DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1980/2

GEOLOGY OF THE GILBERTON 1:100 000 SHEET AREA (7659), NORTH QUEENSLAND: DATA RECORD

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I.W. Withnall[1], B.S. Oversby[2], J.H.C. Bain[2] & E.M. Baker[1]

1 Geological Survey of Queensland

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ERRATA SLIP

CORRECTIONS:

Where symbols Ᵽ and Ꞓ appear in notations for Palaeozoic/Permian and Carboniferous rocks, read P and C respectively.

Pre-Mesozoic Faulting (heading, p. 130) is not a 'new name'.

CONTENTS

3

Page

Page

6

Page

Page

4

Page

Figures

9

SUMMARY

The Gilberton 1:100 000 Sheet area, in the central part of the Georgetown Inlier of northeastern Queensland about 300 km west of Townsville, contains mid-Proterozoic metasedimentary and meta-igneous rocks and mid-Proterozoic to Palaeozoic granitoids, locally overlain unconformably by late Devonian to early Carboniferous, Mesozoic, and Cainozoic sedimentary rocks, and Carboniferous to Permian volcanic rocks.

The mid-Proterozoic metasedimentary rocks are assigned to four formations: Bernecker Creek Formation consisting of lower greenschist to lower amphibolite facies calcareous siltstone, sandstone and shale, and its amphibolite facies calc-silicate phase; Robertson River Formation which is mostly non-calcareous siltstone and shale, and subordinate basic volcanics (Dead Horse Metabasalt Member) of lower greenschist to lower amphibolite facies, and its amphibolite facies schist phase; Juntala Schist, similar to the schist phase of the Robertson River Formation but geographically separated from it; Einasleigh Metamorphics which are predominantly upper amphibolite facies biotite and calc-silicate gneiss and subordinate migmatite, quartzite, and schist. Boundaries between Einasleigh Metamorphics, Juntala Schist, and the high-grade phases of the Bernecker Creek and Robertson River Formations are gradational. The Dead Horse Metabasalt is probably comagmatic with basic intrusive rocks in both low and high-grade parts of the Robertson River and Bernecker Creek Formations. Amphibolite in the schist and calc-silicate phases of these formations and in the Juntala Schist and Einasleigh Metamorphics is a higher-grade equivalent of these basic rocks. Metamorphism was of the low to intermediate pressure type.

At least five discrete deformations of regionally variable intensity have affected the Proterozoic rocks. However, apart from rare kinks and weak crenulations, the effects of only the first deformation - i.e. tight to isoclinal folds with east-trending axial planes (slaty cleavage) - are evident in the Robertson River and Bernecker Creek Formations west and northwest of "Gilberton". Second generation folds, which have northeast-trending axial planes, increase in intensity east from "Gilberton"; they range from relatively open structures in the Robertson River Formation to isoclinal folds in the Einasleigh Metamorphics. Third generation folds are open, and have east-trending axial planes. Fourth and fifth generation folds are very open, but little is known of their orientation in the Gilberton 1:100 000 Sheet area. Prograde metamorphism, possibly a single sustained event, accompanied the first two deformation events. The later deformation events were associated locally with mild retrogressive metamorphism, but in much of the area there is little evidence for any metamorphism at all. The ages of the first three deformation events, and accompanying metamorphism, are approximately 1570, 1470, and 970 million years respectively.

Late Devonian to early Carboniferous Gilberton Formation unconformably overlies the Robertson River and Bernecker Creek Formations. It consists predominantly of fluviatile arkose and minor siltstone, which accumulated in depressions and were subsequently disrupted by faulting.

Rhyolitic ignimbrite of the probably Carboniferous Butlers Volcanics overlies the basement rocks in the northeast corner of the Sheet area. A small exposure of similar rocks overlying the Gilberton Formation could be a distal equivalent of either the Butlers or Newcastle Range Volcanics. However, it is equated at present with the Permian Agate Creek Volcanics (basalt or andesite, rhyolitic agglomerate and flows, and some intercalated sediments).

Mid-Proterozoic to Carboniferous plutonic rocks crop out in the Sheet area. The Welfern Granite, Oak River Granodiorite, Sawpit Granodiorite, and Digger Creek Granite are of mid-Proterozoic age; the Mount Hogan Granite is thought to be of late Proterozoic age. The ages of the Anning Granite, Dumbano Granite, Loafers Granodiorite, and Robin Hood Granodiorite are uncertain, but are probably late Proterozoic or Silurian-Devonian. In addition to these named granitoids, various unassigned leucogranitoids intrude the Einasleigh Metamorphics; most are probably of mid-Proterozoic age. The Purkin Granite, and probably the Culba Granodiorite, are Carboniferous in age. The Sawpit Granodiorite, Digger Creek Granite, Loafers Granodiorite, Anning Granite, Dumbano Granite, Culba Granodiorite, and some of the unassigned leucogranitoids constitute the Glenmore Batholith.

The late Palaeozoic Bagstowe Ring Dyke Complex intrudes the Glenmore Batholith. It consists of rhyolite, microgranite, microgranodiorite, and andesite ring dykes, rhyolite cone-sheets, and a microgranite stock. The complex includes three major overlapping ring structures, and may represent a deeply eroded cauldron subsidence area.

A large late Proterozoic or pre-Permo-Carboniferous fault (Gilberton Fault) strikes northeast through the centre of the sheet area, separating high-grade Einasleigh Metamorphics from low-grade Robertson River Formation and its schist phase. Right-lateral displacement may have been as much as 50 km. Only small displacements occurred on other faults in the sheet area. The two most common trends of fault traces are northwest and north-northeast.

Mesozoic sandstone and conglomerate of the Hampstead Sandstone, Loth Formation, and Gilbert River Formation overlie the Proterozoic and Palaeozoic rocks in the western and southern parts of the Sheet area. The Sheet area was uplifted in the Early Pliocene by a combination of tilting, warping, and block-faulting.

Gold and silver were the principal mineral commodities produced from the Sheet area, but copper, lead and minor bismuth, tantalum and tungsten have also been mined. Most of the gold was from alluvial sources, but reefs were also mined in the three main production centres (Gilberton, Mount Hogan, and Percyville). Minor uranium occurs with the Mount Hogan gold deposits.

Mineralisation and exploration in the Sheet area are dealt with only briefly in this report; they are discussed in more detail by Withnall (1976b, and in prep.).

INTRODUCTION

Area of investigation

The Gilberton 1:100 000 Sheet area (7659) covers an area of about 2900 km^2 bounded by latitudes 19°00' and 19°30'S and longitudes 143°30' and 144°00'E. It lies within the Georgetown Inlier about 300 km southwest of Cairns (Figs. 1 and 2).

Object and method of investigation

The mapping of this area was part of the Georgetown Project, a joint Bureau of Mineral Resources (BMR) and Geological Survey of Queensland (GSQ) project which aims primarily to assess the mineral resource potential of the Georgetown Inlier.

In the first stage of this project, the aim was to map three 1:100 000 Sheet areas (Georgetown, Forsayth, and Gilberton) which form a north-south strip through the central part of the Georgetown Inlier (Fig. 1). This strip was chosen because it contains most of the rock types, structures, and mineral deposits that characterise the inlier, and is easily accessible; it also appeared to offer the best chance of containing solutions to some of the stratigraphic problems outlined by earlier mapping. The Forsayth and Georgetown Sheet areas were mapped in 1973 and 1974 and are described by Bain & others (1976a) and Oversby & others (1978) respectively. Gilberton was mapped in June-July 1975 by Bain, Oversby (both BMR), Withnall and Baker (both GSQ). Withnall and Bain did several weeks of additional fieldwork in the area in 1978.

Coloured airphotos were used for photo-interpretation and to locate and record field data. The data, on transparent overlays, were compiled at photo scale, and the resulting sixteen compilation sheets were reduced to 1:100 000 scale, (Bain & others, 1976a). The reduced compilation sheets have been combined with a legend and references to form the accompanying preliminary edition of the Gilberton 1:100 000 geological sheet.

Annotated airphoto overlays and notebooks are held at BMR. Field numbers assigned to observation points (and accompanying hand specimens where collected) are made up of photo run/photo number/observation number. Thin sections have registered numbers, generally prefixed by 7530, and are held at BMR.

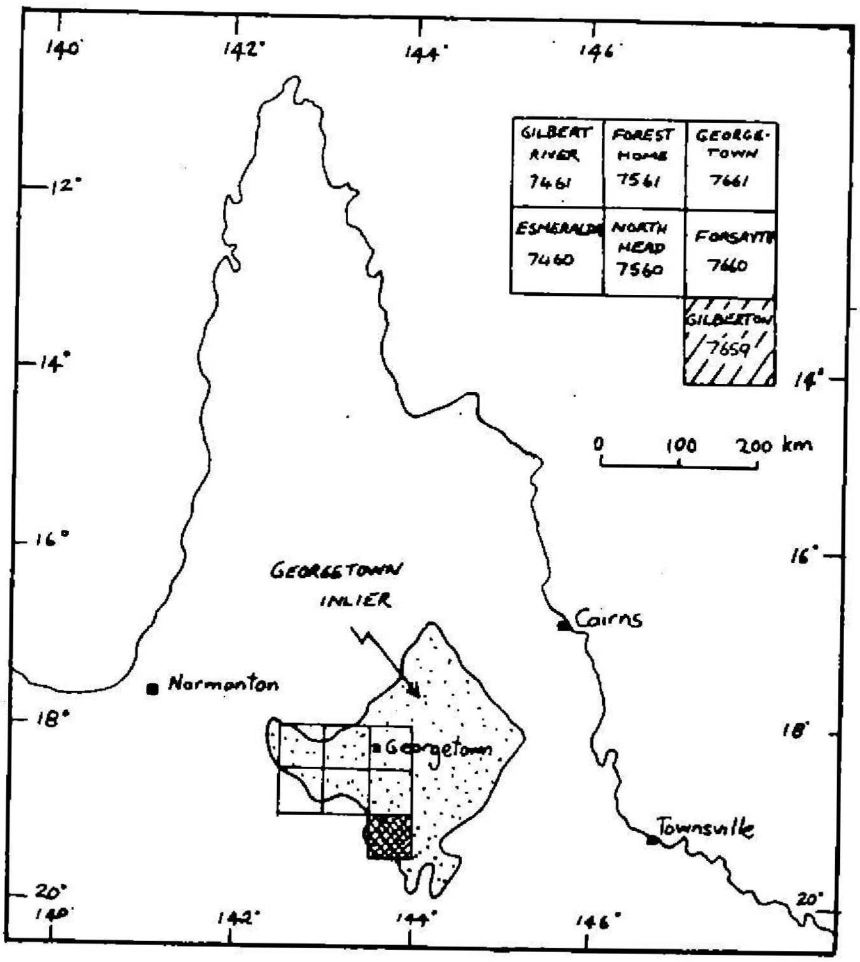


FIG. 1 LOCATION

Record 1980/2

The Sheet area was mapped by both vehicle and helicopter-supported traverses. The party was based near "Gilberton" homestead in the centre of the sheet area. Twenty-four man-weeks were devoted to vehicle traversing (four of these in 1978); a normal week consisted of five days on traverse, and one to two days in the camp, compiling overlays and doing photo-interpretation. A further eight man-weeks were spent on helicopter-supported traverses and spot checking.

Geochemical and geophysical studies are also being carried out in the Gilberton Sheet area. A stream sediment geochemical survey of the entire Sheet area was completed in 1976. A gravity survey was conducted over the Agate Creek Volcanics in 1978. The metamorphic and some granitic units were sampled for age determination by the Rb/Sr method in 1975. The results of these various studies will be reported on separately although some preliminary results are incorporated in this Record.

The mines and mineral deposits are described by Withnall (in prep.).

Access (Figs. 2 and 3)

Access to the Gilberton Sheet area is by unsealed road from Einasleigh, the nearest railhead; the distance from Einasleigh to Gilberton is about 140 km. Einasleigh is connected by partly sealed roads to Townsville via Greenvale, and to Cairns via Mount Garnet; the railway connects Einasleigh with Cairns via Almaden. Graded roads connect the station homesteads in the sheet area with the Einasleigh-"Gilberton" road. Networks of tracks to bores, yards, and dams are present on most of the grazing properties.

The nearest post office, telephone, and serviceable airstrip are at Kidston on the Einasleigh-"Gilberton" road, about 100 km by road from "Gilberton" homestead.

Settlement (Fig. 3)

No settlements other than station homesteads occur within the sheet area. Six station homesteads are occupied permanently; the remainder are abandoned, or serve as outstations. Cattle grazing is the sole industry. The main service and administrative centre for the district is Georgetown, about 250 km by road from Gilberton homestead. Georgetown is the headquarters of the Etheridge Shire council, and contains the office of the Warden for the Georgetown Mining District.

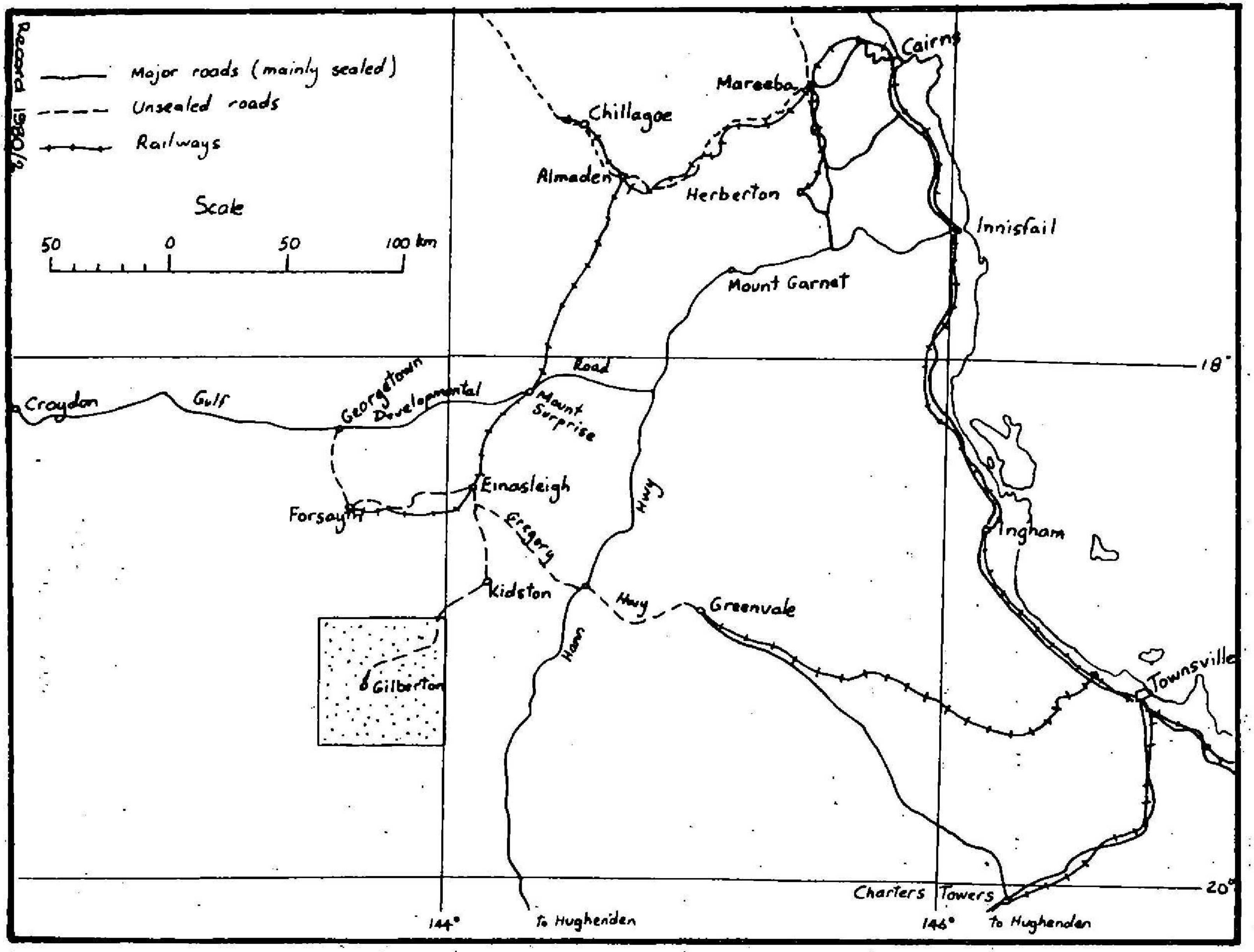


Fig. 2 – Cairns - Townsville hinterland showing location of Gilberton 1:100 000 Sheet area and main access routes

Relief and drainage (Fig. 4)

