and rare volcanic rock fragments, in a rather dirty matrix (20-30%) of fine sericite and small crystal fragments. Shard-like shapes in the matrix suggest the presence of original glassy ash. Most of the feldspar shows considerable alteration to sericite and carbonate, and there are small patches and veins of clear albite.

A similar tuff about 60 m further east (P20) contains about 30% angular quartz and feldspar grains in a recrystallised glassy matrix consisting mostly of fine feldspar.

A fine-grained laminated pale tuff (P21) from near the north-eastern margin of the main lens of basic volcanics consists almost entirely of glassy ash material in which shards and original bubble shapes are well preserved. A similar glass shard tuff (P22) occurs on the ridge south of Specimen Creek.

Porphyritic dacite(?) east of Miners Ridge

Several lenses of massive, brown-weathering chloritic rock have been mapped to the east of Miners Ridge, and possibly represent an originally continuous horizon. A chemical analysis (C7, Appendix A) shows 67.2% SiO_2, suggesting the rock is dacite. The fresh rock is greenish-grey and fine- to medium-grained, with small phenocrysts of feldspar and chlorite visible in hand specimen. Thin sections (P35, P36) show fairly abundant phenocrysts and glomerocrysts of moderately altered plagioclase, euhedral to irregular patches of chlorite (possibly after pyroxene), scattered small embayed quartz phenocrysts and patches of quartz, and scattered chloritised hornblende phenocrysts (P35 only). The dusty groundmass shows a blurred granophyric texture under crossed nicols, with intergrown feldspar blebs and some fine chlorite and sericite.

A sample from the northernmost lens near Roaring Meg Creek (P37) is essentially a feldspar porphyry with only rare chlorite patches. The groundmass has the same unusual granophyric texture which seems to overprint a finer primary texture of microlaths and fine chlorite and sericite.

Upper quartz-rich tuff in Reservoir Creek

A distinctive unit of white, coarse-grained quartz-rich tuff containing slate fragments overlies the slate unit between Roaring Meg Creek and Reservoir Creek. The contact with the slates is exposed in several places, and is abrupt and apparently erosional. The unit is about 10 m thick in the lower Reservoir Creek area, and appears to represent a single coarse ash-flow. In most areas it is overlain by a green chloritic agglomerate, but relationships are complicated and obscured by a number of small intrusions of feldspar porphyry and andesite.

In the Reservoir Creek area the unit grades from breccia at the base, with contorted fragments of slate and small clasts of quartz porphyry and feldspar porphyry, through coarse tuff to fine tuff at the top. Faint layering is evident in places as alternations of coarser and finer material. Large embayed quartz grains are abundant in the lower part, which in places contains rounded and apparently water-worn pebbles of quartz and acid porphyry.

Thin sections (P38, P39, P40) from the middle and upper parts of the unit on the north side of Reservoir Creek show it to consist of well-preserved pumice fragments, rock fragments, altered feldspar crystals, scattered quartz crystals, and opaque grains, in a matrix of glass shards. Many of the pumice fragments are strongly flattened, with an internal streaky appearance, but others show perfectly preserved bubble shapes. Rock fragments include feldspar porphyry, quartz porphyry, dark basaltic rock with small feldspar phenocrysts, fine glassy tuff, and greenish feldspar-rich rock. The proportion of rock fragments, as opposed to pumice, decreases markedly towards the top, where the unit consists mostly of fine pumice and shards. The shards have largely recrystallised to very fine sericite. All specimens preserve a good eutaxitic foliation, and the unit appears to represent a hot ash-flow. The shale clasts and rounded pebbles suggest it may have flowed across a beach into shallow water.

The upper part of the unit on the south bank where it crosses Reservoir Creek is also a pumiceous ash-flow rock (P41), but an overlying sandy white tuff (P42) consists mostly of glassy ash but shows no signs of pumice fragments or welding. The latter may be a non-welded part of the flow, or an associated ash-fall deposit.

The upper part of what is probably the same unit in Roaring Meg Creek (P43) contains abundant quartz and feldspar grains in a matrix of altered shards with a few pumice fragments. There are some swirly patches of glassy material, but otherwise no evidence of compaction or flow.

Upper quartz-rich tuff in Lynchford area

A unit of white, quartz-rich tuff and agglomerate, with intercalated siltstone and shale, gradationally overlies the greywacke sequence and underlies the Lynchford tuff sequence in the western part of the area. The unit appears to wedge out over the large lens of basaltic volcanics in Lynch Creek. Contorted fragments of mudstone occur in several of the tuff beds, suggesting they represent submarine flows of some kind, and several units contain clasts of quartz-feldspar porphyry. Rounded pebbles of porphyry are common within the unit north of the Huxley Track (on the original track), where the rock resembles a volcaniclastic conglomerate.

The contact with brown-weathering agglomerate of the Lynchford tuff sequence, where exposed near the western end of the Huxley Track, is marked by a unit of laminated tuffaceous siltstone and sandstone a few metres thick. Underlying this is a thick unit (about 35 m) of pale-coloured sandy quartz-rich tuff showing overall grading from coarse to fine. In thin section (P44) the tuff consists of crystals and crystal fragments of quartz, many of them embayed, and fresh to partially altered feldspar grains (mainly plagioclase, possibly some K-feldspar), and scattered small rock fragments of quartz porphyry and quartz-feldspar porphyry, in a rather dirty quartzo-feldspathic matrix. Recrystallisation of the matrix largely obscures the original composition. Below this, a series of at least four similar quartz-rich tuff-agglomerate units, up to 30 m thick, alternate with thinner units of interbedded grey slate, siltstone and tuffaceous sandstone over a stratigraphic thickness of about 100 m. The proportion of sediments increases below this, but massive tuff units still occur. Rounded blocks of quartz porphyry up to 250 mm long occur in one unit, and small black slate fragments are common in several units. An irregular, apparently erosional contact on slate at the base of one tuff unit was noted. Some of the thin sandstone beds in the sediment units show grading, sole marks and cross-laminated tops.

On the ridge south of Specimen Creek the greywacke sequence is overlain by a massive white porcellanous tuff showing 'elephant-skin' weathering. Crude layering is indicated by lines of cellular weathering structures parallel to joint-like parting planes. This fine- to medium-grained tuff in thin section (P45) consists of broken and embayed quartz crystals and scattered, completely altered feldspar grains, in a chert-like matrix in which abundant stumpy glass shard shapes are evident under crossed nicols. There is some indication of compaction and welding of shards in places, suggesting the rock might be a slightly welded ash-flow tuff. It is unlike the white tuffs on the Huxley Track and is probably not the same unit.

Quartz-feldspar porphyry intrusive

A major sub-concordant body of quartz-feldspar porphyry extends through the mapped area, passing east of Miners Ridge. The unit abuts the Miners Ridge Sandstone for much of its length, and appears to split into a series of smaller dykes, enclosing narrow strips of country rock, in the Huxley Track area. What appears to be the same body has been mapped in the West Queen River north of Queenstown, and in the King River Gorge to the south.

Intrusive contacts with the Miners Ridge Sandstone are exposed in several areas in the vicinity of Roaring Meg Creek, and there are a number of large xenoliths of sandstone and of siltstone-shale, in this area.

The porphyry is mostly deeply weathered and pale yellowish in colour, the fresher rock being pale greenish grey. The prominent large quartz phenocrysts (up to 7 mm) and less prominent altered feldspar phenocrysts are contained in a fine-grained groundmass which is usually strongly cleaved. Fresh outcrops on the West Queen River also show scattered biotite phenocrysts, and a chemical analysis from here (Appendix B) shows a dacite composition (68.3% SiO_2).

In thin sections (P46, P47) the large quartz phenocrysts (up to 4 mm) are deeply embayed and corroded. Some appear as an aggregate of broken fragments annealed with fine chert-like silica. The feldspar phenocrysts (also up to 4 mm) are mostly completely altered to fine sericite, but some remnants show multiple twinning. Many have ragged edges and pressure beards along the cleavage. Several small, altered biotite flakes occur in P46, which also contains tabular masses of fibrous chlorite with abundant inclusions of opaque dust and granular epidote(?), possibly representing altered biotite flakes. P46 also contains rounded to tabular masses of pinkish mosaic feldspar with intergrown chlorite, epidote(?) and opaques, possibly representing altered K-feldspar. There are scattered apatite crystals and zircons. The groundmass is very fine-grained and strongly foliated, with a fine-scale diamond pattern formed by oriented fine chlorite and sericite developed on two intersecting foliations around cores of intergrown feldspar and quartz.

Porphyritic basalts and andesites of Lynch Creek area

Several lenses of basic-intermediate volcanics occur on the western limb of the Miners Ridge anticline but do not appear to the east. Available chemical analyses (Appendix A) indicate that the rocks range from basalt to basaltic andesite in composition and have calc-alkaline affinities (figs 4,5,6). They are typically porphyritic in plagioclase (mainly albite) and pyroxene (mainly augite), and less commonly hornblende, and are dense, dark grey to greenish grey rocks which form brown-weathering outcrops.

The largest body is a complex of lava, breccia, tuff and possible intrusives, and is about a kilometre wide and 3 km long, terminating just south of the mapped area. Its relationship to the surrounding sequence is difficult to establish. Its eastern margin appears to be concordant with greywackes which locally dip and face east in Lynch Creek. The southern boundary is clearly discordant, but is only partly faulted. The nose-like northern boundary is suggestive of a fold closure, but no evidence for a fold could be found in the sequence on the Huxley Track to the north. To the west the sequence is overlain by the intermediate tuffs and agglomerates of the Lynchford tuff sequence. This sequence contains abundant detrital pyroxene and fragments of porphyritic basalt, suggesting it could be partly derived from basaltic eruptions of Lynch Creek type. Although the Lynch Creek mass is largely surrounded by the western greywacke sequence, it is possible that it represents a later volcanic edifice which pushed through an earlier marine sequence. This would help to explain the locally discordant contacts and the relationship with the overlying Lynchford tuff.

Outcrops are mainly in the form of isolated, brown-weathering tors, and are surrounded by large areas underlain by deep, clayey brown soil. The old King River gold mine workings are located in such deeply weathered material. The most typical rock type is a breccia containing fragments of pale grey feldspar-pyroxene porphyry, commonly vesicular, in a darker 'matrix' also containing pyroxene phenocrysts. The fragments may be up to a metre across but are usually less than 200 mm, and may be angular or somewhat rounded due to corrosion. Vesicles may be up to 150 mm long and 40 mm across. The pyroxene phenocrysts (mainly augite?) are usually fresh, and may be up to 8 mm long. These rocks appear to be autobrecciated lava flows. Massive porphyritic bodies, some with phenocrystic hornblende as well as pyroxene, also occur, and probably represent both flows and minor intrusives. Tuffs and agglomerates are also abundant in some areas.

A fragment from the prominent tor of autobreccia on the ridge 300 m north of the old King River mine (P23) contains abundant plagioclase phenocrysts and less common pyroxene phenocrysts in a dark groundmass rich in fine plagioclase laths and small rounded pyroxene grains. Flow texture is evident in the groundmass in a few places. The plagioclase phenocrysts are extensively altered, mainly to sericite, but the pyroxene is remarkably fresh. The single vesicle present is filled with carbonate, with a rim of opaque mineral and clear albite(?). P24 from the same outcrop has fragments of vesicular porphyry in which the abundant small round vesicles mostly have a carbonate filling and chlorite rim. Some have a rim of quartz followed by chlorite then an albite core, while some larger ones are almost entirely filled with albite. The 'matrix' material between the fragments has more abundant secondary fine albite and chlorite, and contains small vesicles of chlorite with an albite rim.

Another autobreccia from 200 m up the main north tributary of Lynch Creek (P25) has pale fragments of vesicular porphyry in which sericitized plagioclase phenocrysts and large to small fresh pyroxene phenocrysts are contained in a strongly flow-textured groundmass of fine shredded plagioclase laths and brown granular altered pyroxene(?). Elongate vesicles aligned parallel to the flow in the fragments are filled mainly with albite and lesser chlorite and carbonate. One fragment is cut by a series of albite veins (perpendicular to flow) which thin or die out towards the margin like tension cracks. The matrix between fragments comprises feldspar and pyroxene phenocrysts in a dark, chlorite-rich flow-textured groundmass of shredded feldspar and brown granular pyroxene(?).

Closely associated with this breccia is a massive rock (P26) with abundant very altered (sericite-carbonate) feldspar phenocrysts, less common fresh, colourless pyroxene phenocrysts, some of which are embayed and broken, and some brown chloritised hornblende grains, in a dark glassy(?) groundmass with fine laths showing flow structure in places.

P27 is from a lava with a few dispersed fragments in it near Lynch Creek. It contains abundant small phenocrysts of feldspar, all completely altered and some showing zonal alteration, small to large (5 mm) phenocrysts of pyroxene, some of which show marginal alteration to chlorite or partial replacement by hornblende, and pseudomorphs of chlorite, in a very dark, very fine-grained groundmass in which tiny laths showing flow texture in places are just visible. There are scattered vesicles up to 6 mm with an unusual froth-like filling which includes chlorite, epidote and unidentifiable material.

A massive rock from the north-east corner of the mass (P28) is a feldspar-chlorite porphyry with abundant altered feldspar phenocrysts and some elongate chlorite masses which appear to be after hornblende. The lath-rich groundmass shows flow texture in places, and contains brownish remnants of small pyroxene(?) crystals.

A fine- to medium-grained crystal tuff (P29) from the south bank of Lynch Creek at the western margin of the mass contains abundant feldspar crystals, all extensively altered to chlorite, and fresh to partially altered pleochroic hornblende cyrstals, in a matrix rich in chlorite and brownish altered pyroxene(?). A pyroclastic breccia from the ridge south of Lynch Creek at the western margin of the lens (P30) contains numerous weathered rock fragments, many of which are dark and vesicular like the typical basalt. They contain remnants of feldspar phenocrysts and much secondary chlorite and epidote, but there is no fresh pyroxene. It is difficult to distinguish small rock fragments from one another, and from other material, in the matrix between the larger fragments, which consists largely of chlorite, fine-grained epidote, and altered feldspar. The variety of rock fragments suggests an air-fall origin.

A narrower, concordant body of similar rocks, some 150 m wide and 1.5 km long, occurs some 250 m further east in Lynch Creek. The northern end of this body is offset by the NW-trending cross-fault. The dominant rock type is a dark grey lava with phenocrysts of pyroxene and feldspar visible, and well-developed autobreccia texture in places. A lens of bedded slate (xenolith?) occurs within the body in Lynch Creek. The section north of the fault is poorly exposed, but includes porphyritic rocks, fine-grained massive basaltic rock, and breccias. A prospect adit is located on the eastern margin of the body south of the fault.

About 400 m south of Lynch Creek the rock contains pyroxene phenocrysts up to 5 mm long, and has a breccia texture with paler fragments up to 100 mm long in a more crystal-rich matrix. A thin section (P31) shows one of the fragments to be an amygdaloidal feldspar-pyroxene porphyry in which the plagioclase phenocrysts are very altered and in many cases completely replaced by carbonate. The pyroxenes also show some replacement by carbonate, which is very abundant. The numerous amygdales are up to 15 mm long, and are mostly completely filled with carbonate, although albite and two varieties of chlorite (brown and pale green) also occur. Some of the larger amygdales appear to have inclusions of the vesicular inter-fragment material in them. The dark groundmass is rich in brown chlorite-like material and minute feldspar laths (largely replaced by calcite) and shows flow texture in places. The inter-fragment matrix is very chlorite-rich and finely vesicular, with pyroxene and feldspar crystals and secondary albite. There appears to have been considerable reaction between fragments and matrix, between groundmass and crystals, and between volatiles and other components.

Massive lava from near the northern end of the main body (P32) shows very altered plagioclase phenocrysts and partially chloritised pyroxene in a dark, finely-crystalline flow-textured groundmass of plagioclase laths, small pyroxene grains and chlorite. A compositionally banded pinkish-grey rock (P33) occurs near the eastern margin of the body in Lunch Creek. It contains abundant feldspar as phenocrysts and groundmass material, but no apparent pyroxene. Chlorite is fairly abundant in the groundmass, and there are scattered large red opaque grains. The texture is variable and not clearly igneous or pyroclastic, although some bands have irregular flowy boundaries suggestive of some kind of flow.

A smaller body on the north side of the fault near the Lynch Creek ford is a dark green plagioclase-pyroxene porphyry (P34). Abundant, very altered plagioclase phenocrysts, partially chloritised pyroxene phenocrysts, and some large chlorite plates, are set in an opaque-rich, chlorite-rich groundmass with feldspar laths and brown, altered pyroxene grains. Small patches of clear albite probably represent vesicles.

LYNCHFORD TUFF - AGGLOMERATE SEQUENCE

A distinctive sequence of brown-weathering, massive to banded intermediate tuff and agglomerate ('augite trachyte' of Solomon, 1960) occurs along the hills facing the Queen River between Lynchford and South Queenstown. Typical outcrops are in the form of large rounded tors. The sequence has an apparently conformable, and possibly gradational, contact with the underlying white tuff, and lenses of similar white-weathering quartz-rich crystal tuff and acid vitric tuff occur within the sequence. These lenses can be seen to grade laterally and vertically into the brown-weathering, more basic variety. Some of the acid lenses have abundant quartz veins through them which produce a residual quartz gravel. Quartz veins are rare within the brown tuff, however, which tends to weather to a brown clayey soil. Chemical analyses (Appendix A) show an andesitic composition which appears to be due to mixing of acid and basaltic detritus.

Lenses of fawn-weathering laminated siltstone, grey shale and tuffaceous sandstone also occur within the sequence. Rare individual sandstone units are up to a metre thick and show grading and sole marks typical of turbidites. The sequence generally dips steeply west to steeply east, but all facings obtained were westerly. The northern part of the sequence is displaced eastwards on a cross-fault, and bedding directions are locally variable north of the fault. A small area of similar tuff occurs in a fault block between outcrops of Pioneer Beds near Queenstown.

The typical rock type is a greenish grey to pink, crystal-rich granular tuff or agglomerate, with grains of feldspar, quartz and pyroxene, and a variable proportion of small volcanic rock fragments, in a matrix of chlorite, albite and epidote. Flecks and irregular patches of pink albite and green chlorite give the rock a characteristic splotchy coloration on fresh surfaces. The larger lithic clasts commonly have a halo of secondary pink albite around them, and in some places these have coalesced to form crude banding. Bedding or banding is commonly evident in the finer tuffs as alternating green (chlorite) and pink (albite) bands a few centimetres thick. Bedding planes are poorly defined except in the very fine-grained tuffs, however, and the coarser units are commonly massive. These features are also characteristic of the Comstock Tuff in the Comstock Valley (Corbett *et al.*, 1974).

Feldspar (mostly plagioclase) is generally the most abundant grain component, and quartz (often embayed) is ubiquitous although variable in amount. Granular detrital clinopyroxene is as common as quartz in many units, and small rock fragments of porphyritic basalt with phenocrysts of pyroxene, similar to the Lynch Creek basalts, occur in some samples. Epidote is very abundant in some units as a matrix component and in basaltic rock fragments. Altered hornblende grains have also been noted. Glass shards or pumice fragments have not been seen, although they may have been present in some of the fine-grained white tuffs.

The tuffs appear to be dominantly of air-fall origin, although a significant proportion may be water-deposited. There has clearly been mixing of acid detritus (quartz, occasional acid rock fragments) and basic-intermediate detritus (pyroxene, hornblende, basaltic rock fragments), probably in contemporaneous eruptions. The white acid tuffs presumably represent eruptions of acid material only.

P48 is from an outcrop of typical banded tuff beside the Huxley Track. It contains very abundant angular to well rounded plagioclase grains, rather murky in colour but mostly unaltered; less common quartz grains, mostly angular and some embayed; rare small grains of pyroxene, partially altered to chlorite; fairly numerous opaque grains and scattered rock fragments, in a fine-grained rather dirty matrix. Rock fragments include several of dark green pilotaxitic basaltic rock, one of albite crystal tuff with quartz and feldspar grains, and several of granophyrically recrystallised albitic groundmass material such as occurs in the feldspar porphyries. The matrix consists largely of finely recrystallised feldspar (albite?) intergrown with chlorite and very fine-grained epidote. Small to large patches of pure chlorite seem to be replacing the matrix and feldspar grains.

A brown crystal-lithic tuff from near the base of the sequence south of the Huxley Track (P49) is a similar close-packed granular rock, but contains pyroxene (probably augite) in equal abundance to quartz, as grains up to 2 mm showing alteration to chlorite along cleavage and fractures. Rock fragments include porphyritic basalt-andesite with phenocrysts of plagioclase and pyroxene and small scattered quartx phenocrysts in a brownish, very fine-grained groundmass of epidote, chlorite, feldspar and sub-isotropic material. The fine-grained matrix of the tuff consists mostly of intergrown epidote, chlorite and fine albite(?). Again there are patches of green chlorite apparently replacing the matrix.

A striking epidote-rich tuff from near the southern end of the belt (P50) consists of a jumbled mixture of feldspar, quartz, pyroxene, rock fragments and opaque grains in an epidote-chlorite base. The feldspar grains are altered. The quartz grains include some large (>4 mm) deeply embayed grains, with embayments filled with chlorite and epidote, as well as numerous, smaller very angular fragments. The abundant pyroxenes mostly show some replacement by chlorite along cleavage and fractures. Rock fragments include altered feldspar-pyroxene porphyry rich in epidote; coarse-grained pyroxene-plagioclase basalt; tuffaceous fine sandstone; fine-grained epidote rock, and carbonate rock. The matrix consists of intergrown epidote and chlorite.

A tuff from near the western margin of the belt at the old Lynchford piggery (P51) contains feldspar, quartz and pyroxene grains and scattered rock fragments in an abundant chloritic matrix with minor epidote. It is more deformed than previous samples, and there are strong pressure fringes between grains.

A fine-grained white tuff (P52) from near the beginning of the Huxley Track consists mostly of felted fine sericite with scattered small angular quartz grains. Two strong secondary foliations are evident. The rock may originally have consisted mostly of glassy ash, but primary textures have been completely obliterated.

THE CENTRAL VOLCANIC - INTRUSIVE SEQUENCE

General description

The eastern part of the volcanic belt is considerably more complex and difficult to interpret than the western part, because of the presence of large intrusive bodies, the general paucity of marker horizons, and considerable tectonic and metamorphic overprinting. Several sub-areas are isolated from one another by intrusive bodies, and their relationships to one another are uncertain. The sequences in general are quartz-poor, in contrast to the western units, although tuffs containing significant quartz occur in several areas. Fragments of feldspar porphyry are common in all sequences.

In the northern part, a complex sequence of agglomerate and tuff on Little Owen abuts the western sequence along a contact which at first sight appears conformable but may be locally cross-cutting. Easterly dips and facings are recorded from this sequence on the lower western slopes of Little Owen. On the lower eastern slopes of Little Owen, and in the upper reaches of Conglomerate Creek, is a west-dipping and west-facing unit of shale and agglomerate which apparently underlies the bulk of the Little Owen sequence. Equivalents of this shale-rich unit have not been recognised on the western limb of the syncline, however. A sill-like intrusive body of feldspar porphyry separates this unit from another complex sequence of agglomerate, tuff and feldspar-phyric lava in the Waterfall Gully area.

