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TASMANIA DEPARTMENT OF MINES

GEOLOGICAL SURVEY
BULLETIN 55

THE BLUE TIER
BATHOLITH

by *D.I. GROVES, B.Sc., Ph.D., A.M.Aus.I.M.M.,*
J.D. COCKER, B.Sc. (Hons) and
D.J. JENNINGS, B.Sc. (Hons)

ISSUED UNDER THE AUTHORITY OF THE HONOURABLE
G. D. CHISHOLM, M.H.A.
MINISTER FOR RESOURCES AND ENERGY

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PREFACE

The Blue Tier Batholith has been recognised for a long time as the source for important mineralisation in north-eastern and eastern Tasmania. Over the years many reports have been prepared on various portions of the batholith and on the mineral deposits associated or derived from it. This is the first in-depth study of the entire complex.

The work will surely lead to a very much better understanding of the relationship of the mineral deposits of this area to their host rocks. Future prospecting for both lode and alluvial deposits should be guided by this study and we can look forward to the possibility of new mineral discoveries or extensions of known deposits. Perhaps most importantly the work will guide mineral exploration to the most appropriate areas with a concomitant saving in exploration expenditure.

The contribution to this study by J.D. Cocker, a research student from the Department of Geology of the University of Tasmania, is gratefully acknowledged.

J.G. SYMONS, Director of Mines

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The geology, geochemistry and mineralisation of the Blue Tier Batholith

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ABSTRACT

The Upper Devonian Blue Tier Batholith is a composite body intruded in general evolutionary sequence from early mafic granodiorites to late leucocratic granites: the dominant granitic type is a porphyritic biotite granite/adamellite. The granitic plutons are normally steep sided and have been controlled by fractures both parallel and perpendicular to the pre-intrusion fold axis of the intruded Mathinna Beds. The plutons have sharp discordant contacts, narrow zones of contact metamorphism, and appear to be high-level, magmatic intrusions that were generally passively emplaced with minor marginal deformation associated with granodiorite emplacement. Early-formed granodiorite plutons were fragmented during subsequent emplacement of granite/adamellites, and significant dilation is envisaged.

Small bodies of muscovite-biotite granite are the youngest major intrusions of the batholith, probably representing about 1-2% of its total volume. These granites form essentially sheet-like bodies with feeder dykes and are confined to the upper levels of the batholith that are presently exposed. They appear to represent the products of crystallisation of the low volume, ultimate residual liquid of the primary calc-alkaline magma from which the Blue Tier Batholith formed. They are strongly fractionated with low K/Rb and OH/F ratios, high Li and Sn and low MgO contents. Their high Sn contents appear to be due to partitioning of Sn into residual liquids during fractional crystallisation of the magma.

Cassiterite-bearing greisenised granites and greisens are generally confined to irregularities in the upper contact of the muscovite-biotite granite sheets, where essentially unaltered granite is typified by higher Li and Sn at lower K/Rb, OH/F and Mg/Li ratios than granite from lower contacts. The vertical geochemical zonation of the granites and the mineralisation is considered an autometasomatic effect caused by uprise of aqueous fluids related to second boiling within crystallising magma at a high structural level. The precise nature of mineralisation depends on the nature and degree of jointing or fracturing of the intruded rocks.

The geochemical characteristics of the muscovite-biotite granites may be a useful adjunct to other geological evidence indicating the degree of unroofing of the granite sheets. This is important in exploration for both primary and alluvial cassiterite mineralisation. Other mineralisation, particularly Au, does not show such a distinctive spatial relationship to specific granitic rocks, although there are some indications of a broad association with biotite- and hornblende granodiorites.

INTRODUCTION

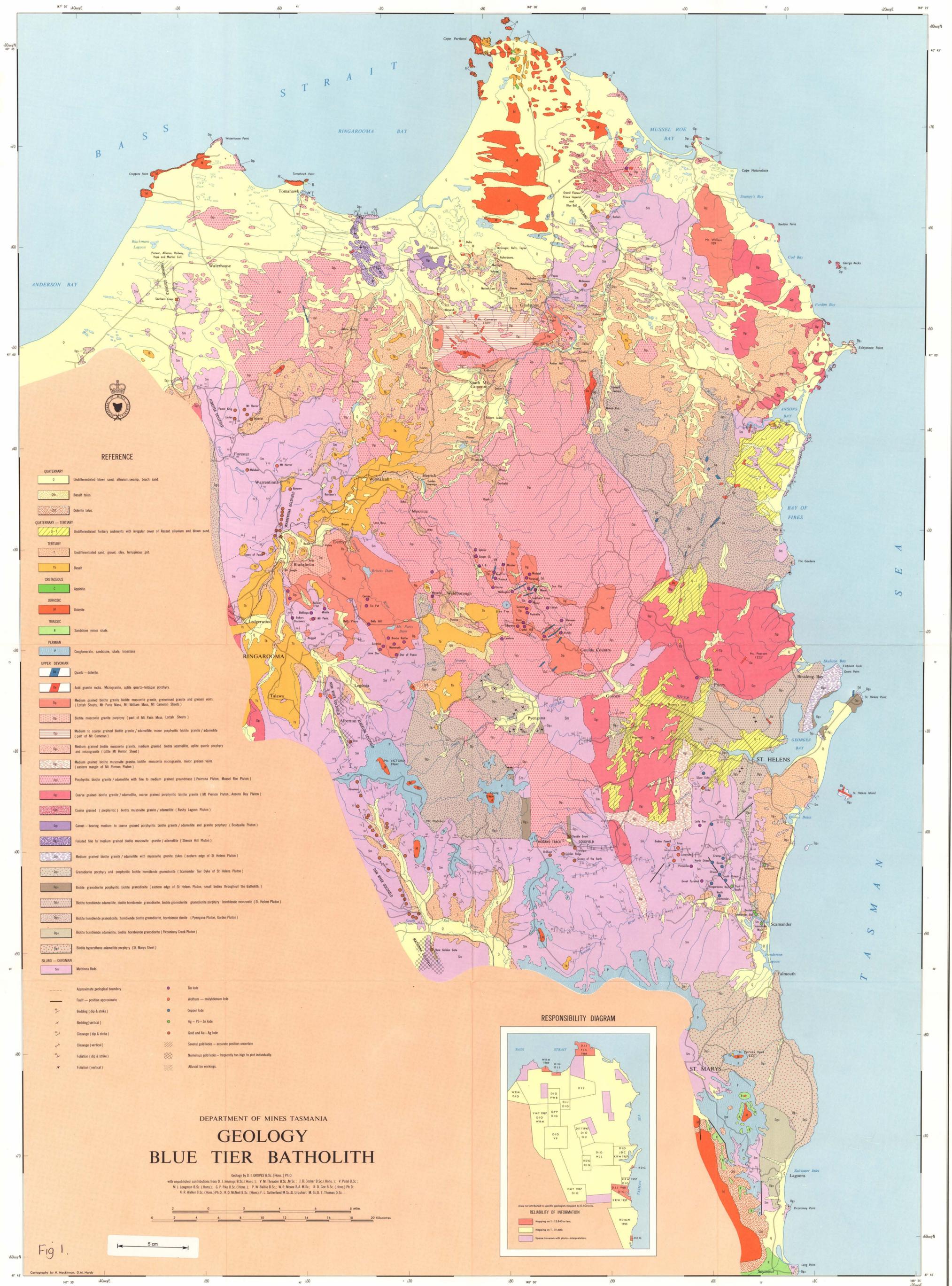
Geological mapping of the Blue Tier Batholith was carried out by the author between late 1968 and late 1970. Mapping was initially compiled on 1:31 680 topographic sheets of the area, and was subsequently reduced to a scale of 1:125 000 (fig. 1). The study was completed in 1974.

The major objective of the project was to determine whether a correlation existed between specific granitic rocks and tin mineralisation within the batholith, and if so to determine the diagnostic characteristics of such granitic rocks as an aid to exploration. Previous work on this problem in north-east Tasmania included studies by Thomas (1943) and Rattigan (1960), and some success was achieved in solving similar problems in western Tasmania (e.g. Groves, 1968b; Groves *et al.*, 1973).

Due to the large size of the area, there were problems in covering the area adequately in a reasonably short time. Therefore an initial reconnaissance map was made by compilation of all existing work, particularly Reid and Henderson (1928), Thomas (1943), Walker (1957), McNeil (1965), Threader (1967), unpublished maps by M.J. Longman, D.J. Jennings, and exploration companies, particularly Utah Development Co. Reconnaissance mapping was then carried out by traversing all available roads, tracks and rivers. On completion of this stage, areas of essentially homogeneous granitic rocks were delineated and mapping was concentrated on more heterogeneous areas, where more detailed mapping was required to accurately define boundaries between granitic rocks. During this stage two such heterogeneous areas were suggested as Honours projects for B.Sc. graduates of the University of Tasmania. A study of the geology of the St Helens area was successfully completed (Cocker, 1971), but V. Patel working on the Mt Paris area did not complete his study, thus leaving important gaps in the knowledge of this area.

Further detailed studies included interpretation of well-exposed granitic contacts (Gee and Groves, 1971, 1974), detailed mapping of the Little Mt Horror area (Baillie, 1973), examination of a coastal section between Tomahawk and Boobyalla (Groves and Jennings, 1973), and detailed mapping of the Mt Cameron and Mt William areas by D.J. Jennings. The Scamander area was described by Groves (1972) with particular emphasis on the mineral deposits of the area. Due to scale differences much of the detailed information obtained in these studies could not be included in the final map (fig. 1), but larger scale maps of some of these areas are presented in this Bulletin. It is stressed that the coverage of the area is not uniform; that much information from previous authors remains unchecked; that the mapping project was completed extremely swiftly by normal standards; and that in places the map is still essentially a reconnaissance map.

In this Bulletin the field relationships, petrography and geochemistry of the granitic rocks of the Blue Tier Batholith are described with particular emphasis on granitic rocks containing tin deposits. Interpretations of emplacement mechanisms, fractionation trends and mineralisation mechanisms are presented, but the origin of the granitic rocks is beyond the scope of the present investigation. All data collected during work on the batholith are presented irrespective of whether used in the discussion. Descriptions and locations of all specimens referred to in the text are given in Table 34 (p. 82).



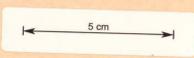
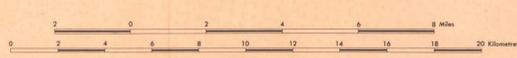
REFERENCE

- QUATERNARY**
- Q Undifferentiated blown sand, alluvium, swamp, beach sand
- Sn Basalt talus
- Ds Dolerite talus
- QUATERNARY - TERTIARY**
- Q-T Undifferentiated Tertiary sediments with irregular cover of recent alluvium and blown sand
- TERTIARY**
- T Undifferentiated sand, gravel, clay, terrigenous grit
- Ts Basalt
- CRETACEOUS**
- C Argillite
- JURASSIC**
- J Dolerite
- TRIASSIC**
- Ts Sandstone minor shale
- PERMIAN**
- P Conglomerate, sandstone, shale, limestone
- UPPER DEVONIAN**
- Qz-dolerite
- Qz-dolerite
- Acid granite rocks, Microgranite, apite quartz-feldspar porphyry
- Medium grained biotite granite biotite muscovite granite, potassic granite and gneiss veins (Littah Sheets, Mt. Paris Mass, Mt. William Mass, Mt. Cameron Sheets)
- Biotite muscovite granite porphyry (part of Mt. Paris Mass, Littah Sheets)
- Medium to coarse grained biotite granite / adamellite, minor porphyritic biotite granite / adamellite (part of Mt. Cameron)
- Medium grained biotite muscovite granite, medium grained biotite adamellite, apite quartz porphyry and microgranite (Little Mt. Horror Sheet)
- Medium grained biotite muscovite granite, biotite muscovite microgranite, minor gneiss veins (eastern margin of Mt. Pierson Pluton)
- Porphyritic biotite granite / adamellite with fine to medium grained groundmass (Piemont Pluton, Mussel Roe Pluton)
- Coarse grained biotite granite / adamellite, coarse grained porphyritic biotite granite (Mt. Pierson Pluton, Assos Bay Pluton)
- Coarse grained (porphyritic) biotite muscovite granite / adamellite (Razby Lagoon Pluton)
- Garnet-bearing medium to coarse grained porphyritic biotite granite / adamellite and granite porphyry (Boodyella Pluton)
- Foliated fine to medium grained biotite muscovite granite / adamellite (Sheak Hill Pluton)
- Medium grained biotite granite / adamellite with muscovite granite dykes (eastern edge of St. Helens Pluton)
- Granodiorite porphyry and porphyritic biotite hornblende granodiorite (Scamander Tier Dyke of St. Helens Pluton)
- Biotite granodiorite porphyritic biotite granodiorite (eastern edge of St. Helens Pluton, small bodies throughout the Batholith)
- Biotite hornblende adamellite, biotite hornblende granodiorite, biotite granodiorite granodiorite porphyry hornblende monzonite (St. Helens Pluton)
- Biotite hornblende granodiorite, hornblende biotite granodiorite, hornblende diorite (Pyangana Pluton, Garden Pluton)
- Biotite hornblende adamellite, biotite hornblende granodiorite (Pecannay Creek Pluton)
- Biotite hypersthene adamellite porphyry (St. Marys Sheet)
- SILURO - DEVONIAN**
- Ss Mathinna Beds

- Approximate geological boundary
- Fault - position approximate
- Bedding (dip & strike)
- Bedding (vertical)
- Cleavage (dip & strike)
- Cleavage (vertical)
- Foliation (dip & strike)
- Foliation (vertical)
- Tin lode
- Wolfram - molybdenum lode
- Copper lode
- Ag - Pb - Zn lode
- Gold and Au - Ag lode
- Several gold lodes - accurate position uncertain
- Numerous gold lodes - frequently too high to plot individually
- Alluvial tin workings

DEPARTMENT OF MINES TASMANIA
GEOLOGY
BLUE TIER BATHOLITH

Geology by D. I. GROVES B.Sc. (Hons.) Ph.D.
 with unpublished contributions from D. J. Jennings B.Sc. (Hons.), V. M. Thresher B.Sc. M.Sc., J. D. Coker B.Sc. (Hons.), V. Pahl B.Sc.,
 M. J. Longman B.Sc. (Hons.), C. P. Pike B.Sc. (Hons.), P. W. Baillie B.Sc., W. R. Moore B.A. M.Sc., R. D. Gae B.Sc. (Hons.) Ph.D.,
 K. R. Walker B.Sc. (Hons.) Ph.D., R. D. McNeil B.Sc. (Hons.), F. L. Sutherland M.Sc. G. Urquhart M.Sc. D. E. Thomas D.Sc.



RESPONSIBILITY DIAGRAM

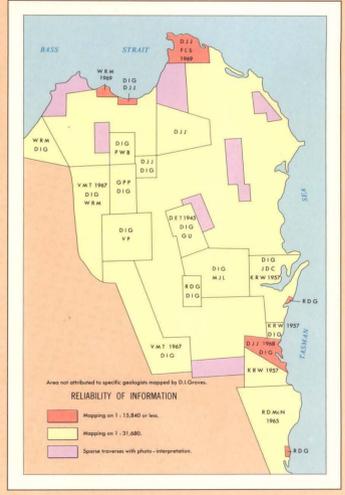


Fig 1.

Cartography by H. Mackinnon, D.M. Hardy

ACKNOWLEDGMENTS

The author has drawn heavily on previous published and unpublished information on the Blue Tier Batholith. The source of this information is shown on the responsibility diagram in Figure 1.

The author is indebted to I.B. Jennings and A.J. Noldart for continued encouragement and assistance within the project. D.J. Jennings has contributed a considerable amount of information towards this research, both in mapping and in stimulating discussions concerning the granitic rocks of this area. Discussions with J.D. Cocker have also been most beneficial, and his detailed mapping of the St Helens area has been invaluable. Joint studies with Drs R.D. Gee and R.G. Taylor are also acknowledged.

The author is also indebted to P. Bannister of the University of Western Australia for chemical analyses of rocks and micas. This work was partly financed by a University Research Grant. The Department of Mines Laboratories at Launceston provided some chemical analyses, and also provided biotite concentrates from granitic rocks. M.H.R. Shipp, Government Analyst and Chemist, kindly provided fluorine analyses of rocks and micas.

REGIONAL GEOLOGY OF THE BLUE TIER BATHOLITH

INTRODUCTION

The granitic rocks of north-east Tasmania are part of a large belt of essentially post-kinematic granitic bodies within the Tasman Orogenic Zone (Solomon et al., 1972). In this zone the granitic plutons occupy about 35% of the exposed surface area of Palaeozoic rocks and are generally composed of calcic adamellites and granodiorites. North-east Tasmania is one of several distinctive areas where granites and alkaline adamellites occur, accompanied by tin and, or, tungsten mineralisation.

The granitic rocks of north-east Tasmania crop out over an area of more than 2500 km², the largest masses being the Blue Tier and Scottsdale Batholiths with areas of about 1800 km² and 750 km² respectively. Radiometric dating of these granitic rocks indicates an Upper Devonian age (Table 1). Although the broad external shapes of these batholiths have been known for a considerable time, the internal configuration of the granitic rocks and their relative ages have previously been considered only in relatively small areas (e.g. Reid and Henderson, 1928; Thomas, 1943).

The granitic rocks have been emplaced into the Mathinna Beds, which are the only exposed Palaeozoic sedimentary sequence in the area. They are unconformably overlain by Permian and minor Triassic sedimentary sequences, which have been intruded by Jurassic dolerite sills. An extensive cover of Tertiary sedimentary rocks and basaltic lavas exists, particularly in the north-eastern and northern part of the mapped area. Recent sediments are most commonly developed in coastal areas where they obscure bedrock geology. The main features of the geology of the mapped area are briefly described below.

MATHINNA BEDS

Physiographic expression

The Mathinna Beds in the southern and western parts of the area form a youthful, low, mountainous region commonly with a trellised drainage

Table 1. ISOTOPIC AGE DETERMINATIONS ON BIOTITES FROM GRANITIC ROCKS FROM THE BLUE TIER BATHOLITH

Rock type	Granitic Pluton	K-Ar age	Rb-Sr age	Initial Sr ⁸⁷ /Sr ⁸⁶
Biotite-hypersthene adamellite porphyry	St Marys Sheet	377 my*		
Biotite-hypersthene adamellite porphyry	St Marys Sheet	374 my*		
Foliated biotite granodiorite	Pyengana Pluton	367 my†		
Biotite-hornblende granodiorite	Gardens Pluton	347 my†		
Biotite adamellite	Piccaninny Ck Pluton	371 my*		
Biotite adamellite	St Helens Pluton	375 my*	389 my*	0.708±0.001
Hornblende-biotite adamellite	St Helens Pluton	368 my*		
Muscovite granite dyke	St Helens Pluton	321 my†		
Porphyritic biotite granite/adamellite	Poimena Pluton	369 my*		
Porphyritic biotite granite/adamellite	Poimena Pluton	363 my*		
Porphyritic biotite granite/adamellite	Poimena Pluton	367 my*		

*from McDougall and Leggo (1965) †from C. Brooks (pers. comm.)

Table 2. SUMMARY OF FOLD ORIENTATIONS IN THE AREA OF THE BLUE TIER BATHOLITH COMPARED WITH OTHER AREAS OF EASTERN TASMANIA.

Author	Locality	Trend and Plunge of Dominant Fold Axis
<i>Blue Tier area</i>		
McNeil (1965)	Elephant Pass	3-30° towards 320-350°
Threader (1967)	Fingal-Alberton	20° towards 142° and 20° towards 322°
	Warrentinna-Forester	30° towards 353°
Groves (1972a)	Upper Scamander-St Helens	10° towards 143°
Groves and Jennings (1973)	Boobyalla-Tomahawk	15° towards 325°
<i>Other areas in Eastern Tasmania</i>		
Blissett (1959)	Rossarden	30° towards 140-150°
Bravo (1968)	Rossarden-Tower Hill	10° towards 159°
Jennings (1967)	Stony Head	12° towards 150°
Legge (1968)	Ormley-Rossarden	10° towards 162°
Longman (1966)	Launceston Quadrangle	10° towards 150° and 10° towards 330°
Marshall (1970)	Pipers River Quadrangle	10° towards 139°

pattern. In these areas exposure is excellent in road cuttings and some streams, but elsewhere exposures are obscured by veneers of angular blocks that have migrated down slope. Coastal exposure of the Mathinna Beds is excellent at small isolated localities such as Piccaninny Point [68/075630], Dianas Basin [69/075010], south of Ansons Bay and between Boobyalla and Tomahawk. In the north, exposures of Mathinna Beds are very poor and outcrops are commonly represented by sporadic accumulations of angular rock fragments partly obscured by sand. Some exposures occur in the floor of alluvial tin workings. In areas of poor exposure the thick clay soils developed over the Mathinna Beds may serve to distinguish them from areas of granitic rocks which locally have a coarse-grained sandy soil.

Stratigraphy

The Mathinna Beds in the mapped area represent the arenite-lutite association (e.g. Banks, 1962) or arenaceous sequence (e.g. Marshall, 1970). The main rock type is a sandstone or coarse siltstone, generally in units from 10 cm to one metre thick, commonly graded, having fine siltstone or mudstone tops. Massive ungraded sandstone or coarse siltstone beds, up to 5 m thick, occur in places. Sequences of finely laminated mudstone up to 4 m thick appear to be less common, although this may be partly due to their selective weathering and erosion. An estimate of the total stratigraphic thickness of the arenaceous sequence of the Mathinna Beds is not possible because of folding, faulting and discontinuous exposure, but is at least 200 m along the Upper Scamander Road and probably more than 500 m to the north of Dianas Basin. Banks (1962) suggested that the total thickness of the Mathinna Beds was in excess of 2000 m.

The sand-grade rocks are generally poorly sorted with a high proportion of argillaceous or siliceous matrix. The most common rock type is an impure quartz sandstone or quartz greywacke (Williams et al., 1954). Detailed descriptions of these rock types are given by Walker (1957), Williams (1959), Groves (1965) and Marshall (1970) and are not repeated here. Massive beds of quartzite, up to 10 m thick, commonly occur in areas of mineralisation and appear to represent silicified sandstones, the silification probably being related to mineralisation (Everard, 1964; Groves, 1972a).

Williams (1959) has described numerous sedimentary structures including flute casts, drag marks, load casts and flame structures, festoon cross bedding and convolute folding from road sections in the Upper Scamander area. These structures, although less perfectly exposed elsewhere, do generally allow determinations of the facing of the beds. Williams (1959) concluded that the sedimentation features suggested deposition of sands and coarse silts from currents that came from the south-west. Similar current directions were postulated by McNeil (1965), but currents from the east were suggested by Walker (1957) and other variations were noted by Legge (1968) and Bravo (1968). Current directions have not been determined systematically throughout the mapped area.

Worm-like grooves on the surface of mudstone layers are generally the only evidence of life that existed at the site of deposition. Transported fragments of vascular plants and fragmented marine fossils occur in the graded sandstone beds at Scamander and the presence of *Hostimella* has been taken as indicative of a Silurian or Devonian age for the rocks (Cookson, 1937; Banks, 1962). Graptolites from thin mudstone layers exposed along Forestry Commission roads near the tributaries of Wrinklers Creek (near Scamander) include *Monograptus aequabilis* (Přibyl) indicating a Lower Devonian age for rocks in this area (M.R. Banks, pers. comm.).

Structure

Folding of the Mathinna Beds has been attributed to Tabberabberan orogenesis which has been dated elsewhere (Burns, 1965) as upper Middle Devonian. This is consistent with field evidence in the mapped area as part of the Mathinna Beds are Early Devonian in age and the folds are clearly truncated by the Upper Devonian granitic rocks.

Several workers (e.g. Lyon, 1957; McNeil, 1965; Longman, 1966; Threader, 1967) have demonstrated that the Mathinna Beds are generally folded into a series of major folds with superimposed, coaxial folds of smaller wavelength. The evidence of major anticlinoria and synclinoria postulated by Carey (1953) is not supported. The major folds have wavelengths of about 3-4 km (Threader, 1967; Groves, 1972a). Folds are generally symmetrical with steep axial surfaces, long relatively planar limbs and sharp closure (c.f. Marshall, 1970). Measurement of fold axes, lineations, bedding-bedding and bedding-cleavage intersections by various authors (Table 2) indicates that the folds are doubly plunging towards the NNW and SSE at angles of less than 30°. The rocks are characterised by variable development of slaty cleavage, although bedding is almost inevitably the more dominant planar element in the rocks in contrast to the lutite associations where cleavage is generally more prominent (e.g. Groves, 1965; Marshall, 1970).

The regional folds have been modified by later folding associated with the emplacement of the St Helens and Pyengana granodiorite plutons (e.g. Gee and Groves, 1971), and this is discussed below.

Faults and fractures occur within the Mathinna Beds throughout the area and have been locally important in controlling the distribution of hydrothermal gold, tin, and copper-lead-zinc mineralisation (e.g. Threader, 1967; Groves, 1972a). These fractures may be broadly divided into long persistent fractures that are subparallel to the regional fold axial surface (e.g. Orieco Mine; Groves, 1972a) and generally smaller, less persistent tension fractures that are variable in orientation but are generally normal to the trend of the regional fold axis. These two fracture systems appear to be related to folding, and to have been present prior to the emplacement of granitic rocks as they have influenced the shape of these intrusions.

Metamorphism

The Mathinna Beds are generally slightly recrystallised sedimentary rocks. Where penetrative cleavage is well developed a planar-preferred orientation of sericite, muscovite and chlorite is apparent, and it is probable that these have crystallised from pre-existing clay minerals. The lack of suitable rock compositions for the formation of critical metamorphic assemblages precludes a precise assessment of metamorphic conditions. However, the rocks appear to have been subject to very low-grade regional metamorphism.

The sediments have suffered contact metamorphism during emplacement of the granitic rocks, and contact aureoles of several metres to 2 km in width are developed dependent on the disposition of the rock boundaries. Adjacent to vertical granitic boundaries contact aureoles seldom exceed 250 m in width.

The rocks close to the contact zone are generally interbanded quartz hornfels and spotted hornfels. The spotted hornfels commonly display ellipsoidal spots, up to one centimetre in diameter, of muscovite, quartz and biotite with small irregular grains of cordierite partially replaced by sericite in a granoblastic groundmass of quartz with minor biotite and muscovite. In other specimens K-feldspar, plagioclase, epidote and chlorite may be present

in minor amounts. Although the assemblages are not diagnostic, the presence of cordierite suggests low pressure, hornblende hornfels facies metamorphism (e.g. Turner, 1968, p.129, 195). Farther from the contact cordierite is absent and assemblages are generally quartz-muscovite-biotite-chlorite indicating albite-epidote hornfels facies metamorphism (e.g. Turner, 1968, p.192). McNeil (1965) recorded the assemblage sillimanite-corundum-quartz-cordierite-biotite-K-feldspar from within 25 mm of the granite contact at Piccaninny Point indicating the possible local attainment of pyroxene hornfels facies metamorphism (Turner, 1968, p.225).

UPPER DEVONIAN GRANITIC ROCKS

The granitic rocks of the Blue Tier Batholith are essentially post-tectonic bodies that truncate the regional folds in the Mathinna Beds. They have sharp contacts, relatively narrow contact aureoles and most features generally attributed to emplacement at shallow to intermediate depths (e.g. Buddington, 1959). Associated extrusive rocks have not been recognised anywhere in north-eastern Tasmania. Their absence today does not preclude the possibility of their production in the past, as there was a prolonged period of erosion between Upper Devonian granite intrusion, with possible equivalent extrusives and subsequent deposition of flat-lying Permian sediments.

In the batholith there are seventeen petrologically distinct granitic types or groups which form eighteen major bodies (fig. 2). These bodies are generally discrete structural entities and are termed plutons, sheets or masses consistent with the terminology adopted by Gee and Groves (1971). Plutons are steep-walled, and usually have a crudely rectangular shape with long north-south sides and shorter east-west sides. Sheets are generally flat-lying or gently undulating bodies of limited thickness. Bodies of uncertain shape have been termed masses. The granitic rocks may also be divided into three major groups on the basis of mineralogical composition viz: hornblende-bearing granodiorites and adamellites, biotite granites and adamellites, and muscovite biotite granites. The petrology and geochemistry of these bodies is discussed below in terms of these groups.

PERMIAN SEDIMENTARY ROCKS

Flat-lying sedimentary rocks of Permian age occur most commonly in the western and southern extremities of the mapped area. To the west in particular, they lie on an essentially flat-lying erosional surface at an elevation of more than 600 m (no accurate contour maps are available for this area). These rocks have been briefly described by Threader (1967). In the Upper Scamander area Permian sedimentary rocks crop out on the interfluves of several streams, and consist of basal arkoses or quartz conglomerates and grits with sandstone and siltstone at higher levels (Groves, 1972a). In the southern part of the area, particularly around St Marys, successions of sandstone, greywacke sandstone, mudstone, conglomerate and limestone cap the higher ground attaining thicknesses of up to 145 m (McNeil, 1965). At Elephant Pass spores from basal rocks have been dated as Lower Artinskian, but elsewhere the age of basal units is uncertain.

Permian rocks also crop out among low hills in sand-covered country north of Gladstone and west of Musselroe Bay (fig. 1). These outcrops have not been examined in detail by the author, but in places fossiliferous Permian sediments appear to be faulted against granitic rocks, Mathinna Beds or dolerite, and elsewhere appear to unconformably overlie granitic rocks and carry a capping of dolerite. The Permian rocks here are at a much lower topographic level than elsewhere in the Blue Tier Batholith area.

TRIASSIC SEDIMENTARY ROCKS

Disconformably overlying the Permian system in the St Marys area is a sequence of flat-lying subgreywacke sandstone with interbedded shale, mudstone and allochthonous coal seams of Triassic age (McNeil, 1965). Triassic rocks are absent elsewhere in the area, although Moore (1969) records possible Triassic sandstone on a rock platform at Tomahawk Point [59/625665].

JURASSIC DOLERITE

Thick dolerite sills cap the Permian sedimentary sequences in the western part of the area, forming a series of prominent peaks including Mt Victoria [59/670070] and Mt Young [59/780035] (fig. 1). In the southern part of the area dolerite also forms several prominent peaks including St Patricks Head [68/025775] and Mt Elephant about 4 km further south. In most of this area it forms slightly transgressive sills emplaced in Triassic strata, although St Patricks Head may be a neck-like intrusion (McNeil, 1965). Dolerite is absent in the central part of the area occupied by the Blue Tier Batholith, but it occurs on the northern coastline as low, serrated rocky headlands or further inland in the form of rounded hills and ridges partly covered with sand (e.g. Jennings and Sutherland, 1969). Whether the dolerite is emplaced into granitic rocks and Mathinna Beds in this area or faulted against them is uncertain. Cretaceous appinites intrude the dolerite in the Cape Portland area (Jennings and Sutherland, 1969).

TERTIARY SEDIMENTARY ROCKS

Tertiary sediments including sand, gravel and clay are widespread over the area of the Blue Tier Batholith. In coastal areas south of St Helens they generally represent a well sorted, relatively unconsolidated beach deposit of coarse sand and well rounded quartz and quartzite pebbles. Valley-fill deposits also occur and consist of poorly sorted boulders of quartzite and quartz veins in a variable clay, sand or gravel matrix.

In the southern, western and eastern parts of the area Tertiary sediments commonly occupy Tertiary river channels, whereas in the Mt Cameron area they may have formed in a lacustrine environment. In the northern and eastern coastal areas they have formed in local bedrock depressions. Throughout the area it is difficult to distinguish with certainty between Tertiary sediments and reworked Tertiary sediments of Quaternary age. Tertiary cover in the northern part of the area hinders the interpretation of bedrock geology.

Incised in the southern part of the batholith, Mid-Tertiary sediments (Harris, 1968) form Thureau's Lead [59/960120] in the area of the present George River and Golden Fleece Rivulet (Jack, 1964). In the south-east, Tertiary sediments occupy the old course of the Scamander River (Jennings, 1968) and further west crop out in the Dan Rivulet and South Esk River valleys (Threader, 1967). Sediments from alluvial tin workings at Branxholm and to the south and east of Mount Cameron have been ascribed a mid-Tertiary age (Harris, 1968). Tributaries of the Ringarooma River commonly occupy valleys incised in granite by their Tertiary predecessors. The course of the present Ringarooma River is not precisely related to the former Ringarooma mainstream, which remains as a deep lead filled with Tertiary sediments and locally capped with basalt lava flows (e.g. Nye, 1925). This deep lead is narrow in the vicinity of Derby, but broadens progressively north to the low-lying area south of Mount Cameron which may represent the site of a Tertiary lake filled with accumulated sediments. Fluvial Tertiary sediments also occur in the drainage basins of the Great Musselroe and Great Fraser Rivers east of Mt Cameron, and the Boobyalla River and tributaries west of Mt Cameron. The

economic importance of Tertiary lead systems in north-east Tasmania is summarised by Jennings et al. (1967).

TERTIARY BASALT

Small, isolated basalt flows occur in the southern part of the area (e.g. McNeil, 1965; Groves, 1972a), and have also been found near the base of the Tertiary sequence during drilling of Thureau's Lead (Jack, 1964). However the most extensive development of basalt occurs in the valleys of the Ringarooma River system, on high ground about the Weldborough Pass and sporadically as remnants throughout the large area between Ansons Bay and Cape Portland (i.e. the north-east segment of the Blue Tier Batholith).

The most extensive occurrence of basalt is within the old Ringarooma River system, where several individual flows have been recognised. The main lava type is an alkali olivine basalt (Branxholm-type of Edwards, 1950) although nepheline basanites are present at the Briseis Mine [59/660320], Derby (Edwards, 1950) and other variants have been recognised between Winnaleah and Warrentinna (Everard, 1971). In the Weldborough Pass area there are thick lava flows mainly of alkali olivine basalt. Local volcanic centres are indicated by agglomerates and breccias containing blocks of granitic rocks, with peripheral tuff and tuffaceous sandstone. Samples have been collected for further study by F.L. Sutherland. These basalts include both alkali olivine basalt and tholeiitic olivine basalt (e.g. Jennings and Sutherland, 1969). Small basalt outcrops located include an occurrence on the southern end of George Rocks [69/150560], suggesting a submarine source for the numerous basalt boulders on beaches of the north-east coastline.

QUATERNARY SEDIMENTS

Coastal Quaternary deposits include dunes and blown sand which obscure bedrock geology, particularly along the northern coastline. Reworking of Tertiary deposits has commonly occurred in present drainage systems and alluvial flats are extensive in some major river valleys. In the western and southern parts of the area dolerite talus deposits have been derived by erosion of high dolerite peaks, and these locally hide geological detail.

The nature of the coastline, and the quality of exposure of bedrock, vary considerably. South of Lagoons there is an extensive coastal plain with bedrock prominently exposed at Piccaninny Point and Long Point, whereas between Lagoons and Falmouth bedrock exposure is almost continuous. North of Falmouth a wide coastal plain and dune system is developed, but again between St Helens Point and Ansons Bay there is almost continuous exposure. Between Ansons Bay and Cape Portland the coastline is typified by long sweeping beaches backed with extensive coastal plains and interrupted by small rocky knolls and promontories. The main feature of the northern coastline is Ringarooma Bay, and bedrock exposure is limited to Cape Portland, Tomahawk Point, a small area between Tomahawk and Boobyalla (Groves and Jennings, 1973), and Waterhouse Point [59/545710] (fig. 1).

FIELD CHARACTERISTICS AND PETROGRAPHY OF THE BLUE TIER BATHOLITH

INTRODUCTION

The various plutons, sheets or masses of granitic rocks that form the Blue Tier Batholith may be subdivided on a mineralogical basis dependent on whether they contain pyroxene, hornblende, biotite or muscovite or combinations of these minerals. Divisions on this basis also roughly coincide with

divisions between granodiorites (hornblende and biotite), adamellites (biotite with minor hornblende) and granites (biotite and muscovite). Subdivision of the granitic rocks on this petrographic basis is also convenient as rocks within groups have been emplaced in similar ways, probably at similar times. The granitic rocks of the batholith are therefore described below under convenient petrographic groupings. Due to considerable variation within individual granitic bodies these petrographic descriptions are not exhaustive, but indicate the major features of the rocks. Where more exhaustive petrographic studies have been undertaken, the appropriate reference is given.

PYROXENE-BEARING ADAMELLITES

St Marys Sheet

The St Marys Sheet lies south of the main mass of the Blue Tier Batholith (fig. 1, Dg17). It is generally well exposed, is sheet-like in form with a maximum thickness of 1300 m, and underlies an area in excess of 85 km². The northern contacts appear to represent the base of the sheet dipping at approximately 15°SE (Walker, 1957). On the western margin the top of the sheet dips at 10-30°SW (McNeil, 1965). The emplacement of the sheet was subsequent to regional folding (McNeil, 1965).

The St Marys Sheet consists of a homogeneous, hypersthene biotite adamellite porphyry (table 3, fig. 3). It is a hard, brittle, blue-grey to light grey rock which is always porphyritic, although in coarser grained varieties the porphyritic character is not so pronounced. A detailed description is given by McNeil (1965). In thin section the porphyry consists of quartz, plagioclase, K-feldspar, hypersthene and biotite phenocrysts in a groundmass dominated by K-feldspar, but also containing plagioclase and quartz. Quartz phenocrysts, average diameter 1.5 mm, are commonly corroded or contain inclusions of groundmass material. Plagioclase phenocrysts are euhedral to subhedral, average one millimetre in length, and are commonly corroded and broken. The plagioclase is zoned from An₄₅ to An₆₀, and the average composition is An₅₀ (i.e. andesine-labradorite), in contrast with the groundmass plagioclase which is more sodic andesine. K-feldspar phenocrysts are less abundant, have less corroded margins, and are generally 0.4-0.6 mm in length. The phenocrysts are mainly anorthoclase and sanidine whereas the groundmass K-feldspar is orthoclase and, or, microcline. Hypersthene phenocrysts are olive grey and form anhedral to euhedral crystals with a mean diameter of 0.6-0.7 mm. Crystals are cracked, reaction rims of amphibole are common, and inclusions of groundmass or plagioclase occur. There appears to be an antipathetic relationship between abundance of quartz and hypersthene. Biotite with small zircon inclusions occurs as bent or fractured flakes from 0.1-2 mm in length. It is pleochroic; α = yellow-brown, β = red-brown, γ = dark red-brown.

The porphyry sheet is less porphyritic towards the margins where the groundmass may represent 60-80% of the rock in contrast to an average groundmass content of about 40%. Some assimilation of Mathinna Beds is indicated by small, angular quartz grains in the porphyry in the contact zone. The degree of deformation exhibited by phenocrysts increases sharply away from the boundary, and one metre from the contact cracked quartz and plagioclase and kinked biotite phenocrysts are common.

HORNBLLENDE-BEARING GRANODIORITES

Pyengana Pluton

The Pyengana Pluton forms the south-west margin of the Blue Tier

Table 3. MODAL ANALYSES (VOL. %) OF GRANITIC ROCKS FROM THE PICCANINNY CREEK PLUTON AND ST MARYS SHEET, BLUE TIER BATHOLITH.

Thin section no. Chemical analysis no.	PICCANINNY CREEK				
	70-170 702714	*Average	*Contact	*Sill	*Contact with St Marys Sheet
Quartz	34.9	34.0	33.0	34.0	26.0
K-feldspar perthite	30.8	33.0	24.0	31.0	4.5
Plagioclase	28.2	28.0	29.0	31.0	47.5
Biotite	6.2	4.0	9.0	4.0	13.0
Chlorite	0.1	0.0	0.0	0.0	0.0
Hornblende	0.0	1.0	5.0	0.0	9.0

Thin section no. Chemical analysis no.	ST MARYS	
	70-172 702718	*Average
Quartz	18.9	35.0
K-feldspar perthite	2.0	23.0
Plagioclase	26.5	28.0
Biotite	8.6	8.0
Hyperthene	4.3	6.0
Groundmass	39.7	

*From Walker (1957).

Table 4. MODAL ANALYSES (VOL. %) OF GRANODIORITES FROM THE PYENGANA AND GARDENS PLUTONS, BLUE TIER BATHOLITH.

Thin section no. Chemical analysis no.	PYENGANA			GARDENS	
	69-263	69-390	70-150 702692	69-385	69-386
Quartz	25.5	25.9	35.3	36.4	25.5
K-feldspar perthite	5.5	14.9	10.3	19.8	9.0
Plagioclase	33.0	37.4	38.9	33.6	40.7
Biotite	13.8	14.2	9.3	7.8	16.2
Hornblende	21.6	7.2	6.1	2.4	8.3
Accessories	0.5	0.5	0.0	0.1	0.3

Batholith (fig. 1, Dg15). Exposure is generally good, consisting of low, rounded tor-like outcrops separated by moderately clay-rich soils. The granitic rocks are obscured by thick alluvium in the George and North George River valleys, and are covered by Permian sedimentary rocks and Jurassic dolerite in the Mt Victoria and Mt Young areas. The pluton consists of two segments (fig. 1, 4); a rectangular north-eastern segment at Pyengana that is elongate NW-SE, and a larger south-western segment that is elongate with a similar alignment and has a tapering extension northwards to about 1.5 km west of Weldborough. The pluton is intrusive into Mathinna Beds along the western, southern and part of the eastern contact of the south-western segment, and along the eastern contact of the north-western segment. The two segments are separated by a dyke-like extension of the Poimena Pluton (fig. 1, 4).

The greater part of the pluton consists of relatively homogeneous biotite hornblende granodiorite and hornblende biotite granodiorite, although parts of the eastern margins of both segments consist of biotite granodiorite. The granodiorites are generally massive, but the north-western segment and part of the north-western margin of the south-western segment are strongly foliated, and porphyritic granodiorite with plagioclase phenocrysts occurs rarely. The rocks are blue-grey to dark grey in colour, medium-grained and contain abundant enclaves, particularly near the contacts with Mathinna Beds. These enclaves are of two types; rounded inclusions of dioritic composition, and subangular biotite-rich xenoliths of recrystallised country rocks.

In thin section the granodiorites (fig. 3) consist of variable proportions of anhedral quartz with undulose extinction, subhedral to euhedral zoned oligoclase-andesine (mean An_{40}), and biotite and hornblende with interstitial K-feldspar, probably microcline. Modal analyses are given in Table 4. The rocks are medium grained, with average grain size 2 mm in diameter, and are generally massive. Biotite is pleochroic; α = yellow-pale brown, β = green, γ = dark (bluish) green with a $2V \approx 65^\circ$. Some granodiorites (e.g. Table 5, 69-263) are foliated with alignment of biotite and hornblende, and a crude mineralogical banding with quartz-, plagioclase-, biotite-, and hornblende-rich bands. Quartz forms elongate aggregates of grains that have generally recrystallised to form a fine-grained mosaic of subgrains with 120° triple point junctions. Plagioclase grains have bent cleavages, twin lamellae and are commonly microfaulted (plate 7). In places plagioclase crystals are stacked together, forming irregular aggregates of tabular crystals with fractured terminations. Microquartz commonly forms wedge-shaped blocks in this micro-faulted and fractured plagioclase. K-feldspar shows undulose extinction, and some subgrains have developed by recrystallisation of larger deformed grains. The K-feldspar is generally not perthitic. Biotite crystals are bent, fractured or kinked, and form discontinuous aggregates of crystals aligned in the foliation (plate 8). Homoaxial growths of muscovite and, or, chlorite with a characteristic augen-like shape occur within some biotite grains. Biotite also contains inclusions of zircon and apatite.

Gardens Pluton

The Gardens Pluton has a roughly rectangular outcrop in the north-eastern part of the Blue Tier Batholith (fig. 1, Dg15). Exposure is generally poorer than that of the Pyengana Pluton, although coastal exposure at The Gardens is excellent, and sporadic low mounds of exfoliated granodiorite provide good exposure away from the coast. The relatively clay-rich sandy soils have been favoured for agriculture, and a large part of the area covered by the Gardens Pluton is under pasture. The northern part of the pluton is covered with Tertiary and Quaternary sediments, and the boundaries of the pluton in this area are not clear (fig. 1, 2). Granodiorite extends east of the coastline in the vicinity of The Gardens.

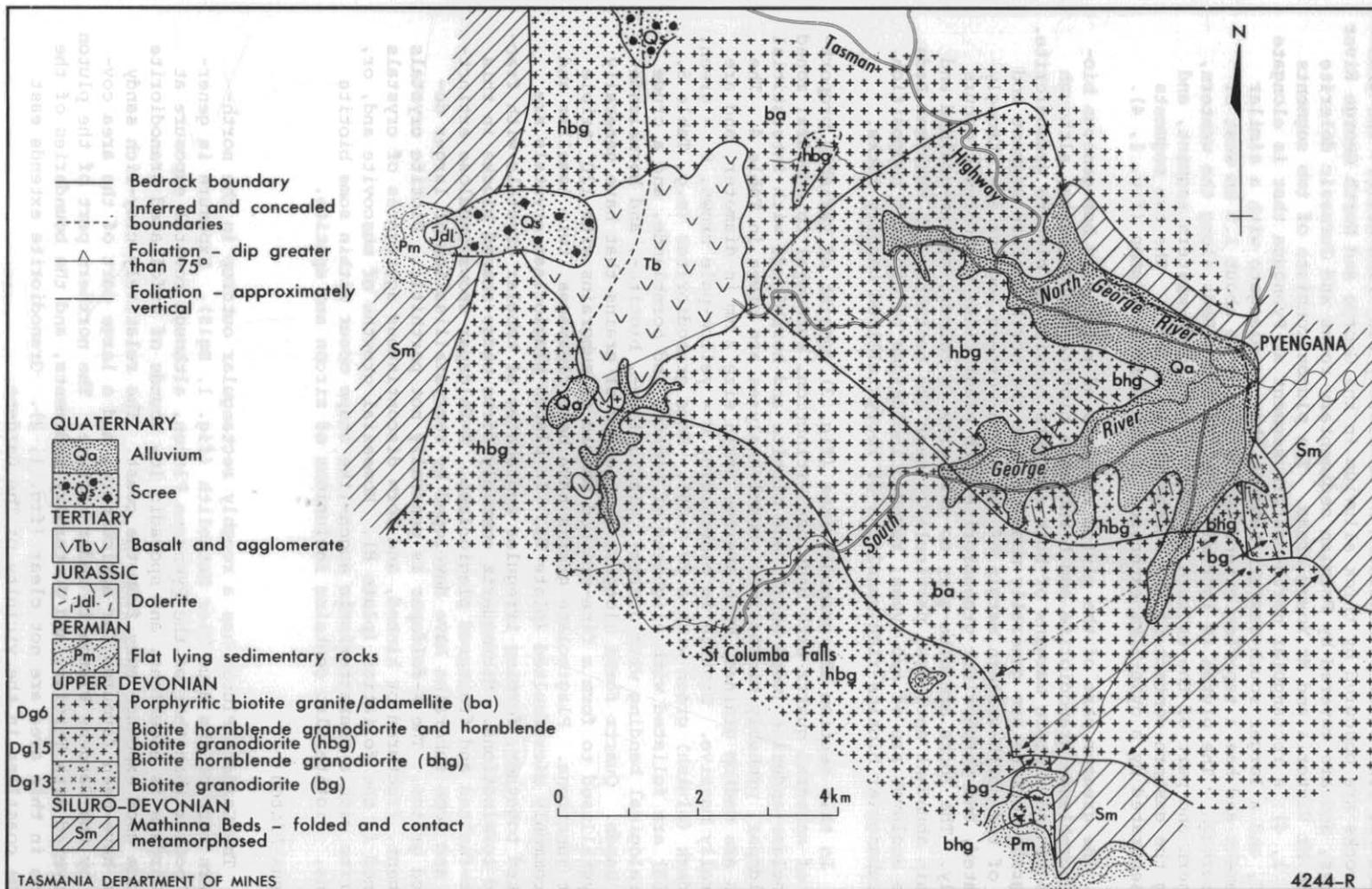
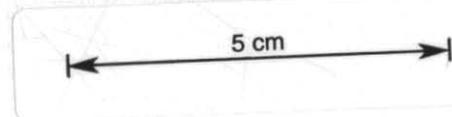


Figure 4. Geological map of the Pyengana area showing the fragmentation of the Pyengana Pluton by the southern extension of the Poimena Pluton. Tie lines join matching dyke-wall irregularities, and a matching triple-point (from Gee and Groves, 1971).



The southern boundary of the pluton has a relatively straight, sharp contact against the Mt Pierson Pluton. The western contact is also straight and for most of its length is separated from the Poimena Pluton by a thin screen of hornfelsed Mathinna Beds. To the north and east the pluton abuts broad tracts of hornfelsed Mathinna Beds, which separate the granodiorite from the granite/adamellites of the Musselroe and Rushy Lagoon Plutons to the north and the Ansons Bay Pluton to the north-east. Porphyritic biotite granite/adamellites similar to those of the Poimena Pluton occur within the northern part of the Gardens Pluton east of Gladstone, but extensive alluvial cover in the area precludes a clear interpretation of their relationships (fig. 2).

The Gardens Pluton consists mainly of hornblende biotite granodiorite with minor hornblende diorite and biotite granodiorite (table 4, fig. 3). The rocks are petrographically similar to the granodiorites of the Pyengana Pluton. Although the granodiorites are generally massive, those exposed near The Gardens have a cataclastic foliation similar to that near some north-eastern contacts of the Pyengana Pluton.

HORNBLLENDE-BEARING ADAMELLITE/GRANODIORITES AND BIOTITE GRANODIORITES

Piccaninny Creek Pluton

The Piccaninny Creek Pluton (fig. 1, Dgl6) is a N-S trending elongate pluton that has intrusive contacts with the Mathinna Beds on its western and possibly southern margins, and intrudes the St Marys Sheet at its northern extremity (McNeil, 1965). It crops out over an area of about 15 km² and is partly obscured by Permian sedimentary rocks to the north-west and Quaternary alluvium to the south-east. The eastern margin is presumably seawards of the present coastline. Exposure is poor in the southern part of the pluton where the granitic rocks form low hills partly covered by Recent sediments, but is good at the northern end where granitic rocks form deeply dissected hills up to 350 m above sea level. Well exposed contacts with the Mathinna Beds occur at Piccaninny Point and the lower part of the Elephant Pass section of the Tasman Highway.

The major rock type is a biotite adamellite or hornblende biotite adamellite, but hornblende biotite granodiorite occurs at the contacts with the St Marys Sheet and the Mathinna Beds at Piccaninny Point (table 3, fig. 3). Over most of the pluton the adamellite is a homogeneous, massive, light grey, medium-grained rock that contains biotite as the dominant ferromagnesian phase.

In thin section the normal adamellite is a medium-grained rock with an average grain size of 1.5 mm. Plagioclase occurs as slightly sericitised, subhedral to euhedral zoned crystals forming 30% ($\pm 6\%$) of the rock. The composition is andesine (An₄₀) with zoned rims to oligoclase (An₂₀). Biotite occurs as small flakes, less than one millimetre in diameter, forming 3-5% of the rock. It is pleochroic; α = yellow-brown, β = orange-brown, γ = dark red-brown, and crystals are occasionally kinked or bent. Rarely, small hornblende crystals occur as aggregates associated with biotite. Quartz occurs as anhedral crystals with undulose extinction, in places forming mosaic-like subgrain aggregates, that consist of 34% ($\pm 5\%$) of the rock. K-feldspar forms a late stage phase that poikilitically includes all other minerals or, more rarely, is intergrown with quartz. It is the most coarse-grained mineral in the rock, with average length 2-3 mm, and forms 33% ($\pm 3\%$) of the rock. Accessory minerals include sphene, zircon, apatite and magnetite, but muscovite is absent.

Granodiorite occurs adjacent to contacts with the St Marys Sheet and Mathinna Beds. These rocks are a darker grey than the normal adamellite,

possess a greater proportion of ferromagnesian minerals including significant hornblende, and also contain abundant enclaves. In thin section the plagioclase/K-feldspar ratio is variable (McNeil, 1965; fig. 3) and the plagioclase is generally andesine (An_{45}) although rims of zoned crystals are oligoclase. Hornblende is generally abundant (3-10%) and is pleochroic; α = yellow green, β = green, γ = dark (bluish) green. Biotite is commonly partly altered to chlorite. The total ferromagnesian content of the rock ranges from 10-30%, with hornblende commonly forming the coarsest grained crystals in the granodiorite (up to 5 mm in length).

At Piccaninny Point the granodiorite has a strongly developed cataclastic foliation which is slightly oblique to the compositional banding described by McNeil (1965) and shown in Plate 1. Mesoscopically the foliation is expressed as elongate aggregates of quartz partly enveloped by biotite and hornblende which produces an impersistent banding on a small scale. In thin section quartz crystals are fractured; display strong undulose extinction and appear as structured aggregates that wrap around feldspars. Subgrains have formed in places due to recrystallisation of strained crystals. Plagioclase twin lamellae and cleavages are kinked and microfaulted and biotite flakes are strongly kinked. Interstitial K-feldspar exhibits little deformation.

St Helens Pluton

The St Helens Pluton (fig. 1, Dg14) is virtually a microcosm of the Blue Tier Batholith, representing the complex sequential emplacement of granitic rocks with a variable composition including monzonites, diorites, granodiorites, adamellites and granites. Its status as a pluton is questionable as it is far more heterogeneous than other plutons, and it has been divided into a number of mappable units by Cocker (1971). A detailed description of the pluton is presented elsewhere in this Bulletin; only information gained during regional mapping is presented here.

The St Helens Pluton is in contact with the Mt Pierson Pluton along its northern and north-western margins, and is intrusive into the Mathinna Beds to the south. It extends east of the present coastline and is intruded by the Constables Creek Sheet along part of its western margin. The shape of the pluton is more irregular than that of the other granodiorite plutons of the Blue Tier Batholith. Exposure is variable, generally poor inland, but with excellent coastal sections at St Helens Point [69/185130], Grant Point [69/165160] and Binalong Bay [69/120155]. Tertiary and Quaternary cover obscure the bedrock geology to the south-west of St Helens Point and east of Priory (fig. 1).

The major rock type of the pluton ranges from a hornblende biotite granodiorite to a hornblende biotite adamellite or biotite adamellite (table 5, 69-246, 69-394). These granodiorites/adamellites form the major components of the pluton west of the Narrows in Georges Bay (fig. 1, Dg14). Irregular masses of hornblende monzonite occur within granodiorites between St Helens and Priory, and porphyritic biotite adamellites occur 2.5 km north-west of the bridge at St Helens. A long narrow dyke of hornblende biotite granodiorite porphyry (table 5, 69-244) extends south from the major southern contact of the pluton and to the north at least as far as the bridge at St Helens (fig. 1, Dg12). Cocker (1971) considered that the dyke extended in a NNE direction to the coast west of Binalong Bay, and intruded the northern contact between the St Helens and Mt Pierson Plutons. The most easterly granitic mass centred 3 km south-west of St Helens Point (fig. 1, Dg13) consists of biotite granodiorite (table 5, 69-415, 49-417, 70-149). An arcuate dyke-like body of biotite granite/adamellite occurs immediately west of this biotite granodiorite mass and extends from Grant Point in the north, to

Table 5. MODAL ANALYSES (VOL. %) OF GRANITIC ROCKS FROM THE ST HELENS PLUTON, BLUE TIER BATHOLITH.

Thin section no.	70-171	70-149	69-244	69-246
Chemical analysis no.	702716	702690		702689
Quartz	15.7	29.4	33.2	36.4
K-feldspar perthite	0.0	23.4	20.9	24.6
Plagioclase	37.7	36.7	33.4	31.1
Biotite	4.7	8.6	8.9	7.8
Muscovite	0.0	0.1	0.0	0.0
Chlorite	0.0	1.8	0.0	0.0
Hornblende	4.3	0.0	3.3	0.0
Groundmass	37.4	0.0	0.0	0.0
Accessories	0.0	0.0	0.3	0.1

Thin section no.	69-147	69-394	69-415	69-416
Chemical analysis no.				
Quartz	33.2	34.8	36.1	40.5
K-feldspar perthite	15.2	10.5	14.4	37.5
Plagioclase	42.1	39.9	40.0	14.6
Biotite	9.5	13.0	9.3	0.6
Muscovite	<0.1	0.0	0.3	6.9
Hornblende	0.0	1.2	0.0	0.0
Accessories	0.0	0.5	0.0	<0.1

St Helens Island in the south (fig. 1, Dg11). Each of these main rock units is briefly described below.

The major component of the St Helens Pluton (fig. 1, Dg14) has been termed the George River Granodiorite by Cocker (1971). It is heterogeneous, ranging from mainly hornblende biotite granodiorite north of St Helens (e.g. table 5, 69-394) to biotite adamellite, with rare hornblende, south of St Helens (table 5, 69-246). It is generally a dark grey, medium-grained rock containing 5-20% of ferromagnesian minerals with biotite generally predominant. Although it contains dioritic enclaves they are less abundant than in the granodiorites of the Pyengana and Gardens Plutons. The granodiorite is generally massive although a cataclastic foliation, steeply dipping to the north, is developed in places, particularly in the north-east of the pluton and 1-2 km south-west of the bridge at St Helens. In thin section the granodiorite/adamellite is medium-grained with an average grain size of 1.5 mm, and consists of subhedral, zoned plagioclase, anhedral quartz and K-feldspar, green-brown biotite and dark green hornblende. Plagioclase is usually andesine, with normal and oscillatory zoned crystals ranging from An₄₀-An₅₀ in core areas, to oligoclase (An₂₀) on rims. K-feldspar with well developed cross-hatch twinning poikilolitically encloses the other components. Impersistent mineralogical banding and alignment of biotite and hornblende define a foliation in some rocks. These deformed rocks have similar characteristics to those with cataclastic foliations from the Pyengana Pluton, but evidence of annealing is less apparent.

The George River Granodiorite includes irregular bodies of monzonite which have been termed the Priory Monzonite by Cocker (1971). Their relationship to the granodiorites is not clear. The monzonites are medium- to coarse-

Table 6. COMPOSITION AND TRICLINICITY OF K-FELDSPARS FROM GRANITIC ROCKS, BLUE TIER BATHOLITH

Pluton	Specimen No.	Nature of K-feldspar	Mole % K-feldspar	Mole % K-feldspar-heated	Δ
St Helens Pluton	70-23	Phenocrysts in granodiorite porphyry	93	80	<0.18
	70-24		99	74	<0.18
Poimena Pluton	65-230A	Phenocrysts in porphyritic biotite granite/adamellite	92	-	<0.18
	65-230B		93	-	<0.18
	68-133		99	-	<0.18
	68-138		94	-	<0.18
	70-20		95	73	<0.18
	70-26A		93	87	<0.18
	70-26B		93	82	<0.18
	70-26C		93	78	<0.18
Mt Pierson Pluton	69-389A	Coarse-grained K-feldspar crystals	88	-	0.99
	69-398B		84	-	0.97
	70-25A	Phenocrysts in porphyritic biotite granite/adamellite	94	80	<0.18
	70-25B		93	78	<0.18
Ansons Bay Pluton	69-383A	Phenocrysts in coarse-grained porphyritic biotite granite	93	74	<0.18
	69-383B		88	74	<0.18
	69-383C		93	77	0.34
	70-18B	Sub-phenocrysts to coarse-grained crystals in porphyritic to coarse-grained biotite granite/adamellite	92	73	0.36
	70-18C		90	74	0.45
	70-18D		92	75	<0.18
	69-374		88	73	<0.18
	69-383D	Coarse crystals in coarse-grained biotite granite/adamellite	92	74	0.25
69-383E	92		74	0.45	
70-18A	92		73	0.81	
Poimena Pluton	68-141	Coarse crystals in pegmatite	100	-	0.61
	68-146		95	-	0.30

grained rocks with a mottled appearance due to contrasting pink K-feldspar and dark green hornblende. In thin section the monzonites consist of anhedral plagioclase (probably oligoclase), K-feldspar (probably microcline) and euhedral hornblende which is partly replaced by chlorite and epidote. Although the rock does not have a macroscopic foliation, most grains are deformed and recrystallisation has produced subgrains in feldspar aggregates and possible recrystallisation of hornblende.

An irregular mass of porphyritic biotite adamellite is centred about 2 km west of the bridge at St Helens. It is poorly exposed and on a regional scale was not separated from the dominant granodiorites of the area. However Cocker (1971) mapped it as a separate unit and termed it the Medeas Cove Adamellite. It is a medium-grained rock with phenocrysts of K-feldspar, subhedral broadly zoned oligoclase, anhedral quartz and less than 5% biotite.

The long granodiorite porphyry dyke that extends southwards from St Helens to Scamander has been termed the Scamander Tier Granodiorite (Cocker, this Bulletin, p. 132) and previously the Scamander Tier Granodiorite Porphyry by Cocker (1971). It forms part of the granitic rocks mapped, and grouped under the collective name of the Coastal Range Quartz Monzonite by Walker (1957). The major rock type is a granodiorite porphyry although porphyritic granodiorite, hornblende biotite adamellite (table 6, 69-244) and porphyritic biotite adamellite also occur. Although outcrops are relatively rare, the dyke is easily mapped from the abundant round boulders of the granitic rocks and exposures in road cuttings. The rock is generally light grey to dark grey in colour with scattered large (1-10 cm) orthoclase microperthite phenocrysts (triclinicity: $\Delta = <0.18$, table 6) and smaller (1-5 mm) quartz, plagioclase, biotite and hornblende phenocrysts in a fine-grained groundmass. Both round dioritic enclaves and sub-angular xenoliths of Mathinna Beds are moderately abundant, particularly adjacent to contacts. Some alignment of orthoclase phenocrysts subparallel to the dyke walls is evident near the centre of the dyke.

In thin section quartz and plagioclase phenocrysts are strongly embayed, and quartz phenocrysts are rarely rimmed by fine-grained hornblende. Plagioclase phenocrysts are usually normally zoned from andesine (An_{45}) to oligoclase (An_{20} - An_{25}). The groundmass is fine-grained (generally less than 0.1 mm) and consists of anhedral quartz, K-feldspar, plagioclase, hornblende and biotite. Hornblende forms clots up to 5 mm in diameter in places and is pleochroic; α = pale yellow-green, β = green, γ = dark blue-green. Biotite is also pleochroic; α = yellow, β = red-brown, γ = dark brown and is slightly bent or kinked in places. Other evidence of strain is sparse, although quartz grains have a weakly developed undulose extinction. The porphyry is finer grained adjacent to both contacts, which appear to be chilled margins.

At Binalong Bay, well developed mineralogical layering occurs in granitic rocks which Cocker (1971; this Bulletin, p. 133, 148) considers to be continuous with the Scamander Tier Granodiorite. The main feature is rhythmic banding of biotite-rich and biotite-poor layers which are often gently inclined (plate 4). Structural features include small-scale slump structures, pot-holed filled with biotite, and small-scale unconformities within the layering. The layering is remarkably continuous when compared to biotite schlieren in other granitic rock types of the Blue Tier Batholith, and is similar to that described by Claxton (1968).

The granite extending as a broad arcuate dyke from Grant Point to St Helens Island has been termed the Grant Point Granite by Cocker (1971; this Bulletin, p. 135). There are excellent coastal exposures of the granite at Grant Point and on hills 2 km to the south-west, but elsewhere there is little but weathered granite rubble. Its contact with granodiorites to the east

and west is not well exposed but dykes of similar granite intrude both granodiorite bodies. Similar rocks also occur on St Helens Point and have been tentatively correlated with the Grant Point Granite (fig. 1). Aplite and pegmatite dykes are more common cutting the granites at St Helens Head than invading other granitic rocks of the batholith. The granite is porphyritic with K-feldspar phenocrysts in a fine-grained groundmass. Mafic enclaves are relatively common in places. In thin section the granite consists of K-feldspar phenocrysts, 1-2 cm in length, with both Carlsbad and cross-hatch twinning, in a fine-grained, 0.1-0.3 mm, groundmass of quartz, plagioclase and biotite. Plagioclase is zoned from andesine (An_{40}) to oligoclase (An_{20}), and biotite is pleochroic; α = yellow-brown, β = red-brown, γ = dark brown. Both biotite and plagioclase are included in K-feldspar phenocrysts. Biotite comprises 5-8% of the rock.