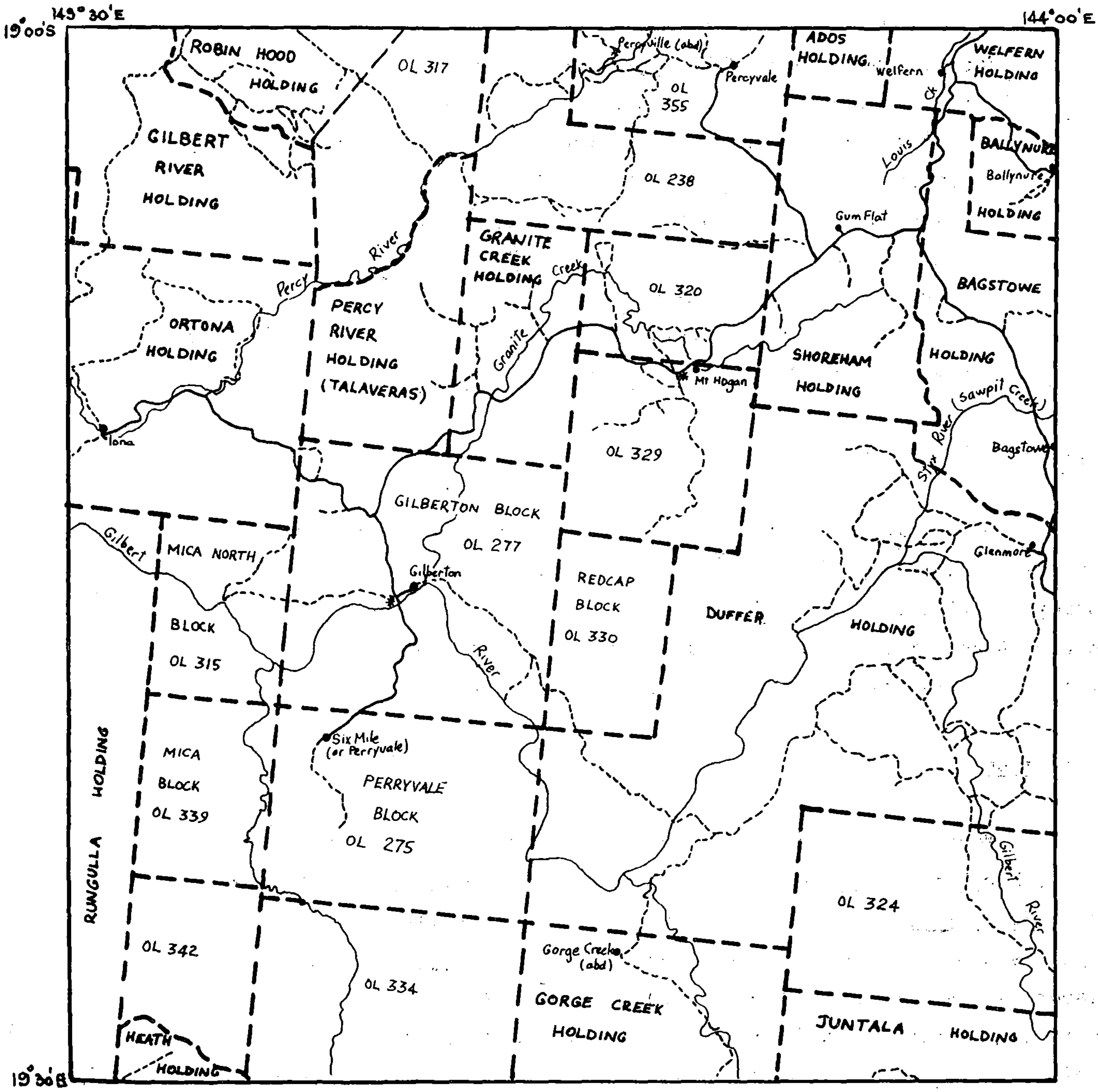
Most of the area is hilly; elevations are between 420 and 970 m above sea level, being highest in the southeast. Although the area is rugged and closely dissected, local relief rarely exceeds 150 m, except in the Gorge Creek area, where it is over 200 m. Dissected plateaux and mesas of Mesozoic sedimentary rocks cover much of the western and southern parts of the Sheet area; the southern part of the Sheet area impinges on the undissected Gilberton Plateau, the highest part of the Gregory Range. The Gilbert River and its tributary, the Percy River, drain most of the area; streams in the northeast corner are part of the Einasleigh-Copperfield River system.

Climate

The climate is humid tropical to semi-arid with warm to hot humid summers and warm to cool dry winters. Frosts are occasionally experienced during the winter months. Annual rainfall is 600 to 700 mm, most falling between November and March although there are occasional falls during the winter. For additional data, refer to Perry (1964).

Vegetation

Most of the area is covered by ironbark woodland consisting predominantly of Eucalyptus crebra (ironbark) and Eu. dichromophloia (bloodwood); many other Eucalyptus species are present but are less common. A sparse low tree layer is also present. Lancewood scrub (Acacia shirleyi) is common on areas of dissected Mesozoic sandstone, and on parts of the Gilberton Formation where soil is thin or absent; ironbark woodland occurs on the more extensive plateau surfaces. The most common grasses are the three-awns (Aristida spp.), kangaroo grass (Themeda australis), spear grass (Heteropogon australis), and ribbon grass (Chrysopogon fallax). Spinifex (Triodia spp.) occurs in the Ortona area on both metasediments and Hampstead Sandstone; it is also particularly common on the wide bench formed by the Loth Formation, around the edge of the Gilberton Plateau. For other details refer to Perry (1964).



graded road

vehicle track (1978)

major stream

boundaries of pastoral holdings & occupation leases (from Department of Lands Four Mile Series Cadastral map, 4M 37 N.S. - 1970)

• Welfern homestead

(abd) abandoned

* abandoned townsite

0 5 10 km

Fig 3 : Settlement and access, Gilberton Sheet area

Record 1980/2

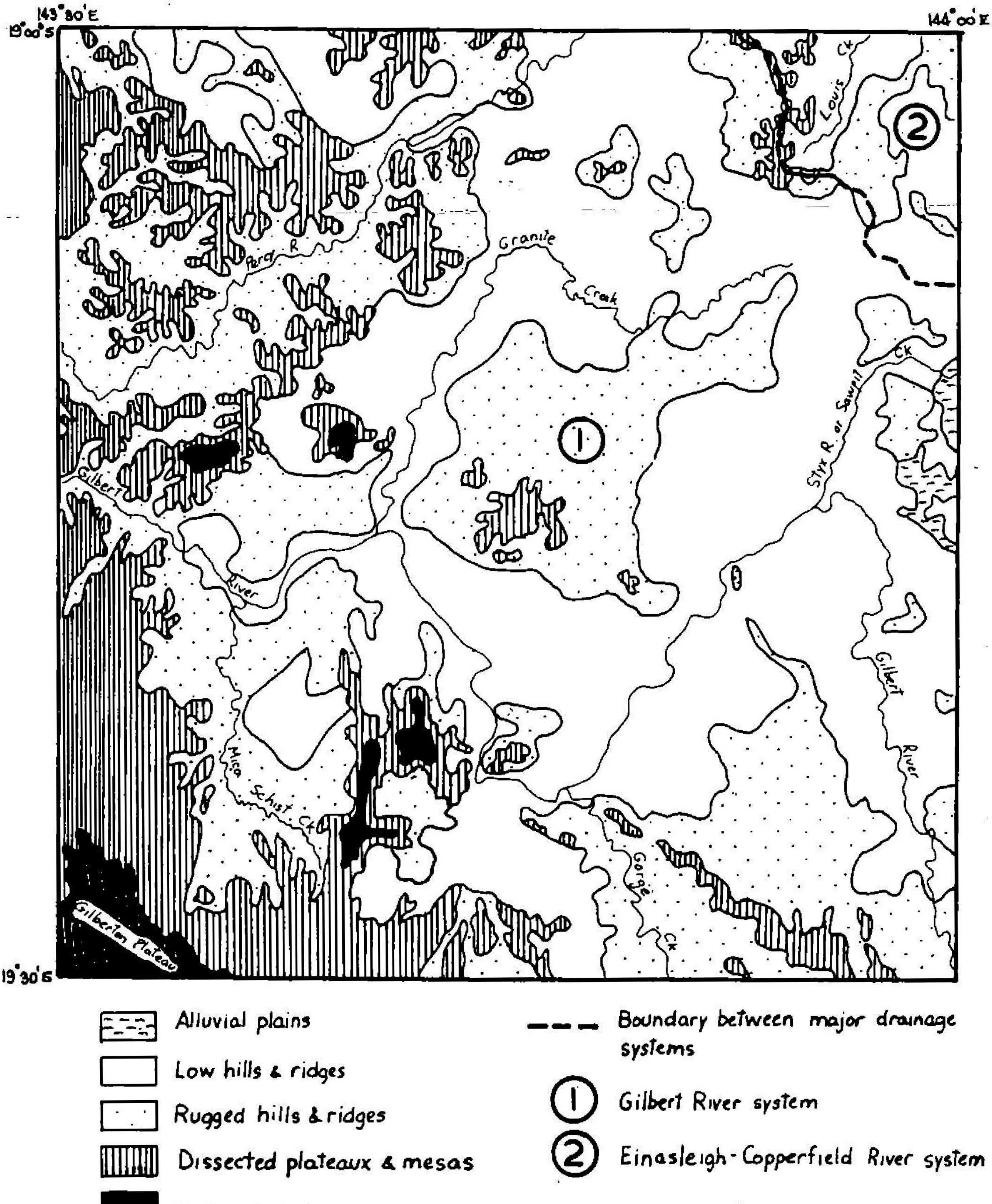


Fig 4: Relief and drainage, Gilberton Sheet area
Record 1980/2

Previous geological investigations

A summary of previous geological work, up to and including the BMR-GSQ 1:250 000 scale regional reconnaissance in 1956-59, was given by White (1965). However, White omitted to cite the work of Daintree who in 1869 made the first important geological observations in the area (Queensland Legislative Assembly, 1869a, b, c). Branch (1966) described the Late Palaeozoic igneous rocks of the Georgetown Inlier, including those in the Gilberton 1:100 000 Sheet area. Sheraton & Labonne (1978) collected and analysed specimens of some of the Proterozoic and Palaeozoic acid igneous rocks in the area as part of a regional study of the geochemistry of these rocks. Richards & others (1966), Black (1973), and Black & others (1979) isotopically dated granitic and metamorphic rocks from the area. Black's work is continuing. Exploration company activity in the area up to mid-1976 was summarised by Withnall (1976a).

Acknowledgements

We gratefully acknowledge the assistance, both direct and indirect, of our colleagues at BMR and GSQ, particularly Lance Black. Permanent and temporary field staff who assisted with the mapping were Jim Pollard, Kjell Ellingsen, Robin Wills, Claire Jollife, and Ian Chandler (field hands). Joe Mifsud (BMR Geological Drawing office) transferred the data from airphoto overlays to the field compilation sheets. Bob Rapkins (Mines Department Drafting Branch) drew the Preliminary Edition map.

We are indebted to geologists of various mining companies who participated in a free exchange of information, in particular Peter O'Rourke (Central Coast Exploration NL), Peter Onley (CRA Exploration Pty Ltd), and Jim Shaw (AGIP Nucleare Pty Ltd). Tim Bell, Mike Rubenach, and Peter Llewellyn of James Cook University have undertaken detailed studies of Proterozoic metamorphic rocks in several areas, complementing our regional coverage.

Local land-holders gave us friendship and ready assistance at every opportunity, in particular Mrs Michellmore and her late husband, Tom, of "Gilberton", Eddie Hoolihan of "Iona", the Dixons of "Bagstowe", and the Lethbridges of "Glenmore". Tom Michellmore's help in locating and identifying many mines of the old Gilberton field was an important contribution.

21

PROTEROZOIC METAMORPHIC ROCKS

STRATIGRAPHIC NOMENCLATURE

Fieldwork in 1977-78 in the nearby North Head and Forest Home 1:100 000 Sheet areas has recently permitted revision and rationalisation of the stratigraphic nomenclature of most of the Proterozoic metamorphic rocks of the Georgetown Inlier (Withnall & Mackenzie, in press; Withnall & others, in press). Consequently the stratigraphic nomenclature used in this section differs from that used on the Preliminary edition of the Gilberton 1:100 000 Geological Series map issued in 1977, as outlined below:

1. the Etheridge Formation has been raised to group status and extended to include (in the Gilberton Sheet area) the Bernecker Creek Formation, Robertson River Formation, Einasleigh Metamorphics and Juntala Schist;

2. the rocks shown as Etheridge Formation on the 1977 Preliminary edition map are now part of the Robertson River Formation;

3. the Robertson River Metamorphics are Robertson River Formation (schist phase);

4. the calc-silicate facies of the Robertson River Metamorphics (map unit Pmr_3) is the calc-silicate phase of the Bernecker Creek Formation.

BERNECKER CREEK FORMATION (Pmb)

Introduction

White (1959b) defined the Bernecker Creek Formation as a calcareous sequence underlying the Etheridge Formation, and designated Bernecker Creek as the type area; no type section was specified or described. Our mapping has shown that calcareous rocks are not as common in Bernecker Creek as White suggested and probably represent no more than the uppermost few hundred metres of the Bernecker Creek Formation, exposed in the cores of anticlines. It has not been possible to map out the calcareous rocks in White's type area because the structure there is relatively complex and poorly known, and because the outcrops are leached and consequently difficult to distinguish from otherwise similar non-calcareous sediments.

A reference section is described as no suitable type section has been found in Bernecker Creek. The section, in the Percy River near the Ortona copper mine, between GR 645764 (lowermost exposed part of the unit) and GR 633788 (top of the unit), contains about 2000 m of calcareous to non-calcareous siltstone and well-bedded, fine to medium-grained calcareous quartz sandstone.

The Bernecker Creek Formation corresponds with the "Mount Moran Formation" of White & Hughes (1957).

The Bernecker Creek Formation (excluding the calc-silicate phase) crops out over about 90 km^2 in three main areas: (a) south from the Lower Percy stock camp for 6 km; (b) east from the Ortona mine for 11 km; and (c) west-southwest from the Iona turnoff for 8 km.

The Bernecker Creek Formation has been metamorphosed to greenschist and amphibolite facies. The calc-silicate gneiss of the high-grade part of the Formation is described separately as Bernecker Creek (calc-silicate phase).

The Bernecker Creek Formation crops out in hilly well-dissected country, relatively recently exhumed from beneath Mesozoic cover rocks. Outcrop is good, the best exposures being in the Percy River.

Lithology and petrography

The Bernecker Creek Formation consists mainly of phyllitic siltstone and shale (See Appendix I), and in places fine sandstone. The rocks are generally calcareous, and impure limestone crops out locally. Purer limestone lenses apparently occur, as locally derived limestone was used as flux and burnt for lime at some of the gold mines; none were located during this survey. Sandstone and siltstone are more abundant than in the Robertson River Formation, and generally more abundant than shale, e.g. near Ortona and in the Eight Mile area.

The rocks are usually various shades of green, buff, and grey. They are well-bedded and/or laminated, laminae and beds ranging from 1 to 30 cm; cross laminae, ripple laminae, small slump structures, and scour channels are common in siltstone and sandstone (Figs. 6-11). A cleavage is commonly developed. Sandstone dykes are present in places. Limonite and hematite pseudomorphs after pyrite are common.

The boundary between the Bernecker Creek Formation and Robertson River Formation is gradational and probably interfingering; it is marked by a change from predominantly calcareous to predominantly non-calcareous rocks. Precise location of the boundary is difficult in places where the carbonate rocks have

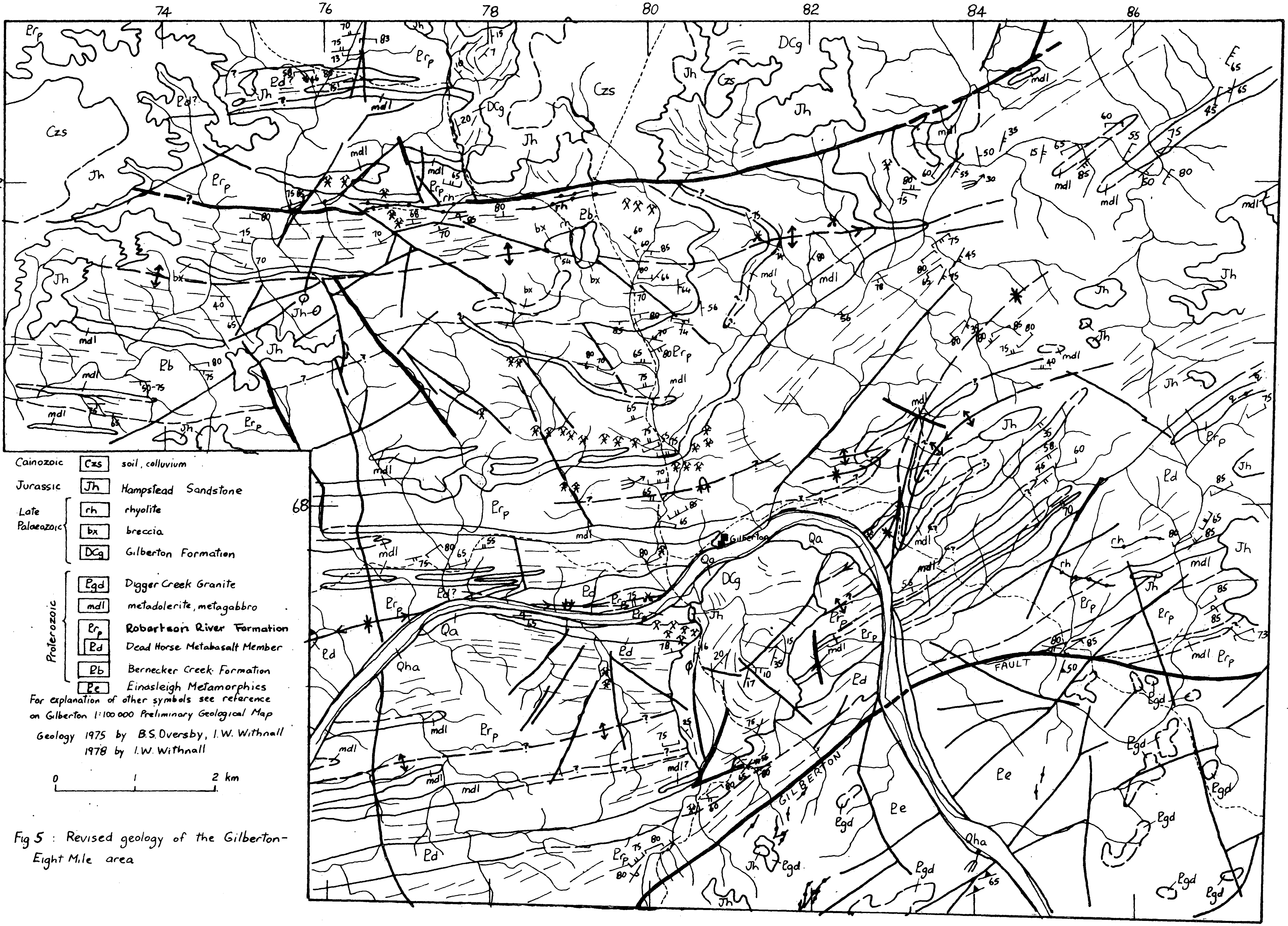


Fig 5 : Revised geology of the Gilberton-Eight Mile area been leached. The photo-patterns of the two units are difficult to differentiate, but that of the Bernecker Creek Formation tends to have a slightly more reddish tone.