A large mass of feldspar porphyry abruptly truncates the Little Owen sequence at Roaring Meg Creek. This mass extends southwards beyond the mapped area, and has a slightly transgressive contact against the western sequence. A poorly-exposed sequence of tuff and agglomerate occurs between the porphyry mass and the Owen Conglomerate on the southern flanks of Mt Owen. Isolated within the porphyry mass on Whip Spur, and forming a kind of mega-xenolith, is a distinctive sequence of brown-weathering agglomerate, tuff, sandstone and shale. This sequence includes rocks similar to the Lynchford tuff sequence, chloritic agglomerates similar to those in the Reservoir Creek part of the Little Owen sequence, and shale-agglomerate units similar to those in upper Conglomerate Creek, but definite correlation with any of these has not been possible.

Two large bodies of plagioclase-pyroxene porphyry (generally referred to as 'andesites') intrude the Little Owen sequence, and smaller basic-intermediate bodies and dykes occur in all the central sequences. The larger bodies are discussed separately.

Shale-tuff unit in upper Conglomerate Creek

A unit of interbedded black shale, slate, tuffaceous siltstone, sandstone, tuff and agglomerate, about 80 m thick, crops out along Conglomerate Creek on the eastern side of Little Owen Spur. The sequence dips and faces west, but no equivalent on the western flank of the syncline has been recognised. The top of the unit has generally been taken as the last major shale horizon, but this is difficult to map in some areas. The unit, or at least the shale component, appears to wedge out around the northern end of the spur in a zone of intense alteration. The sequence is not so distinctive at the southern end, where it is truncated abruptly by the feldspar porphyry mass. Similar porphyry forms a sill-like body along the eastern margin of the unit, and appears to intrude through it in one area. An anticlinal fold is evident in the unit at Waterfall Gully, where the eastern margin appears faulted.

The sequence consists essentially of a series of massive tuff-agglomerate units separated by intervals of laminated slate, siltstone and sandstone. A roughly measured section through the unit in a small creek down the north-east flank of Little Owen is shown in Figure 7. The individual tuff-agglomerate units range from 150 mm to 10 m thick, and are commonly graded from agglomerate with small rock fragments (usually less than 50 mm) and blocks of contorted sediment (up to 500 mm) in the lower part, to laminated sandy tuff or tuffaceous mudstone at the top. Bottoms of the units are always abrupt, and in some cases are clearly erosional. Each unit appears to have been deposited by a single, large, bottom-hugging density flow. Sedimentary features of the intervening zones include ripple marks, cross-lamination, parallel lamination, deformed lamination, and graded bedding in the thick sandstone beds.

A sample (P57) from near the base of a massive unit consists of a jumble of poorly-defined small rock fragments, altered feldspar grains, scattered quartz grains, chlorite blebs, carbonate blebs, and opaque grains in a murky matrix of fine chlorite, feldspar, carbonate and sericite.

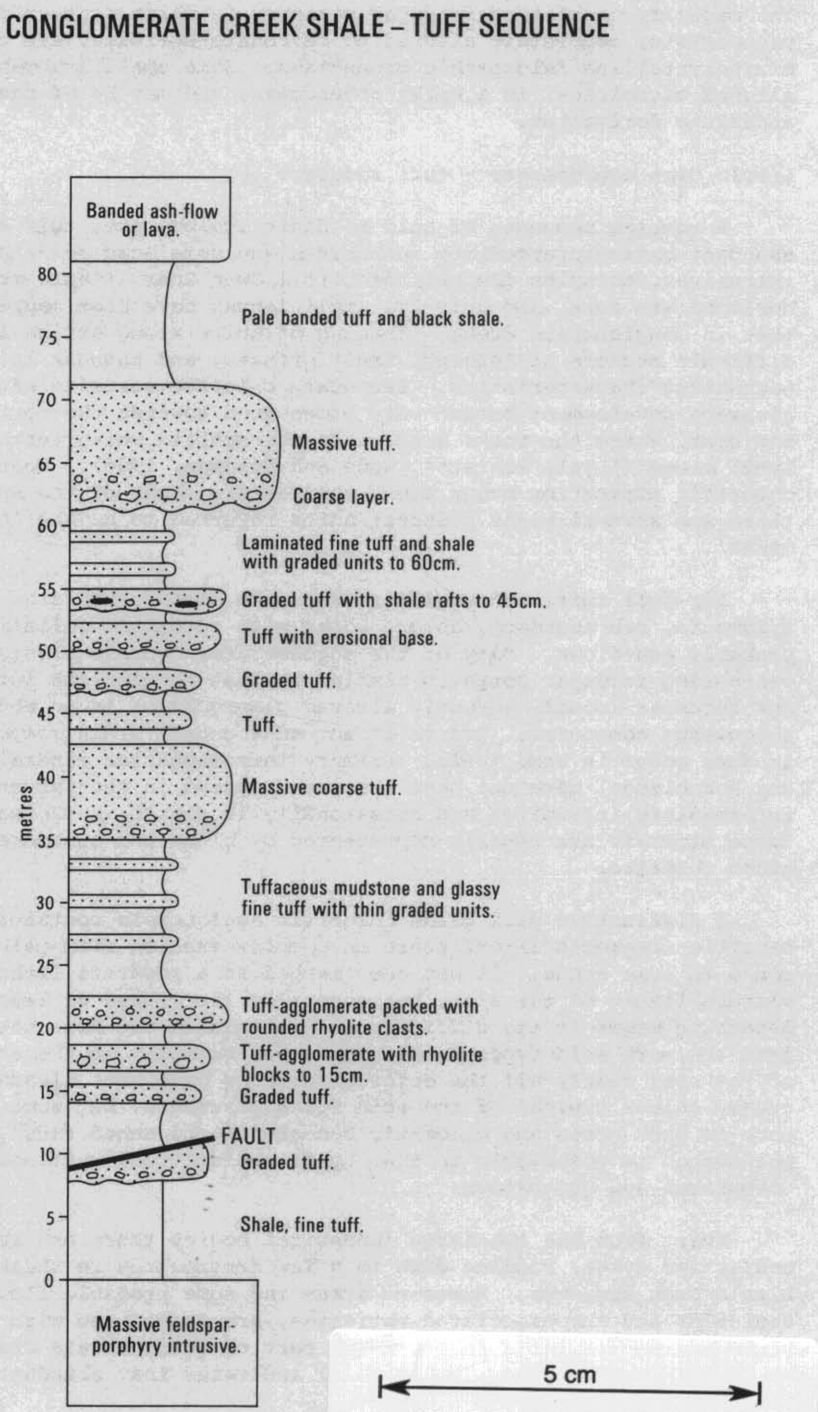


Figure 7. *Stratigraphic section through shale - tuff - agglomerate unit in upper Conglomerate Creek, measured down small creek on north-east flank of Little Owen Spur.*

The rock fragments are mostly somewhat rounded, with vague outlines. The majority consist of feldspar porphyry in which scattered feldspar phenocrysts, completely altered to carbonate-sericite, are contained in a microcrystalline feldspathic groundmass. Some small fragments show aligned microlaths, in a murky groundmass, and may be of basaltic or andesitic derivation.

Little Owen agglomerate - tuff sequence

A complex sequence of acid to basic agglomerate, tuff and lava, with abundant basic-intermediate intrusives and some acid feldspar porphyry intrusives, occupies the bulk of Little Owen Spur. Shale-mudstone horizons are rare, and only two small lenses have been mapped apart from that in Conglomerate Creek. Tracing of units along strike is extremely difficult because of lensing, fault offsets, and changes in alteration and weathering characteristics. Secondary chlorite-sericite alteration and cleavage development become very pronounced towards the northern end of the spur, where the rocks grade into the schists which surround the Mt Lyell mines ('Lyell schists', Wade and Solomon, 1958). Zones of similar chloritic alteration occur along the eastern flank of the spur, where there are several major prospect adits referred to as the 'Great Lyell mines'.

Air-fall tuffs and agglomerates, some containing large bomb-like fragments, are abundant, as are rocks with eutaxitic foliation which are probably ash-flows. Many of the agglomerates contain clasts of pale-weathering feldspar porphyry similar to that forming the intrusive bodies, and feldspar (mostly strongly altered plagioclase) is an abundant and ubiquitous component. Quartz is not an abundant grain component, although it does occur in some tuffs. Primary ferromagnesian minerals (pyroxene and hornblende) have not been observed, except in the larger basic-intermediate intrusives and occasionally in clasts in the agglomerates. These minerals are usually represented by blebs and subhedral masses of green chlorite.

A distinctive dark green chloritic agglomerate containing abundant basaltic fragments interfingers in complex fashion with paler, more acid rocks in some areas. It has been mapped as a separate lithology on the western flanks of the spur, but generally the degree of leaching and bleaching makes it too difficult to distinguish the more basic pyroclastics from the more acid types in outcrop. For example, on the steeper slopes of the spur nearly all the outcrop surfaces have been bleached to a pale creamy colour typical of the acid rocks elsewhere, but some of the fresh rock is dark green and chloritic beneath the bleached crust. A similar phenomenon is observable in the 'Lyell schist' road cuttings between Gormanston and Queenstown.

Apart from the two large 'andesite' bodies there are abundant smaller bodies and dykes, ranging down to a few centimetres in thickness, in the Little Owen sequence. Numerous dykes and some probable flows, including vesicular and autobrecciated varieties, are associated with chloritic agglomerates and tuffs in the lower part of Conglomerate Creek, and mapping by the Mt Lyell Company (Reid, 1976) indicates that abundant intermediate rocks occur north of the creek.

Green chloritic agglomerate apparently overlies the white quartz-rich tuff in Reservoir Creek, and forms the base of the Little Owen sequence in this area. It consists of close-packed, elongate and irregular clasts of dark fine-grained rock up to a few centimetres long, which appear to have been moulded against one another. In thin section (P53) the fragments range from extremely vesicular, dark, glassy rock to more crystalline but still fine-grained, slightly porphyritic rock with plagioclase phenocrysts in a groundmass of microlaths showing flow structure. All the fragments appear to be basaltic, and the rock has a basaltic composition (Appendix A).

Large bladed tors of this agglomerate, somewhat similar to the Lynchford tuff in outcrop, occur on the east bank of the upper part of Reservoir Creek. In thin section (P54) it consists of small, close-packed, glassy chloritised basaltic fragments, some of which have abundant microvesicles and small chlorite flecks which might originally have been ferromagnesian phenocrysts. A few have small feldspar phenocrysts, and nearly all have microlaths in the groundmass with more or less prominent flow structure. Some secondary carbonate is present. A larger pale grey fragment from this agglomerate (P55) is a feldspar-hornblende porphyry, with abundant altered feldspar phenocrysts, some partly-chloritised hornblende phenocrysts (commonly intergrown with the feldspar), and scattered large opaque grains, in a dark, dusty groundmass with abundant microlaths showing good flow texture. The rock resembles some varieties of the Lynch Creek basalts.

A similar green agglomerate (P56) from the irregular lens near Roaring Meg Creek consists almost entirely of fine-grained basaltic fragments in which altered feldspars and flecks of chlorite are contained in a flow-textured groundmass.

The agglomerates appear to be similar to the 'unusual agglutinated andesitic breccias' described by Lipman (1975, p. 64) from the Platoro Caldera Complex in Colorado. The latter breccias are thought to have been formed by near-source eruptions of hot lava fragments which welded together and partly flowed down the steep caldera wall.

The complexities and mapping problems make it impossible to establish a succession within the Little Owen sequence, and as yet there are no units which can be matched between the two limbs of the syncline. There are, however, several more or less distinct lithological zones around the northern flanks of the spur which could form the basis for further detailed stratigraphic mapping. Overlying the shale-tuff unit on the lower north-east slopes is a sequence of banded, pale-weathering, feldspar-phyric rocks which in places at least resemble banded lavas. This unit appears to continue north-west into Conglomerate Creek, where the banding is very prominent despite the strong sericite-chlorite-quartz alteration and pyrite mineralisation. The banding is complexley folded in places, like typical flow banding, but elsewhere is discontinuous and lenticular like that seen in some ash-flows. Autobreccia-like texture also occurs. P58 from this unit is a greenish-grey feldspar porphyry in which the feldspars are altered to masses of felted sericite and are contained in a microcrystalline groundmass of secondary feldspar, quartz and sericite, with stringers of chlorite.

The banded rocks grade up into a sequence of pale-weathering agglomerates containing rounded fragments of feldspar porphyry up to 200 mm across, many of which are crudely bomb-shaped. In some units the clasts are very tightly packed, with little matrix. The rocks are well exposed down a steep gully on the northern end of the spur, where both clasts and matrix are heavily pyritized.

The agglomerates appear to grade into a sequence of ash-flow tuffs

PART OF LITTLE OWEN SEQUENCE

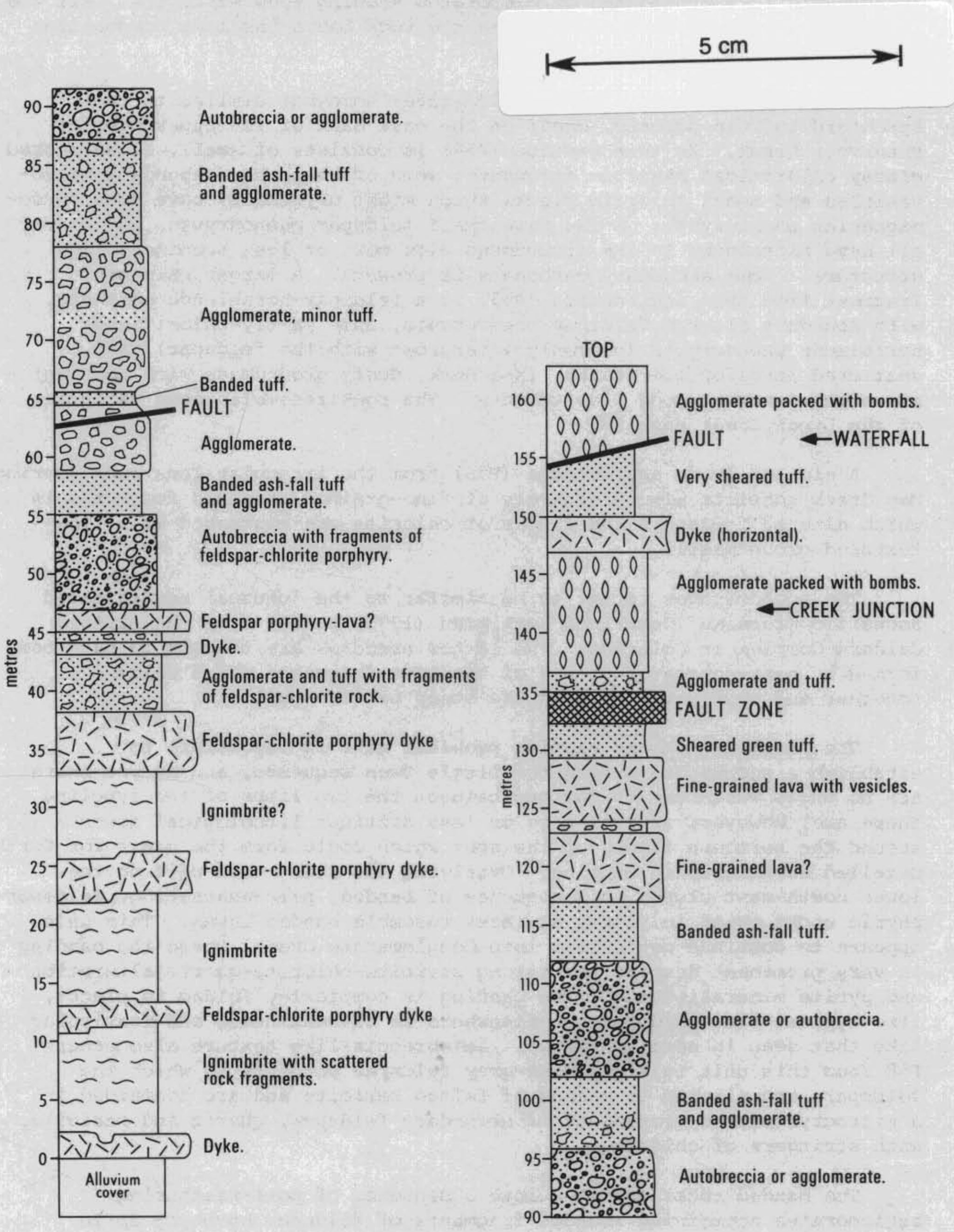


Figure 8. *Stratigraphic section through part of Little Owen volcanic sequence, measured down north-flowing creek on north-west flank of Little Owen Spur.*

and agglomerates exposed on the south bank of Conglomerate Creek near the upstream end of the alluvial plain. Small basic-intermediate dykes are common in this area (lower part of section in Figure 8). The ash-flow rocks are pale green, with abundant wisps of darker sericite-chlorite forming a prominent eutaxitic foliation. A thin section (P59) shows altered feldspar crystals and large, irregular pumice-like fragments (altered to fine sericite-chlorite) in a sericitic matrix in which glass shards are clearly discernable. Some welding and compaction of shards is apparent, but many preserve original Y-shapes. Similar ash-flow rocks, with glass shard textures preserved, occur in the interfluve area between Reservoir Creek and Roaring Meg Creek (*e.g.* P60).

The sequence above the ash-flows consists mainly of air-fall agglomerate and tuff with abundant basic-intermediate dykes and probable flows. It is well exposed in a small tributary of Conglomerate Creek draining the lower north-west flank of Little Owen Spur, and a roughly measured section along this creek is shown in Figure 8. Some of the agglomerate units are rich in chloritic fragments and may be of basic-intermediate composition, but others are possibly acid. Bedding and lamination are well preserved in some of the tuffs. Several units of breccia composed of angular dark fragments of feldspar-chlorite porphyry in a paler groundmass may be autobrecciated flows, and several massive fine-grained units with chlorite flecks and small vesicles(?) are probably also flows. A sample (P61) from one of the latter units is a strongly cleaved, altered rock with abundant small feldspar phenocrysts (completely altered to sericite) and scattered large chlorite blebs, in a foliated sericite-chlorite groundmass.

The sequence is faulted against an extensive agglomerate sequence, rich in bomb-like fragments, which appears to be continuous with that forming the crest of Little Owen Spur. Some of the latter units contain large bomb-like and pudding-like clasts of feldspar porphyry, up to 400 mm across, some of which show ropy flow surfaces.

The basic-intermediate dykes and flows have been sampled in a number of places west of the measured section. Two major types appear to be present, *viz*. those with feldspar and chlorite phenocrysts (P62, P63), and those with feldspar only (P64, P65). The rocks are mostly cleaved and altered, with abundant small altered plagioclase phenocrysts in a fine groundmass of sericite, chlorite and feldspar in which flow texture in microlaths is occasionally evident. The chlorite blebs include crystal-shaped masses which appear to be after hornblende.

Agglomerates with small bomb-like fragments occur extensively to the north-east of the lower andesite body, where they are intruded by a parallel series of basic-intermediate dykes 1 - 3 m thick (see analysis, Appendix A). The matrix of an agglomerate from below the Pioneer Beds contact (P66) contains numerous large, very altered feldspar crystals and clumps of crystals in a completely-reconstituted, strongly cleaved matrix consisting mostly of chlorite with some sericite, altered feldspar and opaque dust. A small rounded bomb-like clast from this unit (P67) is an acid, highly vesicular feldspar porphyry, with completely altered small feldspar phenocrysts in a very fine sericitic groundmass. The abundant small vesicles are filled entirely with mosaic quartz, commonly showing radiating sheaf structure. There are no ferromagnesian minerals although other clasts were noted with chlorite blebs.

Bedded pumice-rich pyroclastics of probable acid composition are well exposed on the crest of a minor spur at the western margin of the Little Owen andesite body. Erosional contacts beneath some of the beds indicate east-facing. Some of the coarser units contain scattered rounded fragments of feldspar porphyry up to 120 mm long, but otherwise consist mostly of well-preserved pumice fragments. In P68 some of the pumice fragments show undeformed bubble shapes, but others are strongly compacted. Many contain plagioclase phenocrysts, and nearly all show granophyric recrystallisation. There is a considerable amount of secondary coarse carbonate. A tuff unit (P69) consists of a mixture of feldspar crystals, scattered quartz crystals, glass shards and small pumice fragments, some of the latter preserving original bubble shapes. Banding in the tuff is defined by variations in the crystal content.

Coarse breccia deposits rich in feldspar porphyry fragments occur in the lower part of the Little Owen sequence near the western margin of the lower andesite body ('Reservoir andesite'). A spectacular example, consisting of close-packed, sub-rounded fragments up to a metre long, occurs around the eastern and southern margins of the plug-like body of feldspar porphyry near the Conglomerate Creek bridge. This unit may be a vent breccia. Some examples along the western margin of the andesite appear to be autobrecciated flows with gradational contacts into massive or flow-banded porphyry.

Waterfall Gully tuff-agglomerate-lava sequence

A complex sequence of mainly feldspar-phyric tuff, agglomerate and lava is exposed between the Owen Conglomerate and the sill-like body of feldspar porphyry along the upper reaches of Conglomerate Creek. The area is along strike from the main zone of 'Lyell schist' alteration, and many of the rocks are schistose and altered. Pyrite mineralisation occurs in many places, and there are a number of minor prospects. Basic-intermediate dykes are common.

No facings have been obtained, and no succession established in the sequence. The complex relationship with the Owen Conglomerate suggests that a number of thrust faults could be present, but it has not been possible to delineate these. Several steeply-dipping crush zones are evident in the Waterfall Gully section, but their continuity has not been established. The rocks in general resemble those of the Little Owen sequence, but the relationship to that sequence is uncertain because of the sill of feldspar porphyry (which could be along a fault zone) which separates the two.

A belt of apparently less altered feldspar-phyric lava-like rocks, flanked by schists, occurs in the central part of Waterfall Gully. These rocks are greenish to pinkish-grey when fresh and show beautifully preserved flow-banding and autobrecciation textures. The flow bands are generally a few millimetres to a few centimetres across, and may persist for many metres. They are most evident on weathered surfaces, and show complex folds and convolutions in places. The autobreccias generally contain disoriented fragments of flow-banded lava up to 300 mm across, but in some cases the close-packed fragments are only a few centimetres in diameter. Gradations from flow-banded to autobrecciated structure are apparent in some outcrops.

In thin section (P70) the flow-banded rock contains phenocrysts and glomerocrysts of partially altered albite, and a few small corroded quartz phenocrysts, in a strongly cleaved, fine-grained ground-mass of rounded feldspar and quartz grains with sericite and lesser chlorite. Many of the phenocrysts have pressure beards of sericite-chlorite, and some of the feldspars have veins and cracks filled with chlorite. Some of the feldspar crystal forms appear to have been replaced by clear quartz with flash extinction. A sample from an autobreccia (P71) shows the albite phenocrysts to be somewhat cracked and veined, but not strongly altered, and there is a single, large, deeply embayed quartz phenocryst. The fine-grained groundmass is sericite-rich and strongly foliated, and contains scattered small spherulites of feldspar.