The biotite granodiorite (table 5, 69-415, 69-417, 70-149) extending from St Helens Point to Akaroa, 5 km to the south-west, has been termed the Akaroa Granodiorite by Cocker, (1971; this Bulletin, p. 135). It is well exposed along the coastline and on a small hill near Akaroa, where the granite has been quarried, but elsewhere it is obscured by sand dunes or the sea. Where exposed it occurs as large rounded outcrops with widely spaced joints, and contains only rare mafic enclaves or biotite schlieren. Its most distinctive feature is the large, optically continuous K-feldspar crystals that poikilitically enclose biotite, quartz and plagioclase (plate 9). These crystals are up to 5 cm in diameter and can be seen in hand specimen where the cleavage face coincides with the rock surface. In thin section the K-feldspar has well developed cross-hatch twinning and appears to be microcline. It encloses anhedral quartz, red-brown biotite and subhedral zoned plagioclase (An_{35} - An_{10}) which average one millimetre in diameter. Myrmekitic intergrowths of plagioclase and quartz are common. Biotite constitutes 8-10% of the rock and hornblende is absent.

Other rock types recorded from the St Helens Pluton by M.J. Longman (pers. comm.) are diorite and gabbro. These have not been detected in any major bodies in the present study, but chemical analyses of these rocks (611470 and 611471) are presented in Table 21. Cocker (1971) has included 611470 in the Priory Monzonite.

Minor granodiorite bodies

Within the Hogan Track goldfield, approximately 18 km WSW of St Helens bridge, a narrow granodiorite body occurs on the eastern margin of the Poimena Pluton (fig. 1, Dg13). It is poorly exposed, but appears similar in texture and composition to the marginal phase (eastern contact) of the Pyengana Pluton. It is a medium-grained, pale grey rock comprising abundant anhedral quartz and subhedral zoned crystals of andesine that are poikilitically enclosed in K-feldspar with cross-hatch twinning (microcline?). Small clots of red-brown biotite, partly altered to chlorite, are scattered throughout the rock and contain abundant inclusions of magnetite, zircon and apatite. Evidence of deformation of the rock includes bent cleavages in andesine, kinked and bent biotite flakes and undulose extinction in quartz. The granodiorite is the host rock to gold-silver mineralisation at the Trafalgar and Double Event mines.

A small body of biotite granodiorite and hornblende-biotite granodiorite occurs about 3 km south of Goshen (fig. 1, Dg15). It is similar in mineralogy and texture to the granodiorite described above, but hornblende occurs commonly as irregular clots, with or without biotite, scattered throughout the rock. A common feature of this rock in thin section is the delicate graphic intergrowth of quartz and K-feldspar that occurs interstitially to plagioclase (andesine, An_{35} - An_{40}) and quartz.

A small exposure of a dark grey granitic rock occurs on the coast about 3 km north of Scamander, and is probably related to rocks of the St Helens Pluton. It is a hornblende granodiorite or tonalite porphyry, consisting of phenocrysts of hornblende and zoned basic andesine-oligoclase ($An_{45}-An_{25}$), up to 4 mm in length, with minor quartz and chloritised biotite in a fine-grained groundmass of quartz, plagioclase, and K-feldspar.

PORPHYRITIC AND COARSE-GRAINED BIOTITE GRANITE/ADAMELLITES

Poimena Pluton

The Poimena Pluton (fig. 1, Dg6) is the largest pluton of the Blue Tier Batholith, and occupies about 45% of its surface area and probably a greater percentage of its volume. The major part of the pluton, south of South Mt Cameron and north of Goshen, is rectangular in shape with the longer sides trending NNW. The northern part of the western contact is with Mathinna Beds, and the eastern contact is marked by a thin screen of Mathinna Beds separating it from the Gardens Pluton. About one kilometre south of Gladstone the NNW-trending eastern contact swings abruptly E-W for about 12 km. About one kilometre south of Banca the western contact has an equivalent abrupt change to an E-W direction for about 8 km (fig. 1, 2). The contacts revert in a similar manner to a NNW trend, and a further rectangular segment of the pluton extends to the northern limit of exposure on Waterhouse Point. The southern part of the pluton is an irregularly shaped segment, elongate NW-SE, that separates two parts of the Pyengana Pluton, and extends as far south as the Hogans Track goldfield.

Exposure of the granitic rocks of the pluton is variable. In the Blue Tier area exposure is excellent with large, round tors providing regions of almost continuous exposure. Elsewhere scattered tor-like exposures are separated by sandy soils or by granite-derived gravel. Soils are particularly poor for agriculture, and very little of the pluton is under pasture. Areas of extensive Tertiary cover occur north and north-west of Pioneer, but sufficient bedrock is exposed in river valleys and alluvial tin workings (fig. 1) to enable a bedrock map to be produced (fig. 2). Exposure is generally poor north of Waterhouse, and the western margin of the pluton is poorly defined towards Waterhouse Point. Poor exposure precludes precise mapping east of Gladstone where the Poimena Pluton apparently forms a bulge-like projection into the Gardens Pluton. Here bedrock exposure is restricted by the occurrence of thick sequences of Tertiary sediments and by remnants of Tertiary basalt.

Considering its size the pluton is remarkably homogeneous, consisting of porphyritic biotite granite/adameellites throughout (table 7, fig. 3). The normal granite/adameellite consists of large K-feldspar phenocrysts, generally about 5 cm in length, in a medium-grained groundmass. Within the pluton variations occur in the proportion of phenocrysts (5-50%) and biotite (5-15%), and in the grain size of the groundmass. Variations are commonly as great within an area as they are between areas, and no systematic variations were detected that could be mapped on a regional scale. In places the granite/adameellites have a well developed foliation defined by the planar alignment of tabular K-feldspar phenocrysts. A detailed study of the orientation of this foliation was carried out in the Blue Tier area (Groves, 1968a). Here steeply dipping foliations form a major set, approximately mutually perpendicular, which trend NW ($297-317^\circ$) and NE ($22-42^\circ$), and subhorizontal foliations are also present. There is no clear regional distribution of foliations to form discrete cells, but rather the three foliation orientations may all be present within a small area. The steeply-dipping foliation directions are roughly coincident with the long and short axes of the pluton, and possibly with major joint sets (Groves, 1968a). The significance of the foliation

Table 7. SIMPLIFIED COMPOSITIONS (% MASS) OF PORPHYRITIC BIOTITE GRANITE/ADAMELLITES (*) CALCULATED FROM ROCK ANALYSES USING CHEMICAL ANALYSES OF BIOTITE AND X-RAY DETERMINATIONS OF K-FELDSPAR COMPOSITIONS, AND MODAL ANALYSES (VOL. %) OF PORPHYRITIC AND COARSE-GRAINED BIOTITE GRANITE/ADAMELLITES (†) FROM POIMENA, MT PIERSON AND ANSONS BAY PLUTONS, BLUE TIER BATHOLITH.

POIMENA PLUTON				
Thin section no.	*68-133, 134	*68-135, 136	*68-138, 140	*68-147
Chemical analysis no.	682046	682047	682048	682059
Quartz	37.1	38.5	35.1	40.7
K-feldspar perthite	33.7	32.9	34.6	34.5
Plagioclase	21.1	20.7	23.2	18.4
Biotite	8.1	7.8	8.1	6.3

		POIMENA	MT PIERSON	ANSONS BAY
Thin section no.	*68-151, 152	†70-155	†69-398	†69-374
Chemical analysis no.	682062	702701		
Quartz	41.0	37.7	36.7	44.6
K-feldspar perthite	28.5	33.5	34.0	29.7
Plagioclase	23.3	22.0	22.5	18.1
Biotite	7.1	6.8	6.8	6.8
Muscovite	0.0	0.0	0.0	0.8

is not clear. It has the characteristics of a flow foliation, there are no deformational fabrics in the groundmass and the phenocrysts are not broken or bent, but the three distinctive orientations suggest a relationship to regional structures rather than flow (convection?) cells.

The porphyritic biotite granite/adameellites are pale grey, porphyritic rocks containing minor biotite schlieren and rare biotite-rich enclaves. Calculations from chemical analyses of rocks, combined with mineral compositions from chemical, optical and X-ray diffraction data, indicate that K-feldspar is always in excess of plagioclase and that the rock compositions cluster around the boundary between granite and adamellite on Nockolds (1953) classification (fig. 3). The orthoclase phenocrysts (triclinicity: $\Delta = <0.18$) have Carlsbad twins and vary from stringlet microperthites to string and bead microperthites that appear to be exsolution perthites. The composition of the K-feldspar phase (measured by X-ray diffraction following Orville, 1958) ranges from $Or_{92}Ab_8$ to $Or_{99}Ab_1$, and the pre-exsolution composition measured on homogenised feldspars ranges from $Or_{73}Ab_{27}$ to $Or_{82}Ab_{18}$ (table 6).

In thin section the groundmass (or rock mass dependent on the abundance of phenocrysts) consists of quartz, K-feldspar and biotite. Clusters of anhedral quartz crystals, with slight undulose extinction, and discrete, subhedral, sericitised plagioclase crystals are poikilitically enclosed in cloudy K-feldspar microperthite which displays patchy cross-hatch twinning. The plagioclase (An_{25}) displays rare oscillatory zoning with cores of andesine (up to An_{32}), and commonly has a rim of clear albite. Biotite, which is pleochroic; α = yellow-brown, β = red-brown, γ = dark brown, occurs as clusters of ragged crystals that are partly altered to muscovite and more rarely chlorite, and contain inclusions of magnetite, zircon and apatite. Biotite generally constitutes 6-8% of the rock (table 7).

Despite the foliation defined by the orientation of tabular orthoclase phenocrysts, mineralogical banding in the granite/adamellites of the pluton is rare. However, such banding is well-developed in an isolated coastal exposure which forms a window in an outcrop of Mathinna Beds where the eastern boundary of the pluton strikes the north coast, between Tomahawk and Boobyalla (Groves and Jennings, 1973). Here biotite-rich and biotite-poor bands define a subhorizontal mineralogical layering in a small domal intrusion of granite/adamellite. Zones rich in xenoliths of hornfelsed Mathinna Beds are commonly subparallel to the mineralogical banding.

Mt Pierson Pluton

The Mt Pierson Pluton (fig. 1, Dg7) is the second largest biotite granite/adamellite pluton in the Blue Tier Batholith. It is irregular in outline, but can be divided into two roughly rectangular sections: a northern section with its longer E-W axis centred near Mt Pierson, and a southern section with a long N-S axis, extending south of Goshen (fig. 1, 2). Its northern boundary is an essentially straight, sharp contact with the Gardens Pluton, and its western margin is an irregular, poorly-defined contact with the Poimena Pluton. North of Binalong Bay, the Mt Pierson Pluton extends east of the present coastline, whereas south of Priory the eastern margin is initially in contact with the St Helens Pluton for about 5 km, and then, further to the south with the Constables Creek Sheet, which wraps around the southern contact. The boundary between the Mt Pierson and St Helens Plutons between Binalong Bay and Priory is convex towards the south, and is defined by an offshoot of the Scamander Tier Granodiorite (Cocker, 1971), although this minor intrusion was not recognised during regional traversing. Extending to the south from the Mt Pierson Pluton is a concordant, southward-tapering dyke composed of coarse-grained granite/adamellite (fig. 1, Dg7) in the north, and consisting mainly of pale pink aplite and microgranite (fig. 1, Dg5) near its southernmost extension in the Avenue River [58/930915].

The major rock type of the pluton is a coarse-grained biotite granite/adamellite (table 7, fig. 3), but porphyritic varieties occur in places. Exposure is generally in the form of large round tors with intervening areas covered by gravel composed of quartz with minor feldspar and biotite. Outcrops are often deeply weathered, and composed of quartz, K-feldspar, plagioclase and biotite with minor muscovite as coarse-grained aggregates with an average grain size of 1-1.5 cm. Phenocrysts of K-feldspar, up to 10 cm long, occur in some exposures, but show no well-defined alignment. Biotite schlieren occur in places, but enclaves are rare.

In thin section the granite/adamellites consist of phenocrysts of perthitic orthoclase (triclinicity: $\Delta = <0.18$, table 6) in a coarse-grained aggregate of anhedral quartz, subhedral microcline ($\Delta = 0.97-0.99$, table 6), subhedral, broadly zoned plagioclase ($An_{20}-An_{35}$) and biotite, commonly in small aggregates. Biotite generally constitutes 6-8% of the rock and is pleochroic; $\alpha =$ yellow-brown, $\beta =$ red-brown, $\gamma =$ dark brown. Minor muscovite is present as an alteration of plagioclase. Microcline microperthite poikilolitically enclosed both biotite and plagioclase, and forms graphic intergrowths with quartz.

Ansons Bay Pluton

The Ansons Bay Pluton (fig. 1, Dg7) is elongate north-south with an eastern margin seaward, to the east of Georges Rocks. The pluton is intrusive into Mathinna Beds along its southern and western boundaries with the Mt William Sheet overlying part of this contact to the north-west (fig. 1, 2). The relationship of the Ansons Bay Pluton to the Musselroe Pluton west of

Cape Naturaliste is not known. Small areas of hornfelsed Mathinna Beds are observed within the Ansons Bay Pluton about 3 km north-west and 3 km south-west of Eddystone Point and elsewhere along the coastline (fig. 1, 2). Their significance in terms of the pluton margin is unclear.

The main rock types of the pluton are coarsely porphyritic to coarse-grained biotite granite/adamellites (table 7, fig. 3). Much of the bedrock is covered by Tertiary and Quaternary deposits, and with large round tors and low whalebacks of weathered granite constituting the exposures. When mapped in greater detail, a field distinction can be made between the main rock of the pluton, a coarse densely porphyritic granite/adamellite, and a more variable, medium-grained, sparsely-porphyritic variety with which it merges to the north and west. It is difficult to distinguish between the latter and marginal varieties of rocks forming the Musselroe Bay Pluton (fig. 30).

The granite/adamellites are similar to those of the Mt Pierson Pluton but are commonly coarser grained, with some very large phenocrysts up to 20 cm in length. Phenocrysts are orthoclase perthite (triclinicity: $\Delta = <0.18-0.34$, table 6), in a rock mass of quartz, oligoclase - acid andesine, biotite and K-feldspar with variable triclinicity ($\Delta = <0.18-0.81$, table 6). K-feldspar crystals which are slightly coarser grained than other components have low triclinicities ($\Delta = <0.18-0.45$) compared to normal K-feldspar crystals that poikilitically enclose other minerals ($\Delta = 0.25-0.81$). The biotite content of the granite/adamellites ranges from 6-8%.

A white finer-grained biotite adamellite (fig. 3) is well exposed on Eddystone Point [69/170480] but its relationship to the main mass of the Ansons Bay Pluton is uncertain. It is an even-grained adamellite with an average grain size of 3 mm, composed of quartz, oligoclase - acid andesine ($\sim An_{30}$), biotite and microcline patch- and string-micropertthite which poikilitically encloses the other components. Some graphic intergrowths of quartz and microcline are present, and minor muscovite occurs in places. Biotite has similar optical properties to that from the coarser grained rocks of the Ansons Bay Pluton, but is less abundant (generally 4-5%).

At Georges Rocks porphyritic biotite granite/adamellites similar to those of the Poimena Pluton intrude coarse-grained biotite granite/adamellites more typical of the Ansons Bay Pluton. Contacts are generally sharp, although commonly irregular. Such contacts are marked by abundant enclaves (generally of dioritic composition see plates 2, 3) and by accumulations of red-brown garnets, partly altered to biotite. The garnet has a refractive index of 1.802, a cell size $a = 11.593$, and contains 1.9% MnO. According to the diagrams of Winchell (1958) this corresponds to an approximate molecular composition of 85% almandine, 5% pyrope, 5% grossular and 5% spessartine. This lies within the compositional range given by Cocker (1973) for garnets from Tasmanian granitic rocks.

Boobyalla Pluton

The Boobyalla Pluton (fig. 1, Dg9) is a small isolated pluton whose relationship to the remainder of the batholith is unclear. Exposure is generally poor due to extensive cover of Tertiary and Quaternary sediments, except for patches of continuous exposure among low hills adjacent to the main Waterhouse-Gladstone Road (fig. 1). The main rock types are porphyritic biotite granites and granite porphyries (table 8, 70-158, fig. 3) which contain disseminated coarse-grained garnets or garnet-rich clots. The pluton is intrusive into hornfelsed Mathinna Beds to the west and south; elsewhere the margins are obscured. Within the Mathinna Beds are a series of discontinuous

pods of foliated to massive, porphyritic to medium-grained biotite granodiorite (table 8, 70-157), which occupy the topographic lows of the area. South of the Waterhouse-Gladstone Road, and to the west of the Boobyalla River there is a complex zone of discontinuous bulbous-shaped intrusions of biotite granodiorite into Mathinna Beds, and similar intrusions occur on the coastline in the northern extension of this zone between Tomahawk and Boobyalla (Groves and Jennings, 1973).

The normal rocks of the pluton are porphyritic biotite granite (comprising orthoclase micropertthite phenocrysts in a fine- to medium-grained groundmass of quartz, oligoclase, microcline and biotite) or granite porphyry with phenocrysts of quartz, orthoclase and oligoclase in a fine-grained groundmass. Red-brown garnets are scattered throughout the rocks or occur in small clusters or clots, commonly partly replaced by biotite which is optically similar to biotite (4-5%) scattered throughout the rock i.e. α = pale brown, β = red-brown, γ = dark brown. The garnet has a refractive index of 1.803, cell size $a = 11.537$, and contains 1.2% MnO. According to the diagrams of Winchell (1958), this corresponds to an approximate molecular composition of 80% almandine, 12% pyrope, 5% grossular and 3% spessartine, which is a similar composition to that recorded by Cocker (1973) for garnets from Tasmanian granitic rocks.

Granodiorites (fig. 1, Dg15) within the Mathinna Beds adjacent to the Boobyalla Pluton are even-grained to porphyritic rocks containing rare clots of hornblende. They consist of andesine, quartz and microcline, and biotite which is optically similar to that in the granites of the Boobyalla Pluton but is more abundant (8-10%). Evidence of strain includes quartz with strongly undulose extinction, kinked and bent biotite flakes and plagioclase twins.

Musselroe Pluton

The Musselroe Pluton (fig. 1, Dg6) is poorly defined and its status as a discrete, structurally significant unit is questionable, because its relationships to the Ansons Bay Pluton in the south-east, and the Rushy Lagoon Pluton in the west are unclear. The pluton occupies low-lying swampy ground and is largely covered by Quaternary sand. It crops out as isolated headlands along the coast, and forms low hills south-east and south-west of Musselroe Bay. Locally the pluton is unconformably overlain by Permian sediments intruded by Jurassic dolerite, but generally the relationships are obscure and faulted contacts are suspected.

Cursorry traversing suggests the main rock type is a porphyritic biotite granite/adamellite with large K-feldspar and biotite (6-8%). However coarse-grained biotite granites, similar to those of the Ansons Bay Pluton also occur, particularly in coastal exposures north-west of Cape Naturaliste (fig. 1). The main rock type exposed on the headland at the eastern extremity of Musselroe Bay is a microgranite or porphyritic microgranite, which appears to have been intruded by the normal porphyritic biotite granite/adamellite of the pluton.

Rushy Lagoon Pluton

The status of the Rushy Lagoon Pluton (fig. 1, Dg8) as a discrete body is also questionable, as its contact with the Musselroe Pluton is not clearly defined, and may be gradational. The major rock type is a coarsely porphyritic to coarse-grained muscovite biotite granite/adamellite similar to the granitic rocks of the Ansons Bay Pluton but containing significant muscovite. In general the granite/adamellites are coarser grained than those of the Musselroe Pluton. The present exposure of the pluton defines a rectangular

shape (long axis, NNW-SSE) but the true limits of the pluton are unknown due to extensive Jurassic dolerite and Permian sedimentary sequences which obscure the granitic basement.

BIOTITE AND MUSCOVITE-BIOTITE GRANITES AND ADAMELLITES

Introduction

Although biotite and muscovite-biotite granites form relatively small bodies throughout the batholith, they are important components because of their close association with the cassiterite mineralisation of the area. Several of these granites have almost identical major petrographic and chemical characteristics. These are the Mt William Sheet, the Mt Paris Mass, the Mt Cameron Sheets and the Lottah Sheets. Other granites are broadly similar petrographically, but have important chemical differences to the group above. These include the Constable Creek Sheet and the Little Mt Horror Sheet. The Sheoak Hill Pluton has been included within this broad group, although its strong cataclastic foliation distinguishes it from the others.

Sheoak Hill Pluton

The Sheoak Hill Pluton (fig. 1, Dg10) is a rectangular pluton with a long axis trending NNW-SSE. Its western and southern contacts are against the Poimena Pluton, and its eastern contact is with hornfelsed Mathinna Beds. At its northern extremity it is faulted against granodiorites which intrude the Mathinna Beds (Groves and Jennings, 1973). The Sheoak Hill Pluton forms well exposed, blocky, well-jointed outcrops in low hilly country, although contacts with adjacent rocks are not observed and outcrop to the north is partly obscured by Quaternary sands. The pluton encloses an elongate screen of hornfelsed Mathinna Beds disposed NNW within its southern region.

The pluton consists of foliated biotite-muscovite adamellite (table 8, fig. 3), which contains very rare enclaves, generally xenoliths of recrystallised Mathinna Bed lithologies. The cataclastic foliation, defined by the alignment of biotite and muscovite and weak compositional banding, generally trends NNW, parallel to the elongation of the pluton, although adjacent to the coast the foliation strikes ENE. Throughout the pluton the foliation is near-vertical. In thin section the rock is fine- to medium-grained, with an average grain size of 0.5 mm. It consists of anhedral quartz, subhedral K-feldspar and sericitised plagioclase, and ragged flakes of biotite and muscovite. Accessory yellow-green tourmaline is common, and topaz and apatite are both present. The plagioclase is oligoclase ($\sim\text{An}_{10}$), and biotite is pleochroic; α = pale yellow-brown, β = red-brown, γ = dark red-brown. Biotite and muscovite occur as discrete grains, and there is no direct textural evidence for replacement of biotite by muscovite. Evidence of deformation and recrystallisation is abundant, and includes kinked cleavages in biotite and muscovite, and microfaulted twinning in plagioclase. Quartz has an undulose extinction, and in some sections shows recrystallisation textures including subgrain development. The degree of deformation and recrystallisation of the adamellite is variable throughout the pluton, but is most marked at its northern extremity in the coastal section.

Constable Creek Sheet

The Constable Creek Sheet (fig. 1, Dg5, Dg7) is a composite body of microgranites and fine- to medium-grained biotite granites and adamellites that fringe the eastern and southern margins of the Mt Pierson Pluton. The outcrop width is about one kilometre although isolated exposures within hornfelsed Mathinna Beds occur in Constable Creek. The granites appear to form an essentially flat-lying but undulating sheet which shelves beneath

Table 8. MODAL ANALYSES (VOL. %) OF GRANITIC ROCKS FROM THE BOOBYALLA AND SHEOAK HILL PLUTONS, BLUE TIER BATHOLITH.

Thin section no.	BOOBYALLA		SHEOAK HILL
	70-157	70-158	70-156
Chemical analysis no.	702705	702706	702704
Quartz	47.9	24.8	32.0
K-feldspar perthite	10.8	52.8	32.8
Plagioclase	31.9	16.6	25.3
Biotite	9.4	4.0	4.2
Muscovite	0.0	0.6	5.3
Accessories	0.1	1.1	0.4

Table 9. MODAL ANALYSES (VOL. %) OF MUSCOVITE-BIOTITE GRANITES FROM MT CAMERON SHEETS, BIOTITE GRANITE/ADAMELLITES FROM CONSTABLES CREEK SHEET, AND MUSCOVITE-BIOTITE GRANITE/ADAMELLITE FROM LITTLE MT HORROR SHEET, BLUE TIER BATHOLITH.

Thin section no.	70-153	MT CAMERON SHEETS		
		70-154	71-569	71-570
Chemical analysis no.	702699	702700	702702	702703
Quartz	28.2	43.0	37.6	35.6
K-feldspar perthite	29.0	17.7	27.2	32.0
Albite-acid oligoclase	35.6	29.3	33.1	25.9
Biotite	3.6	1.6	1.6	5.0
Muscovite	3.3	8.4	0.6	1.5
Accessories	0.2 ¹	0.0	0.0	0.0

Thin section no.	CONSTABLES CREEK SHEET		LITTLE MT HORROR SHEET	
	70-168	70-169	70-176	70-152
Chemical analysis no.	702712	702713	702697	702698
Quartz	43.0	40.2	33.0	40.6
K-feldspar perthite	34.6	31.1	30.1	25.1
Albite-acid oligoclase	20.2	24.1	28.2	22.9
Biotite	1.9	4.3	4.7	4.0
Muscovite	0.1	0.3	2.5	1.8
Chlorite	0.0	0.0	1.4	0.0
Accessories	0.2	0.0	0.1	5.6

Mathinna Beds to the east and south (Groves, 1972a). The granites have sharp contacts with the overlying Mathinna Beds, but a gradational contact zone against the Mt Pierson Pluton at the base of the sheet. This contact zone is marked by a gradual decrease in the number of fine- to medium-grained granite intrusions into the coarser grained rocks of the Mt Pierson Pluton.

The Constable Creek granitic rocks are well exposed as bedrock in creek sections, but elsewhere appear mainly as rubble on hill slopes. These rubble blocks are characteristically smaller and more angular, due to closer spaced jointing, than those derived from the coarse-grained granites of the Mt Pierson Pluton. The Constable Creek granites and adamellites are characteristically pink coloured and are rarely fresh. They are generally even-grained, although porphyritic rocks with K-feldspar phenocrysts up to 10 mm in length are present at some localities. Mirolitic cavities, partly filled with quartz and tourmaline, occur in some of the coarser grained rocks, and pegmatitic patches and quartz and tourmaline veins are also present. The average grain size of the rocks ranges from 0.5-2.0 mm (usually 1.0-1.5 mm). They consist of granular intergrowths of quartz, K-feldspar, plagioclase and biotite with accessory muscovite, magnetite, tourmaline and apatite. Graphic and myrmekitic intergrowths are common. Less biotite is present than in the adjacent Mt Pierson granites, generally comprising 2-5% of the rock. The pleochroic scheme varies with β green-brown, brown or red-brown. Muscovite is never a dominant component, and appears to have replaced biotite and, or, plagioclase. Plagioclase ranges from albite (An_5) to oligoclase (An_{15}) and the rocks range from granites to adamellites (fig. 3). At the Echo Mine in Constable Creek [68/000020], mineralised greisens occur in a local dome in the roof zone of the sheet. The variation in composition of the granitic rocks is well displayed at this locality.

Little Mt Horror Sheet

The Little Mt Horror Sheet (fig. 1, Dg4) has a subcircular outcrop pattern, and occurs within the Poimena Pluton approximately 2.5 km north of a contact with Mathinna Beds. It is essentially a sheet-like body, about 100-120 m in thickness, emplaced in the Poimena Pluton. The mapped boundary is the basal contact of the sheet, although porphyritic biotite granite/adamellites at the top of Little Mt Horror may represent the roof of the intrusion. The sheet is well exposed on the low hills surrounding Little Mt Horror with blocky outcrops partly obscured by screes of subangular rubble.

The sheet has been described by Baillie (1973) and a brief summary is presented here. The sheet is a composite body consisting of muscovite-biotite granites and adamellites, quartz porphyries, and aplites which contain tourmaline nodules up to 5 cm in diameter. The main rock type is a pink, even-grained muscovite-biotite granite with an average grain size ranging from 0.5-1.0 mm. It consists of quartz, K-feldspar with Carlsbad twinning, albite (An_5), biotite and muscovite with accessory tourmaline, magnetite and apatite. The total mica content ranges from 5-10% (generally 6-8%, table 9), which is considerably higher than most of the muscovite-bearing, even-grained granites of the batholith. The biotite is pleochroic; α = pale yellow-brown, β = red-brown, γ = dark brown or dark red-brown. Muscovite occurs as discrete flakes and as an alteration product of biotite and albite. In places more mafic rocks occur and these commonly contain oligoclase (An_{15}) rather than albite, and are adamellites (fig. 3). In these rocks the oligoclase may be broadly zoned with a sericitised core area, and myrmekitic intergrowths are common. K-feldspar phenocrysts are present at some localities.

The base of the sheet is transitional into the porphyritic biotite granite/adamellites of the Poimena Pluton over about 10 m. The transitional rock is a slightly porphyritic biotite adamellite containing up to 10%

biotite and minor muscovite. K-feldspar phenocrysts constitute about 5% of the rock and smaller quartz phenocrysts are also present.

Mt William Sheet

The Mt William Sheet (fig. 1, Dg1) is an elongate body that straddles the regional contact between the Ansons Bay Pluton in the east and Mathinna Beds in the west. The mapped contact to west, south and east appears to be the subhorizontal base of a sheet whose upper contact has not been preserved. Near the southern extension of the sheet there are 'windows' through the intrusion into the Mathinna Beds, exposed beneath. The area covered by the sheet has been mapped more precisely by D.J. Jennings and R.F. McShane (fig. 30). Exposure is generally good with the granitic rocks of the sheet forming the elongate ridge and summit of Mt William [69/030585] rising to 140 m above the coastal plain. The sheet is partly obscured by marshy lagoons and sandy plains at its northern and southern ends but bedrock contacts are observed in the central part of the exposed area.

The sheet consists throughout of even, medium-grained muscovite-biotite granite or biotite-muscovite granite. These rocks are invariably pink to yellow-brown in colour, and seldom fresh. The total mica content is typically low (2-5%; table 10), and biotite is generally the more common although granites with dominant muscovite are present. Enclaves are virtually absent, even adjacent to the contact with Mathinna Beds, and biotite schlieren and compositional layering are rare. In thin section the rocks are even-grained granular aggregates of quartz, K-feldspar microperthite, albite (An₇-An₁₀), biotite and muscovite with minor accessory apatite. The average grain size of individual rocks ranges from 0.8-2.0 mm (generally 1.5-2.0 mm). The K-feldspar is either untwinned or shows combinations of microcline and Carlsbad twinning, and commonly forms graphic intergrowths with quartz. Biotite is generally pleochroic; α = yellow-brown, β = green-brown, γ = dark brown, and contrasts with the red-brown biotite of the adjacent Ansons Bay Pluton. Muscovite occurs as discrete flakes, and more rarely replacing feldspar and biotite. The relative proportions of albite and K-feldspar vary but are approximately equal.

Mt Cameron Sheets

The Mt Cameron Sheets can be broadly divided into two categories: a discontinuous series of sheets that flank the eastern, southern and western slopes of Mt Cameron (fig. 1, Dg1) and are intrusive into the Poimena Pluton, and an intrusive mass of indeterminate form (fig. 1, Dg3) that constitutes the northern flank of Mt Cameron and lies between Mathinna Beds to the north and the Poimena Pluton to the south (fig. 1, 2, 5). Almost continuous outcrop exists on Mt Cameron, but the southernmost sheets plunge beneath thick Tertiary sedimentary sequences which extend south and west from the mountain. Aplite and microgranite (fig. 1, Da) also intrude the Poimena Pluton in the Mt Cameron area and are grouped with the Mt Cameron Sheets. They form an anastomosing pattern of rapidly lensing and subhorizontal sheets linked by steep discontinuous dykes.

The sheets form large tor-like outcrops and elevated platforms on the flanks of Mt Cameron. The rocks are pink to yellow-brown in colour, and are commonly weathered. Smallmiarolitic cavities are present in places and are partly filled with quartz, tourmaline and minor wolframite. Enclaves, biotite schlieren, and compositional layering are rare.

The southernmost sheets (Dg1) are composed of even-grained muscovite-biotite granites and biotite-muscovite granites. These are fine- to medium-grained rocks with an average grain size of about 1.5 mm. They consist of

Table 10. MODAL ANALYSES (VOL. %) OF MUSCOVITE-BIOTITE GRANITES FROM THE MT WILLIAM SHEET AND A MUSCOVITE-BIOTITE GRANITE FROM THE MT PARIS MASS, BLUE TIER BATHOLITH.

Thin section no.	69-387	70-159	70-160	70-162
Chemical analysis no.		702722	702723	702707
Quartz	36.1	47.8	36.8	38.1
K-feldspar perthite	39.6	28.5	29.4	30.3
Albite	21.3	19.9	31.8	27.9
Biotite	1.5	2.7	1.5	1.3
Muscovite	1.2	1.1	0.6	2.3
Accessories	0.1	0.1	0.0	0.1

Thin section	70-163	70-164	70-165	70-19*
Chemical analysis no.	702725	702708	702709	
Quartz	34.1	34.8	35.7	40.8
K-feldspar perthite	35.1	27.3	25.7	28.4
Albite	26.7	33.8	33.5	27.2
Biotite	2.4	2.4	3.0	2.3
Muscovite	1.7	1.7	2.1	0.7
Accessories	0.0	0.0	0.0	0.6

*Muscovite-biotite granite, Mt Paris Mass.

Table 11. MODAL ANALYSES (VOL. %) OF MUSCOVITE-BIOTITE GRANITES AND LEUCOGRANITES, ANCHOR MINE, PART OF LOTTAH SHEETS, BLUE TIER BATHOLITH.

Thin section no.	68-142	68-143	68-129	68-153	71-3	71-1
Chemical analysis no.	682049	682050	682055	682063	682066	682068
<i>Muscovite-biotite granites</i>						
Quartz	37.1	36.0	35.2	35.0	32.7	35.2
K-feldspar perthite	32.8	32.2	29.8	32.4	25.1	25.6
Albite	22.8	25.1	31.0	25.3	34.7	31.1
Biotite	4.0	1.4	1.5	2.8	4.4	4.2
Muscovite	2.8	0.7	0.8	0.5	0.1	2.7
Accessories	0.6 ¹	4.5 ²	1.7 ³	4.0 ³	2.9 ³	1.2 ³

Thin section no.	68-144, 145	68-154	71-2
Chemical analysis no.	682051	682064	682067
<i>Leucogranites</i>			
Quartz	25.3	37.9	29.8
K-feldspar perthite	17.5	14.5	25.1
Albite	49.6	40.3	44.6
Biotite	0.6	0.4	0.0
Muscovite	4.8	6.9	0.5
Accessories	2.1	0.0	0.0

¹Cassiterite and topaz, ²Topaz and carbonate, ³Topaz.

quartz, K-feldspar with Carlsbad and microcline twinning, albite (An₈), biotite and muscovite with accessory topaz, apatite and purple fluorite. They are similar to the granites of the Mt William Sheet, but contain slightly more total mica (2-12%) with muscovite commonly in excess of biotite (table 9). Biotite is normally pleochroic; α = pale yellow-brown, β = green-brown, γ = brown and is partly replaced by muscovite along cleavage traces. Muscovite also replaces K-feldspar, forming anastomosing irregular veinlets through K-feldspar grains. Discrete muscovite flakes occur rarely (plate 11).

The northernmost mass (Dg3) is distinct from the southern sheets. It consists of medium- to coarse-grained biotite granite/adamellites which are slightly porphyritic in places. Although muscovite is present it is generally secondary after K-feldspar and is always subordinate to biotite which constitutes about 5-6% of the rock (table 9, 71-570). The granite/adamellite appears to be intermediate in texture and composition between the porphyritic biotite granite-adamellites of the Poimena Pluton and the even-grained granites of the southern Mt Cameron Sheets. In contrast to the green-brown biotites of the southern sheets, the biotites are pleochroic; α = pale brown, β = yellow-brown, γ = red-brown.

Mt Paris Mass

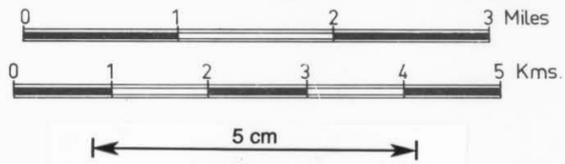
The Mt Paris Mass (fig. 1, Dg1, Dg2) has been mapped on a regional scale. The area was the subject of a B.Sc. Honours project which was not completed, so that anticipated information is not available, particularly details of the petrography of the granitic rocks.

The Mt Paris Mass intrudes Mathinna Beds near the western regional boundary of the Poimena Pluton (fig. 1, 5), has an irregular shape in plan as the mapped boundaries (at least on the western and southern margins) represent the contact between the gently undulating roof of the granitic mass and the Mathinna Beds in which it was emplaced. The northern contact is largely obscured by Tertiary sedimentary sequences and overlying basalts, and the eastern contact appears to be a steep contact against the Mathinna Beds and Poimena Pluton. An E-W trending dyke apparently extends from the eastern contact and intrudes the Poimena Pluton about 2 km north of Weldborough. Exposure is generally good, as the Mt Paris Mass forms a rough, mountainous area up to 920 m above sea level, and granite outcrop is virtually continuous in places. The precise form of the mass is uncertain as the basal contact is nowhere exposed, but by analogy with other muscovite-biotite granite bodies it is considered most likely to be a thick subhorizontal sheet.

The major rock type is a pink to yellow-brown even-grained muscovite-biotite granite. It is usually medium-grained with an average grain size of 1.5-2.0 mm, although fine-grained granites do occur, particularly adjacent to the granite roof in the southern part of the mass. Contacts with the Mathinna Beds are very sharp, and xenoliths of Mathinna Bed lithologies are rare. Mafic enclaves are absent. Poorly defined compositional layering is evident near Bells Hill [59/685225], but is not observed elsewhere. Along the northern margin of the sheet granite porphyry is the main granitic type, although patches of even-grained granite also occur. The boundary between granite porphyry (Dg2) and even-grained granite (Dg1) in Figure 1 is idealised, and divides areas dominated by each granitic rock type. The relationship between the two granites is unknown.

In thin section the even-grained granites are similar to those from the Mt William and Mt Cameron Sheets. They contain albite (An₈), green-brown biotite, and muscovite as discrete flakes and replacements of biotite and K-feldspar. Topaz is a common accessory mineral. The granite porphyry consists of large euhedral orthoclase perthite phenocrysts, 0.5-2 mm in length, subhedral quartz phenocrysts, 2-10 mm in diameter, and smaller acid

GEOLOGY TOMAHAWK - MT. CAMERON AREA BLUE TIER BATHOLITH



GEOLOGY by D.I. GROVES and D.J. JENNINGS
DRAUGHTING by T.R. BELLIS

- Approximate geological boundary
- 80° Bedding - strike and dip
- X Bedding - vertical
- 80° Cleavage - strike and dip
- | Cleavage - vertical
- ~ Foliation - strike and dip
- ~ Foliation - vertical
- Alluvial tin workings
- Rivers
- Roads
- Tracks
- Contours up to 600 ft. - 100 ft interval
over 600 ft. - 200 ft interval

- QUATERNARY**
- Undifferentiated alluvium, swamp, blown sand, beach sand
- TERTIARY**
- Sand, gravel, clay, ferruginous grit
 - Basalt
- JURASSIC**
- Dolerite
- UPPER DEVONIAN**
- Acid bodies: aplite, microgranite, quartz-feldspar porphyry
 - Dg¹ Medium-grained-muscovite biotite granite greisenized granite and greisen veins
 - Dg² Medium-to coarse-grained biotite granite/adamellite, minor porphyritic biotite granite/adamellite
 - Dg⁴ Medium-grained-muscovite biotite granite, medium grained biotite adamellite, aplite, quartz porphyry and microgranite
 - Dg⁶ Porphyritic biotite granite/adamellite with fine-to medium-grained ground mass
 - Dg⁷ Garnet-bearing medium-to coarse-grained biotite granite/adamellite and granite porphyry
 - Dg¹⁰ Foliated fine-to medium-grained biotite-muscovite granite/adamellite
 - Dg¹³ Porphyritic biotite granodiorite
 - Dg¹⁵ Hornblende-biotite granodiorite and biotite granodiorite
- SILURO-DEVONIAN**
- Mathinna Beds (hornfelsed)

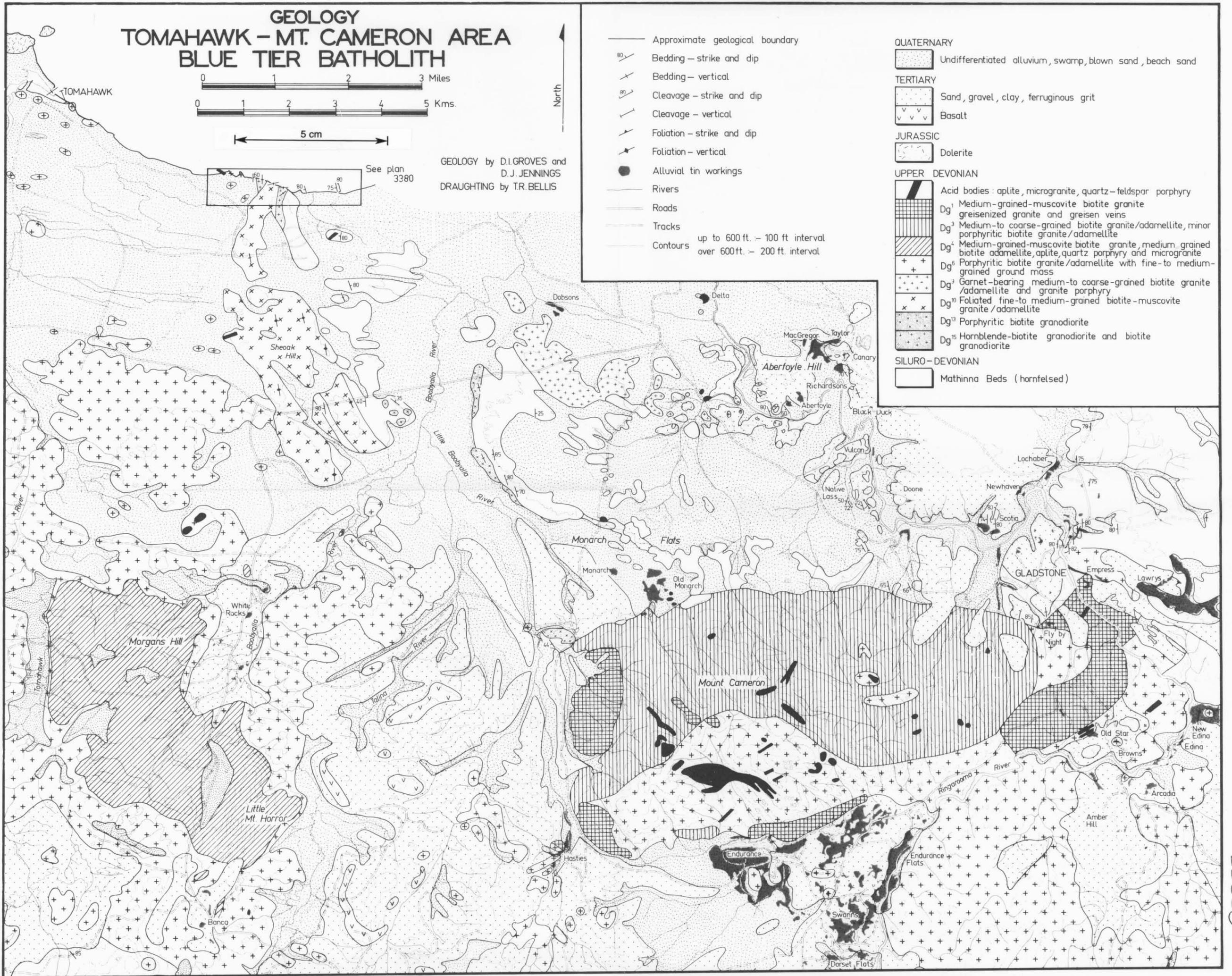


Figure 5.

G5855

oligoclase phenocrysts, generally 2-5 mm in length, with rare clusters of biotite in a fine- to medium-grained groundmass. This groundmass is similar in texture and composition to the even-grained granites.

In the roof zone of the mass along its south-western contact there are numerous greisen bodies which are generally thin veins (0.1-3 m in thickness), but irregular pods are also present (fig. 6). The veins trend either NW-SE or ENE-WSW and are near-vertical. The greisens are medium-grained rocks composed almost entirely of quartz and muscovite with accessory topaz, fluorite, cassiterite, wolframite and sulphides (chalcopyrite, arsenopyrite, pyrrhotite, pyrite, sphalerite). Joint surfaces are coated with coarsely crystallised cassiterite, wolframite and quartz, and some greisens have been worked for cassiterite (e.g. Bells Hill, Mammoth, Star of Peace (Jack, 1966)). The greisen veins commonly have a central fracture surface, and the host granite is often bleached along the margins of the veins. The greisen veins appear to be controlled by the major joint set of the granite. Occasionally associated with the veins are elongate zones of kaolinised granite, which have been sluiced as low-grade cassiterite deposits (e.g. Jack, 1962). Contacts between these kaolinised granites and the normal, slightly weathered granites are relatively sharp (e.g. Ruby Flat, Mt Paris, Walsh's; fig. 6). The greisen veins are commonly hard, resistant rocks and stand up as discontinuous 'walls' in sluiced areas of kaolinised granites.

Lottah Sheets

The Lottah Sheets (fig. 1, Dgl) are a group of bodies probably of sheet-like form, composed of even-grained muscovite-biotite granites, granite porphyries, leucogranites, aplites, pegmatites and greisens that are emplaced in the Poimena Pluton in the Blue Tier area. The tops of the sheets are gently undulating but essentially flat-lying (e.g. Thomas, 1943; Groves and Taylor, 1973), but the shape of the floor is unknown. The sheets are commonly connected by steeply-dipping granite dykes. Contacts with the porphyritic biotite granite/adamellites of the Poimena Pluton are sharp, or are marked by pegmatites, and there are no enclaves in the muscovite-biotite granites. Exposure is generally excellent, although contacts are often incised by streams and partly obscured by alluvium. The sheets have been intensively studied in a series of drill cores from the Anchor mine area where greisenisation and mineralisation occur in the irregular roof zone of one sheet (Groves and Taylor, 1973; fig. 7, 8, 9).

The major rock type is an even-grained (average grain size 0.5-1.5 mm) muscovite-biotite granite (table 11, fig. 3). It is a granular rock consisting of subhedral albite (An_5), anhedral quartz and K-feldspar with scattered clusters of biotite and muscovite comprising 2-7% (generally 2-4%) of the rock. Partly sericitised albite crystals are poikilitically enclosed in K-feldspar and less commonly in quartz. Quartz crystals have slightly undulose extinction and sutured boundaries. K-feldspar is generally present as un-twinned, cloudy crystals that contain irregular replacement perthites with patchy microcline twinning. Yellow-brown biotite occurs as ragged crystals, partially interleaved with muscovite. Some discrete muscovite crystals occur, and it is not possible on textural grounds to distinguish a primary or secondary origin. Topaz is a significant component of the rocks, and is present as scattered anhedral crystals, or as skeletal crystals that are partly replaced by fine-grained micaceous minerals. Small, subhedral grains of cassiterite occur in some sections as discrete, cracked crystals unrelated to any alteration products (plate 13). Minor fluorite is also present.

Leucogranites or alaskites are less common and macroscopically similar to the muscovite-biotite granites, but are deficient in biotite (table 11).

GEOLOGY MT. PARIS MASS



North ↑

- RECENT**
 Alluvium
- PLEISTOCENE - TERTIARY**
 Sediments - gravels and sands
 Basalt
- UPPER DEVONIAN**
 Dg₁ Muscovite biotite granite and granite porphyry
 Dg₆ Porphyritic biotite granite/adamellite
 Dg₁₅ Biotite hornblende granodiorite
- SILURO-DEVONIAN**
 Sm Mathinna Beds
- Area worked for alluvial cassiterite
 Greisen veins or disseminated tin mineralization
 Areas of greatest potential
- Geology by D.I. GROVES

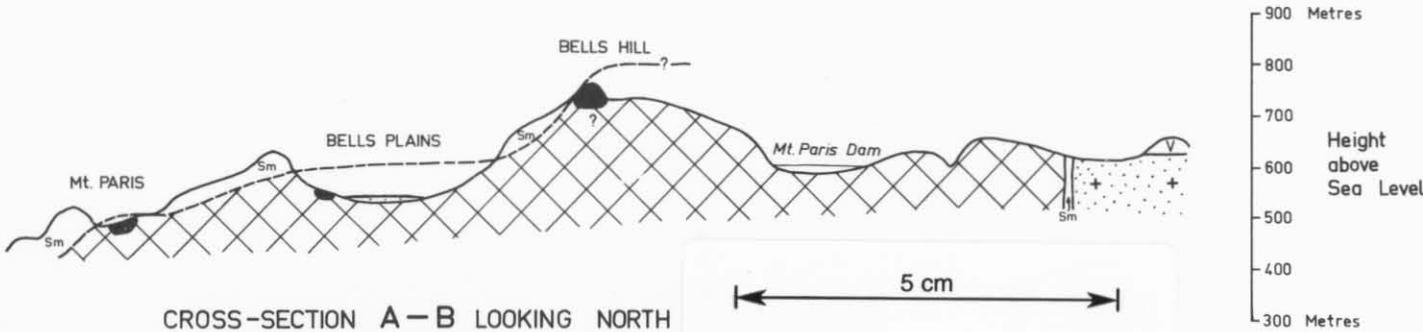
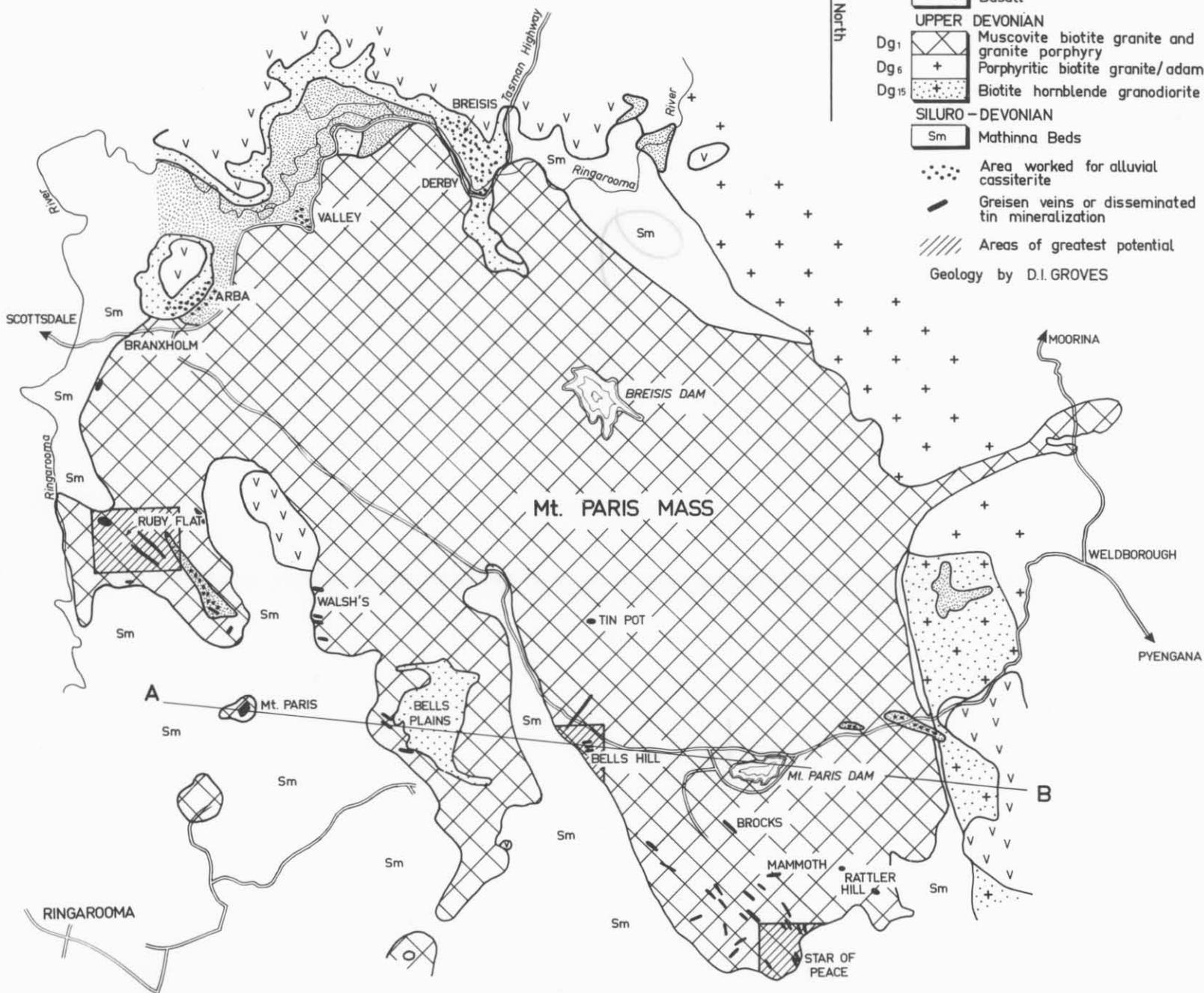


Figure 6.

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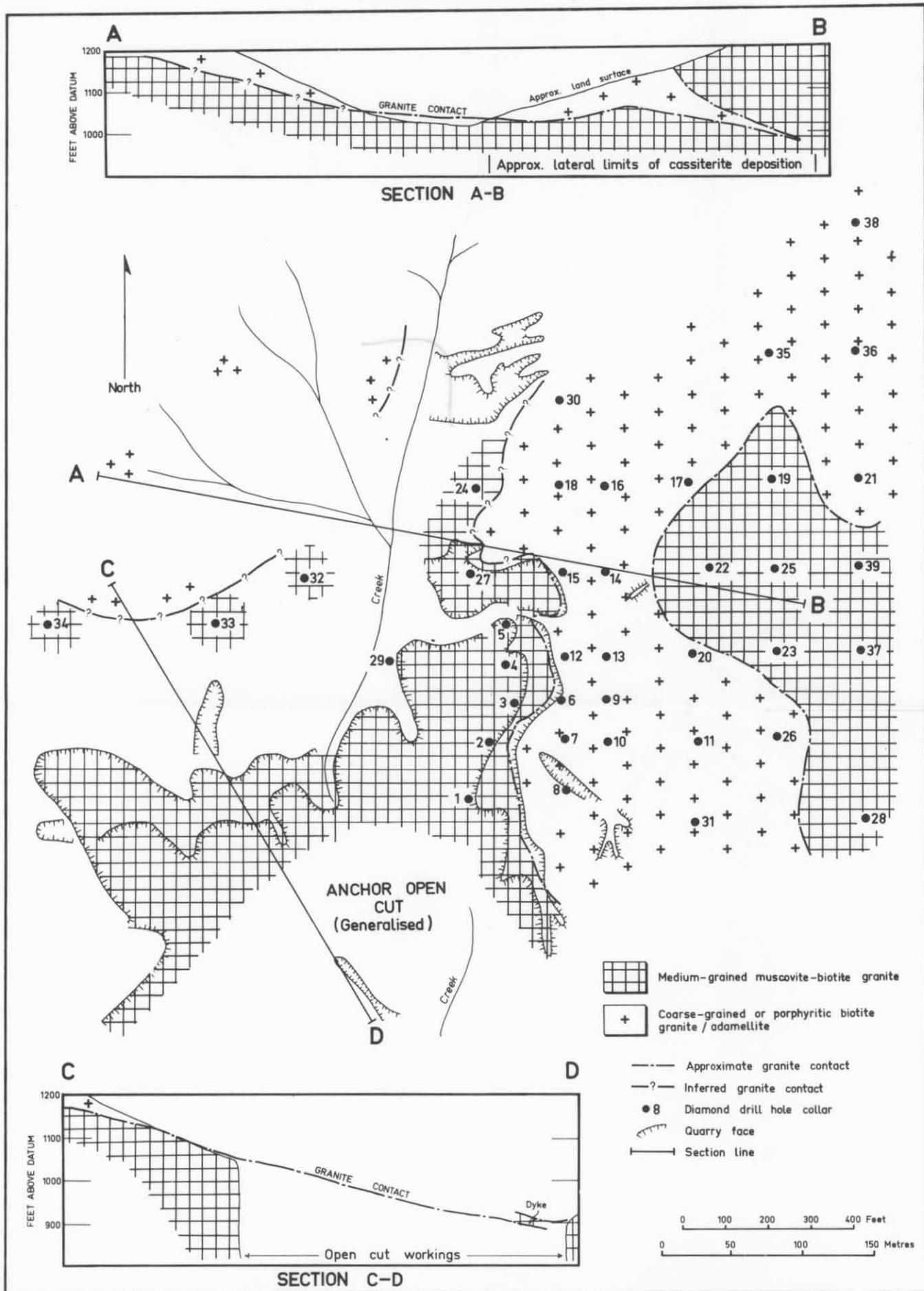


Figure 7. Geology of the Anchor mine area showing distribution of granitic rocks and location of diamond drill holes. Cross-sections show normal relationships of granitic rocks.

5 cm

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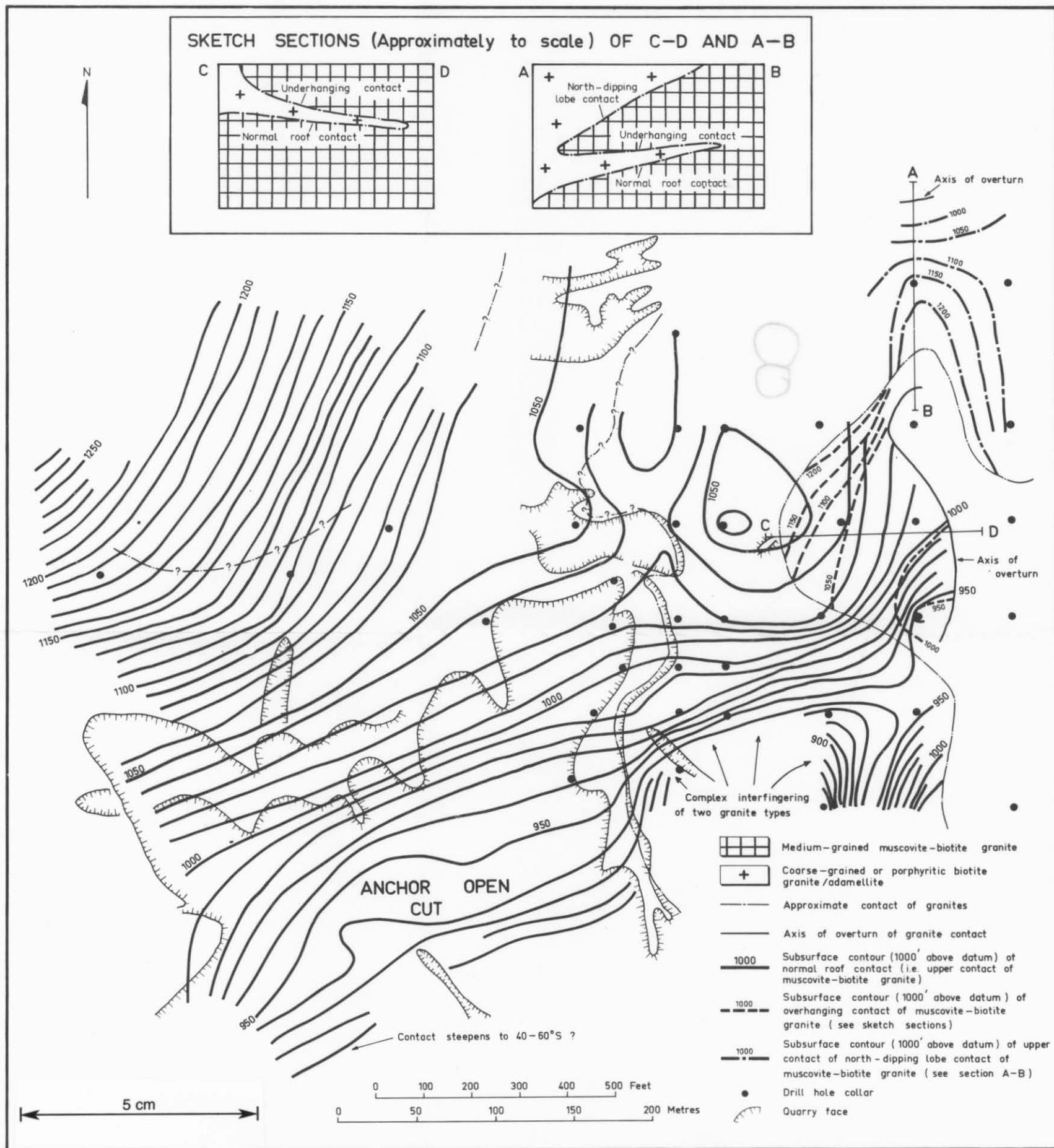


Figure 8. Subsurface contour plan of the upper contact of muscovite-biotite granite with coarse-grained biotite granite/adamellite in the Anchor mine area.

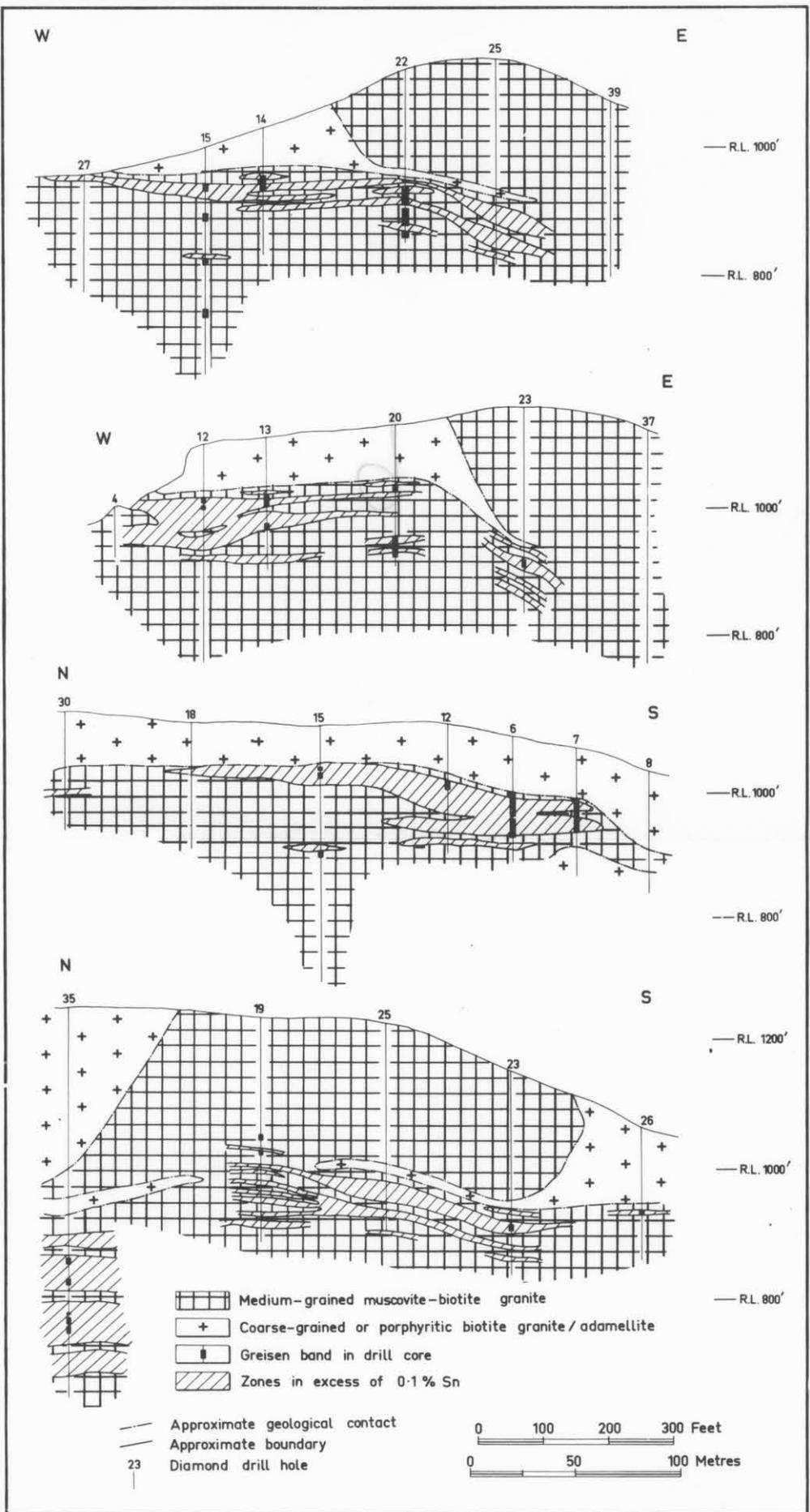


Figure 9. Sections showing relationships between granitic rocks, position of mineralised horizons, and greisen bands in the Anchor mine area.