Petrographically the rocks of the Bernecker Creek Formation are similar to their non-calcareous equivalents in the Etheridge Formation except for the presence of calcite, which forms discrete grains up to 0.2 mm across. The shales and siltstones consist of quartz, sericite, and chlorite in various proportions. The amount of calcite ranges from traces in the shale, to 80 percent in the impure limestone; generally it is less than 20 percent.

The sandstones are generally feldspathic, and as well as quartz, contain up to 20 percent plagioclase, with minor microcline and detrital muscovite; siltstone clasts are present locally. Some sandstones have grains up to 0.75 mm across but the average grainsize is mostly 0.1 mm or less. The calcite in the sandstone may have originally been a cement, now recrystallised to discrete grains, or a fine limey mud which may have formed part of the matrix. Tourmaline is an accessory in all of the rocks, and zircon is present in the sandstone.

Towards the east and north, where the metamorphic grade increases, biotite becomes more common than chlorite.

Relation to other units

The Bernecker Creek Formation grades into the calc-silicate phase, and is overlain conformably by the Robertson River Formation. Proterozoic metadolerite and metagabbro sills and dykes, and Permian or Carboniferous rhyolite dykes, intrude the Bernecker Creek Formation. The Devonian-Carboniferous Gilberton Formation, Permian Agate Creek Volcanics, and Jurassic Hampstead Sandstone unconformably overlie the unit.

Thickness

The thickness of the Bernecker Creek Formation is not known because the base is nowhere exposed. Almost 2000 m is exposed on the northern limb of the anticline near Iona homestead. However, this is a very approximate figure, because of probable repetition of this sequence by minor folds, and thinning and thickening in the fold limbs and axial zones.

Fig 6: Small scale cross-stratification and scour-and-fill structure in calcareous sandstone (Bernecker Creek Formation) Percy River near Ortona copper mine (GR 639776). Negative M2382/11.

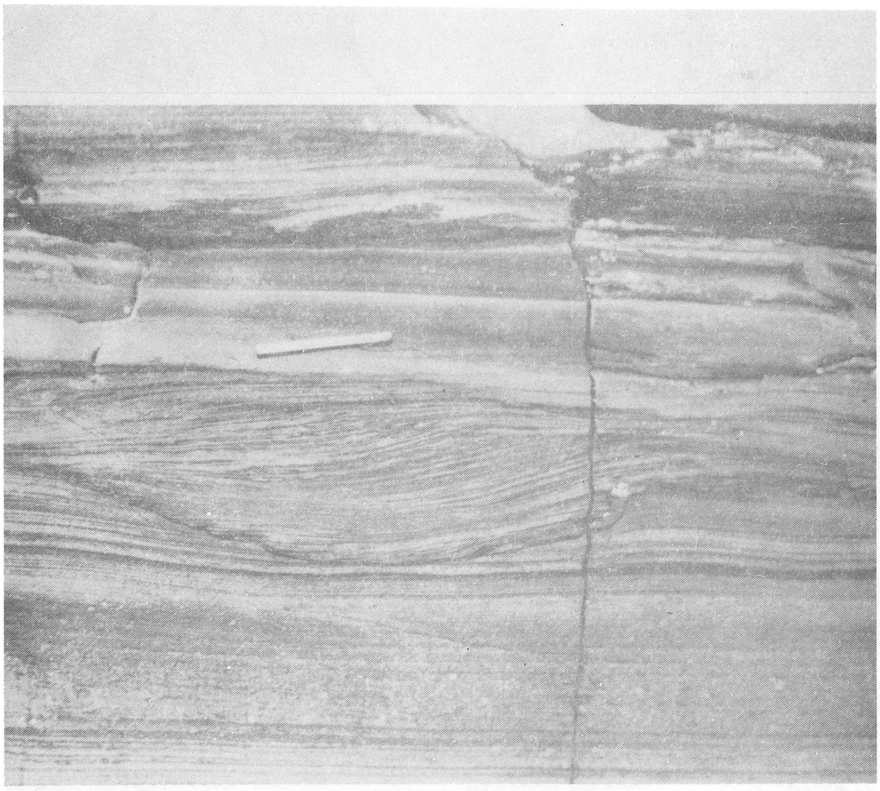


Fig 7: Scour-and-fill structure in fine calcareous sandstone (Bernecker Creek Formation). Percy River near Ortona copper mine (GR 639778) Negative M2382/10

Fig 8: Well bedded and laminated, buff to reddish brown siltstone (Bernecker Creek Formation). Percy River at "Iona" homestead (GR 648761) Negative GB 1497.

Fig 9: Small-scale cross stratification in calcareous sandstone (Bernecker Creek Formation) Percy River near Ortona copper mine (GR 639776) Negative GB 1482

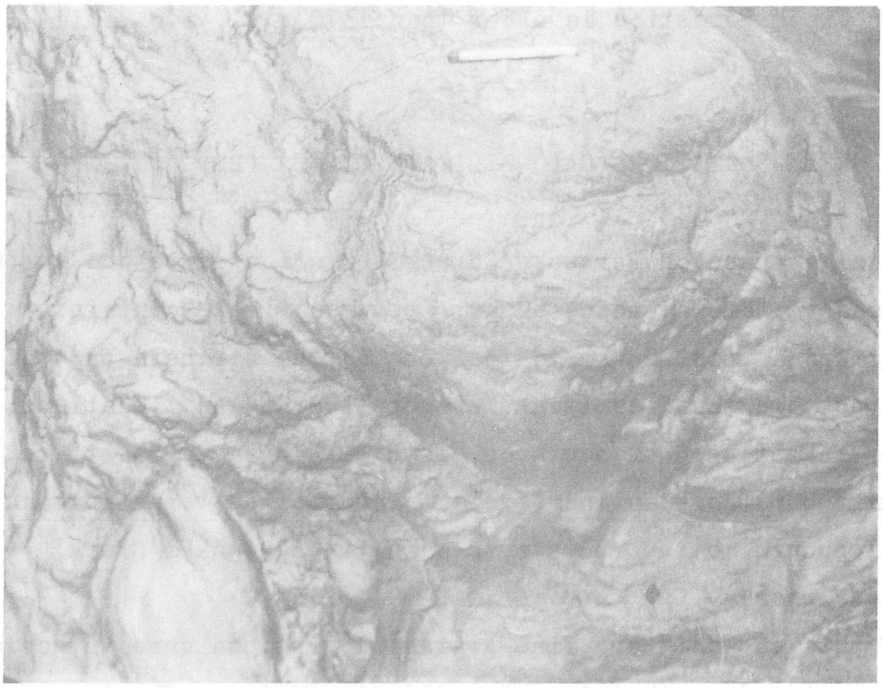


Fig 10: Load casts on the base of a sandstone bed (Bernecker Creek Formation). Same locality as Fig 9. Negative M2382/1A

Fig 11: Flute casts (Bernecker Creek Formation). Field of view about 40 cm wide. Same locality as Fig 9. Negative M2382/12

Age

The Bernecker Creek Formation is older than 1570 m.y., i.e., mid-Proterozoic or older.

BERNECKER CREEK FORMATION (CALC-SILICATE PHASE) (Pmr_3)

The calc-silicate phase of Bernecker Creek Formation crops out in two main east-trending areas (totalling about 60 km^2) between Black Mountain (GR132865) in the east and a point 26 km to the west in the northern part of the Sheet area. Similar rocks in the Einasleigh Metamorphics at many locations, and in the Robertson River Formation 5 km south of Tin Hill (Forsayth Sheet area), may be part of this unit but there is insufficient information to establish their correlation well enough to incorporate them in the Bernecker Creek Formation (calc-silicate phase).

The rocks of this sub-unit are fine-grained layered calcareous schist and quartzite grading east and north into calc-silicate gneiss. The layering is primary, and ranges in thickness from less than one centimetre to over a metre. In some cases small scour channels and sedimentary cross-laminae are preserved (in the more highly deformed rocks, oblique sections of intrafolial folds can be confused with cross-laminae).

The rocks are generally foliated but less so than the metapelites of the schist phase of the Robertson River Formation; the foliation is parallel to the layering. One or more sets of later folds deform the foliation locally. The more highly deformed rocks in the eastern part of the outcrop area contain intrafolial folds within the layers.

The outcrops show typical carbonate surface features such as solution channelling and differential weathering forms.

Petrography

The rocks of this sub-unit show great petrographic variation. The high-grade calc-silicate gneisses in the eastern part of the outcrops area are similar to those in the Einasleigh Metamorphics (see pp. 42-43) and are not described here in detail. In brief they consist of layered rocks containing various proportions of quartz, microcline, plagioclase, hornblende, clinopyroxene, epidote, scapolite, garnet, and accessory sphene.

The medium-grade rocks (lower or middle amphibolite facies) are fine-grained (0.1 to 0.5 mm), grey to greenish grey, and well laminated. They consist of quartz, microcline, plagioclase, epidote, biotite, muscovite, hornblende, and clinopyroxene. The clinopyroxene belongs to the diopside-hedenbergite series. Calc-silicate assemblages containing hornblende and clinopyroxene formed at higher grades than those in which biotite is the main mafic mineral.

Granoblastic to granuloblastic quartzo-feldspathic and calcite layers alternate with layers containing biotite, hornblende, and/or clinopyroxene. Some of the fine layers are almost mono-mineralic microcline, calcite, or clinopyroxene. The foliation (S_1) is defined by biotite, hornblende, and muscovite, and is parallel to the layers; these minerals also form grains which cut across S_1 at low angles and are aligned parallel to S_2. The same minerals commonly define both S_1 and S_2 suggesting that the grades of metamorphism during D_1 and D_2 were similar.

Hornblende commonly also forms randomly orientated skeletal porphyroblasts up to 5 mm across. According to Llewellyn (1974) these were formed in response to contact metamorphism by the Mount Hogan Granite. However, the lack of a conspicuous aureole where the granite intrudes the lower-grade Robertson River Formation suggests the hornblende porphyroblasts in the calc-silicates may be due to earlier regional metamorphism.

Poikiloblastic grains of scapolite up to 2 mm across form up to 30 percent of some layers. The high birefringence suggests a Ca-rich composition in the range Me_{70-80}. The grains are commonly turbid, and locally are partially altered to epidote. Microcline also locally forms poikiloblastic grains up to 1 mm across enclosing biotite and quartz.

Sphene, apatite, zircon, and tourmaline are present as accessories.

ROBERTSON RIVER FORMATION (Emt)

Introduction

The Robertson River Formation crops out over about 500 km^2, mostly in the northwestern quarter of the Gilberton 1:100 000 Sheet area. It consists of low-grade fine-grained metasediments, and basic metavolcanics (the Dead Horse Metabasalt Member). The unit is more extensive to the northwest in the North Head and Forest Home 1:100 000 Sheet areas.

30

Good outcrop is restricted to watercourses, the best exposures occurring along the Gilbert and Percy Rivers, and Six Mile and Mica Schist Creeks.

Metasedimentary rocks

Lithology

The metasediments are predominantly slaty and phyllitic shale and siltstone (see Appendix I); overall, shale predominates over siltstone. The shale and siltstone are commonly green, grey-buff, or purple, finely laminated and thinly bedded. The laminae range from less than a millimetre to several centimetres in width, but massive beds of siltstone up to several metres thick are also present in many places. Siliceous siltstone layers are more resistant to weathering than the shale; locally the siltstone grades into fine sandstone. The laminated shale and siltstone commonly have a well developed bedding fissility in addition to a slaty cleavage. Where the two structures are almost parallel, the outcrops are particularly fissile. Areas of unbedded phyllite or phyllitic shale also occur.

Scour channels and small cross-laminae are commonly well preserved in the siltstone and fine sandstone. Small sandstone or siltstone dykes up to 10 cm wide cut the shale in places (Fig. 12). White & Hughes (1957) noted slump folds in the rocks in Bernecker Creek. "Devil's dice" (limonite pseudomorphs after pyrite) are present locally, for example near "Gilberton". Beds of intraformational breccia consisting of dark grey angular shale clasts up to 4 cm in maximum dimension in a sandy matrix are present near the large bluff at Eight Mile Waterhole on the Gilbert River; some of the beds show normal grading.

Beds of fine calcareous sandstone and siltstone containing large ellipsoidal structures are exposed in several localities. The structures were observed in the Gilbert River at three localities: (a) near the Irrigation and Water Supply Commission gauging station (GR 830 668); (b) near the bluff at the Eight Mile Waterhole (GR 708 670); and (c) at GR 756 637 (Fig. 13). In all three cases these occupy a stratigraphic position within 200 m of the base of the metavolcanics, and may represent a single horizon. The structures range from about 20 cm up to 1 m in length; they lie parallel to bedding, showing little flattening parallel to the cleavage. They contain a central core which consists of a calcite lacework commonly formed of a mass of small spheroidal bodies up to 3 mm across, each containing a core of detrital quartz grains. It is possible that the central parts of the ellipsoidal structures are of organic

91

origin, the outer shell being concretionary. Some form of carbonate-secreting algae may have bound patches of sand and silt together, later outward migration of carbonate having occurred during diagenesis or metamorphism. The "fossils" referred to by White & Hughes (1957, p. 9) in the "Mount Moran Formation" (a preliminary informal name used by White & Hughes for the Bernecker Creek Formation) may have been these structures.

Other calcareous rocks in the Robertson River Formation are present in Bernecker Creek, and within the folds just west of the Mount Hogan Granite. These and the calcareous rocks exposed in the Gilbert River between Gilbertson and the Eight Mile Waterhole probably represent the transition between the Robertson River Formation and the underlying Bernecker Creek Formation.

South of the Gilbert River prominent beds of grey quartzite up to 50 m thick form markers, useful in determining direction of movement along faults.

Petrography

The phyllite and phyllitic shale in the Robertson River Formation consist of quartz, sericite, chlorite, in some places biotite (depending on the grade of metamorphism), and iron oxides; tourmaline is the most common accessory mineral. The grainsize is generally in the range 0.01 to 0.05 mm. Chloritoid is present locally, particularly in the northwestern corner of the Sheet area, as small flakes up to 1 mm across in greenish grey phyllite and slate; the flakes generally cut across the foliation at a low angle, but have no definite preferred orientation.

Laminae are due to different proportions of quartz and phyllosilicates, as well as iron oxides and carbon.

The usually well developed cleavage is represented by: 1/ thin films or layers of phyllosilicates, commonly iron-stained, alternating with quartz-rich layers up to 0.2 mm wide and containing randomly orientated phyllosilicate flakes (domainal) (Fig. 14); and 2/ parallel phyllosilicate flakes uniformly distributed through the rock (non-domainal).

A bedding fissility is common in the laminated rocks, and appears to be largely due to the alternation of thin quartz-rich laminae with laminae rich in phyllosilicates.

Locally a strong crenulation cleavage (S_2) cuts across the earlier cleavage (S_1). The crenulation cleavage planes are 1 to 3 mm apart; metamorphic differentation and growth of muscovite has occurred along these planes (Fig. 15) in some specimens.

32

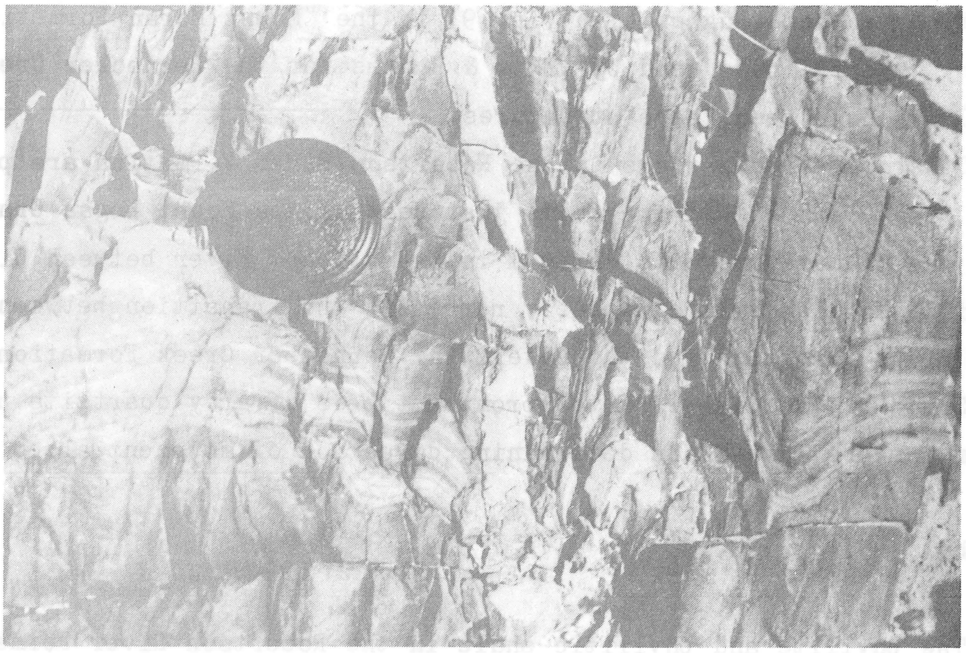


Fig 12: Sandstone dyke cutting laminated siltstone. (Robertson River Formation). Percy River at GR 758837. Negative GB 1486.