A distinctive variety of the feldspar porphyry occurs at the confluence with the creek draining Gormanston Gap. It has a splotchy appearance due to irregular wisps and lenses of fine-grained greenish and pinkish material which define a crude eutaxitic foliation similar to that in some ash flows. In thin section (P72) the rock contains plagioclase phenocrysts and glomerocrysts (mostly rather altered to sericite), and scattered quartz phenocrysts (many with reaction coronas), in a finely-crystalline feldspar-quartz groundmass. Patches of the groundmass show irregular chlorite-rich 'swirls' which wrap around the phenocrysts and in some places display pumice-like texture. It appears to be intermediate between a lava and an ash-flow.

A distinctive green chloritic agglomerate occurs west of the feldspar porphyry sequence, and appears to have an irregular inter-fingering contact with it. It contains abundant rounded pink clasts up to 200 mm across, as well as smaller, darker fragments. In thin section (P73) the majority of fragments consist of feldspar porphyry (some have scattered quartx phenocrysts also), but there are also finely-vesicular chloritic fragments of basaltic rock. The matrix is strongly foliated and chlorite-rich.

South of the finger-like spur of Owen Conglomerate the rocks include agglomerates, 'rubble-textured' rocks similar to those on Philosophers Ridge, feldspar-phyric crystal-vitric tuffs, feldspar porphyry, and glassy tuff. The rocks are cleaved and altered, and exposures are poor. A nodular-weathering feldspar-phyric rock from this area (P74) consists of close-packed, rounded to irregular, pink bodies up to 30 mm across separated by greenish chloritic matrix rich in feldspar crystals. The pink bodies consist largely of a fine patchy mosaic of secondary albite and quartz, with scattered phenocrysts of feldspar. The rock resembles some varieties of the feldspar porphyry, but its original nature is uncertain. The nodular structure may be a secondary albitisation phenomenon.

A fine-grained, massive, purplish rock is exposed in the creek south-east of this spur. A thin section (P75) contains scattered small feldspar phenocrysts, and one quartz phenocryst, in a very fine, foliated groundmass of sericite, chlorite and feldspar. The rock is probably an intrusive porphyry and has a sharp, chilled-looking contact against a coarser-grained feldspar-phyric vitric-crystal tuff (P76).

Huxley Saddle agglomerate-tuff sequence

A complex sequence of acid to intermediate tuff and agglomerate, with possible minor acid lava, occurs on the south-west slopes of Mt Owen between Whip Spur and Mt Huxley, and is bounded to the west by massive feldspar porphyry. Small dykes and irregular bodies of feldspar porphyry intrude the sequence towards the Huxley Saddle, and there are scattered small basic-intermediate dykes. Exposure is poor due to extensive cover by bouldery superficial deposits. Strikes in the layered rocks are generally NNW-SSE, except for a zone of east-west strikes along a creek towards the southern part of the area. Dips are invariably steep to vertical, and no facings have been obtained.

The lithologies range from laminated glassy ash-like tuffs through various vitric, crystal-vitric, and lithic tuffs to agglomerates with clasts up to a metre long. Rocks with a prominent eutaxitic foliation resembling ash-flows are fairly common. An unusual 'flow-breccia' mass occurs in the central part of the area, with coarse agglomerates around its southern margin. West and south of this are abundant vitric tuffs, not unlike those in the western sequence above the Miners Ridge Sandstone, with some intercalated agglomerates. In the southernmost part of the area are crystal tuffs rich in feldspar and quartz. Rocks exposed on the higher slopes, near the Owen Conglomerate contact, are generally strongly cleaved, and include altered feldspar porphyry, rubble-textured rocks, and green chloritic agglomerate.

A complex relationship is apparent between this sequence and the massive porphyry at the head of Whip Spur, and requires further detailed mapping for elucidation. A band of distinctive green basic-intermediate agglomerate (possible a xenolith?) occurs around the eastern and southern sides of a prominent knob of red porphyry, and there are also several patches of pale tuff and agglomerate apparently also surrounded by porphyry.

The relationship between the Huxley Saddle sequence and the Whip Spur agglomerate sequence is also problematical. The typical Whip Spur rocks - massive pink-green agglomerate alternating with greenish shale, greywacke and tuff - are not obviously present, although the coarse agglomerates in the central part of the Huxley area are not unlike some of the coarser Whip Spur varieties. There is no physical connection between the two, however, and it appears that there may be considerable displacement associated with the margin of the feldspar porphyry mass in this area. The rocks in the southern part of the Whip Spur sequence include various vitric tuffs and nondescript agglomerates, and there is no clear-cut distinction between these and the Huxley Saddle rocks. The east-west strikes occur in both sequences in this area.

The 'flow-breccia' in the central part of the area consists of numerous irregular lumps, lenses and stringers of pale pink, fine-grained faintly banded material in a slightly darker, coarser grained 'matrix'. The rock has the appearance of having been churned up in a plastic state, and it is difficult in places to determine which is matrix and which is blocks. In thin section (P77) the matrix material consists of large, embayed clear feldspar phenocrysts, and smaller, rounded quartz phenocrysts, in an unusual patchy groundmass of stumpy crystals of quartz and feldspar set in a paste of yellowish felted sericite-chlorite. What appear to be finer grained parts of the groundmass are in some cases small fragments of the other rock type. Nearly all the phenocrysts have large reaction rims of fine-grained material. None of the feldspar shows twinning, and the clearness of the phenocrysts (many of which resemble quartz except for the feldspar cleavage) is most unusual.

The fragments in the breccia (P78) consist mostly of a fine-grained groundmass of stumpy quartz and feldspar set in a sericitic paste, with scattered small quartz phenocrysts and a few larger corroded feldspar phenocrysts. The similarity of the two rock types involved suggests both are igneous rather than pyroclastic. The origin of the rock is problematical, but mixing of lava with chilled surface material in a vent is a possible explanation. Rather similar breccias with abundant contorted fragments of laminated glassy material occur on the south side of the Huxley Track near the coarse agglomerates, and in the creek at the southern margin of the mapped area.

The coarse agglomerates which occur to the south of the 'flow breccia' form large rounded tors or blade-like outcrops of pink to brownish grey colour. They consist of close-packed angular to rounded clasts, mostly less than 100 mm but up to a metre across, of pink to greenish fine-grained rock in a greenish-grey matrix. Many of the larger clasts are of flow-banded feldspar porphyry. In thin section (P79) the predominant rock fragments are pinkish feldspar porphyry in which the groundmass has a prominent spherulitic texture. There are several opaque-rich fragments, and one feldspar-phyric basalt fragment. The matrix is rich in both sericite and chlorite, and is strongly cleaved.

A typical vitric tuff (P80) from the main creek near the western margin of the area consists almost entirely of well-preserved small pumice fragments, up to 5 mm long, in a shard-rich matrix with considerable secondary carbonate. Some of the fragments show bubble texture, but most are compacted. Fine-scale recrystallisation obscures the texture somewhat, but there is a strong suggestion of welding and the rock is probably an ash-flow.

A prominently banded fine-grained vitric tuff occurs in a tributary creek west of the Track. It contains scattered small rock fragments, and in thin section (P81) consists of extremely fine-grained indeterminable glassy material in which are scattered small feldspar and quartz grains, chlorite blebs, and more numerous secondary carbonate blebs. This rock appears to grade laterally into agglomerate, with clasts up to 300 mm long, to the east. In thin section (P82) many of the rock fragments in the latter show beautiful spherulitic texture, and there are also sericitised feldspars and irregular chlorite blebs in the extremely fine-grained glassy matrix.

A vitric tuff with numerous small cavities from the Huxley Track at the north-western margin of the area (P83) consists wholly of very fine-grained glassy ash in which shard-like fragments are just visible. Several small cavities retain a filling of mosaic quartz, and a few of the larger ones have a rim of coarse sericite.

A sandy-textured massive rock from near the Owen Conglomerate contact shows autobreccia texture in places, with fragments outlined by paler 'veins' of finer grained material. In thin section (P84) it consists largely of small, rounded, spherulite-like feldspars intergrown with small, irregular corroded quartz patches and set in a paste of felted sericite. The larger feldspars and quartz grains, some of which are embayed and have reaction rims, approach phenocryst size, but the texture is not porphyritic. The texture resembles a coarse variety of the spherulitic groundmass of the feldspar porphyry in the Mt Jukes area. Another massive, sandy textured rock from this area (P85) consists dominantly of small quartz grains, many of which are polycrystalline with sutured internal boundaries. A small amount of very altered feldspar remains, and there is a fine sericite-chlorite matrix. Although superficially resembling a quartz sandstone, the texture of the rock suggests it could be an altered porphyry in which quartz has replaced most of the feldspar.

Whip Spur agglomerate-sediment sequence

A distinctive sequence of brown- to pink-weathering acid to basic agglomerate, tuff, greywacke and shale, with scattered basic dykes and flows, forms a large irregular lens surrounded by massive feldspar porphyry in the Whip Spur area. The sequence dips and faces west for the most part, but easterly dips and facings have been recorded locally near the western

EASTERN PART OF WHIP SPUR AGGLOMERATE SEQUENCE

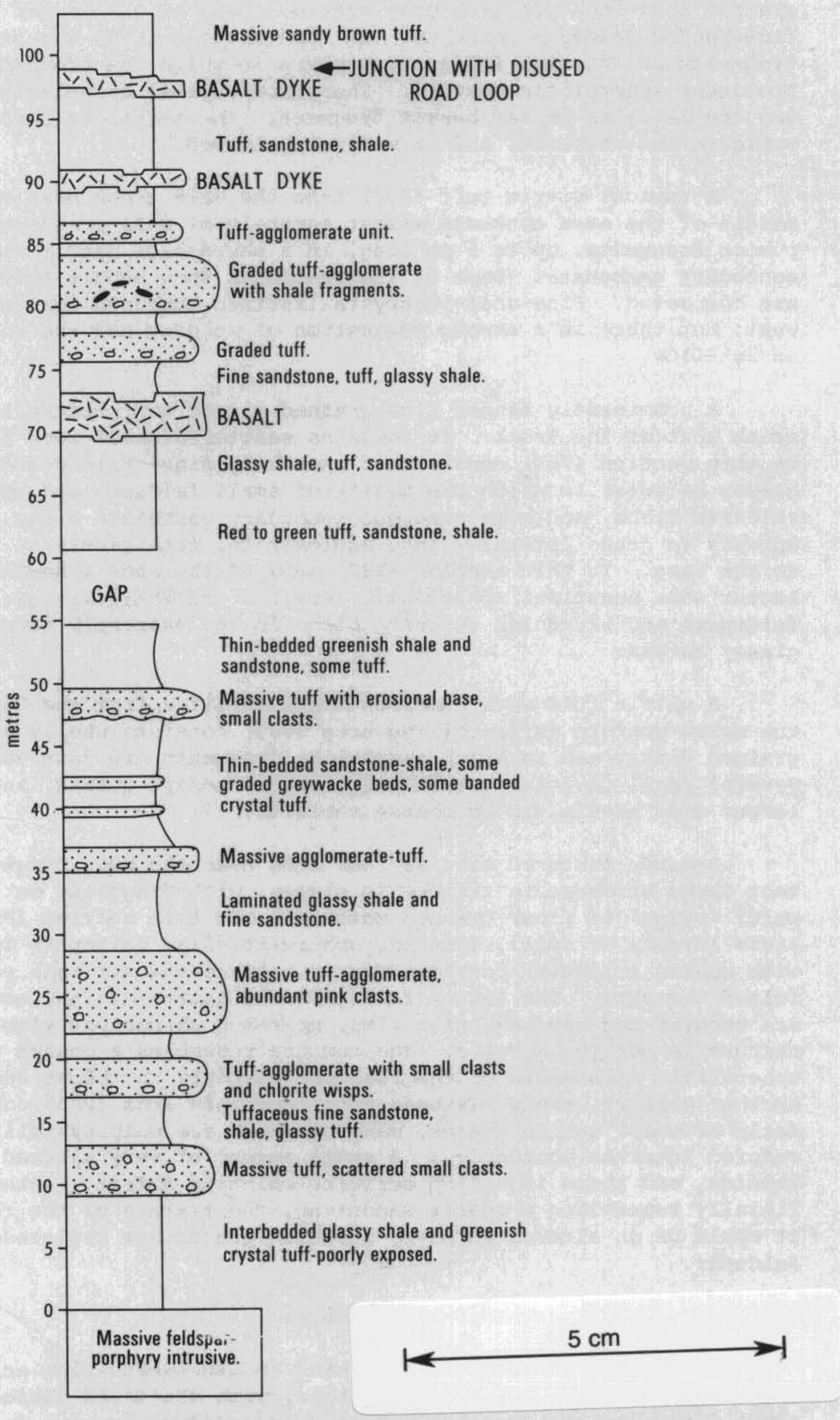


Figure 9. *Stratigraphic section through eastern part of Whip Spur agglomerate sequence, measured along Huxley Track.*

margin. The sequence is penetrated and apparently disrupted by the porphyry in the southern part of the area, where strikes are mainly east-west, and the intrusive nature of the porphyry is also evident in other areas.

The sequence has some features in common with the Lynchford tuff sequence (*e.g.* abundance of massive, brown-weathering agglomerates, pink and green patchy coloration, abundant secondary albite) but differs in some aspects (*e.g.* paucity of quartz, lack of detrital pyroxene, presence of basic dykes and flows). Green chloritic agglomerates which occur in the north-western part of the sequence are virtually identical to the basal green agglomerates of Little Owen sequence north of Roaring Meg Creek. However, the bulk of the Whip Spur sequence does not closely resemble that on Little Owen.

Much of the sequence in the eastern half of the outcrop area consists of massive, graded agglomerate-tuff beds alternating with intervals of thin-bedded sandstone, crystal tuff, shale, and glassy ash. Graded bedding is not so apparent in the western part of the area. A roughly measured section through the eastern part of the sequence along the Huxley Track is shown in Figure 9. The graded units are up to 10 m thick, and are superbly exposed in a cliff section on the eastern face of the large knoll on Whip Spur. Bases of the units are invariably sharp and erosional, and a partly torn up mudstone layer, still attached at one end, is exposed at the base of one unit. Many units contain irregular and contorted blocks of tuffaceous mudstone. The tops of the units commonly grade into bedded sandy tuff or into laminated ash typical of that which occurs in the intervening zones. The fine-grained tops of some units show crudely developed polygonal columnar jointing, perpendicular to bedding. An analysis of a typical agglomerate (Appendix A) shows a dacite-andesite composition.

The graded units apparently represent the deposits of large, bottom-hugging, subaqueous density currents - large turbidity currents in fact. Thinner graded beds of sandy tuff or tuffaceous greywacke, commonly showing convolute lamination in the upper part, occur in the intervening zones, and appear to be normal turbidites. The general similarity to the shale-tuff sequence in Conglomerate Creek is notable (compare fig. 7).

Clasts in the agglomerates in the eastern area are predominantly of feldspar porphyry, and range up to 300 mm long. They range from angular to rounded, and some show distinct flow banding. Many of the smaller clasts are bright pink in colour and irregular in shape, and there is an apparent gradation to small pink splotches of secondary albite. The tuffaceous matrix is generally dark greenish grey in colour, and rich in chlorite and pink feldspar grains. Volcanic quartz grains occur in some samples, but are not a prominent component. Splotches of dark green chlorite are common in the matrix, and many fresh surfaces show a characteristic pink and green splotchy colouration (*e.g.* P86, P87, P88). This same feature is typical of the Lynchford tuff sequence and the Comstock Tuff.

Thin sections of the agglomerates (P86 - P90) show pink fragments of feldspar porphyry in which phenocrysts and glomerocrysts of fresh albite are contained in a finely to coarsely recrystallised feldspathic groundmass. Rare small clasts have a lath-rich groundmass. The matrix material consists mainly of plagioclase (albite) and chlorite, with scattered opaque grains, carbonate blebs, and rare small quartz grains. The chlorite occurs as large irregular blebs and as finely shredded material, usually oriented in the strong cleavage. Extensive recrystallisation of the matrix to a fine albite mosaic has obviously occurred in some samples, and this tends to blur the outlines of the clasts (which already have a similar groundmass) to produce a feldspar porphyry texture (*e.g.* P86). Lobate 'fronts' of albite recrystallisation are apparent in some sections.

The thin-bedded zones generally include a high proportion of laminated, greenish glassy fine tuff or tuffaceous shale, in places showing pink and green banding similar to that in the Comstock Tuff. In thin section (P91) this material consists of very finely recrystallised feldspar (albite?), quartz and extremely fine chlorite, with small opaque grains and carbonate (?) flecks. Fine laminations seem to be due to slight variations in chlorite content. There is no indication of shard shapes or of original clastic grains. An analysis of this fine-grained material (Appendix A) shows a sodic rhyodacite composition.

A slightly coarser tuff (P92) has numerous slightly altered plagioclase grains in a strongly cleaved, finely recrystallised matrix of feldspar and chlorite with fairly numerous small opaque grains and some sericite along cleavage traces. A typical banded pink and green crystal tuff (P93) contains abundant crystals and crystal aggregates of plagioclase, fairly numerous opaque grains, and a few scattered quartz grains and feldspathic rock fragments, in a dusty, finely-recrystallised matrix. In the pink band, the matrix consists mostly of very fine secondary pink albite, whereas the green band has a high proportion of fine chlorite.

A pale-coloured tuff which superficially resembles feldspar porphyry but shows bedding in places, occurs beside the Huxley Track west of the junction with the disused loop. In thin section (P94) it contains abundant fresh plagioclase crystals and scattered quartz grains in a recrystallised sericite-feldspar matrix in which are numerous small secondary carbonate blebs.

A typical graded tuffaceous sandstone bed from near the top of the knoll on Whip Spur (P95) is a fine- to medium-grained rock with small ragged feldspar crystals and quartz crystals, and some larger secondary carbonate blebs, in a fine-grained feldspar-quartz-chlorite base in which recrystallisation has obscured the clastic texture.

Massive, green, chloritic basic-intermediate agglomerate is common in the north-western part of the area, intercalated with sandstone-shale horizons. The agglomerates (P96, P97) tend to be strongly cleaved and altered, and typically contain abundant pilotaxitic and finely-vesicular porphyritic basalt clasts. The boundaries between clasts tend to be poorly defined, and there is abundant secondary chlorite and opaques. Vesicles are mostly filled with chlorite. A rather similar rock from near the eastern margin of the sequence, south of the Huxley Track (P98), contains clasts of finely-vesicular basaltic rock as well as clasts of very calcite-rich rock and fairly numerous quartz crystals, and is thus a mixture of both acid and basic detritus.

A probable basic lava is exposed in several places south of the Huxley Track towards the western margin of the sequence. It resembles a breccia in outcrop, with irregular to sub-rounded clasts of grey rock in a darker greenish matrix. Some of the smaller clasts have sharp boundaries, but the larger ones (up to 200 mm) are commonly diffuse and tend to weather like limestone. In thin section (P99, P100) both fragments and matrix are basaltic and are similar except that the clasts have abundant micro-vesicles filled with chlorite and a darker, more opaque rich groundmass of fine plagioclase laths, chlorite blebs, tremolite-actinolite needles and fine granular epidote.

Basic dykes up to a few metres thick occur in the sequence in several areas. P101 and P102 are typical examples from the north-west part of the area, and P103 is from the Huxley Track at the junction with the disused loop. The first two are porphyritic in plagioclase, with a fairly coarse groundmass of plagioclase laths, chlorite blebs and opaque dust. Very fine-grained epidote(?) occurs in P102. The Huxley Track dyke has a fine-grained basaltic texture with aligned small feldspar laths and abundant fine chlorite and dusty opaques. Small quartz grains are also fairly common. An analysis is given in Appendix A.

The feldspar porphyries

General description. Feldspar porphyry forms a large mass on Whip Spur and a series of smaller bodies along the western and eastern flanks of Little Owen. Available chemical data (Appendix A) indicate a range from rhyolite to dacite in composition, but the reasons for the variation are not clear. The rock is mostly massive and structureless, with close-spaced jointing in several directions in the more aphanitic varieties. Columnar jointing is well developed in the body at Conglomerate Creek bridge, and has also been noted in the King River, on Mt Jukes, and in several areas north of Queenstown. The colour varies from white (on leached surfaces) to pale grey, green or pink, but a purplish-red variety ('potash rhyolite' of Solomon, 1960) occurs on the upper part of Whip Spur.

The rock typically consists of fresh to somewhat altered plagioclase (mainly albite) phenocrysts up to 3 mm long, and glomerocrysts, in a fine-grained feldspar-quartz-sericite-chlorite groundmass. Quartz-chlorite clots, large chlorite blebs, and rare small quartz phenocrysts, occur in some samples. The groundmass commonly shows micro-spherulites of murky pink feldspar or incipient 'snowflake' texture of intergrown feldspar and quartz.

The Whip Spur mass appears to be largely intrusive, and several of the smaller bodies also have intrusive contacts. Some of the bodies, however, have well-developed flow banding and autobrecciation textures (*e.g.* Waterfall Gully), and are probably lavas. Flow banding also occurs on the upper part of Whip Spur. There is no clear petrological or field distinction between lavas and intrusives, and clear evidence on the nature of the contacts is commonly lacking. A further complication arises in that there appears to be a gradation from typical porphyry into feldspar-phyric tuffs with textures indicative of hot ash-flows, and in areas of strong cleavage development and secondary alteration it may be impossible to classify such rocks with any certainty.

The abundance of fragments of typical feldspar porphyry in the pyroclastic rocks of all the central sequences, and the presence of ash-flows and lavas of similar composition, strongly suggests that the larger porphyry bodies are shallow, sub-volcanic, probably penecontemporaneous, intrusions.

Whip Spur mass. This mass has a subconcordant but slightly transgressive contact with the western sequence, but appears to be markedly discordant with all the central units. Particular attention was given to the contact with the Whip Spur agglomerate sequence, since earlier mapping had suggested that this sequence overlay the porphyry 'lava' unit (Corbett *et al.*, 1974). Intrusive contacts with the sequence have now been mapped in several areas, *e.g.* the dyke-like protrusion on the north-west flank of the spur, and the larger, cross-cutting protrusions south of the Huxley Track. Xenoliths of shale occur near the contact in several places, and a large xenolith is exposed on the disused road loop east of the knoll on

Whip Spur.

The northern boundary of the Whip Spur mass, against the Little Owen sequence, is poorly exposed and is complicated by the occurrence in the latter of feldspar-phyric rocks resembling the porphyry. A boundary between massive porphyry and porphyry-like rock with chlorite wisps and rare pumice fragments (P104) occurs in Roaring Meg Creek near the north-west tip of the Whip Spur agglomerate sequence. The easterly continuation of this line marks the abrupt northern contact of the Whip Spur sequence on the south bank of the creek, and a narrow sliver of the pseudo-porphyry separates the agglomerate sequence from the large andesite body on the north bank. Further east there is more of the pseudo-porphyry on the south bank of the creek, but then the main porphyry mass transgresses northwards. In the head of Conglomerate Creek the porphyry truncates an agglomerate-shale sequence, and appears to be continuous with the narrow sill which extends down the east bank of Conglomerate Creek.

The bulk of the Whip Spur mass is pale grey in colour, weathering to pale fawn or white. A pink variety occurs on the ridge south of Whip Spur, and a deep pink to purplish-red variety at the head of Whip Spur. The red porphyry has a fairly sharp, mappable western contact with the pale variety, and has previously been shown as a distinct body (Solomon, 1960; Corbett *et al.*, 1974). However, there is gradation through pale pink to white porphyry on the uppermost part of the spur, and also elsewhere, suggesting the variations may not reflect separate bodies. There appear to be no major petrological differences between the types.