5 cm

In thin section albite has more-irregular albite twinning and irregular growth structures (replacement features?) occur obliquely across the twinning. Topaz and muscovite are both common and fine-grained, saccharoidal aplites are locally present. The aplites contain relatively small amounts of mica. Pegmatites occur as discontinuous sheets and as irregular pods.

Adjacent to the upper contact, the granites of the sheets are commonly greisenised, although this alteration does not extend into the overlying porphyritic granite/adamellites. Greisenised granites retain the original textures of the muscovite-biotite granite and consequently are distinguished from greisens, which typically have no relict texture. In greisenised granites, K-feldspar is replaced to a varying degree by rosettes and sheaves of muscovite which define lath-shaped aggregates up to one millimetre in length (plate 12). Albite is partly replaced by muscovite, and biotite occurs as slightly altered ragged crystals. Topaz, where present, is almost completely replaced by muscovite, and minor fluorite and interstitial sericite are also present. Cassiterite occurs sporadically, generally in the form of small scattered fractured crystals, but larger crystals may be present (plate 14).

Greisens typically consist of aggregates of quartz and muscovite with minor albite. They are coarser grained (up to 4 mm average grain size) than the greisenised granites, and almost invariably contain abundant coarse-grained, fractured cassiterite crystals. Pale-green biotite and carbonate are present in some greisens, and topaz is more common than muscovite in other specimens. Minor chalcopyrite, bornite, molybdenite and fluorite may be present.

MISCELLANEOUS ROCKS

Introduction

There are a large number of small dyke-like bodies of acid and basic composition that intrude the major granitic rocks of the Blue Tier Batholith. They are generally 1-25 m in thickness, and at least 100 m in length.

Acid dykes include microgranites, muscovite granites, aplites and pegmatites. They are not uniformly distributed throughout the batholith, but tend to occur locally in groups or swarms. They are generally more abundant in the biotite granite/adamellites than in granodiorites, and reach their greatest development in the muscovite-biotite granite sheets.

Basic dykes include quartz dolerites and, more commonly, lamprophyres. They intrude all granitic types, although lamprophyres appear most abundant in the granodiorite plutons. Several varieties of basic dykes form mixed swarms which occur locally, each swarm having a strong directional conformity, as for example at Mt William*. Studies on well-exposed coastal platforms indicate that the dykes have a dilational mode of emplacement (e.g. Williams and Groves, 1967).

Microgranites

Microgranite dykes occur throughout the batholith, but are most abundant in the Constable Creek Sheet. They are fine-grained, generally pink to yellow-brown rocks containing little mica (usually less than 5% biotite and minor muscovite). They consist of quartz, cloudy K-feldspar and sericitised plagioclase (An_5-An_{15}), and contain accessory fluorite and tourmaline. Porphyritic microgranites and microgranite porphyries occur locally. A particularly unusual microgranite occurs in the Pyengana Pluton in the North George

*Similar swarms also occur at Franklin Sound (Furneaux Group) and on the Freycinet Peninsula.

Valley [59/78801445]. This rock (thin section 70-53) is aphanitic and finely flow banded. Macroscopically it closely resembles a rhyolite, but is clearly intrusive into granodiorite. A chemical analysis (table 21, 702693) indicates that it is rich in Na₂O relative to K₂O, and therefore that albite is the dominant feldspar.

Muscovite granites

Muscovite granites are a minor component of the batholith, but are abundant in the St Helens Point-St Helens Island area of the St Helens Pluton. Here the dykes trend mainly E-W, are near-vertical in attitude and generally about 10 m in thickness. They are commonly banded with adjacent bands distinguished by changes in grain size and the proportion of biotite and muscovite. Miarolitic cavities are abundant and tourmaline-quartz clots are common, but enclaves of other lithologies are absent. In thin section the granites consist of anhedral grains of quartz, albite (An₅-An₁₀), muscovite, and biotite poikilitically included in K-feldspar with patchy microcline twinning. The average grain size of the rocks ranges from 1-2 mm. Some muscovite has clearly replaced K-feldspar and biotite, but it also occurs as discrete grains. Andalusite has been detected (Cocker, 1971). A chemical analysis of one of these dykes (table 21, 611464) indicates their highly potassic nature.

Aplites

Aplites occur throughout the batholith, but are most abundant in the muscovite-biotite sheets as dykes ranging in width from 1-50 m. They are commonly observed on Mount Cameron and are also abundant around the southern margin of the Mt Pierson Pluton. The aplites are typically fine-grained, mica-deficient, saccharoidal rocks that contain scattered mica or tourmaline-quartz clots. In thin section they consist of anhedral quartz, albite (An₂-An₅) and cloudy K-feldspar with scattered ragged crystals of pale yellow-brown biotite. Accessory topaz, fluorite, and tourmaline are common.

Quartz-feldspar porphyries

Quartz-feldspar porphyry dykes are less common than microgranite and aplite dykes, but occur on the Blue Tier and adjacent to the northern coastline between Tomahawk and Boobyalla. They consist of sutured, subhedral quartz and euhedral K-feldspar phenocrysts in a groundmass of quartz, albite-oligoclase, microcline and biotite. They resemble the dykes in the Mount Bischoff area (Groves et al., 1973).

Pegmatites

Pegmatites occur in all rock types within the batholith. They appear as either small pod-like bodies within granitic rocks commonly associated with miarolitic cavities, or are dyke-like or sheet-like in form. The former type consist almost entirely of K-feldspar, quartz and biotite, whereas the latter type may contain significant albite, muscovite, topaz and cassiterite. All are simple pegmatites. K-feldspars from pegmatites at the Anchor Mine (table 6, 68-141, 68-146) have intermediate triclinicity ($\Delta = 0.3-0.6$) and are patch perthites. Rims of muscovite occur on biotite crystals from these pegmatites.

Quartz dolerites

Quartz dolerite dykes have previously been recorded by Reid and Henderson (1928), Thomas (1943) and Walker (1957). They are not abundant, although they appear to cut all granitic rocks in the batholith and the Mathinna Beds.

They have a dilational mode of emplacement and have been dated in a preliminary palaeomagnetic study as Devonian (B. Wyatt, pers. comm. in Cocker, 1971). They are dark grey, fine-grained rocks containing visible pyrite and small xenoliths of granitic rocks. In thin section the average grain size is about 0.5 mm, although plagioclase crystals up to 2 mm in length are present. The rocks are intergranular to sub-ophitic, and consist of augite or titanaugite and normally zoned plagioclase (An_{60} - An_{35}) with quartz (1-10%), K-feldspar (1-5%) and minor biotite. Augite is commonly partly altered to fibrous amphibole, and chlorite and epidote are present as alteration products of plagioclase. Opaque minerals include magnetite, ilmenite, pyrite and chalcopyrite.

The chemistry of dolerites from St Helens Head (table 21, 611463) and from Wineglass Bay (95 km south of St Helens) (Spry, 1962) indicate tholeiitic affinities (fig. 13). They clearly do not follow the calc-alkaline trend shown by the granitic rocks, and furthermore they fall within the trend shown by Jurassic dolerites of Tasmania as plotted from information given by Edwards (1942). Their derivation is unknown.

Lamprophyres

Lamprophyre dykes are more common than quartz dolerite dykes and are particularly abundant in the St Helens Pluton and the Gardens Pluton. Those from the St Helens area have been described as diorite porphyries by Walker (1957). They are poorly exposed, dyke-like bodies 1-10 m in thickness and at least 100 m in length. They have phenocrysts of plagioclase, hornblende and rare quartz or biotite, 0.1-1 mm in length, in a fine-grained, dark coloured groundmass. Similar rocks containing olivine phenocrysts occur in the Little Mt Horror area (Baillie, 1973). The phenocrysts are commonly embayed or fractured. Xenoliths of granitic rocks occur locally, and coarse-grained plagioclase-hornblende enclaves are also present. The lamprophyres have not been studied in thin section.

The lamprophyres appear to be similar to Cretaceous spessartites described by Jennings and Sutherland (1969) from Cape Portland. Insufficient data precludes classification of the lamprophyres within the Blue Tier Batholith, and the determination of their age and parentage.

SUMMARY OF MAJOR COMPONENTS

The St Marys Sheet is an homogeneous body of hypersthene biotite adamellite porphyry. It is the only granitic body within the batholith to contain essential pyroxene. Deformation and corrosion of phenocrysts are consistent with the emplacement of the sheet as a crystal mush.

The Pyengana and Gardens Plutons are relatively homogeneous hornblende biotite granodiorite and biotite hornblende granodiorite plutons. The granodiorites are normally massive, but there is a strongly developed, cataclastic foliation along the eastern margin of both plutons. They are medium-grained rocks consisting essentially of andesine (An_{40}), K-feldspar, quartz, dark brown biotite and green hornblende. Mafic minerals comprise 10-30% of the rock. Biotite, quartz and plagioclase are strongly deformed in foliated granodiorites. Mafic enclaves are abundant and xenoliths of Mathinna Bed lithologies are common near the margins of the plutons.

The Piccaninny Creek and St Helens Plutons are multiple intrusions consisting predominantly of biotite adamellites and hornblende biotite adamellites and granodiorites. These are generally medium-grained massive rocks although foliated rocks occur in both plutons. Adamellite/granodiorites consist of andesine (An_{40} - An_{45}), K-feldspar, quartz, red-brown to green-brown

biotite and green hornblende. Mafic minerals comprise 6-15% of the rock. The St Helens Pluton is virtually a microcosm of the entire batholith with all the major granitic rocks present. It includes hornblende monzonites and granodiorite porphyries which are not present elsewhere in the batholith.

The Poimena, Mt Pierson, Ansons Bay, Boobyalla, Musselroe and Rushy Lagoon Plutons are dominated by either porphyritic or coarse-grained biotite granite/adamellites. These rocks are generally massive although aligned orthoclase phenocrysts occur in granites from some areas. Cataclastic foliations are absent, and mafic enclaves are less abundant than in the granodiorite or adamellite/granodiorite plutons. Contacts with Mathinna Beds are sharp, with xenoliths relatively abundant adjacent to the boundaries. The rocks consist of orthoclase microperthite phenocrysts in a groundmass of quartz, oligoclase (An_{25}), microcline, and red-brown biotite. K-feldspar generally constitutes about 60% of total feldspar and the biotite content is 6-8%. Almandine-rich garnets occur in coarse-grained granites of the Ansons Bay and Boobyalla Plutons, and biotite schlieren are common in all units.

Muscovite-biotite granites generally form sheet-like bodies, although the Mt Paris Mass may be a steep-sided intrusion with a gently undulating roof. The Lottah Sheets, the southern part of the Mt Cameron Sheets, the Mt William Sheet and the Mt Paris Mass are composed of essentially similar, even-grained granites that contain both biotite and muscovite. The Mt William Sheet appears to be the basal part of a flat-lying sheet whereas most of the mapped contacts of the other bodies define the upper margins of sheets. The most common granitic rock is a pink coloured, medium-grained muscovite-biotite granite consisting of quartz, cloudy K-feldspar, albite (An_5 - An_8), green-brown or yellow-brown biotite, and muscovite. The total mica content is generally less than 5%. Adjacent to the upper contacts of the sheets, topaz and cassiterite may be accessory phases. Granite porphyries are locally abundant in the Mt Paris Mass and greisenised granites and greisen veins occur adjacent to the upper contacts of the Mt Paris Mass and Lottah Sheets. Contacts with other granitic rocks and Mathinna Beds are very sharp, and neither mafic enclaves nor xenoliths of Mathinna Bed lithologies are present.

The Sheoak Hill Pluton, Little Mt Horror Sheet, Constable Creek Sheet and the northern part of the Mt Cameron Sheets are composed of similar rocks to those described above, but there are important differences. The Sheoak Hill Pluton is clearly a steep-sided pluton and its component granitic rocks have a cataclastic foliation. The rock is also an adamellite containing oligoclase (An_{10}) rather than albite, and the biotite is a red-brown variety. The Little Mt Horror Sheet consists of both granites and adamellites that have a significantly higher biotite content than the muscovite-biotite granites described above. The biotite is also usually red-brown in colour. The Constable Creek Sheet consists of biotite microgranites, granites and adamellites, but muscovite is never a dominant component, and biotite ranges in colour from green-brown, brown to red-brown. The northernmost Mt Cameron Mass is composed of coarser grained granite/adamellites than those discussed above, with biotite generally more abundant and muscovite rare.

There is strong textural evidence to suggest that at least part of the muscovite in these rocks is secondary, and has replaced biotite, K-feldspar, and to a lesser extent albite. However, in some specimens there are discrete muscovite flakes that appear to be primary crystals. Experimental studies on the stability of quartz and muscovite at $P_{H_2O} < P_{total}$ (e.g. Kerrick, 1972) indicate that muscovite is unlikely to crystallise from a granite melt at pressures less than 3800 MPa (i.e. at depths of less than about 13 km). As discussed above (p. 17; Gee and Groves, 1971), field evidence supports a shallow to intermediate depth of emplacement (probably less than 5 km), and the textures of the granites indicate that they have not crystallised prior

to emplacement. Therefore it appears most likely that all the muscovite in the muscovite-biotite granites has a secondary origin.

SEQUENCE OF EMPLACEMENT OF MAJOR COMPONENTS

The relative ages of several major components of the batholith can be established from field relationships, although the relationship between others is obscure. Isotopic age determinations by the K-Ar method are unfortunately of limited precision, and only one Rb-Sr date is available (table 1). No distinction can be made between K-Ar dates for a wide variety of granitic rocks if an uncertainty of $\pm 2.5\%$ at 363 to 377 m.y., is accepted (McDougall and Leggo, 1965). A single Rb-Sr date of 389 m.y. was obtained on a biotite adamellite from the St Helens Pluton (table 1). A biotite hornblende granodiorite from the Gardens Pluton yielded a K-Ar date of 347 m.y., and a muscovite granite dyke from the St Helens Pluton provided a K-Ar date of 321 m.y.; however the significance of these dates is not clear.

McNeil (1965) demonstrated that the Piccaninny Creek Pluton intruded and metamorphosed the St Marys Sheet, and is therefore younger. The relationship of these two units to the more northerly bodies is unknown, although the Piccaninny Creek Pluton does show similarities to the southernmost part of the St Helens Pluton and they may be related.

The Poimena Pluton is clearly younger than the Pyengana Pluton as it cuts the foliation in the granodiorite. Similarly the Mt Pierson Pluton is younger than the Gardens Pluton and the granodiorite mass (George River Granodiorite) of the St Helens Pluton for the same reason. The relationship between the Ansons Bay Pluton and the Gardens Pluton is not clearly defined. Therefore where relationships are well established, the porphyritic or coarse-grained biotite granite/adamellite bodies are younger than the hornblende biotite granodiorite bodies of the batholith.

The relationship between the various biotite granite/adamellite plutons is not well established. The boundary between the Poimena and Mt Pierson Pluton is not clearly defined, and may well be gradational. The possible regional-scale layering of the granitic rocks subparallel to the pluton margins has been discussed above (p. 18). At George Rocks irregular dykes of porphyritic biotite granite/adamellites with a fine- to medium-grained groundmass (i.e. rocks similar to those of the Poimena Pluton) intrude coarse-grained biotite granite/adamellites of the Ansons Bay Pluton, but whether this is significant on a regional scale is doubtful. The relationship of the Boobyalla, Musselroe and Rushy Lagoon Plutons to the other biotite granite/adamellite plutons is unknown.

The muscovite-biotite granite bodies are clearly younger than the biotite granite/adamellite plutons. The Lottah Sheets intrude the Poimena Pluton on the Blue Tier, and a dyke-like extension of the Mt Paris Mass appears to intrude the Poimena Pluton north of Weldborough. The Little Mt Horror Sheet intrudes the Poimena Pluton near Banca (Baillie, 1973), and the Mt Cameron Sheets intrude that pluton north of South Mt Cameron. The Mt William Sheet intrudes the regional contact between the Ansons Bay Pluton and the Mathinna Beds, and the Constable Creek Sheet intrudes the Mt Pierson Pluton - Mathinna Beds contact west of St Helens.

The St Helens Pluton exhibits a similar emplacement sequence to that shown by the whole batholith. The oldest rocks appear to be the granodiorites (George River Granodiorite and Akaroa Granodiorite), although the hornblende monzonites (Priory Monzonite) may be older if they represent large inclusions

within the George River Granodiorite. The granodiorites are intruded by the Scamander Tier Granodiorite Porphyry and biotite granites (Grant Point Granite), but the relationships between these bodies is unknown. Finally the pluton was intruded by swarms of muscovite granite dykes, and the microgranites and biotite granites of the Constable Creek Sheet.

There is thus an evolutionary trend towards more alkali-rich acid rocks as suggested in general terms by Reid and Henderson (1928) and Carey (1953). This trend is paralleled by a marked decrease in the proportion of mafic enclaves (cognate?) and xenoliths of Mathinna Bed lithologies adjacent to contacts. These are abundant in the hornblende-bearing granodiorites, and absent in the muscovite-biotite granites. The degree of deformation, shown by cataclastic foliation, also decreases in successive intrusions within the batholith. The intrusion of acid dykes apparently increased, as the major, more-acid granitic rock units were emplaced.

Intrusive magmatic granitic rocks located at shallow and intermediate depths are generally considered to have been emplaced by a combination of the following mechanisms:

- (1) Piecemeal stoping, with assimilation or sinking of stoped blocks (e.g. Daly, 1933);
- (2) Cauldron subsidence involving the foundering of blocks during magma relaxation;
- (3) Reactive emplacement by melting of the roof and crystallisation at the floor (e.g. Dickson, 1958);
- (4) Upwardly expanding balloon-shaped plutons actively rising under the influence of density differentials with country rocks (e.g. Balk, 1937; Hamilton and Myers, 1967);
- (5) Forcible intrusions involving horsting of fracture-controlled slices or blocks (e.g. Noble, 1952);
- (6) Lateral magmatic wedging involving the shouldering aside and folding of country rocks (e.g. Pitcher and Read, 1960);
- (7) Permissive emplacement into zones of reduced pressure due to crustal forces (Mayo, 1941).

Gee and Groves (1971) discussed the emplacement of the Blue Tier Batholith in terms of these mechanisms, and this is summarised below. A variety of mechanisms have operated during the emplacement of the batholith including (5), (6) and (7), but the dominant mechanism appears to have been the emplacement of large masses of biotite granite/adamellite in a terrain with regional horizontal dilational components.

STRUCTURAL FEATURES OF THE GRANODIORITE PLUTONS

PICCANINNY CREEK PLUTON

General features

The Piccaninny Creek Pluton is a steep-walled, N-S trending, elongate composite pluton that intrudes the Mathinna Beds and St Marys Sheet with sharp transgressive contacts (McNeil, 1965). It is generally massive, although fractured and undulose quartz and bent biotite are relatively common. A cataclastic foliation is locally present. At Piccaninny Point there is a well-exposed contact between foliated hornblende biotite granodiorite and hornfelsed sandstone and siltstone of the Mathinna Beds. Structures displaced at this contact have an important bearing on the emplacement of granodiorite plutons within the batholith. The contact was described by McNeil (1965) and

reinterpreted by Gee and Groves (1974): a summary of the critical feature is given below.

Piccaninny Point Contact

The structures at this contact can be divided into those of the intrusive phase, the late-intrusive phase and the post-intrusive phase (fig. 10; Gee and Groves, 1974).

Intrusive phase. The contact is concordant in places, but elsewhere it breaks irregularly across bedding and tectonic folds at a high angle. A discordant dyke extends to the south from the main mass. The form of the dyke-wall irregularities indicate rupture and dilation during emplacement. Sharp contacts with thin mafic selvages indicate only minor assimilation or reaction, but there is no evidence of stoping. Primary banding within the essentially granodiorite mass (plate 1) appears to result from sequential intrusions of magma rather than flow banding. Both mafic enclaves (cognate?) and xenoliths of hornfels are present.

Late-intrusive phase. A network of secondary leucocratic dykes occurs within the main mass of granodiorite. These dykes exhibit features of dilatational emplacement including the matching of earlier intersecting planar structures (Williams and Groves, 1967). These features indicate a direction of distention of 5° . Dyke-wall irregularities can also be matched, but have been modified by flattening, which produced folds with steeply plunging axes and an axial surface foliation that trends $0-5^\circ$ across dykes and dyke-wall irregularities. The foliation is oblique to the trend of the main dyke and primary banding within the granodiorite and has been described above.

The mafic enclaves are ovoid in section; are flattened in the foliation with a maximum ellipticity in the foliation surface, and major axis plunging gently to the north. These enclaves may be used as strain indicators, because their 'average' shape in unfoliated granodiorite approximates to a sphere. A strain analysis (Gee and Groves, 1974) indicated a 47% flattening across the foliation surface, a 38% extension along an axis plunging shallowly north in the foliation surface, and an extension of 30% along an axis which is close to vertical in the foliation surface. A petrofabric analysis of the granodiorite by McNeil (1965) indicated a strongly developed linear fabric, with the lineation trending $165-175^\circ$. This is similar to the result obtained from the strain analysis of the enclaves.

Flattening in the hornfels is expressed as a weakly developed foliation adjacent to the contact, and boudinage and pygmatic structures in quartz veins away from this contact.

Post-intrusive phase. Conjugate faults and a more recent generation of quartz veins characterise the post-intrusive structures at Piccaninny Point, and cut both the granodiorite and hornfels. The faults are dextral wrenches trending 90° and sinistral wrenches trending 120° . The faults are approximately symmetrical about the foliation and intersect in a near-vertical axis.

Interpretation. A dilatational mode of emplacement of the initial magma is suggested by the alternate concordant and discordant contacts, the minor role of assimilation, and lack of evidence of stoping. The lack of marginal deformation related to the intrusive phase supports passive emplacement.

All the structures of the late-intrusive phase indicate east-west flattening of the granodiorite at its contact and north-south distention before complete crystallisation. A stress field is indicated in which P_{max} is

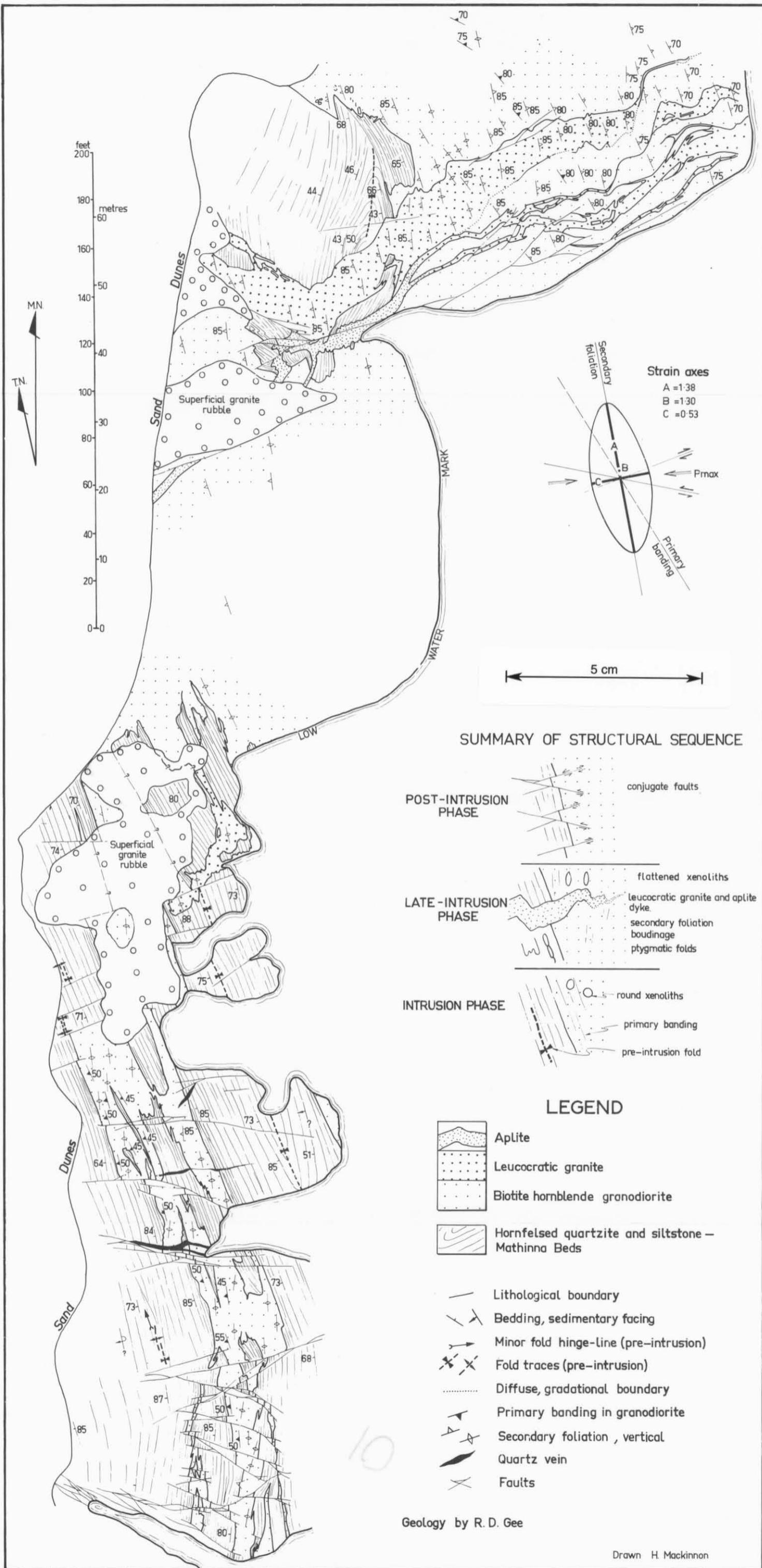


Figure 10. Geological map of part of the Piccaninny Point contact between hornblende biotite granodiorite and the Mathinna Beds. [Bull. geol. Surv. Tasm. 55]

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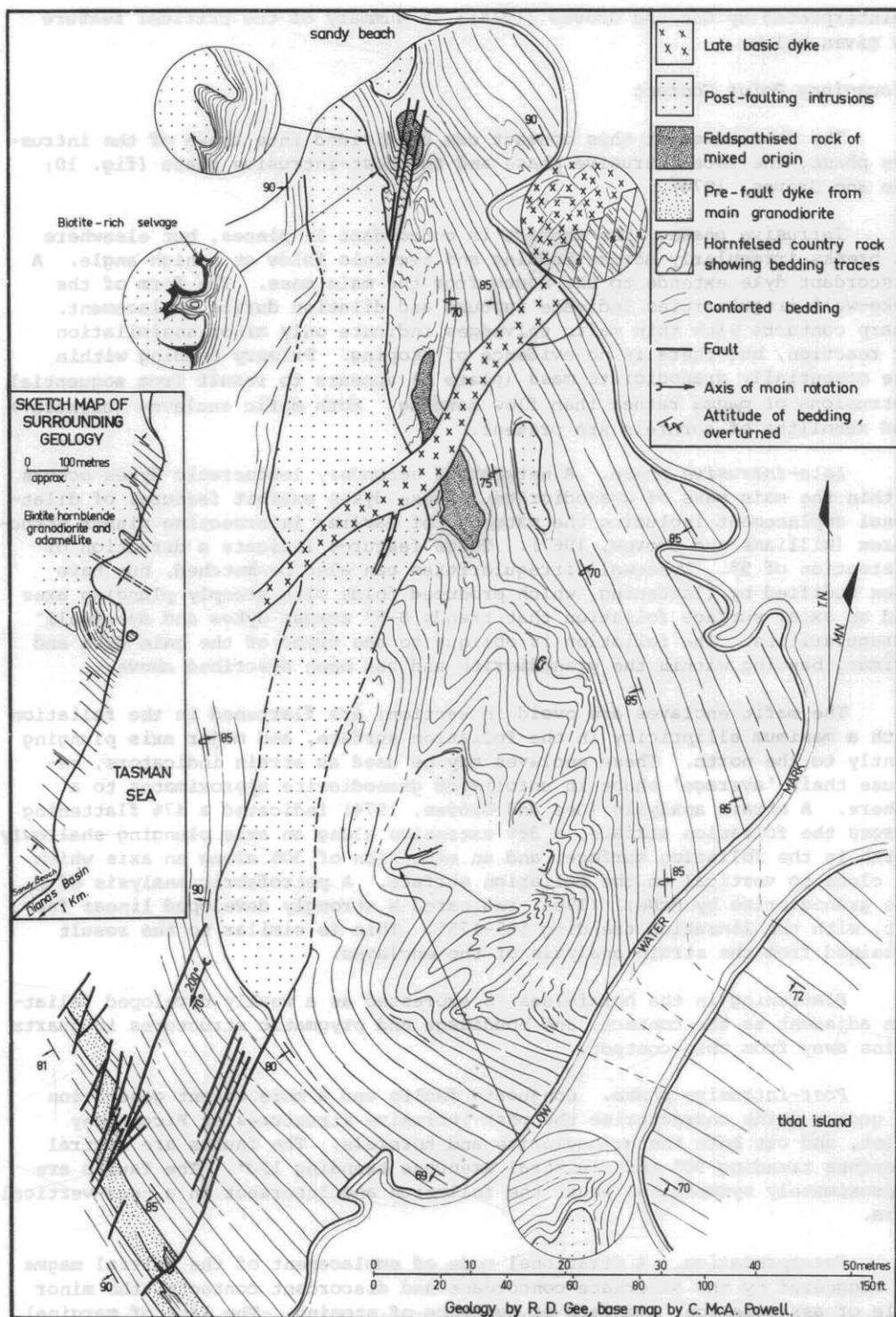


Figure 11. Detailed geological map of part of the contact zone of the St Helens Pluton, 1.5 km north of Dianas Basin, showing marginal deformation associated with forcible intrusion (from Gee and Groves, 1971).

directed horizontally at 95-100°, and P_{int} is vertical. These features resemble cataclastic borders, but involve lateral flattening rather than a continued upward movement of partly consolidated magma against its wall (e.g. Sherlock and Hamilton, 1958).

The post-intrusive structures also indicate a P_{max} directed towards about 105° and a vertical P_{int} . The direction of displacement on the faults indicates continued E-W shortening and N-S distention.

ST HELENS PLUTON

General features

The granodiorites and adamellites of the St Helens Pluton are generally massive, although the George River Granodiorite has a locally cataclastic foliation. The overall shape of the pluton is difficult to envisage as the eastern margin extends seaward of the coastline. The northern contact is concave against the Mt Pierson Pluton and the western contact is complicated by the Constable Creek Sheet. The southern contact, west of Scamander Tier, is irregular in outline and Cocker (1971) suggests that it represents the roof contact of the pluton dipping shallowly south-east. East of Scamander Tier the contact is steeply dipping and is subparallel in strike to the regional fold hinge lines. The lack of a rectangular outline shown by other plutons may be partly related to the relatively high level of exposure of the southern contact.

The Scamander Tier dyke is concordant with the pre-granite structures in the Mathinna Beds south of the main southern margin of the granitic mass. It has intruded about 600 m west of one of the regional anticlines in the area. The dyke appears to have been forcibly emplaced, possibly due to vertical displacement of country rock, although some lateral pressure is indicated by locally overturned strata along the eastern contact. In general, dyke-wall irregularities cannot be matched by lateral restoration, and the blunt southern termination would appear to negate a dilational emplacement.

Conclusive evidence of forcible emplacement is not apparent on a regional scale. However, an excellent coastal exposure at Dianas Basin of a granodiorite-hornfels contact does indicate the complex deformation involving both lateral and vertical movements, associated with forcible intrusion adjacent to the margin of the pluton (Gee and Groves, 1971).

Dianas Basin Contact

At Dianas Basin the main mass of hornblende biotite adamellite and granodiorite intrudes the axial zone of a NW-trending anticline (fig. 11, inset), which is part of the regional pre-intrusion structure. In the contact zone there is a swing in the bedding of the hornfeldes to a N-S alignment; and concordant dykes, commonly wedge-shaped in plan, are demonstrably dilational into rotated bedding surfaces. The main features of the contact zone are shown in Figure 11, and a summary of Gee and Groves' (1971) description of the contact is presented below.

The strike-swing occurred about an axis plunging 70° towards 200°, and was associated with strongly developed, co-axial concentric folding in the core region. Folds are bounded by detachment surfaces, away from which the intensity of the deformation increases and finally fold axes and axial surfaces become chaotic and bedding surfaces are diffuse. Discrete bodies of feldspathised rock (plate 10) occur in low pressure positions in concentric

folds, generally core areas, although some discordant bodies with angular hornfels xenoliths also occur. These rocks result from partial disaggregation of hornfels combined with metasomatic alteration resulting from the emplacement of the granitic rocks.

A set of vertical dextral faults cuts the early granodiorite dykes and the feldspathised rock, and is subparallel to the axial surface of most folds in the contorted zone. Late-stage, discordant, chloritised hornblende biotite granodiorite intrusions, containing xenoliths of the feldspathised rock, have segments of their contacts parallel to these faults. The only concordant contact of the main dyke is its blunt southern termination (fig. 11). This, together with the lack of matching dyke-wall irregularities negates horizontal dilation as a possible emplacement mechanism. The most likely emplacement mechanism was intrusion from below into a fault-bounded block with upwards displacement of this block. Smaller bodies of similar rocks are partly discordant domal intrusions that refold the earlier folds (fig. 11, lower inset), and confirm an essentially vertical upward movement.

The upper insets of Figure 11 demonstrate the style of small-scale protuberances from the wall of the major late-stage dyke. They are distinct in scale and style from the structures associated with the main strike-slip, and do not modify the gross aspect of the dyke wall. The granodiorite is bulbous into the hornfels, leaving cusped re-entrants of country rock in the granodiorite. Contacts are sharp, although commonly marked by a thin biotite-rich selvage indicating limited reaction. The style of these structures suggests forcible intrusion due to lateral pressure on the essentially plastic dyke walls.

Gee and Groves (1971) concluded that the major swing about the steeply plunging axis at Dianas Basin was due to the bending of splayed edges of an irregular discordant contact, allowing the emplacement of wedge-shaped dilation dykes. The bedding in the country rocks has been bent anticlinally, with a downward component of rotation, indicating a lateral push by the magma. The later intrusions however were partly controlled by NNE-trending faults, and displaced slices of hornfelsed country rocks upwards. The bulbous folds on the dyke walls are evidence of the force of the intrusion. The rotation of the country rocks about steep axes and their upward displacement by vertically emplaced dykes indicate forcible intrusion of the granodiorite body (e.g. Noble, 1952; Bateman, 1965).

PYENGANA PLUTON

The Pyengana Pluton consists of two major parts that have distinctly rectangular segments. The western contact is slightly discordant to the bedding in the country rocks, but is parallel to the regional axial surface of the pre-intrusion folds. The southern contact is perpendicular to the regional fold axis, and is generally straight and near-vertical.

The pre-intrusion structure shows some regional distortion due to the emplacement of the granodiorite. Adjacent to the western contact the fold axes in country rocks have a NNE trend subparallel to the contact in contrast to the NNW-trending axial surfaces of the pre-intrusion folds. The re-orientation of fold axes is more pronounced along the discordant southern margin, but is still confined to the contact aureole of the intrusion. Steeply plunging fold axes characterise this superimposed folding. The moulding of the structures around the granodiorite contact (fig. 1, 2) indicates the forcing aside of the country rocks during intrusion.

Remnant blocks of the Mathinna Beds are present on the eastern contact,

which is also marked by the presence of foliated granodiorite in a zone up to 3 km in width. The cataclastic foliation, described in detail above, strikes subparallel to the eastern contact and dips very steeply towards the east. Local changes in strike reflect changes in the strike of the contact.

The regional shape of the pluton suggests an initial fracture control, possibly by axial surface faults and transverse faults related to the regional folding. The cataclastic foliation may result from lateral pressure in a late-intrusive phase by analogy with Piccaninny Point, but the reason for its absence from the western contact where there is evidence of outward pressure is uncertain. The partial annealing of deformation fabrics within the foliated granodiorite may be related to the later emplacement of the Poimena Pluton.

GARDENS PLUTON

The Gardens Pluton is also roughly rectangular in plan, with straight boundaries and angular irregularities. It is intruded and partly assimilated by the Mt Pierson Pluton on its southern margin, and is intrusive into Mathinna Beds at its northern extremity. Exposure of the Mathinna Beds in this area is poor, but there appears to be only minor disruption of the pre-intrusion fold axis.

Screens of hornfelsed Mathinna Beds characterise the southern parts of the western and eastern margins, which are intruded by the Poimena and Ansons Bay Plutons respectively; north of a line joining Ansons Bay and South Mt Cameron (fig. 1, 2). The screens are interpreted as remnants of the original contacts of the pluton, which are structurally controlled and 'welded' on to the granodiorite margin. The western screen is only 300 m wide, and although it is elongate subparallel to the regional pre-granite structural trend, its internal structure is unknown. The screen is terminated by an irregular extension of the Poimena Pluton which appears to intrude the Gardens Pluton in an area partly concealed by extensive Tertiary cover. Due to similar cover it is not clear whether the eastern screen is continuous north of Ansons Bay, or whether the Ansons Bay Pluton and Gardens Pluton are in direct contact as shown in Figure 2. The eastern or northern margin of the screen however clearly diverges abruptly to an E-W direction in this area and is perpendicular to the pre-granite axis. The structures within the screen indicate a sub-horizontal axis trending NNW, subparallel to the western contact of the screen and to the pre-intrusion axis elsewhere.

The granodiorite is generally massive, but along the eastern margin in The Gardens area biotite-rich granodiorite has a well-developed cataclastic foliation with enclaves flattened in this foliation. North of this area is an irregular mass of strongly hornfelsed Mathinna Beds which are complexly deformed, but the structure of these rocks has not been resolved. The foliated granodiorite is considered to lie close to the eastern margin of the pluton in this area, based on the southward projection of the observed eastern contact and the occurrence of Mathinna Beds in the area.

NORTHERN AREA

The Mathinna Beds occurring between the Sheoak Hill Pluton and the Boobyalla Pluton to the north-west of Mt Cameron have been intruded by hornblende biotite granodiorites that crop out near the Boobyalla River adjacent to the Waterhouse-Gladstone road, and on the coastline between Boobyalla and Tomahawk (Groves and Jennings, 1973). The regional significance of these granodiorites is unclear, but contact structural features confirm observations at other localities and thus the exposures are important from this viewpoint.

Bulbous protuberances of granodiorite similar in style, although larger than those described from Dianas Basin, project into hornfelsed Mathinna Beds. The hornfelses adjacent to these granodiorite lobes have been plastically deformed and bedding surfaces are diffuse. Some contacts are fractures, indicating possible contemporaneous intrusion and faulting. The position and shape of intrusions, and the shape of folds within the hornfelses indicate upward forcible intrusion of the granodiorite in its roof zone. The granodiorite has a strongly developed cataclastic foliation, and contains abundant mafic enclaves which are flattened in the foliation (plates 5, 6). Xenoliths of recrystallised country rocks are also abundant, and disoriented bedding slabs of hornfelsed Mathinna Beds are present.

Where the steeply dipping sides of the granodiorite are exposed the contact with Mathinna Beds is more sharply defined, although irregular pods and anastomosing veinlets of granodiorite intrude the country rocks for several metres from the contact. The regional pre-intrusion axis of folding is only disrupted within about 50-100 m of the steep-sided contact, and bedding is more diffuse in this zone. Although these contacts are discordant in the coastal section, they are subparallel to the axial surface of pre-intrusion folds.

STRUCTURAL FEATURES OF THE BIOTITE GRANITE/ADAMELLITE PLUTONS

The uncertainty of the nature of the contact between the Poimena and Mt Pierson Plutons has been discussed earlier. In terms of their mode of emplacement the two plutons are similar in structural behaviour and are grouped together in the following discussion.

All biotite granite/adameellites have sharp contacts with country rocks, which are hornfelsed for up to 2 km from the contact. There is no evidence of assimilation or stoping. Xenoliths of hornfelsed country rocks are scattered throughout the plutons, but they only occur abundantly in the immediate contact area, or in rare 'pudding-stone' (plate 2) accumulations (e.g. Groves and Jennings, 1973). Internally the granitic rocks appear generally to be devoid of structure, although possible regional-scale compositional and, or, grain size banding, and alignment of orthoclase phenocrysts have been noted above. The regional features that relate to the emplacement of the biotite granite/adameellites are described below. Most of this discussion is summarised from Gee and Groves (1971).

FRAGMENTATION OF THE PYENGANA PLUTON

The fragmentation of the Pyengana Pluton resulted from the intrusion of the Poimena Pluton, and appears to be an example of large-scale dilation. The cross-cutting relationships are shown in Figure 4. The contacts with granite/adameellite are straight and sharp, and the granite/adameellites away from the contact contain no enclaves of granodiorite, although marked by float of microgranite and hybrid rocks.

The granite/adameellite was emplaced along the transitional zone between massive and foliated granodiorite, roughly parallel to the foliation, although angular dyke-wall irregularities are perpendicular to the foliation. It is possible to match these dyke-wall irregularities and pre-existing planar structures (in this case the pre-existing granodiorite-hornfels contact) reasonably well, thus indicating a dilational mode of emplacement of the granite/adameellite using the criteria of Goodspeed (1940) and Williams and Groves (1967). Matching features are designated in Figure 4, and indicate components of dilation in the horizontal phase of 3 km in the north-west to 4.5 km

in the south-east, with an essential north-east direction of dilation. The match of structures is not perfect, and this may be explained by slight differential vertical movement during fragmentation of the granodiorite pluton.

THE SOUTHERN MARGIN

The southern margin of the granite/adamellite component of the Blue Tier Batholith has a general E-W trend, with large orthogonal irregularities due to alternate concordant and discordant contacts. This feature is common to the granodiorite plutons, but in contrast with the latter the pre-intrusion structures are truncated abruptly by the granite/adamellite.

The southern boundary is heterogeneous with thin marginal slices of granodiorite on N-S trending contacts. Small isolated bodies of metamorphosed and metasomatised country rocks cap the higher hills within the boundary, and appear to be remnants of the roof. Their disposition suggests that near this contact the roof is shelving to the south at a moderate angle; *i.e.* similar to the south-western margin of the St Helens Pluton.

ANSONS BAY PLUTON

The Ansons Bay Pluton is separated from The Gardens Pluton along its southern border and most of its western border by a dog-leg shaped screen of hornfelsed country rocks. These margins of the pluton are also alternately concordant and discordant to the pre-intrusion axis of folding and appear to be fracture controlled.

THE NORTHERN MARGIN

The Poimena Pluton exhibits on a large scale, the alternate concordant-discordant boundaries shown by individual contacts or smaller plutons. The abrupt swing in the eastern contact just south of Gladstone to E-W (*i.e.* normal to the pre-intrusion axis), is matched by the abrupt change in the western contact just south of Banca. The change to concordant contacts is equally abrupt (fig. 1, 2). Pre-intrusion folds generally appear to be abruptly truncated in these areas.

The shapes of the Boobyalla, Rushy Lagoon and Musselroe Plutons cannot be precisely determined due to superficial cover, but are believed to be rectangular by analogy with the other biotite granite/adamellite plutons.

STRUCTURAL FEATURES OF THE MUSCOVITE-BIOTITE GRANITES

The general sheet-like or essentially flat-roofed nature of the muscovite biotite granites has been discussed above. The broad structural features of these bodies are summarised below.

The Constables Creek Sheet is a multiple intrusion of sheet-like form, dipping shallowly to the south-east with a roof of Mathinna Beds and a basal contact against the Mt Pierson Pluton. The Little Mt Horror Sheet is essentially the basal part of a sheet with a feeder dyke at its southern contact. The Mt William Sheet is the basal remnant of a more extensive sheet, straddling the regional contact between the Ansons Bay Pluton and Mathinna Beds. The Mt Cameron Sheets are also generally sheet-like in form, but are relatively thin bodies. The Mt Paris Mass has a flat-lying but undulating roof, although the eastern margin appears to be steep-sided and includes an E-W trending dyke. It is the only major muscovite-biotite granite body that does not have areas which are demonstrably sheet-like in form. The Lottah Sheets are

essentially sheet-like in form, although interconnecting (? feeder) dykes are common.

These granite bodies show features of magmatic intrusion including sharp, transgressive contacts, connecting dykes and hornfelsing of intruded rocks. Enclaves are virtually absent, and undoubted xenoliths of country rocks are absent even in contact zones. An origin by replacement, assimilation and, or, stopping is clearly not tenable, and a dilational emplacement is indicated. Earlier structures in the country rocks are not distorted on a regional scale. The Mathinna Beds adjacent to the roof of the Mt Paris Mass are in places essentially flat-lying for up to 5 m above the contact, but whether this is a pre- or syn-intrusion feature is not evident. It therefore appears most likely that the muscovite-biotite granite bodies were intruded by the lifting of their roofs.

LATE- OR POST-INTRUSIVE STRUCTURAL FEATURES

Within the batholith there is only limited evidence for small-scale post-granite faulting and no evidence for major faulting. In the southern part of the area, post-Permian faults with throws of up to 20 m are fairly common and the maximum throw is about 200 m (e.g. McNeil, 1965). The generally similar elevation of the pre-Permian surface precludes any major post-Permian faulting in the central part of the area. The basal Permian sequences and the Jurassic dolerite sills are at a lower elevation along the exposed northern margin of the Blue Tier Batholith, but this may indicate a lower pre-Permian erosional level rather than a major fault system downthrowing to the north. Further study of the Permian sequences in this area is required. It therefore appears most likely that the presently exposed level of the Blue Tier Batholith represents an essentially single level of emplacement. The features described above suggest that this level was close to the original roof zone.

Faults which displace granite contacts are rare. McNeil (1965) recorded a major lineament within the St Marys Sheet, and Groves (1972a) showed faults with minor movement cutting the Scamander Tier Granodiorite Porphyry. Cocker (1971) also described faults with horizontal displacements of up to 200 m within the St Helens Pluton. The only area in which faults within granitic rocks are clearly exposed is on the foreshore between Tomahawk and Booby-alla (Groves and Jennings, 1973). Here mylonite zones up to 2 m in width are bordered by cataclastically deformed granodiorites and muscovite-biotite granites of the Sheoak Hill Pluton. The faulting has resulted in micro-brecciation of the granitic rocks with the subsequent formation of persistent 'shred-zones' adjacent to fault surfaces. The granitic rocks are also strongly recrystallised suggesting deformation and annealing at raised temperatures, possibly while the granitic rocks were still cooling. Although the fault zones are relatively narrow, the 'shred-zones' are extensive over at least 100 m from the fault zones. The lack of such features in the batholith suggests that such faulting is not common, although it is possible that it has been overlooked elsewhere due to a combination of poor exposure and the regional nature of the mapping.

EMPLACEMENT OF THE BLUE TIER BATHOLITH

Although the major granodioritic components of the St Helens Pluton and the granitic rocks of the Piccaninny Creek Pluton may have been emplaced at a different time to the Pyengana and The Gardens Plutons, their emplacement mechanisms appear to be essentially similar.

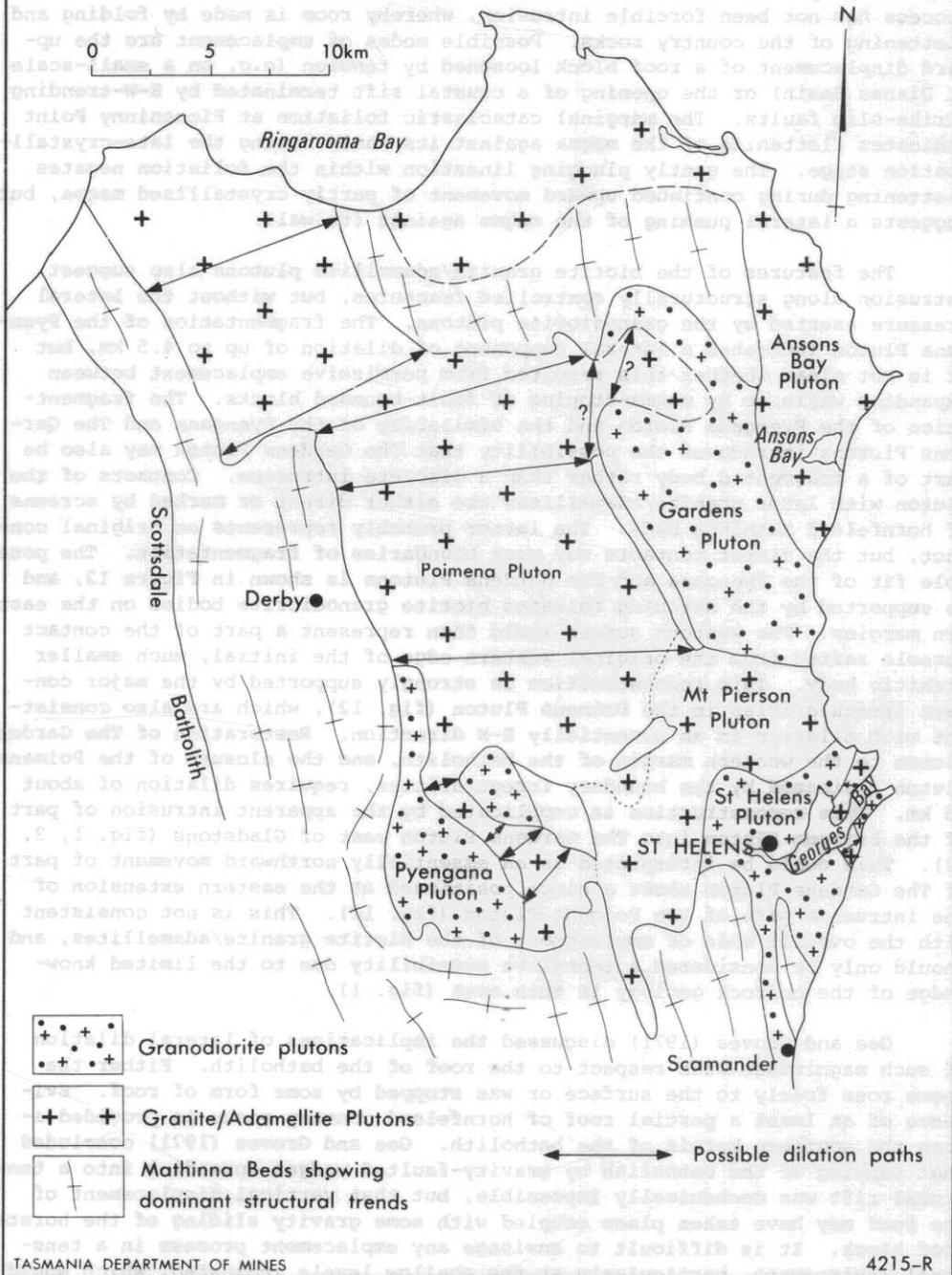
The significant structural feature of the latter plutons is their rectangular shape in plan. This appears to be an original feature resulting from emplacement along major fractures both parallel and perpendicular to the pre-intrusion fold axial surfaces. Marginal deformation by lateral pressure has been documented at Piccaninny Point and on the south-western boundary of the Pyengana Pluton, but it is not of sufficient magnitude to restore the country rock to its pre-intrusion state. It is clear that the dominant emplacement process has not been forcible intrusion, whereby room is made by folding and flattening of the country rocks. Possible modes of emplacement are the upward displacement of a roof block loosened by tension (e.g. on a small-scale at Dianas Basin) or the opening of a crustal rift terminated by E-W-trending strike-slip faults. The marginal cataclastic foliation at Piccaninny Point indicates flattening of the magma against its walls during the late-crystallisation stage. The gently plunging lineation within the foliation negates flattening during continued upward movement of partly crystallised magma, but suggests a lateral pushing of the magma against its wall.

The features of the biotite granite/adamellite plutons also suggest intrusion along structurally controlled fractures, but without the lateral pressure exerted by the granodiorite plutons. The fragmentation of the Pyengana Pluton indicates a lateral component of dilation of up to 4.5 km, but it is not clear whether this resulted from permissive emplacement between expanding walls or by magma-stopping of fault-bounded blocks. The fragmentation of the Pyengana Pluton and the similarity of the Pyengana and The Gardens Plutons introduces the possibility that The Gardens Pluton may also be part of a fragmented body rather than a discrete intrusion. Contacts of the pluton with later granite/adamellites are either direct or marked by screens of hornfelsed Mathinna Beds. The latter probably represents an original contact, but the direct contacts may mark boundaries of fragmentation. The possible fit of the Pyengana and The Gardens Plutons is shown in Figure 12, and is supported by the matching foliated biotite granodiorite bodies on the eastern margins. The western screen would then represent a part of the contact aureole rafted from the original western edge of the initial, much smaller granitic body. This reconstruction is strongly supported by the major contact irregularities in the Poimena Pluton (fig. 12), which are also consistent with dilation in an essentially E-W direction. Restoration of The Gardens Pluton to the western margin of the batholith, and the closure of the Poimena Pluton indicated by the boundary irregularities, requires dilation of about 18 km. This reconstruction is complicated by the apparent intrusion of part of the Poimena Pluton into The Gardens Pluton east of Gladstone (fig. 1, 2, 12). This could be interpreted as an essentially northward movement of part of The Gardens Pluton about a hinge positioned at the eastern extension of the intrusive part of the Poimena Pluton (fig. 12). This is not consistent with the overall mode of emplacement of the biotite granite/adamellites, and should only be considered a tentative possibility due to the limited knowledge of the bedrock geology in this area (fig. 1).

Gee and Groves (1971) discussed the implications of lateral dilation of such magnitudes with respect to the roof of the batholith. Either the magma rose freely to the surface or was stopped by some form of roof. Evidence of at least a partial roof of hornfelsed country rocks is provided along the southern margin of the batholith. Gee and Groves (1971) concluded that capping of the batholith by gravity-faulted wedges spreading into a tensional rift was mechanically impossible, but that vertical displacement of the roof may have taken place coupled with some gravity sliding of the horsted roof block. It is difficult to envisage any emplacement process in a tensional environment, particularly at the shallow levels indicated, which would prevent some magma reaching the surface, although Devonian extrusive rocks

SIMPLIFIED GEOLOGICAL MAP OF THE BLUE TIER BATHOLITH

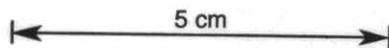
GEOLOGIST : D.I.GROVES



TASMANIA DEPARTMENT OF MINES

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Figure 12. Simplified geological map of the Blue Tier Batholith. Tie lines indicate possible paths of dilation during intrusion of the later biotite granite/adamellites.



are not known from north-eastern Tasmania. However, the time interval between granite emplacement and the first deposition of Permian sediments is of the order of 100 million years, and it is unlikely that remnants of a capping volcanic pile would be preserved, even if once present. The movement of fracture-bounded blocks upward to solve the room problem introduces other major problems. Uplift of such large blocks would be expected to initiate extensive erosion and widespread sedimentation, but again there is no evidence for such sedimentation in north-eastern Tasmania.

The final major event in the formation of the batholith was the emplacement of sheets or flat-topped plutons of muscovite-biotite granite. There appears no other alternative than that these bodies were emplaced by lifting their roofs, and were fed from feeder dykes that were commonly located adjacent to regional boundaries within the batholith. Flat-lying major joints within earlier crystallised granites may have been suitable structures to control emplacement of sheets, although most structural surfaces within the Mathinna Beds are steeply inclined. However, there is some evidence of sub-horizontal decollement (thrust) surfaces north of Mt Victoria. Late-stage acid dykes were emplaced into all granitic rocks of the batholith, and appear to have a dilational mode of emplacement where exposure allows contacts to be carefully studied (e.g. Williams and Groves, 1967).

The stress environment during emplacement of the batholith is one of dilation across pre-intrusion structures in the country rocks, and appears to have been mainly tensional. It is unclear whether a regional tensional field existed in this part of the crust during emplacement, or whether the tensional field was the high-level effect of granitic intrusion at depth. It appears most likely that magma actively rising from deeper levels may have shouldered aside country rocks producing active tension and lateral dilation at upper levels (i.e. the present level of exposure of the batholith). The exact mechanisms for the generation of tension in these upper crustal levels prior to, or during granitic emplacement is part of the larger problem of the relationship of granitic emplacement to the evolution of the Tasman Orogenic Zone (e.g. Solomon et al., 1972).

GEOCHEMISTRY OF GRANITIC ROCKS

INTRODUCTION

Major and trace element analyses of granitic rocks from the Blue Tier Batholith are presented in Tables 12 to 21, and chemical analyses of micas from these rocks in Tables 22-27. The geochemical variation shown by these rocks and micas is illustrated by Figures 13 to 19. The major features of the geochemistry of the granitic rocks are summarised below, but the origin of the granitic magmas is not discussed. A more detailed description of the geochemistry of the granitic rocks of the Poimena Pluton and Lottah Sheets is given by Groves (1972b).

MAJOR ELEMENT GEOCHEMISTRY

The granitic rocks, including the St Marys porphyrite and the Priory monzonite, clearly fall into the calc-alkali field on an AFM diagram (fig. 13) as defined by Tilley (1951). The low FeO + Fe₂O₃ content and the exceedingly low MgO content of the muscovite biotite granites is shown by their position close to the alkali corner of the diagram. Only two other granitic rocks fall into the field defined by these muscovite-bearing granites on this diagram.

The granitic rocks, with a few exceptions, define relatively smooth

are not known from north-eastern Tasmania. However, the time interval between granite emplacement and the first deposition of Permian sediments is of the order of 100 million years, and it is unlikely that remnants of a cap- and volcanic pile would be preserved, even if once present. The movement of tectonic blocks upward to solve the root problem introduces other major problems. Uplift of such large blocks would be expected to initiate extensive erosion and widespread sedimentation, but again there is no evidence for such sedimentation in north-eastern Tasmania.

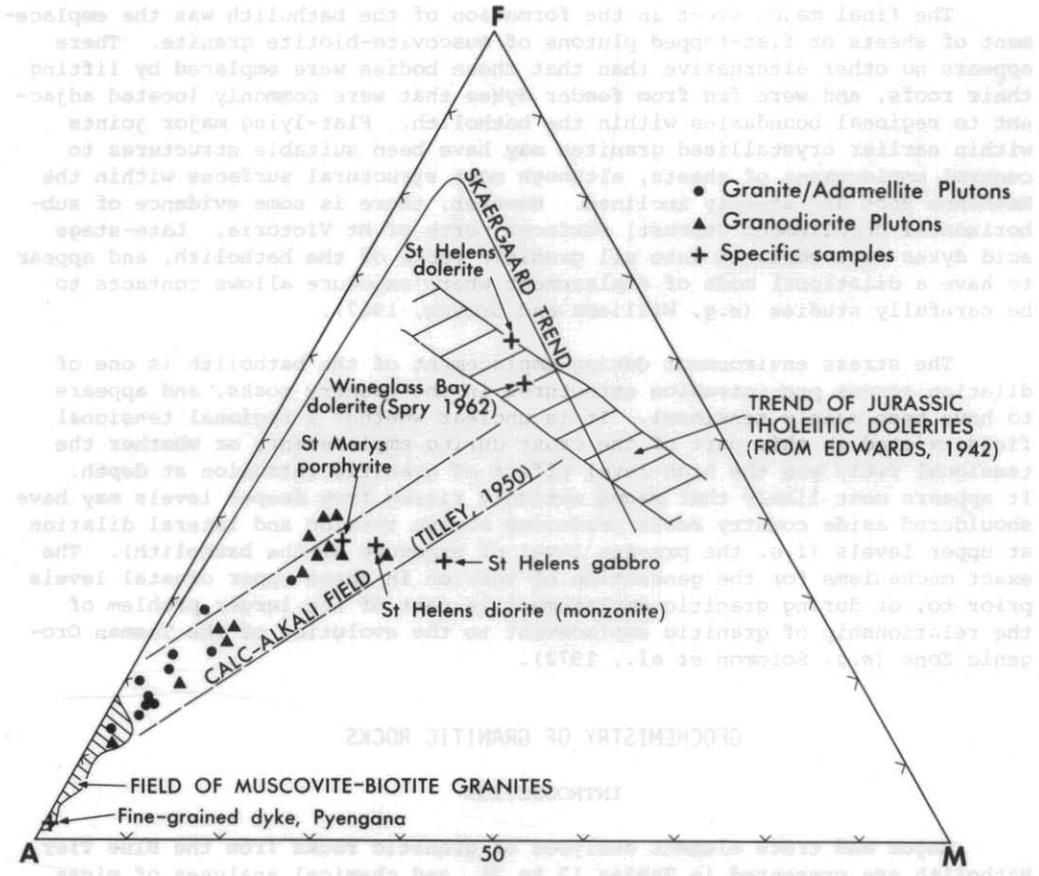


Figure 13. AFM diagram showing plot of granitic rocks and dolerites from the Blue Tier Batholith, including the calc-alkali field after Tilley (1950), and the field of Tasmanian tholeiitic dolerites from data of Edwards (1942).

variation curves (fig. 14) as shown by most calc-alkaline granitic suites. In general alkalis (particularly K_2O and Na_2O to a lesser extent) and Al_2O_3 increase, and Fe oxides, MgO and CaO decrease, with increasing SiO_2 . The major element geochemistry confirms the increasingly acidic nature of the successively emplaced granitic rocks. The granitic rocks of the St Helens and Piccaninny Creek Plutons have a wide range of composition, as indicated by petrographic studies, and cover almost the complete variation shown by the rocks of the batholith (fig. 14). A feature of the variation diagram is the limited variation shown by the muscovite-biotite granites. There is virtually no significant variation in *al*, *akl*, *fm* or *c* with *si*, so that the variation curves for these values are subparallel to the *si* axis of the diagram.

Normative values for the analysed rocks are also presented in Tables 12 to 21. The rocks are corundum normative with two exceptions, both of which are biotite hornblende granodiorites. The biotite granite/adamellites and muscovite-biotite granites contain >80% normative Or + Ab + Qz, but the granodiorites commonly contain less than this. Allowing for the progressively higher An content of the adamellites and granodiorites, all the granitic rocks plot close to the region of the ternary minimum at low water pressures (fig. 15; Tuttle and Bowen, 1958; Luth *et al.*, 1964; Winkler, 1967). In particular, the muscovite-biotite granites, which have high Ab/An ratios, cluster closely around the minimum at low water pressure. These features are consistent with the formation of the granitic rocks by crystallisation-differentiation in a magma, but are not uniquely indicative of formation by this process.

TRACE ELEMENT GEOCHEMISTRY

Element ratios commonly used as indicators of increasing fractionation in granitic rocks are decreasing Mg/Li ratios (*e.g.* Kuts and Mishchenko, 1963) and decreasing K/Rb ratios (*e.g.* Heier and Billings, 1970). These ratios are plotted in Figure 16, and demonstrate the successive decrease in both K/Rb and Mg/Li from the granodiorites to the muscovite-biotite granites, confirming the fractionation trend discussed above. The K/Rb ratios range from 180 to ~30, and Mg/Li ratios range from ~1500 to ~0.25. The muscovite-biotite granites have K/Rb ratios between 110 and 30 indicating extreme fractionation (*e.g.* Taylor *et al.*, 1956; Heier and Taylor 1959a; Taylor, 1965), and also have very low Mg/Li ratios (0.25-25).