Fig 13. Large ellipsoidal concretion in calcareous sandstone (Robertson River Formation). Gilbert River 6 km southwest of "Gilberton" homestead at GR 756637. Negative GB 1464

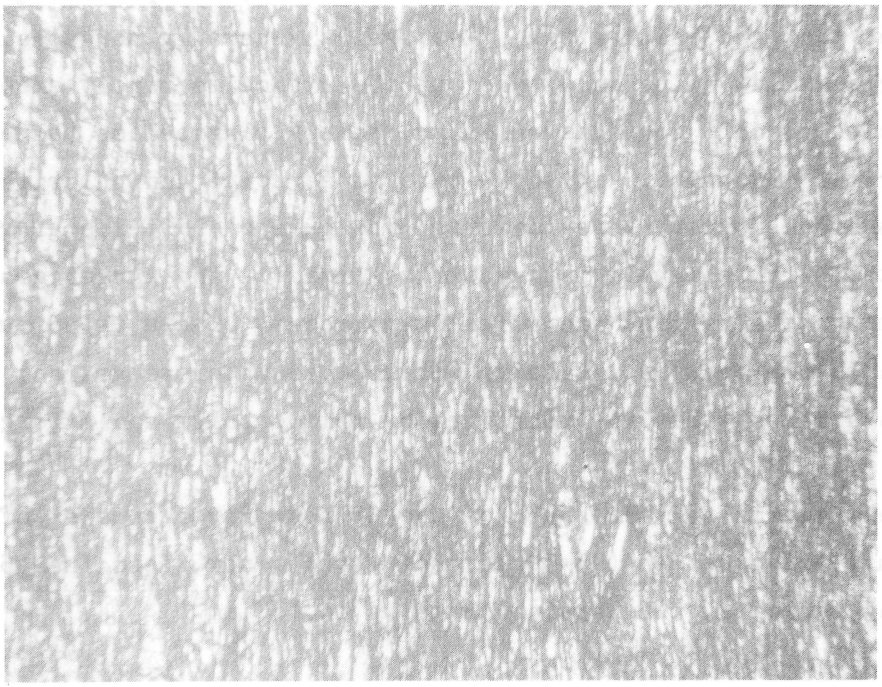


Fig 14. Photomicrograph showing well-developed domainal slaty cleavage; thin films of parallel chlorite and sericite separate quartz-rich layers containing randomly orientated phyllo-silicates. Specimen 75300379. Magnification x 60 (plane polarised light). Negative M2382/16.

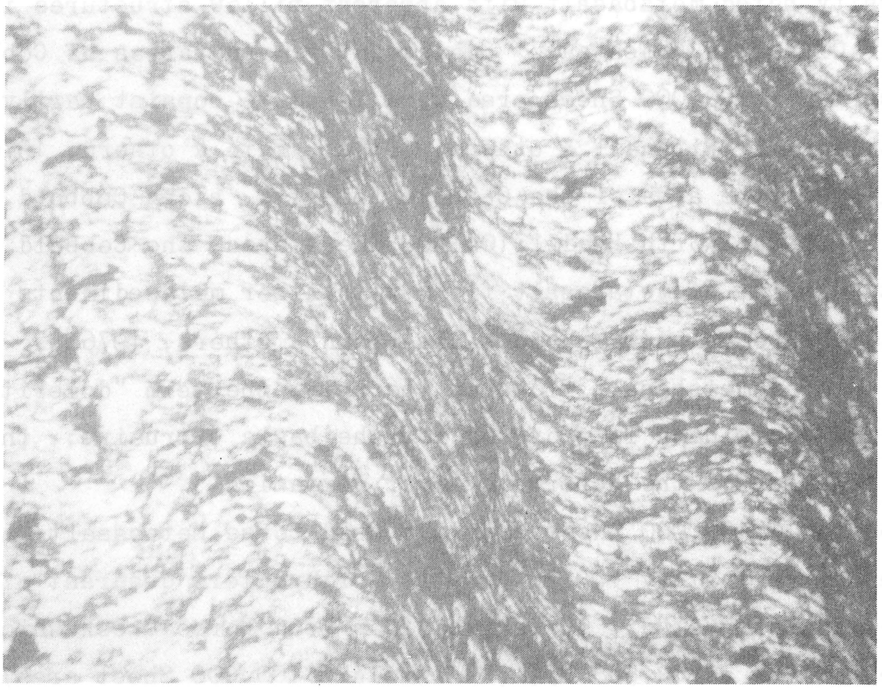


Fig 15: Photomicrograph showing well-developed differentiated crenulation cleavage S_2 cutting across S_1. Specimen 75300320. Magnification x 25 (plane polarised light). Negative M2382/14

The phyllitic siltstones are similar to the shales, except that quartz is more abundant than the phyllosilicates. Cleavage is generally non-domainal.

Siltstone grades into fine sandstone but the grainsize rarely exceeds 0.1 mm. The sandstone commonly contains feldspar, mainly plagioclase (altered to albite), and detrital muscovite. Up to 20 percent sericite and chlorite in the sandstone represents a former clayey matrix. The quartz and feldspar grains are strongly compacted, with slightly interlocking margins; the larger grains are subrounded, although the margins are slightly corroded. There is no cement except for minor quartz overgrowths. Calcite (present as discrete grains) may originally have been a cement that was mobilised by metamorphism and strong deformation.

The prominent quartzite beds south of the Gilbert River consist of quartz (60-70 percent), plagioclase (25-30 percent), and minor (less than 5 percent) chlorite and sericite. The grainsize is up to 1.0 mm.

<u>Dead Horse Metabasalt Member</u> (Pmt_1)

Introduction

Basic igneous rocks of Proterozoic age are common in the Georgetown Inlier; they were all originally thought to be intrusive, and were assigned to a single unit, the Cobbold Dolerite (White, 1959b). In 1973, Dr M.J. Rubenach of James Cook University noted metabasalt with apparent pillow structures in Cobbold Dolerite near Gilberton homestead. Subsequently, many areas of Cobbold Dolerite in the Gilberton 1:100 000 Sheet area were found to consist partly or wholly of metabasalt flows. (Withnall & others, 1976a; Bain & others, 1976b).

In the nominated type area of the Cobbold Dolerite, along Cobbold Creek (White, 1959b, p. 446) in the North Head 1:100 000 Sheet area, the Cobbold Dolerite was found to consist of metabasalt flows with minor metasediments and only subsidiary metadolerite and metagabbro sills (Bain & others, 1976b). Because of the abundance of metabasalt flows in the unit, the term "dolerite" is not appropriate. Hence a new name is proposed for the basic extrusive: the Dead Horse Metabasalt Member of the Robertson River Formation.

In the Gilberton 1:100 000 Sheet area the Dead Horse Metabasalt (Pmt_1) crops out over approximately 100 km^2 in the northwestern quadrant of the Sheet area. The name of the unit is derived from Dead Horse Creek which flows into the Gilbert River at GR 588 834 (Bellfield 1:100 000 Sheet area). It is formally defined by Withnall & Mackenzie (in press).

The metavolcanics can be recognised on coloured airphotos by their reddish brown photo-pattern, although thin layers are difficult to distinguish from intrusive basic rocks; belts of basic rocks more than 2 km wide are most likely to be mainly volcanic. Good outcrops occur mainly in watercourses, where extrusive structures such as pillows may be clearly displayed.

The Dead Horse Metabasalt consists mainly of lava flows, with minor interbedded shale, siltstone, and quartzite. In much of the outcrop area the metabasalts are massive, and only the fine grainsize indicates that the rocks are probably parts of flows rather than intrusives. However, unambiguous extrusive structures such as pillows, amygdales, and hyaloclastites were observed in enough places to confidently assign most areas of metabasalt to the sub-unit.

The pillows (Figs. 16 and 17) generally range from 20 cm to 1 metre in diameter; finer-grained selvedges, vesicles, and amygdales, and radiating cooling joints filled with silica or calcite are commonly preserved. Where good exposures occur, even the "massive" flows commonly have curved joint surfaces suggestive of pillows. Many pillows observed were not noticeably distorted in spite of the tight folding. Those exposed along the Ortona-Agate Creek track at GR 636 844 are the most distorted, indicating a higher strain in this area than elsewhere; the pillows there are flattened parallel to the axial planes of the large folds, and to slaty cleavage in the interbedded metasediments; the metabasalt in such outcrops is commonly folidated.

Hyaloclastites (Fig. 18 and 19) consist of irregular fragments of metabasalt, some of which show curved surfaces with fine-grained selvages indicating that they are fragments of pillows; the matrix to these fragments and also the material locally filling interstices between pillows consists of white siliceous material commonly containing epidote.

Outcrops of metadolerite and metagabbro occur locally in the areas mapped as metabasalt; they probably represent sills and/or dykes but are difficult to map because their photo-pattern is similar to that of the metabasalt.

Petrography

The metabasalts are fine-grained, green rocks consisting of albite, epidote, chlorite, actinolite or hornblende, calcite, sphene, and opaques; minor quartz is present. Albite commonly forms randomly orientated laths up to 0.5 mm long which preserve the original igneous texture. The matrix consists of pale green acicular actinolite, pale yellow or colourless epidote, aggregates of fine chlorite flakes, sphene, and opaques. The average grainsize is 0.1 to 0.5 mm. South of the Gilbert River near the Gilberton Fault, where the rocks are of upper greenschist facies grade, hornblende is present instead of actinolite. Up to 10 percent calcite is present in some unfoliated metabasalt. Amygdales are filled with quartz, minor epidote, and/or calcite. Chalcopyrite is generally present in trace amounts, either disseminated through the metabasalt or in the amygdales.

In the foliated metabasalt the igneous texture is less commonly preserved. The foliation is defined by calcite and chlorite, or by anastomosing fractures less than 0.5 mm apart, filled with brown, iron-stained chlorite.

The fragments in the hyaloclastites consist of generally extremely fine-grained (less than 0.1 mm) actinolite, chlorite, saussurite, albite, opaques, and patches of relict spherulites; smaller grains are completely replaced by chlorite and epidote. The fine grainsize and spherulitic textures suggest the fragments were originally glassy, consistent with a hyaloclastic origin. The matrix consists of quartz, saussurite or fine epidote and minor actinolite. Angular patches of quartz probably represent former cavities.

Origin

The presence of pillows and hyaloclastites indicate that the metabasalts are of submarine origin. Chemical analyses of metabasalts from Cobbold Creek and the Gilberton Sheet area indicate a composition intermediate between that of modern ocean-floor basalts and low-potassium tholeiites. It is likely that the numerous metadolerite and metagabbro sills intruding the Robertson River Formation are comagmatic with the metavolcanics. Further chemical studies to investigate the relations between the various basic igneous rocks of the Georgetown Inlier are in progress.

Stratigraphic relations

The Robertson River Formation grades laterally into the higher-grade schist phase and conformably overlies the Bernecker Creek Formation.

The Dead Horse Metabasalt Member is interbedded with the Robertson River Formation. It is probable that the metavolcanics north of Ortona and those west and southwest of Gilberton homestead are at the same stratigraphic level, and that their present distribution is due to repetition by folding. The

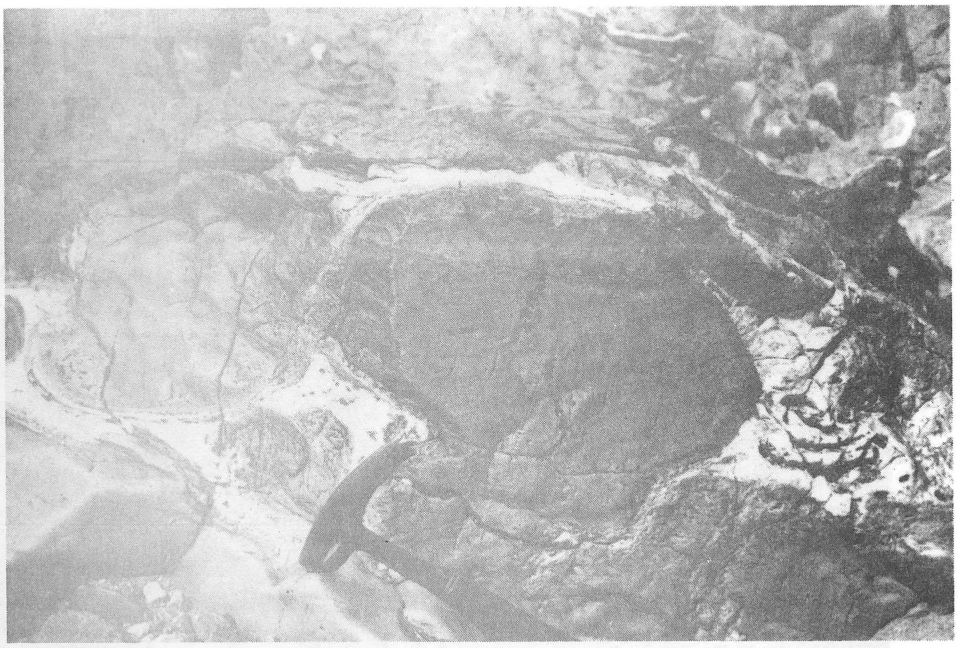


Fig 16: Pillowed metabasalt (Dead Horse Metabasalt Member) Gilbert River about 2 km west-southwest of 'Gilberton' homestead (GR 784666)

Fig 17: Pillowed metabasalt showing radial fractures and small amygdales. (Dead Horse Metabasalt Member). "Iona" - Agate Creek track aboout 4 km north of Ortona copper mine (GR 632815).

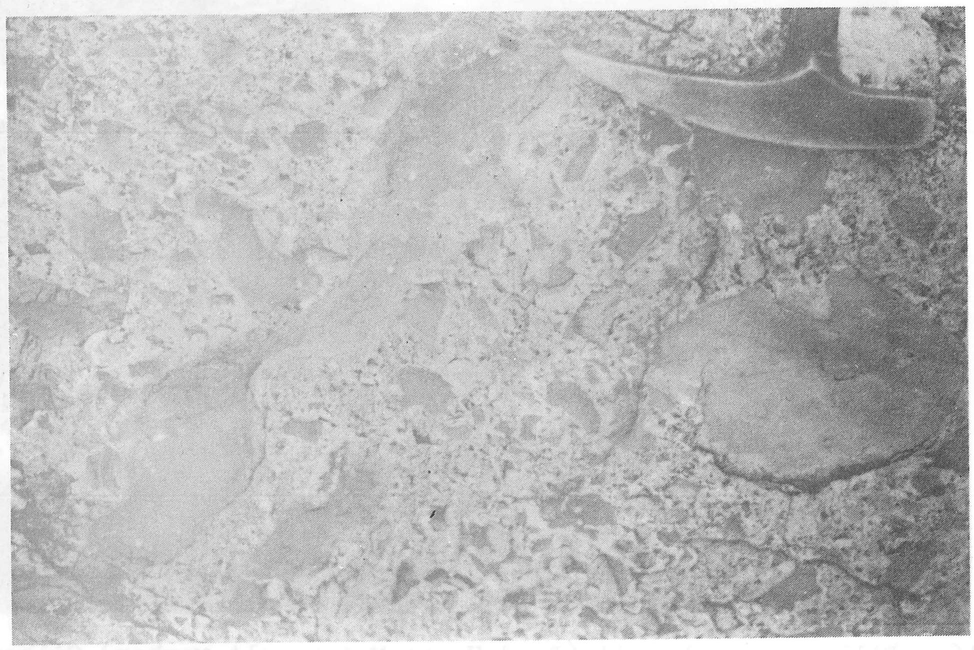


Fig 18: Hyaloclastic breccia - irregular clasts of metabasalt in a siliceous matrix (Dead Horse Metabasalt Member). About 3 km north-northwest of Carsons copper prospect (GR 660739) Negative 6B 1468

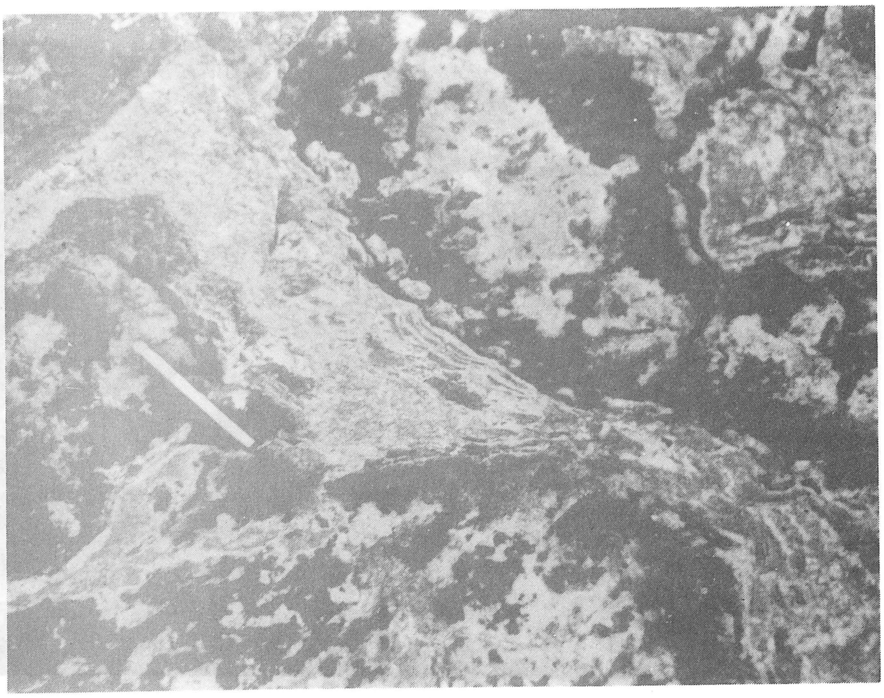


Fig 19: Portions of two metabasalt pillows showing detail of interstitial hyalocalastite. (Dead Horse Metabasalt Member). Same locality as Fig 17. Match-stick give scale. Negative M2382/6.

metavolcanics can probably also be correlated with those in the Cobbold Creek and South Head areas in the North Head 1:100 000 Sheet area. The metavolcanics and interbedded metasediments appear to interfinger in places although some apparent interfingering patterns could result from tight folding.

In the Gilberton Sheet area the Rovertson River Formation is intruded by Proterozoic metadolerite and metagabbro sills and dykes, late Proterozoic Mount Hogan Granite, the Siluro-Devonian or late Proterozoic Robin Hood Granodiorite and Permian and/or Carboniferous rhyolite, andesite, and dolerite dykes. The Devonian-Carboniferous Gilberton Formation, Permian Agate Creek Volcanics, and Jurassic Hampstead Sandstone, overlie the unit.