The red porphyry at the head of the spur (P105) contains scattered fresh plagioclase phenocrysts (to 3 mm) and glomerocrysts (usually with intergrown chlorite), and scattered opaque grains, in a fine-grained groundmass of pink, murky, poorly crystallised material (mixture of feldspar, chlorite and opaque dust) intergrown with ragged, mosaic-textured quartz patches. There are scattered small pink spherulites of feldspar, only some of which show radial structure. Staining tests and the relatively high potash content (4.5%) shown by chemical analysis (Solomon, 1960), suggest that much of the groundmass material is K-feldspar.

A red porphyry (P106) near the contact with the white variety is similar in texture to P105, although lacking spherulites. Some of the plagioclase phenocrysts have cores of mosaic secondary albite and/or chlorite. The groundmass is uniformly pink and fine-grained but appears to be recrystallised, with abundant fine quartz intergrown with the rather shredded feldspar. Several veins of clear albite which cut the rock pass through some of the feldspar phenocrysts, and the two appear to be identical in composition. Another reddish porphyry (P107) from the northern slopes of the spur has fresh plagioclase phenocrysts and glomerocrysts, as well as small patches of mosaic quartz and quartz-chlorite, in a pink granular-looking groundmass dominated by rounded to squarish spherulites. The spherulites have an overgrowth of clear feldspar around the original dark brown border, and a pink core showing well-developed radial structure in some cases. Some have lost the radial structure and appear to have re-crystallised to solid K-feldspar. A strong cleavage is evident as pressure shadows and stringers of chlorite-sericite flakes.

The pale porphyry (P108) from the upper part of Whip Spur, where some of the rocks may be extrusive, has partially to completely sericitised feldspar phenocrysts in a foliated groundmass in which small quartz patches and rounded pink feldspar grains (probably after spherulites) are contained in a web of sericite. Small clusters of secondary monazite(?) crystals occur within sericite masses after feldspar. Also from this area, in Diorite Creek, is a somewhat altered feldspar porphyry (P109) with a granular groundmass (like P107) containing abundant small rounded bodies of pink feldspar (probably recrystallised spherulites) and small quartz grains set in a cleaved sericitic base. Coarse mosaic patches of intergrown quartz and carbonate are common.

The massive pink porphyry on the ridge south of Whip Spur is purplish-grey when fresh, with prominent small flecks of chlorite. In thin section (P110, P111, P112) many of the abundant plagioclase phenocrysts have an altered core of chloritic material surrounded by clearer feldspar. Unusually large patches or clumps of coarse feldspar intergrown with chlorite occur in P111. Chlorite is common as irregular patches and also as large flakes suggestive of original phenocrysts. Carbonate occurs as large blebs and scattered grains in P111. The groundmass shows incipient micro-spherulitic texture, or fine-scale 'snowflake' texture, in which the poorly formed pink feldspathic 'snowflakes' are outlined by concentrations of fine chlorite and opaque dust. There are also small patches of mosaic quartz and quartz-chlorite, and rare small quartz phenocrysts. Monazite(?) and zircon are accessories.

A sample from one of the small porphyry bodies in the Huxley Saddle area (P113) is glomeroporphyritic but slightly unusual in that the groundmass shows a primary crystalline texture of fine plagioclase laths and intermediate-size feldspars (many of them altered to sericite) with interstitial sericite and chlorite.

The porphyry to the west of the Whip Spur agglomerate sequence is mostly pale grey to white in colour. In thin section (P114, P115) phenocrysts and glomerocrysts of partially altered plagioclase (some with zonal alteration), and scattered chlorite blebs, are contained in a fine-grained groundmass showing micro-snowflake texture of intergrown feldspar and quartz with fine chlorite and opaque dust. There are scattered small cavities lined with monazite(?) and filled with sericite. A vesicular variety (P116) near a small prospect contains sparse, very altered phenocrysts in a strongly cleaved groundmass of graphically intergrown feldspar and quartz with considerable sericite and carbonate. The small vesicles (up to 10 mm) are filled with coarsely-crystalline carbonate, with an irregular rim of sericite in some cases.

A sample from the porphyry dyke (P117) at the western margin of the agglomerate sequence shows the typical glomeroporphyritic texture, with relatively fresh plagioclase phenocrysts and quartz-chlorite clots and some large chlorite flecks, but has a distinctive pilotaxitic groundmass of fine plagioclase laths intergrown with quartz and fine chlorite.

Upper Conglomerate Creek sill. This body is about 150 m wide, and extends the full length of upper Conglomerate Creek. It is generally massive and pale grey to pinkish-green in colour. A vesicular variety, with carbonate-filled vesicles up to 70 mm long, occurs on the west flank of a small ridge east of the Great Lyell adits, and a coarsely spherulitic variety, with packed spherulites up to 3 mm across, was noted about 200 m south of the Waterfall Gully confluence. A strong cleavage is usually present.

Thin sections of the normal porphyry (P118, P119) show partially to completely sericitised feldspar phenocrysts and glomerocrysts, mosaic quartz patches, scattered small quartz phenocrysts, patches of felted sericite, and scattered large opaque grains. The groundmass has two cleavages apparent, and shows micro-snowflake texture of intergrown feldspar and quartz in a web of fine sericite, chlorite and opaque dust.

Reservoir Creek bodies. Several elongate masses of pale-weathering porphyry occur in the basal part of the Little Owen sequence along Reservoir Creek, and also intrude the upper part of the underlying sequence. Flow banding and autobrecciation texture occurs in several places in the largest body, which may be partly extrusive.

A sample from the flow-banded part near the southern end of the largest body (P120) shows fresh to partially altered plagioclase phenocrysts in a very fine-grained groundmass of intergrown feldspar, quartz, chlorite and sericite. Variations in the amount of chlorite define a crude banding Massive porphyry at the knob near the southern end of this body (P121) contains very abundant rather small plagioclase phenocrysts in a very fine-grained groundmass dominated by scaly sericite and chlorite and strongly modified by two cleavages. Flow-banded porphyry from the northern end of the body (P122) contains large, somewhat rounded plagioclase phenocrysts, and scattered opaque grains. There is some suggestion of micro-snowflake texture in the groundmass, and some scattered rounded pink grains which appear to be recrystallised spherulites.

The next body to the north (P123) is a strongly cleaved porphyry with partially sericitised feldspar phenocrysts in a murky, pinkish-brown groundmass of feldspar-quartz-chlorite-sericite showing micro-snowflake texture and scattered small spherulites.

Conglomerate Creek bridge body. A lens-shaped body of white-weathering pink feldspar porphyry occurs on either side of Conglomerate Creek at the Lyell Highway bridge (see analysis, Appendix A). Its northern margin is a sharp, vertical contact, faulted and offset in places, against an unusual contorted crystal-vitric tuff(?) unit containing large deformed lenses of pale cherty material. The porphyry is massive and closely jointed, and shows columnar jointing in most areas. The columns are 150-200 mm across, and plunge moderately west near the large quarry on the south bank. Small elongate vesicles define a crude flow foliation perpendicular to the columns in some areas. Small basic-intermediate dykes penetrate the body at its northern and southern ends.

Thin sections of samples from the quarry area (P124, P125) show sparse, sericitised feldspar phenocrysts in a murky, fine-grained groundmass of intergrown feldspar, quartz, sericite and chlorite. There are scattered small spherulite-like bodies and some tendency towards micro-snowflake texture. Elongate vesicles up to about 10 mm long in P125 are filled with fine felted sericite.

The basic-intermediate intrusives

General features. Brown-weathering bodies of basic-intermediate rock, generally referred to as 'andesite', occur in all the central units but are most abundant around Little Owen and Conglomerate Creek. They range from large bodies of fresh, uncleaved rock down to strongly cleaved and altered dykes a few centimetres wide. Irregular dyke-like offshoots from the larger bodies resemble the isolated smaller dykes and lenses, strongly suggesting that most of the intrusives are related to the fresh andesites. In places there is a close association between intrusives and basic-intermediate pyroclastics, suggesting that some of the bodies may be sub-volcanic. Chemical analyses (Appendix A) indicate an andesite composition, with calc-alkaline affinities (figs. 4,5,6). The rocks are slightly richer in silica and potash than the Lynch Creek basalts, but are otherwise similar.

Distinction between small dykes and lava flows is often difficult or impossible in the field, and some of the units in the lower Conglomerate Creek area are probably flows, as previously described. The major bodies are porphyritic in plagioclase and clinopyroxene, and less commonly hornblende, and appear to belong to the same suite as the 'hornblende andesites' of the Crown Hill area, north of Queenstown (Solomon, 1960; Corbett *et al.*, 1974).

Some of the dykes are clearly younger than some of the feldspar porphyry bodies which they intrude (*e.g.* Conglomerate Creek bridge, Waterfall Gully), but the relationship to the larger feldspar porphyry units (*e.g.* the Whip Spur mass) is uncertain.

Reservoir andesite. This lens-shaped body surrounds the new water supply reservoir, and is about 300 m wide and one kilometre long. Hematitic veins at the contact have been prospected in one area. The rock is weathered to a deep red soil over much of the area, and outcrops tend to be spheroidally weathered. Fresh rock is exposed in the creek valley north of the reservoir (see Analysis, Appendix A), and is massive, dark greenish grey and medium-grained, with pale greenish feldspar phenocrysts and darker ferromagnesian minerals just visible.

Thin sections (P126, P127) show a porphyritic texture in plagioclase, clinopyroxene and chlorite. The abundant plagioclase phenocrysts are up to 2 mm long, and range down to groundmass size. They range from fairly fresh to completely altered. Some glomerocrysts occur, and many of the crystals are somewhat rounded. Twinning measurements indicate that these crystals are mostly albite. The fresher crystals show spotty sericite alteration and sheaves of fine actinolite needles, while the more altered ones are almost completely replaced by fine sericite and chlorite. The pyroxenes are mostly euhedral to subhedral, and generally slightly smaller than the feldspars (up to 2 mm). Most crystals show some alteration along margins and cracks to actinolite, chlorite, or both, and some are almost completely replaced by chlorite. Epidote occurs as a marginal replacement product (after actinolite in some cases) in P126, while some crystals in P127 have a narrow rim of pleochroic hornblende. Extinction angle measurements indicate augite or diopside. Large masses of chlorite, some of them crystal-shaped, also occur and are commonly associated with patches or inclusions of quartz. Euhedral apatite crystals, to 0.35 mm across, are common, and there are scattered large opaque grains. The fine-grained groundmass contains significant quartz, and consists of interlocking plagioclase and quartz, with chlorite, actinolite and granular epidote. Several quartz-epidote-chlorite veins occur in P126.

Little Owen andesite. This body has an irregular H-shaped outcrop pattern, which may be partly due to folding, and breaks into a series of irregular dykes at its northern end. Several prospects are located near the contact on the east flank of Little Owen. The rock is very similar to the Reservoir andesite, and in thin section (P128) is a medium-grained plagioclase-pyroxene-chlorite porphyry (see analysis, Appendix A). The abundant plagioclase phenocrysts are up to 3 mm long and are strongly altered to fine sericite and chlorite. The margins of many of the crystals are corroded and poorly defined. Small euhedral pyroxene phenocrysts (mostly less than one millimetre) are abundant, and most show only slight marginal alteration to chlorite, actinolite or both. Some are zoned and have a broad outer rim of clearer material. There are scattered large chlorite masses, small apatites, and opaque grains. The groundmass consists of intergrown feldspar and quartz, with chlorite, actinolite needles, and fine granular epidote.

Lens east of Reservoir andesite. Several small lenses of strongly cleaved, altered and rather weathered basic-intermediate rock occur east of the Reservoir andesite. A thin section from the freshest material available (P129) in the largest lens (see analysis, Appendix A) shows an altered porphyry texture, with abundant small completely altered feldspar phenocrysts (up to one millimetre) and larger elongate chlorite blebs (up to several millimetres), strung out on the cleavage. There are also fairly numerous small quartz grains and patches of mosaic quartz. The dark, dusty, foliated groundmass consists of feldspar, quartz, chlorite and opaque dust. There are no primary ferromagnesian minerals or epidote.

Waterfall Gully dyke. Several dyke-like bodies of basic-intermediate rock occur within the schists and feldspar porphyries in Waterfall Gully. A thin section (P130) from one of these shows a well-preserved feldspar-pyroxene porphyry texture with a spaced cleavage which does not markedly affect the groundmass texture. The plagioclase phenocrysts (up to 2 mm) are slightly to moderately altered, and show zoning in many cases. Clumps of phenocrysts intergrown with pyroxene are common. The sparse, subhedral to anhedral pyroxenes (up to one millimetre) are rather strongly altered, and are mostly either intergrown with feldspar or form small, rather shredded crystals extensively altered to chlorite. There are scattered large opaque grains, mosaic quartz patches, and rare apatite crystals. The groundmass consists of intergrown quartz and feldspar, with chlorite, actinolite, epidote and sericite.

INTERPRETATION OF STRATIGRAPHIC RELATIONSHIPS

Summary of major features

The following features appear to be significant when considering the relationships of the various units and their possible interpretation:

(1) The apparently unique tholeiitic composition of the basal spilites at Miners Ridge, as opposed to the calc-alkaline affinities shown by the later basalts and andesites.

(2) The predominantly marine nature of the western sequence, as indicated by the abundance of greywacke, shale and laminated tuff, and the occurrence of rare trace fossils and acritarchs.

(3) The presence of significant amounts of Precambrian metamorphic detritus in the western greywackes, and particularly in the Miners Ridge Sandstone, but its apparent absence from the central sequence.

(4) The abrupt change to dominantly subaerial volcanic deposits, with abundant ash-flow tuffs and coarse agglomerates, at the contact with the Little Owen sequence, and the general paucity of shale and sandstone in the latter sequence.

(5) The lack of appearance of the various western units in the Little Owen area, and the marked lack of correlation between the western and central sequences.

(6) The predominance of feldspar-phyric volcanics and intrusives in the central sequence, as opposed to the quartz-feldspar-phyric

rocks of the western sequence.

(7) The occurrence of hydrothermally altered and mineralised rocks in the central sequence but not (apparently) in the western sequence.

(8) The close relationship between the pyroxene-bearing Lynchford tuffs and the adjacent Lynch Creek basalts.

(9) The intrusive relationship between the Whip Spur feldspar-porphyry mass and the Whip Spur agglomerate sequence.

There appears to be a fairly fundamental distinction between the western and central sequences, and comparison with modern rhyolitic volcanic fields suggests a possible explanation for this.

Significant features of rhyolitic caldera complexes

The predominance of rhyolitic rock types and the presence of significant amounts of ash-flow tuff and related lavas and intrusives, invites comparison with major rhyolite-ignimbrite provinces elsewhere. One of the features of such provinces is the common occurrence of caldera collapse structures in which large volumes of ash-flows and lavas have been ponded. A number of such structures have now been mapped and described in some detail, particularly those in the western U.S.A., where the sequence of events involved in the evolution of caldera complexes is now fairly well known. A brief review of the geology of such complexes reveals some striking similarities with the Queenstown sequence, and provides a possible framework for interpreting the complex relationships.

One of the best known volcanic fields in which calderas are prominent is that of the San Juan Mountains area in Colorado, where some fifteen Tertiary calderas, averaging about 20 km across, are known. A comparison of this volcanic field with western Tasmania at the same scale is given in Figure 10. The Mt Read Volcanics belt, although more linear in outcrop, is of roughly comparable size, and it is apparent that the average caldera would roughly span the present width of the belt. In general, the western United States calderas appear to have developed in areas subject to regional extension, and they may be associated with, and modified by, major tensional fault systems.

A sequence of evolutionary stages (fig. 11) associated with more or less distinctive eruptive and intrusive products, has been determined from detailed studies of many calderas (Smith and Bailey, 1968; Byers *et al.*, 1976; Lipman, 1975). These stages are generally only recognisable in the younger, better exposed and less deformed calderas, and may be very difficult to unravel in older or poorly exposed structures. Interpretation is further hampered by the fact that the calderas tend to occur in clusters and to overlap one another to varying degrees, so that five or six intra-caldera sequences may be closely juxtaposed. A variety of rock types, ranging from rhyolite through to basalt, is commonly present, but the main caldera fill is usually dominated by rhyolitic ash-flows, lavas and intrusives.

In the San Juan region, the initiation of caldera formation coincided with a change from early intermediate volcanism (lavas and breccias), marked by scattered central volcanoes with extensive volcaniclastic deposits between them, to voluminous eruptions of silicic ash-flows. However, some intermediate and basaltic eruptions continued during the caldera phase. Following the caldera phase, which lasted for only about five million years,

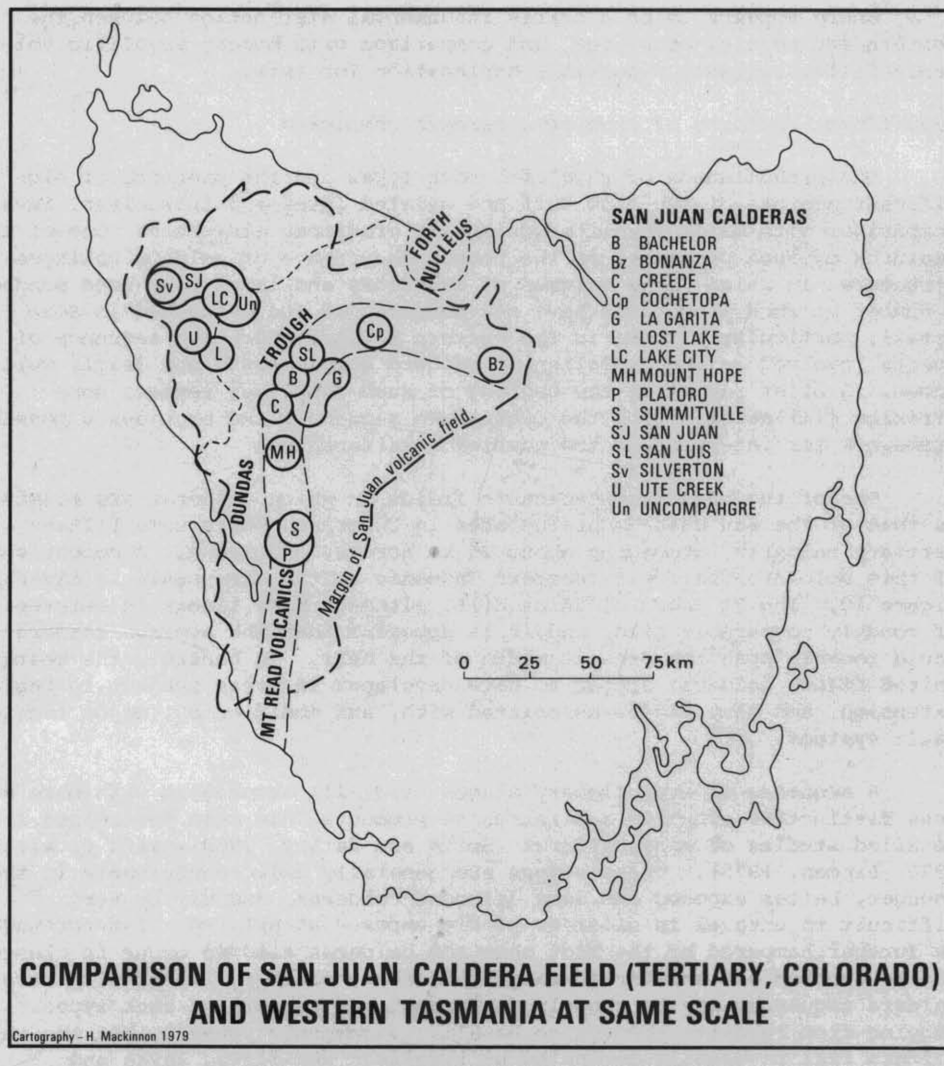


Figure 10. *Comparison between San Juan caldera field (Tertiary, Colorado) (after Lipman, 1975) and western Tasmania at the same scale.*

there was a change to bimodal basalt-rhyolite volcanism comprising widespread basalt-andesite flows and local rhyolitic plug-domes.

Each caldera cycle begins with regional doming (Stage I) and eruption of extensive ash-flows from a ring-fracture system (Stage II). These fractures may partly follow existing basement structures, and the early dykes and vents may be difficult to locate because of later complexity. The caldera is formed (Stage III) by collapse of the roof of the magma chamber after the early ash-flow eruptions. The major subsidence occurs on the inner part of the ring system, producing a sub-circular depression 10 - 30 km across and 1 - 3 km deep. The caldera floor consists mainly of the early ash-flows, through which local andesitic highs may project in some cases. Ash-flow eruptions commonly continue during collapse, and may be intercalated with landslides, debris flows, megabreccias etc. from the caldera walls, which tend to be scalloped by large slumps (Lipman, 1976).

Rhyolite lavas, ash-flows and other pyroclastics are erupted from the ring-fracture zone onto the caldera floor (Stage IV), where they may interfinger with slope deposits, alluvium and lacustrine deposits. Most of the eruptions are ponded against the caldera walls, but some ash-flows may drain over the rim in low areas to form outflow deposits. The intra-caldera sequence may be up to several kilometres thick, with the thickest deposits near the caldera wall.

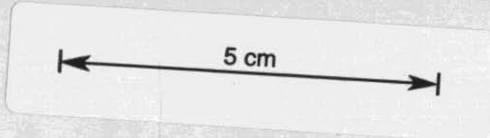
In many cases there is a resurgence of magma pressure at this stage to form a pronounced dome in the central part of the caldera (Stage V or resurgent phase). This dome may be cut by radial fractures and commonly has a central graben with a structural relief of up to 1000 metres (fig. 11). Rhyolite lavas are erupted from parts of the ring-fracture zone and from within the central graben. The feeder dykes, domes and lavas in the central grabens of some calderas are distinctive high-silica rhyolites (76-78% SiO_2), possibly resulting from compositional zoning in the upper part of the magma chamber (*e.g.* Byers *et al.*, 1976). This zoning may be reflected in some of the larger ash-flow sheets.

A caldera lake commonly forms in the moat zone surrounding the central dome, and considerable thicknesses of alluvial and lake deposits and bedded tuffs may form, associated with hot springs and travertine deposits (*e.g.* Steven and Ratté, 1965). There may be considerable re-working of dome material into the moat area. Ring-zone rhyolites mostly overlie, but may be interbedded with these deposits.

The final major effusive phase (Stage VI) in many calderas comprises late rhyolites erupted peripheral to the central dome and forming a discontinuous ring of pyroclastic cones, domes and flows in the moat area. These may be very large and in some cases overtop the caldera rim. Removal of these surface volcanoes by subsequent erosion has sometimes exposed dacitic quartz-porphyry feeder dykes and plugs (*e.g.* Lipman, 1975).

In some calderas the post-collapse phase was marked by voluminous eruptions of andesitic flows and pyroclastics similar in composition to the pre-caldera intermediate rocks. These eruptions included distinctive agglutinated andesitic breccias at Platoro (Lipman, 1975). The associated intrusive rocks are notably less acid than those associated with the ash-flow tuffs, and may have been derived from lower levels in the magma chamber (fig. 11).