Other trace elements that are dependent on the degree of fractionation are Sr and Ba. Both substitute for K in early-formed minerals, and are generally depleted in the late differentiates (*e.g.* Heier and Taylor, 1959b; Nockolds and Allen, 1953). Strontium is generally high in the granodiorites (150-465 ppm) compared to the granite/adamellites (25-160 ppm) and the muscovite-biotite granites (4-70 ppm). The Ca/Sr ratio is much higher in the muscovite-biotite granites than in the granodiorites and granite/adamellites (tables 12-21), although both Ca and Sr are present in low concentrations and the ratios should be regarded with caution. Increasing Ca/Sr ratio is generally consistent with increasing degree of fractionation (Turekian and Kulp, 1956; Bradshaw, 1967). Barium is high in the granodiorites (480-1100 ppm), slightly lower in the granite/adamellites (125-780 ppm), and very low in the muscovite-biotite granites (generally 10-65 ppm, but up to 555 ppm).

Zirconium also shows a general variation between granitic types, being high in granodiorites (135-275 ppm) and significantly lower in the muscovite-biotite granites (generally 30-95 ppm). The zirconium content is related to the content of zircon, which is largely concentrated as inclusions in biotite.

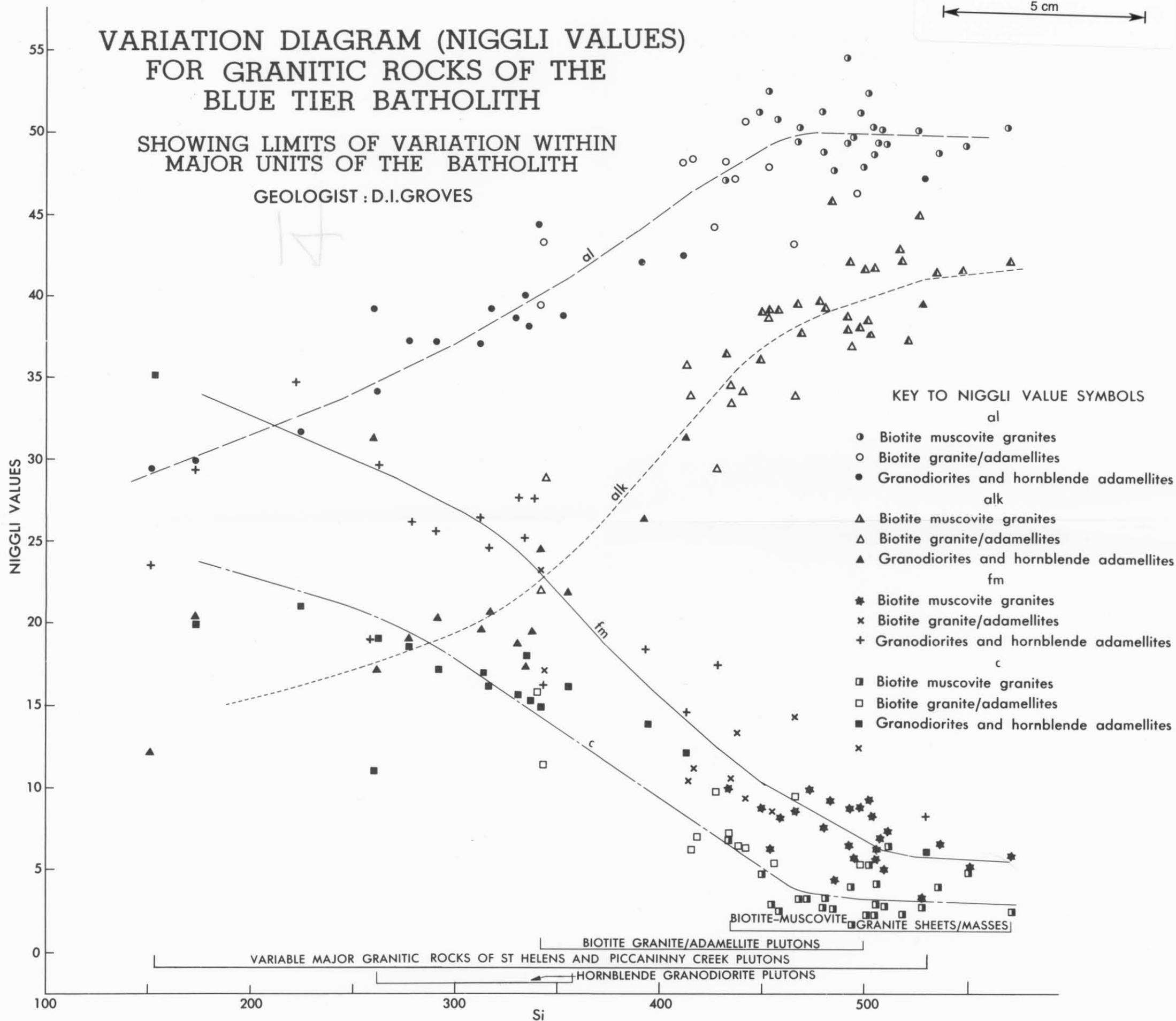
Tin and tungsten are trace elements that are important from an economic standpoint. Granodiorites and granite/adamellites contain less than 20 ppm Sn and generally less than 5 ppm W, whereas the muscovite-biotite granites

VARIATION DIAGRAM (NIGGLI VALUES) FOR GRANITIC ROCKS OF THE BLUE TIER BATHOLITH

SHOWING LIMITS OF VARIATION WITHIN
MAJOR UNITS OF THE BATHOLITH

GEOLOGIST : D.I.GROVES

5 cm



TASMANIA DEPARTMENT OF MINES

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Figure 14.

variation curves (Fig. 14) as shown by most calc-alkaline granitic suites in general alkalis (particularly K₂O and Na₂O to a lesser extent) and Al₂O₃ increases, and Fe oxides, MgO and CaO decrease, with increasing SiO₂. The major element geochemistry confirms the progressively acidic nature of the successively erupted granitic rocks.

and Piccaniny Creek plutons have a wide range of composition, as indicated by petrographic studies, and cover about a complete variation shown by the rocks of the batholith (Fig. 14). In contrast to the variation diagram in the field variation diagram for muscovite-biotite granites, there is virtually no alignment of the data points to the Ab-Or axis of the diagram.

Normative values for the analysed rocks are also presented in Tables 12 to 15. The rocks are compared normative with the compositions of muscovite-biotite granites. The biotite compositions of the muscovite-biotite granites generally maintain a high normative Qz + Ab + Or, but the muscovite-biotite granites commonly contain less than this. Allowing for the progressively higher Al content of the muscovite-biotite granites, the muscovite-biotite granites also show a trend towards higher Al content of the muscovite-biotite granites (Fig. 15). Little and Bowen (1962) have shown that the muscovite-biotite granites around the minimum of low water activity, the formation of the granitic rocks is not necessarily indicative of low water activity, but is not necessarily indicative of low water activity.

Elementary ratios commonly used as indicators of increasing fractionation in granitic rocks are decreasing Mg/Al ratios (e.g. Little and Nicholson, 1963) and decreasing Ca/Al ratios (e.g. Little and Nicholson, 1963). The Ca/Al ratio is plotted in Figure 15, and the Ca/Al ratio ranges from 1.40 to 1.80. The Mg/Al ratio is plotted in Figure 16, and the Mg/Al ratio ranges from 0.30 to 0.40. The Ca/Al ratio and the Mg/Al ratio are plotted in Figure 17, and the Ca/Al ratio ranges from 1.40 to 1.80, and the Mg/Al ratio ranges from 0.30 to 0.40.

Other trace elements like Rb, Sr and Ba, both in the rocks and in the granitic liquids, are also plotted in Figure 18, and the Rb/Sr ratio ranges from 1.40 to 1.80, and the Ba/Sr ratio ranges from 0.30 to 0.40. The Rb/Sr ratio and the Ba/Sr ratio are plotted in Figure 19, and the Rb/Sr ratio ranges from 1.40 to 1.80, and the Ba/Sr ratio ranges from 0.30 to 0.40.

MUSCOVITE-BIOTITE SHEETS/MASSES

- ★ Lottah Sheets
- × Mt Cameron Sheets
- MP × Mt Paris Mass
- + Mt William Sheet
- Little Mt Horror Sheet
- Constables Creek Sheet
- ◎ Sheoak Hill Pluton

BIOTITE GRANITE/ADAMELLITE PLUTONS

- ABO Ansons Bay Pluton
- Mt Pierson Pluton
- B ● Boobyalla Pluton
- Poimena Pluton

GRANODIORITE AND HORNBLENDE-ADAMELLITE PLUTONS

- △ St Helens Pluton
- △ Piccaniny Creek Pluton
- G ▲ Gardens Pluton
- ▲ Pyengana Pluton
- ★ St Marys Sheet

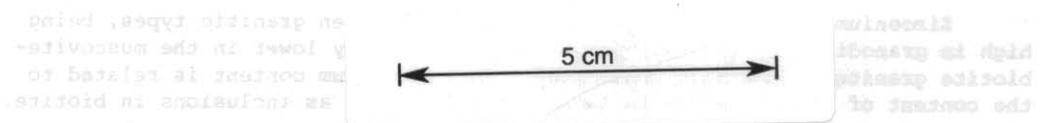
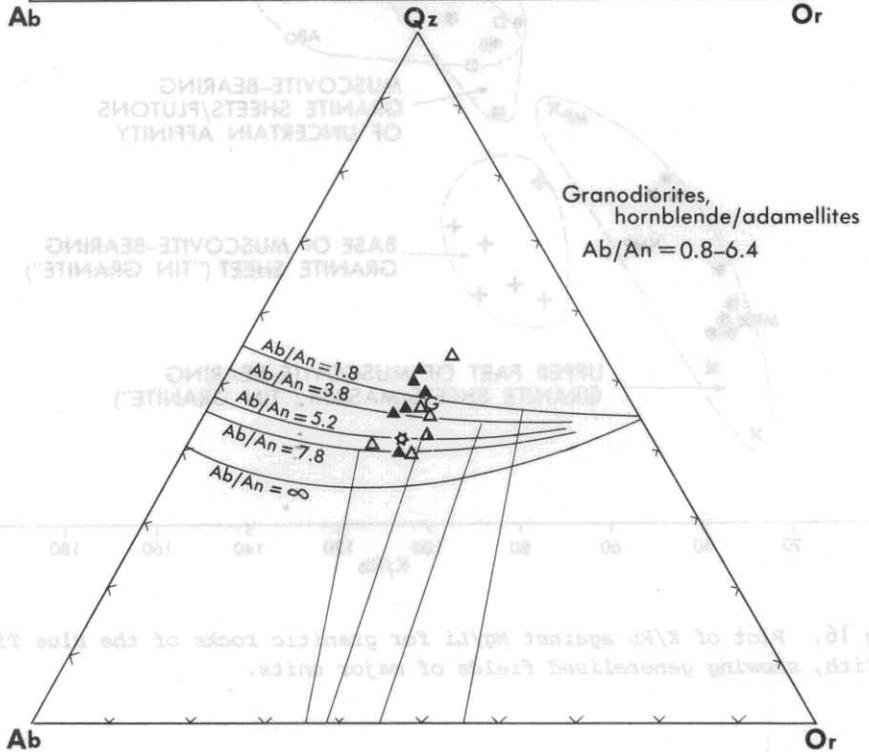
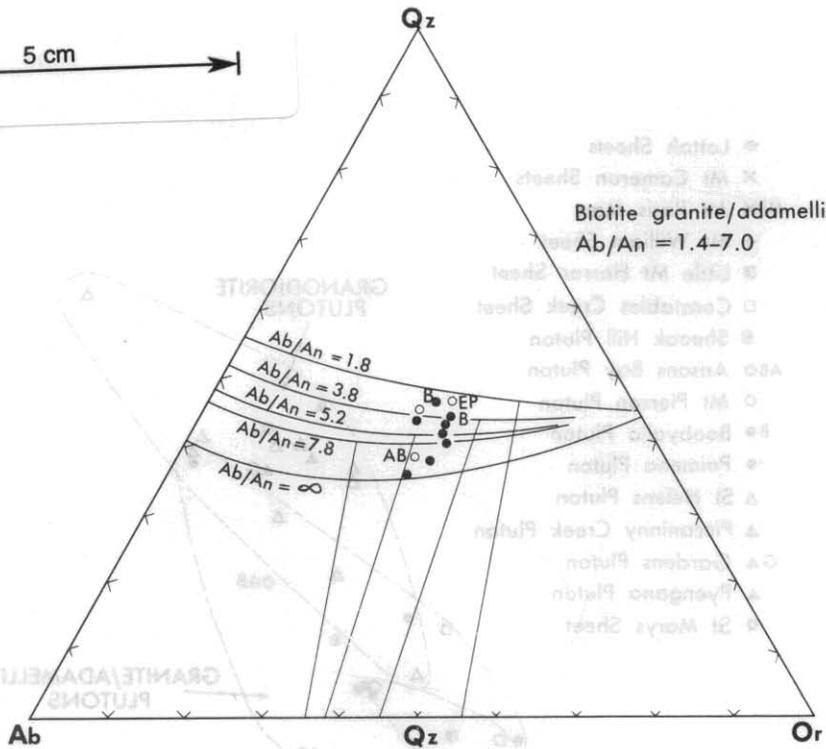


Figure 15. Plots of normative Qz-Ab-Or ratios of granitic rocks from the Blue Tier Batholith.

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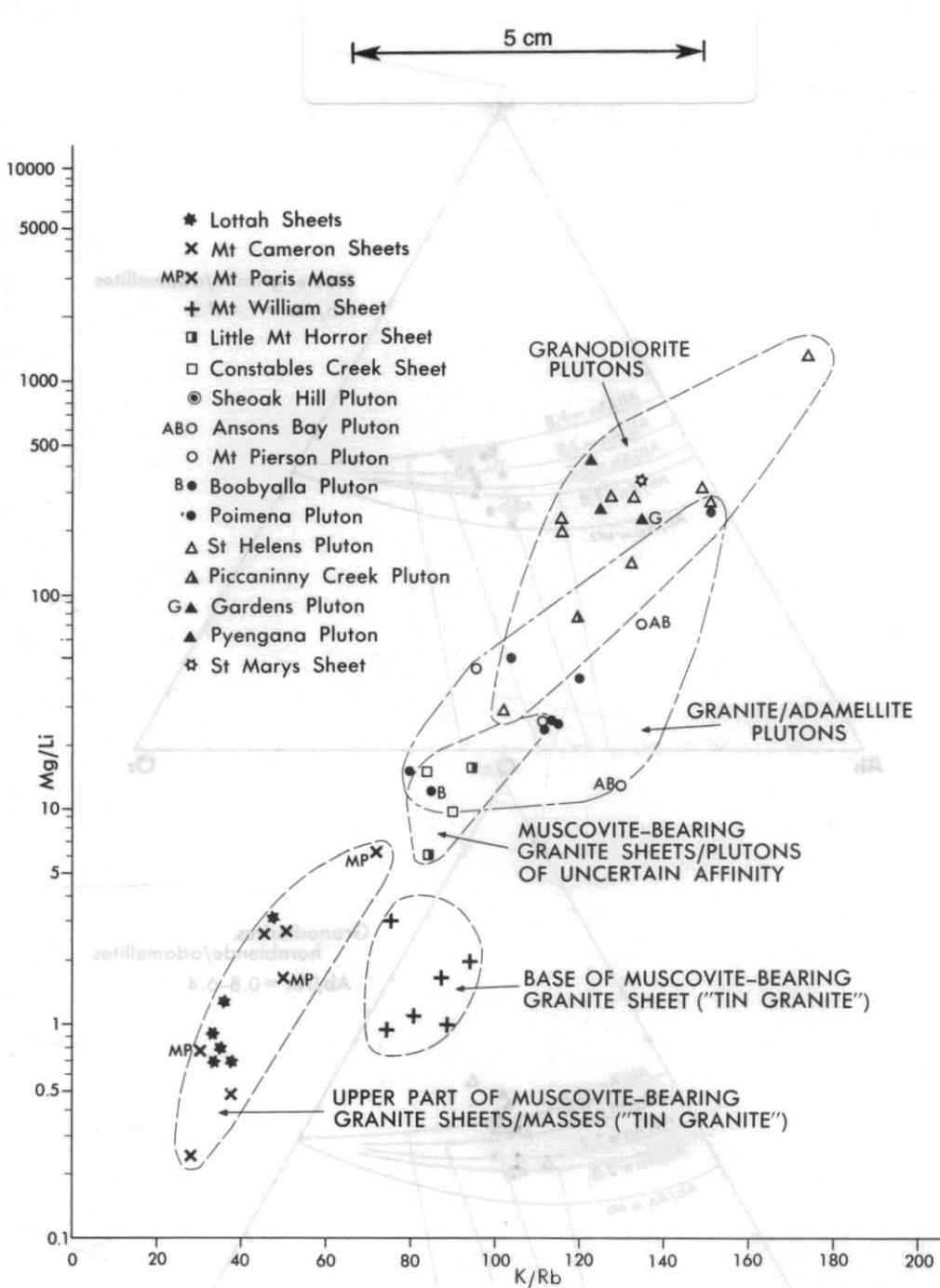


Figure 16. Plot of K/Rb against Mg/Li for granitic rocks of the Blue Tier Batholith, showing generalised fields of major units.

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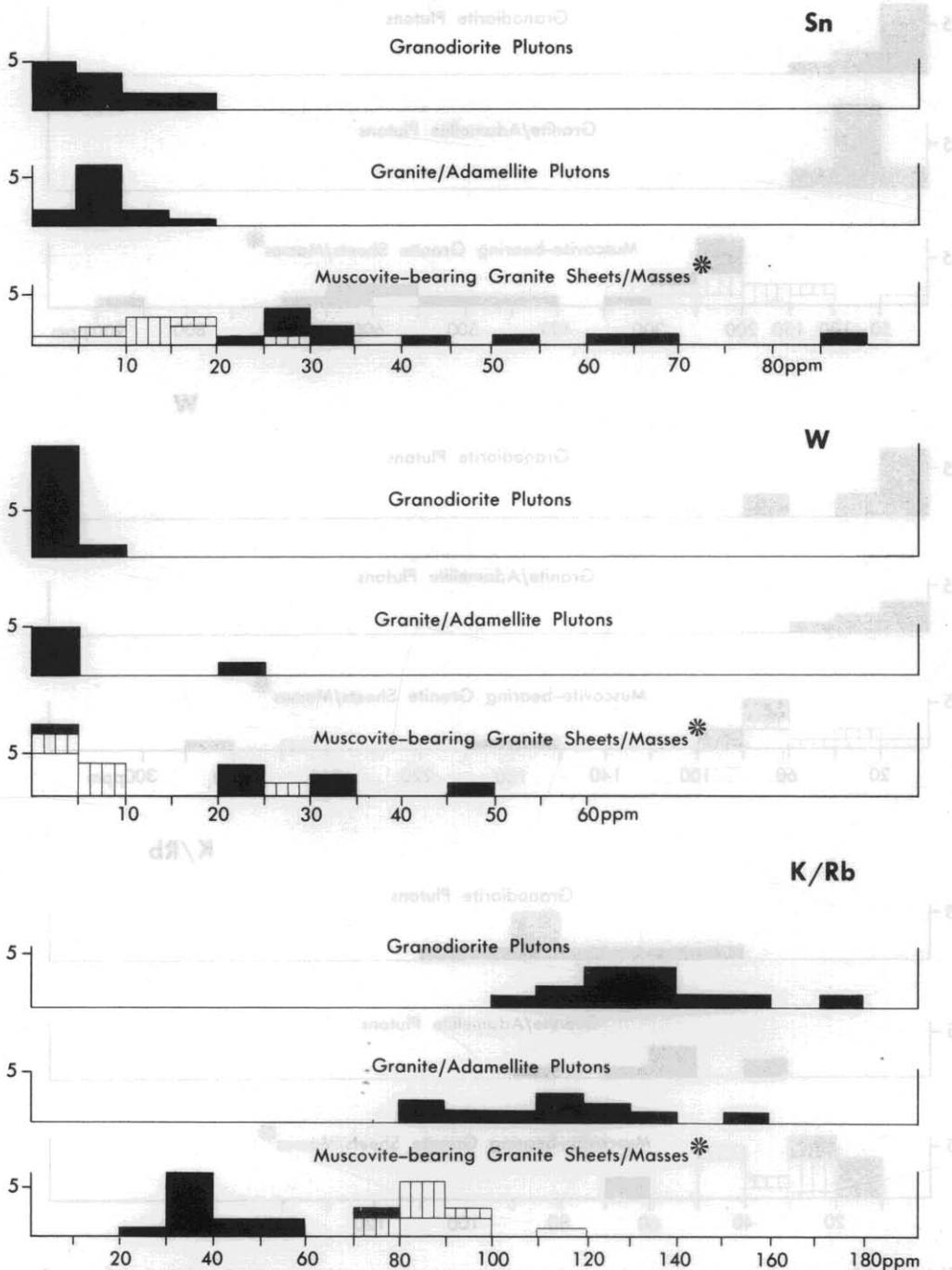
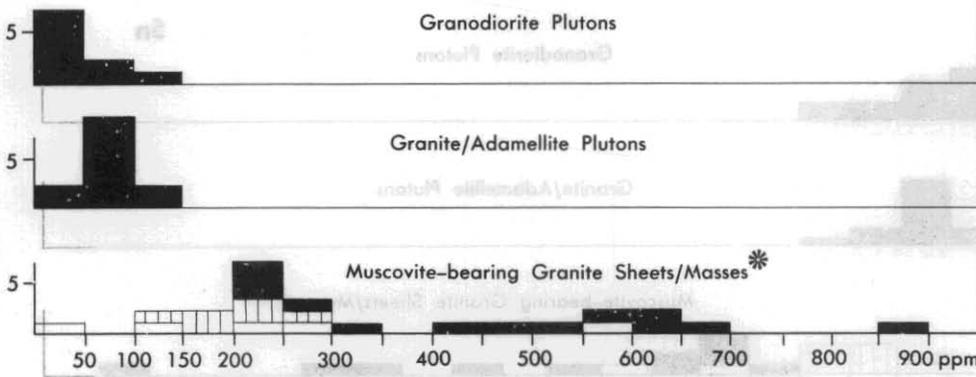


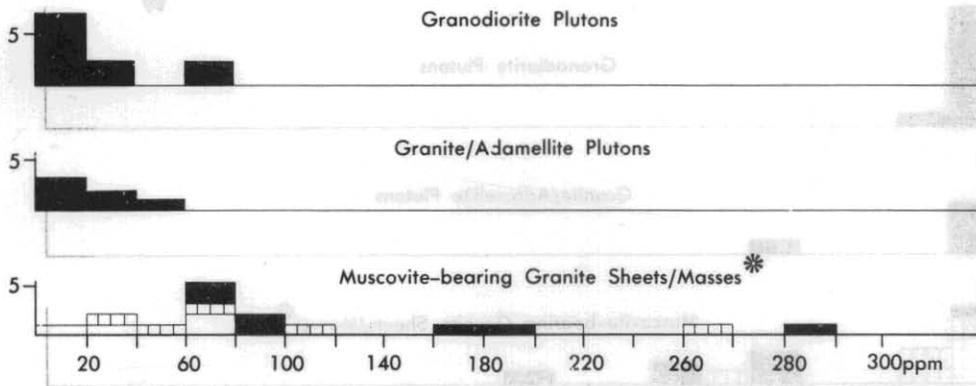
Figure 17. Histograms showing tin and tungsten contents and K/Rb ratios of granitic rocks from the Blue Tier Batholith. *For muscovite-bearing granites solid shading represents the Mt Paris Mass and Lottah and Mt Cameron Sheets, vertical stripes represent the Mt William Sheet, and unshaded areas represent the Little Mt Horror and Constables Creek Sheets and Sheoak Hill Pluton.

5 cm

Sn



W



K/Rb

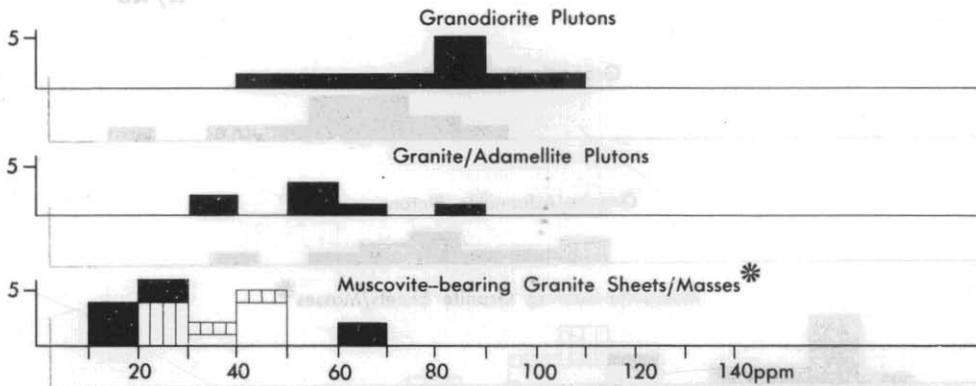


Figure 18. Histograms showing tin and tungsten contents and K/rb ratios of biotites from granitic rocks of the Blue Tier Batholith. *For biotites from muscovite-bearing granites solid shading represents the Mt Paris Mass and Lottah and Mt Cameron Sheets, vertical stripes represent the Mt William Sheet, and unshaded areas represent the Little Mt Horror and Constables Creek Sheets and Sheoak Hill Pluton.

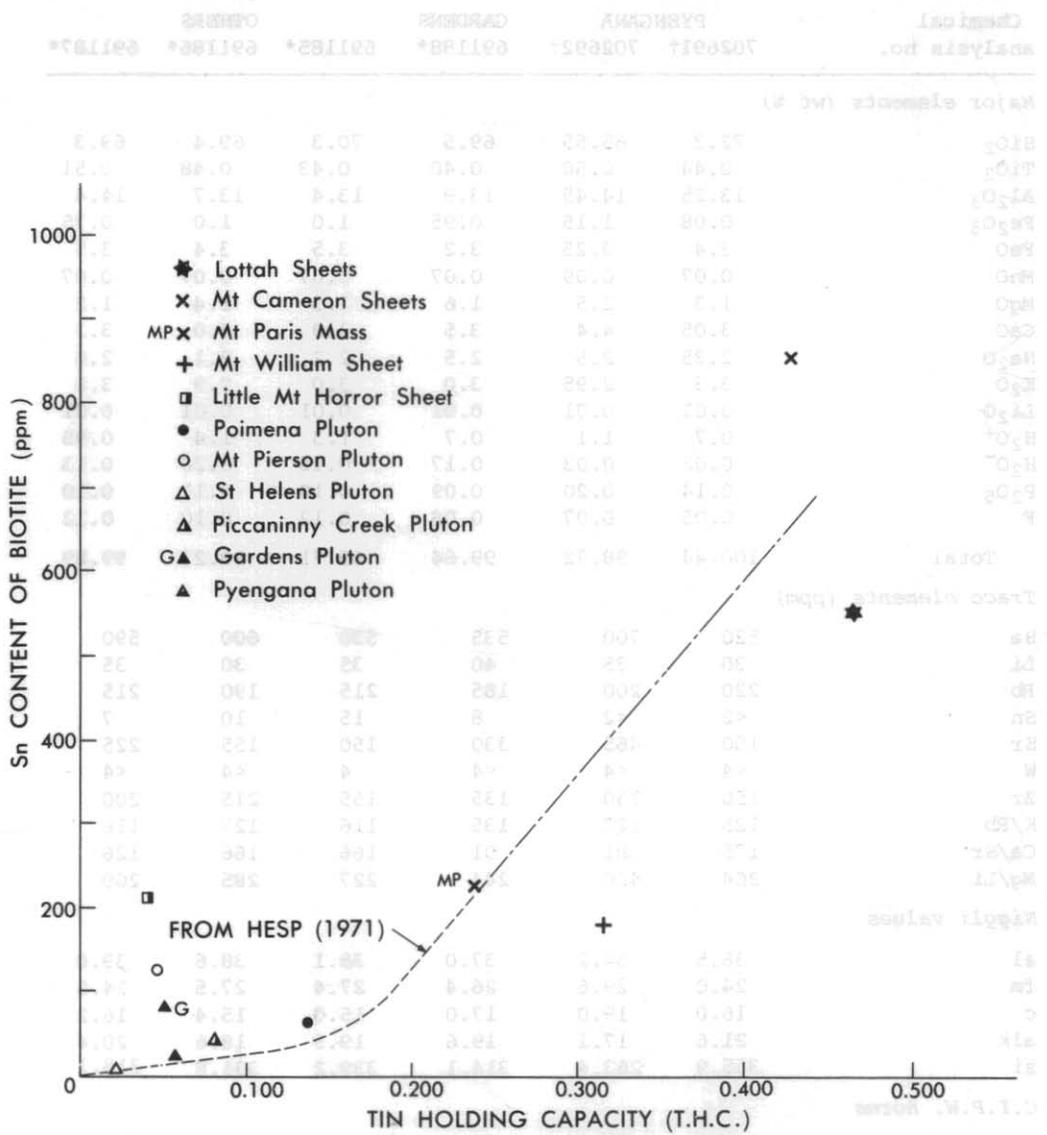


Figure 19. Plot of 'tin-holding capacity' against tin content of biotites from granitic rocks of the Blue Tier Batholith. Correlation derived by Hesp (1971) for Australian granitic rocks is shown for comparison.

Table 12. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR GRANODIORITES FROM PYENGANA AND GARDENS PLUTONS AND SMALL GRANODIORITE PLUTONS IN THE SOUTHERN PART OF THE BLUE TIER BATHOLITH.

Chemical analysis no.	PYENGANA		GARDENS		OTHERS	
	702691†	702692†	691188*	691185*	691186*	691187*
<i>Major elements (wt %)</i>						
SiO ₂	72.3	65.55	69.5	70.3	69.4	69.3
TiO ₂	0.44	0.50	0.40	0.43	0.48	0.51
Al ₂ O ₃	13.25	14.45	13.9	13.4	13.7	14.4
Fe ₂ O ₃	0.08	1.15	0.95	1.0	1.0	0.75
FeO	3.4	3.25	3.2	3.5	3.4	3.5
MnO	0.07	0.09	0.07	0.07	0.07	0.07
MgO	1.3	2.5	1.6	1.3	1.4	1.2
CaO	3.05	4.4	3.5	2.9	3.0	3.3
Na ₂ O	2.35	2.5	2.5	2.2	2.1	2.6
K ₂ O	3.3	2.95	3.0	3.0	2.9	3.0
Li ₂ O	0.01	0.01	0.01	0.01	0.01	0.01
H ₂ O ⁺	0.7	1.1	0.7	1.3	1.4	0.95
H ₂ O ⁻	0.02	0.03	0.17	0.13	0.20	0.13
P ₂ O ₅	0.14	0.20	0.09	0.10	0.11	0.10
F	0.05	0.07	0.08	0.12	0.10	0.12
Total	100.44	98.72	99.64	99.71	99.23	99.89
<i>Trace elements (ppm)</i>						
Ba	520	700	535	530	600	590
Li	30	35	40	35	30	35
Rb	220	200	185	215	190	215
Sn	<2	<2	8	15	10	7
Sr	150	465	330	150	155	225
W	<4	<4	<4	4	<4	<4
Zr	150	150	135	155	215	200
K/Rb	125	123	135	116	127	116
Ca/Sr	175	81	91	166	166	126
Mg/Li	264	436	244	227	285	209
<i>Niggli values</i>						
al	38.5	34.2	37.0	38.1	38.6	39.0
fm	24.0	29.6	26.4	27.4	27.5	24.5
c	16.0	19.0	17.0	15.0	15.4	16.2
alk	21.6	17.1	19.6	19.5	18.6	20.4
si	355.9	263.4	314.1	339.2	331.8	318.1
<i>C.I.P.W. norms</i>						
Q	35.9	25.5	32.0	36.2	36.8	32.1
Or	19.5	17.8	17.7	17.7	17.1	17.7
Ab	19.9	21.6	21.2	18.6	17.8	22.0
An	14.3	19.6	16.2	12.9	11.5	14.9
C	0.7	0.0	0.6	1.8	2.9	1.4
Di	0.0	1.0	0.0	0.0	0.0	0.0
Fs	5.6	4.3	4.5	5.0	4.7	5.1
En	3.2	6.0	4.0	3.2	3.5	3.0
Mt	0.1	1.7	1.4	1.5	1.5	1.1
Ilm	0.8	1.0	0.8	0.8	0.9	1.0
Ap	0.3	0.5	0.2	0.2	0.3	0.2

†Analyst: P. Bannister, Department of Geology, University of Western Australia.

*Analyst: Department of Mines Laboratories, Launceston.

Table 13. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR GRANITIC ROCKS FROM THE ST HELENS PLUTON AND PICCANINNY CREEK PLUTON*, BLUE TIER BATHOLITH.

Chemical analysis no.	702686	702687	702688	702689	702690	611465	702714
<i>Major elements (wt %)</i>							
SiO ₂	70.0	65.5	77.35	72.8	70.9	68.0	73.35
TiO ₂	0.41	0.30	0.06	0.23	0.33	0.59	2.72
Al ₂ O ₃	14.05	16.75	11.6	13.15	15.65	14.7	12.7
Fe ₂ O ₃	2.5	1.7	0.35	0.25	0.35	0.45	0.3
FeO	1.1	1.95	0.7	2.25	2.15	3.8	1.6
MnO	0.08	0.07	0.07	0.05	0.05	0.07	0.03
MgO	1.6	1.2	0.2	0.85	0.85	1.55	0.65
CaO	3.45	2.5	0.8	2.35	2.85	3.7	1.95
Na ₂ O	1.6	5.85	2.9	2.6	3.3	2.65	2.85
K ₂ O	3.2	3.35	4.5	3.65	3.05	3.4	4.35
Li ₂ O	0.00	0.00	0.01	0.00	0.01	0.01	0.01
H ₂ O ⁺	0.8	0.8	0.4	1.1	0.8	1.05	0.4
H ₂ O ⁻	0.00	0.05	0.03	0.01	0.02	0.00	0.06
P ₂ O ₅	0.17	0.07	0.00	0.08	0.11	0.13	0.06
F	0.06	0.03	0.02	0.06	0.07	0.10	0.07
Total	99.00	100.11	98.98	99.40	100.46	100.16	101.17
<i>Trace elements (ppm)</i>							
Ba	610	1100	115	785	480	660	525
Li	25	5	45	20	35	30	50
Rb	200	160	365	200	190	190	300
Sn	<2	18	12	<2	5	6	3
Sr	285	285	27	105	215	265	175
W	<4	<4	<4	<4	<4	4	5
Zr	130	135	65	275	145	175	140
K/Rb	133	174	102	151	133	149	120
Ca/Sr	104	75	983	192	114	120	96
Mg/Li	390	1464	27	260	148	315	79
<i>Niggli values</i>							
al	39.8	39.2	46.9	41.9	44.3	37.2	42.4
fm	25.1	18.9	8.2	18.2	16.2	25.4	14.6
c	17.9	10.8	5.8	13.6	14.8	17.0	11.9
alk	17.3	31.1	39.1	26.3	24.6	20.4	31.2
si	335.7	261.2	530.5	393.8	342.6	292.5	414.2
<i>C.I.P.W. norms</i>							
Q	39.9	11.5	41.3	36.5	31.8	27.1	35.0
Or	19.3	19.9	27.0	21.8	18.1	20.0	25.5
Ab	13.8	50.0	24.9	22.3	28.2	22.6	23.9
An	16.3	9.6	3.9	11.2	13.4	17.4	8.7
C	2.1	0.0	0.6	0.9	2.1	0.2	0.1
Di	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Fs	0.0	1.4	1.0	3.7	3.2	5.7	0.0
En	4.1	2.4	0.6	2.1	2.1	3.9	1.7
Mt	2.7	2.5	0.5	0.4	0.5	0.7	0.0
Ilm	0.8	0.6	0.1	0.4	0.6	1.1	3.4
Ap	0.4	0.2	0.0	0.2	0.3	0.3	0.2

*702714 only.

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 14. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR PORPHYRITIC BIOTITE GRANITES, FROM THE ANCHOR MINE, BLUE TIER BATHOLITH.

Chemical analysis no.	682046	682047	682048	682059	682062	Mean
Major elements (wt %)						
SiO ₂	72.9	74.0	72.7	73.9	73.8	73.5
TiO ₂	0.19	0.16	0.17	0.10	0.16	0.16
Al ₂ O ₃	14.3	13.9	14.3	14.3	13.4	14.0
Fe ₂ O ₃	0.30	0.30	0.30	0.24	0.33	0.30
FeO	1.4	1.4	1.4	1.2	1.7	1.4
MnO	0.02	0.02	0.02	0.02	0.04	0.02
MgO	0.40	0.38	0.40	0.31	0.35	0.38
CaO	1.1	1.1	1.0	0.97	1.0	1.03
Na ₂ O	2.9	2.9	3.2	2.7	3.1	3.0
K ₂ O	4.9	4.8	4.9	4.8	4.1	4.7
Li ₂ O	0.02	0.02	0.02	0.01	0.03	0.02
H ₂ O ⁺	1.4	1.3	1.3	1.1	1.2	1.3
H ₂ O ⁻	0.0	0.0	0.0	0.0	0.0	0.0
P ₂ O ₅	0.14	0.11	0.10	0.14	0.15	0.13
CO ₂	0.20	0.30	0.22	0.27	0.30	0.28
SO ₃	0.06	0.06	0.03	tr.	tr.	0.03
Cl	0.04	0.04	0.00	0.00	0.00	0.02
F	0.11	0.15	0.14	0.10	0.21	0.14
Total	100.30	100.82	100.08	100.08	99.81	100.32
Trace elements (ppm)						
Sn	6	5	6	5	16	9
Rb	360	355	355	335	425	365
Sr	95	85	105	30	65	75
K/Rb	113	112	115	120	80	108
Ca/Sr	102	112	85	270	130	140
Mg/Li	26	25	26	40	15	25
Niggli values						
al	48.3	48.2	48.1	50.5	47.0	
fm	10.9	10.3	10.2	9.2	13.2	
c	6.8	6.9	6.1	6.2	6.4	
alk	34.0	34.6	35.6	34.0	33.4	
si	417.8	435.4	415.2	442.8	438.9	
C.I.P.W. norms						
Q	34.3	35.8	32.4	37.3	37.2	
Or	29.4	28.8	29.4	28.8	24.6	
Ab	24.9	24.9	27.5	23.2	26.6	
An	4.6	4.8	4.4	4.0	4.0	
C	2.6	2.2	2.2	3.3	2.4	
Fs	2.1	2.1	2.1	1.9	2.7	
En	1.0	1.0	1.0	0.8	0.9	
Mt	0.4	0.4	0.4	0.4	0.5	
Ilm	0.4	0.3	0.3	0.2	0.3	
Ap	0.3	0.3	0.2	0.3	0.4	

Major element analyses: Department of Mines Laboratories, Launceston.

Trace element analyses: J. Klomínský and D.I. Groves.

Table 15. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR GRANITIC ROCKS FROM POIMENA, MT PIERSON, ANSONS BAY AND BOOBYALLA PLUTONS, BLUE TIER BATHOLITH.

Chemical analysis no.	POIMENA 702701	MT PIERSON 691191	ANSONS BAY 702711 702710		BOOBYALLA 702705 702706	
Major elements (wt %)						
SiO ₂	69.95	75.6	74.4	75.75	69.55	76.6
TiO ₂	0.36	0.16	0.35	0.08	0.41	0.13
Al ₂ O ₃	14.9	11.8	12.95	13.45	13.55	12.05
Fe ₂ O ₃	0.3	0.6	0.2	0.3	0.4	0.2
FeO	2.2	1.6	2.6	1.05	2.95	1.65
MnO	0.05	0.04	0.03	0.02	0.07	0.02
MgO	0.8	0.3	0.4	0.13	1.25	0.14
CaO	2.1	1.4	1.55	0.85	2.95	0.75
Na ₂ O	3.25	2.9	2.3	3.45	2.25	2.6
K ₂ O	4.2	4.1	4.4	4.75	3.55	4.9
Li ₂ O	0.02	0.01	0.01	0.01	0.01	0.01
H ₂ O ⁺	0.6	0.65	0.6	0.4	1.1	0.6
H ₂ O ⁻	0.06	0.05	0.00	0.06	0.01	0.03
P ₂ O ₅	0.14	0.04	0.14	0.00	0.09	0.08
F	0.09	0.21	0.11	0.05	0.08	0.17
Total	98.98	99.38	100.00	100.33	98.19	99.86
Trace elements (ppm)						
Ba	725	285	780	320	565	125
Li	95	40	35	55	30	65
Rb	335	355	270	305	195	480
Sn	12	9	<2	3	6	10
Sr	160	60	95	75	140	25
W	20	<4	<4	<4	<4	4
Zr	180	130	250	95	140	120
K/Rb	104	96	135	129	151	85
Ca/Sr	113	201	140	97	181	258
Mg/Li	51	46	70	14	254	13
Niggli values						
al	43.2	43.0	43.9	47.7	39.3	46.1
fm	16.9	14.1	17.3	8.3	23.1	12.1
c	11.2	9.3	9.7	5.4	15.7	5.1
alk	28.7	33.6	29.1	38.6	21.9	36.7
si	345.0	467.6	429.1	455.6	342.9	498.8
C.I.P.W. norms						
Q	28.4	39.3	38.9	34.9	33.8	40.1
Or	25.1	24.2	26.2	28.3	21.6	29.3
Ab	27.6	24.5	19.8	29.2	19.6	22.1
An	9.5	5.2	6.8	4.2	17.5	3.2
C	1.5	0.7	1.9	1.1	0.9	1.3
Di	0.0	0.0	0.0	0.0	0.0	0.0
Fs	3.3	2.2	4.1	1.6	4.7	2.7
En	2.0	0.7	1.1	0.3	3.3	0.4
Mt	0.4	0.9	0.3	0.5	0.6	0.3
Ilm	0.7	0.3	0.7	0.2	0.8	0.3
Ap	0.3	0.1	0.3	0.0	0.2	0.2

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 16. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR GRANITIC ROCKS, LITTLE MT HORROR SHEET, CONSTABLES CREEK SHEET, AND SHEOAK HILL PLUTON, BLUE TIER BATHOLITH.

Chemical analysis no.	LITTLE MT HORROR		CONSTABLES CREEK		SHEOAK HILL
	702697	702698	702712	702713	702704
Major elements (wt %)					
SiO ₂	74.25	77.0	78.7	76.8	74.4
TiO ₂	0.21	0.06	0.02	0.06	0.11
Al ₂ O ₃	13.7	12.55	11.7	12.5	14.4
Fe ₂ O ₃	0.25	0.25	0.4	0.2	0.2
FeO	1.2	0.55	0.4	0.85	0.95
MnO	0.05	0.03	0.01	0.03	0.04
MgO	0.25	0.07	0.04	0.09	0.25
CaO	1.05	0.55	0.3	0.9	0.65
Na ₂ O	2.9	3.35	3.0	2.8	2.9
K ₂ O	5.35	4.8	4.55	4.55	4.85
Li ₂ O	0.02	0.02	0.00	0.01	0.01
H ₂ O ⁺	0.4	0.2	0.3	0.3	0.9
H ₂ O ⁻	0.05	0.05	0.02	0.04	0.04
P ₂ O ₅	0.14	0.01	0.00	0.02	0.19
F	0.10	0.03	0.04	0.07	0.05
Total	99.88	99.51	99.46	99.25	99.92
Trace elements (ppm)					
Ba	555	25	50	90	280
Li	95	75	15	55	60
Rb	470	475	455	420	360
Sn	16	35	9	3	17
Sr	70	<5	<5	<5	30
W	<4	4	<4	<4	<4
Zr	145	50	60	90	70
K/Rb	94	84	83	90	112
Ca/Sr	129	>945	>515	>1550	186
Mg/Li	16	6	16	10	25
Niggli values					
al	47.0	48.6	50.2	49.2	51.3
fm	9.8	5.9	5.7	7.2	8.4
c	6.7	4.0	2.2	6.4	4.4
alk	36.5	41.5	41.9	37.2	36.0
si	434.5	507.1	572.9	512.0	450.9
C.I.P.W. norms					
Q	34.1	37.8	43.3	41.7	37.2
Or	31.7	28.3	26.9	27.9	28.9
Ab	24.6	28.3	25.3	24.7	24.9
An	4.4	2.6	1.6	4.5	2.1
C	1.6	1.0	1.3	1.4	3.6
Di	0.0	0.0	0.0	0.0	0.0
Fs	1.8	0.8	0.4	1.4	1.5
En	0.6	0.2	0.1	0.2	0.7
Mt	0.4	0.4	0.6	0.3	0.3
Ilm	0.4	0.1	0.0	0.1	0.2
Ap	0.3	0.0	0.0	0.1	0.5

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 17. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR MUSCOVITE BIOTITE GRANITES, MT WILLIAM SHEET, BLUE TIER BATHOLITH.

Chemical analysis no.	702707	702708	702709	702722	702723	702725	Mean
Major elements (wt %)							
SiO ₂	77.4	77.45	76.5	76.5	76.45	76.1	76.75
TiO ₂	0.02	0.06	0.02	0.02	0.00	0.08	0.03
Al ₂ O ₃	12.4	13.1	12.75	12.55	12.8	13.0	12.95
Fe ₂ O ₃	0.15	0.45	0.35	0.6	0.35	0.4	0.4
FeO	0.35	0.55	0.5	0.55	0.45	0.6	0.5
MnO	0.01	0.02	0.02	0.02	0.02	0.02	0.02
MgO	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CaO	0.35	0.4	0.35	0.30	0.35	0.45	0.35
Na ₂ O	3.9	3.8	3.85	3.75	4.1	3.85	3.85
K ₂ O	4.3	4.25	4.25	4.2	5.1	4.2	4.4
Li ₂ O	0.00	0.01	0.01	0.01	0.01	0.01	0.01
H ₂ O ⁺	0.3	0.5	0.5	0.5	0.3	0.3	0.4
H ₂ O ⁻	0.03	0.05	0.05	0.01	0.03	0.05	0.03
P ₂ O ₅	0.00	0.00	0.00	0.02	0.00	0.00	0.00
F	0.08	0.09	0.09	0.01	0.03	0.05	0.06
Total	99.27	100.70	99.29	99.05	99.99	99.10	99.74
Trace elements (ppm)							
Ba	30	65	30	45	10	20	35
Li	20	65	55	35	30	60	45
Rb	475	475	430	400	445	395	435
Sn	8	18	25	10	13	11	15
Sr	10	12	<5	<5	<5	<5	<7
W	<4	5	4	25	5	5	8
Zr	80	85	75	70	65	<4	75
K/Rb	75	74	82	87	95	88	84
Ca/Sr	300	285	>600	>515	>600	>775	>500
Mg/Li	3.1	0.9	1.1	1.7	2.0	1.0	1.4
Niggli values							
al	50.0	50.2	50.0	49.2	47.7	49.6	
fm	2.9	5.5	4.8	6.8	4.2	5.5	
c	2.5	2.7	2.4	2.0	2.3	3.1	
alk	44.7	41.6	42.8	42.0	45.8	41.8	
si	528.7	506.3	510.0	510.0	486.3	495.3	
C.I.P.W. norms							
Q	37.6	38.1	37.1	37.9	32.2	36.1	
Or	25.4	25.1	25.3	25.0	30.2	25.0	
Ab	32.9	32.4	32.6	32.0	34.9	32.9	
An	1.6	2.1	1.7	1.4	1.5	2.2	
C	0.8	1.5	1.2	1.4	0.0	1.3	
Di	0.0	0.0	0.0	0.0	0.3	0.0	
Fs	0.5	0.6	0.6	0.5	0.4	0.7	
En	0.0	0.0	0.0	0.0	0.0	0.0	
Mt	0.2	0.6	0.5	0.9	0.5	0.6	
Ilm	0.0	0.1	0.0	0.0	0.0	0.2	
Ap	0.0	0.0	0.0	0.1	0.0	0.0	

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 18. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR GRANITIC ROCKS, MT CAMERON SHEETS AND MT PARIS MASS, BLUE TIER BATHOLITH.

Chemical analysis no.	MT CAMERON				MT PARIS		
	702699	702700	702702	702703	702694	702695	702696
Major elements (wt %)							
SiO ₂	78.15	77.75	76.35	77.05	75.9	75.6	76.35
TiO ₂	0.00	0.04	0.04	0.08	0.01	0.04	0.07
Al ₂ O ₃	14.6	11.9	12.45	12.4	13.35	13.65	13.0
Fe ₂ O ₃	0.4	0.2	0.45	0.35	0.2	0.25	0.25
FeO	0.7	0.7	0.4	1.05	0.95	1.2	1.1
MnO	0.02	0.06	0.01	0.04	0.05	0.05	0.04
MgO	0.01	0.01	0.02	0.07	0.03	0.06	0.09
CaO	0.2	0.5	0.65	0.7	0.3	0.45	0.55
Na ₂ O	3.45	3.5	3.55	3.35	3.35	3.2	2.9
K ₂ O	4.1	4.05	4.35	4.15	3.9	4.55	4.85
Li ₂ O	0.03	0.05	0.01	0.03	0.05	0.05	0.02
H ₂ O ⁺	0.5	0.3	0.5	0.7	0.5	0.8	0.8
H ₂ O ⁻	0.04	0.05	0.10	0.08	0.04	0.04	0.03
P ₂ O ₅	0.03	0.00	0.00	0.04	0.09	0.09	0.05
F	0.32	0.41	0.14	0.23	0.55	0.43	0.30
Total	102.42	99.69	99.26	100.22	99.04	100.28	100.27
Trace elements (ppm)							
Ba	15	10	10	45	20	35	65
Li	120	250	45	160	230	215	90
Rb	950	1190	735	765	1070	755	560
Sn	25	85	30	30	40	25	20
Sr	4	5	8	25	4	4	4
W	20	20	30	45	20	30	<4
Zr	40	95	75	175	35	70	85
K/Rb	37	29	51	45	30	50	72
Ca/Sr	430	860	700	240	645	970	1185
Mg/Li	0.5	0.25	2.7	2.7	0.8	1.7	6.1
Niggli values							
al	54.2	48.5	49.0	47.7	52.2	50.2	49.2
fm	6.4	6.6	4.8	9.0	8.0	9.4	8.5
c	1.5	3.7	4.8	5.1	2.0	3.0	3.9
alk	37.9	41.1	41.4	38.3	37.8	37.5	38.4
si	493.6	537.8	551.4	501.6	504.0	471.9	493.4
C.I.P.W. norms							
Q	40.7	40.3	37.7	39.7	40.8	38.2	39.3
Or	23.8	24.0	25.8	24.7	23.5	27.1	28.8
Ab	28.7	29.9	30.4	28.7	28.8	27.2	24.9
An	0.9	2.6	3.3	3.3	0.9	1.8	2.3
C	4.1	0.8	0.6	1.2	3.4	2.9	2.1
Di	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fs	1.0	1.2	0.0	1.6	1.7	2.1	1.7
En	0.2	0.0	0.1	0.2	0.4	0.2	0.2
Mt	0.6	0.3	0.6	0.5	0.3	0.3	0.4
Ilm	0.0	0.1	0.1	0.2	0.0	0.1	0.1
Ap	0.1	0.0	0.0	0.1	0.2	0.2	0.1

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 19. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES AND C.I.P.W. NORMS FOR MUSCOVITE-BIOTITE GRANITES, LOTTAH SHEETS, BLUE TIER BATHOLITH.

Chemical analysis no.	682049	682050	682055	682063	682066	682068	Mean
Major elements (wt %)							
SiO ₂	75.3	74.7	74.6	74.3	75.8	75.2	75.0
TiO ₂	0.00	0.00	0.00	0.00	0.03	0.03	0.01
Al ₂ O ₃	12.9	13.3	14.6	13.9	13.2	13.5	13.6
Fe ₂ O ₃	0.14	0.45	0.33	0.35	0.43	0.29	0.33
FeO	1.4	1.1	0.74	1.1	1.0	0.97	1.05
MnO	0.04	0.04	0.09	0.04	0.04	0.02	0.04
MgO	0.06	0.05	0.05	0.05	0.05	0.07	0.06
CaO	0.46	0.44	0.39	0.35	0.33	0.37	0.39
Na ₂ O	3.2	3.1	3.5	3.2	3.5	3.5	3.3
K ₂ O	4.7	5.1	4.7	5.0	3.7	4.3	4.6
Li ₂ O	0.10	0.10	0.02	0.09	0.07	0.07	0.08
H ₂ O ⁺	0.92	0.87	1.0	0.73	0.78	0.96	0.88
H ₂ O ⁻	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P ₂ O ₅	0.21	0.21	0.24	0.26	0.21	0.19	0.22
CO ₂	0.09	1.10	0.16	0.07	0.10	0.11	0.11
SO ₃	0.03	0.07	0.05	0.08	0.07	0.09	0.07
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	1.4	1.4	0.11	1.3	0.78	1.1	1.02
Total	99.78	99.86	100.44	99.73	99.40	99.85	99.90
Trace elements (ppm)							
Sn	1820	740	66	61	52	28	49*
Rb	1105	1115	840	1225	935	980	1035
Sr	4	4	6	4	7	6	5
K/Rb	35	38	47	34	33	36	37
Ca/Sr	1100	1035	560	835	400	520	740
Mg/Li	0.8	0.7	3.2	0.7	0.9	1.3	1.0
Niggli values							
al	48.8	49.2	52.5	50.7	51.3	50.9	
fm	19.0	8.6	6.1	8.0	8.4	7.4	
c	3.2	3.0	2.6	2.3	2.3	2.5	
alk	39.1	39.3	39.0	39.0	38.0	39.2	
si	482.8	468.8	454.7	460.1	500.2	480.8	
C.I.P.W. norms							
Q	37.3	36.2	35.7	35.7	40.6	37.6	
Or	27.8	30.1	27.8	29.6	21.9	25.4	
Ab	27.1	26.2	29.6	27.1	29.6	29.6	
An	0.3	0.2	0.0	0.0	0.0	0.0	
C	2.4	2.6	3.8	3.2	3.4	3.1	
Fs	2.5	1.7	1.2	1.7	1.4	1.4	
En	0.2	0.1	0.1	0.1	0.1	0.2	
Mt	0.2	0.7	0.5	0.5	0.6	0.4	
Ilm	0.0	0.0	0.0	0.0	0.1	0.1	
Ap	0.5	0.5	0.6	0.6	0.5	0.5	

*excluding 682049, 682050

Major element analyses: Department of Mines Laboratories, Launceston.

Trace element analyses: J. Klomínský and D.I. Groves

Table 20. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR LEUCOGRANITES AND APLITES FROM THE LOTAH SHEETS, ANCHOR MINE, BLUE TIER BATHOLITH.

Chemical analysis no.	LEUCOGRANITES			APLITES	
	682051	682064	682067	682052	682060
<i>Major elements (wt %)</i>					
SiO ₂	70.5	74.3	75.6	74.8	74.9
TiO ₂	0.00	0.00	0.02	0.00	0.02
Al ₂ O ₃	17.2	14.4	13.7	13.7	13.4
Fe ₂ O ₃	0.61	0.31	0.00	0.29	0.11
FeO	0.29	0.65	0.26	0.87	1.2
MnO	0.02	0.04	0.00	0.03	0.04
MgO	0.06	0.06	0.06	0.06	0.14
CaO	0.91	0.60	0.28	0.44	0.74
Na ₂ O	5.7	4.9	5.3	3.7	3.2
K ₂ O	3.0	2.9	4.3	3.7	5.0
Li ₂ O	0.04	0.03	0.01	0.07	0.04
H ₂ O ⁺	1.1	0.91	0.61	1.0	1.1
H ₂ O ⁻	0.0	0.0	0.0	0.0	0.0
P ₂ O ₅	0.24	0.32	0.18	0.28	0.19
CO ₂	0.10	0.09	0.10	0.08	0.26
SO ₃	0.09	0.03	0.10	0.01	0.05
Cl	0.00	0.00	0.00	0.00	0.00
F	1.1	0.21	0.03	0.34	0.28
Total	100.04	99.58	100.52	99.07	100.43
<i>Trace elements (ppm)</i>					
Sn	160	20	3	50	12
Rb	670	700	705	930	840
Sr	4	6	3	15	6
K/Rb	37	34	50	33	50
Ca/Sr	1625	860	665	240	1060
Mg/Li	2	2.5	8	1	4.5
<i>Niggli values</i>					
al	52.4	51.0	48.8	51.9	48.4
fm	4.2	5.4	1.9	6.8	8.2
c	5.0	3.9	1.8	3.0	4.9
alk	38.4	39.7	47.6	38.2	38.6
si	364.2	446.8	456.5	480.9	459.2
<i>C.I.P.W. norms</i>					
Q	24.8	34.0	28.1	38.4	35.6
Or	17.7	17.1	25.4	21.9	29.6
Ab	48.2	41.5	49.9	31.3	27.1
An	2.3	0.3	0.0	0.0	0.8
C	3.7	3.1	0.3	3.6	2.4
Fs	0.0	1.0	0.4	1.4	2.1
En	0.2	0.2	0.2	0.2	0.4
Mt	0.9	0.5	0.0	0.4	0.2
Ilm	0.0	0.0	0.0	0.0	0.0
Ap	0.6	0.8	0.4	0.7	0.5

Major element analyses: Department of Mines Laboratories, Launceston.

Trace element analyses: J. Klomínský and D.I. Groves.

Table 21. MAJOR AND TRACE ELEMENT ANALYSES, NIGGLI VALUES, AND C.I.P.W. NORMS FOR MISCELLANEOUS GRANITIC ROCKS, BLUE TIER BATHOLITH.

Pluton etc.	ST HELENS				PYENGANA	ST MARYS
Chemical analysis no.	¹ 611470*	² 611471*	³ 611464*	⁴ 671463*	⁵ 702693†	⁶ 702718§
<i>Major elements (wt %)</i>						
SiO ₂	58.0	55.3	73.75	48.3	77.05	67.4
TiO ₂	0.71	0.75	0.11	3.2	0.00	0.58
Al ₂ O ₃	17.15	18.0	14.25	11.9	13.95	15.25
Fe ₂ O ₃	1.5	0.45	0.45	4.55	0.04	0.55
FeO	4.55	3.8	0.95	11.1	0.18	3.75
MnO	0.10	0.30	0.01	0.13	0.02	0.06
MgO	3.25	3.15	0.20	5.15	0.01	1.8
CaO	6.15	11.8	0.55	7.8	0.2	4.15
Na ₂ O	5.35	4.35	2.95	3.0	5.45	2.6
K ₂ O	2.25	0.25	5.25	1.35	1.9	3.0
Li ₂ O	nd	nd	0.00	0.01	0.00	0.0
H ₂ O ⁺	1.05	0.95	1.05	1.6	0.3	0.5
H ₂ O ⁻	0.03	0.10	0.09	0.13	0.03	0.1
P ₂ O ₅	0.22	0.17	0.22	0.55	0.11	0.18
F	nd	nd	nd	nd	0.03	nd
Total	100.31	99.37	99.83	98.77	99.26	99.92
<i>Trace elements (ppm)</i>						
Ba	nd	nd	120	570	50	655
Li	nd	nd	15	30	5	30
Rb	nd	nd	335	65	340	185
Sn	nd	nd	20	8	120	9
Sr	nd	nd	15	445	20	260
W	nd	nd	6	8	<4	<4
Zr	nd	nd	50	230	25	195
K/Rb	-	-	130	172	46	135
Ca/Sr	-	-	315	151	86	137
Mg/Li	-	-	81	1050	12	366
<i>Niggli values</i>						
al	30.5	29.3	50.5	17.7	53.9	37.2
fm	29.6	23.5	8.6	51.7	2.0	26.1
c	19.9	35.0	3.6	21.1	1.6	18.4
alk	20.0	12.2	37.3	9.5	42.5	18.4
si	174.9	153.0	443.5	171.9	505.5	278.9
<i>C.I.P.W. norms</i>						
Q	0.8	4.0	35.1	2.5	37.8	27.3
Or	13.3	1.4	31.0	8.0	11.8	17.9
Ab	45.4	37.0	25.0	25.4	46.4	22.2
An	16.1	28.7	1.3	15.0	0.3	19.6
C	0.0	0.0	3.2	0.0	2.8	0.6
Di	11.0	19.3	0.0	14.1	0.0	0.0
Fs	3.7	1.9	1.2	8.3	0.3	5.6
En	5.0	2.5	0.5	9.2	0.0	4.5
Mt	2.2	0.6	0.6	6.6	0.1	0.8
Ilm	1.3	1.4	0.2	6.0	0.0	1.1
Ap	0.4	0.4	0.5	1.3	0.3	0.4

¹Diorite, ²Gabbro, ³Muscovite-granite, ⁴Dolerite, ⁵Fine-grained dyke, ⁶Porphyrite.

*Analyst: Department of Mines Laboratories, Launceston. †From Spry (1962).

†Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 22. COMPOSITION OF BIOTITES FROM GRANODIORITES, ADAMELLITES AND GRANITE/ADAMELLITES, BLUE TIER BATHOLITH.

Pluton	PYENGANA	GARDENS	ST HELENS	PICCANINNY CREEK	MT PIERSON	POIMENA
Chemical analysis no.	¹ 702692*	² 691188*	³ 702689*	⁴ 702714*	⁵ 691191*	⁶ 691930†
Major elements (wt %)						
SiO ₂	35.8	35.7	37.4	40.9	35.05	34.4
TiO ₂	2.8	2.8	2.4	2.2	2.55	2.8
Al ₂ O ₃	14.4	14.6	17.1	13.75	15.8	18.4
Fe ₂ O ₃	3.45	3.05	1.7	3.3	2.35	4.2
FeO	17.15	17.6	19.6	17.75	22.35	20.3
MnO	0.35	0.35	0.35	0.35	0.7	0.4
MgO	10.0	9.55	6.05	6.7	4.1	5.3
CaO	1.95	0.85	1.4	1.15	0.8	0.4
Na ₂ O	0.25	0.25	0.5	0.55	0.4	0.2
K ₂ O	8.1	8.1	7.75	8.25	8.35	8.1
Li ₂ O	0.05	0.06	0.04	0.08	0.12	0.31
Rb ₂ O	0.10	0.14	0.08	0.11	0.15	0.19
P ₂ O ₅	0.40	0.18	0.22	0.22	0.15	0.09
H ₂ O ⁺	3.8	4.0	4.2	2.6	4.9	4.0
H ₂ O ⁻	0.1	0.2	0.05	0.08	0.15	0.4
F	0.3	0.3	0.5	0.7	0.9	1.5
Total	98.87	97.60	99.14	98.40	98.45	100.36
Trace elements (ppm)						
Cu	50	380	100	30	30	nd
Sc	20	100	85	75	95	75
Sn	20	80	<4	40	120	65
Sr	30	30	65	25	30	15
W	<4	25	<4	5	25	20
Zn	340	1290	290	340	455	nd
Zr	280	420	575	455	405	nd
OH/F	11.6	12.5	8.3	3.6	5.3	2.5
K/Rb	71	53	84	68	51	39
Mg/Li	255	220	210	105	43	22

¹Biotite-hornblende granodiorite, ²Hornblende-biotite granodiorite, ³Biotite granodiorite, ⁴Biotite-hornblende adamellite, ⁵Coarse-grained biotite granite/adamellite, ⁶Porphyritic biotite granite/adamellite.

*Analyst: P. Bannister, Department of Geology, University of Western Australia.

†Analyst: J. Furst, Department of Mines Laboratories, Launceston.

Table 23. COMPOSITION OF BIOTITES FROM MUSCOVITE-BIOTITE GRANITES, BLUE TIER BATHOLITH.