Thickness

No realistic estimate of the thickness of the Robertson River Formation in the Gilberton Sheet area can be made because of the complex folding. The thickness of the metabasalt member ranges from 300 m near the Eight Mile Waterhole on the Gilbert River, to at least 1000 m in the Dead Horse Creek area, assuming there has been no significant repetition of the sequence by minor folds on the major fold limbs. Southwest of "Gilberton" the metabasalt crops out in a belt 3 km wide, but the sections traversed along Mica Schist and Six Mile Creeks indicate that there is some repetition by folding in this area.

Age

Older than 1570 m.y., i.e. mid-Proterozoic or older.

ROBERTSON RIVER FORMATION (SCHIST PHASE) (Ᵽmr)

Introduction

The schist phase of Robertson River Formation crops out in an area of about 200 km^2, in a northwest-trending belt which lies north of the Gilberton Fault between the Einasleigh Metamorphics and the lower-grade parts of the Robertson River and Bernecker Creek Formations. This belt is continuous with more extensive outcrop areas in the Forsayth, Georgetown, North Head, and Forest Home 1:100 000 Sheet areas to the north. The type area of the unit is along the Robertson River in the Forsayth 1:100 000 Sheet area (White, 1959, p. 444; Bain & others, 1976a, p. 19).

Outcrops are mostly confined to stream beds in undulating country that is generally less rugged than the areas underlain by lower-grade parts of the Formation.

General

The schist phase grades westwards into phyllite with decreasing metamorphic grade and grainsize.

Like the shales from which they are derived, the schists are commonly laminated. Primary structures other than gross lithologic layering ("bedding") were mostly obliterated by strong deformation and associated metamorphism. Schistosity is generally parallel to the lithologic layering, and is locally deformed by small folds and crenulations.

Quartzite and minor calc-silicates are interlayered with the schist. The abundance of leucogranite veins (mainly muscovite-bearing) in the schist is directly proportional to the metamorphic grade of the schist phase. Most veins were probably derived in situ.

Petrography

Rocks of the schist phase in the Gilberton Sheet area have relatively simple mineral assemblages in contrast to those in the Forsayth Sheet area.

Rocks of the middle amphibolite facies cannot be differentiated from those of the lower amphibolite facies in this Sheet area because sillimanite is rarely preserved. The term "medium-grade" is used here to include both lower and middle amphibolite grade rocks. They are distinguished from the high-grade (upper amphibolite) rocks by the absence of syntectonic muscovite in the latter.

The medium-grade rocks consist predominantly of fine to medium-grained biotite-muscovite-quartz schist, which is grey to greyish yellow when fresh and buff when weathered. A well developed schistosity is generally present; it is locally crenulated. Towards the east and north where the second deformation was more intense, the crenulation cleavage is better developed and the first foliation (S_1) is transposed into a second foliation (S_2). Muscovite predominates over biotite and both occur as parallel or subparallel flakes generally less than 0.5 mm long which define the schistosities. Chlorite porphyroblasts up to 2 mm long, and generally randomly orientated, are common. Biotite is also replaced by chlorite. The chlorite probably resulted from post-D_2 retrogression.

44

No andalusite or staurolite was observed in the schist phase in the Gilbertson Sheet area; sericite pseudomorphs of these minerals were observed in only two areas (at GR 863062 and between 008763 and 003781). They appear to have formed post-S_1, and probably syn-S_2 as indicated by the "andalusite" porphyroblasts being parallel to B_1 crenulations. Garnet is present in some places, and forms small porphyroblasts up to 1 mm across; sigmoidal helicitic inclusion trails suggest it grew syntectonically with S_1. Plagioclase is the main feldspar.

The high-grade rocks (upper amphibolite facies) are typically biotite-sericite-quartz schists. Biotite forms reddish brown flakes 0.2 to 0.5 mm long generally parallel to, but locally cutting across, the main foliation; in some specimens biotite is altered to chlorite. Sericite occurs as lenses up to 5 mm long, and as discontinuous bands defining the foliation; these lenses are pseudomorphs after sillimanite. Trace amounts of sillimanite occur locally, usually as inclusions in randomly orientated porphyroblasts of muscovite that cut across (and hence postdate) the main foliation. Minor plagioclase is present in most specimens, particularly where the schist phase Robertson River Formation grades into the Einasleigh Metamorphics.

With less mica, the schists grade into quartzites. The quartzites generally contain more plagioclase than the schists, and probably represent feldspathic sandstone beds.

The calc-silicate rocks which are locally interlayered with the schist and quartzite are generally similar petrographically to those of the Bernecker Creek Formation. One lithology interlayered with the schist in the Percy River, but not present in the Bernecker Creek Formation, is "quartzite" consisting of 40 to 50 percent quartz and 35 to 40 percent plagioclase, with 10 percent poikiloblastic green hornblende porphyroblasts up to 4 mm long, and 5 percent poikiloblastic garnet grains up to 1 mm across; the rocks are similar to those in the Robertson River Formation (schist phase) (formerly Robertson River Metamorphics, sub-unit $Ēmr_1$) of the Forsayth Sheet area, described by Bain & others (1967a, pp. 24-25).

Relation to other units

White (1959b) and White & Hughes (1957) originally considered the "Etheridge Formation" and "Robertson River Metamorphics" to be equivalent in age, the latter possibly overlying the "Etheridge Formation". Later, however, White (1965) suggested that the "Robertson River Metamorphics" were equivalents of the Einasleigh Metamorphics, and had been thrust over the "Etheridge Formation". White (1959b) and White & Hughes (1957) did not recognise the isoclinal folding and transposition. Fitzgerald (1974) demonstrated that, in the Forsayth Sheet area, both the "Etheridge Formation" and the "Robertson River Metamorphics" have been affected by the same series of folding events. In the Forsayth Sheet area, Bain & others (1976a) mapped the low-grade metapelites as the "phyllite phase" (Pmr_p) of the "Robertson River Metamorphics" rather than as "Etheridge Formation". As indicated previously in this report the "Robertson River Metamorphics" are now recognised as the schist phase of the Robertson River Formation - a unit that consists of much of what was originally called "Etheridge Formation". The schist phase is equivalent in age to the Einasleigh Metamorphics although the actual relative stratigraphic positions cannot be determined (for reasons see Einasleigh Metamorphics).

The schist phase is intruded by ?mid-Proterozoic metadolerite, metagabbro and amphibolite, mid-Proterozoic Digger Creek Granite, late Proterozoic Mount Hogan granite, late Proterozoic or Siluro-Devonian Robin Hood Granodiorite, and Permian and/or Carboniferous rhyolite, andesite, and dolerite. The Devonian or Carboniferous Gilbertson Formation, Permian Agate Creek Volcanics, and Jurassic Eulo Queen Group overlie the unit.

Age

The schist phase of Robertson River Formation is mid-Proterozoic (1570 m.y., Black & others, 1979).

JUNTALA SCHIST (Pmj)

Introduction

The Juntala Schist crops out in the southeast corner of the Sheet area but is more extensive in the adjacent Lyndhurst 1:100 000 Sheet area. Well defined strike ridges outlining major folds are a feature of the unit, particularly in the Lyndhurst Sheet area; this contrasts with the subdued relief and general lack of trend lines in country underlain by the Einasleigh Metamorphics.

The unit is mostly schist but along its western margin grades into gneiss of the Einasleigh Metamorphics. White (1962a, c, 1965) correlated these rocks with the Paddys Creek Formation (see p. 32).

43

The name is derived from the Parish of Juntala, County of Percy (Queensland Lands Department 4-Mile Cadastral Series - also Juntala Holding). The name has been published by Withnall & others (1979) but no formal definition nor the type area were given. The unit will be formally defined by workers at James Cook University. The main section examined by us was from GR 883486 (Lyndhurst 1:100 000 Sheet area) westwards to GR 142521 (Gilberton 1:100 000 Sheet area), where exposures of quartzo-feldspathic gneiss mark the boundary with the Einasleigh Metamorphics. All of the metamorphics exposed in the section are quartz-mica schist; downstream from GR 860504 veins and irregular masses of muscovite granite and pegmatite intrude the schist.

Lithology and petrography

The predominant lithology in the Juntala Schist is quartz-mica schist, with subordinate quartzite. The schist is buff to grey or greenish grey, and poorly laminated in places; it has a well developed foliation which is parallel to the laminae. The foliation is cut by several sets of crenulations.

The schists consist predominantly of quartz and subparallel flakes of muscovite and biotite generally 0.2 to 1.0 mm long; in most specimens biotite has been at least partly altered to chlorite. Near the boundary with the Einasleigh Metamorphics the schist becomes feldspathic. Some of the schist is carbonaceous containing up to 5 percent of fine graphite specks; carbonaceous schists tend to be relatively finer grained, the mica flakes rarely exceeding 0.2 mm. Garnet porphyroblasts up to 5 mm occur locally. Tourmaline is the main accessory mineral.

No alumino-silicates were observed although small patches of sericite in one specimen (75300346) may be retrogressed andalusite or sillimanite; the abundant syntectonic muscovite indicates the facies is middle amphibolite or lower (see pp. 46). Chloritoid occurs in one specimen (75300219) as colourless or pale blue randomly orientated flakes, generally about 0.5 mm long.

Relation to other units

The Juntala Schist grades into the Einasleigh Metamorphics in the Gilberton 1:100 000 Sheet area and both units appear to have had a similar history of deformation. Because the units have been isoclinally folded and transposed it is impossible to determine their relative stratigraphic positions or the thickness of the Juntala Schist; the gradation may originally have been either lateral or vertical (as in the case of the relation between the Robertson River Formation (schist phase) and the Einasleigh Metamorphics, discussed above). The Juntala Schist may be younger than the Einasleigh Metamorphics, and the Rovertson River Formation older, or vice versa; alternatively all these units may be of equivalent age, and simply represent original lateral lithofacies variations. Although there are lithological similarities between the Juntala Schist and the schist phase Robertson River Formation, they may not be stratigraphically equivalent. The Juntala Schist is more homogenous than, and is geographically separate (by at least 20 km) from, the Robertson River Formation (schist phase). It is also quite separate from the main outcrop area of the Paddys Creek Formation 80 km away, on the eastern edge of the Georgetown Inlier, and inclusion of the Juntala Schist in the Paddys Creek Formation (White, 1962a-c, 1965) is therefore not justified. It is considered appropriate to regard the Juntala Schist as a separate unit in its own right.

Near "Werrington", in the Lyndhurst 1:100 000 Sheet area, the photo-interpreted boundary between the Juntala Schist and Einasleigh Metamorphics is sharp and probably faulted, as shown by White (1962a); the Einasleigh Metamorphics at "Werrington" are mainly calc-silicate gneiss (Trezise, 1971).

The Juntala Schist is intruded by rare bodies of amphibolite and numerous dykes and small bodies of muscovite granite. The latter are foliated and folded around the major D_2 folds and are here equated with the Digger Creek Granite, which is probably mainly if not entirely syn-D_2; A. Duncan (pers. comm. 1978) believes, however, that the muscovite granite and pegmatite in the Juntala Schist range from syn- to post-D_1.

Origin

The abundance of mica schist indicates the Juntala Schist was probably originally a sequence consisting mainly of shale and siltstone.

Age

Probably the same as Einasleigh Metamorphics, i.e. a minimum age of 1570 ± 20 m.y.

45

EINASLEIGH METAMORPHICS (Ᵽme)
(White, 1959b)

Introduction

In the Gilberton 1:100 000 Sheet area the Einasleigh Metamorphics are exposed in two main areas: (a) the northeast corner of the Sheet area (Welfern-Percyvale), and (b) the southern half of the Sheet area, southeast of the Gilberton Fault.

Biotite gneiss is the characteristic rock type of the unit in both areas, but calc-silicate gneiss, schist, quartzite, migmatite, and granite gneiss also occur. Southeast of the Gilberton Fault an unnamed subunit ($Ᵽme_1$) contains mostly calc-silicate gneiss and some biotite gneiss and schist. Pegmatoid and leucogranitoid dykes and veins (see pp. 110-112), some of anatectic origin, are common throughout the metamorphics. Bodies of amphibolite are common, and are described in a separate section (p. 41).

The metamorphics are generally not well exposed, the best outcrop being in creek sections.

The Einasleigh Metamorphics are intruded by Proberozoic Sawpit Granodiorite, Loafers Granodiorite, Oak River Granodiorite, Welfern Granite, Digger Creek Granite, and various leucogranitoids; the Siluro-Devonian? Robin Hood Granodiorite, Dumbano Granite, and possibly some leucogranitoids; the Carboniferous Bagstowe Ring Complex and related hypabyssal intrusives, the Culba Granodiorite and the Purkin Granite; and minor late Palaeozoic basic to acid hypabyssal intrusives. Volcanics related to the Bagstowe Ring Dyke Complex and the Jurassic Eulo Queen Group overlie the unit.

Lithology and petrography

(a) Biotite gneiss

The biotite gneiss generally has a strong foliation and commonly consists of alternating melanocratic and leucocratic layers a few millimetres to several centimetres thick. The main foliation is mostly parallel to the layering although locally a later foliation may cut across it at a low angle. One or more sets of folds (see pp. 52-71) commonly deform the layering and foliation. The layering is probably largely primary although it has undoubtedly been modified by transposition and metamorphic differentiation.

The gneiss is fine to medium-grained and consists mainly of quartz, plagioclase, and biotite; other constituents include microcline, sercite, muscovite, and garnet. Quartz and feldspar are granoblastic and have curved, slightly interlocking margins. Plagioclase ranges in composition from An_{20} to An_{65} but is generally andesine; locally it is sericitised or replaced by clinozoisite or epidote.

Biotite is the main mafic mineral, forming reddish brown to dark brown flakes up to 1.5 mm; the flakes define the main foliation and in some cases a second foliation. Zircon inclusions surrounded by pleochroic haloes are common. In many specimens, particularly those examined from southeast of the Gilberton Fault, biotite is partially or completely altered to chlorite.

Sericite is present in some of the gneisses as lenses up to 1 cm long or as discontinuous layers parallel to the biotite foliation. However, it is not generally as common as in the Stockman Creek area (Forsayth 1:100 000 Sheet area - Bain & others, 1976a) or Georgetown 1:100 000 Sheet area (Oversby & others, 1978). In some cases it is recrystallised to fine muscovite flakes up to 0.3 mm long. Muscovite also forms large irregular flakes cutting across and postdating the foliation. In the southeast corner of the Sheet area foliation in lower-grade Einasleigh Metamorphics is defined by muscovite and biotite. At Percyville muscovite cuts across the main foliation and defines a second foliation.

Sillimanite occurs only as traces in the specimens examined because it has been extensively replaced by sericite or muscovite. The main accessory minerals are zircon, apatite, and allanite. Allanite generally forms reddish brown cores in epidote.

(b) Schist

Schist is not as abundant as gneiss, into which it grades with increasing feldspar and decreasing mica content. It appears to be most abundant in the Einasleigh Metamorphics southeast of the Gilberton Fault.

The schist is grey to brown, medium-grained, and generally well foliated, and consists mainly of quartz, biotite, chlorite, sericite, and muscovite. Feldspar, mainly plagioclase, is present but usually constitutes less than 5 percent; the schist at Percyville, however, is feldspathic, containing up to 60 percent plagioclase and microcline. Biotite, commonly replaced by chlorite, forms reddish brown flakes up to 2 mm. Sericite has a similar habit to that in the gneiss, i.e., discontinuous layers and lenses, but is more abundant. Muscovite occurs as large irregular flakes up to 1 cm cutting across the foliation, generally with no preferred orientation; some large flakes do lie along the foliation but their (001) cleavage planes are at large angles to it. In the southeastern corner of the sheet area, where the Einasleigh Metamorphics grade into the Juntala Schist and are of lower grade, muscovite is syntectonic and defines the foliation. Sillimanite is rarely preserved, but "ghost" outlines are present in post-tectonic muscovite.

(c) Quartzite

Quartzite is interlayered with biotite gneiss and grades into it with increasing biotite content; quartzite containing spots of calc-silicate minerals is interlayered with the calc-silicate gneiss.

Micaceous quartzite consists mainly of fine to medium-grained, subequant to equant granoblastic quartz (65 to 80 percent) and plagioclase (15 to 30 percent) with minor biotite, chlorite, and muscovite. Epidote and clinozoisite, (probably of retrogressive origin) occur locally in place of plagioclase. Hornblende and garnet are the main calc-silicate minerals.

(d) Calc-silicate gneiss and granofels

Calc-silicate gneiss and granofels interlayered with biotite gneiss are common to all areas of the Einasleigh Metamorphics in the Gilberton 1:100 000 Sheet area, but are most abundant southeast of the Gilberton Fault (shown as Pme_1).

The rocks are usually layered or laminated; the laminations range from a few millimetres to several centimetres thick and are probably of primary origin modified by transposition and metamorphic differentation. Laminated rocks are referred to as gneiss whereas non-laminated rocks are granofels. The foliation is parallel to the layering. Later tight, almost isoclinal folds are associated in places with a second foliation or mineral lineation defined by hornblende. More open folds with no associated foliation are also present. Rare layers of impure marble occur locally in the calc-silicate gneiss. Hornblende-rich para-amphibolite layers up to several metres thick are common; they generally grade into ordinary calc-silicate gneiss thereby distinguishing them from ortho-amphibolite bodies, which have sharp contacts.

The calc-silicate gneiss typically consists of leucocratic quartzofeldspathic layers alternating with melanocratic hornblende/clinopyroxene layers. The texture is granoblastic and generally equigranular although hornblende locally forms porphyroblasts.

The leucocratic layers consist predominantly of various proportions of quartz and feldspar grains up to 1 mm across. Some layers consist almost entirely of either plagioclase or microcline. The plagioclase is generally andesine or labradorite and in some specimens is altered and replaced by epidote.

The melanocratic layers contain hornblende and clinopyroxene (diopside-hedenbergite series - generally loosely referred to as diopside). The clino-pyroxene forms pale green grains up to 2 mm across, partly replaced by horn-blende. Hornblende is generally bluish green or green in the Z direction and forms grains up to 2 mm long; the foliations are usually defined by hornblende. Biotite is present in some specimens. Quartz, feldspar, and epidote/clinozoisite also occur in the melanocratic layers.