The terminal phase (Stage VII) in the caldera cycle consists of solfateric and fumerolic activity, and may include significant hydrothermal



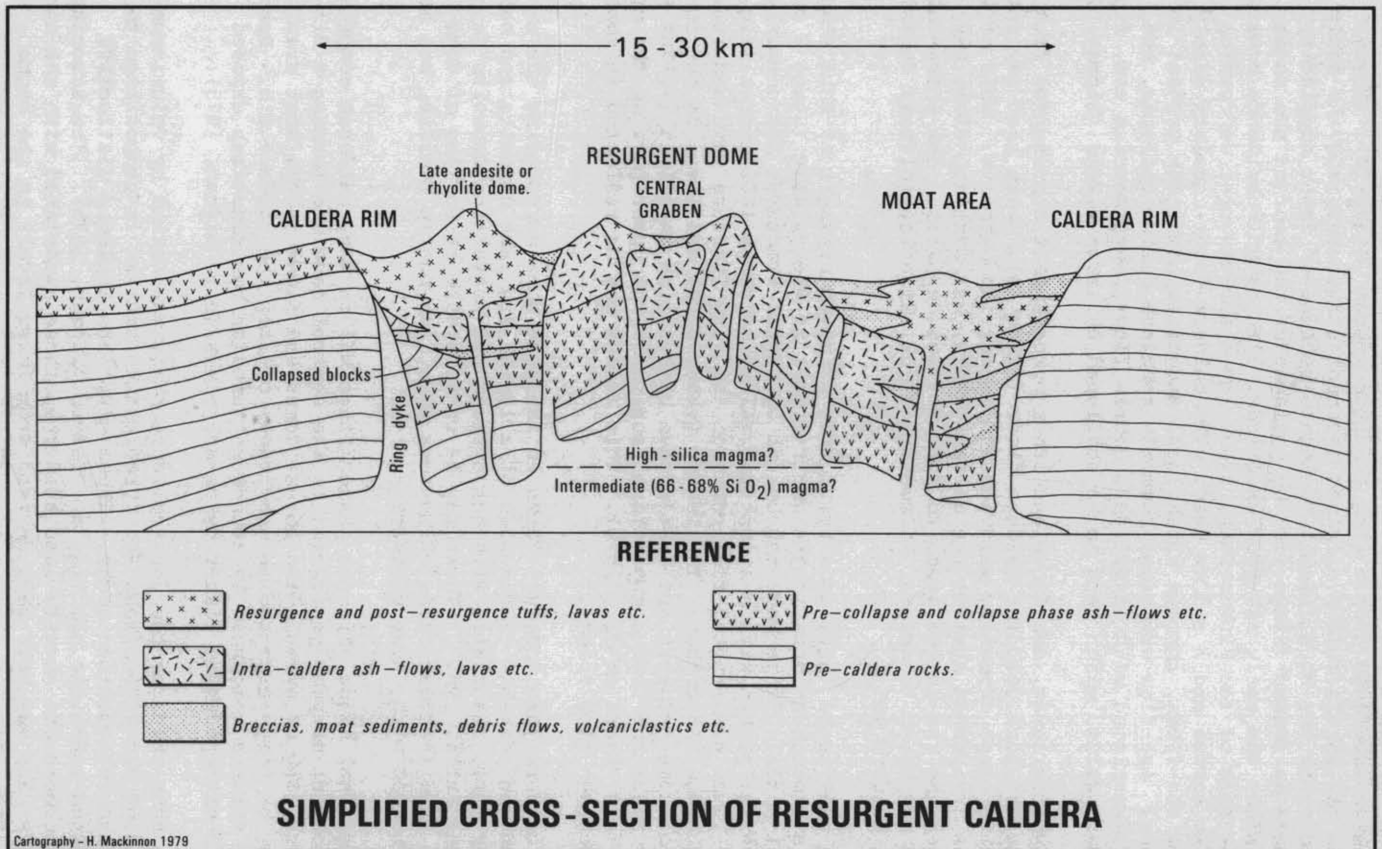


Figure 11. *Simplified cross-section of a resurgent caldera complex (modified from Byers et al., 1976, and Lipman, 1976).*

alteration and some mineralisation (Pb, Zn, Cu, Ag, Ag, Mo). Such hydrothermal activity may continue for long periods of time, the length of time possibly depending on the size of the caldera. Significant mineralisation may occur along the central graben faults (*e.g.* Creede caldera, Steven and Ratté, 1965), or around the ring fracture system, particularly where the latter intersects a regional fault system. Most of the richest ore deposits in the San Juan field, however, appear to have formed some 5 - 15 million years after the main caldera phase, during an extended period when minor quartz-porphyry intrusives were emplaced along caldera-related structures (Lipman *et al.*, 1976). Hydrothermal activity and mineralisation may also occur within some of the pre-caldera intermediate stratovolcanoes, particularly related to late-stage core intrusions of granitic or monzonitic rocks (Lipman *et al.*, 1976).

Comparison of the South Queenstown sequence with caldera complexes

The above review indicates some possible analogies with the South Queenstown sequence, and suggests an explanation for the differences between the western and central sequences. The western sequence could be interpreted as a pre-caldera volcano-sedimentary sequence developed in a large marine basin deepening westwards. This basin received considerable detritus from a Precambrian metasedimentary terrain (probably the Tyennan region) and also acid volcanic detritus (pumiceous ash, quartz and feldspar crystals, quartz-porphyry clasts, etc.) from local volcanic centres. Much of this detritus was brought in by density flows, including 'normal' turbidity currents, with mixed detritus to produce the greywackes, and large submarine tuff flows, probably similar to those described by Fiske and Matsuda (1964), to produce the agglomerate-tuff beds. Deposition of tuffaceous material by settling of air-fall eruptions may also have made a significant contribution. The Miners Ridge Sandstone appears to represent a hiatus in volcanism during which the depositing currents brought in only Precambrian detritus.

It is notable that the oldest unit in the western sequence, the Miners Ridge basalts, is tholeiitic in composition as opposed to the calc-alkaline affinities shown by all the later volcanics. Trace element studies of basalts in the Dundas Trough sedimentary sequences to the west of the Mt Read Volcanics belt (Foden, 1973; White, 1975; Varne, 1978) indicate that these rocks also have affinities with low-K tholeiites and ocean-floor basalts rather than calc-alkaline suites. The basalts at Miners Ridge may therefore represent the final stages of tholeiitic volcanism prior to the development of the calc-alkaline Mt Read arc.

Because of its relative complexity, and the abundance of ash-flows, agglomerates, lavas and intrusives, the central sequence may be compared with intra-caldera sequences. The relative scales suggest that only a small portion of such a complex is likely to be represented in the South Queenstown area (fig. 11, 12), and the complexities introduced by steep tilting, folding and faulting of the rocks must be borne in mind. The relatively abrupt change to subaerial-type eruptives which occurs at the western margin of the Little Owen sequence, and the association with plugs(?) and linear dykes, suggests analogy with a caldera-margin situation with associated ring dykes. The ignimbritic white quartz-rich tuff which seems to mark the top of the western sequence in this area has an erosional sedimentary contact on the underlying shale, and hence must be a pre-caldera unit. This tuff and the underlying shale unit are apparently missing in the northernmost part of the area, near Conglomerate Creek, and this is perhaps due to later slumping into the caldera.

The chloritic basic-intermediate agglomerates which mark the beginning of the Little Owen sequence in Reservoir Creek bear a remarkable similarity to the 'agglutinated andesitic breccias' described from the wall of the Platoro caldera by Lipman (1975, p.64). These are described as varying from 'a weakly indurated mass containing monolithologic blocks of scoriaceous and dense lava, to an indurated compact breccia, to an extremely indurated breccia that has undergone flowage to such an extent that it appears flow layered'. The breccias are part of the Summitville Andesite, a late-stage body of andesitic lavas and fragmentals that formed near the margin of the caldera. The breccias were apparently formed by eruption of hot fragmental material which draped against and partly flowed down the caldera wall.

Caldera margin deposits commonly consist of ash-flows, lavas and agglomerates intercalated with landslide material, mudflows, rock falls, megabreccias etc. derived by slumping from the steeply-dipping caldera walls. Lipman (1976) has described some of these breccia deposits, and indicates a range from megabreccias, with clasts up to several hundred metres long, to mesobreccias with clasts mostly less than one metre in diameter. Such breccias are more common in the deeper, older parts of the caldera fill, and may be blanketed by later eruptive rocks near the caldera margin. They may be difficult to recognise except where exposures are exceptionally good or the blocks are of distinctive lithologies. Such breccias have not yet been recognised in the South Queenstown area, but the mapping was done before the author was aware that such features might exist, and hence their presence may have been overlooked in the general complexity. The very complex area between Roaring Meg Creek and Reservoir Creek includes laminated glassy tuffs and small tuffaceous shale units similar to those of the western sequence, mixed with chloritic agglomerates, ash-flows and other rocks, and further detailed work may show breccia deposits in this area.

Sedimentary deposits related to the lakes which form in the moat area of resurgent calderas, or in low-lying parts of non-resurgent calderas, are represented in most caldera sequences. These may include alluvial gravels and sands, lake clays, reworked tuffs, debris flows, etc. and may be intercalated with lavas or ash-flows. Two minor shale units on the western flank of Little Owen, and several units of bedded or laminated tuffs (*e.g.* P60) may be of this type. Distinctive tuffs containing abundant contorted fragments of dark shale occur on the upper part of Little Owen Spur and also in the southern part of the Huxley Saddle sequence, and may represent slide deposits which have intermixed with lake sediments.

The largest sedimentary unit in the central sequence is the shale-tuff-agglomerate unit in upper Conglomerate Creek. The apparently wedging nature of this unit suggests the body of water was restricted in extent. The coarse graded beds which characterise this unit clearly represent mass flows of some kind, and may be the subaqueous distal parts of large debris flows. The report by Vidal (pers. comm.) of the acritarch *Bavlinella faveolata* (Shepeleva) and carbonaceous material in shale from this unit suggests it could be at least partly marine, and several species of acritarchs are also reported from shale in an approximately similar situation in the conveyor drive tunnel north of the mapped area. It is possible, therefore, that the major shale bodies are marine, indicating that the caldera structure may have been breached to the sea for part of the infilling stage. The base of the Conglomerate Creek unit is not exposed, however, and it is possible that it represents an uplifted part of the marine pre-caldera basement.

The various feldspar porphyry bodies which characterise the central sequence probably represent a variety of dykes, plugs, domes and flows such as occur in typical caldera sequences. Distinction between intrusive and extrusive varieties can be difficult even in well-exposed, undeformed sequences, and gradations from intrusive to extrusive within a single body are common (*e.g.* Lipman, 1975). Flow banding and autobrecciation may occur in both intrusive and extrusive units. Similarly, the andesite intrusives and pyroclastics could correspond to the andesitic rocks which occur in some caldera complexes.

Further discussion of the caldera analogy will now be deferred until the volcanic sequences to the south and north of Queenstown have been considered.

The problem of the Whip Spur agglomerate, Lynchford tuff and Comstock Tuff

The relationship of the Whip Spur agglomerate sequence to the other central sequence units, to the Lynchford tuff sequence, and to the Comstock Tuff remains an important unsolved problem. The Whip Spur sequence is clearly intruded by the feldspar porphyry mass, and hence is older than one of the major intrusive phases of the central sequence. It includes basic-intermediate agglomerates which are virtually identical to those in the western part of the Little Owen sequence, interpreted as probably intra-caldera deposits. The bulk of the sequence, however, is quite unlike that of Little Owen, and includes no known ash-flows. The eastern part of the sequence is similar in depositional features to the shale-tuff-agglomerate unit in upper Conglomerate Creek and a similar environment of deposition (subaqueous, possibly marine or deep lake) is indicated. On these grounds it might be argued that the Whip Spur agglomerate sequence represents part of the early caldera-fill, with possibly some pre-caldera basement, brought up as a mega-xenolith by the feldspar porphyry mass. On the other hand, the similarities with the Comstock Tuff, which overlies rocks of the central sequence, might suggest that the Whip Spur sequence represents a relatively young unit which was intruded by an even younger feldspar porphyry body. This explanation seems less likely, and it is considered that the similarities with the Comstock Tuff are fortuitous.

The Lynchford tuff sequence is closely associated spatially and compositionally with the Lynch Creek basalt mass, and a genetic connection seems likely. The basalts are virtually surrounded by the western sequence greywackes, interpreted as pre-caldera rocks, and at first sight would appear to be part of that sequence. If this is so, then the Lynchford tuffs are probably also part of that sequence, and the very marked similarity with the Comstock Tuff is fortuitous. On the other hand, there is some evidence to suggest that the Lynch Creek basalts could be much younger than the western sequence, and essentially intrusive through that sequence, in which case the Lynchford tuffs might also be younger and probably equivalent to the Comstock Tuff. The apparent absence of any disconformity or structural break between the Lynchford tuffs and the underlying western sequence rocks is puzzling in this case, but might be due to local concordance of strikes. Further comments on this problem are made after consideration of surrounding areas.

THE KING RIVER GORGE - MT JUKES AREA

INTRODUCTION

A well-exposed section through the Mt Read Volcanics is available in the King River Gorge between Mt Huxley and the mouth of the Queen River (fig. 3; Corbett, 1976*c*). Three distinct sequences are present - a western sequence of interbedded greywacke, sandstone, shale, quartz-phyric tuff and quartz-feldspar porphyry; a central sequence dominated by feldspar porphyries with minor bedded tuff-sediment lenses; and an eastern sequence of volcaniclastic conglomerate and sandstone mixed with quartz-feldspar-phyric volcanic rocks. The central and eastern sequences extend onto Mt Jukes, and have been mapped in the Jukes Proprietary and Lake Jukes areas (Corbett, 1976*b*).

WESTERN SEQUENCE

The western sequence for the most part dips steeply east and faces east towards the contact with the central belt. The distinctive quartz-rich Miners Ridge Sandstone occurs towards the western part of the river section, where it is underlain by interbedded greywacke, shale and quartz-feldspar-phyric tuff. Massive quartz-feldspar-(biotite) porphyry forms large bodies at the old packbridge, and similar porphyry occurs abundantly to the east of the Miners Ridge Sandstone. Xenoliths of slate occur in the porphyry in places, and much of it is clearly intrusive. However, there are also large sections showing autobreccia textures and flow banding which may be extrusive, and some varieties with fiamme-like wisps which could be ash-flows. Massive and autobrecciated porphyry forms a series of spectacular waterfalls in the lower part of Diorite Creek.

The top of the western sequence, adjacent to the central belt contact, consists of interbedded quartz-feldspar phyric crystal tuff, vitric tuff, agglomerate, sandstone and slate, with small sills and dykes of altered porphyritic basalt. Some of the tuffs have a splotchy pink and green coloration due to secondary albitisation, and resemble the Comstock Tuff.

The contact between the western and central sequences is abrupt and appears to be faulted where exposed in the King River. To the north of the river there is feldspar porphyry in contact with quartz porphyry in some areas and with the upper tuff-sediment unit of the western sequence in other areas, but it is not clear how much of this apparent irregularity is due to later cross-faulting and how much is primary.

CENTRAL SEQUENCE

The typical rock type of the central sequence is a dense, pink to pale grey, fine-grained rock with rare to abundant small feldspar phenocrysts. Massive porphyry of this type, showing well-developed columnar jointing in a few places, occurs down the precipitous northface of Mt Jukes and also in the western part of the gorge section. The western porphyry mass appears to be continuous with that on Whip Spur. Thin sections of the porphyry commonly show micro-spherulites with a core of clear quartz, and some samples consist almost entirely of graphically intergrown quartz and murky feldspar. Several units of bedded shale, sandstone and tuff occur in the central part of the river section, where most of the porphyries show fiamme-like wisps and shard textures suggestive of ash-flows.

The porphyry is oxidised to a deep reddish-brown colour in the vicinity of the Jukes Proprietary adits, where disseminated and massive copper sulphides occur within a chloritised schistose zone at the contact with the eastern sequence. Similar altered graphic-textured porphyry, with lenses of breccia, forms a prominent brown knob projecting through the eastern sequence at upper Lake Jukes, where bornite-hematite veins have been prospected.

EASTERN SEQUENCE

A complex sequence of mixed quartz-feldspar-phyric volcanics (agglomerate, tuff, lava) and volcaniclastic conglomerate and sandstone occurs on the eastern flanks of Mt Jukes and in the upper section of the King River Gorge. The contact with the central sequence plunges steeply down the north face of Mt Jukes, and is at least partly faulted. However, an apparently non-faulted contact between red feldspar porphyry and a breccia containing fragments of porphyry in a quartz-phyric matrix, is exposed east of the main fault near the Jukes Proprietary adits. The contact suggests that the quartz-phyric sequence overlies the central sequence. At Lake Jukes, the contact between the Adit Knob porphyry and the eastern sequence is faulted in part but on the north-east side is again marked by a quartz-phyric breccia containing abundant fragments of porphyry.

On the eastern flanks of Mt Huxley, an apparently unconformable contact is exposed between chloritised and fractured feldspar-phyric rocks below, and south-dipping volcaniclastic conglomerate and sandstone typical of the eastern sequence above. The bedded volcaniclastic rocks pass conformably and apparently gradationally up into the siliceous Owen Conglomerate on Mt Huxley, and in this area, as in several other areas (*e.g.* Lake Jukes, lower Traveller Creek) it is impossible to separate the eastern sequence from the 'Jukes Conglomerate'. The latter is a locally-occurring volcaniclastic conglomerate or breccia which occurs at the base of the Owen Formation (*e.g.* north face of Mt Jukes). The eastern sequence apparently wedges out against the Owen Conglomerate contact north-east of Mt Huxley.

Well-exposed flow banded and autobrecciated quartz-feldspar-phyric lavas occur within the eastern sequence near Lake Jukes, and agglomerates with abundant clasts of similar porphyry (as well as feldspar porphyry fragments) are common in most areas. Other common rock types include quartz-feldspar-phyric crystal tuff, volcaniclastic pebble-cobble conglomerate rich in quartz- and feldspar-porphyry clasts, and laminated tuffaceous sandstone. Boundaries between units are generally difficult to map.

Minor pyrite-chalcopyrite mineralisation occurs in an unusual chloritised quartz-poor agglomerate at Bean and Thows prospect east of Lake Jukes, and there is minor pyrite mineralisation in an altered quartz-feldspar-phyric volcanic rock at the Jukes Consols prospect on the King River.

THE SOUTH DARWIN PEAK - INTERCOLONIAL SPUR AREA

INTRODUCTION

Three volcanic sequences have been mapped at the southern end of the main Mt Read Volcanics belt in the vicinity of South Darwin Peak (Corbett, 1976*a*). The central and eastern sequences are continuous with those in the Mt Jukes area, as indicated by reconnaissance mapping at Snake Peak and Intercolonial Spur. A western quartz-phyric sequence is present in the Clark Valley, and although it lacks the extensive greywacke of the northern areas, correlation with the western sequence at the King River seems likely. Much further work remains to be done in this area.

CLARK VALLEY SEQUENCE

Quartz-feldspar-phyric volcanic rocks occur extensively on the western and northern sides of the Clark Valley and on Slate Spur. The rocks are mostly massive, strongly cleaved, and difficult to classify. Flow banded and autobrecciated lavas occur in a few areas, and some of the rocks appear to be bedded tuffs. Part of a major slate-siltstone unit, at least 100 m thick, is exposed beneath extensive moraine cover on the western side of the valley, and a smaller slate unit occurs at the contact with the central sequence in the north-eastern corner of the valley. The few dips recorded are mostly steep west or east, and no clear facings are known. A coarse quartz-phyric agglomerate containing abundant slate fragments which occurs near the eastern contact in the upper Clark River possibly indicates west-facing.

The contact with the central sequence is poorly exposed, and its nature is problematical. In the north-eastern corner of the valley, two units of feldspar-phyric rock similar to the central sequence occur within the quartz-phyric sequence about 100 m west of the unexposed contact marked by the slate unit. The contact is faulted in the Clark River in the central part of the valley, but further south is marked by a zone of intense cleavage development and appears to be gradational over about 100 m.

CENTRAL FELDSPAR PORPHYRY SEQUENCE

This sequence consists largely of pink to green, fine-grained, feldspar-phyric rocks which appear to include lavas, ash-flows, agglomerate, ash-fall tuffs, and probable intrusives. It has not been examined in detail by the author except at 'Humpty Dumpty', west of South Darwin Peak. A large body of pink to white, coarse-grained granite, known as the Darwin Granite (Solomon, 1960) intrudes the sequence on the South Darwin Plateau, and a smaller body occurs on the west flank of 'Humpty Dumpty'. Small intrusive bodies of quartz-feldspar porphyry also occur.

The sequence at 'Humpty-Dumpty' is surprisingly complex, and includes various fine-grained feldspar-phyric rocks as well as several lenses of volcaniclastic conglomerate and sandstone. Rocks along the eastern side of the Clark Valley are mainly micro-spherulitic feldspar porphyries. Fine-grained basalt occurs near the western margin of the sequence in the north-eastern corner of the valley.

Massive pink to green feldspar porphyry with lenses of breccia forms the bulk of Mt Darwin and extends onto Intercolonial Spur. Banded ash-fall tuff and agglomerate containing well-preserved volcanic bombs occurs within the sequence in the latter area.

Patchy chloritic alteration, associated with hematite, pyrite and minor copper mineralisation in places, is widespread within the central sequence between South Darwin Peak and Intercolonial Spur, and there are numerous prospects. Magnetite-hematite veins are common in the massive feldspar porphyries and in the granite, and a dyke-like barite body occurs at the southern end of Intercolonial Spur.

EASTERN SEQUENCE

A mixed sequence of volcaniclastic conglomerate, sandstone, breccia, quartz-feldspar-phyric tuff and quartz-feldspar porphyry occurs along the eastern flank of the South Darwin Plateau. The sequence is well exposed near South Darwin and on the access road from Ten Mile Hill. An unconformable contact on the Darwin Granite is clearly exposed north-west of South Darwin Peak, but further north the contact appears to be faulted and the adjacent rocks are highly cleaved. The high proportion of volcaniclastic rocks within the lower part of the sequence has led previous workers to correlate it with the 'Jukes Conglomerate' (*e.g.* Hills, 1914; Bradley, 1954; Solomon, 1960), but an unconformable relationship with the overlying Owen Conglomerate is clearly exposed on the western flanks of South Darwin Peak.

The sequence dips moderately to steeply east and faces east near South Darwin Peak, where the basal beds contain blocks of granite and feldspar porphyry up to a metre long. Clasts of granite, feldspar porphyry, quartz porphyry and hematite occur in higher units. Disoriented cleaved fragments of quartz-feldspar-porphyry, with a penetrative cleavage, have been noted in the sequence in places. Some of the quartz-feldspar-phyric tuffs in the access road section and near South Darwin Peak appear to be ash-flows, and a massive porphyry exposed in the road is either a lava or intrusive. A conglomerate containing clasts of quartzite as well as volcanic types occurs towards the eastern margin of the sequence, which is faulted against the Owen Conglomerate at Ten Mile Hill.