Chemical analysis no.	702697*	702709*	702695*	702700*	691931†
Major elements (wt %)					
SiO ₂	36.0	38.85	35.2	41.1	38.7
TiO ₂	5.55	0.65	0.7	0.25	0.5
Al ₂ O ₃	17.4	21.75	21.45	23.25	23.0
Fe ₂ O ₃	2.35	3.9	3.45	1.65	2.7
FeO	19.65	18.4	21.2	14.9	17.5
MnO	0.85	0.75	0.95	1.1	0.7
MgO	4.2	0.25	0.75	0.2	0.2
CaO	1.1	0.15	0.3	0.4	0.1
Na ₂ O	0.45	0.3	0.3	0.3	0.25
K ₂ O	7.65	7.7	7.75	8.4	9.2
Li ₂ O	0.20	0.59	0.56	1.13	1.3
Rb ₂ O	0.15	0.28	0.32	0.73	0.78
P ₂ O ₅	0.41	0.02	0.12	0.02	0.05
H ₂ O ⁺	2.8	4.1	3.8	3.0	2.7
H ₂ O ⁻	0.03	0.25	0.04	0.1	0.2
F	0.55	0.95	1.9	2.8	3.9
Total	99.11	98.49	97.99	98.14	100.14
Trace elements (ppm)					
Cu	70	40	45	100	nd
Sc	60	215	55	110	50
Sn	200	190	225	865	555
Sr	30	8	30	10	7
W	<4	35	85	85	nd
Zn	500	1425	800	1005	nd
Zr	515	285	305	150	nd
OH/F	4.9	4.1	1.9	1.0	0.7
K/Rb	46	25	22	10.5	11
Mg/Li	28	0.55	1.75	0.23	0.20

¹Little Mt Horror, ²Mt William, ³Mt Paris, ⁴Mt Cameron, ⁵Lottah.

*Analyst: P. Bannister, Department of Geology, University of Western Australia.

†Analyst: J. Furst, Department of Mines Laboratories, Launceston.

Table 24. BIOTITE ANALYSES. NUMBER OF IONS ON THE BASIS OF 24(O,OH,F).

	702692	691188	702689	702714	691191	691930	702697	702709	702695	702700	691931
Si	5.55	5.56	5.71	6.34	5.45	5.24	5.62	5.84	5.44	6.08	5.75
Al	2.45	2.44	2.29	1.66	2.55	2.76	2.38	2.16	2.56	1.92	2.25
Al	0.18	0.24	0.78	0.85	0.35	0.54	0.82	1.69	1.35	2.13	1.78
Ti	0.33	0.33	0.28	0.26	0.30	0.32	0.65	0.07	0.08	0.11	0.06
Fe ³⁺	0.40	0.36	0.19	0.38	0.27	0.48	0.28	0.44	0.40	0.18	0.30
Fe ²⁺	2.22	2.29	2.50	2.30	2.91	2.59	2.57	2.31	2.74	1.84	2.17
Mn	0.05	0.05	0.04	0.05	0.09	0.05	0.11	0.09	0.12	0.14	0.09
Mg	2.31	2.22	1.37	1.55	0.95	1.20	0.98	0.06	0.17	0.04	0.04
Li	0.03	0.04	0.02	0.05	0.07	0.19	0.12	0.35	0.35	0.67	0.77
Ca	0.23	0.10	0.18	0.14	0.10	0.05	0.09	0.02	0.02	0.06	0.0
Na	0.07	0.07	0.01	0.16	0.12	0.06	0.13	0.09	0.09	0.08	0.07
K	1.60	1.61	1.51	1.63	1.65	1.57	1.52	1.47	1.53	1.58	1.74
Rb	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.07	0.07
OH	3.93	4.15	4.27	2.69	5.08	4.06	2.92	4.11	3.92	2.96	2.67
F	0.15	0.15	0.21	0.34	0.44	0.72	0.27	0.45	0.93	1.31	1.83
T.H.C.*	0.057	0.051	0.022	0.081	0.049	0.140	0.037	0.317	0.238	0.427	0.469

*'Tin-holding capacity' defined by Hesp (1971).

Table 25. PARTIAL ANALYSES OF BIOTITES FROM GRANODIORITE AND GRANITE/
ADAMELLITE PLUTONS, BLUE TIER BATHOLITH.

Plutons	Chemical analysis no.	CaO	K ₂ O	Rb	Sc	Sn	Sr	W	K/Rb
<i>Granodiorites</i>									
Pyengana	702691	0.95	8.45	825	75	25	20	70	85
Pyengana	702692*	1.95	8.1	945	20	20	30	<4	71
Gardens	691188*	0.85	8.1	1275	100	80	30	25	53
St Helens	702686	1.85	8.1	785	50	4	20	17	86
St Helens	702688	0.7	7.85	1435	80	370	7	70	45
St Helens	702689*	1.4	7.75	765	85	<4	65	<4	84
St Helens	702690	1.5	7.8	750	55	55	55	<4	86
Piccaninny Creek	702714*	1.15	8.25	1010	75	40	25	4	68
Various bodies near south margin of Batholith	691185	0.75	8.3	765	70	40	30	15	90
	691186	0.85	7.55	590	80	25	17	10	106
	691187	1.0	8.0	800	40	50	25	20	83
<i>Granite/Adamellites</i>									
Boobyalla	702705	0.7	8.4	860	75	50	10	<4	81
Boobyalla	702706	0.55	7.8	1660	50	17	2	45	39
Mt Pierson	691191*	0.8	8.35	1360	95	120	30	25	51
Ansons Bay	702711	0.75	8.55	1120	50	35	10	<4	63
Poimena	702701	1.3	7.85	1105	65	120	15	12	59
Poimena	682046	nd	nd	1935	75	60	20	nd	
Poimena	682047	nd	nd	1550	70	65	3	nd	
Poimena	682048	nd	nd	1685	75	60	4	nd	
Poimena	682059	nd	nd	1520	75	65	20	nd	
Poimena	682062	nd	nd	1840	75	70	20	nd	
Poimena	691930*	0.4	8.1	1705	75	65	15	nd	39
Eddystone Point	702710	0.07	8.7	1430	145	75	8	25	50

*
Analyst: P. Bannister, Department of Geology, University of Western Australia.

Species, glass etc.	Chemical analysis no.	CaO	K ₂ O	Rb	Sc	Sn	Sr	W	K/Rb
Little Mt Hector	702698	0.12	8.0	1248	85	262	8	43	
Mr William	702707	0.1	8.2	1620	292	252	7	44	
Mr William	702708	0.2	8.2	1182	292	420	2	49	
Mr William	702722	0.07	8.22	1250	292	442	4	52	
Mr William	702725	0.17	8.3	1700	260	302	4	61	
Mr Paris	702682	0.17	8.1	2292	30	182	10	100	27
Mr Paris	702684	0.22	7.1	1422	60	160	7	140	41
Mr Cameron	702699	0.12	7.2	2670	72	112	5	80	23
Mr Cameron	702702	0.22	8.72	2270	42	82	7	122	29
John	682042	nd	nd	2270	nd	240	10	nd	nd
John	682044	nd	nd	2400	nd	120	12	nd	nd

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 26. PARTIAL ANALYSES OF BIOTITES FROM MUSCOVITE-BIOTITE GRANITES AND ADAMELLITES, BLUE TIER BATHOLITH.

Sheets, mass etc.	Chemical analysis no.	CaO	K ₂ O	Rb	Sc	Sn	Sr	W	K/Rb
Sheoak Hill	702704	0.2	7.3	1395	70	280	12	60	43
Little Mt Horror	702697*	1.1	7.65	1395	60	200	30	<4	46
Little Mt Horror	702698	0.1	7.75	1760	95	590	<2	64	37
Constables Creek	702712	0.4	8.0	1595	145	145	10	210	42
Constables Creek	702713	0.2	7.7	1520	125	35	15	20	42
Mt William	702707	0.03	7.7	2265	210	250	6	1630	28
Mt William	702708	0.15	7.25	2060	230	235	6	45	29
Mt William	702709*	0.15	7.7	2550	215	190	8	35	25
Mt William	702722	0.1	7.75	1640	255	140	4	110	39
Mt William	702723	0.07	8.25	1640	255	180	<2	275	42
Mt William	702725	0.07	8.2	2560	215	220	6	70	27
Mt Paris	702694	0.00	8.9	6725	75	325	7	75	11
Mt Paris	702695*	0.3	7.75	2920	55	225	30	85	22
Mt Paris	702696	0.75	7.65	1020	75	205	4	160	62
Mt Cameron	702699	0.2	7.6	3305	140	210	4	195	19
Mt Cameron	702700*	0.4	8.4	6700	110	865	10	85	10
Mt Cameron	702702	1.05	7.5	1005	135	295	5	280	62
Mt Cameron	702703	0.35	7.75	3115	95	210	4	65	21
Lottah	682049	nd	nd	6795	40	635	4	nd	nd
Lottah	682050	nd	nd	6940	45	680	8	nd	nd
Lottah	682055	nd	nd	6810	10	450	8	nd	nd
Lottah	682063	nd	nd	7570	75	505	15	nd	nd
Lottah	682066	nd	nd	6790	45	435	4	nd	nd
Lottah	682068	nd	nd	7520	105	630	3	nd	nd
Lottah	691931*	0.1	9.2	7070	50	555	7	nd	11

*

Analyst: P. Bannister, Department of Geology, University of Western Australia.

Table 27. PARTIAL ANALYSES OF MUSCOVITES FROM BIOTITE-MUSCOVITE GRANITES, BLUE TIER BATHOLITH.

Sheets, mass etc.	Chemical analysis no.	CaO	K ₂ O	Rb	Sc	Sn	Sr	W	K/Rb
Little Mt Horror	702698	0.12	8.0	1545	65	585	6	70	43
Mt William	702707	0.1	8.8	1650	295	255	5	95	44
Mt William	702708	0.5	8.5	1485	290	670	5	225	48
Mt William	702722	0.07	8.95	1350	595	495	4	1740	55
Mt William	702725	0.17	8.3	1600	260	305	4	140	43
Mt Paris	702695	0.17	9.1	2795	30	165	10	100	27
Mt Paris	702696	0.55	7.1	1435	40	160	7	130	41
Mt Cameron	702699	0.12	7.5	2670	75	235	6	80	23
Mt Cameron	702700	0.65	8.75	3570	45	815	3	125	20
Lottah	682055	nd	nd	2370	nd	340	10	nd	nd
Lottah	682068	nd	nd	2400	nd	130	13	nd	nd

Analyst: P. Bannister, Department of Geology, University of Western Australia

have very variable Sn contents (<5-90 ppm) and W contents (<5-50 ppm). This extreme variation exhibited by the muscovite-biotite granites is shown graphically in Figure 17. The granodiorites and granite/adamellites may be classed as 'tin-poor' granites, and the muscovite-biotite granites as 'tin-rich' granites (e.g. Barsukov, 1967; Flinter, 1971).

GEOCHEMISTRY OF BIOTITES

Chemical analyses of biotites are presented in Tables 22 to 26. The biotites exhibit variations in composition which broadly parallel the variations shown by the granitic rocks. Biotites (magnesian siderophyllites) from granodiorites have high MgO, TiO₂, K/Rb, Mg/Li and OH/F relative to biotites (siderophyllites) from granite/adamellites, and biotites (lithian siderophyllites or protolithionites; Foster, 1960) from muscovite-biotite granites are typified by low MgO, TiO₂, K/Rb, Mg/Li, and OH/F. In general, Al₂O₃ is higher in the biotites from the most fractionated rocks. Biotites from all granitic types have low Sr contents, presumably due to the difficulty for the usually 8- or 10- co-ordinated Sr to occupy the larger co-ordinated K positions of the micas (Taylor, 1965).

The Sn content is much higher in biotites from the muscovite-biotite granites (50-900 ppm) than from granodiorites and granite/adamellites (<150 ppm), and the W content is similarly higher (fig. 18). The enrichment of Sn in biotite relative to the rock is greater for the muscovite-biotite granites than for the other granitic rocks. This is a common feature in 'tin-rich' compared with 'tin-poor' granites (e.g. Hesp, 1971).

Hesp (1971) has looked at relationships between biotite compositions and their Sn contents, and introduced a factor termed the 'tin-holding capacity' which he defined as:

$$\frac{\text{Fe}^{3+} + \text{Li}^+}{\text{Fe}^{2+} + \text{Mg}^{2+}} - \frac{\text{Ti}^{4+} + \text{Mn}^{2+}}{10}$$

The 'tin-holding capacity' shows a positive correlation with Sn contents of biotites (Hesp, 1971). The 'tin-holding capacity' of 11 biotites from granodiorites, granite/adamellites and muscovite-biotite granites is plotted against their Sn content in Figure 19. It can be seen that there is a broad positive correlation as suggested by Hesp (1971), but also that there is considerable scatter at low 'tin-holding capacities'. This is possibly due to errors in Sn analysis at relatively low levels, although features such as the high TiO₂ content of the biotite from the little Mt Horror Sheet also contribute to this scatter.

The distribution of Sn and W within the granitic rocks is a further interesting problem. In the majority of granodiorites and granite/adamellites most of the Sn is present in the biotite (table 28). Although the Sn values in the rock are near the detection limit for Sn by X-ray spectrographic techniques, it is significant that the Sn contribution from biotite very closely approximates the Sn content of the rock. This indicates, assuming the Sn content of the quartz to be negligible (e.g. Flinter, 1971), that Sn is preferentially concentrated in biotite where biotite and feldspar or biotite, hornblende and feldspar are co-existing.

In some of the muscovite-biotite granites (e.g. Little Mt Horror Sheet and Mt William Sheet) most of the Sn is also accounted for in micas, but in others, particularly the Lottah Sheets, the Sn contribution from micas is relatively small. Rattigan (1964) has shown that feldspars from 'tin-rich' granites from Australia contain less than 8.5 ppm Sn. Allowing for this contribution there is still a high proportion of Sn in these granites which

Table 28. DISTRIBUTION OF TIN IN ROCKS AND MICAS FOR VARIOUS GRANITIC ROCKS, BLUE TIER BATHOLITH

Granitic body	Chemical analysis no.	Sn in rock ppm	Sn in biotite ppm	Sn in muscovite ppm	Biotite wt %	Muscovite wt %	Sn accounted for in biotite ppm	Sn accounted for in muscovite ppm	approx. % of total Sn	approx. % of total Sn
Pyengana	702692	<2	20	-	9.8	-	2	100	-	-
Piccaninny Creek	702714	3	40	-	6.8	-	3	100	-	-
St Helens	702689	<2	<4	-	8.6	-	<1	Unknown	-	-
St Helens	702690	5	55	nd	9.5	0.1	5	100	nd	nd
Small granodiorite	691186	10	25	-	14.6	-	4	40	-	-
Boobyalla	702705	6	50	-	10.4	-	5	85	-	-
Boobyalla	702706	10	17	nd	4.4	0.65	1	10	nd	nd
Sheoak Hill	702704	17	280	nd	4.5	5.6	13	75	nd	nd
Mt Pierson	691191	9	160	-	7.5	-	12	135	-	-
Ansons Bay	702710	3	75	nd	4.6	0.7	3.5	115	nd	nd
Ansons Bay	702711	<2	35	nd	7.5	0.9	2.5	>125	nd	nd
Poimena	682046	6	60	-	8.1	-	5	85	-	-
Poimena	682047	5	65	-	7.8	-	5	100	-	-
Poimena	682048	6	60	-	8.1	-	5	85	-	-
Poimena	682059	5	65	-	6.3	-	5	100	-	-
Poimena	682062	16	70	-	7.1	-	6	40	-	-
Poimena	702701	12	120	-	7.5	-	9	75	-	-
Little Mt Horror	702697	16	200	nd	5.0	2.7	10	65	nd	nd
Little Mt Horror	702698	35	590	585	4.3	1.9	25	70	11	30
Constables Creek	702712	9	145	nd	2.05	0.1	3	35	nd	nd
Constables Creek	702713	3	35	nd	4.6	0.3	2	65	nd	nd
Mt William	702707	8	250	255	1.4	2.45	3.5	45	6	75
Mt William	702708	18	235	670	2.55	1.8	6	35	12	65
Mt William	702709	25	190	430*	3.2	2.25	6	25	10	40
Mt William	702722	10	140	495	2.9	1.2	4	40	6	60
Mt William	702723	13	180	430*	1.6	0.6	3	25	2.5	20
Mt William	702725	11	220	305	2.55	1.8	5.5	50	5.5	50
Mt Paris	702694	40	325	nd	2.45	0.75	8	20	nd	nd
Mt Cameron	702699	25	210	235	3.85	3.55	8	30	8.5	35
Mt Cameron	702700	85	865	815	1.7	9.0	15	20	74	85
Mt Cameron	702702	30	295	nd	1.7	0.6	5	15	nd	nd
Mt Cameron	702703	30	210	5.35	5.35	1.6	11	35	nd	nd
Lottah	682049	1820	635	235*	4.3	3.0	25	2	7	1
Lottah	682050	740	680	235*	1.5	0.75	10	2	2	1
Lottah	682055	66	450	340	1.6	0.85	7	10	3	5
Lottah	682063	61	505	235*	3.0	0.5	14	25	1	1
Lottah	682066	52	435	235*	4.7	0.1	19	35	0	0
Lottah	682068	28	630	130	4.5	2.9	26	95	4	15

*Average value for muscovite.

Table 29. DISTRIBUTION OF TUNGSTEN IN ROCKS AND MICAS FOR VARIOUS GRANITIC ROCKS, BLUE TIER BATHOLITH.

Granitic body	Chemical analysis no.	W in rock ppm	W in biotite ppm	W in muscovite ppm	Biotite wt %	Muscovite wt %	W accounted for in biotite ppm	W accounted for in muscovite ppm	approx. % of total Sn	approx. % of total Sn
Pyengana	702692	<4	<4	-	9.8	-	<1	Unknown	-	-
Piccaninny Creek	702714	5	5	-	6.8	-	<1	<20	-	-
St Helens	702689	<4	<4	-	8.6	-	<1	Unknown	-	-
St Helens	702690	<4	<4	nd	9.5	0.1	<1	Unknown	nd	nd
Small granodiorite	691186	<4	10	-	14.6	-	1.5	>40	-	-
Boobyalla	702705	<4	<4	-	10.4	-	<1	Unknown	-	-
Boobyalla	702706	4	45	nd	4.4	0.65	2	50	nd	nd
Sheoak Hill	702704	<4	60	nd	4.5	4.6	2.5	>60	nd	nd
Mt Pierson	691191	<4	25	-	7.5	-	2	>50	-	-
Ansons Bay	702710	<4	25	-	4.6	0.7	1	>25	nd	nd
Ansons Bay	702711	<4	<4	nd	7.5	0.9	<1	Unknown	nd	nd
Poimena	702701	20	12	-	7.5	-	1	5	-	-
Little Mt Horror	702697	<4	<4	nd	5.0	2.7	<1	unknown	nd	nd
Little Mt Horror	702698	4	64	70	4.3	1.9	3	75	1	25
Constables Creek	702712	<4	210	nd	2.05	0.1	4.5	>110	nd	nd
Constables Creek	702713	<4	20	nd	4.6	0.3	1	>25	nd	nd
Mt William	702707	<4	1630	95	1.4	2.45	23	>575	2.5	>60
Mt William	702708	5	45	225	2.55	1.8	1	20	4	80
Mt William	702709	4	35	nd	3.2	2.25	1	25	nd	nd
Mt William	702722	25	110	1740	2.9	1.2	3	10	21	85
Mt William	702723	5	275	nd	1.6	0.6	4.5	90	nd	nd
Mt William	702725	5	70	140	2.55	1.8	2	40	2.5	50
Mt Paris	702694	20	75	115	2.45	0.75	2	10	1	5
Mt Cameron	702699	20	195	80	3.85	3.55	7.5	40	3	15
Mt Cameron	702700	20	85	125	1.7	9.0	1.5	10	11	55
Mt Cameron	702702	30	280	nd	1.7	0.6	5	15	nd	nd
Mt Cameron	702703	45	65	nd	5.35	1.6	3.5	10	nd	nd

is not accounted for. Sphene has been shown to be a major concentrator of Sn (e.g. Barsukov and Durasova, 1966; Petrova and Legeydo, 1965), but sphene has not been observed in thin sections of these granites, and analyses of rocks and biotites show that all the TiO_2 in these rocks can be accounted for in biotite. The excess Sn that cannot be accounted for in micas or feldspars in several muscovite biotite granites may be present as scattered cassiterite grains, or as minute inclusions of cassiterite in other minerals. The occurrence of visible cassiterite in several sections of granites from the Lottah Sheets supports this suggestion.

The relatively high detection limit for W and the low content in most rocks does not allow a comparable study of the distribution of W in the granitic rocks (table 29). It is however, noticeable that almost all the W in the Mt William Sheet is accounted for in micas, whereas only a small proportion is accounted for in micas from the Mt Cameron Sheets and the Mt Paris Mass. The abnormally high W contents of biotite from 702707 and muscovite from 702722 of the Mt William Sheets (table 17) suggests that minute wolframite or scheelite inclusions may be present in these minerals. Small wolframite grains have been observed in the miarolitic cavities in granites from Mt Cameron, but have not been recorded from Mt William.

SUMMARY

The Blue Tier Batholith consists of a calc-alkaline suite of granitic rocks, which show a normal fractionation trend with increasing SiO_2 , Al_2O_3 , alkalis (particularly K_2O), Li_2O , F, and Rb and decreasing Fe oxides, MgO, CaO, Sn, Ba and Zr. Useful fractionation indicators are K/Rb and Mg/Li ratios. Geochemical data is consistent with the granitic rocks representing a single magmatic fractionation series, although the possibility that several separate magmas crystallised to form the components of the batholith cannot be ruled out.

The muscovite-biotite granites occupy a small surface area within the batholith (<10%), and assuming that they are essentially sheet-like in form, they represent an even smaller volume (perhaps 2%). They are exceedingly fractionated rocks with very low K/Rb and Mg/Li ratios, low Sr, Ba, Zr and high F. Within this group of rocks there is limited major element variation. These rocks are also enriched in Sn and W relative to the earlier-formed granodiorites and granite/adamellites, and in contrast to these rocks some of the Sn is present in discrete cassiterite grains.

Biotites exhibit a sympathetic chemical variation with the granitic rocks themselves. The Sn content of the biotites varies with the composition of the biotite as indicated by Hesp (1971). Tin apparently shows correlations with cations occupying octahedral sites in the biotite lattice, but the broad positive correlations with Fe^{3+} and Li^+ and negative correlations with Ti^{4+} , Mn^{2+} , Fe^{2+} and Mg^{2+} are not those predicted for selective substitution of Sn from considerations of ionic radius, co-ordination number, ionisation potential, and electro-negativity (Hamaguchi and Kuroda, 1970). The change in composition of biotites is consistent with crystal fractionation, with later liquids having increased Li/Mg and Fe/Mg ratios. It is probable that the Sn (and W) content is also related to fractionation and therefore only indirectly related to changes in biotite composition and not to preferential substitution for particular cations.

PRIMARY MINERALISATION IN THE BLUE TIER BATHOLITH

The primary mineral deposits of north-eastern Tasmania fall into three main groups: cassiterite and wolframite deposits; gold and gold-silver deposits; and copper and Pb-Zn-Ag deposits. The deposits of these types that occur within the Blue Tier Batholith and its environs are shown in Figure 1. The nature and associations of the gold-silver and copper and Pb-Zn-Ag deposits are briefly discussed below, and the nature of tin and tin-tungsten mineralisation is discussed in more detail. A possible genetic model for the generation of some tin deposits is also discussed.

GOLD AND GOLD-SILVER DEPOSITS

Gold and gold-silver deposits occur almost exclusively in discordant quartz veins in the Mathinna Beds at considerable distances from exposed granitic rocks. Examples include Beaconsfield (Noldart, 1964) and Lefroy (Groves, 1965), and a major belt between Mangana and Forester to the west of the Blue Tier Batholith that includes Mathinna, Alberton and Dan Rivulet (Threader, 1967). At Lisle and Golconda (Twelvetrees, 1909; Reid, 1926) and along Hogans Track, west of Scamander (Twelvetrees, 1900; Groves, 1972a) gold-quartz veins occur within, or adjacent to, biotite- and biotite hornblende granodiorites.

Several authors (e.g. Twelvetrees, 1909; Reid and Henderson, 1929; Carey, 1947; Hughes, 1947) have suggested a genetic relationship between the gold deposits and the granodiorite plutons, although the evidence is not conclusive. Klomínský and Groves (1970) found that the chemistry of these granitic rocks was similar to that of granitic rocks from other gold provinces of the world, and thus supported this relationship. Studies of trace elements in sulphides from gold veins (Groves and Baker, 1971) were inconclusive in determining genetic associations with particular granitic rocks.

The Portland Goldfield is a small goldfield extending along the NNW flank of The Gardens Pluton, north of Gladstone. The proposed reconstruction of the granodiorite plutons prior to the emplacement of the Poimena Pluton (fig. 12) returns The Gardens Pluton to the western edge of the batholith, and would bring the Portland Goldfield in juxtaposition with the Forester and Warrentina Goldfields if they existed prior to granite/adamellite emplacement. A comparison of the nature of mineralisation within these three goldfields may indicate whether this reconstruction is probable or not. Gold mineralisation is generally spatially separated from tin mineralisation, but where the Mt Paris Mass projects into the Mathinna line of gold mineralisation small deposits of both metals occur in juxtaposition. It is possible that in this area the tin mineralisation is superimposed on gold mineralisation, and that the emplacement of the Mt Paris Mass has disrupted the almost continuous line of gold mineralisation along the western margin of the Blue Tier Batholith; i.e. in the proposed position of the early major granodiorite pluton forming the embryonic batholith.

COPPER AND Pb-ZN-AG DEPOSITS

Copper and Pb-Zn-Ag deposits occur almost exclusively in the Scamander district (Groves, 1972a), although Cu-, Pb- and Zn sulphides are common minor phases in both gold deposits (Threader, 1967) and tin deposits (Groves and Taylor, 1973). In the Scamander district uneconomic deposits occur as quartz-sulphide veins between a zone of tin-tungsten deposits (adjacent to the Constable Creek Sheet) and the Scamander Tier dyke of granodiorite porphyry that extends parallel to the eastern coastline. A zone of copper deposits occurs adjacent to the tin-tungsten mineralisation, and an outer zone of Pb-Zn-Ag deposits occurs further east, some of which occur within the granodiorite porphyry (Groves, 1972a).

The spatial zonal sequence shown by these deposits is similar to many other zoned hydrothermal deposits (e.g. Both and Williams, 1968). Twelvetrees (1911) recognised the zoned nature of the mineralisation but considered that the outer Pb-Zn-Ag veins were genetically related to the granodiorite porphyry dyke. Carey (1947) suggested that the copper and Pb-Zn-Ag mineralisations were related to gold mineralisation and the granodiorites, and were not related to the adjacent tin-tungsten mineralisation. Geochemical studies of sulphide minerals (Groves and Baker, 1971; Groves, 1972b) suggest that the tin-tungsten deposits, copper, and possibly the Pb-Zn-Ag, mineralisation are part of a single phase of mineralisation that is related to the emplacement of the Constable Creek Sheet.

TIN AND TIN-TUNGSTEN MINERALISATION

Tin and tin-tungsten mineralisation shows a close spatial relationship to the muscovite-biotite granite bodies. In the Blue Tier area lode tin deposits are primarily associated with the Lottah Sheets and Mt Paris Mass (fig. 1), although small lode deposits occur within the Constable Creek Sheet (e.g. Echo mine) and the Poimena Pluton close to the Lottah Sheets (e.g. Cambria, Lottah, Ransom mines). Tin-tungsten deposits generally occur either as quartz-wolframite veins or as quartz-wolframite-cassiterite veins in hornfelsed Mathinna Beds adjacent to muscovite-biotite granite bodies (e.g. Upper Scamander area), although quartz-wolframite veins at Mt Horror, about 2 km north of Warrentinna, occur at some distance from granitic rocks (Noldart, 1969). The deposits may be broadly classified into four groups which are described below:

- (1) Quartz-wolframite-cassiterite veins in Mathinna Beds;
- (2) Cassiterite stockworks in Mathinna Beds;
- (3) Steeply-dipping greisen veins or pipes in granite; and
- (4) Flat-lying greisen sheets in granite.

Quartz-wolframite-cassiterite veins

Vein-like deposits of quartz-wolframite-cassiterite with minor sulphides occur mainly above the roof of muscovite-biotite granite sheets or cupolas. The major deposits of this type in eastern Tasmania are at Aberfoyle and Storys Creek (e.g. Edwards and Lyon, 1957; Kingsbury, 1965), but small deposits of this type occur within the Upper Scamander area of the Blue Tier Batholith (Groves, 1972a). The veins appear to occupy discrete fractures in the contact aureole of the underlying granites. They are generally small, patchy and uneconomic. The larger veins at Aberfoyle and Storys Creek exhibit mineralogical zoning with increase in wolframite/cassiterite ratios at depth, and Patterson (1968) demonstrated the existence of a poorly-defined gradient of deposition temperatures from the bottom to the top of the Storeys Creek mine. No detailed studies of veins within the Blue Tier Batholith have been carried out, although the composition of wolframites from deposits within an area appears to be relatively constant (Groves and Baker, 1972).

Cassiterite stockworks

The main cassiterite stockwork deposit is the Great Pyramid Tin Mine in the Upper Scamander area [68/005950] (Groves, 1972a). Here fine grained cassiterite occurs in small fractures, and as the matrix to breccias in localised fault zones. The cassiterite is concentrated in fractured sandstone-quartzite beds in a faulted anticlinal structure. The deposit is probably genetically related to the Constable Creek Sheet to the north-west.

Similar, but smaller, deposits are present in the roof zone of the Mt

Paris Mass to the north of Legunia. The deposits appear to occur in more competent beds within the Mathinna Beds, where discrete anastomosing fractures allowed the ready passage of mineralising fluids.

Greisen veins and pipes

Steeply-dipping greisen veins and pipes occur adjacent to the roof contacts of muscovite-biotite granites of the Lottah Sheets and Mt Paris Mass, particularly in association with roof irregularities (fig. 6). They are variable in width and lateral extent, but generally occur in groups or swarms (e.g. Bells Hill). The smaller veins commonly have a central fracture, about which the veins are symmetrical. The greisens consist of quartz and muscovite in granular intergrowths, with no relict granitic textures. Cassiterite is intergrown with quartz and muscovite, but is more abundant as coarsely crystalline aggregates on fracture surfaces within the greisen veins. Sulphides occur in places.

The greisens are fracture-controlled, commonly trending NNW subparallel to the elongation of the batholith and individual plutons, although approximately E-W trending veins also occur. The greisens appear to have formed by alteration of granite along pre-existing fractures. Although the contacts of the greisens with granite are relatively sharp, the granite is commonly bleached or altered for several centimetres from the contact. Fracture-controlled zones of kaolinisation have accompanied greisenisation locally within the Mt Paris Mass.

Greisen sheets

Sub-horizontal sheets of greisenised granite and greisen occur subparallel to the upper contact of muscovite-biotite granite-sheets within the Lottah Sheets. These greisen sheets also occur close to the upper contact of the granite with the overlying porphyritic biotite granite/adamellite of the Poimena Pluton. Significant tin mineralisation roughly overlaps the limit of greisenisation, and is associated with minor molybdenite, chalcopyrite and fluorite. The main deposit of this type is at the Anchor mine [59/845190] and other deposits include the Crystal Hill, Liberator, North Liberator, Don, Australia, Summit, Mount Michael, New Moon and Kent deposits. The deposits are described by Reid and Henderson (1928), Thomas (1943; 1953) and Jack (1965). These deposits also appear to be controlled by irregularities in the roof of the granite sheets.

Greisenisation at the Anchor mine

Groves and Taylor (1973) studied the Anchor tin deposit in detail and suggested a genetic model for greisenisation and mineralisation that has implications in the interpretation of geochemical variation within the muscovite-biotite granites. The main features of the Anchor mine greisenisation and mineralisation are outlined below, and the model is discussed.

Greisenisation at Anchor is confined to a flat-lying, undulating part of the upper contact of the muscovite-biotite granite sheet, and extends to a depth of about 40 m below the upper contact (fig. 7, 8, 9). The upper contact is marked by a discontinuous pegmatite band up to 0.3 m in thickness. The porphyritic granite/adamellite above this contact is unaltered except for a slight pink colouration of the feldspars for a few metres above the contact. Greisenisation below the upper contact is variable with alternating sub-horizontal lenses of muscovite-biotite granite, greisenised granite retaining granitic textures, and greisen in which no relic textures remain (fig. 9). The most important changes in major element chemistry during greisenisation

are a large decrease in K_2O , a slight decrease in Na_2O and F, and a large increase in H_2O^+ (table 30). Greisens have a more variable chemistry than the greisenised granites. These characteristics are consistent with petrographic evidence of replacement of K-feldspar, and to a lesser extent albite and topaz, by muscovite. A feature of greisenisation is the very low K/Rb ratios of the greisenised granites and granites (table 30). Information on chemical changes during greisenisation elsewhere is scarce (e.g. Hall, 1971), although there is always a decrease in Na_2O , and frequently increases in F, Li, Rb and Sn. Cassiterite distribution is consistent with the maximum intensity of greisenisation, and some mineral zoning is evident with molybdenite in the north-west succeeded by overlapping zones of cassiterite and chalcopyrite in the east and south.

The restricted occurrence of the greisenisation and mineralisation to the roof zone of the younger granite at Anchor is a common feature among many other tin deposits. The close association between greisenisation and mineralisation suggests that they formed by a common process. The general absence of alteration in the overlying granite further suggests that this rock was totally impermeable to alteration fluids or that the greisenisation-mineralisation processes were related to internal processes of crystallisation in the younger granite. There is also generally no sharp distinction between zones of relatively unaltered granite and greisenised granite, and commonly the unaltered granite shows evidence of incipient greisenisation. The chemical changes that occurred during greisenisation are consistent with the idea that the fluids responsible were essentially non-renewable, and this combined with the above evidence strongly suggests that alteration of the granite has occurred late in its crystallisation history, as the result of an essentially *in situ* reaction between crystals and late-stage residual fluids. On the other hand the greisens appear to have formed by continued movement of fluids along channelways within the granite, resulting in extensive chemical changes and considerable concentration of cassiterite.

The following model has been proposed on the basis of these features (Groves and Taylor, 1973). The granitic melt that finally crystallised as the muscovite-biotite granite, is considered to have been emplaced at a high level into the previously crystallised porphyritic granite/adamellite, with heat loss during ascent of the melt probably resulting in minor crystallisation. Continued cooling following emplacement resulted in an increase in crystallisation of various anhydrous minerals which increased the H_2O content of the remaining melt until P_{H_2O} in this melt exceeded the confining pressure, and second boiling began. The resultant aqueous phase separated as discrete bubbles which rose slowly through the remaining melt. This second boiling probably first occurred at the margins of the sheet where temperature loss promoted faster crystallisation. Initiation of second boiling near the roof possibly provided a low-viscosity medium which allowed crystallisation of the discontinuous pegmatite layer and minor alteration of the overlying granite/adamellite.

Continued upward flow of the aqueous phase resulted in its concentration beneath layers of crystallised muscovite-biotite granite, or beneath the granite/adamellite roof. These concentrations occurred in structural traps where upward and lateral movement was restricted by a sheet edge or downward steepening of the contact (fig. 8, 9). Reaction of this impounded phase with previously formed crystals *in situ* resulted in the development of lensoid zones of greisenised granite in an essentially closed system. It is possible that a granitic layer may have crystallised beneath a lensoid aqueous-rich layer while that layer was only partly consolidated because of its lower crystallisation temperature. Thus a series of alternate layers of granite and greisenised granite may be formed. Gradual depletion in aqueous phase provided

Table 30. MAJOR-AND TRACE-ELEMENT ANALYSES OF GREISENISED GRANITE AND GREISEN VEINS FROM ANCHOR MINE, NORTH-EAST TASMANIA. (Muscovite-biotite granite average of six samples, porphyritic biotite granite adamellite average of five samples).

Specimen No.	Porphyritic adamellite (average)	Biotite-muscovite granite (average)	Greisenised granite		682061	682065	Average	Greisen 682056	682053
			682057	682058					
<i>Major elements (mass %)*</i>									
SiO ₂	73.5	75.0	75.6	73.6	74.9	76.0	75.0	74.9	73.0
TiO ₂	0.16	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Al ₂ O ₃	14.0	13.6	14.3	14.8	11.9	13.3	13.5	11.6	12.6
Fe ₂ O ₃	0.30	0.33	0.21	0.22	0.77	0.47	0.42	1.2	0.0
FeO	1.4	1.05	1.6	1.1	3.1	1.2	1.75	3.4	2.5
MnO	0.02	0.04	0.07	0.05	0.05	0.05	0.07	0.25	0.08
MgO	0.38	0.06	0.06	0.07	0.17	0.06	0.09	0.06	0.04
CaO	1.03	0.39	0.35	0.35	0.71	0.79	0.55	0.52	0.46
Na ₂ O	3.0	3.3	2.4	3.6	1.9	3.2	2.7	0.20	2.2
K ₂ O	4.7	4.6	3.3	3.7	1.6	2.9	2.9	3.2	2.0
Li ₂ O	0.02	0.08	0.08	0.05	0.07	0.09	0.07	0.09	0.14
H ₂ O ⁺	1.3	0.88	1.7	1.6	2.3	1.2	1.7	2.2	1.3
H ₂ O ⁻	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P ₂ O ₅	0.13	0.22	0.25	0.23	0.31	0.27	0.26	0.32	0.24
CO ₂	0.28	0.11	0.16	0.13	1.3	0.11	0.42	0.84	0.07
SO ₃	0.03	0.07	0.06	0.03	0.10	0.12	0.08	0.52	0.18
Cl	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
F	0.14	1.02	0.49	0.21	1.4	1.3	0.85	1.4	2.2
Total	100.32	99.90	100.22	99.56	99.47	99.97	99.80	99.61	95.17
<i>Trace elements (ppm)†</i>									
Sn	9	49	1837	412	3	52	576	4795	18200
Rb	365	1033	1132	1122	1088	1402	1186	1521	774
Sr	75	5	10	3	5	7	6	11	26
K/Rb	108	37	24	27	12	17	20	17	21

*Major-element analyses: Department of Mines Laboratories, Launceston. †Trace element analyses: D.I. Groves and J. Klomfinsky.

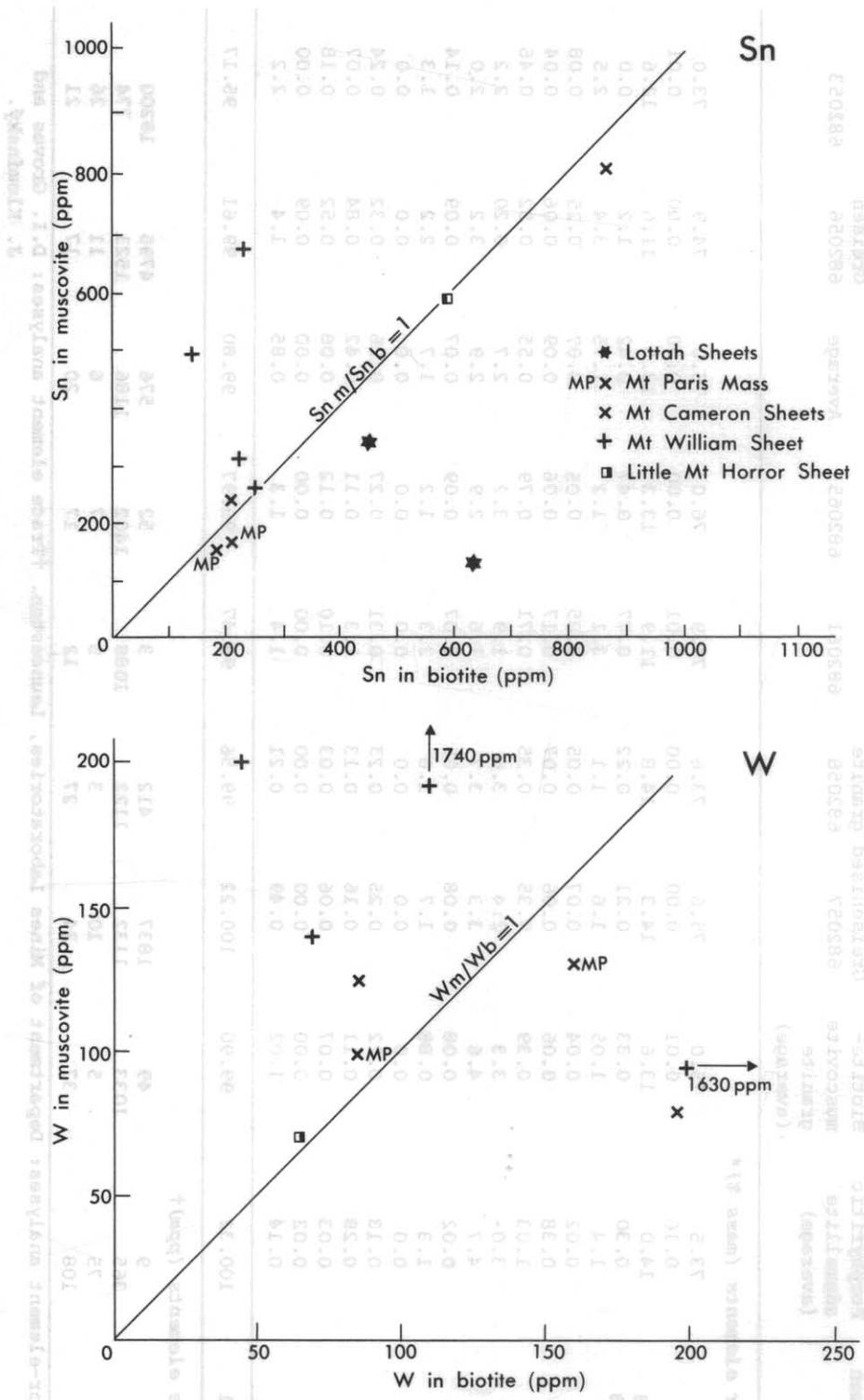
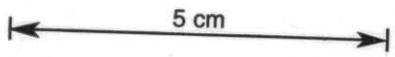


Figure 20. Plot of Sn (and W) in biotite against Sn (and W) in muscovite for coexisting mica pairs from muscovite-biotite granites of the Blue Tier Batholith.



by second boiling below the roof, would result in a limit to alteration below the roof zone. The irregular greisen bodies may develop in such a system in consolidated, poorly-jointed granite with the joints providing channelways for renewal of aqueous phase from below.

These processes involve a delicate balance between a rising aqueous phase and crystallisation of the residual melt, which may explain the complex variations in shape and composition of zones of greisenised granite and greisen. They are also consistent with the penecontemporaneous development of effectively closed and open systems of greisen development. They also provide a mechanism for the almost ubiquitous formation of muscovite in these granites, as the aqueous phase is reacting with previously formed minerals throughout the granite body.

The nature of mineralisation depends on the permeability of the capping rocks, and the formation or otherwise of jointing in the roof zone of the mineralising granite. Where extensive fractures existed in the roof aqueous fluids may escape upwards, possibly with dilution from circulating meteoric waters, into the country rocks to form discordant vein deposits. Much of the quartz present in these veins may be redistributed from the siliceous country rocks. Where fractures are less open, stockwork deposits may develop. The formation of joint systems in the muscovite-biotite granites prior to release of aqueous fluids may depend on the thickness of the emplaced bodies, and their depth of emplacement which will affect the onset of second boiling and the rise of aqueous fluid towards the roof. The larger and thicker Mt Paris Mass appears to be dominated by greisen vein mineralisation, whereas the smaller and probably thinner Lottah Sheets are characterised by lensoid sheets of greisenised granite and greisens.

The possibility that at least part of the tin forming the mineralisation was derived during the breakdown of the biotite and formation of muscovite (e.g. Tischendorf *et al.*, 1971) has been considered. The Sn content of co-existing biotite-muscovite pairs is plotted in Figure 20. In general the Sn contents of co-existing muscovites and biotites are similar, thus precluding the general release of Sn during the breakdown of biotite. Further, the experimental study of Hesp and Rigby (1972) has indicated the difficulty of removing tin from biotite using halide solutions. However the two analysed samples from the Lottah Sheets at the Anchor mine have muscovites with lower Sn contents than co-existing biotites, and release of Sn during the formation of muscovite is a possibility in this instance. Additional analyses of co-existing mica pairs are required to determine the potential importance of this process. Tungsten contents of co-existing micas are erratic (fig. 20), but do not show a trend of depletion in muscovite.

GEOCHEMICAL VARIATION WITHIN MUSCOVITE-BIOTITE GRANITES

The chemical characteristics of the muscovite-biotite granites have been described above. In summary they are characterised by high SiO_2 , Li_2O , Rb, Sn and W, and low CaO, MgO, Fe oxides, Sr, Ba and Zr, and low K/Rb, Mg/Li and OH/F ratios. These features are essentially similar to characteristics of tin-bearing granitic rocks from other localities, as summarised by Flinter (1971) and Hesp (1971). Their distinction from other granitic rocks is best shown by MgO and Li_2O (Mg/Li ratio), Sn, F (OH/F ratio) and K/Rb ratio. These ratios have been used by other authors (e.g. Tischendorf *et al.*, 1971).

It has been shown above that the major rock types of the Lottah Sheets, Mt Paris Mass, Mt William Sheet and southern Mt Cameron Sheets are petrographically similar but show distinct differences with the Little Mt Horror

Sheet, Constable Creek Sheet and the northern part of the Mt Cameron Sheets. This is partly confirmed by the geochemistry of these rocks, and their component biotites. The major element compositions of the petrographically similar granites are almost identical. The granites of the Little Mt Horror Sheet have high CaO and MgO and a high K_2O/Na_2O ratio compared to the other granites (table 31), and its biotites have high MgO and TiO_2 and a high OH/F ratio together with low Li_2O (table 32). The granites of the Constable Creek Sheet have high CaO and MgO and a high K_2O/Na_2O ratio and low Sn relative to the other granites, and their biotites also have low Sn contents. The granites forming the northern part of the Mt Cameron Sheets have higher TiO_2 , total Fe oxides, MnO, MgO and CaO than the sheets representing the southern part of the Mt Cameron Sheets (table 18). The granite porphyry of the Mt Paris Mass has higher TiO_2 , MgO, and CaO and lower Li_2O and F than the more common even-grained granites of the Mt Paris Mass.

The similarity of the major element chemistry, mineralogical composition, texture and intrusion form of the Lottah Sheets, Mt William Sheet, Mt Paris Mass, and southern Mt Cameron Sheets, suggests that these granites represent parts of a series of identical, strongly fractionated melts. This is an important assumption in the study of vertical changes in chemical composition of these granites, as in no case has both the roof and base of a single sheet been unequivocally defined. There is insufficient topographic relief where relationships are clear, and a lack of sufficiently deep drill holes in any one intrusion to examine such vertical variations.

However the geochemistry of granites from near basal contacts in the Mt William Sheet can be compared with that of mineralogically and texturally similar granites from upper contacts of the Lottah Sheets and Mt Paris Mass (table 33). The southern Mt Cameron Sheets have been excluded from this discussion as their exact form is unclear, but they exhibit similar chemical characteristics to granites from the Lottah Sheets and Mt Paris Mass. The elements and ratios showing most variation in both granites and biotites are Li_2O , Sn, OH/F and K/Rb (table 33). Both Li_2O and Sn are higher, and OH/F and K/Rb are lower in granites from the upper contact compared to those from the lower contact. Vertical changes in a tin-bearing granite have also been described by Štemprok and Šulcek (1969). They established that Li_2O and Rb decreased from the roof downwards, while K_2O increased downwards and Na_2O remained essentially constant. However, they found that high Sn, W and F values were clearly related to the position of greisenised granites, and did not decrease systematically with depth.

The chemical changes in the muscovite-biotite granite sheets are consistent with the genetic model for greisenisation proposed by Groves and Taylor (1973), as granites from the lower contact would be expected to be depleted in elements that partition towards the upward-moving aqueous phase (e.g. Li, Rb, Sn, F). The fact that muscovites contain more Sn than co-existing biotites in granites from the lower part of the sheets (fig. 20) negates the possibility that Sn is leached from pre-existing minerals during the upward ascent of the aqueous phase.

As discussed above, the vertical zonation in geochemistry of the muscovite-biotite granites is dependent on the assumption that the Mt William Sheet crystallised from a melt identical to that from which the Lottah Sheets and the Mt Paris Mass crystallised. Further studies of this vertical zonation should be made, either by careful sampling of the Mt Paris Mass where there is considerable relief, or preferably by a stratigraphic drill hole in the Anchor mine area.

Table 31. MEAN VALUES OF SOME CRITICAL COMPONENTS OF MUSCOVITE-BIOTITE GRANITE BODIES OF THE BLUE TIER BATHOLITH COMPARED TO THE MEAN COMPOSITION OF ANALYSED GRANITE/ADAMELLITES FROM THE POIMENA PLUTON. (Specimen 702703 has been excluded from the Mt Cameron Sheets as it represents the northern mass which is petrographically distinct from the southern sheets. Specimen 702696 has been excluded from the Mt Paris Mass as it is a granite porphyry rather than a muscovite-biotite granite).

	Poimena Pluton	Constable Creek Sheet	Little Mt Horror Sheet	Mt William Sheet	Mt Cameron Sheets	Mt Paris Mass	Lottah Sheets
SiO ₂	73.5	77.8	75.7	76.7	77.4	75.7	75.0
CaO	1.0	0.6	0.8	0.4	0.5	0.4	0.4
MgO	0.4	0.07	0.16	0.01	0.01	0.05	0.06
Na ₂ O	3.0	2.9	3.1	3.9	3.5	3.3	3.3
K ₂ O	4.7	4.6	5.1	4.4	4.2	4.3	4.6
Li ₂ O	0.02	0.01	0.02	0.01	0.03	0.05	0.08
Sn	9	6	26	15	47	33	50
W	-	4	4	8	23	25	-
OH/F	8.9	5.0	4.0	6.3	1.4	1.3	0.9
K/Rb	108	87	89	84	39	40	37

Table 32. MEAN VALUES OF SOME CRITICAL COMPONENTS OF BIOTITES FROM MUSCOVITE-BIOTITE GRANITES OF THE BLUE TIER BATHOLITH COMPARED TO THE MEAN COMPOSITION OF ANALYSED BIOTITES FROM GRANITE/ADAMELLITES OF THE POIMENA PLUTON

	Poimena Pluton	Constable Creek Sheet	Little Mt Horror Sheet	Mt William Sheet	Mt Cameron Sheets	Mt Paris Mass	Lottah Sheets
MgO	4.7	-	4.2	0.25	0.2	0.8	0.2
TiO ₂	2.8	-	5.5	0.6	0.3	0.7	0.5
Li ₂ O	0.2	-	0.2	0.6	1.1	0.6	1.3
Sn	68	90	395	185	460	250	560
W	18	115	34	93	143	106	-
OH/F	4.2	-	4.8	4.1	1.0	1.9	0.7
K/Rb	55	42	36	32	28	22	11

Table 33. CONTRAST IN SOME CRITICAL COMPONENTS OF MUSCOVITE-BIOTITE GRANITES AND THEIR BIOTITES FROM THE BASAL AND ROOF ZONES OF GRANITE SHEETS.

	Upper contact			Lower contact		
Rocks			(Mean)			(Mean)
Li ₂ O (%)	0.02-	0.10	0.06	0.00-	0.01	0.01
Sn (ppm)	25 -	66*	45	8 -	25	15
OH/F	0.5 -	9.0	1.0	3.8 -	50	6.3
K/Rb	30 -	50	38	74 -	95	84
<i>Biotites</i>						
Li ₂ O (%)	0.6 -	1.3		0.6		
Sn (ppm)	225 -	680	500	140 -	250	185
OH/F	0.7 -	1.9		4.1		
K/Rb	11 -	22	13	25 -	42	32

*Excluding samples with visible cassiterite.

ALLUVIAL TIN DEPOSITS AND BEDROCK GEOCHEMISTRY

Following erosion, transport and deposition, cassiterite, a 'heavy' heavy mineral, is generally concentrated close to its source, usually within 15 km, unless steep river gradients can be maintained for considerable distances (e.g. Emery and Noakes, 1968; Noakes, 1970). Therefore, in prospecting for alluvial tin deposits in unproven areas, location of a source can be a critical factor.

In the Blue Tier region there are four major areas of concentration of alluvial cassiterite deposits. One of these areas surrounds Mt Cameron, extending for a radius of approximately 16 km about Mt Cameron peak (fig. 1). Offshore tin deposits in Ringarooma Bay (e.g. Young, 1969) may be related to these deposits. A second area extends between Branxholm and Derby, and includes the Briseis workings. The third area occurs near Pioneer, and the fourth area between Goshen and St Helens. All these alluvial deposits flank highland areas containing muscovite-biotite granite bodies with partial roof exposure (e.g. Lottah Sheets and Mt Paris Mass), or granites with similar geochemical characteristics to those from the roof zones of muscovite-biotite granites (Mt Cameron Sheets). Only small alluvial deposits appear to have been derived from the Little Mt Horror Sheet and Constable Creek Sheet (fig. 1), and only minor occurrences of cassiterite are known from the vicinity of the largely unroofed Mt William Sheet.

It therefore appears that alluvial cassiterite deposits are closely spatially related to partly unroofed muscovite-biotite granite bodies. It is probable that during an earlier erosional cycle, unroofing of the Mt William Sheet resulted in the formation of alluvial cassiterite concentrations which have been redistributed during subsequent erosional cycles. Some evidence that this mineral was carried offshore is provided by concentrations of very fine-grained cassiterite in an old beach deposit to the west of Eddy-stone Point.

The vertical chemical zonation shown by the muscovite-biotite granites may thus be used as an indication of the degree of unroofing of these granites where other evidence is lacking. This may then be used in determining the potential of surrounding alluvial areas for cassiterite concentrations. This approach appears directly applicable to Cape Barren Island and Flinders Island to the north-east of the northern Tasmanian coastline, where similar granites to those of the Blue Tier Batholith occur, and where large areas of alluvium are present.

The drilling of buried river channels between the Fraser and Anson Rivers (Jack, 1965) is an example of exploration for alluvial cassiterite in which an appreciation of bedrock geology would have been useful. The river channel is part of a Tertiary-Quaternary drainage system that is virtually confined to The Gardens Pluton. The lack of cassiterite in such an area is not unexpected, and the presence of abundant ilmenite is consistent with the mineralogy of the rocks over which the river system was developed.

SUMMARY AND CONCLUSIONS

The Blue Tier Batholith of Upper Devonian age has been shown to be a composite body intruded in a general evolutionary sequence from early mafic granodiorites to late leucocratic granites. The granitic plutons have sharp discordant contacts, narrow zones of thermal metamorphism, and appear to be high-level, magmatic intrusions that were generally emplaced passively with minor marginal deformation associated with granodiorite emplacement. Early-formed granodiorite plutons were fragmented during the subsequent emplacement of granite/adamellites, and dilation of up to 18 km in an east-west direction is envisaged. All steep-sided plutons appear to have been controlled by fractures both parallel and perpendicular to the pre-intrusion fold axis.

A series of relatively small bodies of medium-grained muscovite-biotite granites ('tin granites') are the latest major intrusions in the batholith, and the primary tin deposits show a definite spatial association with them. Taking evidence from several localities (e.g. Mt William, Little Mt Horror, Lottah, Mt Cameron), it appears that these granites form essentially sheet-like bodies, with probable feeder dykes in some areas, although the precise three-dimensional shape of the Mt Paris Mass is unclear. The occurrence of such tin-bearing granites suggests that they are confined to the upper levels of the batholith which are presently exposed. They occupy about 10% of the surface area of the batholith, but if as suggested, they are sheets of limited thickness, they may occupy only 1% or 2% of its volume.

These granites appear to represent the products of crystallisation of the low volume, ultimate residual liquid of the primary calc-alkaline magma from which the Blue Tier Batholith formed. They are strongly fractionated with low K/Rb and OH/F ratios, high Li and Sn contents and low MgO. The high Sn contents of the granites and their associated tin deposits appear to be due to partitioning of Sn into residual liquids during fractional crystallisation of the granitic magma.

Primary tin deposits are associated with zones of greisen and greisenised granite along the upper contact of the granite sheets, and are particularly associated with structural irregularities in these contacts. The greisenisation appears to be an autometasomatic process caused by the upward migration of aqueous fluids produced during 'second boiling' related to partial crystallisation of an originally H₂O-undersaturated liquid. As the crystallisation of essentially anhydrous phases commenced, the vapour pressure of

the residual liquid increased, and at the shallow level of intrusion envisaged from geological evidence 'second boiling' of an aqueous phase occurred. This aqueous phase rose and was temporarily redissolved in the overlying liquid containing fewer crystals, but as crystallisation proceeded it eventually migrated towards the upper part of the intrusion.

Elements that partition strongly towards the residual liquid and aqueous fluid phase (e.g. Sn, F, Li, Rb) were carried upward in the aqueous fluid, which reacted with feldspars and biotite in partly crystallised granites to form muscovite, topaz, fluorite and cassiterite. If the roof zone crystallised rapidly and fractures were not common, the alteration (greisenisation) occurred in sub-horizontal layers beneath the roof (e.g. Anchor mine), but if fractures were common the movement of fluids was concentrated along these low pressure zones, and near-vertical greisen dykes were formed (e.g. Bells Hill). The main chemical changes involved in greisenisation were the removal of K_2O and Na_2O and the introduction of H_2O , F, Sn, Li, Rb and S. Chemical studies of co-existing muscovite and biotite indicate that Sn was not generally leached from biotite during alteration to muscovite, and that the redistribution of Sn fixed in biotite was not a major process in the formation of tin deposits.

Areas of greisen and greisenised granite (retaining original granitic texture) are relatively sharply defined in the upper parts of muscovite-biotite granite intrusions. The intervening granite from these upper levels of some sheets is texturally and compositionally similar to granite from the base of other sheets, although accessory muscovite and topaz are possibly more common close to the upper contacts. Unfortunately, there is not sufficient topographic relief where relationships are clear, and no sufficiently deep drill holes exist in any one intrusion to examine vertical variations in granite chemistry, such variations may result from readjustment of crystal phases to changing composition of enclosing liquid as aqueous fluids rise through the body.

However, the chemistry of granites from near basal contacts in the Mt William Sheets has been compared with that of granites from upper contacts of the Lottah Sheets and the Mt Paris Mass. Granites from the upper contacts have significantly higher Li_2O and Sn contents and lower K/Rb, OH/F and Mg/Li ratios than those from the basal contacts. It is possible that the Mt William granites represent different granitic types to the Lottah and Mt Paris granites, but this is unlikely in view of the similarity of their major element chemistry, mineralogical composition, texture, and intrusion form. If these granites do in fact represent parts of a series of originally identical liquids, then it appears that reaction of partly crystallised granite with rising aqueous fluids has occurred, and that granites closer to the roof are enriched in Li, Rb, F and Sn and depleted in Mg relative to those near the base. This hypothesis could be further tested by careful sampling of the Mt Paris Mass, or by a stratigraphic drill hole preferably in the Anchor mine area.

The vertical changes in chemistry within these muscovite-biotite granite bodies provide an indication of the degree of unroofing of the bodies where other geological evidence is unavailable or unclear. This may be important in delineating areas of potential alluvial cassiterite deposits, which appear to be clustered around areas of only partly unroofed muscovite-biotite granites within the Blue Tier Batholith.

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Table 34. NATURE AND LOCATION OF GRANITIC ROCKS FOR WHICH MODAL ANALYSES AND, OR CHEMICAL ANALYSES ARE GIVEN.