Porphyroblasts of scapolite, up to 3 mm across, with hornblende and quartz inclusions, and garnet porphyroblasts up to 5 mm across occur locally. Sphene (up to 2 percent) is common in all layers as small roundish grains about 0.1 mm across. Other accessory minerals are apatite and opaques; epidote grains in some specimens contain allanite cores.

The para-amphibolite is similar in composition to the melanocratic layers described above. The impure marble contains calcite, clinopyroxene, microcline, and minor hornblende and clinozoisite.

(e) Migmatite

Migmatite is best developed in parts of the Welfern area where it is interlayered with gneiss. A typical migmatite layer is up to 1 m wide, consisting of thin discontinuous layers, pods, and augen of quartz and feldspar (leucosome) with intervening biotite-rich layers (melanosome). The enclosing gneiss commonly shows no separation of a granitoid phase, presumably because the melting point of its particular composition was higher.

At Percyville, near the junction of Blakos Creek and the Percy River, the leucosomes consist of muscovite granite. The gneiss and schist there contain syntectonic muscovite, and the grade of metamorphism was probably lower than at Welfern. However, because both microcline and plagioclase are present in roughly equal proportions, the rocks probably melted at a lower temperature than gneiss containing only plagioclase; the melts so formed crystallised in the muscovite stability field.

Leucogranitoid veins are abundant in the metamorphics, particularly south of the Gilberton Fault. Although many of these may be related to various larger intrusive leucogranitoids (described later), some were probably derived by local or in situ anatexis.

None of the migmatites from the Gilberton 1:100 000 Sheet area were examined in thin section. However, Bain & others (1976a, p. 11) describe macroscopically identical rocks from near "Fernhill" Outstation in the Forsayth Sheet area. The leucosomes are fine to medium grained and range from granite to trondhjemite (leucotonalite) in composition; very minor biotite, muscovite, hornblende, and garnet may be present. The melanosomes are well foliated and contain quartz, feldspar, and up to 40 percent mafic minerals.

In thin section, the gneisses at Percyville show an allotriomorphic granular texture (similar to granite) rather than the normal granoblastic texture, suggesting that the metamorphics there may have been close to melting completely.

Relation to other units

The various possible relations of the Einasleigh Metamorphics to the other metamorphic units in the Georgetown Inlier were outlined and discussed in detail by Bain & others, (1976a, pp. 15-18). Several lines of evidence from the Gilberton 1:100 000 Sheet area indicate that the Einasleigh Metamorphics are equivalent in age to the Rovertson River and Bernecker Creek Formations. For instance the boundaries between these units are locally gradational: biotite gneiss (Einasleigh Metamorphics) grading through alternating biotite gneiss & calc-silicate gneiss into continuous calc-silicate gneiss (Bernecker Creek Formation) is exposed along a creek upstream from the Ballynure road at GR 132905.

Similarly in a gully upstream from the Kidston-"Gilberton" road at GR 065861, mica schist (schist phase Robertson River Formation) grades through alternating mica schist and calc-silicate rocks into continuous calc-silicate gneiss (Bernecker Creek Formation).

Metamorphic grade and structural complexity appear to increase progressively northeastwards from the Robertson River Formation into the Einasleigh Metamorphics. In particular, D_2 folding becomes tighter, and in the creek downstream from GR 003896 on the "Percyvale" road, outcrops with prominent S_1 and less prominent S_2 are transitional to outcrops showing strong overprinting of S_2 on S_1.

Calc-silicate gneisses (Pme_1) of the Einasleigh Metamorphics south of the Gilberton Fault near Six-Mile Creek are similar to those 50 km to the northeast near "Welfern", mapped as Einasleigh Metamorphics and Bernecker Creek

Formation. Rb-Sr dating of these calc-silicate gneisses has yielded similar D_1 ages for localities south of Gilberton (1582 ± 93 my) and 10 km southwest of Welfern (1569 ± 33 my) (Black & others, 1979).

It therefore seems likely that the Einasleigh Metamorphics and other metamorphic units are roughly coeval and were not separated by any major tectonic event involving metamorphism and deformation. However, the precise stratigraphic position of the Einasleigh Metamorphics relative to the others cannot be determined because the unit has been isoclinally folded and transposed over its entire outcrop area. Unlike the Robertson River Formation (schist phase) it has no known low-grade, less deformed equivalents. Planned future stratigraphic work in the Einasleigh Metamorphics may help to clarify relationships.

Origin

The Einasleigh Metamorphics appear to have been a sequence of feldspathic sandstone, siltstone, and shale with calcareous beds and lenses. The unit grades into both the calc-silicate phase (Pmr_3) of the Bernecker Creek Formation and the schist phase (Pmr) of the Robertson River Formation. Whether these are lateral or vertical gradations, or both, cannot be determined. It is established that the predominantly non-calcareous and pelitic Robertson River Formation overlies the predominantly calcareous Bernecker Creek Formation. If the latter unit is grossly equivalent to the calcareous facies of the Einasleigh Metamorphics, it is possible that the pelitic Robertson River Formation may be grossly equivalent to the gneiss phase of the Einasleigh Metamorphics, representing shaly and sandy facies respectively.

The source of the sediments is unknown. The abundance of quartz and plagioclase and relative paucity of K-feldspar in them suggest that the source was probably composed of plutonic and metamorphic rocks of tonalitic composition - common rock types in many early Proterozoic terrains throughout the world. Such source rocks were probably not much different from the Einasleigh Metamorphics, and some may be present but unrecognised in Einasleigh Metamorphics in the eastern part of the Georgetown Inlier. Recognition of any such "old" Einasleigh Metamorphics would be difficult because older (pre-D_1) structures may have been overprinted and obliterated. Andesitic or dacitic volcanic rocks could also have been the source rocks for some of the sediments.

Age

Black & others (1979) give a preferred age for D_1 in the Einasleigh Metamorphics of 1570 ± 20 m.y. The age of the original sediments is not known.

METAMORPHOSED BASIC INTRUSIVES

Introduction

Metamorphosed basic intrusives are common in the Robertson River and Bernecker Creek Formations and Einasleigh Metamorphics. In the Gilberton Sheet area they range from metadolerite and metagabbro at lower grades (mapped as Ꝑmc, Cobbold metadolerite) to amphibolite at higher grades (mapped as unit "a"). The general term "metabasite" is used here for all these rocks. Some metabasite also occurs within the Dead Horse Metabasalt Member.

Metadolerite and metagabbro (Ꝑmc)

General

In the Gilberton Sheet area most of the outcropping bodies of metadolerite and metagabbro are rarely layered, folded sills that were emplaced before the first deformation. The sills range in width from a few metres to over 500 m, but are generally 100 to 200 m wide. Some are over 10 km long. Dykes are not common; the dyke which is host to mineralisation at Ortona is the most important example, and it is discussed separately. Stocks up to 3 km wide also occur in places.

Although most of the metadolerite and metagabbro probably antedate the first deformation, some may be later. For example, at GR 087 855 a small metadolerite dyke contains a greenschist facies mineral assemblage whereas the country rocks are amphibolite grade; this dyke was probably emplaced after the main metamorphism (post-D_2 and possibly pre- or syn-D_3). Llewellyn (1974) described metadolerites which postdated the main metamorphism and which he interpreted as pre-D_3. In the creek at GR 132 905, near the road to "Ballynure", a metadolerite dyke postdates the main foliation but appears to have been folded by a later deformation. Distinguishing these later metadolerites from earlier (pre-D_1) phases is easier in the high-grade terrain, because of the difference in metamorphic grade, than where all phases are of greenschist grade. The low-grade metadolerites may also be confused with even later

52

(Carboniferous and/or Permian) uralitised dolerites, (p. 128). At Einasleigh some amphibolites are possibly post D_1 but pre D_2 (J. Patrick, pers. comm. 1978); these are even more difficult to distinguish from pre-D_1 amphibolites because both were metamorphosed to amphibolite grade.

Petrography

In the lower greenschist facies the metadolerite and metagabbro consist mainly of albite, epidote, and actinolite. The albite commonly rims randomly orientated saussuritised plagioclase laths that range in length from less than 0.5 mm in the metadolerite to over 1 mm in the metagabbro. Epidote, as well as forming cores in albite laths, also forms larger discrete grains. Actinolite occurs as pale green, brown, or almost colourless, optically continuous grains which are pseudomorphs of clinopyroxene; in rare cases relict clinopyroxene is present in the cores. In blastophitic metadolerite the actinolite forms subequant crystals up to 2 cm across containing albite laths. Some metadolerite contains fibrous actinolite aggregates rather than discrete crystals. Rims of blue-green hornblende around actinolite may be relict igneous hornblende which partially replaced pyroxene in the late-magmatic or post-magmatic stage. Chlorite, where present, generally occurs as small flakes less than 0.1 mm across in clusters both interstitial to albite and included in it (together with fine acicular actinolite). Opaque grains up to 0.5 mm across are commonly skeletal, and generally are partially replaced by sphene. Interstitial quartz may be present. Apatite is the main accessory.

In areas of upper greenschist facies blue-green hornblende is present instead of actinolite; oligoclase may be present instead of albite, but chlorite and epidote still occur.

In samples from the amphibolite facies, the plagioclase is more calcic, generally andesine or labradorite. It commonly occurs as laths (a relict igneous texture) (Fig. 20) although in some specimens it forms a granoblastic mosaic; epidote is absent or only minor, and is probably due to later minor retrogressive metamorphism. Hornblende forms aggregates up to 5 mm across of randomly orientated prisms, or discrete blastophitic crystals containing plagioclase laths; the former may result from recrystallisation of uralite or fibrous actinolite aggregates formed at an earlier, lower-grade stage of metamorphism. Hornblende is commonly zoned, being more deeply coloured and having a lower birefringence on the margins than in the cores (Fig. 21).

Amphibolite (a)

General

Amphibolite is present in the high-grade Robertson River Formation (schist phase) and the Einasleigh Metamorphics. It represents strongly metamorphosed and deformed basic rocks, and is probably equivalent to the metadolerite described above in less deformed, lower-grade areas. It differs from the metadolerite in lacking igneous textures; a metamorphic fabric is usually present.

Although locally the amphibolite forms tabular intrusions ranging from 1 m to a maximum of about 100 m wide, it more commonly appears to be in irregular bodies up to 1 km across. Large sills, such as those in the lower-grade, less deformed rocks, are not apparent in the Einasleigh Metamorphics. However, because of the complex deformation and poor outcrop, it is difficult to map out the extent and shape of the bodies accurately. If the bodies are correctly mapped, their shapes may be due to complex refolding patterns, or alternatively to the original structure or fabric of the host sediment; e.g. the well-bedded, alternating siltstone/shale sequence of the Robertson River Formation may have favoured emplacement of large sills whereas the more uniform sandy protoliths of the Einasleigh Metamorphics may have favoured small irregular intrusions. Overall, basic rocks are less common in the Einasleigh Metamorphics in the Gilberton Sheet area than in, for example, the Stockman Creek area of the Forsayth Sheet area.

Petrography

The amphibolite is black and fine to medium grained, consisting mainly of hornblende and plagioclase. In thin section hornblende forms subequant to elongate polygonal grains, commonly aligned, and rarely more than 1.5 mm long; it is generally brownish green to brown depending on the grade of metamorphism. Plagioclase grains are granuloblastic, and generally less than 0.5 mm across; in unaltered specimens the composition is generally labradorite. Greenschist facies retrogression has saussuritised the plagioclase in some specimens. Quartz generally occurs as small grains interstitial to plagioclase. Diopside, partly replaced by hornblende, is locally present as single grains and aggregates up to 2 mm. No orthopyroxene (indicative of the granulite facies) was observed in amphibolite in the Gilbertson Sheet area.

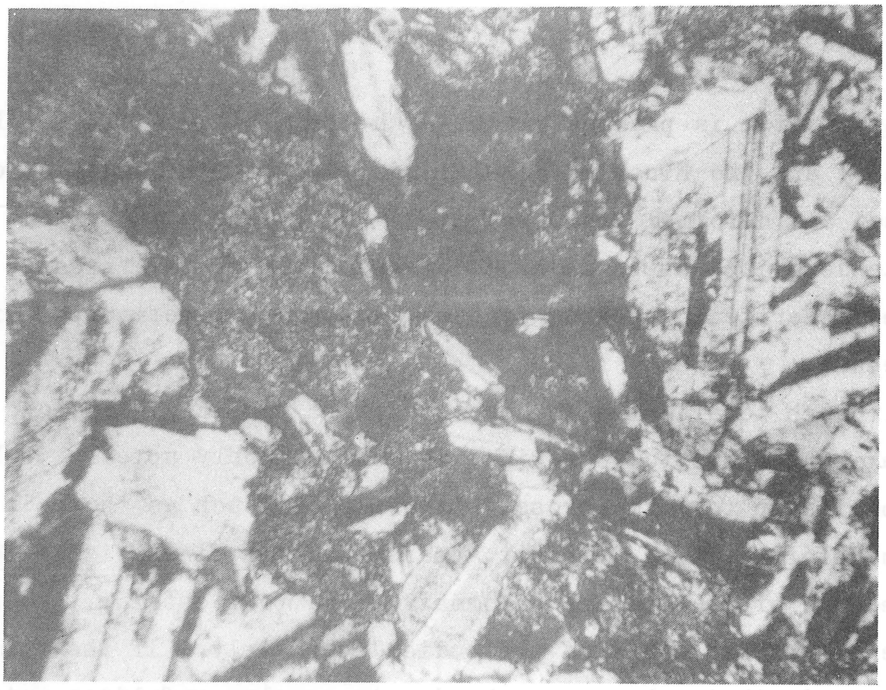


Fig 20: Photomicrograph of metadolerite showing well-preserved igneous texture (plagioclase laths); dark grey is hornblende. Specimen 75300033. Magnification X25 (crossed polars). Negative M2382/17.

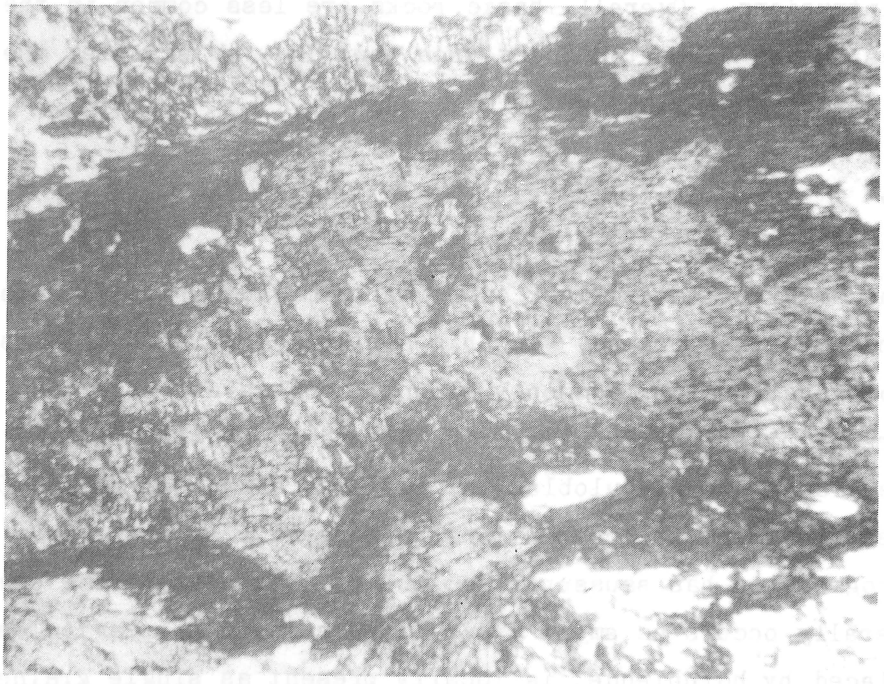


Fig 21: Zoned hornblende crystal in metadolerite showing a deep bluish-green (dark grey) rim around a lighter green (grey) core. Specimen 75300155. Magnification X25 (plane polarised light). Negative M2382/19.

Ortona dyke

The Ortona dyke (Couper, 1965) is about 3 km long, and hosts the Ortona copper deposits. It strikes northwest across the bedding of the enclosing Bernecker Creek Formation and near its northern end intersects a concordant east-striking metadolerite body (Fig. 22). Whether the concordant and discordant metadolerite are part of the one intrusion or separate, intersecting intrusions is not known. Northwest of the intersection, the dyke consists of "diorite" and "quartz-diorite" (Couper, 1965; Glasson, 1966). Small patches of "quartz-diorite" also occur in the east-trending metadolerite.

In thin section the "quartz-diorite" (specimens 75300358, 359) consists of quartz (15 percent) graphically intergrown with albite (65 to 80 percent) which forms laths up to 1.5 mm long; some of these laths contain sericite cores. Biotite (10 to 15 percent) is present in 75300358 as irregularly shaped aggregates, up to 2 mm across, of greenish brown flakes (0.1 mm long slightly replaced by chlorite; in specimen 75300359 all the biotite has been chloritised. Calcite (5 to 10 percent) forms subequant grains up to 0.3 mm across, commonly in aggregates.

The east-trending metadolerite consists of almost completely saussuritised plagioclase laths (35 to 40 percent), pale green optically continuous actinolite crystals up to 1.5 cm long (60 to 65 percent), aggregates of fine chlorite flakes (1 to 2 percent), minor opaques, and sphene; it appears to be a relatively normal metadolerite. The discordant metadolerite has not yet been examined in thin section.

Additional work is needed to determine the relation of the "quartz-diorite" to the metadolerite. The contact between the two rock types is sharp and the "quartz-diorite" could be a younger intrusive, or a later differentiate of the parent magma of the dolerite.

A possible genetic association between the "quartz-diorite" and at least some copper mineralisation is suggested by the fact that similar rocks also occur at the Eight-Mile copper prospect (specimen 75300131).

Relation to other units

Metabasites are present in all of the metasedimentary units cropping out in the Gilberton Sheet area. The pre-D_1 metabasite intrusives are probably genetically related to the Dead Horse Metabasalt Member of the Robertson River Formation. No Proterozoic metabasites are known to intrude the Proterozoic granitoids.