At the East Darwin workings, near Snake Peak, cleaved feldspar-phyric rocks of the central sequence are overlain by, or possibly faulted against, a strongly cleaved sequence of quartz-feldspar-phyric agglomerate and tuff, with some volcaniclastic units. The latter rocks are typical of the eastern sequence elsewhere, and pass up into flow-banded quartz-feldspar-phyric lava followed by tuffs and volcaniclastic rocks. Laminated siltstone and fine sandstone is interbedded with the quartz-phyric volcanics on the lower part of the access track, and higher up with siliceous sandstone and fine conglomerate near the old township of Darwin. This suggests a gradational relationship with the Owen Conglomerate.

A thick sequence of volcaniclastic conglomerate which occurs on the eastern flank of Mt Sorell appears to be a correlate of the eastern sequence. The sequence dips very steeply west and is strongly cleaved. Clast types include quartz porphyry, granite, feldspar porphyry, hematite, quartzite and quartz-mica schist, and the matrix is rich in volcanic quartz. The contact with the Clark Valley sequence is obscured, and the contact with the overlying Owen Conglomerate, although apparently gradational, could be an unconformity (Corbett, 1976*a*).

YOLANDE RIVER - MT LYELL MINES AREA

INTRODUCTION

The area immediately north of Queenstown, around the Mt Lyell Mines and west to the Yolande River (fig. 3), is extremely complex, and severe mapping difficulties are imposed by the extensive alteration of the rocks and the complex tectonic dislocations. Part of the area, mainly west of the East Queen River, was mapped by the author and his wife (E.B. Corbett) in 1971-1972, but this work requires re-checking in the light of the considerable advances in knowledge over the last few years. Mapping done by the Mt Lyell Company geologists and others in the vicinity of the mines is given by Reid (1976). This area has been mapped in detail recently by S.F. Cox as part of a Ph.D. project but this work was unavailable at the time of writing. Much further work is necessary to resolve the many problems still remaining. A complex system of Devonian cross-faults cuts through the area ('Linda Disturbance' of Wade and Solomon, 1958), but although the faults clearly displace the post-Cambrian rocks, their location and effects within the volcanic sequence are difficult to determine.

WESTERN AND CENTRAL SEQUENCES

A belt of rocks comparable with the western sequence is exposed in the vicinity of the Lake Margaret Road, and includes various quartz-phyric agglomerates and crystal tuffs, vitric tuffs and sandstone-shale units. Some of the agglomerate units contain deformed shale clasts and represent large submarine flows. The major quartz-feldspar-biotite porphyry forms a good mapping unit, and the Miners Ridge Sandstone has been identified near the southern dam on the West Queen River. Several analyses from the sequence are given in Appendix B. The sequence appears to be folded about a major anticlinal axis near Davies Hill, and major greywacke=shale units first become prominent west of the Yolande River bridge on the Zeehan Highway. Graded tuff-agglomerate units are interbedded with the west-facing greywacke sequence in this area. Several hornblende-feldspar phyric andesite bodies (Crown Hill andesites of Solomon, 1960) intrude the sequence, and appear to be similar in composition to the Lynch Creek basalts (Appendix B and Figures 4,5,6).

A sequence containing abundant feldspar-phyric ash-flows and bodies of massive, flow-banded or columnar-jointed feldspar porphyry, as well as basic-intermediate rocks, occurs along the East Queen River and is clearly comparable with the central sequence elsewhere. Mapping of individual units within this complex sequence is extremely difficult. Chloritised basic-intermediate dykes are abundant, particularly in the southern part of the mine area. Reid (1976, fig. 2) shows a large area of 'coarse intermediate pyroclastics' west of the mine area, but the extent of intermediate rocks may have been over-estimated because of alteration and weathering. The mine area itself consists of banded feldspar-phyric lavas, ash-flows, agglomerates, and 'rubble-textured' rocks which appear to be intermediate between lavas and ash-flows. A prominently flow-banded lava of rhyodacite composition is exposed near the pumphouse on the Comstock Valley road (Appendix B).

The contact between the two sequences has been mapped by the author in the lower part of the East Queen River, where it is off-set by several cross-faults. Massive feldspar porphyry is in direct contact with quartz-phyric tuff in places, but in other areas the steep contact is marked by a distinctive green basic agglomerate similar to that in Reservoir Creek. The precise location and nature of the contact north of this area has yet to be determined. A large block of quartz-phyric tuff and bedded tuffaceous sandstone-siltstone appears to project into the ash-flow sequence between the East and West Queen Rivers. Typical feldspar-phyric ash-flows are exposed around the northern dam on the West Queen, and similar rocks, together with some massive feldspar porphyry, extend continuously eastwards to the Cape Horn area. Just north of the dam, however, in an area of poor exposure, there appears to be an abrupt change to quartz-phyric crystal-lithic tuffs and non-descript tuffs with scattered outcrops of fine-grained quartzite. A thick sequence of altered andesitic breccias, lavas and tuffs at 'Agglomerate Hill' appears to overlap this contact, which further east corresponds to a major cross-fault in the Comstock Valley. Typical feldspar-phyric ash-flows and lavas are again predominant at Lake Margaret township and up the penstock track to the east, so that it is possible that another roughly east-west contact exists to the north of Crown Hill. Further work is required to evaluate this possible horst structure extending into the ash-flow sequence, but the existence of major cross-faults with considerable vertical displacement in the Comstock Valley area indicates that such a structure would not be unexpected. Alternatively, there may be interfingering of the two sequences in this area, possibly due to outflow from a caldera structure, or some other more complex structural relationship.

COMSTOCK TUFF AND ASSOCIATED ROCKS

The type Comstock Tuff, at the western end of the Comstock Valley, is a brown-weathering quartz-phyric sequence which includes basal shales, laharic breccias, agglomerates, crystal tuffs and volcaniclastic conglomerates. The sequence dips moderately to steeply east, and is conformably overlain by an east-facing volcaniclastic conglomerate-sandstone sequence ('Jukes Formation' of Corbett *et al.*, 1974). At its southwestern margin the sequence conformably overlies a white quartz-phyric tuff or ash-flow, but the relationship of this unit to the poorly-exposed underlying rocks is uncertain. Spotted hornfelsic rocks which appear to have been contact-metamorphosed by the large andesite mass to the north occur close to this white tuff and to the Comstock Tuff, but contacts are not exposed.

On the south side of the cross-fault the Comstock Tuff includes a basal fossiliferous limestone and overlies altered schistose intermediate volcanics which are mineralised at the Comstock open-cut (Jago *et al.*, 1972). The latter rocks appear to be typical of the central sequence. The abundance of volcaniclastic conglomerate in the Comstock Tuff sequence, and its quartz-phyric nature (with some mixing with basic-intermediate detritus), strongly suggests correlation with the eastern sequence in the Jukes-Darwin area.

Typical Comstock-type tuff is also well exposed in a small arcuate area near the Mt Lyell Company mill adjacent to the East Queen River. Here the sequence has a basal, south-facing shale-sandstone unit which rests abruptly on massive intermediate agglomerate to the east and on feldspar-phyric ash-flows to the west. Bedding features are lacking in the underlying rocks except in one area, where discordance with the overlying tuff is suggested. The tuff sequence includes the typical banded pink and green crystal tuffs as well as coarse laharic breccias with blocks up to 4 m long, and laminated pink and green glassy ash. A well-exposed angular unconformity separates the sequence from the overlying siliceous Pioneer Beds correlate.

Volcanic rocks exposed beneath the Owen Conglomerate in the anticlinal core at the eastern end of Mt Lyell provide a link between the Comstock Tuff and the eastern sequence. Some 300 m of volcaniclastic conglomerate and sandstone conformably underlies the Owen Formation, and is conformably underlain by a similar thickness of quartz-phyric tuff, agglomerate and sandstone resembling the Comstock Tuff. Underlying this is a sequence of cleaved quartz-feldspar-phyric volcanics, including flow-banded and autobrecciated lavas similar to those of the eastern sequence at Lake Jukes. This unit is faulted against a north-dipping sequence of volcaniclastic conglomerate and sandstone to the east, near the King River bridge.

MT SEDGWICK - LAKE BEATRICE AREA

INTRODUCTION

The volcanic sequence on the north side of the Comstock Valley between Mt Sedgwick and Lake Beatrice was mapped by the author in 1977 at a scale of 1:15 840. There is moderate outcrop on the higher slopes, but the lower slopes are mostly blanketed by Pleistocene boulder moraine, which in places extends more than 300 m above the present valley level. A number of different rock sequences are present, but most relationships are obscured. The Owen Conglomerate forms a broad, flat-crested anticline across the area, plunging gently north. Permo-Carboniferous tillite is overlain by Jurassic dolerite at the summit of Mt Sedgwick.

SEDIMENTARY SEQUENCE OF LAKE BEATRICE AREA

A sequence of interbedded siliceous granule-pebble conglomerate, quartz sandstone, quartz wacke, grey siltstone and mudstone rests unconformably on Precambrian quartzite, quartz-schist and phyllite at Marble Bluff. The sequence dips moderately west and faces west. Sedimentary structures include large- and small-scale cross-bedding, graded bedding, sole marks, shale clasts and rare bioturbation. Mudstone-rich sequences in which graded bedding predominates appear to alternate with arenite-rich sequences showing cross-bedding. Clasts are predominantly of quartzite and quartz-schist, and a Precambrian derivation is indicated for the bulk of the sequence.

The sequence has an abrupt and probably faulted contact with a volcaniclastic conglomerate sequence to the west. An intrusive quartz-feldspar porphyry body lies along this contact in one area.

CENTRAL FELDSPAR-PHYRIC SEQUENCE

A complex sequence of fine-grained, sericitic, feldspar-phyric rocks, ranging in colour from pale grey to fawn, green, pink or purplish-red, occurs in the central part of the area and also beneath the Owen Conglomerate at the western margin of the area. The rocks include flow-banded lavas, probable ash-flows, 'rubble-textured' rocks, vitric tuffs, agglomerates, and minor grey slate. Most of the rocks are strongly cleaved. Columnar jointing occurs in probable lava in the western area.

A unit of massive to banded, pink to red-weathering albite porphyry forms a prominent knob to the south-east of Mt Sedgwick. The rock is cut by numerous magnetite-hematite veins up to a metre thick, and closely resembles the porphyry outcrops at Mt Darwin and Whip Spur.

QUARTZ-FELDSPAR PORPHYRIES

A thick unit of pink to green quartz-feldspar porphyry forms prominent outcrops along the ridge south-west of Mt Sedgwick. The rock is extensively flow-banded (dips variable but mostly easterly) and also shows autobreccia texture in places. Slate fragments occur within the porphyry in some areas, and there appears to be interbedding with slate at the eastern margin. Contacts with the central sequence appear to be mainly either faulted or intrusive, but a possibly conformable relationship with flow-banded quartz porphyry overlying feldspar-phyric rocks occurs in the north-western part of the area. A small intrusive body of quartz porphyry occurs within the main central sequence in one area.

The porphyries are overlain, possibly unconformably, by a belt of volcaniclastic conglomerate south-east of Mt Sedgwick.

QUARTZ-PHYRIC VOLCANICS AND VOLCANICLASTIC CONGLOMERATES

A poorly exposed sequence of strongly cleaved quartz-feldspar-phyric tuff and agglomerate, with some interbedded volcaniclastic conglomerate, occurs south-east of the large knob of feldspar porphyry. The sequence appears to have an abrupt sub-vertical contact with the massive porphyry to the west, but there is apparent interfingering with feldspar-phyric rocks along the northern margin. The sequence passes east into a less-cleaved sequence of bedded volcaniclastic conglomerate and sandstone. An intrusive body of quartz-feldspar porphyry occurs at the contact.

A sequence of several hundred metres of purple-weathering volcaniclastic conglomerate, up to boulder grade, with intercalated sandstone and rare quartz-feldspar-phyric crystal tuff units, transects the central sequence to the east of Mt Sedgwick. The contact with the overlying Owen Conglomerate is apparently conformable. Clasts in the conglomerate consist mainly of quartz-feldspar porphyry, with a few of quartzite and other volcanic rock types, and the matrix contains abundant volcanic quartz. The sequence is much thinner to the west of Mt Sedgwick, and in places the Owen Conglomerate rests directly on older volcanic rocks.

CORRELATION OF THE MT SEDGWICK UNITS

The central feldspar-phyric sequence corresponds well with that in the Queenstown and Jukes-Darwin areas, and includes some identical rock types. The volcaniclastic conglomerates correspond with those of the eastern sequence in the Jukes-Darwin area, and are clearly the youngest part of the succession. They match those in the upper part of the Comstock Tuff sequence ('Jukes Formation'), and those at the eastern end of Mt Lyell. The quartz-phyric volcanics east of the central belt probably also correlate with the eastern Jukes-Darwin sequence, although the possible interbedding with feldspar-phyric rocks in one area is difficult to explain.

The major quartz-feldspar porphyry unit presents a problem. Some of the rocks appear to be extrusive, and suggest the possibility of a local quartz-phyric phase within the central sequence. Alternatively, and perhaps more likely, the unit may represent a feeder system for the eastern quartz-phyric sequence or a down-faulted block of that sequence. Further information on its relationship to the central sequence is required.

The sedimentary sequence at Lake Beatrice is known to continue northwards for at least 20 km ('Sticht Range sequence' of Corbett *et al.*, 1974). It has no exposed equivalent in the Jukes-Darwin or Mt Lyell areas, where the volcanics-Precambrian contact is buried beneath a syncline of younger rocks. The unconformable contact on the Precambrian, the apparent lack of volcanic detritus, the presence of a quartz-feldspar porphyry intrusive body along its contact with the eastern sequence, and its west-facing nature, all suggest that it is the oldest unit in the area. It is probably equivalent to the western sequence at Queenstown as discussed in the next section.

INTERPRETATION OF THE QUEENSTOWN, JUKES-DARWIN AND MT SEDGWICK SEQUENCES

As is apparent from Figure 3, the feldspar-phyric ash-flows, lavas and intrusives typical of the central sequence at South Queenstown crop out continuously southwards at least to South Darwin Peak, a distance of some 30 km. However, the total present width of the central belt in the Mt Sedgwick area is only about 8 km, and the maximum possible width to the exposed Precambrian margin in the Mt Huxley area is only 12 km. The central belt therefore occupies an elongate north-south structure at least three times longer than it is wide. Recent mapping by the author in the Mt Read-Henty River area (unpublished) and Red Hills area (Corbett, 1975*b*), and work by others in the Rosebery area (see summary by Corbett, Green and Williams, 1977) indicates that a similar belt of ash-flows and lavas extends for at least 25 km between the Henty and Pieman Rivers. At Mt Read this belt has an abrupt north-south contact with a western sequence of interbedded greywacke, shale and quartz-phyric tuff. The width of the central belt in the Red Hills area is about 12 km. Although there is a gap of about 6 km in the mapping between Lake Margaret township and the Henty River area, the close similarity between the sequences and the fact that they lie along strike from one another, strongly suggests that the same elongate structure persists northwards.

The similarity of the central belt to caldera-fill complexes has already been discussed for the South Queenstown area, where it has been suggested that the contact between the western and central sequences represents a caldera-type margin. However, the elongate nature of the central belt suggests the structure must be more in the form of a rift valley than a simple caldera (which should be sub-circular), although the possibility that it represents a linear series of coalesced calderas requires further examination.

Evidence from other areas around Queenstown throws little new light on the nature of the western margin, mainly because of poor exposures and the complicating effects of cross-faults. The contact is abrupt in the King River Gorge area, where it appears to be partly faulted and partly intrusive, and could therefore fit a caldera-margin model. The Clark Valley sequence is considered to be a correlate of the western sequence, on the basis of structural position, lithological similarity, and the presence of abundant cleaved clasts of similar type in the eastern sequence, but too little is known of its contact with the central sequence to draw any conclusions. The complicated contact between the western and central sequences in the area north of Queenstown requires considerably more detailed mapping, but it is known to be abrupt and possibly caldera-like in some areas. If the rocks between Crown Hill and the western end of the Comstock Valley prove to be of western sequence type, then this may be the only area where a possible east-west caldera margin exists.

The eastern margin of the possible rift structure in which the central sequence was deposited is nowhere exposed in the Lyell-Darwin area, but is probably present at Lake Beatrice. The non-volcanic conglomerate-sandstone-siltstone sequence which unconformably overlies the Precambrian in this area represents a marginal marine facies developed near the eastern edge of a basin prior to the major volcanic period. It seems most likely that this sequence is equivalent, in general terms, to the western volcano-sedimentary sequence of the Queenstown area, and was deposited prior to the development of the rift valley structure of the central belt. The extensive marine basin of the western sequence must have had such a margin against the Tyennan Precambrian rocks, since large amounts of metamorphic Precambrian detritus were transported into the basin west of the volcanic belt. The eastern sequence rocks and the overlying Owen Conglomerate might be expected to blanket the eastern margin of the central belt rift valley in most areas, but it appears that later uplift of the Precambrian margin may have exposed the pre-rift sequence in the area between Lake Beatrice and Mt Murchison.

The eastern sequence in the Jukes-Darwin area is clearly younger than the central belt, as indicated by the abundant detritus from that belt (including granite) and is of quite different type. It shows a reversion to the quartz-phyric volcanism of the older western sequence, but the volcanism appears to have been largely swamped by the accumulation of erosional volcaniclastic debris. The unroofing of the Darwin Granite which must have occurred at this time gives some indication of the extent of the erosion, and suggests considerable uplift of at least part of the central belt, reminiscent of the central dome uplifts of resurgent calderas (fig. 11).

The presence of clasts of Precambrian rock types in some of the eastern sequence conglomerates indicates that some detritus was being carried into the rift structure from outside. The apparently gradational contacts between the eastern sequence and the Owen Conglomerate, *e.g.* at Snake Peak, Mt Huxley, eastern Mt Lyell and east of Mt Sedgwick, indicates that in some areas there may have been more or less continuous deposition up to the time when the great influx of siliceous Precambrian detritus blanketed much of the volcanic belt. A similar relationship between a young quartz-phyric volcanic-volcaniclastic sequence and overlying Owen Conglomerate has been mapped in the Newton Creek area, where the siliceous influx is dated as middle Late Cambrian (Corbett, 1975*b*). In a few places, however, it is apparent that the eastern sequence rocks were unconformably overlapped by the Owen Conglomerate, *e.g.* at South Darwin Peak.

The relationship of the type Comstock Tuff to the other volcanic sequences is somewhat uncertain because of the doubt concerning the underlying rocks at Comstock Valley and the lack of an exposed top to the sequence. However, there is good evidence from other areas where the relationship is clearer. In particular, in the Tyndall Range area (Corbett, 1975*b*) typical banded Comstock-type tuff occurs within a quartz-phyric volcanic-volcaniclastic sequence which abruptly overlies andesitic volcanics and feldspar-phyric ash-flows of the central sequence. The quartz-phyric sequence passes upwards conformably into basal Owen Conglomerate, a relationship which matches that of the eastern sequence in the Jukes-Darwin area, and the Comstock-like sequence at the eastern end of Mt Lyell. It seems highly likely, therefore, that the Comstock Tuff in the type area represents the youngest part of the volcanic sequence. Drill holes near the Comstock mine show the tuff and volcaniclastics to be overlain abruptly and probably unconformably by the Pioneer Beds correlate followed by Ordovician limestone (Jago *et al.*, 1972). This is the same situation as exists at the Mt Lyell Company mill area, where the Comstock Tuff abruptly overlies rocks of the central sequence.

We return, then, to the Lynchford tuff sequence, which is virtually identical to the Comstock Tuff and is unconformably overlain by Pioneer Beds correlate. This tuff overlies rocks of the older western sequence with apparent conformity, and at first sight would appear to be part of that sequence. It contains abundant basaltic detritus similar to that of the underlying Lynch Creek basalts. However, as previously mentioned, the Lynch Creek basalt mass is discordant with the greywackes which surround it and may represent a younger (post-rift) volcanic cone, with associated intrusives further east, which has grown through the greywacke sequence. The final explosive basaltic eruptions appear to have mixed with acid detritus to produce the more extensive Lynchford tuff.

PROPOSED EVOLUTION OF THE VOLCANIC SEQUENCE

Recognition of the similarities between the Mt Read Volcanics and rhyolitic caldera complexes allows a simple model to be developed which seems to explain most of the complex relationships and the great variety of rock types in the Queenstown area. The model needs much further testing by detailed field work, but it is encouraging that recent mapping in the Mt Read area, where the sequences are less complex and there is less tectonic disruption, provides even better evidence for the model than that available at Queenstown. The proposed development of the volcanic belt may be considered in terms of three major stages - a pre-rift stage, represented by the western sequence, a rift valley-caldera stage, represented by the central sequence, and a final stage accompanied by considerable erosion, represented by the eastern sequence and its correlates.

THE PRE-RIFT STAGE (WESTERN SEQUENCE)

The oldest sequence represents a thick accumulation of greywacke turbidites, siltstone, mudstone and intercalated volcanics which was deposited in an extensive marine basin (the Dundas Trough of Campana and King, 1963). This basin had a margin against the Precambrian Tyennan region somewhere in the vicinity of the presently exposed Precambrian margin, and was probably oriented roughly north-south. Considerable quantities of Precambrian detritus were fed into the trough, to be mixed with volcanic detritus in many of the greywackes. The oldest volcanic units so far known in the western sequence, the Miners Ridge basalts, are tholeiitic and related to probable ocean-floor basalts in the deeper parts of the Dundas Trough to the north-west. Most of the later volcanic material, however, was quartz-feldspar-phyric and of rhyolite to dacite composition.

The volcanic rocks were probably derived mostly from a line or belt of isolated volcanoes lying roughly along the line of the present central belt sequence, as indicated by the increase in thickness and 'proximality' of the western belt volcanic units as the central belt is approached. Lava flows, possible ash-flows, and intrusive bodies related to these early volcanoes are abundant in some areas (*e.g.* King River Gorge) but elsewhere the volcanic units are mainly submarine tuffs and agglomerates. Access routes for the Precambrian detritus must have existed between the early volcanoes, and there were significant hiatuses in volcanism during which only Precambrian material was deposited (*e.g.* Miners Ridge Sandstone). An increasing input of volcanic material with time might be expected in the western sequence, and the early deposits of that sequence might be largely of Precambrian derivation.

There is no precise evidence as to the age of this early marine sequence in the Queenstown area. However, Blissett (1962, p.40) reports fossils of probable Dundas Group age (Middle to Late Cambrian) from siltstone on the south bank of the Henty River near the Zeehan Highway. This locality is only about 200 m north-west of the mapped area, and is undoubtedly within the western sequence. The fossils include *Chancelloria* sponge spicules, which also occur abundantly in the fossiliferous Que River slate of late Middle Cambrian age (Gee, Jago and Quilty, 1970).

THE RIFT VALLEY - CALDERA STAGE (CENTRAL SEQUENCE)

The thick sequence of distinctive feldspar-phyric rhyolite-dacite ash-flows, lavas, agglomerates, tuffs and intrusives of the central belt appears to have been deposited in an elongate rift-like structure with an abrupt western contact against the western sequence. The flows appear to have been ponded or contained within this structure and not to have overlapped it, at least in the areas where the contact has been precisely located. There may have been some overlap or outflow in the Crown Hill area. The regional extent of the ponding structure suggests that it may not have developed solely as a response to magma depletion, as is the case with typical collapse calderas, but may have been partly induced by regional tectonic distension along a north-south zone.