Granitic Body	Thin Section no.	Chemical analysis no.	Rock Type	Location of Sample	Aust. Nat. Grid 10 yd Reference	Aust. Map Grid 10 m Reference
Pyengana Pluton	69-263	-	Biotite-hornblende granodiorite	Siamese water race, S of Pyengana	59/83801080	EQ84232654
	69-390	-	Hornblende-biotite granodiorite	North George Rd, 0.2 km W of Tasman Highway, Pyengana	59/80401500	EQ81083034
	-	702691	Foliated biotite granodiorite	Kohl Creek, about 2 km S of Pyengana	59/84501170	EQ84862737
	70-150	702692	Hornblende-biotite granodiorite	Road quarry, North George Rd, about 6 km W of Pyengana	59/78401405	EQ70262945
	70-53	702693	Fine-grained felsic dyke	North George Rd, about 5.5 km W of Pyengana	59/78801445	EQ70622982
Gardens Pluton	69-385	-	Hornblende-biotite granodiorite	The Gardens, 12 km S of Ansons Bay	69/09652720	FQ07684180
	69-386	-	Hornblende-biotite granodiorite	Mt Cameron water race, near Mussel Roe River	59/90203965	EQ89775297
	-	691188	Hornblende-biotite granodiorite	Ansons Bay-Gladstone Rd, 4.3 km SE of Ikena	59/96055400	EQ94976614
Small granodiorite plutons, southern Blue Tier Batholith	-	691185	Biotite granodiorite	Ryans Spur, near Ryans Ck, Upper Scamander area	59/87400130	EQ87621790
	69-252	691186	Biotite granodiorite	Trafalgar Mine, Beahrs Rd, Upper Scamander area	58/87909970	EQ88091644
	-	691187	Hornblende-biotite granodiorite	Terryvale Rd, near Power Rivulet, St Helens area	59/9221075	EQ91952658
St Marys Sheet	70-172	702718	Hypersthene adamellite porphyry	Quarry, Tasman Highway, St Marys Pass	68/02508050	FP01639905
Piccaninny Ck Pluton	70-170	702714	Biotite adamellite	Tasman Highway near Piccaninny Creek	68/07506620	FP06358604
St Helens Pluton	69-244	-	Hornblende-biotite adamellite	Loila Tier Rd, Scamander Tier	68/04819814	FQ03561519
	69-246	702689	Biotite adamellite	Road cutting, Tasman Highway, Diana Basin	69/08370146	FQ06781826
	69-394	-	Hornblende-biotite granodiorite	Foreshore, Binalong Bay, St Helens area	69/11401700	FQ09383249
	69-415	-	Biotite granodiorite	Quarry, Akaroa, St Helens area	69/13001050	FQ10912657
	69-416	-	Muscovite granite	Western foreshore, St Helens Pt	69/15451370	FQ13122952

Table 34. (continued)

Granitic Body	Thin Section no.	Chemical analysis no.	Rock Type	Location of Sample	Aust. Nat. Grid 10 yd Reference	Aust. Map Grid 10 m Reference
St Helens Pluton	69-417	-	Biotite granodiorite	Fishermans cottage, western foreshore, St Helens Pt	69/14651300	FQ12392887
	-	611463	Quartz dolerite	Western foreshore, St Helens Head	69/15451370	FQ13122952
	-	611464	Muscovite granite	Western foreshore, St Helens Head	69/15451370	FQ13122952
	-	611465	Granodiorite porphyry	Jason Gates, St Helens	69/05700760	FQ04272385
	-	611470	Diorite	Albion, St Helens area	-	-
	-	611471	Gabbro	George River, St Helens area	-	-
	-	702686	Biotite-hornblende granodiorite	George River Bridge, St Helens	69/07600960	FQ05992569
	-	702687	Hornblende monzonite	Golden Fleece Rivulet, St Helens	67/05050775	FN05804124
	-	702688	Biotite adamellite	St Helens golf course, St Helens	69/02800900	FQ01612509
	-	70-149	702690	Biotite granodiorite	Quarry, Akaroa, St Helens area	69/13001050
Boobyalla Pluton	70-157	702705	Porphyritic biotite granodiorite	Boobyalla River, crossing of new Bridport-Gladstone Rd	59/72105720	EQ73056882
	70-158	702706	Garnet granite porphyry	Road cutting, 2 km E of Boobyalla River	59/74005770	EQ74786929
Sheoak Hill Pluton	70-156	702704	Foliated biotite-muscovite granite/adamellite	0.5 km E of intersection of Winnaleah-Bridport and Bridport-Gladstone Rds	59/67705720	EQ69036877
Mt Pierson Pluton	69-398	-	Coarse-grained biotite granite/adamellite	Quarry, Hogans Rd, 0.5 km S of Tasman Highway	59/95651300	EQ95032867
	-	691191	Coarse-grained biotite granite/adamellite	Quarry, Hogans Rd, 0.5 km S of Tasman Highway	59/95651300	EQ95032867
Ansons Bay Pluton	69-374	-	Coarse-grained biotite granite/adamellite	3 km NE of North Ansons Bay	69/12904585	FQ10455887
	70-166	702710	Biotite granite/adamellite	Quarry, Eddystone Point	69/15854845	FQ13126128
	70-167	702711	Coarse-grained biotite granite/adamellite	Point immediately north of Eddystone Point	69/13654920	FQ11106194

Table 34. (continued)

Granitic Body	Thin Section no.	Chemical analysis no.	Rock Type	Location of Sample	Aust. Nat. Grid 10 yd Reference	Aust. Map Grid 10 m Reference
Poimena Pluton	68-133/34	682046	Porphyritic biotite granite	Aberfoyle DDH 10 65.5-68 ft, Anchor Mine	25101E	5195N*
	68-135/36	682047	Porphyritic biotite granite	Aberfoyle DDH 10 90-97 ft, Anchor Mine	25101E	5195N*
	68-138/40	682048	Porphyritic biotite granite	Aberfoyle DDH 10 133-154 ft, Anchor Mine	25101E	5195N*
	68-147	682059	Porphyritic biotite granite	Aberfoyle DDH 16 47.5-67.75 ft, Anchor Mine	25100E	5800N*
	68-151/52	682062	Porphyritic biotite granite	Aberfoyle DDH 20C 85-90 ft, Anchor Mine	25300E	5400N*
	70-155	702701	Porphyritic biotite granite	Road cutting, Pioneer-Gladstone Rd, Pioneer	59/78353835	EQ78965166
	Little Mt Horror Sheets	70-176	702697	Muscovite-biotite adamellite	Western slope of Little Mt Horror	59/76254710
70-152		702698	Muscovite-biotite granite	North-western slope of Little Mt Horror	59/65804930	EQ67386153
Constables Ck Sheet		70-168	702712	Biotite granite	New junction of Trafalgar Rd and track to Constables Creek dam	59/97800575
	70-169	702713	Biotite granite/adamellite	New Echo mine, Constables Creek, St Helens area	69/00600495	EQ99642137
Mt William Sheet	69-387	-	Muscovite-biotite granite	Mt William trig. point	69/01505880	EQ99907058
	70-162	702707	Muscovite-biotite granite	Icena-Mussel Roe Bay Rd, 8 km NE of Icena	69/00606215	EQ99047364
	70-164	702708	Muscovite-biotite granite	North-western limit of Mt William Ridge	69/01606445	EQ99937575
	70-165	702709	Muscovite-biotite granite	North-eastern limit of Mt William Ridge	69/02606365	FQ00867503
	70-159	702722	Muscovite-biotite granite	0.5 km SW of Mt William trig. point	69/01105835	EQ99547017
	70-160	702723	Muscovite-biotite granite	Mt William trig. point	69/01505880	EQ99907058

*Anchor Mine Grid

Table 34. (continued)

Granitic Body	Thin Section no.	Chemical analysis no.	Rock Type	Location of Sample	Aust. Nat. Grid 10 yd Reference	Aust. Map Grid 10 m Reference
Mt William Sheet	70-163	702725	Muscovite-biotite granite	200 m NW of Mt William trig. point	69/01405895	EQ99817072
Mt Paris Mass	70-19	702693	Muscovite-biotite granite	Quarry, Tasman Highway, Weldborough Pass	59/74502670	EQ75561097
	70-19	702694	Muscovite-biotite granite	Quarry, Tasman Highway, Weldborough Pass	59/74502670	EQ75564097
	70-19	702695	Muscovite-biotite granite	1 km NE of Greys Hill, near Branxholm	59/62802650	EQ64874067
	70-19	702696	Granite porphyry	2 km NNW of Greys Hill, near Branxholm	59/61102790	EQ63314193
Mt Cameron Sheets	70-153	702699	Muscovite-biotite granite	South-west extremity of Mt Cameron	59/74804680	EQ75635934
	70-154	702700	Biotite-muscovite granite	South-east extremity of Mt Cameron	59/85505020	EQ85376256
	71-569	702702	Muscovite-biotite granite	Southern flank of Mt Cameron	59/77504850	EQ78086092
	71-570	702703	Muscovite-biotite granite	North-western flank of Mt Cameron	59/76005100	EQ76686319
Lottah Sheets	68-142	682049	Muscovite-biotite granite	Aberfoyle DDH 10, 154-163 ft, Anchor Mine	25101E	5195N*
	68-143	682050	Muscovite-biotite granite	Aberfoyle DDH 10, 163-172 ft, Anchor Mine	25101E	5195N*
	68-129	682055	Muscovite-biotite granite	Aberfoyle DDH 12, 77-86 ft, Anchor Mine	25000E	5400N*
	68-153	682063	Muscovite-biotite granite	Aberfoyle DDH 20, 125-132 ft, Anchor Mine	25300E	5400N*
	71-3	682066	Muscovite-biotite granite	Aberfoyle DDH 36, 455-470 ft, Anchor Mine	25700E	6100N*
	71-1	682068	Muscovite-biotite granite	Mines Dept DDH A1, 753-756 ft, Anchor Mine		
	68-144/45	682051	Biotite muscovite leucogranite	Aberfoyle DDH 10, 180-191 ft, Anchor Mine	25101E	5195N*
	68-154	682064	Biotite muscovite leucogranite	Aberfoyle DDH 20, 149-151, Anchor Mine	25300E	5400N*
	71-2	682067	Muscovite leucogranite	Mines Dept DDH A1, 729-739 ft, Anchor Mine		

*Anchor Mine Grid

Table 34. (continued)

Granitic Body	Thin Section no.	Chemical analysis no.	Rock Type	Location of Sample	Aust. Nat. Grid 10 yd Reference	Aust. Map Grid 10 m Reference
Lottah Sheets	68-139	682052	Aplite	Aberfoyle DDH 10, 194-201 ft, Anchor Mine	25101E	5195N*
	68-148	682060	Aplite	Aberfoyle DDH 16, 72-73 ft, Anchor Mine	25100E	5400N*
	68-131	682057	Greisenized granite	Aberfoyle DDH 12, 166-176 ft, Anchor Mine	25000E	5400N*
	68-132	682058	Greisenized granite	Aberfoyle DDH 12, 196-206 ft, Anchor Mine	25000E	5400N*
	68-150	682061	Greisenized granite	Aberfoyle DDH 16, 135-143 ft, Anchor Mine	25100E	5800N*
	68-155	682065	Greisenized granite	Aberfoyle DDH 20, 156-165 ft, Anchor Mine	25300E	5400N*
	68-130	682056	Greisen	Aberfoyle DDH 12, 86-100 ft, Anchor Mine	25000E	5400N*
	68-137	682053	Greisen	Aberfoyle DDH 10, 112-114 ft and 175-177 ft, Anchor Mine	25101E	5195N*

*Anchor Mine Grid



Plate 1. *Compositional banding in hornblende-biotite granodiorite from Piccaninny Creek Pluton, Piccaninny Point. The rock type ranges between hornblende biotite granodiorite, biotite granodiorite and hornblende biotite tonalite.*

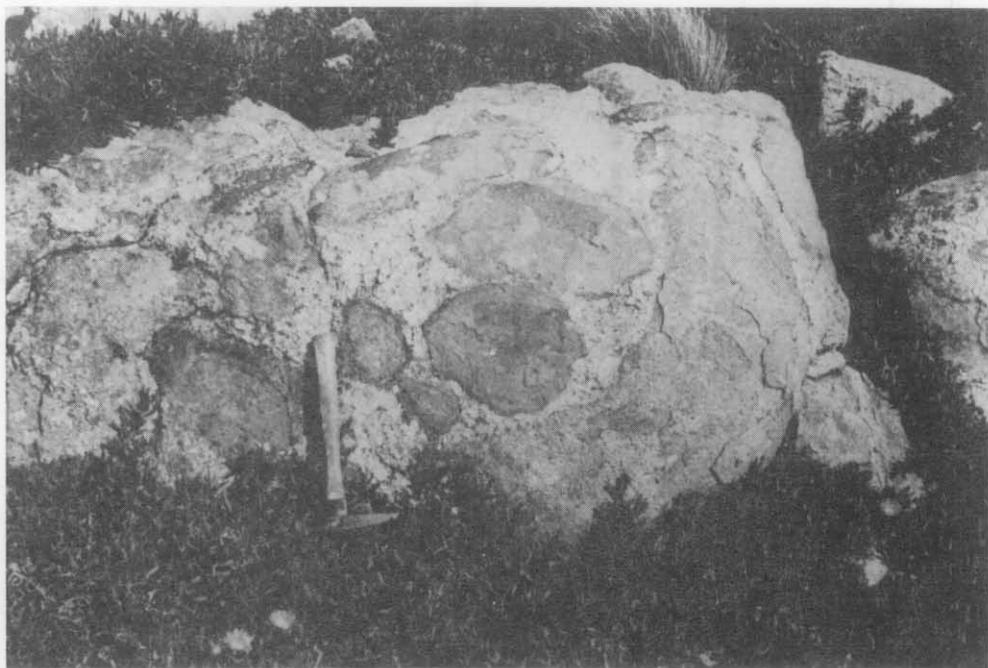
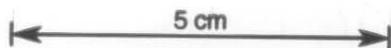


Plate 2. *Accumulation of subrounded enclaves in coarse-grained biotite granite/adamellite (so-called 'pudding-stones'), Ansons Bay Pluton, Georges Rocks.*



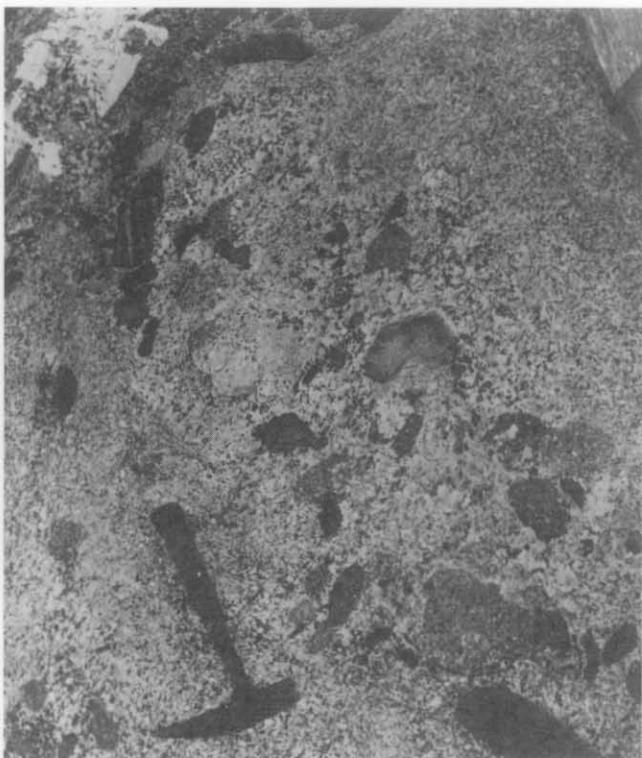


Plate 3. Accumulation of compositionally variable, sub-rounded to angular enclaves in coarse-grained biotite granite/adamellite, Ansons Bay Pluton, Georges Rocks.

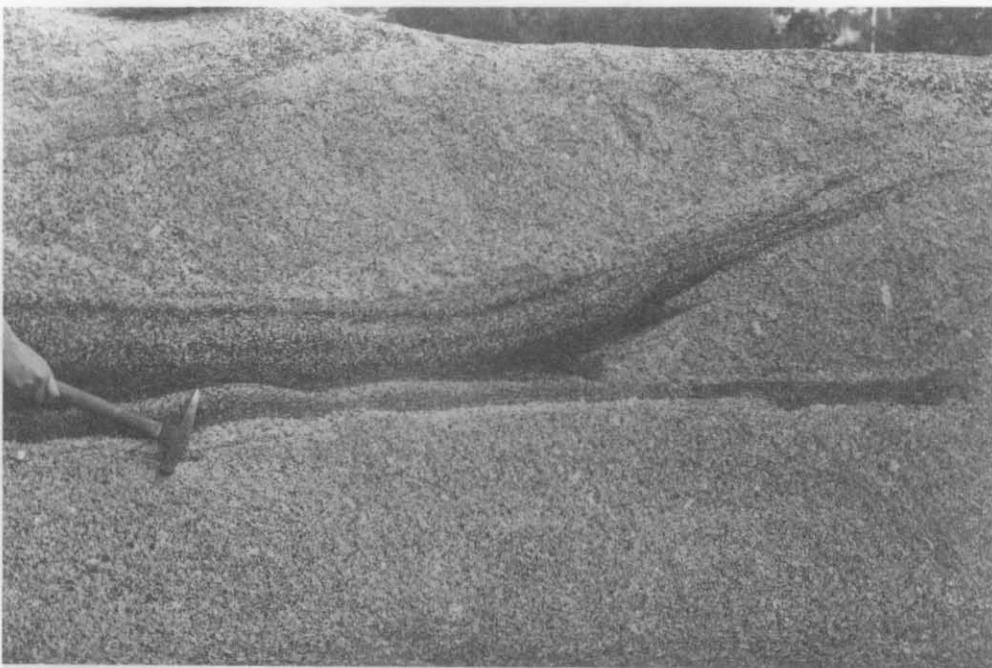


Plate 4. Layering defined by biotite concentration and grain size variations in biotite adamellite, St Helens Pluton, Binalong Bay.

[J.D.Cocker]

5 cm

5 cm



Plate 5. *Flattened, aligned inclusions in foliated biotite granodiorite near contact with Mathinna Beds. Coastal section between Tomahawk and Boobyalla. [D.J.Jennings]*



Plate 6. *Flattened inclusion, disrupted by minor faulting, aligned sub-parallel to the cataclastic foliation in gneissic granodiorite. Coastal section between Tomahawk and Boobyalla. [D.J.Jennings]*

5 cm

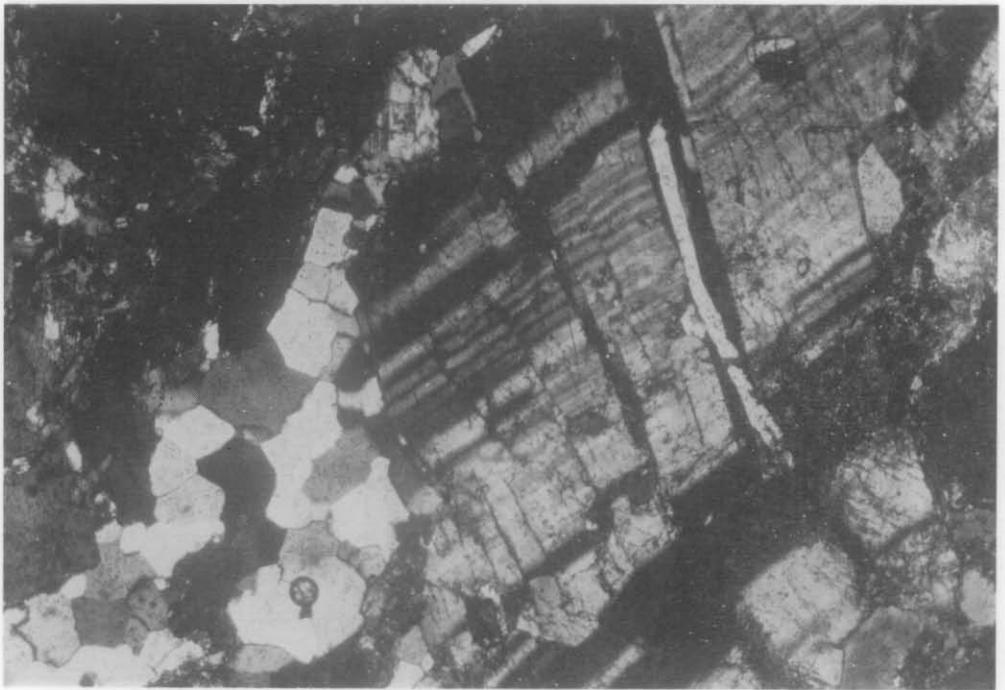


Plate 7. *Microfaulted plagioclase and recrystallised polygonal quartz aggregates in foliated hornblende biotite granodiorite, Pyengana. Specimen 69-390. Crossed nicols, x 48 [P2858].*

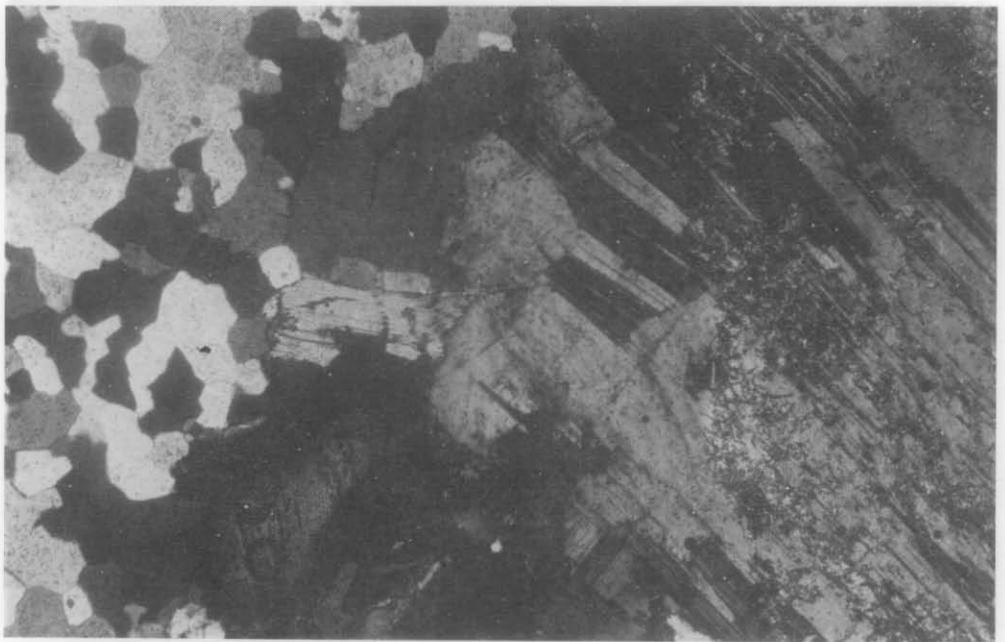


Plate 8. *Deformed plagioclase and biotite and recrystallised polygonal quartz aggregates in foliated biotite granodiorite, Pyengana. Specimen 69-417. Crossed nicols, x 28 [P2859].*



Plate 9. *Plagioclase, quartz and biotite poikilitically enclosed in microcline, Akaroa Granodiorite, St Helens Head. Specimen 70-149b. Plane polarised light, x 48 [P2855].*

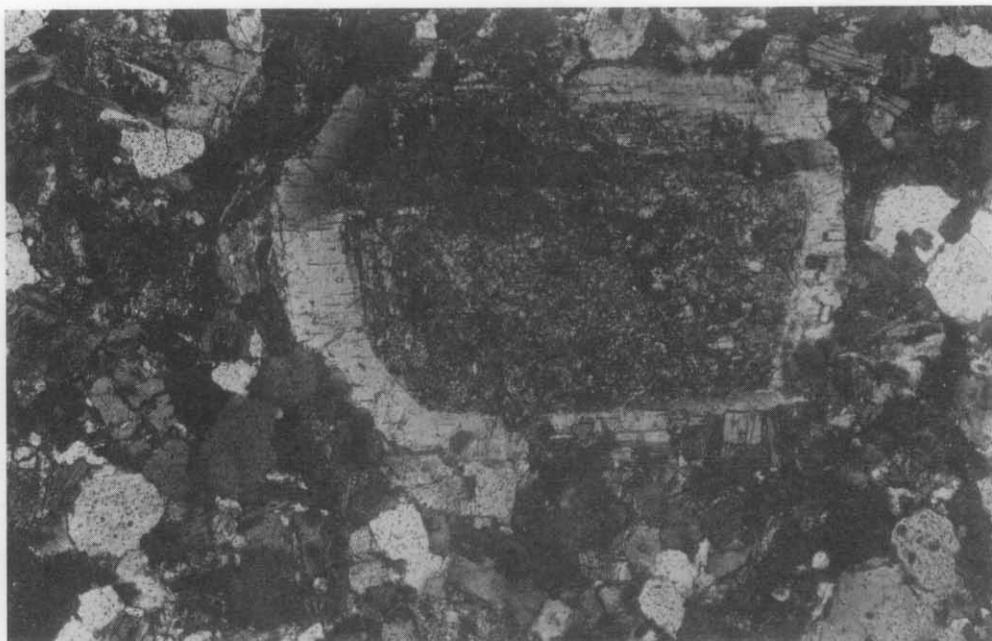
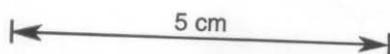


Plate 10. *Zoned plagioclase in feldspathised hornfels, Dianas Basin. Specimen 70-5. Crossed nicols, x 48 [P2852].*



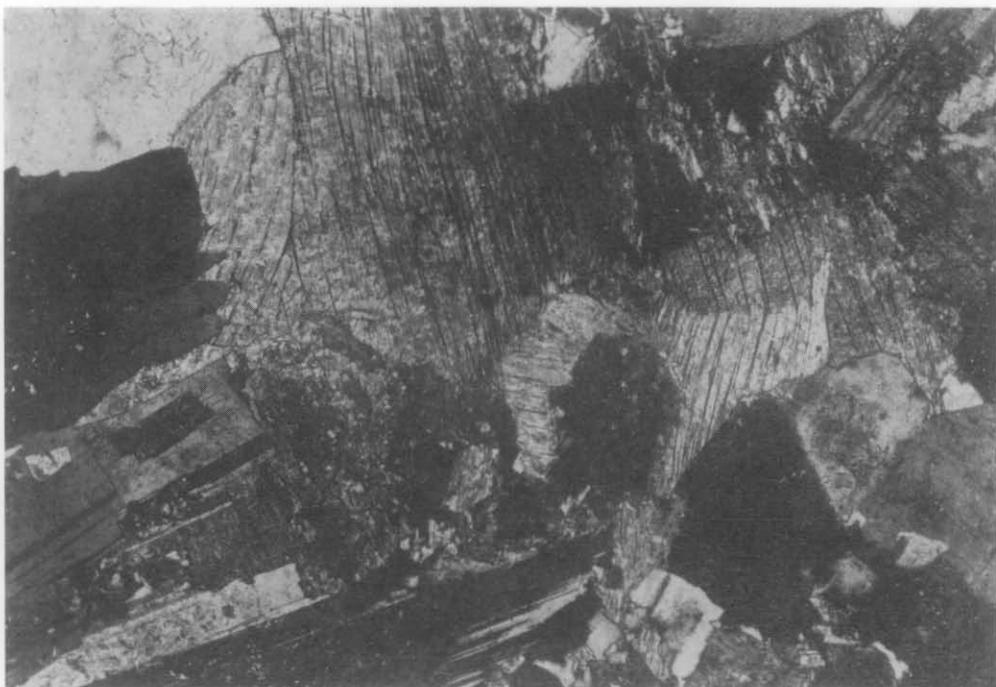


Plate 11. Large discrete muscovite grains in biotite-muscovite granite, Mt Cameron Sheets. Specimen 70-154b. Crossed nicols, x 37 [P2860].

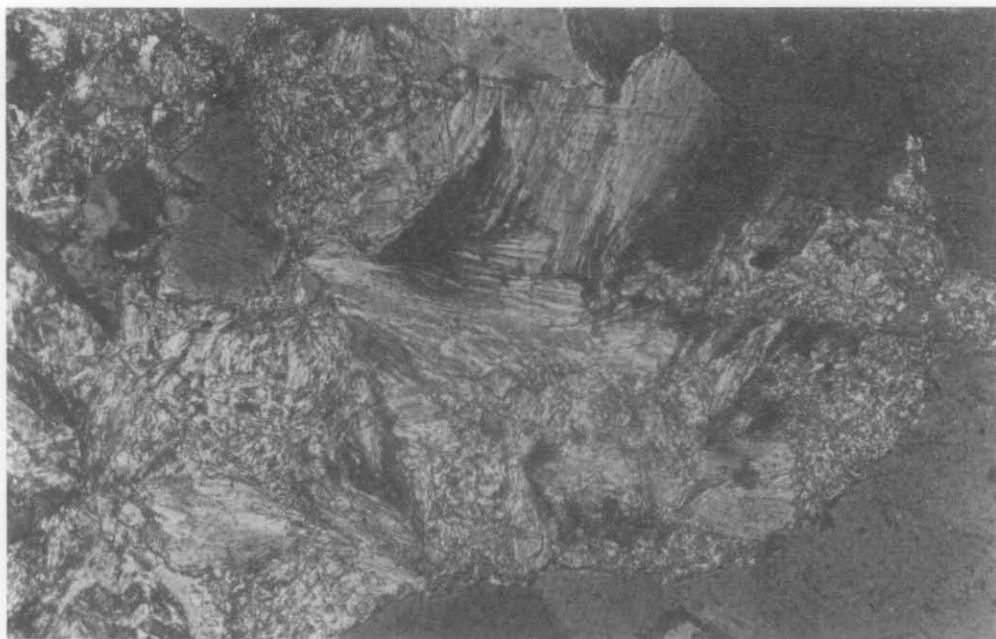


Plate 12. Rosettes of muscovite pseudomorphing microcline in greisenised granite, Anchor Mine, Blue Tier. Specimen 68-131. Crossed nicols, x 48 [P2862].

5 cm

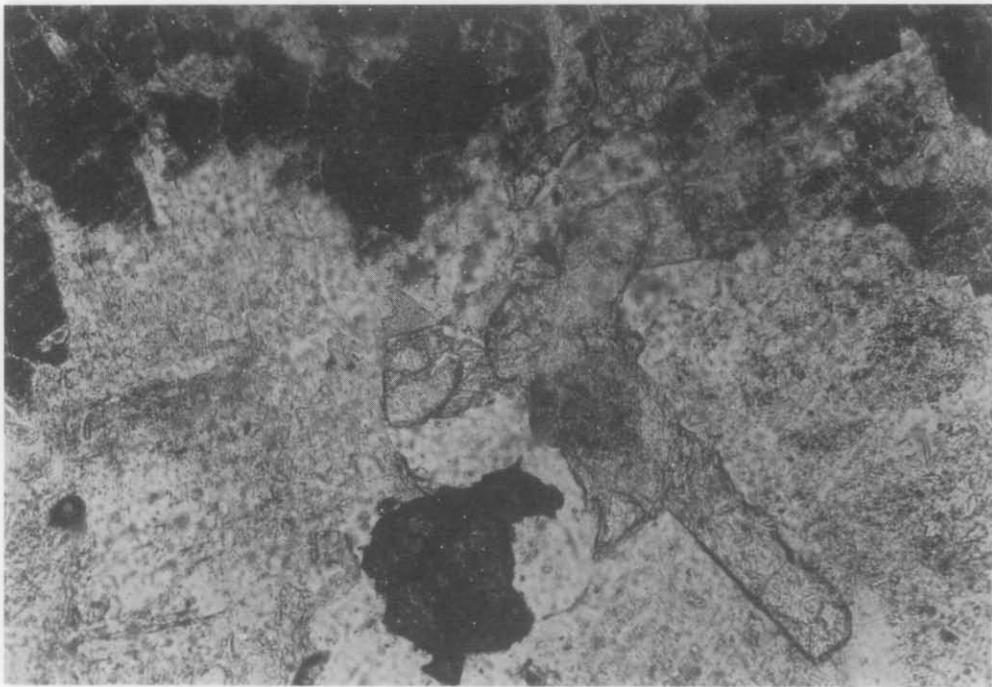


Plate 13. *Small cassiterite grains and topaz in muscovite-biotite granite, Anchor Mine, Blue Tier. Specimen 68-142. Plane polarised light, x 68 [P2863].*

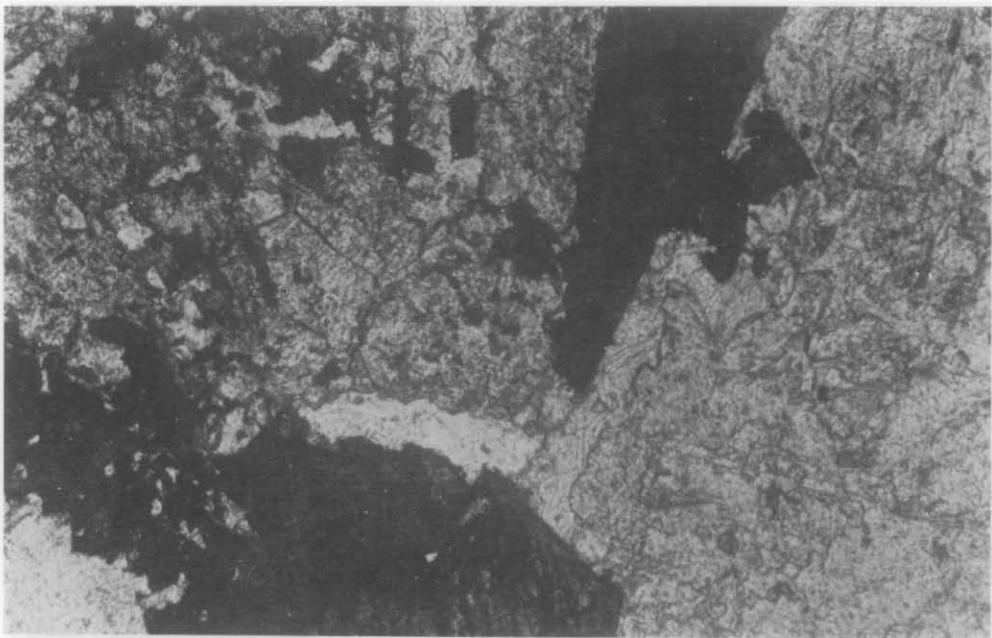


Plate 14. *Large cassiterite grains in greisenised granite, Anchor Mine, Blue Tier. Specimen 68-131. Plane polarised light, x 48 [P2853].*

The geology of the St Helens area:
petrology and structure
of the granitoid rocks

by *J.D. COCKER*

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55:117-156.

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ABSTRACT

In the St Helens area, five Devonian calc-alkaline granitoid rock units occur in an intrusive sequence established on field relationships:

- (1) George River Granodiorite, (2) Mt Pierson Adamellite,
- (3) Scamander Tier Granodiorite, (4) Grant Point Granite,
- (5?) Akaroa Granodiorite (intruded by the Grant Point Granite).

Three other units are the Priory Monzonite, which intrudes the George River Granodiorite (or has formed by the desilication of it) and the Medeas Cove Adamellite (which may be petrogenetically related to the Constable Creek Granite) and also intrudes the George River Granodiorite. These larger granitoid rock units are intruded by minor aplites and microgranites which have not been distinguished in the field except for a series of muscovite-andalusite microgranites in the St Helens Point-St Helens Island area. Intruding the granitoid rocks are plagioclase spessartites of unknown age and petrogenetic association and tholeiitic dolerites of pre-Permian age. A forceful mode of emplacement possibly combined with stoping is the mechanism of intrusion invoked for the George River Granodiorite whereas the Scamander Tier Granodiorite was intruded by forceful dilation into the Silurian Mathinna Beds and the George River Granodiorite. The mechanism of intrusion for the other units is not clear.

The circular outcrop patterns of the Grant Point Granite and Akaroa Granodiorite, however, suggest passive emplacement at high crustal levels possibly in a caldera structure.

The fabric of the George River Granodiorite is an impressed N-S mineral foliation which has been partly annealed and is best developed in the north-eastern sector of the pluton. Mineral alignment and segregation, of two distinct origins, is distinguished in the Scamander Tier Granodiorite: sub-horizontal magmatic biotite layering in the equigranular rock type, and K-feldspar phenocryst alignment and segregation in the central part of the dyke. The early magmatic layering is interpreted in terms of settling of biotite (and plagioclase) from slow moving currents whereas the K-feldspar alignment is attributed to late stage growth of feldspar in a stress field which is commonly parallel to the sides of the dyke. Magmatic settling of biotite also occurred in the Grant Point Granite.

The origin of the mineralisation and the development of the Scamander mineral field, based on the sequence of intrusion and the distribution of ore deposits is related to the Constable Creek Granite (W, Sn, Cu) the Scamander Tier Granodiorite (Pb-Zn-As) and the George River Granodiorite (Silver Echo Prospect). The Priory Lode (Sn) (probably related to the Constable Creek Granite) and the Stoney Ford Mine (Zn) (in the George River Granodiorite) emphasise the complex mineralisation history in the St Helens area.

The granitoid rocks display a typical range of calc-alkaline chemistry and mineralogy. There is no compelling field or chemical evidence to relate the units by fractional crystallisation except perhaps the Constable Creek Granite which may have been derived as a fluid-rich fraction from the Mt Pierson Adamellite.

The granitoid units are consistent with their derivation as separate magmas from the partial melting of different source rocks. The George River Granodiorite, the Scamander Tier Granodiorite and the Grant Point Granite have the features of I-type granitoids, whereas the Mt Pierson Adamellite, the Constable Creek Granite, the Akaroa Granodiorite and the Medeas Cove Adamellite are similar to the S-type granitoids.

INTRODUCTION

The St Helens area is probably the most structurally irregular and petrographically heterogeneous part of the Blue Tier Batholith. Groves (this Bulletin) and Gee and Groves (1971) have used the term the St Helens Pluton to describe all the granitoid rocks south and east of the Mt Pierson Pluton. In this report six intrusive units have been distinguished in the St Helens area and the term pluton is rejected.

The following intrusive sequence has been determined from the structural relationships.

- (1) George River Granodiorite
(?) Priory Monzonite
(?) Medeas Cove Granite
- (2) Mt Pierson Adamellite
and (?) Constable Creek Granite
- (3) Scamander Tier Granodiorite
- (4) Grant Point Granite
- (5) (?) Akaroa Granodiorite

A distinctive group of muscovite-andalusite granite dykes intrudes the Grant Point Granite and the Akaroa Granodiorite, but elsewhere aplites and microgranites have not been distinguished. Mafic dykes of dolerite (pre-Permian) and lamprophyre also intrude the George River Granodiorite, Grant Point Granite and Akaroa Granodiorite.

This report summarises field and laboratory studies carried out as a B.Sc. Honours project (Cocker, 1971) with revisions and additional chemical analyses. The investigation was concerned primarily with the petrology of the granitoid units and the structural relationships between them. The structure and metamorphism at the granitoid rock-Mathinna Beds contacts are considered, and brief descriptions of the economic and Cainozoic geology are included.

The base map for part of the area was compiled from Lands and Surveys Department and Forestry Department maps available in 1970. Most of the Georges Bay area was produced on the scale of 1:31 680 by reduction from aerial photographs (1:24 000). References to localities are given on the Australian National Grid in yards (fig. 21, 22). The absence of contour maps has restricted detailed structural interpretation.

Access to all rock types in the St Helens area is generally good although exposures range from excellent, locally along the coast, to poor elsewhere, especially in the centre and western parts of the George River Granodiorite. In Figure 22 only areas of continuous, relatively deep Cainozoic cover are shown.

Prior to the investigations by Groves (1972, and this Bulletin) and Gee and Groves (1971) work on the geology of the area was mainly concerned with ore deposits in the Tertiary sediments and in the Mathinna Beds of the Scamander mineral field. Montgomery (1893), Nye (1933), Walker (1957) and Jack (1964) discussed aspects of the economic geology and Walker (1957) mapped the granitoid rock-Mathinna Beds boundaries. Geological detail south of grid line 903000 yd N and west of the George River Granodiorite is taken from Groves (1972) and Walker (1957).

Specimens referred to are housed in the Geology Department of the University of Tasmania. Specimens with the prefix 61-, 69-, 70- refer to thin

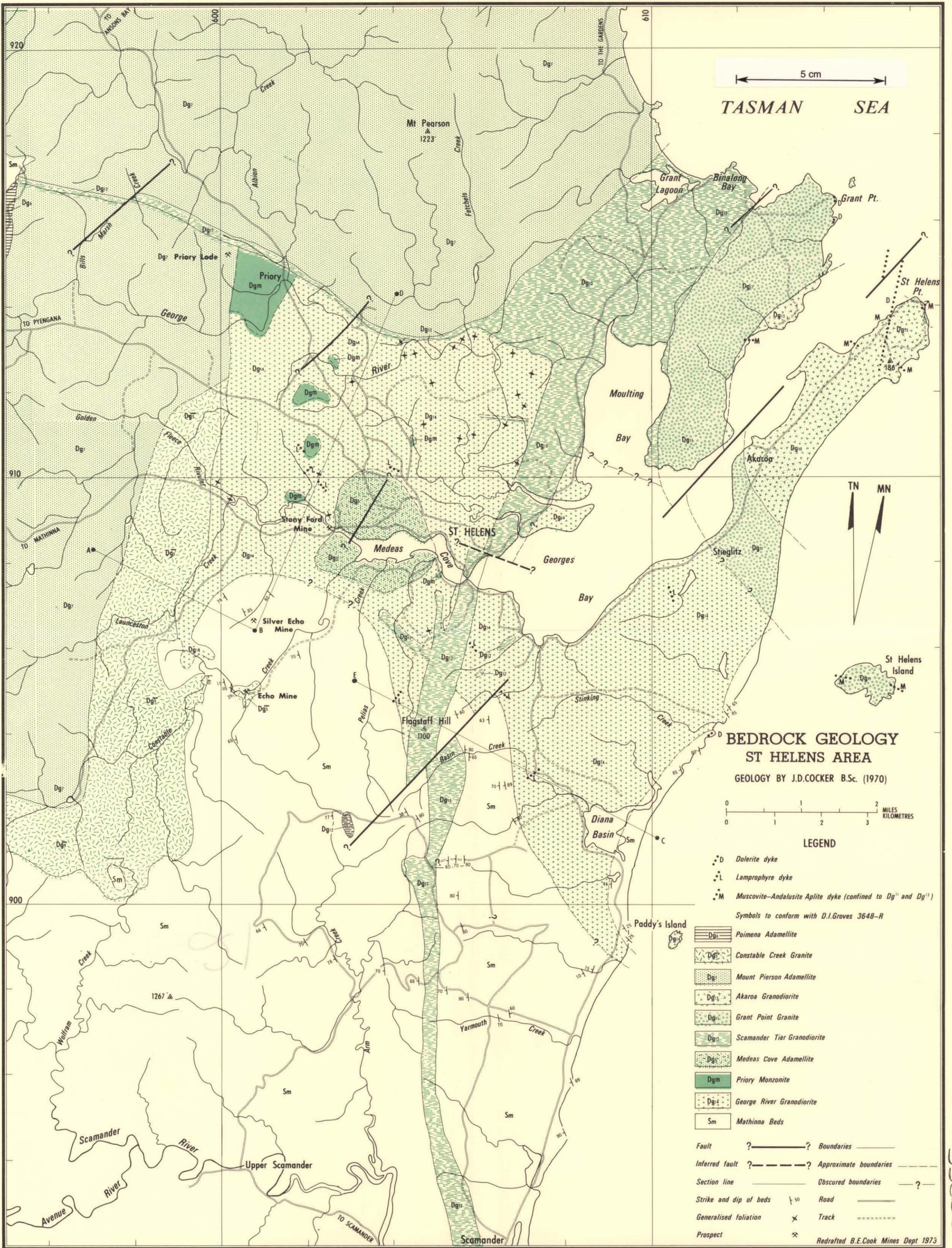


Figure 21

G3356

sections or modal and chemical analyses from the Tasmania Department of Mines, (Groves, this Bulletin).

CENOZOIC GEOLOGY AND GEOMORPHOLOGY

A well developed range of depositional landforms occurs in the St Helens area, and future work on the sediments may reveal a detailed Cenozoic history of north-eastern Tasmania. The sediment distribution was mapped but no quantitative study was made.

Three physiographic units are recognised: the relatively uniform coastal plain south of St Helens Point (with low relief and sub-parallel streams in broad valleys); a rugged hilly region developed in the Mathinna Beds west of Scamander Tier (with trellised and dendritic stream patterns), and a region of moderate relief, developed in the granitoid rocks, with a fault- and joint-controlled stream pattern.

The most significant break in this physiographic pattern is Thureau's Lead which defines the previous course of the George River [Montgomery, (1893)]. Jack (1964) and Jennings (1968) further proved the old course and outlined cross-sections through the channel. Twelvetrees (1904) and Walker (1953) suggest that the former river course may have reached the coast through Diana Basin, but detailed mapping of basement outcrops and interpretation of depth to basement from seismic and gravity traverses (fig. 22) (Geophysics Excursion 1973, University of Tasmania), suggest that the Tertiary river course crossed the coast in the Stieglitz area. North-south gravity profiles in the Stieglitz area show an asymmetric buried channel, with steeper southern slopes. Further evidence is provided by two parallel dune systems between Akaroa and St Helens Point. These dunes (probably Pleistocene in age) have a different orientation to the present beach, suggesting that, at least during part of the Pleistocene, Georges Bay was closed at the present mouth. Interpretation of the seismic traverses (Geophysics Excursion 1972, University of Tasmania) along the sand bar at the mouth of Georges Bay indicates a buried channel some 50 m below present sea level. The age of this channel is unknown. The present George River is incised in bedrock from Bills Marsh Creek to Georges Bay. The reason for the change in course is unknown, but a similar change occurs further south in the Scamander River (Walker, 1957; Leaman, 1973), suggesting a regional rather than an immediately local cause. One complicating feature is the extensive alluvial deposits at least 15 m above the present river level at Priory. An explanation for the change in course of the George River may be obtained by detailed analysis of the sediment sequences, including those of the George River delta.

The nature and distribution of Cenozoic sediments has been described previously (Walker, 1957; Jack, 1964; Groves, 1972). The age of the sedimentary sequences, which are extremely diverse in grain size and fabric, is not known. A mid-Tertiary age is indicated by spores from about 25 m above the base of Thureau's Lead (Harris, 1968). In the lower reaches of Constable Creek [69/020070] the sediment distribution is difficult to map and much of the cover may be Mathinna Beds talus.

The north-east striking fault system (fig. 21) has a horizontal displacement of up to 500 m. It is probably pre mid-Tertiary in age, as Thureau's Lead has apparently not been faulted. NE-trending Tertiary faulting is uncommon in Tasmania (Banks, 1958). An isolated mass of undeformed granodiorite, which occurs adjacent to a fault north of Medeas Cove [69/031090], was originally interpreted (Cocker, 1971) as a late stage Devonian intrusion, but may have been emplaced during the faulting.

Jack (1964) records Tertiary basalt in Thureau's Lead at the base of the channel. Fine-grained, alkali olivine basalt crops out over an area 200 x 50 m, 5 km north-west of Priory [59/980196]. Olivine, pinkish-brown clinopyroxene and labradorite occur as phenocrysts in a sub-ophitic to intergranular groundmass. Large areas of the Mt Pierson Pluton have not been traversed in detail and further outcrops of basalt may occur.

CONTACT METAMORPHISM

Walker (1957), Williams (1959) and Groves (1972, this Bulletin) have discussed the sedimentary and metamorphic petrology of the Mathinna Beds. Generally narrow zones of contact metamorphism are superimposed on slightly recrystallised sediments or low grade regionally metamorphosed rocks. The contact metamorphic zone about the shallowly dipping George River Granodiorite and Constable Creek Granite (Groves, 1972) is up to 2 km wide in the west, but only 100-200 m wide adjacent to the steeply dipping contacts of the George River Granodiorite and the Scamander Tier Granodiorite further east. Some aspects of the Launceston Creek and Stinking Creek contacts are considered further, to demonstrate the variation in contact metamorphic effects.

LAUNCESTON CREEK [59/994080]

Along the south-eastern side of the Launceston Creek valley the sub-horizontal contact of the George River Granodiorite is well exposed. Within 30 m of the contact the granodiorite grades into a pink, fine-grained felsic rock which intrudes the Mathinna Beds as narrow dykes up to one metre in width. The Mathinna Beds are dark, fine-grained quartzite and spotted hornfels and are well exposed on the top of the ridge and south to the Silver Echo mine. The spots, up to 10 mm in diameter, are predominantly muscovite and quartz although in one section (37762) irregular grains of cordierite occur. The spots may result from partial replacement of cordierite, or possibly are incipient growth sites of cordierite or andalusite. The assemblage 'quartz-muscovite-biotite-chlorite-cordierite' belongs in the hornblende hornfels facies of Turner (1968), while rocks further from the contact, lacking cordierite, grade into the albite-epidote hornfels facies.

STINKING CREEK [69/114042]

The granitoid rock is exposed over a distance of 200 m in Stinking Creek, 1.5 km north of Diana Basin, and at the northern end of Stinking Creek beach. In hand specimen and thin section this rock is similar to that from other outcrops of the George River Granodiorite, but contains a lower proportion of mafic minerals and is strictly an adamellite. The structural history of this contact has been outlined by Powell (1967) and Gee and Groves (1971); the following sequence of events at the southern end of Stinking Creek beach is partly taken from Gee and Groves.

- (1) The George River Granodiorite intruded the axial zone of a regional anticline and caused a swing in the bedding to a N-S trend. Small scale complex folds developed near the axis of the main fold.
- (2) In the cores of some of these folds discrete bodies of feldspathised rock of mixed origin formed with a discordant relationship to the bedding. Part of the feldspathised rock was mobilised sufficiently to be intruded as a narrow concordant dyke (pre-fault dyke, Gee and Groves, 1971, fig. 11, this Bulletin).

- (3) The bodies of feldspathised rock were displaced by a series of vertical faults with dextral displacement and with a trend parallel to the hinge of the minor folds in the contorted zone. This fault system also displaced the pre-fault dyke which was still sufficiently mobile to be injected along the fault surfaces.
- (4) A tonalite dyke with contacts discordant to the Mathinna Beds was intruded partly along the fault surfaces. The dyke includes xenoliths of the feldspathised rock and has caused small scale folds in the Mathinna Beds adjacent to its margins.
- (5) The small exposures of granitoid rocks immediately to the east of the tonalite dyke are considered to be part of the main mass of the George River Granodiorite, which assimilated some Mathinna Beds material before emplacement. Intrusion of these small lobes of contaminated granodiorite refolded some of the small folds in the axis of the main fold. In Figure 7-2 of Powell (1967) a wedge-shaped dyke of similar composition is shown.
- (6) A discordant, dilational quartz-dolerite dyke of unknown age intruded the contact zone (table 35, analysis 41701).

The cores of plagioclase crystals in the hornfels and in the tonalite are similar. Powell (1967) proposed that during intrusion of the tonalite, fluids expelled from the magma transported small plagioclase grains throughout the contact zone. However, from the intrusional history outlined and a brief investigation of the petrography of the hornfels and the igneous rocks, it is suggested that the plagioclase of the feldspathised sedimentary rock developed metasomatically before the intrusion of the tonalite.

Typical Mathinna Beds hornfels (34948) is a hard, dark, fine-grained (0.1-0.5 mm) rock in which equant quartz grains (60-70%) form a predominantly granoblastic texture with varying proportions of biotite, muscovite and chlorite. The red-brown biotite occurs as small randomly orientated laths, and also commonly as rounded inclusions (<0.05 mm) in quartz grains. Muscovite plates vary in size and develop a sieve texture enveloping small quartz grains. Adjacent to the contacts there is an increase in grain size of the hornfels and all traces of slaty cleavage are obliterated.

The feldspathised rock of mixed origin is distinct from the hornfels; it has a coarser grained groundmass (0.25-1.5 mm) and grains of plagioclase, quartz and biotite up to 3 mm across. Quartz grains, although larger, are similar to those in the hornfels in shape and in their content of rounded biotite inclusions. Plagioclase, which occurs as anhedral to euhedral grains, is zoned from An_{40} in the core to An_{15} on the rim and usually has fewer albite twins than magmatic plagioclase from the adamellite.

The pre-fault dyke of feldspathised rock has sharp margins and contains numerous xenoliths of Mathinna Beds. In hand specimen this rock has an indefinite texture, in part a quartz-rich hornfels and in part a felsic igneous intrusive. In thin section masses of granoblastic quartz contain rounded biotite inclusions. The proportion of potash feldspar in the dyke rock of mixed origin is higher than that in the discrete bodies of feldspathised hornfels. Further evidence of assimilation of hornfels and mobilisation of the resultant feldspathised rocks is found in outcrops immediately east and south of the tonalite dyke (70-6), and fringing the adamellite at the northern end of Stinking Creek beach (37784). In both these rocks granoblastic quartz grains with minute biotite inclusions can be distinguished from larger masses of igneous quartz which have sutured boundaries.

The tonalite dyke (70-4) has a mineralogy and texture which are different from both the main adamellitic mass and the mobilised, feldspathised sediments. Subhedral, zoned plagioclase ($An_{50}-An_{28}$) (about 40%), red-brown biotite and dark-green hornblende (mafic minerals about 15%), occur with anhedral quartz grains usually including these minerals. The petrogenetic relationship of this dyke to other rocks in the area is unknown. Analysis (table 35, 41699) indicates that it is the most basic granitoid rock analysed from the St Helens area. The small size of the dyke compared with the broad distribution of the feldspathised hornfels at Stinking Creek suggests the dyke was inadequate as a possible source of heat and/or fluids to effect the observed metasomatism.

Gee and Groves (1971) have discussed the structural significance of this contact.



STRUCTURE OF UNIT

The George River Granodiorite* is the largest intrusive unit in the St Helens area. It is a heterogeneous unit, predominantly granodioritic in composition north of grid line 905000 yd N, and predominantly adamellitic to the south (table 35, fig. 24). The Priory Monzonite and Medeas Cove Adamellite are two separate units which are restricted within, but probably petrogenetically unrelated to the George River Granodiorite.

The shape of George River Granodiorite is irregular, with boundaries defined by the intrusion of younger units on the eastern and western margins. The northern margin may be an original contact with Mathinna Beds, with sediments subsequently replaced - or the boundary reshaped - by the intrusion of the Mt Pierson Adamellite. The southern contact between Mathinna Beds and granodiorite dips shallowly east in the Launceston Creek valley, and nearly vertically east of the Scamander Tier Granodiorite (fig. 23, sections A-B, E-C).

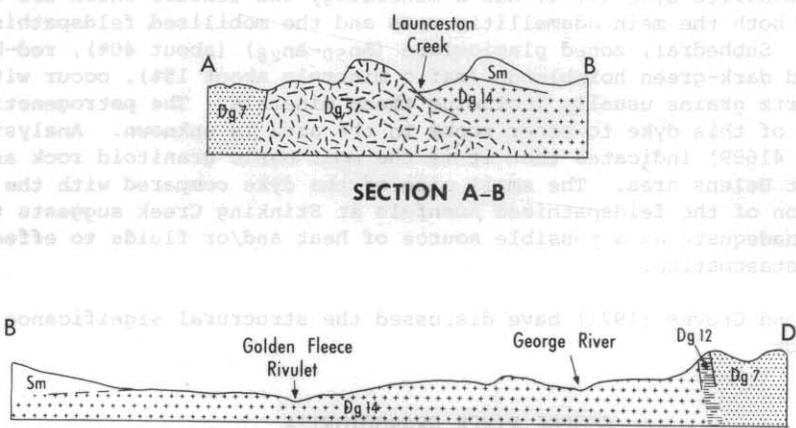
The subhorizontal contact in Launceston Creek and the concordant summit heights in the western half of the George River Granodiorite suggest that the present level of exposure of this unit is near the roof of the intrusion (fig. 23, section B-D). The contact is generally discordant to the Mathinna Beds except in the southern wedge-shaped part of the granodiorite body, where the bedding may have been splayed by the intrusion. On a smaller scale the bedding of the Mathinna Beds is sub-parallel to the intrusive contact for about 30 m above the granodiorite in the Launceston Creek valley. These features are consistent with the forceful mode of intrusion at Stinking Creek, described in detail by Gee and Groves (1971) and Groves (this Bulletin).

FIELD CHARACTERISTICS

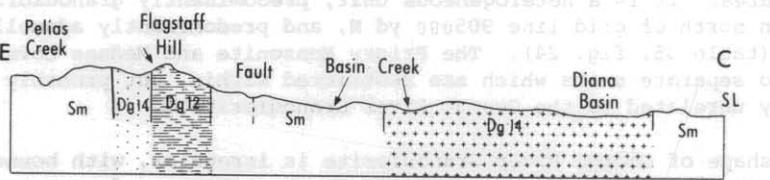
The George River Granodiorite is typically a dark grey, medium-grained rock with visible quartz, plagioclase, biotite and hornblende. The combined proportion of mafic minerals ranges from 5-20%, with biotite exceeding hornblende. Dioritic xenoliths are abundant compared with other units in the St Helens area although their proportion varies widely. Mathinna Beds xenoliths are relatively rare. The granodiorite is generally massive in outcrop with a poorly developed cataclastic foliation, which dips steeply, and strikes generally N-S. The foliation is best exposed in the north-eastern part of the unit and is defined by the alignment of mafic minerals and lenses of small

*Type localities of granitoid rock units are given in Table 36.

The Constable Creek (Cg 5) has a mineralogy and texture which are different from both the main Adamellite and the modified Adamellite. Subhedral, coarse grained (about 400 μ), red-brown diorite and dark-green hornblende quartz grains make up the mineralogy of this type of rock. Analysis of this type of rock analysed from the St Helens area. The distribution of the Adamellite in the St Helens area is indicated on a map in Figure 23. The possible source of heat and/or fluids to effect the upward metamorphism is discussed in the text.

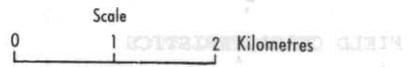


The George River Granodiorite is the largest intrusive unit in the St Helens area. It is a heterogeneous unit, predominantly granodioritic in composition with a few gabbroic and monzonitic dykes. The south-western part of the intrusion is a gabbroic unit which is generally genetically related to the Scamander Tier Granodiorite. The shape of the intrusion is defined by the irregular margins of the gabbro and western margins. The northern margin may be an orogenic tectonic - or the boundary replaced - by the intrusion of the Mathinna Beds, with a concordant contact. The southern contact between Mathinna Beds and the George River Granodiorite is a fault, and nearly vertically east of the Scamander Tier Granodiorite (Fig. 23, section A-B, B-C).



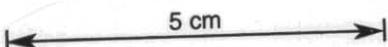
Key

-  Constable Creek Granite
-  Mt Pierson Adamellite
-  Scamander Tier Granodiorite
-  George River Granodiorite
-  Mathinna Beds



The George River Granodiorite is typically a dark grey, medium-grained rock with visible quartz, feldspars, diorite and hornblende. The proportion of mafic minerals ranges from 2-10%, with diorite exceeding hornblende. Biotite xenoliths are common. The Mathinna Beds xenoliths are generally massive in outcrop with a fine-grained, and strikes which dip steeply, and strikes which dip in the north-eastern part of the intrusion. The Mathinna Beds xenoliths are generally massive in outcrop with a fine-grained, and strikes which dip steeply, and strikes which dip in the north-eastern part of the intrusion. The Mathinna Beds xenoliths are generally massive in outcrop with a fine-grained, and strikes which dip steeply, and strikes which dip in the north-eastern part of the intrusion.

Figure 23. Geological sections, St Helens area.



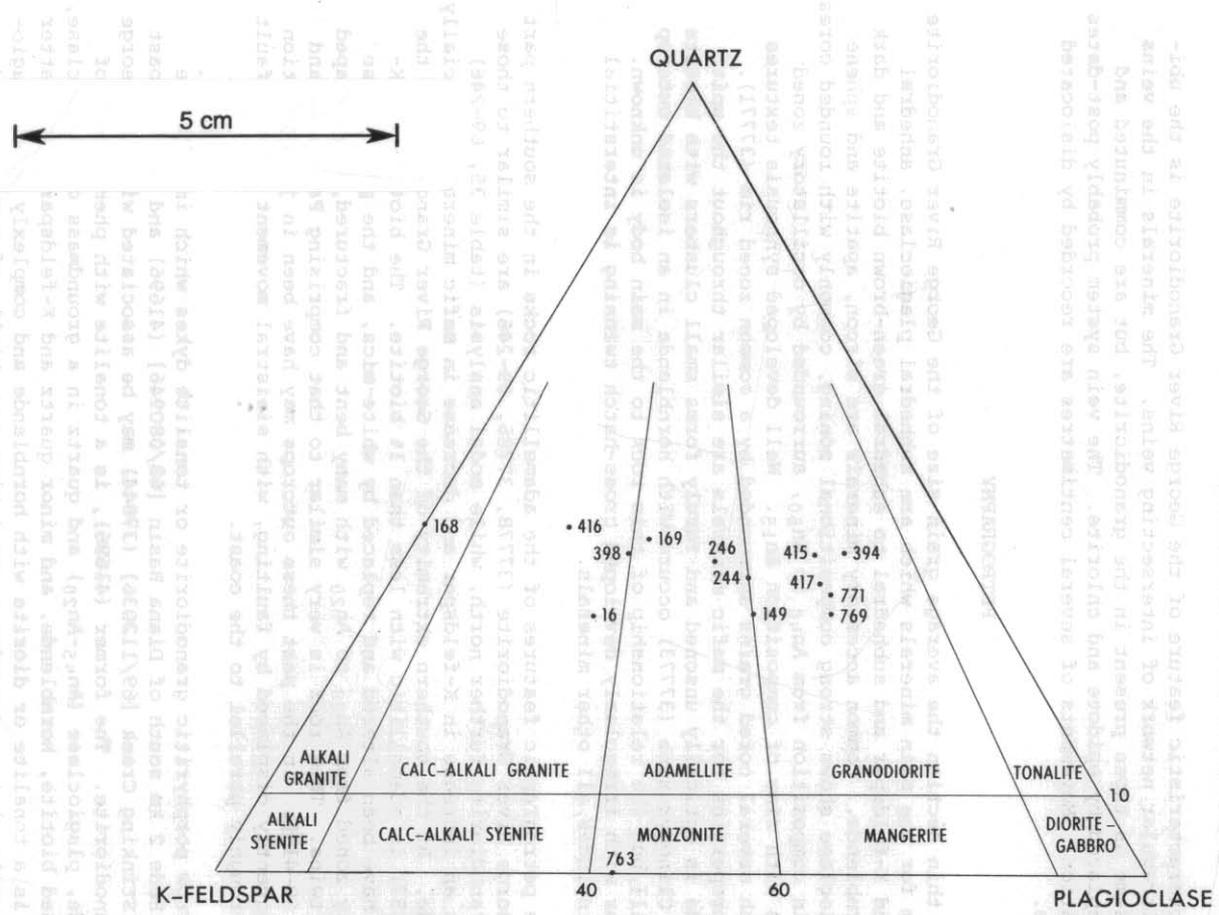


Figure 24. Rock classification from modal analyses: a triangular diagram in terms of quartz, K-feldspar and plagioclase.

quartz grains. A primary foliation, 2.5 km NNW of St Helens bridge [69/023 101], is defined by layers alternately enriched and depleted in mafic minerals, and is roughly parallel to the secondary cataclastic foliation. Four kilometres north of St Helens bridge [69/050110] in the inferred roof zone of the intrusion, the foliation is well developed with alignment of both mafic and felsic minerals. Adjacent to the Scamander Tier Granodiorite [69/070106] (37856), a well developed north-south foliation occurs. This marginal deformation and recrystallisation is poorly exposed. It may be imposed upon the earlier cataclastic foliation, as the result of deformation during the intrusion of the Scamander Tier Granodiorite.

A characteristic feature of the George River Granodiorite is the ubiquitous, irregular network of intersecting veins. The minerals in the veins are the same as those present in the granodiorite, but are comminuted and partly replaced by epidote and chlorite. The vein system probably post-dates the foliation. Movements of several centimetres are recorded by dislocated xenoliths.

PETROGRAPHY

In thin section the average grain size of the George River Granodiorite is 1-2 mm for the main minerals which are subhedral plagioclase, anhedral quartz and K-feldspar and subhedral to euhedral green-brown biotite and dark green hornblende. Common accessory minerals are zircon, apatite and sphene. The plagioclase shows strong compositional zoning, commonly with rounded cores ranging in composition from An_{40} to An_{50} , surrounded by oscillatory zoned sequences with rims of composition An_{15} . Well developed synneusis textures occur with several cored grains surrounded by a common zoned rim (37771). Optical properties for the mafic minerals are similar throughout the unit. Hornblende is optically unzoned and rarely forms small clusters with biotite grains. Clinopyroxene (37773) occurs with hornblende in an isolated outcrop [69/046111], but the relationship of this rock to the main body is unknown. K-feldspar with irregularly developed cross-hatch twinning is interstitial to, and includes, all other minerals.

The petrographic features of the adamellite rocks in the southern part of the George River Granodiorite (37778, 37785, 69-246) are similar to those of the granodiorite further north, while modal analysis (table 35, 69-246) indicates an increase in K-feldspar and decrease in mafic minerals, especially hornblende. At the southern extremity of the George River Granodiorite, the rock (37857) is adamellite with less than 1% biotite. The biotite and K-feldspar have been altered and replaced by white-mica, and the plagioclase is broadly zoned from An_{30} to An_{20} with many bent and fractured, wedge-shaped multiple twins. This rock is very similar to that comprising Paddys Island (69-418, 69-419). In the past these outcrops may have been in juxtaposition and subsequently displaced by faulting, with sinistral movement along a fault striking roughly parallel to the coast.

Narrow porphyritic granodiorite or tonalite dykes which intrude the Mathinna Beds 2 km south of Diana Basin [68/080946] (41696) and on the coast south of Stinking Creek [69/112036] (37844) may be associated with the George River Granodiorite. The former (41696), is a tonalite with phenocrysts of hornblende, plagioclase (An_{45} - An_{20}) and quartz in a groundmass of plagioclase, chloritised biotite, hornblende, and minor quartz and K-feldspar. The latter (37844), is a tonalite or diorite with hornblende and complexly zoned plagioclase (An_{50} - An_{30}) in a groundmass consisting essentially of myrmekite and graphic quartz-feldspar intergrowths. Chlorite has partially replaced hornblende euhedra and large chlorite pseudomorphs may be after clinopyroxene.

In thin section the quartz of the foliated granodiorites appears as elongate aggregates composed of equant subgrains. In unfoliated rocks (37771, 37765, 37850) the quartz grains are anhedral with sutured boundaries. Quartz in the foliated rocks near the Scamander Tier Granodiorite is commonly annealed with straight extinction and polygonal boundaries (37769, 37776). Other thin section evidence of foliation is restricted to rare kinked biotite grains. The foliated rocks adjacent to the Scamander Tier Granodiorite exhibit intense grain and crack boundary granulation (37767, 37783) with the competent felsic minerals strongly comminuted and partly annealed, and the mafic minerals kinked and recrystallised to form irregular masses of small laths.

ROCKS OF THE ROOF ZONE

The granodiorite grades into a pink, porphyritic micro-granite which intrudes the overlying Mathinna Beds in the Launceston Creek valley. The granite in the wedge-shaped extreme southern part of the granodiorite unit contrasts in texture but is superficially similar in composition and colour. These rocks may represent fractionated portions of the granodioritic magma. A large area of leucocratic granodiorite occurs some 3 km north of St Helens bridge [69/060110]. The rock (37774) is well foliated with aligned masses of sutured quartz grains, plagioclase and biotite. Local absence of foliation in these outcrops of the George River Granodiorite (37775) near the Scamander Tier Granodiorite is attributed to hydrothermal alteration.

Hydrothermally altered rocks also occur some 4 km north-west of St Helens bridge [69/023102, 69/037119]. These rocks appear bleached in hand specimen, and in thin section (37775) the altered microcline and plagioclase occur together with fibrous chlorite, minor hornblende, epidote and calcite.

PRIORY MONZONITE

Priory Monzonite occurs as several, poorly exposed, irregular masses rarely exceeding one kilometre in diameter. Superficial cover obscures contacts and the monzonite generally appears as rounded bodies locally occupying hilltops and indicating a minimum thickness of 80 m [69/026128-69/020912].