56

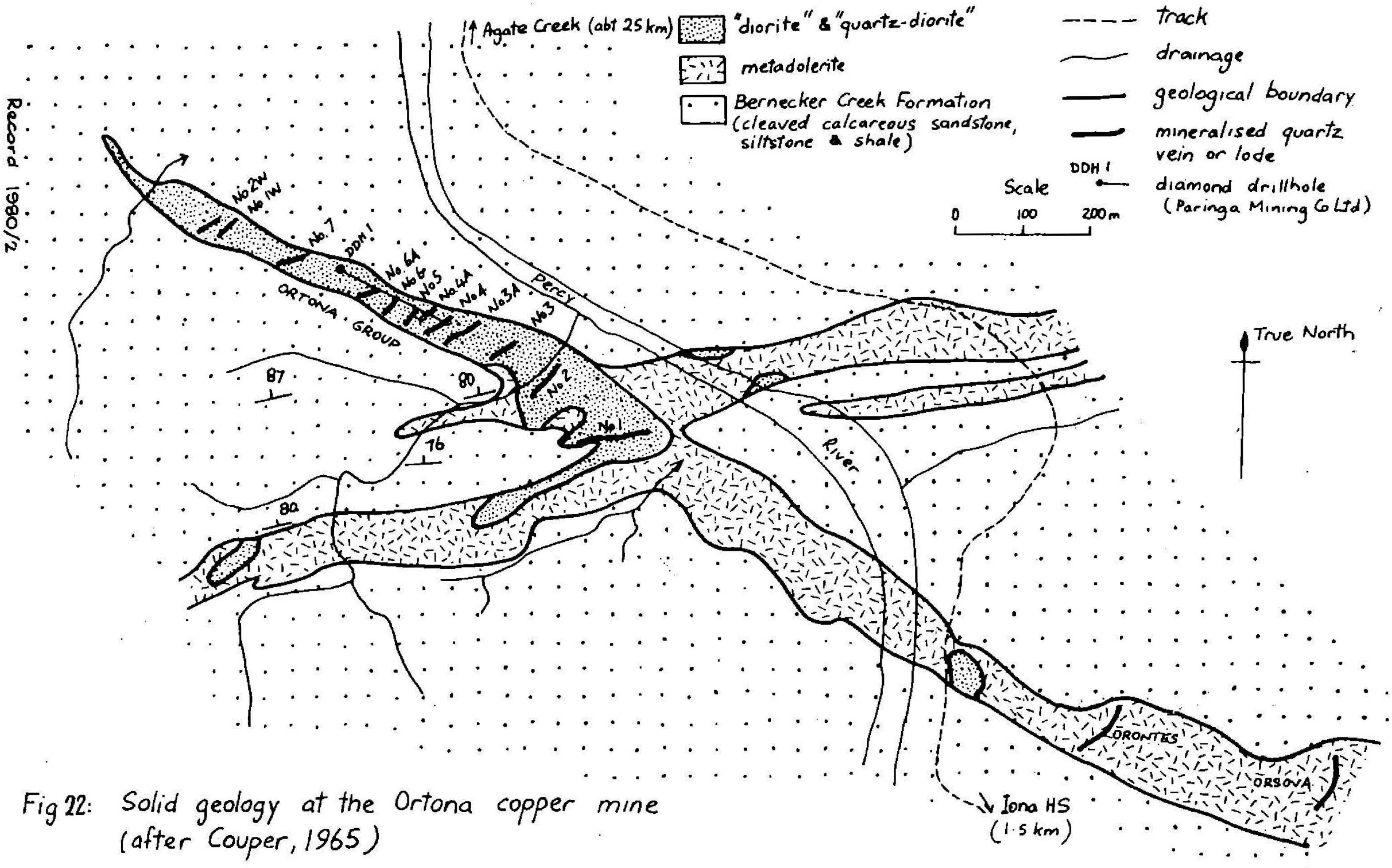


Fig 22: Solid geology at the Ortona copper mine (after Couper, 1965)

All of the Proterozoic and Palaeozoic granitoid units are inferred to intrude the metabasites although only the Digger Creek and Mount Hogan Granites and Robin Hood Granodiorite are in contact with them in the Gilberton Sheet area. Permian or Carboniferous rhyolite also intrudes the metabasites, which are overlain by the Devonian-Carboniferous Gilberton Formation and by the Jurassic Eulo Queen Group.

Age

Most metabasites were probably emplaced before the first deformation (D_1). Therefore they are older than 1570 m.y. Some, however, may be post-D_1 or D_2 but pre-D_3, i.e. not younger than about 1000 m.y.

METAMORPHISM

Einasleigh Metamorphics

All of the Einasleigh Metamorphics were metamorphosed to amphibolite grade, in most places reaching the upper amphibolite facies during the main deformation. In the psammitic and pelitic metasediments this is indicated by the presence of sillimanite, generally partly replaced by fine sericite (post-tectonic), and the absence of syn-tectonic muscovite; and in amphibolites by the presence of diopside and brown or brownish-green hornblende (Oversby & others, 1978). In calc-silicate assemblages, diopside (or clinopyroxene) is present throughout the whole amphibolite facies, and these rocks are less useful in zoning the metamorphics; hornblende in the calc-silicates appears to have a bluish tint regardless of grade.

No granulite facies assemblages were found during this survey, although they were recorded by Oversby & others (1976) from the Woolgar Inlier about 30 km southwest of the Gilbertson Sheet area. However, White (1965, p. 25) described a rock with an igneous appearance from near "Gilberton" that consisted of oligoclase, clinopyroxene, enstatite, and hornblende; this may be a granulite-facies mineral assemblage, but the plagioclase is unusually low in anorthite, and it is possible that the rock may actually be a post-metamorphic intrusive similar to that described on p. 129.

The lowest metamorphic grade (middle amphibolite) is in the south-eastern corner of the Sheet area, where muscovite is a common syntectonic phase.

Muscovite is also common in the gneiss and feldspathic schist at Percyville where, although some cuts across the foliation, much of it appears to be syn-tectonic (syn-S_2). In spite of the rocks being apparently lower in grade there, they have undergone considerable anatexis with the development of muscovite leucogranite. The reasons for this is that gneiss and schist at Percyville contain abundant K-feldspar and muscovite in addition to plagioclase; thus the melting point of these rocks would have been lower than that of the more common gneisses in which plagioclase is the only feldspar and muscovite is absent. The leucosomes in the latter are generally leucocratic varieties of granodiorite and tonalite containing only minor biotite (which did not melt and remained in the melanosomes); muscovite is uncommon in these leucosomes except as a post-tectonic secondary phase because the melts formed and crystallised above the muscovite stability field.

Both D_1 and D_2 were accompanied by high-grade metamorphism. It is difficult to determine whether the deformations occurred during one continuous metamorphic event or during two separate ones. Where two foliations are present (mainly in the calc-silicate gneisses), the same minerals (hornblende and clinopyroxene) grew during both events, but as S_1 and S_2 are sub-parallel or parallel it is difficult to distinguish syn-D_1 and syn-D_2 minerals. Consequently, estimation of whether the grade at a particular locality was higher during one event than during the other is often not possible.

Retrogression of sillimanite to sericite and muscovite, biotite to chlorite, and plagioclase to clinozoisite/epidote probably occurred during D_3, D_4, or D_5 and possible also partly during the waning stages of D_2.

Juntala Schist

The Juntala Schist is of amphibolite grade but lower than the upper amphibolite grade of the Einasleigh Metamorphics to the northwest as it contains abundant syntectonic muscovite which cannot form above middle amphibolite grade. The only metamorphic minerals directly indicative of grade (in this case lower amphibolite grade) is staurolite, which is found in the eastern part of the unit near Werrington homestead (Lyndhurst 1:100 000 Sheet area - M.J. Rubenach, personal communication, 1977). A further indication of grade is provided by the distribution of muscovite granite and pegmatite, which, like similar rocks in the Robertson River Formation (schist phase) of the Forsayth Sheet area (Bain & others, 1976a, p. 48 & fig. 28), probably do not crop out in rocks of lower than middle amphibolite grade.

Foliation in the Juntala Schist is defined by muscovite and biotite which probably grew during both D_1 and D_2; S_1 and S_2 are generally subparallel to parallel, and micas of the different generations are difficult to distinguish. Chloritoid is present in 75300219 as randomly orientated flakes crosscutting the main foliation, S_2; it may be due to a later greenschist(?) metamorphism which also altered most of the biotite to chlorite in some specimens. Chloritoid also grew in some of the rocks during D_2 (A. Duncan, personal communication, 1978) indicating that the grade during D_2 was greenschist facies and lower than that during D_1.

<u>Robertson River Formation, Bernecker Creek Formation, and associated basic rocks</u>

General

The grade of metamorphism in this group of rocks ranges from lower greenschist to upper amphibolite facies. The grade generally increases eastwards, but southwest of Gilberton a southward increase is also apparent (see Fig. 23).

In many parts of the Sheet area, mineral assemblages for greenschist and lower amphibolite facies are for D_1 only. There is no evidence of modification of syn-D_1 assemblages by D_2 events, nor is there overprinting by higher-temperature minerals; hence we assume that during D_2 there was either no metamorphism, or the grade was comparable to that during D_1.

In the higher-grade (middle and upper amphibolite facies) parts of the area, D_2 metamorphism is more apparent. The main foliation is commonly S_2 and where S_1 can be recognised, for example in the calc-silicates, the grade during D_1 was also high.

The coincidence of areas of high-grade metamorphism during D_1 and D_2 has been noted in the Forsayth and Georgetown Sheet areas (Bain & others, 1976a and Oversby & others, 1978, respectively; also Rubenach & others, 1977). It is possible that D_1 and D_2 were superimposed during one more-or-less continuous, although possibly fluctuating metamorphism. This could explain the rather conflicting field relations between various phases of leucogranitoids; generation of granitic melts could have been continuous over a long period, and various leucogranitoids, although similar in petrography and geochemistry, could have widely different ages. However, such a single event would have lasted for about 100 million years (based on the ages obtained for D_1 and D_2 by Black & others, 1979).

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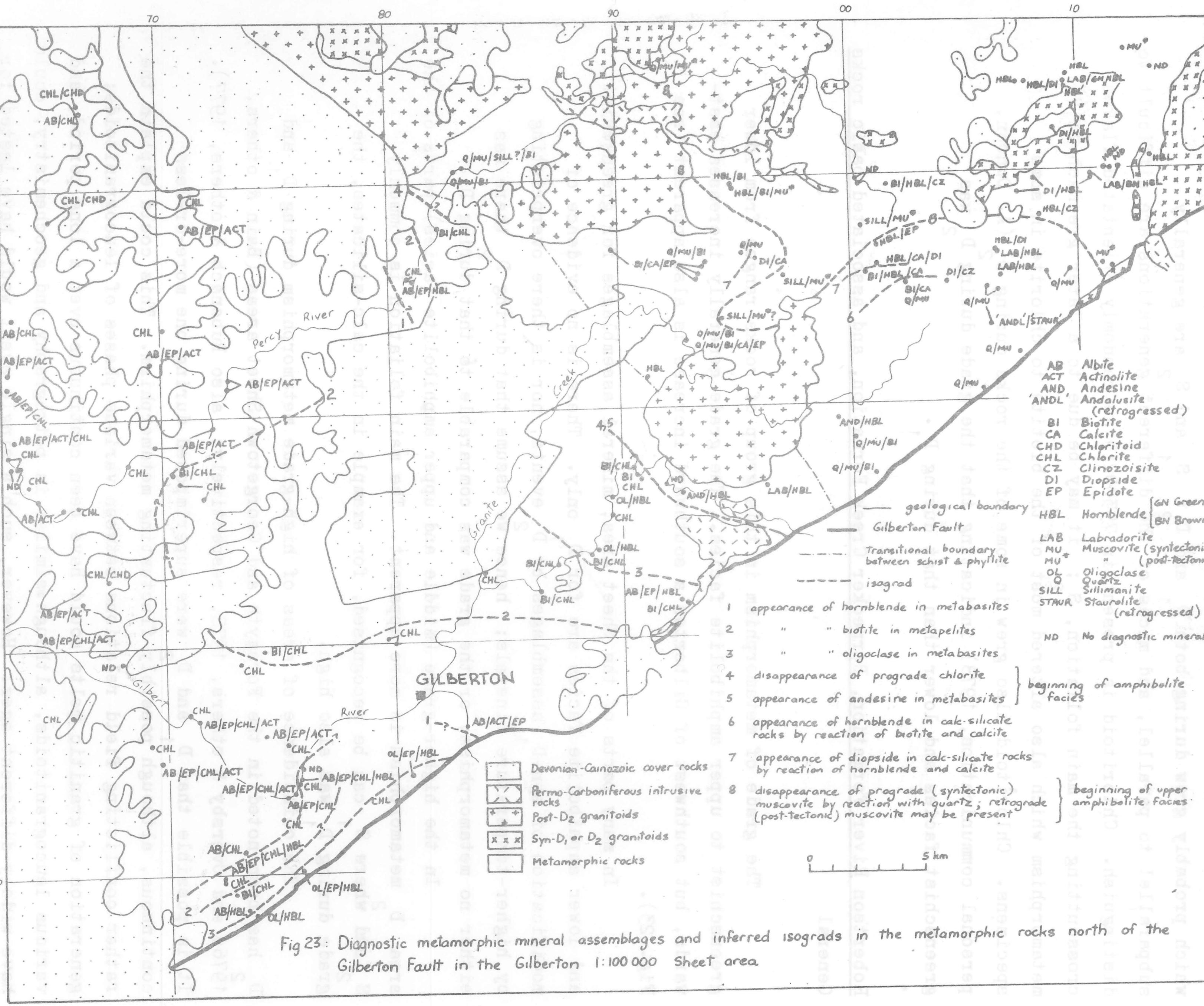


Fig 23: Diagnostic metamorphic mineral assemblages and inferred isograds in the metamorphic rocks north of the Gilberton Fault in the Gilberton 1:100 000 Sheet area

19

Figure 23 shows tentative isograds and mineral assemblages in rocks examined during this survey. The most important diagnostic minerals and assemblages are briefly discussed below.

Greenschist facies

The presence of chlorite as a syntectonic phase (in most cases syn-D_1) signifies greenschist facies. The appearance of biotite in the metapelites (the biotite isograd) probably indicates the upper part of the greenschist facies although its absence in some rocks of apparently suitable grade may be due to composition. The beginning of the amphibolite facies is marked by the disappearance of chlorite. Chloritoid is present in the northwestern part of the area. Although its range extends into the amphibolite facies in some terrains, it has not been observed above the staurolite isograd in the Forsayth Sheet area, and it is probably restricted to the greenschist facies. The breakdown of chloritoid to form staurolite may have been the most important staurolite-producing reaction in the Robertson River Formation.

In the lower part of the greenschist facies, the basic rocks contain albite, epidote, actinolite, and/or chlorite. Actinolite is replaced by hornblende at a grade just below the biotite isograd in the metapelites; the feldspar at this grade is still albite, and the hornblende is a blue-green variety. Higher in the greenschist facies (above the biotite isograd), the basic rocks consist of oligoclase, blue-green hornblende, epidote, and chlorite. The change from albite to oligoclase is well known in many metamorphic terrains (Winkler, 1974, p. 161); it is abrupt, taking place about 20° to 40°C lower than the greenschist-amphibolite facies boundary.

Amphibolite facies

The beginning of the amphibolite facies is marked by the disappearance of chlorite as a syntectonic phase in metasediments and metabasites (post-tectonic retrogressive chlorite may be present), and the presence of plagioclase of composition An_{30} (andesine) or above (Miyashiro, 1973, p. 249). Staurolite, used in the Forsayth and Georgetown Sheet areas to indicate the lower amphibolite facies, has not been identified in thin section in this Sheet area although retrogressed porphyroblasts were noted at GR 863062. Overall, progressive mineral changes in the metabasites are the most useful indicators of grade in the transition from greenschist to amphibolite facies.

The gradational boundary between phyllite and schist is taken as the boundary between the Robertson River Formation and its schist phase. Only in parts of the Forsayth and North Head Sheet areas to the north, where the transition zone is relatively narrow, can the boundary be placed with certainty to within half a kilometre.

Elsewhere the transition zone may be up to several kilometres wide, and in such areas the distinction between phyllite and fine schist is rather subjective. Another problem arises in carbonaceous rocks, where grainsize (which determines whether the rock is classified as phyllite or schist) is controlled by the carbon content; hence in places carbonaceous phyllite and non-carbonaceous schist may be interlayered (see Bain & others, 1976a, p. 24). However, in the Gilberton Sheet area none of the metasediments in the transition zone are markedly carbonaceous.

In terms of metamorphic grade, the schist/phyllite boundary lies within the amphibolite facies above the greenschist/amphibolite facies boundary rather than coinciding with it; this was also noted in the Forsayth Sheet area by Bain & others (1976a, p. 20).

Subdivision of the amphibolite facies into the lower, middle, and upper zones recognised in the Forsayth and Georgetown Sheet areas is more difficult in this Sheet area because of fewer control data, especially the lack of critical assemblages in those rocks sampled; continuous isograds have not been drawn.

In the metapelites the following criteria have been used to indicate grade: (a) retrogressed andalusite and/or staurolite porphyroblasts, where present, indicate lower amphibolite facies; (b) syntectonic muscovite indicates lower or middle amphibolite facies; (c) syntectonic muscovite with sillimanite indicates middle amphibolite facies (unfortunately most sillimanite in this Sheet area is retrogressed to sericite); (d) schists, in which all muscovite is post-tectonic, with or without sillimanite, indicate upper amphibolite facies.