That the rift structure developed after deposition of the western sequence, and not before it, is indicated by: (1) the lack of appearance of typical western sequence rocks overlying the central belt anywhere;

(2) the lack of evidence for an extensive shoreline facies against the central belt on the western side, as might be expected if it were already in existence when the western sequence was being deposited (local shorelines against the isolated volcanoes might be expected); (3) the abundance of Precambrian detritus including quartz-mica-schist, within the western sequence, indicating easy access of transporting currents to the metamorphic Precambrian rocks to the east. Such easy access is difficult to explain if a large belt of dominantly subaerial volcanics stood between the trough and the Precambrian source area. It is likely, however, that contemporaneous deposition occurred in the deeper parts of the trough during filling of the rift valley, and there may be evidence of a change in depositional character or source area within the Dundas Group corresponding to this stage. Some isolated volcanoes outside the rift may have continued to erupt during this stage.

Precisely how much of the central belt is subaerial and how much possibly subaqueous or submarine is difficult to evaluate. The preponderance of ash-flows, lavas and coarse pyroclastics suggests that the great bulk of the sequence is subaerial, and it is difficult to envisage such a sequence forming under any significant depth of seawater. Although welded ash-flows are known to have formed locally under shallow marine conditions (*e.g.* Francis and Howells, 1973), the large sequences of ash-flows and lavas described in the literature appear to be all subaerial. The apparent absence from the central sequence of the graded greywackes which typify the western sequence, the paucity of sedimentary rocks generally, and the apparent absence of Precambrian detritus, all indicate a major change of depositional environment compatible with an absence of open marine conditions. The caldera analogy suggests that regional doming may have occurred prior to rift formation, and that this may have caused at least a temporary retreat of the sea from the area. However, the presence of marine acritarchs from at least one shale unit within the central belt indicates that marine conditions prevailed at least locally, and this important question requires further assessment. The large masses of feldspar porphyry which dominate the central sequence in some areas appear to be complex intrusive-extrusive bodies, probably including domes, plugs and ring-dyke complexes, which could presumably have developed under either subaerial or subaqueous conditions.

Basaltic and andesitic volcanism accompanied the eruption of the more acid pyroclastics and flows within the rift structure, at least in the Queenstown area. There is little evidence as yet to indicate where the bulk of the andesitic rocks occur within the complex central sequence, although the common spatial association of such rocks with the Comstock Tuff suggests at least some were relatively late in the cycle. Large andesite intrusives occur in both the central and western sequences, and smaller dykes are very abundant in parts of the central belt. If the Lynch Creek basalts, which are compositionally related to the andesite, are a late-stage eruptive sequence as suggested, then some andesite-related volcanism occurred immediately prior to and contemporaneous with the Comstock Tuff eruptions.

The intrusion of the Darwin Granite possibly represents one of the final phases of the main rift-filling stage. Hematite-magnetite veins in the granite are similar to those in the adjacent feldspar porphyries, and suggest that much of the localised mineralisation and alteration which affects the central Jukes-Darwin sequence may have occurred at this time. Hematite fragments are common in the overlying eastern sequence. Virtually all the known mineralisation in the area lies either within the central belt or at its contact with the eastern sequence. In the Mt Lyell area the mineralisation also appears to be restricted to the central belt, with some suggestion of concentration near the base of the overlying sequence. The massive sulphide deposit at Comstock (Reid, 1976) lies immediately beneath the base of the Comstock Tuff, and is closely associated with pipe-like chert bodies which may represent geyser vents. The Great Lyell Fault, which marks the Owen Conglomerate contact at the Mt Lyell mines, may represent the contact between the central and eastern sequences (Corbett, 1975*a*). This apparent association between central belt mineralisation and the eastern sequence contact may reflect a concentration along intra-rift faults, reminiscent of the mineralised central graben structures of some calderas (*e.g.* Steven and Ratté, 1965).

THE POST-RIFT OR LATE-RIFT VOLCANIC AND EROSIONAL STAGE (EASTERN SEQUENCE)

The eastern volcanic-volcaniclastic sequence, which is best developed in the Jukes-Darwin area, was deposited after the main rift had developed and been partially filled and uplifted. It consists largely of volcaniclastic detritus derived from weathering of the central belt and other rocks, but also includes major volcanic units in some areas. The accompanying volcanism was mostly quartz-feldspar phyric, and apparently similar to that of the pre-rift sequence. The sequence has an apparently linear distribution in the Jukes-Darwin area, where it appears to have been deposited in a partly fault-bounded graben or trough abutting an uplifted ridge of central belt rocks to the west. The consequent erosion unroofed the Darwin Granite and may, incidentally, have removed much of the mineralisation.

In the Mt Lyell area, deposition of the Comstock Tuff in the late Middle or early Late Cambrian appears to have ended a hiatus in volcanism during which at least some of the mineralisation occurred (Green, 1971). The marine bioclastic limestone at the base of the Comstock Tuff probably accumulated near a shoreline adjacent to an 'edifice' of central belt volcanics, and indicates that at least this part of the rift structure was open to the sea by this stage. It is possible that the Mt Lyell area represents a depressed or subsided part of the rift, where the mineralised sequences were largely preserved, as opposed to the more uplifted and eroded areas to the north and south. Deposition of the Comstock Tuff, probably under shallow marine conditions, spread across the central belt in the Lyell area, and appears to have mixed with local basaltic-andesitic eruptions to fill depressions in the western sequence (*e.g.* the Lynchford tuff) as well.

Volcanism must have declined during the early part of the Late Cambrian, when deposition was mainly in the form of volcaniclastic conglomerate and sandstone. This phase appears to have culminated in the middle Late Cambrian with the influx of huge quantities of siliceous gravel derived from the uplifted Precambrian rocks to the east, to form the Owen Conglomerate. Most of this deposition was on large alluvial fans or in shallow marine environments at their seaward margins, but at least one basin was deep enough to be filled with a proximal flysch sequence (Corbett, 1975*b*). Deposition of much of the conglomerate was in a major graben structure (Campana and King, 1963) with the Great Lyell Fault forming its western margin from Queenstown northwards (Corbett *et al.*, 1974). This margin lies within the central belt rift valley, and may correspond with an intra-rift structure associated with the Comstock Tuff and correlates.

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APPENDIX A

Whole-rock chemical analyses, South Queenstown area.

Sample locations are shown on Figure 2.

Sample:	C1	C2	C3	C4	C5	C6	C7
				%			
SiO_2	47.8	49.3	48.2	48.0	78.5	76.7	67.2
Al_2O_3	15.1	14.3	13.6	13.7	11.7	13.5	14.3
Fe_2O_3	3.6	3.3	6.2	3.3	0.23	0.47	0.76
FeO	5.4	8.5	9.1	7.4	0.89	0.63	4.0
MgO	10.7	9.8	5.7	7.5	0.39	0.49	2.1
CaO	8.7	4.1	4.2	12.1	0.00	0.07	0.41
Na_2O	3.4	3.8	5.2	3.2	4.0	0.51	3.7
K_2O	0.85	1.1	0.32	0.13	2.7	4.1	3.8
TiO_2	0.49	0.49	2.44	1.2	0.17	0.33	0.63
P_2O_5	0.03	0.05	0.26	0.12	0.01	0.04	0.11
MnO	0.19	0.22	0.26	0.20	0.00	0.00	0.03
H_2O+	4.2	4.4	3.3	2.6	1.0	2.2	2.9
H_2O-	0.21	0.35	0.22	0.34	0.20	0.40	0.40
CO_2	0.03	0.05	0.00	0.05	0.01	0.00	0.01
SO_3	0.01	0.02	0.19	0.21	0.03	0.01	0.02
Traces						0.11	0.20
Total	100.71	99.78	99.19	100.05	99.83	99.56	100.6
				ppm			
Ba	237	430	136	<26	665	645	1280
Co	58	52	39	40	<11	<11	<11
Cr	376	21	26	371	<10	<10	75
Cu	132	137	716	87	7	5	9
Nb	<5	<5	8		10	13	13
Ni	182	52	42	90	4	6	25
Pb	<6	<6	<6	7	<6	15	<6
Rb	36	37	8	<3	87	186	100
Sc	33	41	45	4	3	13	
Sr	356	60	33	290	53	<3	82
V	253	279	814	328	10	<4	105
Y	18	18	48	31	29	29	26
Zn	54	96	171	110	<5	7	43
Zr	19	19	132	51	135	223	270

Chemical analyses, South Queenstown area (continued)

Sample:	C8	C9	C10	C11	C12	C13	C14
SiO_2	54.8	54.2	51.4	53.0	59.5	56.9	58.4
Al_2O_3	15.2	16.7	14.6	17.5	13.9	15.2	14.7
Fe_2O_3	1.8	0.90	1.7	1.2	3.2	3.1	2.4
FeO	6.0	6.6	6.8	7.1	4.6	6.1	5.6
MgO	6.0	4.8	5.7	4.9	3.7	4.4	4.5
CaO	5.5	5.7	8.1	5.0	4.3	3.6	3.5
Na_2O	3.2	3.8	2.4	4.2	6.0	4.8	5.3
K_2O	2.5	1.6	2.7	2.3	1.4	1.8	1.1
TiO_2	0.45	0.52	0.44	0.55	0.8	0.99	0.80
P_2O_5	0.27	0.23	0.29	0.34	0.16	0.15	0.19
MnO	0.14	0.16	0.13	0.18	0.15	0.22	0.19
H_2O+	3.4	3.7	3.9	3.6	1.80	2.7	2.9
H_2O-	0.33	0.37	0.36	0.26	0.32	0.25	0.27
CO_2	0.11	0.17	1.9	0.04	0.80	0.08	0.03
SO_3	0.03	0.04	0.06	0.16	0.30	0.21	0.21
Traces							
Total	99.83	99.49	99.48	100.33	99.93	100.50	100.09
Ba	1650	825	1500	1740	270	549	660
Co	27	22	37	26	22	18	23
Cr	152	85	74	74	142	25	50
Cu	105	109	134	125	14	10	18
Nb	<5	9	<5	6		6	9
Ni	57	42	47	39	19	11	16
Pb	<6	<6	11	7	13	<6	6
Rb	34	35	58	45	36	48	29
Sc	21	19	23	26		28	25
Sr	636	372	272	516	427	267	265
V	227	217	257	300	222	229	201
Y	24	20	29	25	23	20	21
Zn	80	76	67	87	79	66	58
Zr	137	114	97	130	76	151	164

Chemical analyses, South Queenstown area (continued)

Sample:	C15	C16	C17	C18	C19	C20	C21
				%			
SiO_2	52.5	56.7	56.6	66.4	63.8	72.0	51.2
Al_2O_3	16.4	14.1	20.3	14.7	15.0	13.20	18.3
Fe_2O_3	2.2	1.7	1.5	1.5	1.0	0.49	2.8
FeO	7.9	5.3	6.7	3.8	4.8	3.2	6.8
MgO	6.1	6.6	1.4	2.2	1.6	0.96	5.2
CaO	2.1	4.0	0.35	0.23	1.5	0.4	1.1
Na_2O	4.8	2.6	3.7	3.5	5.8	5.6	3.7
K_2O	2.3	3.8	2.6	3.6	1.4	0.88	4.4
TiO_2	0.82	0.53	0.70	0.37	0.66	0.53	0.66
P_2O_5	0.17	0.21	0.21	0.08	0.16	0.14	0.35
MnO	0.26	0.18	0.09	0.08	0.13	0.04	0.09
H_2O+	4.2	4.4	4.5	2.9	2.7	1.30	4.4
H_2O-	0.38	0.60	0.51	0.37	0.25	0.26	0.45
CO_2	0.34	0.03	0.00	0.00	0.63	0.00	0.01
SO_3	0.06	0.03	0.02	0.04	0.29	0.04	0.02
Traces			0.13	0.22	0.12		0.59
Total	100.53	100.82	99.3	100.0	99.8	99.04	100.1
				ppm			
Ba	1240	508	469	1430	444	210	4770
Co	39	23	29	<11	<11	<5	37
Cr	40	<10	<10	<10	<10	151	17
Cu	83	38	18	<4	<4	<5	32
Nb	6	<5	<5	13	<5		6
Ni	22	6	15	9	10	15	32
Pb	<6	160	14	7	<6	24	<6
Rb	49	117	99	94	38	19	92
Sc	28	13	20	9	15		23
Sr	195	49	96	67	193	139	347
V	297	144	250	8	61	18	286
Y	22	38	41	39	33	37	22
Zn	108	254	83	244	107	132	65
Zr	178	140	106	320	255	290	162

Chemical analyses, South Queenstown area (concluded)

Sample:	C22	C23	C24	C25	C26	C27	C28
SiO_2	66.6	69.7	74.5	56.6	56.6	58.6	48.5
Al_2O_3	13.7	13.0	12.2	13.5	14.3	13.1	18.5
Fe_2O_3	2.0	1.2	1.0	1.9	1.9	2.1	2.4
FeO	2.5	2.1	1.9	4.9	5.4	4.8	7.6
MgO	1.8	0.78	0.47	5.6	6.9	5.0	8.0
CaO	1.4	2.1	0.00	5.7	3.9	6.0	0.33
Na_2O	4.3	3.6	2.8	3.3	3.4	3.3	2.1
K_2O	4.0	3.4	3.6	3.8	3.6	3.3	0.62
TiO_2	0.41	0.39	0.22	0.52	0.57	0.52	0.85
P_2O_5	0.08	0.06	0.04	0.21	0.26	0.24	0.68
MnO	0.09	0.06	0.07	0.04	0.15	0.11	0.08
H_2O+	1.9	1.5	2.0	2.4	3.0	2.2	7.7
H_2O-	0.16	0.42	0.29	0.28	0.34	0.19	1.6
CO_2	0.60	1.7	0.40	1.7	0.04	0.03	0.01
SO_3	0.02	0.34	0.01	0.02	0.02	0.02	0.09
Traces	0.19				0.24	0.23	0.16
Total	99.8	100.35	99.50	100.19	100.6	99.7	99.2
Ba	1060	1180	596	1270	1360	1160	298
Co	17	9	<11	34	21	24	35
Cr	26	129	<10	161	155	188	124
Cu	25	<5	<4	56	53	31	46
Nb	9		11	<5	<5	<5	12
Ni	14	15	6	44	49	42	69
Pb	<6	7	<6	20	<6	<6	54
Rb	92	88	102	94	96	88	20
Sc	6		8	22	23	19	31
Sr	126	98	29	285	235	286	105
V	53	22	5	184	194	160	284
Y	25	36	39	28	25	23	24
Zn	167	85	20	47	67	47	215
Zr	232	263	279	152	165	196	244

Notes to accompany Appendix A

All analyses by Department of Mines, Launceston (1978-1979)
Locations of all samples shown on Figure 2.

C1-C4	Miners Ridge basalts
C 5	Vitric tuff, western sequence, near Reservoir Creek
C 6	Vitric tuff, western sequence, west bank of lower dam on Reservoir Creek
C 7	Dacite intrusive, east of Miners Ridge
C 8-C11	Lynch Creek basalts
C12	Lynchford tuff on Huxley Track
C13	Lynchford tuff on Huxley Track, near base of sequence
C14	Lynchford tuff, road cutting near golf clubhouse
C15	Basaltic agglomerate, east bank of Reservoir Creek
C16	Altered intermediate dyke, east of Reservoir andesite body
C17	Altered lava or dyke, lower Conglomerate Creek
C18	Flow-banded feldspar-phyric lava, Waterfall Gully
C19	Graded agglomerate unit, Whip Spur agglomerate sequence
C20	Fine glassy ash between agglomerate units, Whip Spur sequence
C21	Basic dyke in Whip Spur agglomerate sequence
C22	Massive pink feldspar porphyry, ridge south of Whip Spur
C23	Pale feldspar porphyry, lower Whip Spur
C24	Pink feldspar porphyry near bridge over Conglomerate Creek
C25	Reservoir andesite body, old track north of dam
C26	Reservoir andesite body, where old track crosses creek
C27	Little Owen andesite body, southern end of Little Owen Spur
C28	Weathered andesite body, north-west flank of Little Owen Spur

APPENDIX B

Whole-rock chemical analyses, areas north of Queenstown

Sample	B1	B2	B3	B4	B5	B6	B7
				%			
SiO_2	72.19	71.85	68.33	71.1	65.0	58.5	65.5
Al_2O_3	12.82	13.25	13.26	13.0	12.3	14.4	13.1
Fe_2O_3				1.1		1.8	1.4
FeO	3.78	3.75	4.08	2.3	5.34	5.3	3.5
MgO	1.78	1.60	1.15	1.3	4.05	3.4	3.0
CaO	0.22	0.22	2.91	0.28	3.72	4.3	2.0
Na_2O	0.00	0.00	2.81	3.5	3.05	4.5	3.0
K_2O	3.06	2.96	4.51	4.2	3.59	2.5	4.1
TiO_2	0.67	0.68	0.61	0.45	0.60	0.50	0.58
P_2O_5	0.25	0.28	0.34	0.07	0.65	0.28	0.11
MnO	0.12	0.12	0.15	0.05	0.20	0.26	0.20
H_2O+				2.4		2.7	2.6
H_2O-	5.9*	5.9*	3.2*	0.33	1.6*	0.22	0.23
CO_2				0.03		0.04	0.04
SO_3				0.02		0.04	0.15
Traces				0.23		0.33	0.41
Total	100.79	100.61	101.35	100.4	100.1	99.1	99.9
				ppm			
Ba	830	860	1030	1550	1460	1500	1900
Co				<11		24	16
Cr				22		20	98
Cu				<4		76	<4
Nb				16		6	10
Ni				16		19	37
Pb				<6		93	513
Rb	180	170	210	128	120	63	156
Sc				9		20	11
Sr	35	35	86	87	390	696	225
V				52		256	99
Y	40	39	46	30	33	23	32
Zn				40		317	746
Zr	160	160	280	302	250	147	257

* Loss on ignition

Chemical analyses, areas north of Queenstown (concluded)

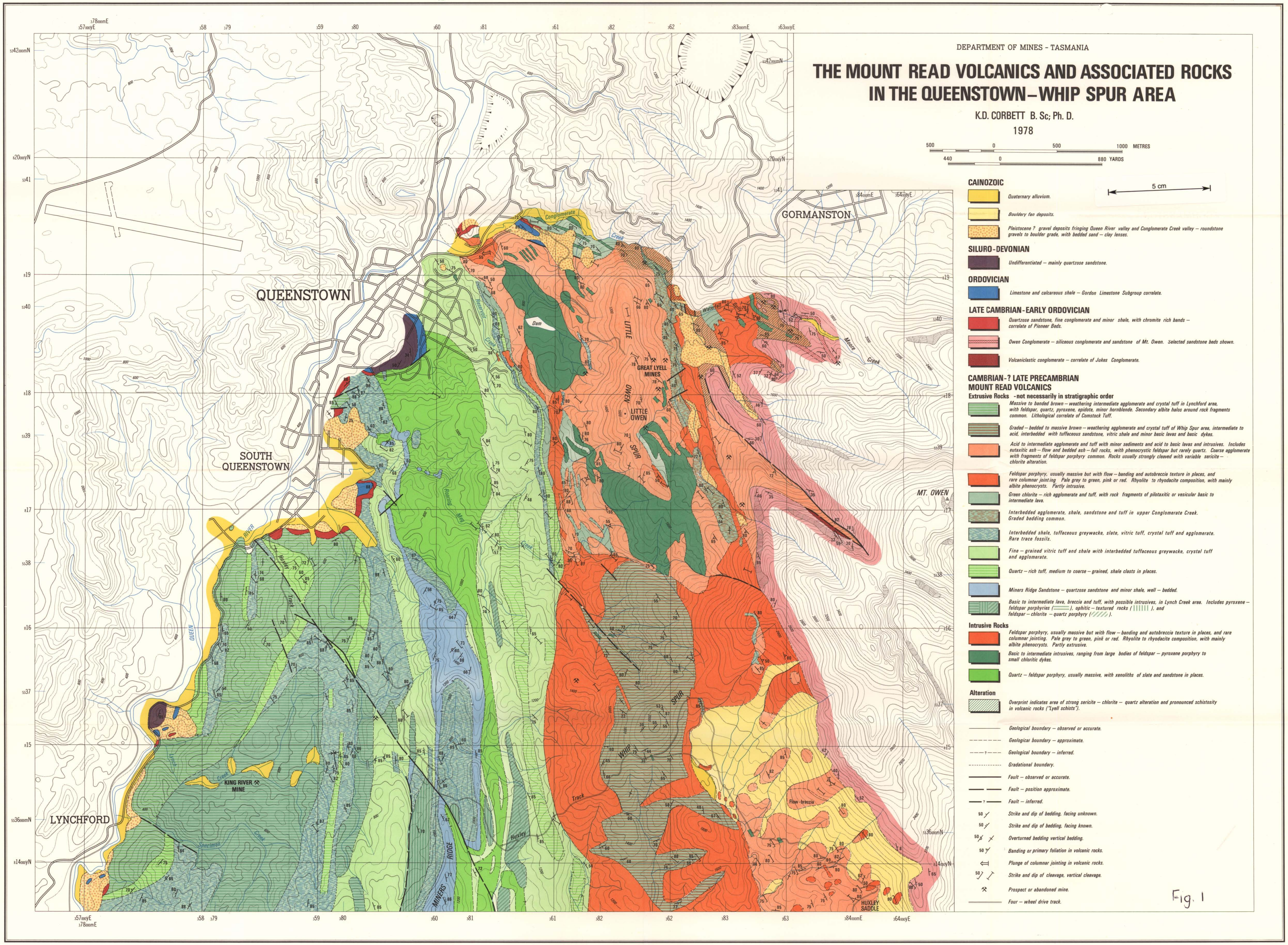
Sample	B8	B9	B10	B11	B12	B13	B14	B15
				%				
SiO_2	66.12	57.0	56.12	59.5	55.3	57.31	71.91	71.56
Al_2O_3	14.19	14.9	16.9	13.0	16.0	15.13	14.73	13.17
Fe_2O_3	5.87	1.1	7.76	2.2	3.1	8.27	3.49	4.85
FeO		6.1		5.1	5.4			
MgO	3.36	5.4	4.49	5.5	4.2	4.63	0.97	0.83
CaO	1.74	5.7	6.40	6.3	3.6	5.57	0.33	1.26
Na_2O	2.84	2.9	2.25	3.4	5.0	5.29	2.94	2.9
K_2O	4.17	2.0	2.42	0.94	2.4	0.55	2.83	2.39
TiO_2	0.71	0.52	0.67	0.51	0.54	0.70	0.51	0.47
P_2O_5	0.41	0.33	0.61	0.35	0.19	0.46	0.30	0.33
MnO	0.30	0.12	0.02	0.11	0.14	0.23	0.13	0.31
H_2O+		3.4		2.8	2.6			
H_2O-	2.2*	0.22	2.3*	0.20	0.21	2.1*	2.0*	3.3*
CO_2		0.01		0.01	0.12			
SO_3		0.69		0.02	0.11			
Traces		0.38		0.21	0.28			
Total	101.9	100.8	99.84	100.2	99.2	100.24	100.14	101.37
				ppm				
Ba	1440	2230	1820	828	1670	380	860	700
Co		25		19	22			
Cr		147		174	36			
Cu		65		65	7			
Nb		7		9	6			
Ni		48		38	19			
Pb		<6		<6	8			
Rb	210	61	140	32	50	4	160	110
Sc		17		17	13			
Sr	190	661	750	496	519	210	76	72
V		203		165	150			
Y	57	24	31	21	20	34	44	65
Zn		87		52	93			
Zr	260	197	200	214	181	210	320	280

* Loss on ignition

Notes to accompany Appendix B

All analyses by Department of Mines, Launceston. B1-B5, B8, B10, B13-B15 in 1972, others 1978.