Outcrops of monzonite are commonly cut by narrow granitoid dykes, and are well jointed; the joints contain chlorite and epidote and joint surfaces are slickensided. No foliation was observed. Fine- to medium-grain sizes occur with the finer grained rocks generally darker in colour. Pink K-feldspar, multiple twinned plagioclase and hornblende are visible in hand specimen.

The three dominant minerals seen in thin section are anhedral microcline and plagioclase, both of which commonly include euhedral hornblende. Most specimens show deformation of all grains and recrystallisation of hornblende, (especially in the finer grained rocks) and feldspars range from bent and wedge-shaped twinned crystals to mosaics of small grains (37761, 37760, 37764, 37768). Strong recrystallisation of large, euhedral hornblendes has produced masses of radiating needles which also occur along cracks and grain boundaries. Chlorite and epidote also partly replace hornblende and plagioclase.

The microcline displays cross-hatch twinning and patch and string microperthite, and poorly zoned plagioclase of composition An_{10} to An_{15} shows growth and/or deformation twinning. Thin section study shows plagioclase composition of An_{10} (37763, modal analysis table 35) and An_5 (37764), the paucity of calcium in the latter resulting in classification of the rock as a syenite.

The euhedral to subhedral hornblende of the undeformed monzonites is commonly twinned and zoned. It has a pleochroic scheme: Z - sea green, X - light green, Y - light brown, with lighter colours in outer zones. Accessory sphene and iron-titanium oxides are relatively abundant in the monzonite.

The granitoid dykes which intrude the monzonite are medium-grained with an interlocking texture. Microperthitic K-feldspar and quartz are irregularly intergrown, and minor plagioclase has a composition of about An₂₀ (37845, 37780).

Intrusion of the Priory Monzonite into the George River Granodiorite, with subsequent deformation and recrystallisation is a possible sequence of events as the monzonite has a younger Sr-isotopic age than the granodiorite (Cocker, unpublished). Many of the characteristics of this unit are similar to isolated syenitic outcrops in the G-2 adamellite of the Barnesmore Complex, Ireland, attributed by Walker and Leedal (1954) to alteration by a hydrothermal solution. Desilification accompanied by deformation may have formed the Priory Monzonite, although the granitoid dykes intruding the monzonite have not been affected. Further mapping and chemical analysis are required to test these hypotheses. The composition of the monzonite (table 36) and its age preclude any relationship with the shoshonites at Cygnet and Cape Portland.

MEDEAS COVE ADAMELLITE

The Medeas Cove Adamellite is exposed around Medeas Cove, 2 km west of St Helens. No contacts with the George River Granodiorite are exposed so boundaries are defined approximately, and evidence of its position in the intrusive sequence is missing. The Medeas Cove Adamellite and the Constable Creek Granite have many common features and are possibly derived from the same magma. Two analyses of the Medeas Cove Adamellite are given in Table 36.

In hand specimen the adamellite is pinkish to cream coloured and rarely fresh. In thin section (38880, 37782, 37779) the average grain size is 0.5-1 mm with phenocrysts of K-feldspar, quartz and plagioclase up to 7 mm in length. The major phases occur as anhedral grains with quartz often included in the larger feldspar grains. Plagioclase is broadly zoned from An₂₀ to An₁₅ and K-feldspar has well-developed cross-hatch twinning. The accessory minerals apatite and zircon are commonly included in the dark green to light brown biotite which forms less than 5% of the rock.

An inclusion of hornblende-rich granodiorite (37846), possibly a fault-bounded block, occurs near the fault which has produced a narrow, intensely jointed NE-SW zone in the adamellite.

A light coloured rock (37781) from a poor exposure [69/042104] may be related to the Medeas Cove Adamellite. It has an average grain size of 1-2 mm, with masses of sutured quartz grains up to 3 mm across. Biotite and hornblende form less than 5% of the rock and the plagioclase is broadly zoned with an average composition of An₁₂. Pebbly outcrops of lamprophyric rock probably represent dyke material.

MT PIERSON ADAMELLITE AND CONSTABLE CREEK GRANITE

The disposition of the Constable Creek Granite marginal to the Mt Pierson Adamellite probably indicates a close temporal and perhaps genetic relationship between these two units. Small dykes of Constable Creek Granite intrude the adjacent George River Granodiorite. The Mt Pierson Adamellite and

the Constable Creek Granite were examined briefly in areas adjacent to the George River Granodiorite and Scamander Tier Granodiorite.

The Mt Pierson Adamellite is well exposed in large rounded tors as a coarse-grained, equigranular to porphyritic adamellite carrying few xenoliths or biotite schlieren. Phenocrysts occur sporadically and generally show no discernible foliation. More detailed traversing may permit delineation of porphyritic and equigranular units. Groves (this Bulletin) describes thin sections of Mt Pierson Adamellite, a modal analysis is given in Table 35 and two chemical analyses in Table 36. One analysis (37827) is of deformed and metasomatised adamellite, 2 m from the Scamander Tier Granodiorite.

The Constable Creek Granite is a composite assemblage of coarse- to fine-grained granites flanking the eastern and southern margin of the Mt Pierson Adamellite. To the south, Groves (1972) describes the eastern margin of the unit as dipping gently beneath the Mathinna Beds while further north, near Launceston Creek, the contact between the Constable Creek Granite and the George River Granodiorite is dipping to the east at 30-40° (fig. 23, section A-B). The granite cropping out near the Echo Mine represents a local high patch in the undulating surface between the Constable Creek Granite and the Mathinna Beds. The western contact between the composite zone and the adamellite is gradational, and is indicated by a progressive decrease in fine-grained dykes and reduction of the pink alteration effects characteristic of the Constable Creek Granite.

Near the George River Granodiorite, marked and irregular variations in grain size occur within the Constable Creek Granite with rocks ranging from microgranites to granites as coarse as those of the Mt Pierson Adamellite. Drill core from three holes in the Echo Mine area (Mortimore and Rattigan, 1970) shows that the structure of the Constable Creek Granite assemblage in this locality is a composite body with subhorizontal stratification. Modal and chemical analyses are presented (tables 35, 36; fig. 24). The modal analyses indicate a range from adamellite to alkali granite depending on the plagioclase composition.

Poor blocky outcrop is typical of the Constable Creek Granite, especially the well jointed fine-grained rocks with aplitic textures. In hand specimens the rocks are pink coloured and rarely fresh. Generally they are equigranular although K-feldspar and muscovite booklets occasionally form phenocrysts in the coarser grained variants. Quartz-tourmaline intergrowths up to 100 mm in length partly fill miarolitic cavities and are associated with irregular pegmatitic lenses up to 2 m long in some coarse-grained rocks. Commonly the finer grained rock types form dykes up to 100 m wide within the coarser grained varieties and extend into the Mt Pierson Adamellite. Quartz-tourmaline veins up to 3 m wide, similar to those at the Priory Lode mine, occur within the Constable Creek Granite [95/054976]. Small microgranitic dykes occur with the vein system in the Priory Lode mine area [69/002152] and suggest the extension of the Constable Creek assemblage, at depth, along the George River Granodiorite/Mt Pierson Adamellite contact. Groves provides a thin section description of the Constable Creek Granite (this Bulletin) which is distinguished from other rocks in the St Helens area by plagioclase of low An content and biotite with variable greenish brown to light green pleochroism (37821, 69-247). These characteristics are similar to other Blue Tier Batholith granitoid rocks which are associated with cassiterite mineralisation.

SCAMANDER TIER GRANODIORITE

INTRODUCTION

The Scamander Tier Granodiorite forms a dyke some 24 km long and ranges in width between 0.3 and 3.0 km. An offshoot from the main body, termed the east-west dyke, defines the contact between the George River Granodiorite and Mt Pierson Adamellite. The granodiorite unit is well exposed as massive outcrops along Scamander Tier and on a prominent ridge from St Helens to Binalong Bay. The boundaries of the dyke are straight and steeply dipping in rare contact exposures (fig. 23, section E-C). North of Flagstaff Hill several small dykes are poorly exposed in the George River Granodiorite (e.g. at 69/068113, fig. 21, and at 69/050081, one metre wide). A small isolated body of rock [69/028020] may represent a fault-displaced extension of an offshoot of the main dyke where it bulges to the west [69/044901].

MODE OF EMPLACEMENT

Gee and Groves (1971) concluded that the dyke was emplaced by forcible intrusion with upward displacement of the country rock and some lateral pushing indicated by local overturning of strata along the eastern contact. However, near Flagstaff Hill the offset of the steeply dipping Mathinna Beds-George River Granodiorite contact suggests a large dilational movement during intrusion.

Near Flagstaff Hill emplacement of the dyke apparently causes horizontal dilation of about one kilometre in a NE-SW direction. Forcible rather than passive dilation is indicated by minor folding and local overturning of the Mathinna Beds along the eastern contact and strong foliation and recrystallisation of the George River Granodiorite marginal to the dyke. The pre-existing foliation in the George River Granodiorite may have controlled the orientation of the Scamander Tier Granodiorite dyke, and the forcible intrusion of the latter perhaps intensified the foliation adjacent to the dyke margins.

The east-west dyke of the Scamander Tier Granodiorite may have been emplaced by forcible dilation, possibly along a fault zone, between the George River Granodiorite and the Mt Pierson Adamellite. No matching dyke-wall irregularities were observed.

Sr-isotopic results (Cocker, unpublished) from biotites of the George River Granodiorite and the Mt Pierson Adamellite indicate that the latter intrusion is younger than the former. This is supported by field observations:

- (1) A weak regional(?) N-S cataclastic foliation in the former is truncated by the intrusive(?) boundary of the latter which appears unfoliated.
- (2) The Mt Pierson Adamellite and the Constable Creek Granite are probably genetically and temporally related and off-shoots of the latter invade the George River Granodiorite.

Mega-xenoliths of hornfelsed Mathinna Beds, which occur in the east-west dyke, may be remnants of a fragmented screen or down-warped roof of country rock trapped between successive intrusions. This suggests that the dyke is situated along an original contact between an igneous body and sedimentary country rock. The altitude of the outcrops including the mega-xenoliths is similar to the concordant summit heights in the George River Granodiorite.

The site of the east-west dyke of the Scamander Tier Granodiorite was probably a fault zone with associated deformation in the adjacent rocks, prior

to dyke intrusion. To the east of Priory the dyke separates granodiorite from adamellite and to the west divides the adamellite. The latter proves more susceptible to deformation and alteration than the granodiorite. Within the adamellite a zone 100 mm wide adjacent to the east-west dyke has been comminuted and now forms a fine-grained mosaic, while throughout a broader zone, 100 m wide, the feldspars have disintegrated, although the original texture can still be distinguished. Deformation and alteration of the George River Granodiorite occurs on a subdued scale. Near the dyke mosaic patches of quartz grains with triple point boundaries suggest that the granulated quartz was heated and annealed by the intrusion. The dyke has chilled margins against the Mt Pierson Adamellite [69/040134] and the George River Granodiorite [69/045133], and along the northern contact has commonly intruded the deformed adamellite as small irregular dykes. The southern margin of the dyke is relatively straight, with deformation mainly confined to a fine-grained, well foliated zone about 10 m wide. Alteration of the original grey feldspars to pink, partly-sericitised grains and recrystallisation of biotite of the Mt Pierson Adamellite to felted masses, is attributed to hydrothermal reactions. The asymmetry of the zone of deformation about the east-west dyke is emphasised by the incidence of multiple slickensiding along joint surfaces for distances of up to 100 m north of the dyke. At 2.5 km ESE of Priory [69/039138] all joint surfaces of the adamellite are slickensided with directions of movement shown by elongated masses of annealed quartz, feldspar and recrystallised biotite.

Four main textural types of Scamander Tier Granodiorite can be distinguished in hand specimen. These are chilled marginal rocks, porphyritic rocks with a trimodal grain size distribution, microporphyritic rocks with a bimodal grain size distribution and equigranular medium-grained rocks. Porphyritic rocks, with phenocrysts up to 50 mm long, are generally restricted to the narrow section of the main dyke where the microporphyritic type is less common, while the microporphyritic type, with phenocrysts up to 10 mm in length, is the main rock of the east-west dyke. The equigranular rock type is restricted to the region north and west of Moulting Bay (north of grid line 913000 yd N) and was originally termed the Binalong Bay Granodiorite (Cocker, 1971).

Well exposed outcrops of chilled contact rocks occur 5 km south-west of Diana Basin [68/047982] and in Basin Creek [69/050032]. Contacts with the George River Granodiorite are poorly exposed, but finer grained rocks occur up to 5 m from the margin of the dyke north of Flagstaff Hill [69/046050]. The texture of narrow dykes of the Scamander Tier Granodiorite is similar to the chilled marginal rocks, and as the dykes become wider the rock increases in grain size until it resembles the microporphyritic type.

The porphyritic rock type is distinguished by large K-feldspar phenocrysts which constitute from 5-60% of the rock. Well defined boundaries between the porphyritic and microporphyritic rock types are exposed in some outcrops (e.g. 2 km north-east of St Helens [69/078097]). These boundaries are parallel to the dyke walls and to the foliation defined by trains of K-feldspar phenocrysts. Narrow vertical biotite-rich layers with both sharp and diffuse margins lie approximately parallel to the K-feldspar foliation on the south-eastern headland of Moulting Bay [69/099102]. In detail the foliations defined by concentrations of K-feldspar and biotite are distinctly cross-cutting. The mineral segregation and alignment may have occurred by separate processes or at different times (see p. 30). Well developed sub-horizontal biotite layering occurs in the Scamander Tier Granodiorite at Binalong Bay (see p. 30). Some 2 km north of St Helens (between grid lines 910000 and 913000 yd N), the width of the main dyke increases rapidly. In this area the orientation of both mineral alignments and patches of segregated rock

is complex and ranges from vertical to sub-horizontal. An outcrop of close-packed aligned feldspar phenocrysts, with little groundmass except for the biotite flakes between them, occurs on the western shore of Moulting Bay [69/084108] and provides possible evidence for an impressed foliation.

Biotite, hornblende, plagioclase, K-feldspar and quartz occur throughout the Scamander Tier Granodiorite. The biotite and hornblende are the main constituents of mafic xenoliths which attain one metre in diameter. Fragments of Mathinna Beds (up to 200 m wide) are common as xenoliths where the granodiorite intrudes the Mathinna Beds and along the east-west dyke.

Recurrent variation of K-feldspar phenocryst content over short distances in the Scamander Tier Granodiorite hinders representative sampling. Two modal analyses are shown in Table 35, one from the porphyritic rock type and the other from the equigranular rock at Binalong Bay. Both samples plot as granodiorites in Figure 24. The proportion of potash feldspar phenocrysts in the porphyritic sample is estimated as 10%, compared with less than 1% in the equigranular rock type. Variation in chemical composition can be related to the proportions of K-feldspar and mafic silicates present. Six analyses are given in Table 36.

PETROGRAPHY

In the Scamander Tier Granodiorite the chilled marginal rocks (37793, 69-239) and rocks from the narrow dykes are distinguished by microphenocrysts (0.75-3.0 mm) of embayed quartz, plagioclase and microcline in a fine groundmass (0.02 mm). The composition of the groundmass varies from mainly K-feldspar to mainly quartz.

In both the microporphyritic rocks (69-244, 37823, 37830, 37787) and porphyritic rocks (70-11, 69-241, 69-236) the microphenocrysts (up to 10 mm) especially the quartz and plagioclase, are commonly embayed by the groundmass (0.1-0.2 mm). The quartz crystals are often armoured by fine hornblende grains. The plagioclase microphenocrysts are euhedral to subhedral with zoned compositions from An_{42} to An_{25} . The zoning is commonly oscillatory with normally zoned sequences. The dark green hornblende occurs as anhedral grains and the biotite of this unit is pleochroic from red to dark brown, a characteristic which distinguishes it from the biotite of the George River Granodiorite. The large K-feldspar phenocrysts which commonly enclose the groundmass have low triclinicities ($\Delta = 0.18$) and are classified as orthoclase microperthites (Groves, this Bulletin). Cross-hatch twinning is uncommon in the phenocrysts except where the dyke increases in width (near grid line 912⁰⁰⁰ yd N), where the internal structure of the dyke is relatively complex and there is a gradation between all textural types and grain sizes. In the coarsely porphyritic rocks the grain size of the groundmass is greater and sutured grains of quartz commonly form aggregates up to 10 mm across (37788, 37789).

The distinctive petrographic feature of the equigranular rocks is the anhedral form and similar grain size (3-4 mm) of the three dominant felsic minerals. The quartz occurs as masses of sutured grains with undulose extinction, and is rarely embayed (69-394, 37795). The cored plagioclase grains are strongly zoned from An_{55} to An_{20} with a reversal in composition in a narrow zone around the core. The K-feldspar commonly displays an interstitial habit and envelops the mafic minerals. Green to brown hornblende often occurs as euhedral laths or clusters of grains in contact with biotite. Little evidence for deformation can be seen in thin section of rocks from this unit, except for occasional kinked biotite plates.

The Scamander Tier Granodiorite represents one body of magma although there is a range of rock types. Evidence supporting this interpretation includes the widespread occurrence of embayed quartz grains, similar zoning sequences in plagioclase crystals and coherence of Sr isotopic values for the different rock types (Cocker, unpublished). The variation in rock type is thought to result from different rates of cooling along the dyke and the variable late-stage development of K-feldspar phenocrysts.

GRANT POINT GRANITE

The Grant Point Granite forms a curved dyke, at least 12 m long and some 1.5 km wide, from Grant Point to St Helens Island. The dyke contacts dip steeply and the shape suggests a ring-dyke structure. The age of the Grant Point Granite relative to the surrounding units is indicated by Grant Point Granite dykes which intrude the Scamander Tier Granodiorite on the eastern shore of Moulting Bay (41703; 50 m west of the contact [69/100101]) and the Akaroa Granodiorite 2 km south of Grant Point [69/139146].

The presence of simply twinned K-feldspar phenocrysts (ranging in size from 10-20 mm) distinguishes the Grant Point Granite from the Akaroa Granodiorite in hand specimen. The groundmass (grain size 1.0-2.0 mm) consists of quartz, plagioclase and biotite, and some grains are enclosed within the phenocrysts. Possibly unique among granites of the Blue Tier Batholith, many specimens of Grant Point Granite carry hornblende (less than 1%). Mafic xenoliths are relatively abundant in this unit, and discontinuous biotite layering is common. A modal analysis (fig. 24) and two chemical analyses are shown in Tables 35 and 36.

In thin section, the K-feldspar forms subhedral grains often with single Carlsbad twins and well developed cross-hatch twinning. The plagioclase grains range in composition from An₄₀ (core) to An₂₅ (rim) and when included in the K-feldspar have a clear albite rim. Red-brown biotite and quartz are also enclosed in the phenocrysts.

The granitic outcrops on the north-eastern side of St Helens Point, one of which is intruded by a dyke of the Akaroa Granodiorite, are similar in hand specimen and thin section to the Grant Point Granite, but their relationship to it is unknown. The proportion of mafic enclaves and biotite schlieren appears greater than in outcrops of Grant Point Granite, and the number of aplitic and pegmatitic dykes intruding these outcrops is higher than in any other unit in the St Helens area.

AKAROA GRANODIORITE

The Akaroa Granodiorite is considered older than the Grant Point Granite and younger than the granite masses on the north-eastern side of St Helens Point. In hand specimen the granodiorite has rare K-feldspar phenocrysts and a low proportion of mafic xenoliths. A prominent textural feature is the occurrence of oikocrysts of K-feldspar (5-50 mm) as large, optically continuous grains which enclose biotite, quartz and plagioclase. Three modal analyses (fig. 24) and two chemical analyses are shown in Tables 35 and 36. In thin section the average grain size of the quartz, plagioclase and red-brown biotite is one millimetre. The plagioclase is strongly zoned from An₅₅ to An₁₅ and is commonly surrounded by a myrmekite rim. The anhedral K-feldspar oikocrysts show irregular cross-hatch twinning. Secondary muscovite replaces plagioclase, but larger grains of muscovite included in the oikocrysts may be of primary origin.

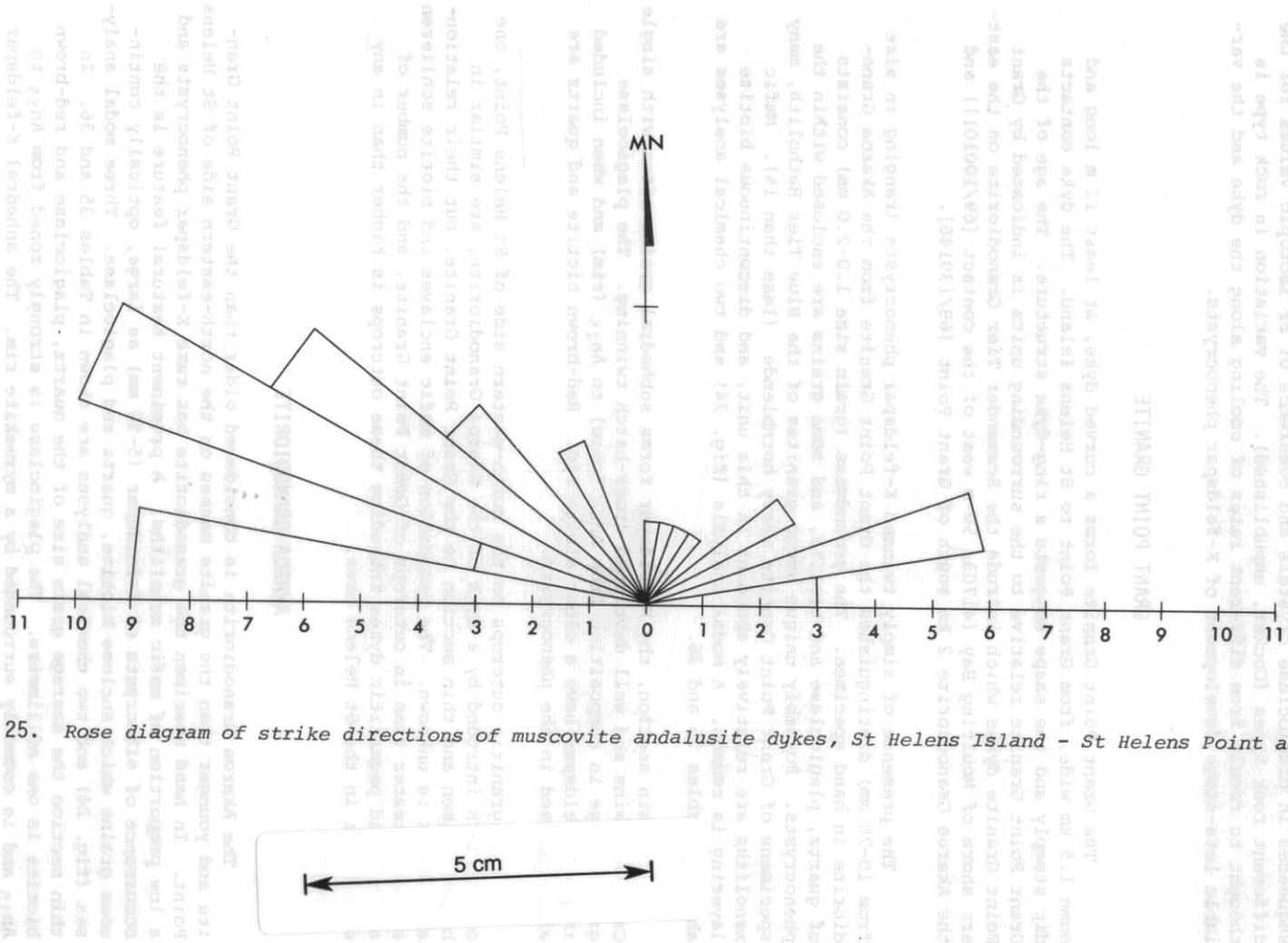


Figure 25. Rose diagram of strike directions of muscovite andalusite dykes, St Helens Island - St Helens Point area.

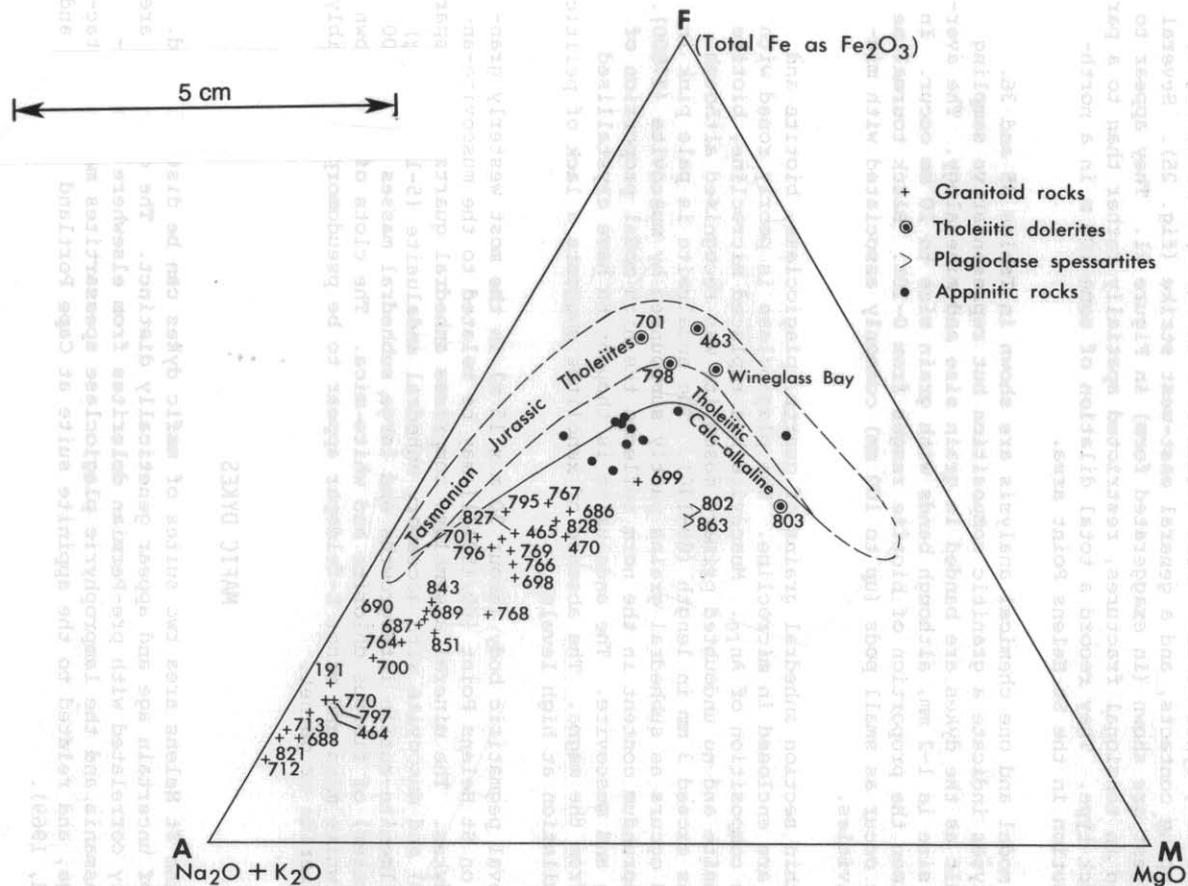


Figure 26. AFM diagram, in terms of alkalis, total Fe and Mg, for igneous rocks, St Helens area.

FELSIC DYKES

Aplitic microgranitic and pegmatitic dykes rarely exceed 5 m in width, and intrude all rock types in the St Helens area. No association with a major unit was established except for the Constable Creek Granite in which aplitic and microgranitic dykes are an important component. Good coastal exposure of felsic dykes on St Helens Point provides examples of a dilational mode of dyke emplacement (Williams and Groves, 1967).

In the St Helens Island-St Helens Point area, a distinctive set of muscovite-andalusite dykes occur. These attain 30 m in width, with straight, steeply dipping contacts, and a general east-west strike (fig. 25). Several of the largest are shown (in exaggerated form) in Figure 21. They appear to be emplaced in tensional fractures, restricted spatially rather than to a particular rock type. They record a total dilation of some 100 m in a north-south direction in the St Helens Point area.

One modal and one chemical analysis are shown in Tables 35 and 36. These analyses indicate a granitic composition but representative sampling is difficult as the dykes are banded in grain size and mineralogy. The average grain size is 1-2 mm, although bands with grain size to 20 mm occur. In hand specimen the proportion of biotite ranges from 0-10%. Black tourmaline and quartz occur as small pods (up to 100 mm) commonly associated with miarolitic cavities.

In thin section anhedral grains of quartz, plagioclase, biotite and muscovite are enclosed in microcline. The plagioclase is poorly zoned with an average composition of An_{10} . Muscovite has replaced microcline, biotite and andalusite and no undoubted primary muscovite was recognised although some grains exceed 3 mm in length (69-146). The andalusite is pale pink in colour and occurs as subhedral grains partly surrounded by muscovite (37800). The high corundum content in the norm reflects the high modal proportion of andalusite and muscovite. The andalusite is thought to have crystallised directly from the magma. The absence of xenoliths suggests a lack of pelitic-rock assimilation at high levels.

An oval pegmatitic body (about 30 m x 15 m) in the most westerly granitic mass on St Helens Point [69/159141] may be related to the muscovite-andalusite dykes. The mineral assemblage comprises anhedral quartz, K-feldspar (up to 2 m) and muscovite with accessory euhedral andalusite (5-100 m long) (37854); ilmenite-rutile intergrowths and large, subhedral masses (up to 200 mm in diameter) of fibrous chlorite and white-mica. The clots of intergrown chlorite, white mica and minor K-feldspar appear to be pseudomorphs, possibly after cordierite or garnet.

MAFIC DYKES

In the St Helens area two suites of mafic dykes can be distinguished. They are of uncertain age and appear genetically distinct. The dolerites are tentatively correlated with pre-Permian dolerites from elsewhere in north-eastern Tasmania, and the lamprophyric plagioclase spessartites may be Cretaceous in age, and related to the appinite suite at Cape Portland (Jennings and Sutherland, 1969).

Walker (1957) and Groves (1972) discussed the distribution of the dolerites which intrude the granitoid rocks and the Mathinna Beds up to 4 km from the granitoid masses. Three dykes studied in the St Helens area crop out at St Helens Point, Grant Point and the shoreline at Stinking Creek (fig. 21).

The dykes have chilled margins and occupy dilational fractures. Strike lengths for two dykes of 3.3 km and 0.5 km have been established from land and marine-based magnetic traverses (Geophysics Excursions 1972 and 1973, University of Tasmania). The magnetic traverses indicate that several small faults are responsible for the total displacement of the dyke through the Georges Bay heads.

The dolerites are fine-grained, dark coloured rocks containing about one per cent of sulphide minerals. In thin section (41701, 37798, 37803) the primary mineral phases are augite or titanaugite, zoned labradorite and skeletal iron oxides, forming an intergranular to sub-ophitic texture with an average grain size of 0.5 mm. Coarser grained labradorite-pigeonite inclusions and euhedral amphibole(?) phenocrysts pseudomorphed by calcite occur in the Grant Point dyke (37803). Quartz and K-feldspar form up to 15% of the rock and may be in part secondary minerals, as are fibrous amphiboles, chlorite, epidote and calcite. Small granitoid xenoliths are common in most dykes (37803) and sphene and needle-like apatite are common accessories.

The four analyses in Table 36 are comparable with analysis 72 in Spry (1962), for a rock from Wineglass Bay. The range in chemistry and mineralogy indicate general tholeiitic affinities (fig. 28), although several different petrographic types (including hornblende-bearing dolerites) may be distinguished.

The distribution of dolerites as individual dykes and dyke swarms throughout north-eastern Tasmania may relate to local tensional zones in the general joint pattern developed after the intrusion of the granitoid rocks. The high degree of alteration suffered by some dolerites may result from the reaction of groundwater with the still warm crystallised rock, rather than reaction with a magmatic aqueous phase to produce deuteric minerals (Taylor and Forester, 1971).

Nine lamprophyric dykes were observed intruding the George River Granodiorite (fig. 21) and Groves (this Bulletin) reports further dykes in the Gardens Pluton. They are several metres wide, up to 100 m long and follow no distinct intrusive pattern. In hand specimen they have phenocrysts of plagioclase, hornblende and sometimes quartz, up to 0.5 mm long, set in a fine-grained, dark groundmass. In thin section the hornblende of the groundmass and the phenocrysts has similar optical properties with dark brown to light green pleochroism. The hornblende phenocrysts occur as embayed individuals and as aggregates of larger grains (37802). Euhedral plagioclase phenocrysts have compositions as calcic as An_{65} , (37802) and rounded, embayed quartz phenocrysts are armoured by hornblende grains (37802, 37804). The groundmass often has a fluidal texture with aligned grains of labradorite, a grain size usually less than 0.02 mm, and includes sphene, sulphides and iron-titanium oxides as accessory minerals. The groundmass and some hornblende phenocrysts show alteration to calcite and chlorite.

Analyses of two spessartites are given in Table 36 (37802, 37863). As a pair, the St Helens spessartites show a similar major element content, but often fall outside the composition range quoted for the Cape Portland appinite complex and other shoshonites in Tasmania (Jennings and Sutherland, 1969; Sutherland and Corbett, 1974). They have a similar K_2O/Na_2O ratio to the rocks at Cape Portland, but plot discretely on an AFM diagram (fig. 26). These dykes have some shoshonite affinities (Joplin, 1968). The SiO_2 to MgO and FeO ratio is high for shoshonites possibly reflecting xenocrystic quartz. The restriction of the lamprophyres to the George River Granodiorite suggests that they may be related to the granodiorite.

Table 35. MODAL ANALYSES OF GRANITOID ROCKS FROM THE ST HELENS AREA.

	GEORGE R. GRANODIORITE			PRIORY MONZON- ITE	MT PIER- SON ADAM- ELLITE	CONSTABLE CREEK GRANITE	
Analysis No.	37769	37771	69-246	37763	69-398	70-169	70-168
ANG Ref.	69/ 078097	69/ 014094	69/ 084015	69/ 016147	59/ 956132	69/ 006049	69/ 077097
AMG Ref.	FQ 062258	FQ 003254	FQ 068183	FQ 005303	EQ 950289	EQ 996213	FQ 061258
Quartz	28.2	29.2	36.4	0.0	37.7	40.2	43.0
K-Feldspar	15.0	13.9	24.6	42.6	33.5	31.1	34.6
Plagioclase	42.5	40.0	31.1	31.5	22.0	24.1	20.2
Biotite	11.1	12.5	7.8	0.0	6.8	4.3	1.9
Muscovite	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Chlorite	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hornblende	3.3	4.2	0.0	23.8	0.0	0.0	0.0
Accessories	0.1	0.1	0.1	2.0	0.0	0.0	0.2
MODAL ANALYSES OF FELSIC MINERALS NORMALISED TO 100%							
Quartz	32.9	35.0	39.5	0.0	40.4	42.1	44.0
K-Feldspar	17.5	16.7	26.7	57.5	35.9	32.6	56.0
Plagioclase	49.5	48.0	33.8	42.5	23.6	25.2	0.0
	SCAMANDER TIER GRANODIORITE		GRANT POINT GRANITE	AKAROA GRANODIORITE			†GRANITE DYKE
Analysis No.	69-244	69-394	70-16	70-149	69-415	69-417	69-416
ANG Ref.	68/ 048820	69/ 114170	69/ 140166	69/ 130105	69/ 130105	69/ 153136	69/ 155138
AMG Ref.	FQ 037004	FQ 094325	FQ 118322	FQ 109266	FQ 109266	FQ 130294	FQ 132296
Quartz	33.2	34.8	30.3	29.4	36.1	33.2	40.5
K-Feldspar	20.9	10.5	40.2	23.4	14.4	15.2	37.5
Plagioclase	33.4	39.9	22.4	36.7	40.0	42.1	14.6
Biotite	8.9	13.0	6.9	8.6	9.3	9.5	0.6
Muscovite	0.0	0.0	0.2	0.1	0.3	<0.1	6.9
Chlorite	0.0	0.0	0.0	1.8	0.0	0.0	0.0
Hornblende	3.3	1.2	0.0	0.0	0.0	0.0	0.0
Accessories	0.3	0.5	0.1	0.0	0.0	0.0	<0.1
MODAL ANALYSES OF FELSIC MINERALS NORMALISED TO 100%							
Quartz	37.9	40.9	32.6	32.8	39.5	36.7	43.7
K-Feldspar	23.9	12.3	43.3	26.1	15.7	16.8	40.5
Plagioclase	38.2	46.8	24.1	41.00	43.7	46.5	15.8

†Muscovite-andalusite Granite Dyke

Table 36. CHEMICAL ANALYSES AND C.I.P.W. MASS PER CENT NORMATIVE MINERALS OF IGNEOUS ROCKS FROM THE ST HELENS AREA.

Analysis No.	GEORGE RIVER GRANODIORITE						PRIORY MONZONITE					MEDEAS COVE ADAMELLITE	
	37767	37769*	37851	702689	37768	41699	37764*	37766	41698	611470	702687	37770*	702688
ANG Ref.	69/	69/	69/	69/	69/	69/	69/	69/	69/	69/	69/	69/	69/
AMG Ref.	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ
	049234	062258	068183	068183	018283	095206	007256	010266	005303	005303	036240	022255	016251
SiO ₂	68.87	68.92	72.55	72.80	71.12	65.46	64.59	57.84	58.89	58.00	65.50	75.96	77.35
TiO ₂	0.53	0.43	0.26	0.23	0.36	0.62	0.37	0.50	0.63	0.71	0.30	0.15	0.06
Al ₂ O ₃	15.17	15.18	13.45	13.15	13.98	15.10	18.01	18.63	17.31	17.14	16.75	13.06	11.60
Fe ₂ O ₃	4.51	4.26	2.62	0.25	3.14	5.81	3.86	5.44	5.56	1.51	1.70	1.64	0.35
FeO	nd	nd	nd	2.25	nd	nd	nd	nd	nd	4.53	1.95	nd	0.7
MnO	0.13	0.07	0.05	0.05	0.08	0.12	0.13	0.18	0.13	0.10	0.07	0.07	0.07
MgO	1.62	1.55	1.05	0.85	1.74	2.94	1.23	2.33	2.69	3.23	1.2	0.34	0.2
CaO	3.64	3.37	2.06	2.35	3.08	4.89	2.49	4.61	5.78	6.16	2.5	1.99	0.8
Na ₂ O	1.92	2.89	2.24	2.60	2.40	1.91	7.24	4.94	5.59	5.36	5.85	3.40	2.9
K ₂ O	3.17	3.12	3.95	3.65	3.98	2.26	3.50	3.23	3.03	2.25	3.35	4.07	4.5
P ₂ O ₅	0.04	0.10	0.06	0.08	0.07	0.18	0.14	0.16	0.17	1.22	0.07	0.03	0.00
L.O.I.	0.62	0.35	0.62	0.10	0.37	1.07	0.30	0.84	0.60	1.05	0.80	0.29	0.40
	100.22	100.24	98.91	99.36	100.32	100.36	101.86	98.70	100.38	100.26	100.04	101.00	98.93
Q	35.5	30.9	38.6	36.0	32.9	31.3	3.4	4.4	2.0	0.9	11.4	36.2	40.8
Or	18.7	18.4	23.3	21.6	23.5	13.4	20.7	19.1	17.9	13.3	19.8	24.1	26.6
Ab	16.2	24.4	19.0	22.0	20.3	16.2	61.3	41.8	47.3	45.4	49.5	28.8	24.5
An	17.8	16.1	9.8	11.1	14.8	23.1	6.3	19.1	13.2	16.1	9.5	8.4	4.0
C	2.1	1.2	1.9	0.8	0.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Di	0.0	0.0	0.0	0.0	0.0	0.0	3.4	1.3	9.9	10.7	1.9	0.8	0.0
Hy	4.0	3.9	2.6	5.8	4.3	7.3	1.5	5.2	2.1	8.9	3.8	0.5	1.5
Mt	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	2.2	2.5	0.0	0.5
Hm	4.5	4.3	2.6	0.0	3.1	5.8	3.9	5.4	5.6	0.0	0.0	1.6	0.0
Il	0.3	0.2	0.1	0.4	0.2	0.3	0.3	0.4	0.3	1.3	0.6	0.2	0.1
Ru	0.4	0.4	0.2	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ap	0.1	0.2	0.1	0.2	0.2	0.4	0.3	0.4	0.4	0.5	0.2	0.1	0.0

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Table 36. (continued)

	MT PIERSON		CONSTABLE CREEK			SCAMANDER TIER GRANODIORITE						GRANT POINT	
	ADAMELLITE		GRANITE									GRANITE	
Analysis No.	691191*	37827	37821*	702712	702713	37701*	702686	37828	611465	37796	37795*	37797	41700*
ANG Ref.	59/	69/	59/	59/	69/	69/	69/	69/	69/	69/	69/	69/	69/
AMG Ref.	956132	037135	982063	978057	006049	007097	076096	037135	057076	083154	120172	138169	124161
	EQ	FQ	EQ	EQ	EQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ
	950289	024292	974226	971220	996213	061258	060257	024292	043238	066310	099327	116324	103317
SiO ₂	75.60	69.39	78.16	78.70	76.80	70.65	70.00	66.63	68.00	67.90	70.71	74.65	72.76
TiO ₂	0.16	0.58	0.09	0.02	0.06	0.53	0.41	0.82	0.59	0.53	0.65	0.41	0.30
Al ₂ O ₃	11.80	14.01	13.08	11.70	12.50	14.50	14.05	14.25	14.68	14.06	14.60	12.85	13.72
Fe ₂ O ₃	0.62	4.62	1.14	0.40	0.20	4.33	2.50	5.03	0.47	4.16	4.84	1.62	2.34
FeO	1.60	nd	nd	0.40	0.85	nd	1.10	nd	3.78	nd	nd	nd	nd
MnO	0.04	0.11	0.07	0.01	0.03	0.14	0.08	0.12	0.07	0.11	0.09	0.09	0.04
MgO	0.30	1.37	0.07	0.04	0.09	1.09	1.60	2.04	1.56	1.32	1.20	0.29	0.58
CaO	1.40	3.30	0.52	0.30	0.90	2.92	3.45	4.05	3.68	3.41	2.97	1.25	1.89
Na ₂ O	2.90	3.08	3.45	3.00	2.80	2.92	1.60	2.43	2.67	2.51	2.46	2.71	2.99
K ₂ O	4.10	3.21	4.38	4.55	4.55	3.21	3.20	3.15	3.39	3.52	3.40	4.81	4.62
P ₂ O ₅	0.04	0.14	0.05	0.00	0.02	0.10	0.17	0.14	0.13	0.13	0.15	0.03	0.12
L.O.I.	0.66	0.25	0.44	0.30	0.30	0.48	0.80	0.53	1.05	0.44	0.44	0.55	0.64
	99.22	100.06	101.45	99.42	99.10	100.87	98.96	99.19	100.07	98.09	100.97	99.26	100.00
Q	39.3	30.6	40.3	43.0	40.5	33.8	39.1	29.2	27.1	30.9	35.1	37.5	33.1
Or	24.2	19.0	25.9	26.9	26.9	19.0	18.9	18.6	20.0	20.8	20.1	28.4	27.3
Ab	24.5	26.1	29.2	25.4	23.7	24.7	13.5	20.6	22.6	21.2	20.8	22.9	25.3
An	5.2	14.9	2.3	1.5	4.3	13.8	16.0	18.7	17.4	16.1	13.8	6.0	8.6
C	0.7	0.0	1.8	1.3	1.4	1.2	2.1	0.0	0.2	0.2	1.8	1.0	0.7
Di	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hy	3.0	3.4	0.2	0.5	1.6	2.7	4.0	5.1	9.6	3.3	3.0	0.7	1.4
Mt	0.9	0.0	0.0	0.6	0.3	0.0	2.6	0.0	0.7	0.0	0.0	0.0	0.0
Hm	0.0	4.6	1.1	0.0	0.0	4.3	0.7	5.0	0.0	4.2	4.8	1.6	2.3
Il	0.3	0.2	0.2	0.0	0.1	0.3	0.8	0.3	1.1	0.2	0.2	0.2	0.1
Ru	0.0	0.3	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.4	0.5	0.3	0.3
Ap	0.1	0.3	0.1	0.0	0.0	0.2	0.4	0.3	0.3	0.3	0.4	0.1	0.3

Table 36. (continued)

Analysis No.	AKAROA		GRANITE		DOLERITE			PLAGIOCLASE- SPESSARTITE		
	GRANODIORITE		DYKE†							
ANG Ref.	37843*	702690	611464	611463	37798	37803	41701	37802	37863	
AMG Ref.	130105	130105	155138	156138	156138	143165	114040	023098	021102	
	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	FQ	
	109266	109266	132296	133296	133296	120321	095206	011258	010262	
SiO ₂	70.88	70.90	73.74	48.30	49.14	51.81	54.65	61.45	59.41	*Type localities for stated units.
TiO ₂	0.42	0.33	0.11	3.17	2.98	1.20	2.47	0.64	0.65	†Andalusite-muscovite granite dyke.
Al ₂ O ₃	15.66	15.65	14.24	11.88	13.60	14.60	13.30	14.49	14.64	Precision at the 95% level for granite 43241.
Fe ₂ O ₃	3.16	0.35	0.43	4.53	14.12	8.56	12.90	6.43	6.45	SiO ₂ 76.73 ± 0.96
FeO	nd	2.15	0.97	11.12	nd	nd	nd	nd	nd	TiO ₂ 0.20 ± 0.02
MnO	0.07	0.05	0.00	0.13	0.43	0.17	0.18	4.10	0.12	Al ₂ O ₃ 12.29 ± 0.24
MgO	0.89	0.85	0.20	5.16	5.10	8.25	2.84	4.98	5.03	Fe ₂ O ₃ 2.06 ± 0.10
CaO	2.75	2.85	0.56	7.80	7.12	7.94	6.52	6.12	6.37	MnO 0.02 ± 0.01
Na ₂ O	3.80	3.30	2.95	3.00	3.12	2.70	2.94	1.88	2.02	MgO 0.25 ± 0.14
K ₂ O	3.00	3.05	5.24	1.35	1.33	1.19	1.81	2.63	2.57	CaO 0.97 ± 0.10
P ₂ O ₅	0.03	0.11	0.22	0.55	0.51	0.20	1.04	0.22	0.20	Na ₂ O 2.76 ± 0.006
L.O.I.	0.62	0.80	1.05	1.58	1.48	1.66	1.74	1.00	0.70	K ₂ O 4.85 ± 0.02
	101.28	100.39	99.71	98.57	98.93	98.28	100.39	99.94	98.16	P ₂ O ₅ 0.09 ± 0.02
Q	30.2	31.5	35.1	2.5	7.2	5.8	17.0	21.7	18.8	L.O.I. 0.32 ± 0.10
Or	17.7	18.0	31.0	8.0	7.9	7.0	10.7	15.5	15.2	Total 100.54
Ab	32.2	28.0	25.0	25.4	26.4	22.8	24.9	15.9	17.1	
An	13.4	13.4	1.3	15.0	19.2	24.2	17.7	23.3	23.3	
C	1.2	2.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	
Di	0.0	0.0	0.0	14.1	3.2	8.1	0.0	3.2	4.1	
Hy	2.2	5.3	1.7	17.6	11.2	16.8	7.1	10.9	10.6	
Mt	0.0	0.5	0.6	6.6	0.0	0.0	0.0	0.0	0.0	
Hm	3.2	0.0	0.0	0.0	14.1	8.6	12.9	6.4	6.5	
Il	0.2	0.6	0.2	6.0	0.9	0.4	0.4	0.2	0.3	
Ru	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Ap	0.1	0.3	0.5	1.3	1.2	0.5	2.5	0.4	0.5	

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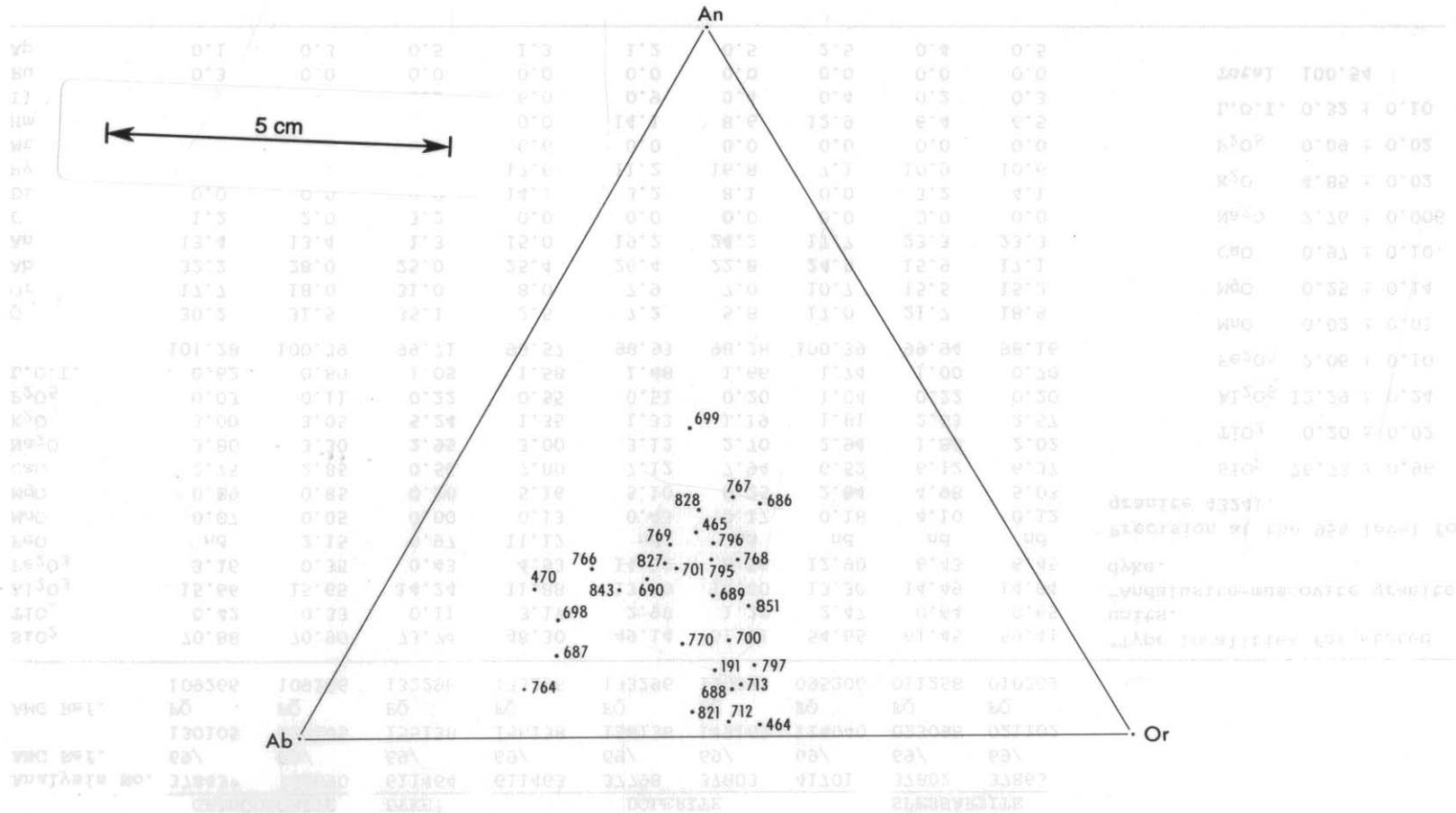


Figure 27. Comparison of igneous rocks, a triangular diagram in terms of normative albite, anorthite and orthoclase.

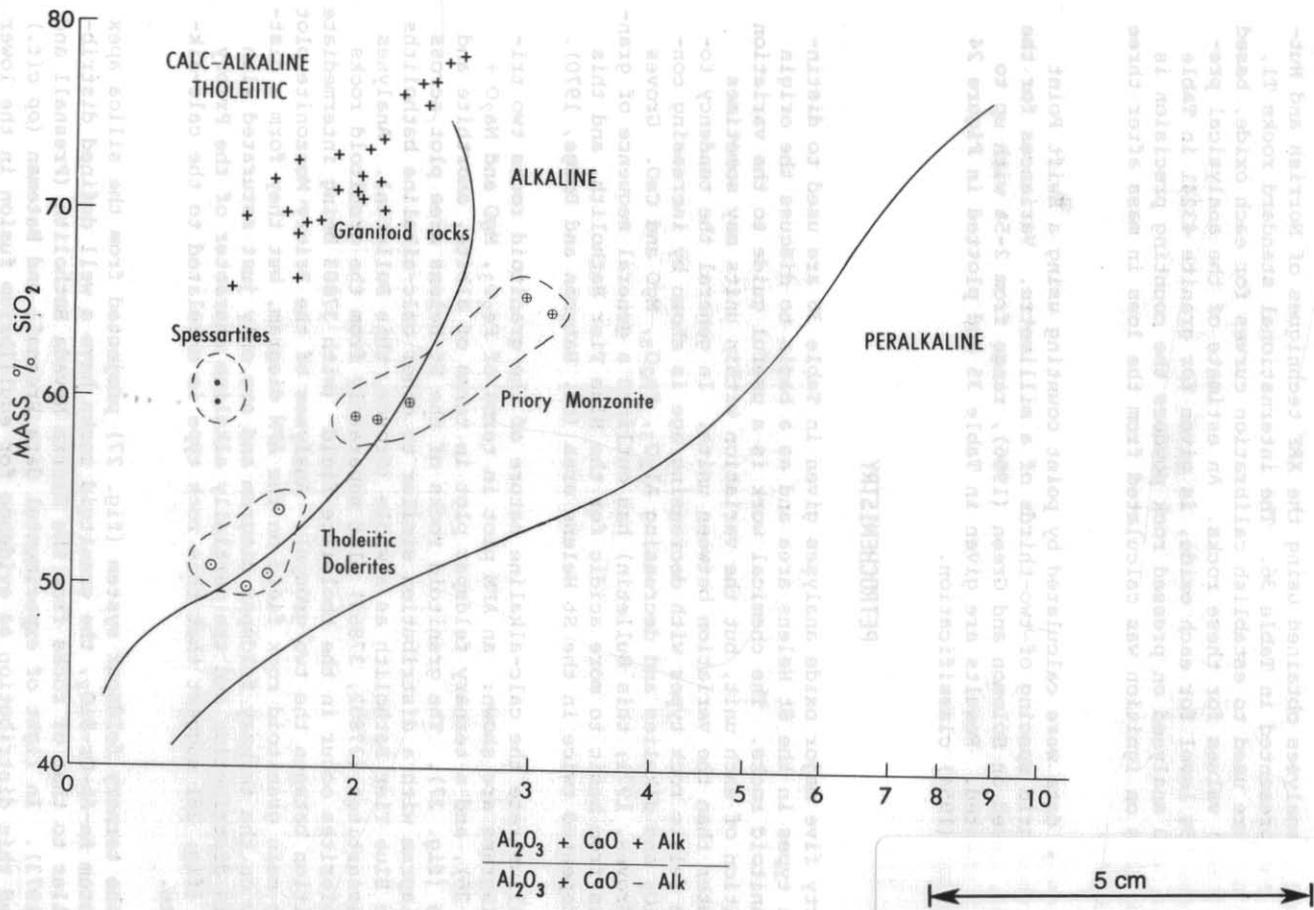


Figure 28. Plot of alkalinity ratio against SiO₂ in mass per cent (Wright, 1969) showing anomalous distribution of the Priory Monzonite.

ANALYTICAL RESULTS

Chemical analyses obtained using the XRF techniques of Norrish and Hutton (1969) are presented in Table 36. The international standard rocks T1, G2, GH and GA were used to establish calibration curves for each oxide, based on Abbey's (1972) values for these rocks. An estimate of the analytical precision at the 95% level for each oxide, is given for granite 43241 in Table 36, but for Na₂O analysed on pressed rock powders the counting precision is given. The loss on ignition was calculated from the loss in mass after three hours at 1000°C.

The modal data were calculated by point counting using a Swift Point Counter with a grid spacing of two-thirds of a millimetre. Variances for the main phases, based on Solomon and Green (1966), range from 2-5% with up to 2500 points counted. Results are given in Table 35 and plotted in Figure 24 using Nockolds (1954) classification.

PETROCHEMISTRY

Thirty five major oxide analyses given in Table 36 are used to distinguish rock types in the St Helens area and as a basis to discuss the origin of the granitoid rocks. The chemical work is a useful guide to the variation in composition of each unit, but the variation within units may sometimes prove greater than the variation between units. In general the tendency towards more felsic rock types with decreasing age is shown by increasing content of SiO₂ and alkalis and decreasing Al₂O₃, Fe₂O₃, MgO and CaO. Groves (Geę and Groves, 1971; this Bulletin) has outlined a general sequence of granitoid rocks from basic to more acidic for the Blue Tier Batholith, and this trend is repeated twice in the St Helens area (cf. Bateman and Dodge, 1970).

To illustrate the calc-alkaline nature of the granitoid rocks two triangular diagrams are shown: an AFM plot in terms of Fe₂O₃, MgO and Na₂O + K₂O (fig. 26), and a ternary feldspar plot in terms of albite, anorthite and orthoclase (fig. 27). The granitoid rocks of the St Helens area plot across the AFM diagram with a distribution similar to other calc-alkaline batholiths and to the Blue Tier Batholith as a whole (Groves, this Bulletin). Analyses of the spessartites (37802, 37863) plot separately from the granitoid rocks and the dolerites occur in the tholeiite field (with 37803 being intermediate in composition between the two groups). Analyses of the Priory Monzonite plot within the main granitoid rock field on the AFM diagram, but they form a distinct group on the ternary feldspar diagram and are only just saturated with SiO₂. This distribution and the partially alkaline character of the Priory Monzonite (fig. 28) suggest that this rock type is unrelated to the calc-alkaline suite.

In the ternary feldspar system (fig. 27) projected from the silica apex in the system An-Ab-Or-SiO₂, the granitoid rocks have a well defined distribution similar to that of rocks from the Sierra Nevada Batholith (Presnall and Bateman, 1973). In light of experimental data Presnall and Bateman (*op cit.*) interpreted this distribution as evidence for equilibrium fusion in the lower crust giving rise to a series of distinct melts related by fractional crystallisation. However, there is no compelling field or chemical evidence to associate any of the units by fractional crystallisation except possibly the Constable Creek Granite with the Mt Pierson Adamellite.

Although the CIPW norm does not express the ferromagnesian mineralogy precisely (especially as the FeO/Fe₂O₃ ratio is unknown) the corundum content reflects the mineralogy, in particular the occurrence of muscovite. The average normative corundum content of the hornblende-biotite bearing rocks is

1% whereas the muscovite-bearing Constable Creek Granite has an average normative corundum value of 1.5% and the muscovite-andalusite dyke, 3.2%.

MINERALISATION

Groves (1972) has described the zoned mineral deposits of the Scamander district and their regional setting. Detailed mapping in the St Helens area allows some relationships of the zoned deposits to be clarified. A succession of wolframite-molybdenite, tin, copper and silver-lead-zinc zones were described from the Constable Creek Granite, flanking the Mt Pierson Adamellite. Groves (*op cit.*) considered that the first three zones were closely related, and that the mineralising hydrothermal fluids were derived from the adjacent Constable Creek Granite. Most of the prospects in the silver-lead-zinc zone occur within the outcrop of the Scamander Tier Granodiorite which on previous evidence is considered to be younger than the Constable Creek Granite. If so, two periods of mineralisation have fortuitously given rise to a classically zoned mineral field.

The Silver Echo prospect [69/007066] was included in the copper zone of the Scamander mineral field (Groves, 1972) although this prospect is not typical, as the ore contains a high proportion of pyrrhotite, and tourmaline and mica occur with the sulphides. Granitic dykes intrude the Mathinna Beds along the Launceston Creek contact and crop out sporadically among the sediments between the contact and the Silver Echo prospect. A similar dyke may be the source of the Silver Echo mineralisation, again suggesting a polygenetic origin for mineralisation in the Scamander-St Helens area.

Near the boundary of the Mt Pierson Adamellite and Priory Monzonite [69/002153] a poorly exposed quartz-tourmaline vein system, known as the Priory Lode, trends in an east-west direction for at least 100 m. The rock (37859) is similar to the Mt Pierson Adamellite. Cassiterite grains up to 50 mm in diameter occur in milky comb-quartz and tourmaline veins, with 10 mm euhedral pyrrhotite crystals in the adamellite adjacent to the veins. The streams below the ridge on which the lode crops out were the site of minor alluvial tin workings.

Nye (1933) recorded a cassiterite-chalcopyrite lode at the Stoney Ford mine [69/025089] near the head of Medeas Cove. The lode is 2-3 m wide, dips steeply and strikes east-west. The host rock is the George River Granodiorite (37839), which is locally fractured and altered. Groves' (1972) suggestion that the lode structure is probably a large xenolith, originally an impure, calcareous sediment or basic igneous rock, is not accepted. In hand specimen the ore consists of sphalerite and minor chalcopyrite in a gangue of quartz and chlorite. In thin section the granodiorite is strongly fractured with the primary ferromagnesian minerals and some of the feldspar replaced by bright green chlorite and hornblende (37835, 37837). Euhedral, colourless garnet and subhedral monazite occur in a matrix of quartz and penninite (37838), with monazite forming up to 2% of the rock. In polished section the main sulphide is sphalerite with minute, exsolved grains of chalcopyrite (37836, 37840). A small proportion of galena and possibly arsenopyrite occur in the ore, but no cassiterite was observed. A similar lode structure about 2 m wide, steeply dipping, and carrying monazite and sulphides (37844) is exposed in the roadside about one kilometre east of St Helens bridge [69/067071].

The main economic mineralisation in the St Helens area was alluvial tin in Thureau's Lead. The characteristics of the sediments and the cassiterite distribution have been summarised by Montgomery (1893), Walker (1957) and Jack (1964). The distribution of old alluvial workings (fig. 22) suggests

that much of the cassiterite was derived from the Constable Creek Granite. The texture, mineralogy and chemistry is similar to other granites associated with lode and alluvial cassiterite in north-eastern Tasmania (Groves, 1972; Groves, this Bulletin; Klominsky and Groves, 1970). Some cassiterite in the lead may have originated from the Lottah Sheets (Groves, this Bulletin) particularly that in the Power Rivulet and Goshen alluvial tin areas. During Tertiary times the area of exposed Constable Creek Granite may have been greater, with consequent shedding of cassiterite over a wider terrain. Similarly isolated placer deposits without obvious source, may owe their origin to lodes totally eroded in Tertiary times.

MINERAL LAYERING

Mineral layering in granitoid rocks is widespread, but is generally poorly developed. The equigranular phase of the Scamander Tier Granodiorite and the Grant Point Granite have widely distributed, discontinuous biotite-rich layers. The layering, best demonstrated in coastal outcrop, is spectacularly exposed in the Scamander Tier Granodiorite at Binalong Bay [69/120173] (fig. 29) and in the Grant Point Granite at Grant Point [69/142159]. Similar layering is described by Emeleus (1963), Bateman et al. (1963), Claxton (1968), Nathan (1971) and Moore and Lockwood (1973). The simple, undeformed nature of the layers distinguishes them from mafic schlieren which can be attributed to plastic deformation of mafic xenoliths (Claxton, 1968). This origin is proposed for some schlieren in the granitic masses on St Helens Point.

In the equigranular phase of the Scamander Tier Granodiorite the layers are commonly sub-horizontal and less than one metre in length except near Binalong Bay. An exposure on the south-western promontory of the eastern shore of Moulting Bay shows a group of thin, sub-horizontal, biotite-enriched layers over 5 m in length [69/099106]. These are succeeded to the south and to the east, in the narrow portion of the main dyke, by steeply dipping mafic mineral layers which have a cross-cutting relationship to K-feldspar segregations. The steeply dipping discontinuous mafic layers are possibly aligned through size sorting of suspended crystals during intrusion (Wiltshire, 1969; Leake, 1974). A similar process probably gave rise to the segregation and alignment of the K-feldspar, although the crystallisation of this phase may have continued to subsolidus temperatures and consequently its distribution may reflect a regional stress field (Berger, 1971; Pitcher and Berger, 1972).