B 1	Black shale, western sequence, road metal quarry beside Lake Margaret Road [CN795460]
B 2	Vitric tuff, western sequence, power pylon just west of Lake Margaret Road [CN794448]
B 3	Quartz-feldspar-biotite porphyry, southern dam on West Queen River [CN802434]
B 4	Quartz-feldspar-biotite porphyry, near pipeline below Lake Margaret township [CN786478]
B 5	Quartz-feldspar-pyroxene porphyry beneath powerline east of Lake Margaret Road [CN793475]
B 6	Andesite body, horse paddock beside Lake Margaret Road [CN791438]
B 7, B 8	Porphyritic dacite, old quarry south of Zeehan Highway, Howard Plains area [CN778445]
B 9	Crown Hill andesite body, beneath power pylon [CN795461]
B10	Crown Hill andesite body, old house site [CN795462]
B11	Hornblende andesite beside Bradshaws Road, Henty River area [CN802557]
B12	Hornblende andesite, Tyndall Drill Hole 1, Henty River area [CN810556]
B13	Intermediate agglomerate, 'Agglomerate Hill', north west of Cape Horn [CN812461]
B14	Ash-flow tuff, spillway below northern dam on West Queen River [CN802454]
B15	Flow-banded feldspar-phyric lava, near pump house on Comstock Valley Road [CN817445]

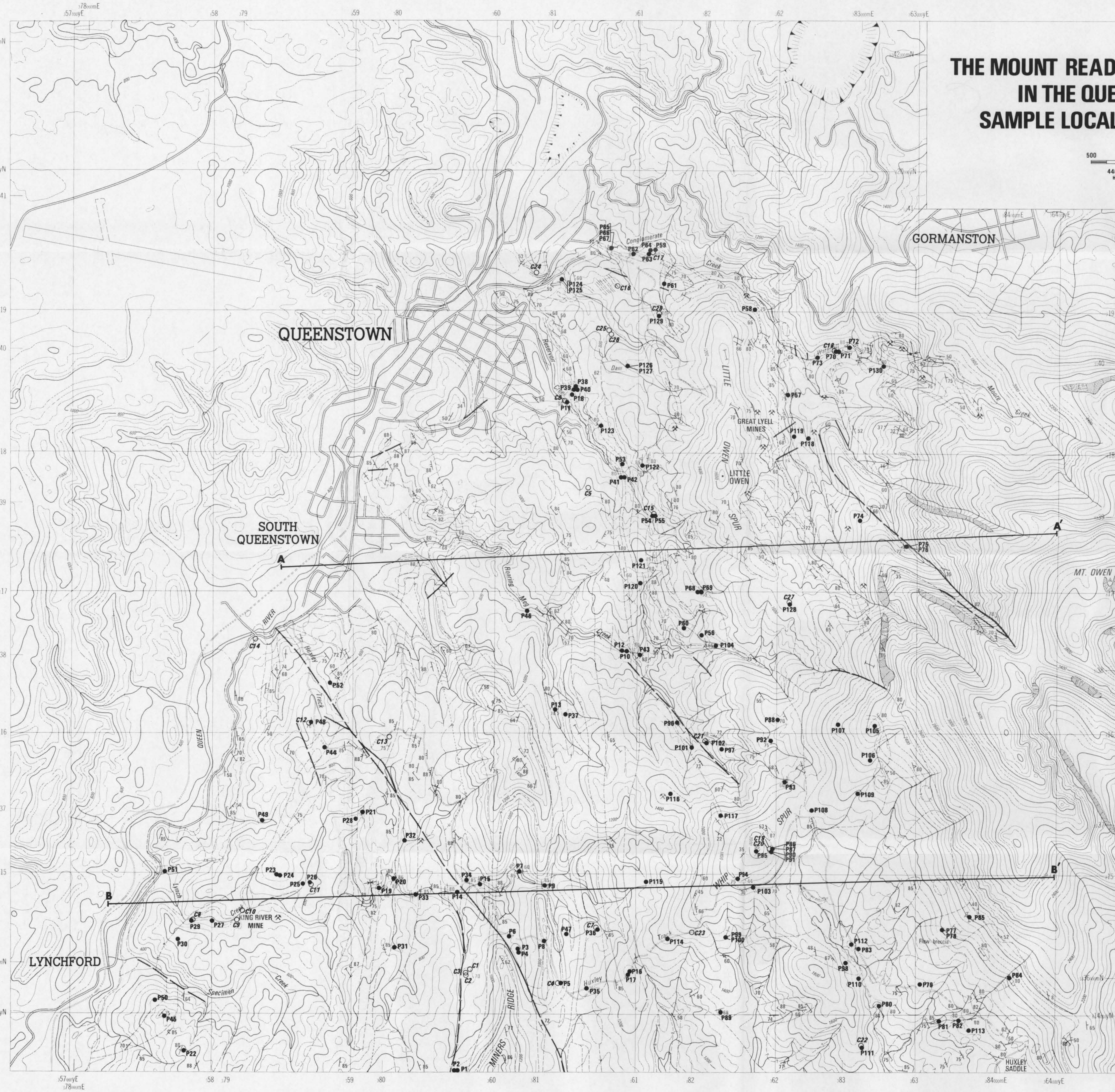

DEPARTMENT OF MINES - TASMANIA
THE MOUNT READ VOLCANICS AND ASSOCIATED ROCKS IN THE QUEENSTOWN-WHIP SPUR AREA
K.D. CORBETT B. Sc; Ph. D.
1978
500 0 500 1000 METRES
440 0 880 YARDS
5 cm
QUEENSTOWN
SOUTH QUEENSTOWN
GORMANSTON
LYNCHFORD
GREAT LYELL MINES
LITTLE OWEN
KING RIVER MINE
MT. OWEN
HUXLEY SADDLE
LITTLE OWEN SPUR
WHIP SPUR
MINERS RIDGE
CAINOZOIC
Quaternary alluvium.
Bouldery fan deposits.
Pleistocene ? gravel deposits fringing Queen River valley and Conglomerate Creek valley – roundstone gravels to boulder grade, with bedded sand – clay lenses.
SILURO-DEVONIAN
Undifferentiated – mainly quartzose sandstone.
ORDOVICIAN
Limestone and calcareous shale – Gordon Limestone Subgroup correlate.
LATE CAMBRIAN-EARLY ORDOVICIAN
Quartzose sandstone, fine conglomerate and minor shale, with chromite rich bands – correlate of Pioneer Beds.
Owen Conglomerate – siliceous conglomerate and sandstone of Mt. Owen. Selected sandstone beds shown.
Volcaniclastic conglomerate – correlate of Jukes Conglomerate.
CAMBRIAN-? LATE PRECAMBRIAN
MOUNT READ VOLCANICS
Extrusive Rocks -not necessarily in stratigraphic order
Massive to banded brown – weathering intermediate agglomerate and crystal tuff in Lynchford area, with feldspar, quartz, pyroxene, epidote, minor hornblende. Secondary albite halos around rock fragments common. Lithological correlate of Comstock Tuff.
Graded – bedded to massive brown – weathering agglomerate and crystal tuff of Whip Spur area, intermediate to acid, interbedded with tuffaceous sandstone, vitric shale and minor basic lavas and basic dykes.
Acid to intermediate agglomerate and tuff with minor sediments and acid to basic lavas and intrusives. Includes eutaxitic ash – flow and bedded ash – fall rocks, with phenocrystic feldspar but rarely quartz. Coarse agglomerate with fragments of feldspar porphyry common. Rocks usually strongly cleaved with variable sericite – chlorite alteration.
Feldspar porphyry, usually massive but with flow – banding and autobreccia texture in places, and rare columnar jointing Pale grey to green, pink or red. Rhyolite to rhyodacite composition, with mainly albite phenocrysts. Partly intrusive.
Green chlorite – rich agglomerate and tuff, with rock fragments of pilotaxitic or vesicular basic to intermediate lava.
Interbedded agglomerate, shale, sandstone and tuff in upper Conglomerate Creek. Graded bedding common.
Interbedded shale, tuffaceous greywacke, slate, vitric tuff, crystal tuff and agglomerate. Rare trace fossils.
Fine – grained vitric tuff and shale with interbedded tuffaceous greywacke, crystal tuff and agglomerate.
Quartz – rich tuff, medium to coarse – grained, shale clasts in places.
Miners Ridge Sandstone – quartzose sandstone and minor shale, well – bedded.
Basic to intermediate lava, breccia and tuff, with possible intrusives, in Lynch Creek area. Includes pyroxene – feldspar porphyries ( ), ophitic – textured rocks ( ), and feldspar – chlorite – quartz porphyry ( ).
Intrusive Rocks
Feldspar porphyry, usually massive but with flow – banding and autobreccia texture in places, and rare columnar jointing. Pale grey to green, pink or red. Rhyolite to rhyodacite composition, with mainly albite phenocrysts. Partly extrusive.
Basic to intermediate intrusives, ranging from large bodies of feldspar – pyroxene porphyry to small chloritic dykes.
Quartz – feldspar porphyry, usually massive, with xenoliths of slate and sandstone in places.
Alteration
Overprint indicates area of strong sericite – chlorite – quartz alteration and pronounced schistosity in volcanic rocks ("Lyell schists").
Geological boundary – observed or accurate.
Geological boundary – approximate.
Geological boundary – inferred.
Gradational boundary.
Fault – observed or accurate.
Fault – position approximate.
Fault – inferred.
Strike and dip of bedding, facing unknown.
Strike and dip of bedding, facing known.
Overturned bedding vertical bedding.
Banding or primary foliation in volcanic rocks.
Plunge of columnar jointing in volcanic rocks.
Strike and dip of cleavage, vertical cleavage.
Prospect or abandoned mine.
Four – wheel drive track.
Fig. 1

DEPARTMENT OF MINES - TASMANIA

THE MOUNT READ VOLCANICS AND ASSOCIATED ROCKS IN THE QUEENSTOWN–WHIP SPUR AREA SAMPLE LOCALITY MAP AND SAMPLE NUMBERS

500 0 500 1000 METRES

440 0 880 YARDS



PETROLOGICAL SAMPLES

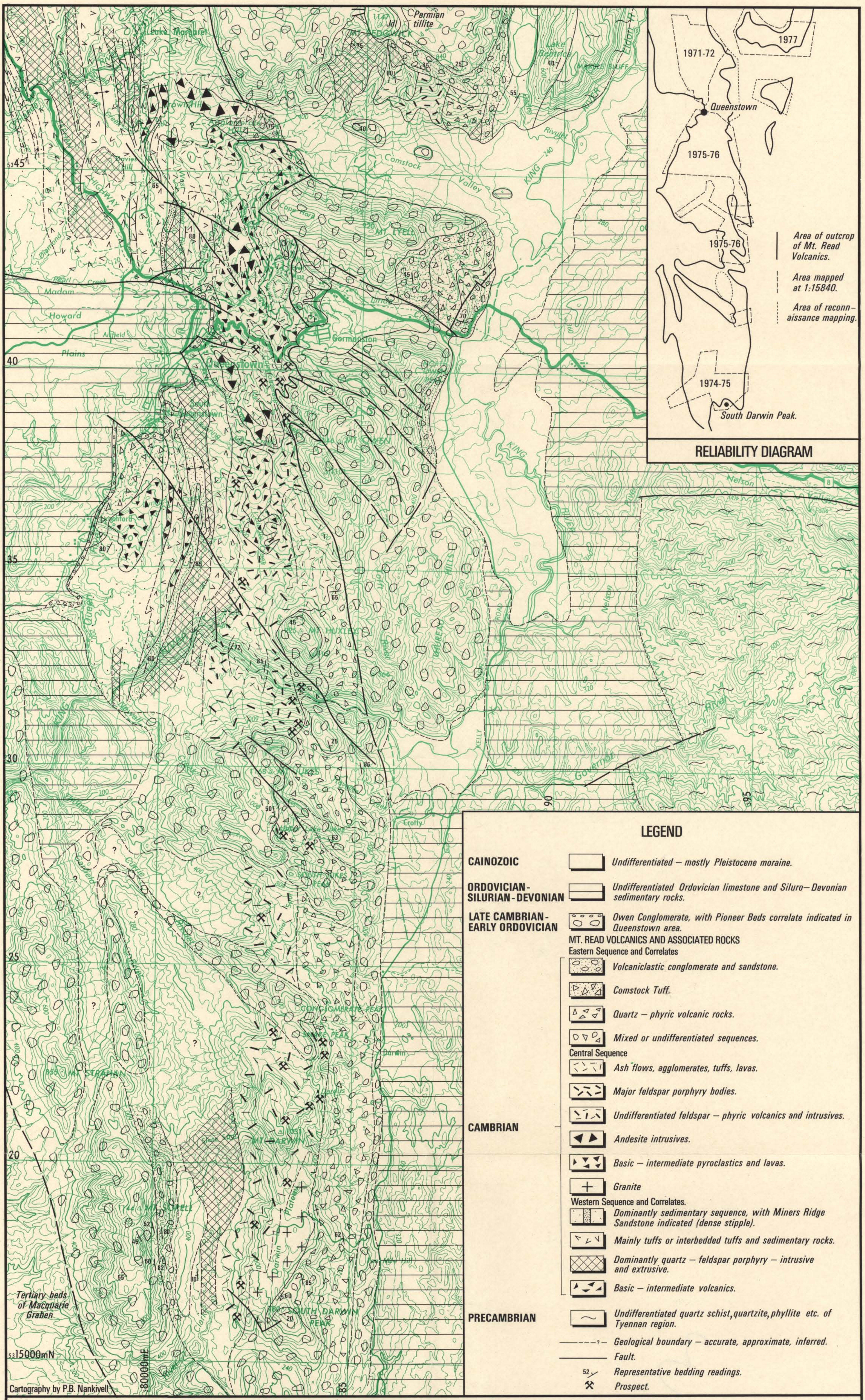
Text ref. in Bull. No. 58	Mines Dept. Cat. No.	Field No.	Text ref. in Bull. No. 58	Mines Dept. Cat. No.	Field No.
P1	77-535	WS5	P66	76-728	W71
P2	77-534	WS4	P67	76-729	W72
P3	76-725	W64	P68	75-556	RM23
P4	76-739	W65	P69	75-557	RM24
P5	76-721	W59	P70	75-870	RM51
P6	76-738	W67	P71	75-871	RM52
P7	76-723	W62	P72	75-872	RM53
P8	76-722	W60	P73	75-869	RM50
P9	76-716	W61	P74	76-388	LO1
P10	75-545	RM12	P75	76-390	LO3
P11	75-544	RM11	P76	76-391	LO4
P12	76-392	LO5	P77	76-419	LO31
P13	75-538	RM4	P78	76-420	LO32
P14	76-395	LO8	P79	76-423	LO35
P15	76-724	W63	P80	76-437	LO49
P16	76-705	W18	P81	76-433	LO45
P17	77-543	WS13	P82	76-434	LO46
P18	75-542	RM9	P83	76-421	LO33
P19	76-398	LO11	P84	76-425	LO37
P20	76-397	LO10	P85	76-418	LO30
P21	76-712	W29	P86	72-299	W11A
P22	77-216	LO65	P87	72-169	W12A
P23	76-741	W27	P88	77-537	WS7
P24	76-711	W28	P89	77-531	WS1
P25	77-215	LO61	P90	77-541	WS11
P26	77-212	LO60	P91	77-542	WS12
P27	77-209	LO59	P92	77-538	WS8
P28	77-205	LO53	P93	77-849	WS22
P29	77-206	LO58	P94	77-845	WS17
P30	77-213	LO64	P95	77-540	WS10
P31	76-400	LO13	P96	75-541	RM8
P32	76-399	LO12	P97	77-848	WS21
P33	76-396	LO9	P98	76-439	LO51
P34	75-868	RM49	P99	77-532	W52
P35	76-706	W19	P100	77-533	WS3
P36	76-718	W55	P101	77-846	WS19
P37	75-537	RM3	P102	77-847	WS20
P38	75-735	RM36	P103	77-844	WS16
P39	75-736	RM37	P104	78-841	W49
P40	75-737	RM38	P105	75-567	W17
P41	75-560	RM27	P106	76-707	W20
P42	75-561	RM28	P107	76-710	W24
P43	75-546	RM13	P108	75-566	W16
P44	77-211	LO55	P109	76-440	LO52
P45	77-207	LO62	P110	76-422	LO34
P46	75-535	RM1	P111	76-438	LO50
P47	76-719	W56	P112	76-715	W45
P48	77-214	LO57	P113	76-429	LO41
P49	76-394	LO7	P114	75-565	W15
P50	77-210	LO63	P115	76-720	W57
P51	72-98	W18A	P116	75-540	RM7
P52	77-208	LO54	P117	77-539	WS9
P53	75-554	RM21	P118	75-861	RM42
P54	75-563	RM31	P119	75-862	RM43
P55	75-564	RM32	P120	75-547	RM14
P56	75-555	RM22	P121	75-558	RM25
P57	75-863	RM44	P122	75-559	RM26
P58	75-867	RM48	P123	75-551	RM18
P59	76-737	W82	P124	75-569	W90
P60	75-548	RM15	P125	75-570	W91
P61	78-838	W83	P126	72-104	W21A
P62	76-730	W75	P127	76-736	W93
P63	76-731	W76	P128	76-714	W40
P64	76-734	W79	P129	78-836	W88
P65	76-727	W69	P130	75-874	RM55

CHEMICAL ANALYSIS SAMPLES

Ref. No. in Appendix A of Bull. No. 58	Mines Dept. Chem. Cat. No.	Field No.	Ref. No. in Appendix A of Bull. No. 58	Mines Dept. Chem. Cat. No.	Field No.
C1	782324	Q78-19	C15	782327	Q78-22
C2	782325	Q78-20	C16	782322	Q78-17
C3	782326	Q78-21	C17	782335	W81
C4	772135	Q77-2	C18	782336	RM51
C5	782330	Q78-23	C19	782338	WS11
C6	782331	Q78-24	C20	772136	Q77-3
C7	782333	W55	C21	782339	WS20
C8	782316	Q78-7	C22	782337	LO50
C9	782317	Q78-12	C23	772134	Q77-1
C10	782318	Q78-13	C24	782323	Q78-18
C11	782319	Q78-14	C25	782320	Q78-15
C12	772137	Q77-4	C26	782321	Q78-16
C13	782328	Q78-8	C27	782332	W40
C14	782329	Q78-11	C28	782334	W89

Figure 2

GSB58



THE MOUNT READ VOLCANICS AND ASSOCIATED ROCKS IN THE DARWIN-LYELL-SEDGWICK AREA

K.D. CORBETT. 1979

0 1 2 3 4 5 6 7 kms

SCALE 1:75,000

5 cm

GSB58

CROSS-SECTIONS A-A',B-B' SOUTH QUEENSTOWN AREA

(See figure 2 for location of section lines)

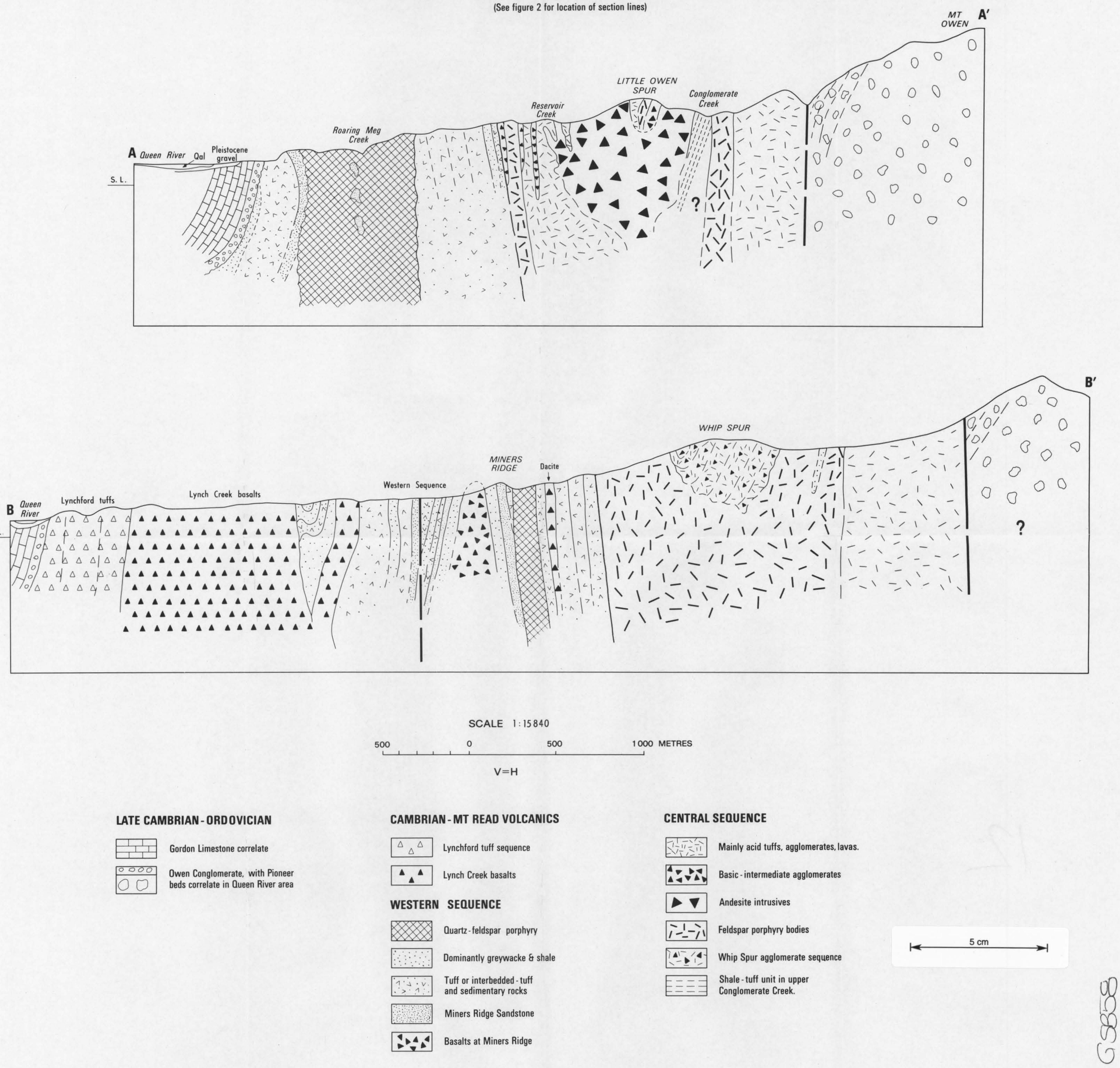


Figure 12