Foreshore exposures at Binalong Bay (fig. 29) have a relief of about 5 m permitting inspection of the various features exposed in three dimensions. The main structure is an isolated synformal lens with regularly developed bands of mafic layers in the east, predominantly sub-horizontal structures in the western half and a steeply dipping margin in the north-west.

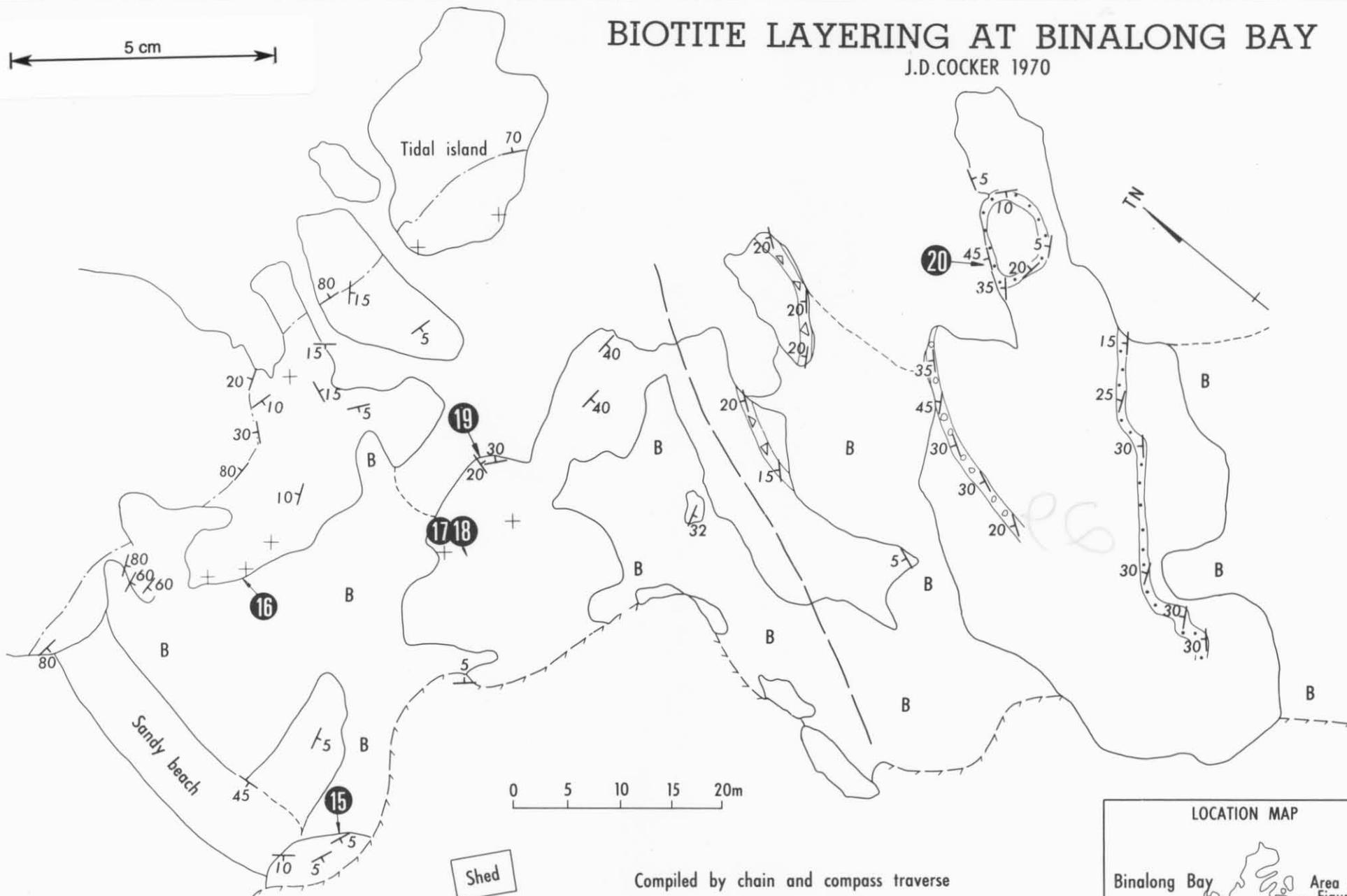
The three west-dipping, undulating bands some 5 m apart are each composed of a one metre thick sequence of cross-cutting biotite-rich layers. A minor synformal structure in the eastern band is illustrated in Plate 20. A fault which has caused disruption and bending of the layers has healed and does not extend beyond the band (plate 20). Individual biotite-rich layers within the band are continuous to 10 m in length, attain 20 mm in thickness and commonly have an overlying complimentary felsic mineral-rich layer. On the western side of the synform the uniformly dipping bands are not duplicated. Most structures are sub-horizontal except near the axis where they dip to the east.

In the central area of the lens, where the gross banding is sub-

BIOTITE LAYERING AT BINALONG BAY

J.D. COCKER 1970

5 cm

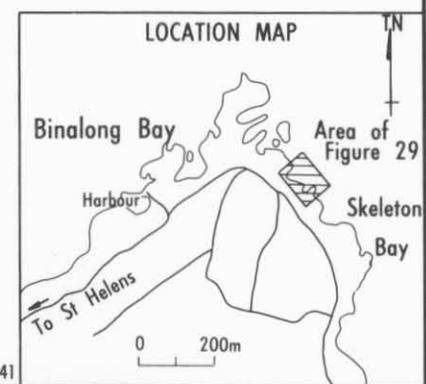


0 5 10 15 20m

Shed

Compiled by chain and compass traverse

- Axial trace of main synformal structure
- - - Low water mark
- · - · - Limit of soil and vegetation cover
- · - · - North-western boundary of lens
- + Subhorizontal layering
- ↘ Strike and dip
- B Boulders
- ⑮ Plate referred to in text
- ⋯ Bands of continuous layers



4151-41

G5855

Figure 29.

horizontal, many exposures show cross-cutting layers, wide variation in mafic mineral content, and size-graded layering (plate 19). The uppermost layer is coarser grained and porphyritic towards the top where miarolitic cavities are common. A similar rock type, visible 4 m north of this location, suggests that further layering may extend below the present level of exposure. A spectacular feature displayed on a vertical surface is the section through a trough or channel structure, with biotite concentrations lining the base and sides, and the centre occupied by coarser grained more felsic rock (plates 17, 18).

In one locality repeated fine-scale layers, only one or two biotite grains in thickness, are grouped in bands (plate 15). At the base of the lowest band of 'laminae' are two suspended lobes possibly caused by lode-casting. Well developed rhythmic layers, coarser grained towards the top and some 150 mm thick, form a sequence with a total thickness of more than one metre (plate 16).

The north-western boundary of the lens is defined by several steeply dipping mafic layers and an irregular layer of rock rich in K-feldspar. These steeply dipping layers truncate the sub-horizontal bands of Plate 16. No dimensional orientation of minerals was observed in the banded structures.

The well exposed layered outcrop in the Grant Point Granite consists of a sequence of steep (about 50°) uniformly dipping layers, rich in biotite and continuous over some 20 m. Along the northern margin of the structure the layers have been disrupted to form a breccia of short mafic segments in a matrix of typical Grant Point Granite.

No detailed modal, chemical or textural studies have been made of the layered structures. However some observations can be made using the field data and theoretical considerations. The layering is interpreted as evidence of restricted flow and gravitational settling within the magma and its wide-spread, but discontinuous, nature suggests that these processes may have operated incipiently throughout the unit. Natural convection is probable in granitoid magmas (Shaw, 1965; Bartlett, 1969), and this will tend to prevent settling and possibly disrupt settled layers. High H₂O content in the magma, suggested by miarolitic cavities, will result in lowered viscosity, which may be a factor favouring the development of layered mineral concentrates. Textural relationships observed in thin section suggest the first minerals to crystallise were biotite, plagioclase and accessory minerals including metamict allanite. This observation accords with experimental rock-water studies (Robertson and Wyllie, 1971), which indicate that significant biotite and plagioclase crystallisation would occur by 750°C at 200 kPa for a magma composition similar to that of the Scamander Tier Granodiorite. Settling rates of 0.1-1.0 m/y for crystals ranging in size from 2-8 mm are obtained using empirical relations to determine viscosity and settling rates (Shaw, 1965; Shaw, 1972). These are considered geologically reasonable, but are based on stagnant conditions and would be slower if currents were involved. Cross-cutting structures in the layered lens at Binalong Bay and in the Grant Point Granite layers are attributed to current activity. The relative importance of gravity settling and current activity in concentrating early-formed minerals may be established by detailed modal, textural and compositional studies.

PETROGENESIS

Gee and Groves (1971) and Groves (this Bulletin) summarise the evidence for mesozonal and epizonal levels of intrusion in the Blue Tier Batholith. More detailed mapping of the St Helens area provides further evidence for

epizonal levels of intrusion, in particular the chilled margins of the Scamander Tier Granodiorite and the disorientation and displacement of joint blocks in the Mt Pierson Adamellite adjacent to the east-west dyke. If the Grant Point Granite-Akaroa Granodiorite is a ring dyke structure, this too suggests high level intrusion.

A progressive intrusive sequence from mafic to more felsic granitoid units is reflected in the chemistry of the rocks and is repeated twice in the St Helens area. The intrusion of the Akaroa Granodiorite into the granitic rock on St Helens point is another example of the reversal of the common mafic to felsic trend. In the St Helens area there is little evidence to establish intrusive suites of units petrogenetically related by fractional crystallisation (cf. Sierra Nevada Batholith, Presnall and Bateman, 1973). The more acidic parts of the George River Granodiorite may have evolved by fractional crystallisation of a granodiorite magma, with partial separation of crystalline phases from residual magma. The Constable Creek Granite may have been derived from the Mt Pierson Adamellite magma by fractional crystallisation through the separation of a late-stage H₂O-rich melt, which underwent second boiling during crystallisation, causing hydrothermal alteration of feldspars and biotite.

The field and compositional characteristics of the granitoid units in the St Helens area are consistent with their derivation, as separate magmas or crystal mushes, by partial melting of different source rocks. Based on chemical and mineralogical criteria, Chappell and White (1974) have distinguished two contrasting types of granitoids in Eastern Australia. They suggest that the S and I-type granitoids have been derived by partial melting of different source rocks, sedimentary and igneous respectively. In the St Helens area, the George River Granodiorite, the Scamander Tier Granodiorite and the Grant Point Granite have similar compositional and mineralogical features to those of the I-type granitoids, whereas the Mt Pierson Adamellite, the Constable Creek Granite, the Akaroa Granodiorite and the Medea Cove Adamellite are similar to the S-type granitoids. Further characterisation of the source rocks and the petrogenetic history of the granitoids will require precise analyses of the rocks and their constituent minerals.

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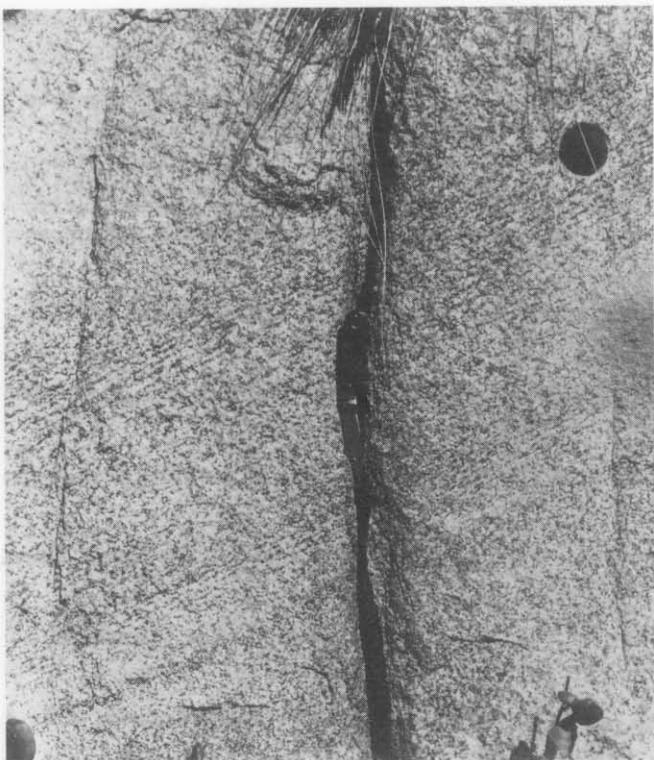


Plate 15. Binalong Bay.
Uppermost band of fine-
scale layering.



Plate 16. Binalong Bay. Rhythmic mineral, and size-graded, layering (thickness of exposed sequence is 1.5 m).



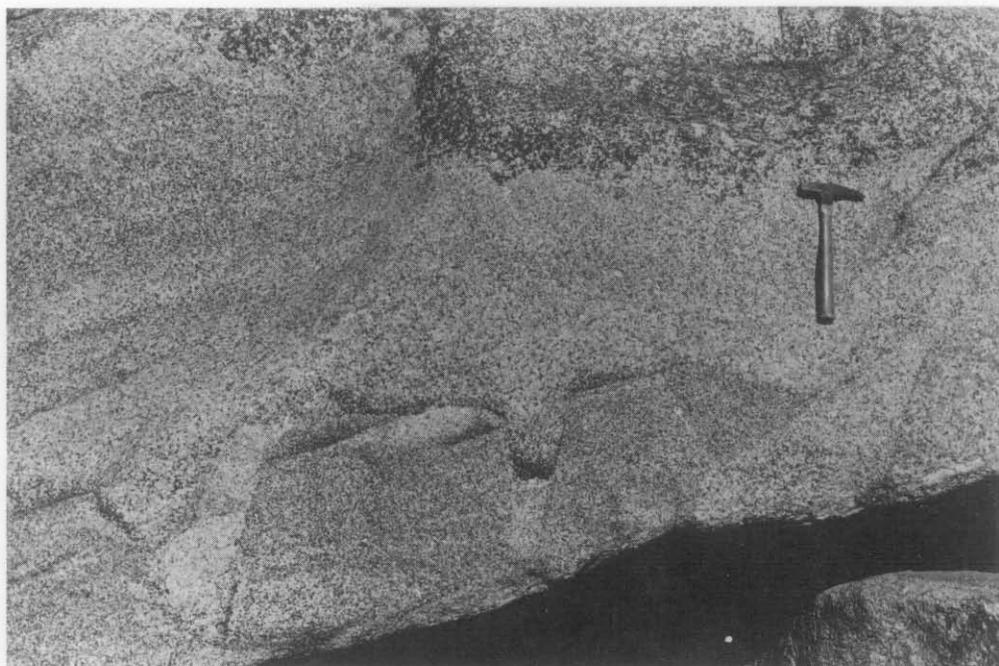


Plate 17. *Binalong Bay. Cross-cutting layers and trough structure, possibly related to erosion by magma currents.*

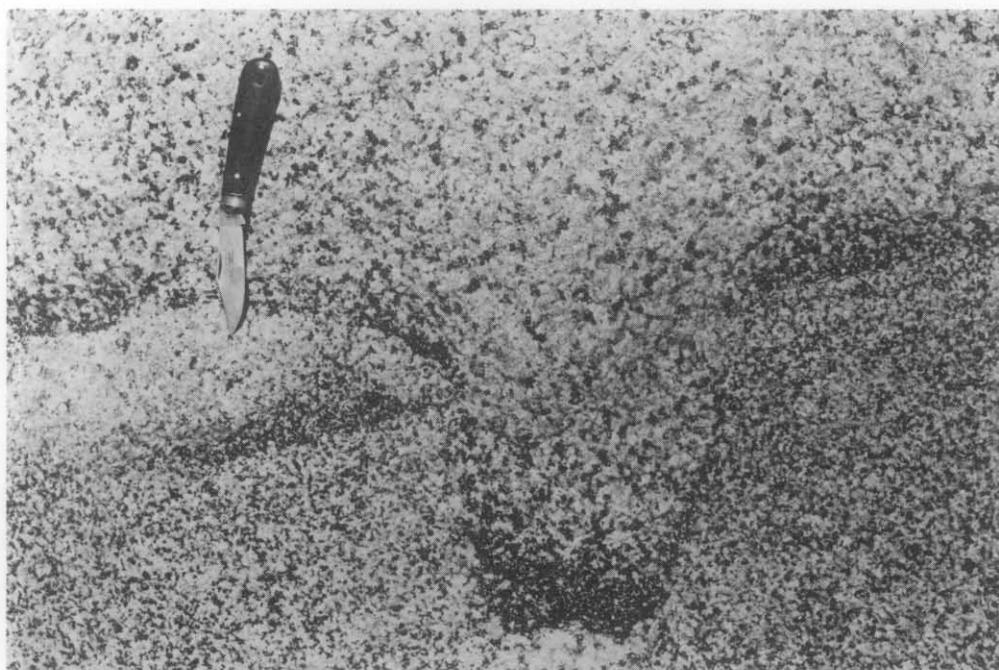


Plate 18. *Binalong Bay. Enlarged view of the trough structure.*

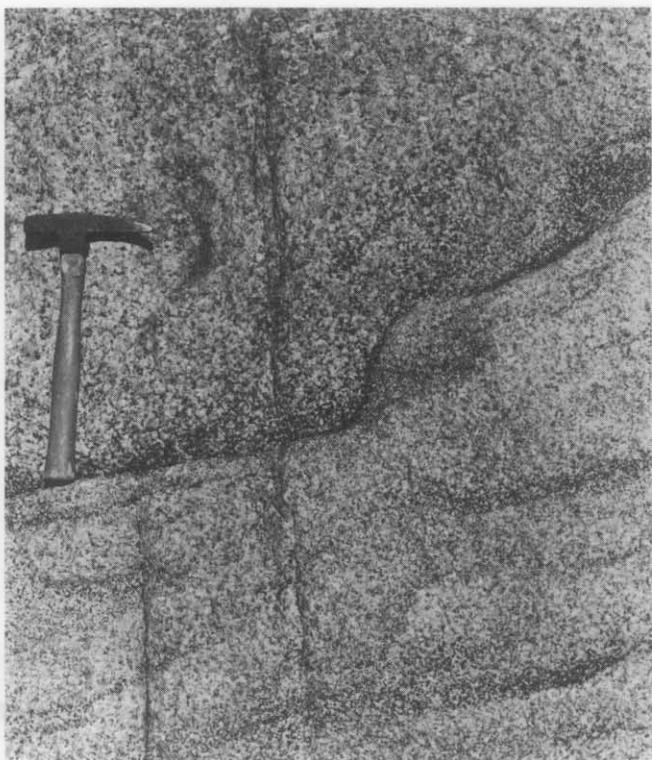


Plate 19. *Binalong Bay.*
Cross-cutting graded layer
with biotite concentrated
towards the base (field of
view 0.9 m).

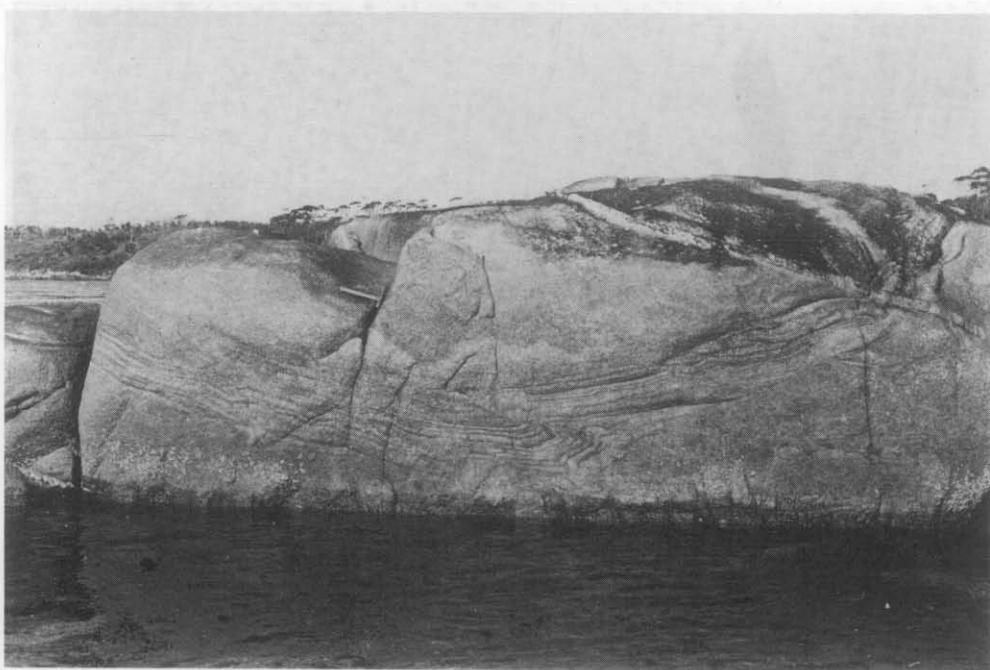


Plate 20. *Binalong Bay.* *Cross-cutting, biotite-rich layers*
displaced by a small fault (centre).

The search for tin at Mt William

by *D. J. JENNINGS*

JENNINGS, D. J. 1977. The search for tin at Mount William. Bull. Geol. Surv. 23:157-171.

The search for tin
at Mt William

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JENNINGS, D.J. 1977. The search for tin at Mount William. *Bull.geol.Surv.*
Tasm. 55:157-171.

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ABSTRACT

The granite rocks of the Mount William ridge appear similar to other granites in north-east Tasmania associated with lode and alluvial tin deposits. Geological outcrop mapping defined tracts of sediment and superficial cover which might conceal alluvial tin deposits, and drilling targets were selected within these areas by geophysical means. Subsequent percussion drilling failed to locate promising gravel horizons or worthwhile traces of tin, and chemical analyses of Mount William granites indicated only limited potential as a source rock for tin mineralisation.

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THE PROJECT

Reconnaissance geological survey traverses by D.I. Groves in poorly exposed terrain north-west of Eddystone Point during 1970 located a tract of medium-grained muscovite-biotite granites. The outcrop is elongate N-S along a regional boundary between biotite granite-adamellite and Mathinna Beds bedrock, and forms an elevated ridge including the summit of Mt William. The appearance of the granite in outcrop, hand specimen and thin section suggests correlation with biotite-muscovite granites from Mt Cameron, Lottah and elsewhere in the Blue Tier Batholith some of which display tin mineralisation. An investigation was undertaken to establish whether the Mt William mass was tin-bearing and whether erosion in Tertiary times might have removed lode tin from levels above the present outcrops and redeposited it as recoverable alluvial concentrates on the flanks of Mt William beneath the surface of the present plains.

There is no evidence of previous prospecting and no tradition for tin mining at Mt William. The nearest alluvial working is on the Great Musselroe River about 10 km to the south-west; the nearest lode tin prospect is south of Great Musselroe Bay, about 10 km to the north-west; and the nearest cassiterite-rich beach sand is about 12 km south-east, near Eddystone Point. However it was argued that low surface gradients, the dry climatic conditions and lack of an obvious water supply together with the abundance of sand cover, would have discouraged early prospectors unable to mine in such conditions, and hence well concealed deposits might yet remain undetected.

An investigation programme was envisaged, comprising:

- (1) sampling and microscopic study of the surface outcrops of the granite;
- (2) bulk sampling and XRD investigations for major and trace elements;
- (3) detailed geological mapping on contoured base maps to establish variations within the granites and suggest targets for more detailed investigation;
- (4) a geophysical survey to define the form of Tertiary channels and basins beneath the Quaternary cover; and
- (5) testing of selected sites for alluvial cassiterite by means of a percussion drilling rig.

In the event, difficulty was experienced in obtaining the required gross chemical and trace element analyses and the decision was made to proceed with the subsequent stages of the programme, incorporating the results of analyses as they became available. A detailed geological map of the area between Great Musselroe Bay in the north and Ansons Bay in the south was produced in late 1970. Areas were selected for a resistivity and seismic investigation, and drilling commenced in April 1971. Bad weather and consequent poor access halted the drilling at the end of July, and the bore hole programme was completed in the first quarter of 1972. The results remain inconclusive but are uniformly discouraging throughout the areas investigated.

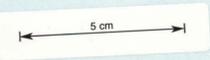
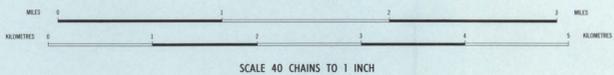
GEOLOGICAL MAPPING

Information was collected in the field on air photographs at a scale of 1:31 680, accumulated on field sheets at a scale of 1:15 840 and ultimately compiled at a scale of 1:31 680 (fig. 30). The southern part was mapped by R.E. McShane and the remainder and final compilation was the responsibility of the author. The aims of the mapping were:

GEOLOGY

MT WILLIAM-EDDYSTONE POINT AREA

D.J.Jennings B.Sc.(Hons) R.F.McShane B.Sc. 1971

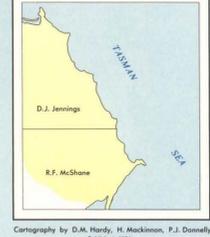


REFERENCE

- QUATERNARY**
 - Q Alluvium, blown sand, lagoon and seasonal marsh deposits.
 - Q Wind blown and locally derived sand.
 - Qd Dune and beach sands.
 - Qc Locally derived and transported grits and fossil beach berms.
 - Qs Silcrete and cemented gravels.
- PALAEZOIC**
 - SILURIAN**
 - * Digested rafts of Mathinna Beds in granite.
 - Sm Mathinna Beds.
 - TRIASSIC**
 - Tb Olivine basalt.
 - Cretaceous (?) lamprophyre.
 - Dolerite.
 - Aplite and leucocratic microgranite.
 - DEVONIAN**
 - Sm Mount William medium-grained biotite-muscovite adamellite (Mt William Sheet).
 - Sm Mussoleux Point microgranites.
 - Sm Variable medium-grained porphyritic biotite (muscovite) adamellite (Ansons Bay Pluton).
 - Sm Eddystone Point coarse-grained biotite adamellite (Ansons Bay Pluton).
 - Sm Coarse-grained porphyritic biotite adamellite (Ansons Bay Pluton).
 - Sm Hornblende-biotite-granodiorite (Gardens Pluton).

- q Abundant quartz float.
- ga Garnet observed.
- v-v Strike and dip of beds.
- Geophysics grid.
- Lighthouse.
- Contour interval 25 feet.

RESPONSIBILITY DIAGRAM



Cartography by D.M. Hardy, H. Mackinnon, P.J. Donnelly
Published 1974

GSB55

Fig 30.

- (1) to produce a detailed bedrock outcrop map to emphasise regions of continuous Cainozoic cover which might conceal Tertiary or later reworked cassiterite deposits accumulated in buried drainage channels and local bedrock depressions. Such areas would then become the foci for the geophysical investigation;
- (2) to observe mineralogical and textural variation throughout the granites of the Mt William area and define precisely the outcrops of the leucocratic biotite-muscovite granite, the most likely potential host rock for tin mineralisation. This information would aid in a reconstruction of the relationship of rock distribution to relief in Tertiary times and indicate possible collection areas and drainage patterns; and
- (3) to recognise and correlate the various Cainozoic sediments with particular reference to fluviatile gravels and dune sands.

The map produced is therefore basically a field interpretation with limited microscopic or analytical confirmation. Problems encountered include poor access, the broad range of superficial variation within, and particularly marginal to, the major bodies of granite; and limited exposure over much of the area which obscures age relations. The uniform vegetation and featureless nature of much of the coastal plains renders precise navigation difficult.

THE SUCCESSION

A succession was established, comprising a Mathinna Beds basement, a number of granite intrusions and a copious blanket of Tertiary to Recent sand, gravel and alluvial deposits. Dolerite and lamprophyric dykes and aplitic minor intrusions succeeded the major granite intrusions probably in Late Devonian times. A dyke sporadically exposed on the intertidal coastal granite platform is a lamprophyre similar to those of Cretaceous age, exposed at Cape Portland, and an isolated hilltop is capped with basalt indistinguishable from some Tertiary basalts in north-eastern Tasmania.

The granitic rocks are subdivided into seven different groups, the age relationships between which are not clear. On the main map (Geology: Blue Tier Batholith, fig. 1) these are represented by:

- (1) Dg15, a hornblende-biotite granodiorite of the Gardens Pluton.
- (2) Dg7, a coarse-grained porphyritic granite-adamellite of the Ansons Bay Pluton.
- (3) Dg6, a porphyritic biotite granite-adamellite of the Musselroe Pluton.
- (4) Dg3, medium- to coarse-grained granite adamellite of Eddy-stone Point.
- (5) Dg1, fine- and medium-grained biotite and biotite-muscovite granite of Mt William and Musselroe Point.
- (6) Da, acid granite rocks; microgranite and aplite of Ansons Bay and the Gladstone-Eddystone Road.

On the larger scale map (Geology: Mt William-Eddystone Point area, fig. 30) some attempt was made to retain uniformity in the symbols and colouring.

- (1) Dg15 remains for the hornblende-biotite granodiorite of the Gardens Pluton.

- (2) Dg7 is the symbol used for the main coarse-grained porphyritic biotite granite-adamellite of the Ansons Bay Pluton; the coarse-grained biotite granite-adamellite of Eddystone Point; and the variable medium-grained porphyritic biotite (muscovite) granite-adamellite of Ansons Bay Pluton, but each rock type appears differently coloured on the map. These rocks were distinguished during field mapping, but their age relations are obscure, and their similarities appear more significant than their differences. On this scale of mapping no evidence was seen to separate the porphyritic biotite granite-adamellites of the Great Musselroe Bay area from those elsewhere so these are included as Dg7.
- (3) Dg6 is the symbol employed for the Musselroe Point micro-granite which contrasts with the coarser grained porphyritic granites further south and, from evidence on the eastern shore section, probably pre-dates them.
- (4) Dg1 is retained as the symbol for the fine- and medium-grained biotite and biotite-muscovite granites of Mt William which apparently post-date the coarser grained porphyritic granites.
- (5) Da includes aplites, microgranites and quartz-feldspar porphyries.

Mathinna Beds (Sm)

The Mathinna Beds form the bedrock of the terrain along the western margin of the mapped area. Agricultural development is in progress and extensive tracts of land have been cleared for pasture, so most of the scarce exposures are in man-made culverts and water holes. Evidence of underlying Mathinna Beds is frequently confined to a sporadic scatter of vein quartz, and angular joint blocks and cleavage flakes of hornfelsed siltstone and mudstone. Often the weathering of Mathinna Beds produces a distinctive variegated clay subsoil.

Outcrops of Mathinna Beds occur northwards towards Great Musselroe Bay, but are obscured by superficial Quaternary deposits before the shore. It is therefore impossible to confirm that the Ansons Bay and Musselroe Bay Plutons are separated by Mathinna Beds extending northwards beneath Great Musselroe Bay.

Mathinna Beds-granite contacts are well exposed in shore sections about 3 km south-west of Eddystone Point; possibly the margins of a large incorporated block of sediments similar to that exposed in the lower reaches of Groves Creek, about 4.5 km north-west of Eddystone Point. The highly hornfelsed state of the sediments and their drawn out flame-like form at the contact suggest a high temperature of granite intrusion. Three exposures of granite on the coast about 6.5, 7.7 and 8.3 km north-west of Eddystone Point, are traversed by tracts of enigmatic variable-banded fine-grained material which may represent remnants of screens of Mathinna Beds sediments highly altered, partly mobilised and incorporated in the granite.

Gardens Pluton: hornblende-biotite granodiorite (Dg15)

Within the area mapped, granodiorite outcrops consist of low whale-backs confined to the wooded valley of Icena Creek and its tributaries in the south-west, but further west they occur in the open pastures and in the valley of the Great Musselroe River. It is inferred that the Icena granodiorite extends south-eastwards beneath superficial cover to join the main

body of the Gardens Pluton. No contact between the Gardens Pluton and the Ansons Bay granite has been seen and these rocks may be separated by an obscured continuation of Mathinna Beds from west of Mt William to the west of Ansons Bay.

The granodiorite appears as a medium-grained light grey rock in which prisms of white feldspar rarely attain 6 mm in length. Quartz occurs in equal amount as 2 mm granules forming aggregates up to 8 mm in diameter. Biotite and hornblende are both common, the former well dispersed as individual books up to 8 mm in length, the latter as stocky prisms up to 4 mm long.

Ansons Bay Pluton: porphyritic biotite adamellite (Dg⁷)

The distinctive coarse-grained porphyritic biotite granite-adamellite of the Ansons Bay Pluton occupies a broad tract of country from Ansons Bay in the south to Boulder Point in the north, and extends beyond the coastline to the east. The western boundary runs N-S and can be mapped precisely against hornfelsed Mathinna Beds and medium-grained biotite-muscovite granites in the south, but with less assurance further north where considerable variation in texture occurs; a finer grained matrix becomes common, with local reduction in size and density of phenocrysts, and muscovite mica appears sporadically.

Characteristically the rock is deeply weathered and typical outcrops consist of hill slopes and low platforms littered with crumbling boulders up to several metres in diameter. Inland the rock is buff-coloured and iron-stained but the fresher material exposed in the low promontories along the coast is mid-grey in colour and locally an incipient foliation has been etched by wind and wave action to develop characteristic fluted surfaces. Inland the adamellite produces a copious mantle of coarse quartz granules on erosion, while on the coast the feldspar phenocrysts are weathered from the fresher rock and form rare monomineralic gravel patches on the beach, composed of rounded fragments often 50 mm in length.

The granite-adamellite consists of a coarse-grained matrix of quartz granules in aggregates up to 30 mm in diameter, and potash and plagioclase feldspars often 10 mm in length showing zoning, twinning, intergrowth and invariably much alteration. Biotite occurs as discrete crystals, 4 mm in diameter and clusters up to 10 mm in diameter. Phenocrysts of K-feldspar are often conspicuously zoned; include flakes of biotite and commonly attain lengths of 50 mm (Groves, this Bulletin, p.34).

Eddystone Point is inundated with dune sand but the coastal fringe provides good exposures of biotite adamellite (also Dg⁷). This rock differs from the Ansons Bay rock and is medium-grained, equigranular and pale grey with quartz-aggregates, plagioclase and K-feldspar (up to 30 mm) accompanied by occasional, dispersed biotite flakes (Groves, this Bulletin, p.34).

A more fine-grained adamellite (average grain size 1.5 mm) crops out on the north shore of Ansons Bay. Dispersed biotite flakes are relatively more abundant, and rare plates of K-feldspar up to 10 mm in diameter enclose grains of matrix.

Ansons Bay Pluton: variable porphyritic biotite (muscovite) adamellite (Dg⁷)

Between the distinctive coarse-grained porphyritic adamellite of the coast and the medium-grained non-porphyritic adamellite-granites of the Mt William ridge, a zone some 3 km wide and 10 km long has been distinguished,

composed of variable medium-grained porphyritic biotite (muscovite) adamellites. This unit is presumed to be a phase of intrusion of the Ansons Bay Pluton (Dg7) and the rock shows an admixture of characteristics of the adjacent rock types. The boundaries are poorly exposed and locally gradational and this unit may have developed as a hybrid, by alteration of a marginal facies of the Ansons Bay adamellite on the intrusion of the Mt William granite. Its broad outcrop in plan; its variable texture and ill-defined boundaries, may result from the intersection by the present sub-horizontal ground surface of composite rocks developed in a sub-horizontal contact zone.

The 'hybrid' adamellite is typically cream-coloured, medium-grained, sparsely porphyritic with discrete biotite flakes, occasional biotite aggregates and rare muscovite. Euhedral K-feldspar phenocrysts show intergrowth and frequent alteration. The matrix consists of quartz, with aggregates of 3 mm granules attaining diameters of 20 mm, and includes plagioclase subhedra, 5 mm in length, locally clear, zoned and well twinned and elsewhere intensely altered. Biotite flakes 3 mm long occur separately, or in clots to 10 mm in diameter where they are associated with quartz and rare skeletal grains of iron oxide. Muscovite appears in some specimens (always less common than biotite) as alteration and overgrowth of biotite and as clear interstitial flakes.

Musselroe Point microgranite (Dg6)

The northern headland terminating in Musselroe Point is traversed by patterns of east-west elongate sand dunes with intervening lagoons or marshy hollows. Bedrock outcrop is almost confined to the peripheral shore platform. The north-western aspect of the headland is composed of sparsely porphyritic microgranite, with contacts against Ansons Bay-type porphyritic adamellite. The contact to the west is obscured on the muddy foreshore at the neck of Great Musselroe Bay but is well exposed to the east on the ocean beach, where xenoliths of microgranite included in adamellite, and dykes of adamellite intruding microgranite suggest the microgranite is the older. Small pods of adamellite are included in the microgranite on the western shore. Two distinctive features are shown by the microgranite in the south-western 500 m of shore platform, opposite the sand spit. Here the uniform, pale, fine-grained texture of the rock is interrupted by darker finer-grained micaceous clots 6-8 mm in diameter distributed patchily, appearing on some surfaces in groups of four or five, some 10 to 15 mm apart. Sparse subhedral feldspar phenocrysts, to 8 mm in length, occur throughout the rock, but sinuous trains of larger feldspar euhedra, occasionally reaching 40 mm in length, are rare.

In describing a thin section of this rock, which he terms a 'hybridised granite', petrologist G. Everard states: 'The texture is uniform except for the presence of dark clots about 7 mm across.....which consist of small crystals of green and brown biotite, arranged peripherally around a core consisting essentially of a phenocryst of cordierite. The cordierite has a somewhat distorted twin plane and contains inclusions, mainly sericite. The main mass of the rock shows an idiomorphic texture, with orthoclase, oligoclase and quartz accompanied by biotite, muscovite and cordierite.'

The Mt William Mass: biotite-muscovite adamellite-granite (Dg1)

The rocks which crop out on the range of hills from 6 km north to 6 km south of the summit of Mt William are usually pink or cream coloured, equigranular, medium-grained granite-adamellite with little biotite and less muscovite. The outcrop is aligned along a regional contact separating hornfelsed Mathinna Beds to the west from varieties of porphyritic biotite adamellite of the Ansons Bay Pluton to the east.

The form of the Mt William Mass is enigmatic, with evidence from different localities amenable to different interpretations. Viewed objectively there is little evidence to suggest a sub-horizontal sheet.

In the extreme south the contact with surrounding bedrock descends from 90 m (300 ft) to 60 m (200 ft) in a northerly direction within one kilometre (fig. 31). This may simply be the result of a near-vertical arcuate igneous contact, or the mass may be shallow here, with a base sloping north-westerly at about 2° . From one kilometre to 1.5 km north of the southern contact a saddle extends 2 km E-W across the ridge, exposing a floor of Mathinna Beds sediments, forming a continuous lobe with the bedrock of the plains to the west. Contacts between Mathinna Beds sediments and granite (which occupies the higher ground) indicate the local base of the intrusion and are consistent at about 60 m (200 ft). These areas provide the best evidence for a sheet-like form for the Mt William Mass.

Further north the contacts between the Mt William Mass and the sediments to the west, and the Ansons Bay Adamellite to the east, can be interpreted in several ways. In the west, in plan, the contact is slightly bowed to the west and in 8 km rises northerly from 55 m (180 ft) to 90 m (300 ft) (opposite the summit) and descends to 37 m (120 ft). In the east the contact shows a similar slight bow to the west, and in 8 km the contact climbs from 60 m (200 ft) to 76 m (250 ft) (opposite the summit) and descends to 46 m (150 ft) in the north. If the contacts define the base of a sub-horizontal sheet, in an E-W sense the floor must undulate from negligible westerly dips at the extremes to a slight easterly dip centrally, in the summit region. At the same time the floor rises for 60 m (200 ft) in the south, to 85 m (280 ft) centrally and descends to 37 m (120 ft) in the north. Slopes on the base would not exceed 2° .

If the intrusion is a sinuous steeply-dipping sheet it may have contacts at any angle, and only if it is planar (and the bowed form of outcrop in plan attributed to relation between dip and surface relief) can one postulate a theoretical dip of some 8° to the east, overlying Mathinna Beds and underlying adamellites of the Ansons Bay Pluton.

Rock of similar composition occurs sporadically among coastal outcrops at Boulder Point.

Aplite and leucocratic microgranite (Da)

Dykes and irregular intrusions of late-stage leucocratic rocks invade Mathinna Beds and granites. A typical microgranite from a dyke exposed at the lagoon behind Purdon Bay, 5.5 km north-west of Eddystone Point is composed of a granular mosaic of quartz and feldspar crystals, 1-2 mm in length, with biotite less common than muscovite, and rare altered feldspar prisms and plates of quartz attaining 2.5 mm in length. A porphyritic microgranite from one kilometre south-west of Boulder Point has a granular matrix of quartz, feldspar, biotite and less common muscovite with grains usually less than 0.5 mm in diameter, but occasional feldspar and biotite phenocrysts up to 4 mm, quartz aggregates up to 10 mm diameter and aggregates of mica up to 10 mm diameter (suggesting replacement of cordierite). An outcrop of porphyry intruding Mathinna Beds, 2 km south-west of Mt William has a flinty grey base with 2 mm of fresh biotite and rotten feldspar phenocrysts and aggregates of glassy quartz to 4 mm. An outcrop of aplite, (one of several used as source rock for the manufacture of aboriginal artifacts), 3.5 km north-east of Mt William is buff coloured and flinty in appearance and composed of a granular mosaic of 0.1 mm grains of feldspar quartz and muscovite.

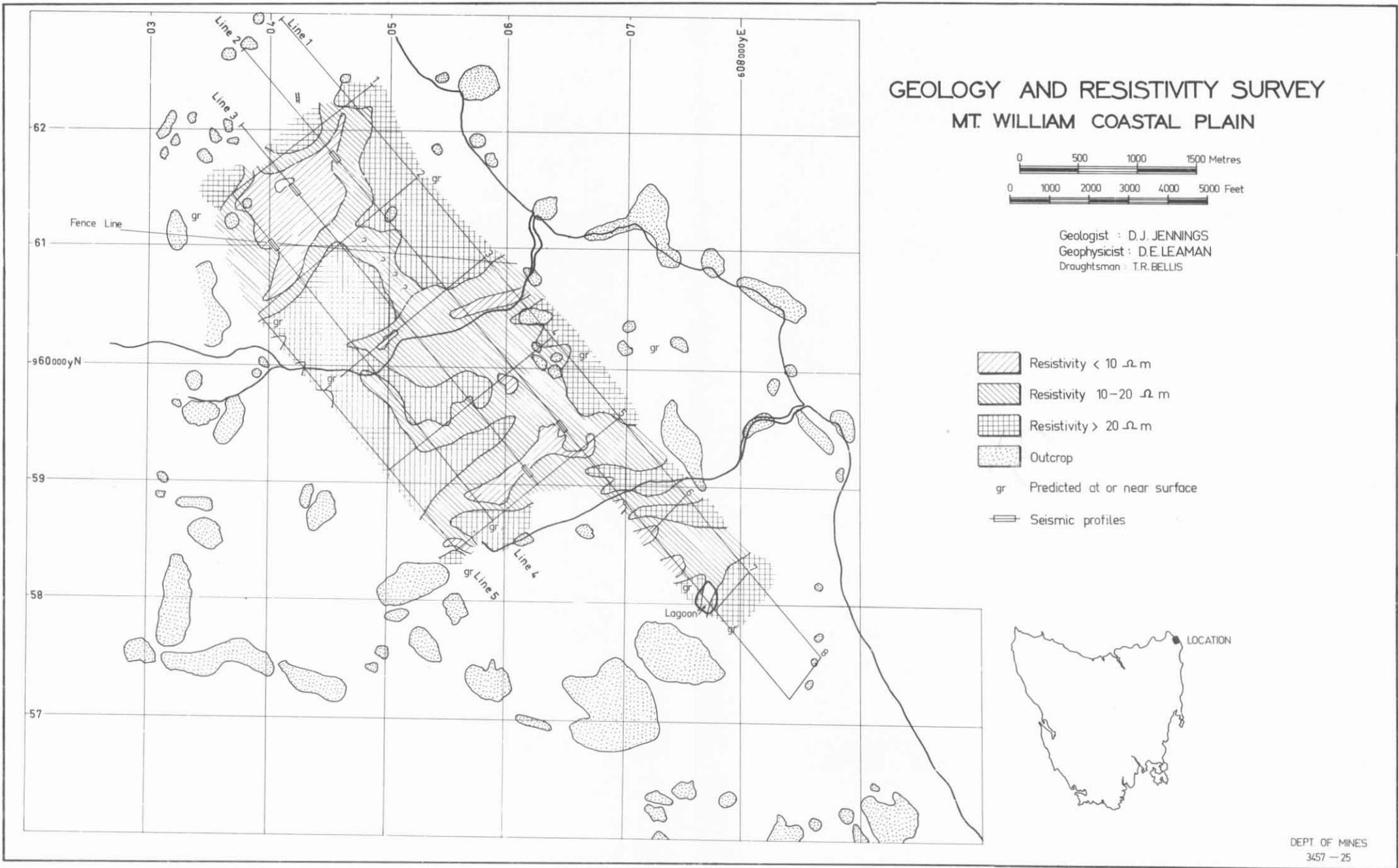


Figure 31.

5 cm

GSBS

Mafic intrusive and extrusive rocks

Small, poor exposures of mafic igneous rocks (frequently nothing more than tracts of weathered rubble) are dispersed over a wide area. They fall into three groups:

- (1) N-S oriented dykes of 'dolerite' of presumed Devonian age (similar to those in the Freycinet, Blue Tier and Furneaux areas).
- (2) A single, narrow, disjointed, lamprophyre dyke, comparable with those of the Mesozoic(?) Appinitic Complex at Cape Portland and probably related to them.
- (3) A small outcrop, probably a remnant of a lava flow composed of olivine basalt comparable with Tertiary lavas inland.

Dolerite dykes. Peter Collins, studying the mafic dykes in the granite terrain of north-east Tasmania, including samples from near Mt William states:

'Porphyritic mafic dykes, of variable thickness and with well-defined margins, intrude the Devonian granitic rocks and the Mathinna Beds of north-eastern Tasmania. The dykes, which have a macroscopic texture similar to the Jurassic dolerites, consist of subidiomorphic plagioclase phenocrysts in a fine to medium-grained subophitic groundmass of augite, hornblende and plagioclase. Chloritised biotite, iron oxides, sulphides and apatite are common although minor constituents, and a little quartz and orthoclase may occur interstitially. The plagioclase is dominantly andesine, and the phenocrysts, which are ubiquitous but not always abundant, are commonly zoned and less than 10 mm in length. Augite is often partially to completely altered to a secondary fibrous amphibole (uralite), and partial sericitisation of the plagioclase is common. The hornblende may be of secondary origin, although this is not obvious.

Chemically, the dykes characteristically contain much iron, lime, magnesia, and soda; are relatively low in potash; and are unusually high in strontium (*i.e.* Rb/Sr = 0.1). Although they have some chemical and mineralogical similarities with Mesozoic(?) lamprophyre dykes at Cape Portland, these dykes are here designated as dolerites because of chemical similarities with the Jurassic dolerite, the subophitic texture of the groundmass, and possible secondary origin of the hornblende. The uralitisation of the pyroxene indicates the dolerite dykes are probably associated with late-stage crystallisation of the Devonian granites.'

Mesozoic(?) lamprophyre. A lamprophyre dyke crops out in a NE-SW erosion gully in the intertidal zone on the promontory forming the southern end of Cod Bay. The quality of exposure varies with the state of the tide and the recent redistribution of massive boulders on the foreshore.

The fine-grained grey rock displays altered dark green prismatic amphibole phenocrysts 2 mm x 3 mm, and pale blebs up to 4 mm in length, recognised as resorbed feldspar phenocrysts, opalescent silica and patches of carbonate.

In thin section the matrix (mainly of 0.1-0.2 mm plagioclase laths and abundant carbonate alteration products) carries hornblende subhedra, pleochroic in shades of khaki and green, up to 3 mm in length; resorbed plagioclase phenocrysts with carbonate reaction rims, up to 2.5 mm; and skeletal iron oxide crystals to 0.25 mm. The rock is a hornblende-plagioclase-spessartite.

Tertiary olivine basalt. The seaward spur of a low hill, 3.5 km south of Boulder Point carries a patch of red-brown soil with local accumulations of basalt boulders. The plains to the north and east display Quaternary sandy deposits, and the hill rises steadily to the south and west displaying sparse granite exposure. The patch of soil and basalt boulders may represent the remnant of a once more extensive flow, or indicate the site of a local vent.

The rock, with fine-grained dark grey matrix carries phenocrysts of ferromagnesian minerals rarely up to 8 mm in length, and clots of olivine grains up to 10 mm in diameter. It is seen in thin section that the matrix consists of grains of olivine and strongly flow-aligned laths of plagioclase up to 0.25 mm in length, carrying abundant rounded phenocrysts of fresh olivine ranging in size up to 4 mm in diameter, and less common pyroxene euhedra up to one millimetre in length.

Cainozoic sediments

None of the superficial cover shows evidence of a Tertiary age. Exposure is poor and the rocks observed are unlike those in the tin workings further west. In the south-west, among the headwaters of Ikena Creek patches of variable, well-cemented grits and gravels form small features in the river banks, and platforms and copious flaggy float in some recently cleared paddocks.

A low cliff at the head of the lagoon, near the mouth of Broad Creek in Purdon Bay shows several metres of superficially similar well-cemented gravel and boulder beds, dipping gently seaward, and of estuarine or littoral origin.

Elsewhere the cover is uncemented and is composed of locally derived and transported material, usually including a high proportion of wind-blown sand. Both north-west and south-east of Boulder Point barely perceptible, low ridges are sub-parallel to the present coastline. They constitute fossil beach berms and display a lag deposit of well-rounded beach-worn grits and occasional small pebbles. Material of similar grain size occurs further inland choking the stream courses and as a lag deposit mantling the flanks of the hills, but the component grits are angular.

Stabilised and well vegetated sand dunes occur at intervals along the coast with the best development and some present activity at Eddystone Point, Boulder Point and Musselroe Point. A WNW-ESE parallel dune system with intervening marshy lagoons reflects the prevailing wind direction and dominates the surface relief north of Stumpys Bay, inland from Cape Naturaliste. Circular deflation hollows with lunettes to the east are common south of Great Musselroe Bay.

GEOPHYSICAL PROGRAMME

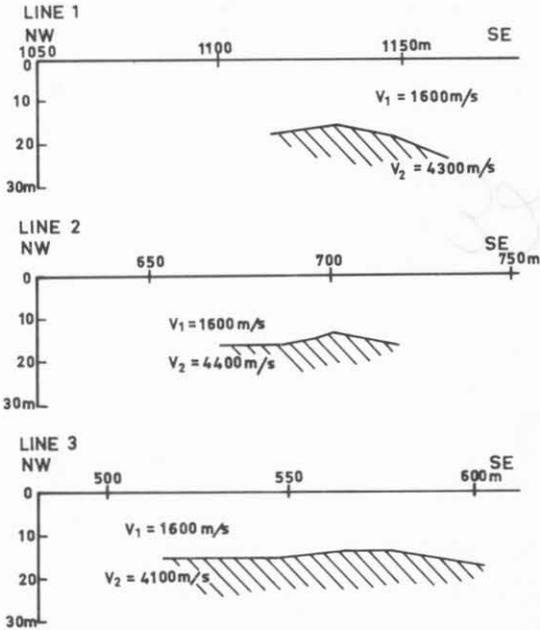
Detailed geological mapping to the east of Mt William produced a pattern of granite outcrops with substantial intervening tracts of Cainozoic sediments of unknown thickness. The possibility then arose that this blanket cover could obscure a featureless erosion platform at shallow depth, or hide a series of basin-like depressions, or conceal a pattern of buried Tertiary river channels infilled with potentially tin-bearing gravels. The largest area of negligible outcrop was selected and a geophysical programme was carried out by Leaman and Moore (1973) using resistivity methods with seismic control. The object of the resistivity survey was the location of the regions of thickest sand cover, as targets for percussion drilling.

MT WILLIAM COASTAL PLAIN

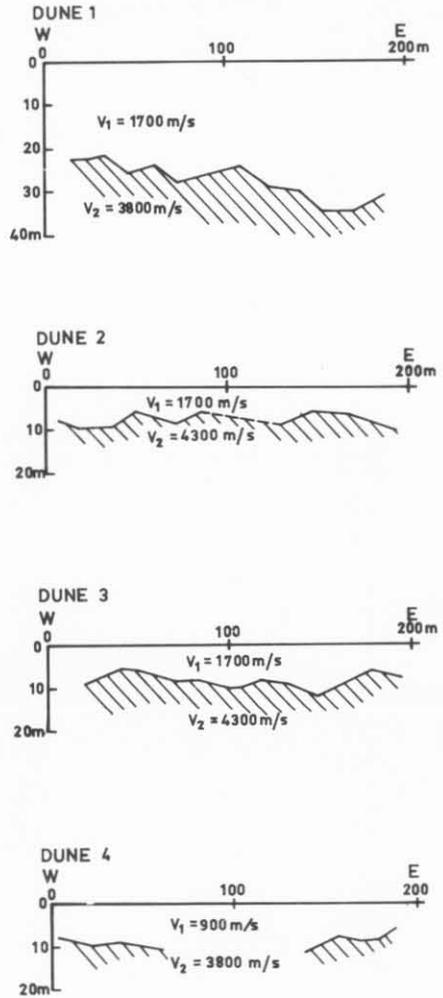
D.E. LEAMAN 1971

SEISMIC PROFILES

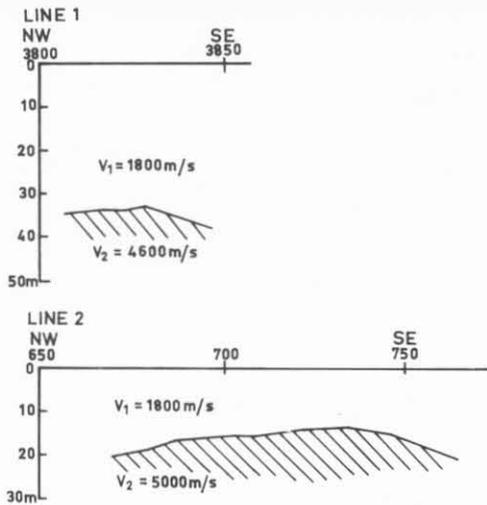
NORTH ANOMALY



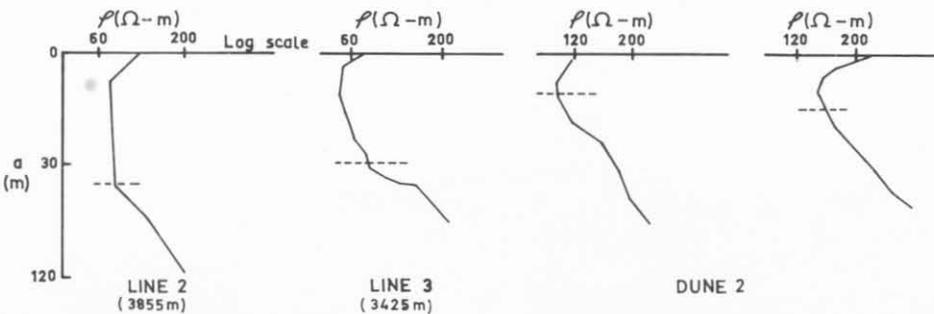
DUNES



SOUTH ANOMALY



RESISTIVITY DEPTH PROBES



TASMANIA DEPARTMENT OF MINES

3458-25

Figure 32.

5 cm

GIBBS

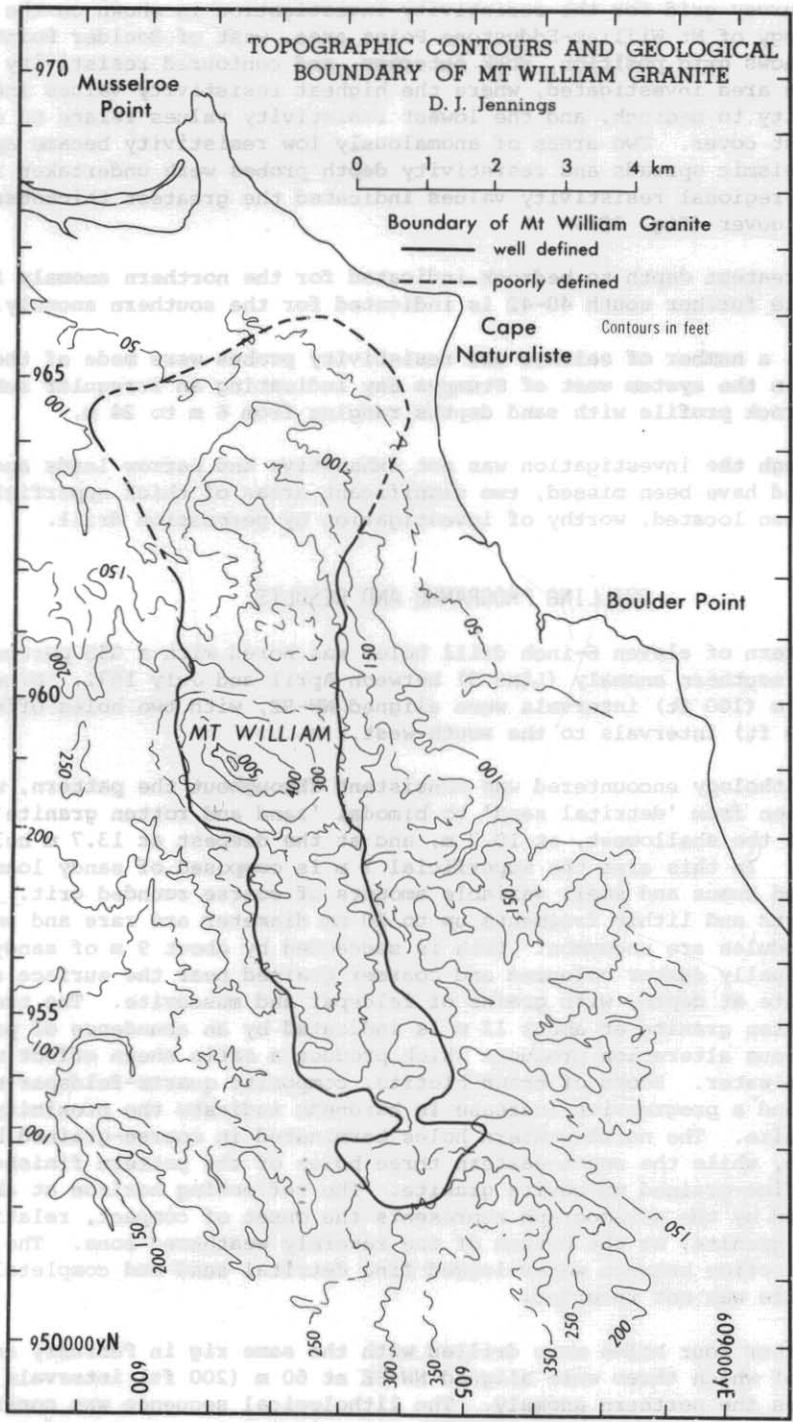
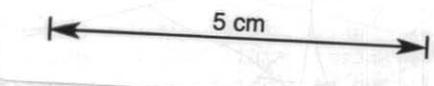


Figure 33.



The survey grid for the resistivity investigation is shown on the map of the Geology of Mt William-Eddystone Point area, west of Boulder Point. Figure 32 shows grid position, rock outcrops, and contoured resistivity values over the area investigated, where the highest resistivity values indicate proximity to bedrock, and the lowest resistivity values relate to areas with thickest cover. Two areas of anomalously low resistivity became apparent and seismic spreads and resistivity depth probes were undertaken in zones where regional resistivity values indicated the greatest thickness of superficial cover (fig. 33).

The greatest depth to bedrock indicated for the northern anomaly is 16-18 m while further south 40-42 is indicated for the southern anomaly.

Later, a number of seismic and resistivity probes were made of the sand dunes in the system west of Stumpys Bay indicating an irregular subsurface bedrock profile with sand depths ranging from 6 m to 24 m.

Although the investigation was not exhaustive and narrow leads and outlets could have been missed, two significant areas of thick superficial cover had been located, worthy of investigation by percussion drill.

DRILLING PROGRAMME AND RESULTS

A pattern of eleven 6-inch drill holes was bored with a G55 percussion rig, on the southern anomaly (Line 3) between April and July 1971. Nine holes at 30 m (100 ft) intervals were aligned NW-SE, with two holes offset at 60 m (200 ft) intervals to the south-west.

The lithology encountered was consistent throughout the pattern, with the transition from 'detrital sand' to bimodal 'sand and rotten granite' occurring at the shallowest, at 10.7 m, and at the deepest at 13.7 m below the surface. In this area the superficial 3 m is composed of sandy loam with some clay and humus and small variable amounts of coarse rounded grit. Rounded quartz and lithic fragments up to 20 mm diameter are rare and small ironstone nodules are uncommon. This is succeeded by about 9 m of sandy material, usually darker coloured and coarser grained near the surface and fine and white at depth, with grains of feldspar and muscovite. The transition to rotten granite at about 12 m is indicated by an abundance of pale green micaceous alteration products which produce a satin sheen effect when suspended in water. Books of brown biotite, composite quartz-feldspar-mica fragments, and a progressive increase in hardness indicate the proximity of fresher granite. The north-western holes terminated in coarse-grained biotite granite, while the south-eastern three holes of the pattern finished in medium- or fine-grained muscovite granite. The reflecting horizon at about 18 m detected by the seismograph represents the onset of compact, relatively unweathered granite, at the bottom of the severely weathered zone. The more subtle distinction between water-logged fine detrital sand and completely rotten granite was not recorded.

A further four holes were drilled with the same rig in February and March 1972 of which three were aligned NW-SE at 60 m (200 ft) intervals along Line 2 across the northern anomaly. The lithological sequence was consistent and similar to the previous site. The superficial 3 m consist of dark sandy loam with occasional rounded quartz and lithic fragments some 2.5 mm in diameter, and limonitic nodules of similar size. Quartz and lithic fragments persist throughout the underlying 3 m of coarse sand. Evidence of rotten granite appears at 7.6 m depth and the holes finished at 12 m in compact granite. Again the seismograph indicated the onset of compact granite but failed to identify the sediment/rotten granite interface.

The final hole was drilled through a sand dune about 250 m from the coast on the track to Stumpys Bay. The 3 m of superficial coarse yellow sand with occasional rounded quartz grit fragments is underlain by 6 m of coarse, dark, humus-rich sand with brown-stained quartz and lithic grit fragments. Rotten granite is located 21 m below surface.

Throughout the programme drill samples were cradled and panned for heavy minerals with monotonously disappointing results. Heavy minerals are nowhere common, and when investigated consisted of uneconomic traces of magnetic iron oxides, rutile, zircon, topaz, tourmaline, pyrite, garnet, spinel, and rarely cassiterite. From one bore hole concentrates from every horizon were analysed for tin, which occurred in uneconomic trace amounts in some of the blown sand samples only. The programme was concluded after these uniformly discouraging results, without establishing an ancient buried drainage system or intersecting littoral or fluvial gravel deposits.

When chemical analyses of the Mt William granites were completed a comparison of trace element ratios, with those of established tin-bearing granite (Groves, this Bulletin, p. 70) suggested only a moderate likelihood of the Mt William biotite-muscovite granite being a major tin carrier.

SUMMARY

Reconnaissance geological mapping revealed the presence of a tract of potential tin-bearing granites in the Mount William area. A detailed geological map was produced utilising (as far as possible) the symbols initiated by D.I. Groves. Characteristics of the granites are noted, and their relative ages and form of outcrop discussed where evidence is available. Minor basic and acidic igneous intrusions were observed. Broad tracts of uninterrupted superficial cover were selected for geophysical investigation by resistivity and seismic methods and from these targets were selected for a percussion drilling programme. Drilling indicated a uniform cover composed mainly of blown sand but revealed no fluvial gravels nor economic traces of tin.

REFERENCE

- LEAMAN, D.E.; MOORE, W.R. 1973. Geophysical survey, Mt William area. *Tech. Rep. Dep. Mines Tasm.* 16:86-88.