Llewellyn (1974) studied the calc-silicate rocks in the Bernecker Creek Formation and recognised five zones in the amphibolite facies: (a) scapolite-bearing zone; (b) biotite zone; (c) biotite-hornblende zone; (d) hornblende zone; and (e) hornblende-pyroxene zone. The critical reactions between these zones are:

$$\text{biotite+calcite+quartz} = \text{hornblende+microcline+sphene+}H_2O\text{+}CO_2$$

and

$$\text{hornblende+calcite+quartz} = \text{diopside+}H_2O\text{+}CO_2$$

63

These zones are valid only for rocks containing calcite, as biotite occurs locally in calcite-free rocks well above Llewellyn's hornblende zone. Llewellyn was uncertain of the significance of his scapolite-biotite zone, and as our work shows the occurrence of scapolite to be more extensive, the zone is probably not real. Specimen 75300069 contains biotite+hornblende+calcite even though it was sampled from within Llewellyn's hornblende-pyroxene zone, supposedly above the stability field of biotite+calcite. Hence although most of the zones and reactions given above are probably valid, the isograds inferred by Llewellyn are apparently not all located accurately. Unfortunately he did not include sample locations and descriptions of, or assemblages in, individual samples, or indicate how many samples were studied; further detailed work is required.

Epidote and clinozoisite coexist with quartz in the calc-silicate rocks, well into the amphibolite facies; some of the epidote is possibly retrogressive.

In the metabasites, the colour of hornblende in thin section is generally slightly bluish green, suggesting that all those metabasites examined from the Robertson River Formation (schist phase) are of lower or middle amphibolite facies.

Conditions of metamorphism

As noted in the Forsayth and Georgetown Sheet areas (Bain & others, 1976a, pp. 34-35; Oversby & others, 1978, pp. 36-39), the pressure during metamorphism was intermediate between that of the classic low-pressure (Abukuma and Buchan) and medium-pressure (Barrovian) facies series. Further studies in the Forsayth and Gilberton Sheet areas confirm this.

Rocks in which the predominant calcic amphibole has changed from actinolite to hornblende still contain plagioclase of albite composition; this is a feature of medium-pressure metamorphic terrains (Miyashiro, 1973, Table 8B-1), as are the persistence of epidote and clinozoisite into the amphibolite facies, and the presence of garnet in lower amphibolie metabasites (Bain & others, 1976a, p. 34). However, other features are more characteristic of low-pressure terrains, for example the existence of andalusite rather than kyanite and the presence of cordierite in the Forsayth and North Head Sheet areas. Detailed studies of the isograd reactions and zonal sequences in the Robertson River Formation (schist phase) in the "Robin Hood" area (Rubenach & others, 1977, and personal communication, 1977), indicate similarities to those of the

Stonehaven area of Scotland; Harte (1975) assigned the rocks there to a separate facies series, the Stonehavian, intermediate in pressure between the Buchan and Barrovian facies series.

Oversby & others (1978) suggested temperatures of 525°, 630°, and 670°C at about 3.5 kilobars for the beginning of the lower, middle, and upper amphibolite facies respectively.

STRUCTURE OF THE METAMORPHIC ROCKS

The metamorphics in the Gilberton Sheet area have been divided into four domains: A, B, C, and D (Fig. 24). A, B, and C are northwest of the Gilberton Fault, and the structure of the metamorphics becomes increasingly more complex from A to C. D is southeast of the Gilberton Fault and is uniformly complex. In addition the metamorphics have been divided into 25 subareas for analysis of the structural data (Fig. 25). Data have been plotted on the lower hemisphere of a Schmidt equal-area net (Figs. 26-30).

A discussion of the general features of the domains is followed by comments on the subarea analysis of the structural data.

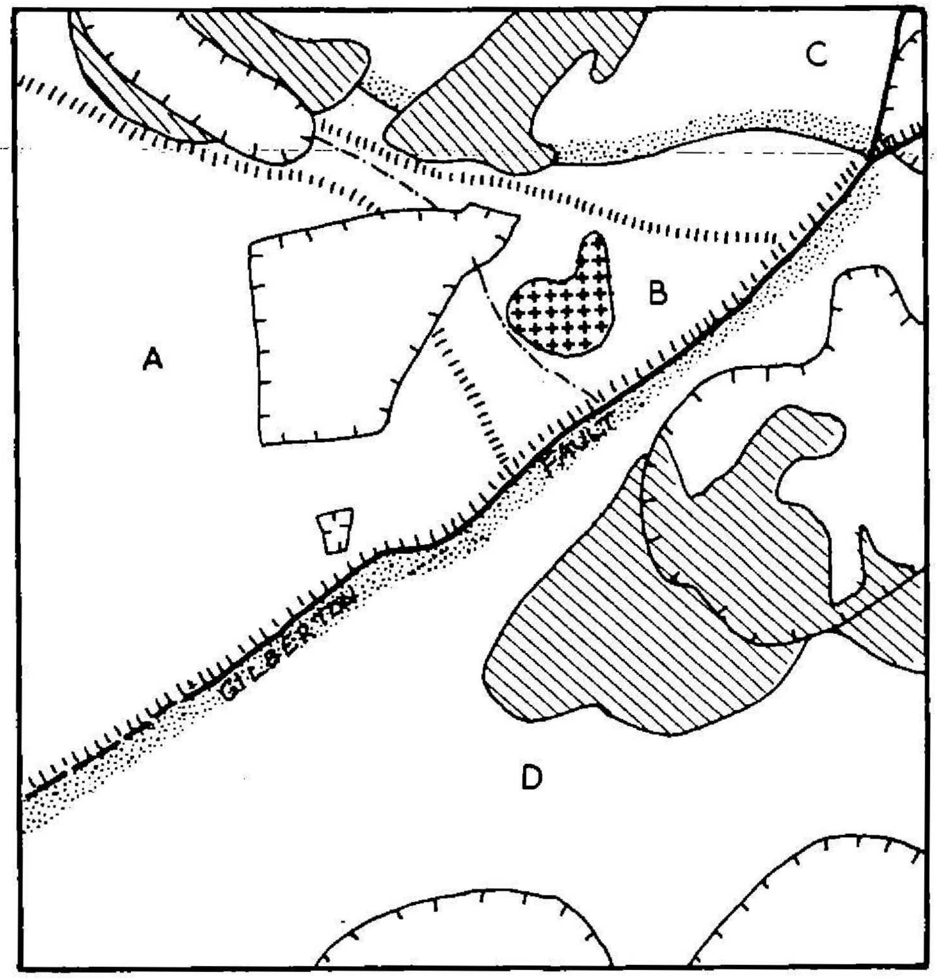
Domain A

Domain A is probably the least deformed area of metamorphics in the Georgetown Inlier. All of the rocks are of greenschist grade and include both Robertson River and Bernecker Creek Formations.

The rocks were tightly folded during the first deformation, D_1. A slaty cleavage (S_1), due to the parallel alignment of minerals in either a domainal or non-domainal fashion (see p. 19), cuts across bedding (S_0). A bedding fissility is locally developed and small, almost isoclinal folds in rocks at Iona homestead suggest that small-scale transposition has occurred locally. Generally, however, the rocks in this domain are not transposed.

Effects of later deformations in this domain are restricted to rare kinking and weak crenulations; no mineral foliation related to later deformation is present.

D_1 folds plunge at shallow angles to the east or west. The axial planes are either vertical or dip steeply north; locally the folds are overturned, e.g. in the Dead Horse Creek area. The folds range in wavelength from 2 to 6 km.



areas of subsidence (tensional) structures, basins, part-grabens, cauldrons, ring complexes, plutons (late Palaeozoic)

areas of ?late Proterozoic or Siluro-Devonian granitoids (post-D_2 ; syn-D_3 or D_4 ?)

?late Proterozoic granitoid (syn-D_3 ?)

extent of mid-Proterozoic granitoids (syn- or pre-D_2); stippled on side of granitoid occurrence

approximate greenschist/amphibolite facies boundary

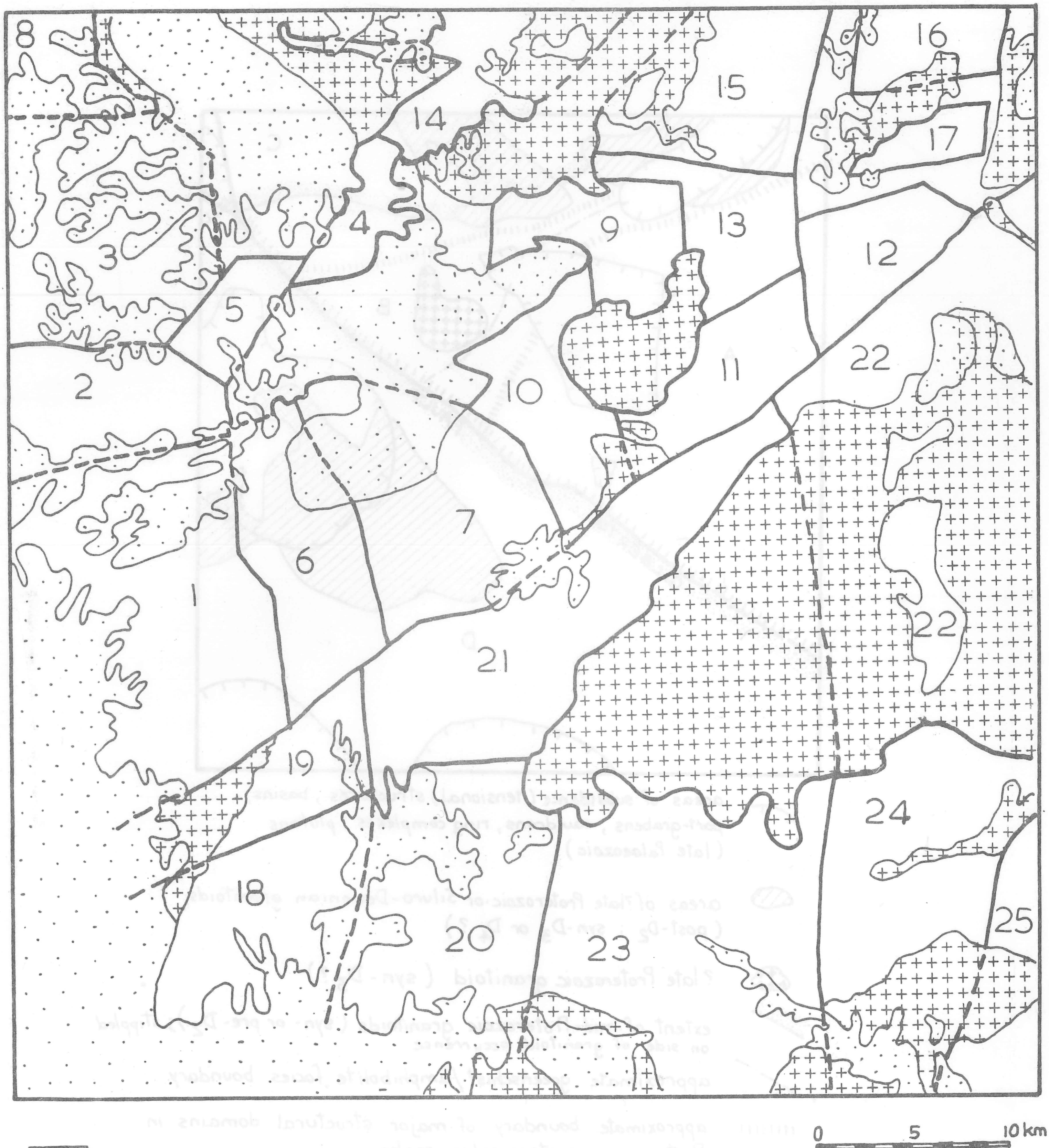
approximate boundary of major structural domains in Proterozoic metamorphic rocks

A, B, C, D structural domains (see text)

major fault

Fig 24: Gilberton 1:100 000 Sheet area showing main pre-Mesozoic structural sub-divisions

Record 1080/2



Devonian - Cainozoic cover rocks

Proterozoic - Permian intrusive rocks

Proterozoic metamorphic rocks

geological boundary

subarea boundary (broken where obscured)

Fig 25 : Gilberton 1:100 000 Sheet area showing subareas used in structural analysis of the Proterozoic metamorphic rocks

Record 1980/2

Domain B

In Domain B, the Robertson River and Bernecker Creek Formations and their higher-grade phases were also tightly folded during the first deformation. S_1 is a slaty cleavage or schistosity depending on the grade of metamorphism, which ranged from greenschist to lower amphibolite facies. The distinguishing feature of this domain is that second-generation folds with northeast-trending axial planes overprinted D_1 folds.

The most conspicuous D_2 folds are those to the west of the Mount Hogan Granite pluton where sills of metadolerite outline open folds with axial planes trending east-northeast to northeast and a half-wavelength of 2.5 km. S_0 and S_1 are both folded around these structures. S_1 cuts across S_0 at angles of up to 20° indicating that D_1 folds were tight but not isoclinal. Another major D_2 fold is outlined by the Dead Horse Metabasalt Member in the northwest corner of the Sheet area; S_1, the slaty cleavage, is folded around the hinge of this fold, which has an axial plane striking northeast.

In domain B, the slaty cleavage or schistosity is commonly crenulated, and locally a differentiated crenulation cleavage is developed. In places the crenulation cleavage is parallel to the axial planes of small B_2 folds. In some parts of the domain, for example in the folds west of Mount Hogan, a crenulation is not developed at all.

Later deformations appear to have produced little observable effect in this domain.

Domain C

Rocks in domain C include Einasleigh Metamorphics and the Robertson River Formation (schist phase) and Bernecker Creek Formation (calc-silicate phase). Together with those of domain D, they are the most complexly deformed in the Sheet area.

At outcrop scale in the Robertson River and Bernecker Creek Formations, S_0 is mostly transposed parallel to S_1 which is a schistosity or gneissic foliation. No definite large-scale D_1 fold closures can be recognised although the belt of Bernecker Creek Formation (calc-silicate phase) in this domain probably represents the core of a major D_1 anticlinorium. The large fold on the map at the eastern end of this belt is possibly a D_2 structure (see below). S_1 is also tightly folded, and in places, particularly in the metapelites, is transposed parallel to S_2. In the metapelites S_2 is represented by a crenulation cleavage, and locally a mineral foliation; in the calc-silicate gneiss, S_2 occurs as a mineral foliation in the hinge zones of tight B_2^1 folds. Such small-scale folds (wavelengths of a metre or less) are common in the calc-silicate rocks. S_1 and S_2 are usually defined by the same minerals (muscovite, biotite, hornblende, and elongate quartz, feldspar, and calcite) so that the two foliations are difficult to distinguish where fold limbs are parallel.

Third-generation structures can be recognised as open fold hinges. Axial plane foliations are rarely evident in the field, except for crenulation cleavages. Llewellyn (1974) found an S_3 foliation defined by weak alignment of muscovite flakes in a thin section of a specimen from GR 024851. This outcrop within the Bernecker Creek Formation (calc-silicate phase) is one of the few localities where an S_3 mineral foliation is known. Whole-rock Rb-Sr dating of a specimen from this locality gave an age of about 970 m.y., presumed to be the age of D_3 (Black & others, 1979).

Structural data (see below) suggest that the D_3 folds are open structures. By contrast, the D_3 folds in the central part of the adjacent Forsayth Sheet area are tight and overturned with axial planes dipping north (Bain & others, 1976a, p. 40); they become more open in the southern part of that Sheet area, for example just north of Cave Creek.

The most obvious fabrics in the Einasleigh Metamorphics are the compositional layering and foliation. The former is probably sedimentary layering, partially modified by metamorphic differentiation and transposed parallel to the foliation. Tight intrafolial folds are present locally within the layering. Because D_2 folds are almost isoclinal over most of the domain, S_1 and S_2 are generally parallel (except in fold hinges) and are difficult to distinguish.

Llewellyn (1974) described a transition zone, in the Einasleigh Metamorphics, in which S_2 becomes more strongly developed. At GR 003897 calc-silicate gneisses have a strong S_1 foliation and only a weakly developed S_2 cutting across it at a low angle. Towards GR 004907, the layering becomes progressively more distorted and tight B_2^1 folds with axial planes almost parallel to the layering are present. At 004907 the folds are isoclinal and the main foliation is S_2; S_1 can be distinguished from it only in fold hinges. The main foliation and tight folds are deformed by younger open folds.

No large-scale first or second-generation folds have been mapped out in the Einasleigh Metamorphics because of the poor outcrop and lack of markers. However, as outlined in the section on subarea analysis (below), most of the structures in the northeast part of the Gilberton Sheet area trend northeast to north-northeast, whereas those in the adjacent part of the Forsayth Sheet area trend southeast. A major open third(?)-generation fold hinge with an approximately east-trending axial plane probably lies along the sheet boundary.

Younger folds (D_4 and D_5) in domain C are probably gentle warps. Their presence may explain some of the scatter in structural elements as described in the section on subarea analysis.

Domain D

All of the rocks southeast of the Gilberton Fault constitute this domain. It contains Einasleigh Metamorphics, Juntala Schist, and numerous large and small granitoid bodies, some of which are also deformed.

The Einasleigh Metamorphics in domain D are similar to those in domain C. The rocks are well foliated parallel to the compositional layering, and the foliation is folded by small-scale tight to isoclinal folds. An S_2 mineral foliation is locally developed but is difficult to distinguish from S_1 except in fold hinges. The rocks are refolded by up to two sets of open folds. No mineral foliations are associated with these folds.

No large-scale structures have been mapped out because of the poor outcrop and lack of markers. Analysis of the structural data (see below), however, suggests that the rocks were deformed by tight, approximately north-trending second-generation folds and refolded by open east-trending third(?)-generation structures. The nature and orientation of the first-generation folds is unknown except that they were probably tight to isoclinal.

In the Juntala Schist, large-scale folds having wavelengths of up to 4 km are outlined by bedding trends on the aerial photographs. These trend north to northeast and are refolded by broad, approximately east-trending folds.

At outcrop scale in the Juntala Schist the main fabric is a schistosity. The S_1 schistosity is generally strongly overprinted by S_2, which is either a schistosity or a strong, very asymmetric crenulation cleavage. In the hinge of the large regional folds S_2 cuts across S_1 and the compositional layering at a high angle, and is parallel to the axial planes of the folds. Two or more sets of more open crenulations are developed on S_1 and S_2 in many outcrops; some resemble conjugate sets but are probably related to different deformations.

Detailed studies by Andrew Duncan of James Cook University confirm that the large north-trending regional folds are second-generation structures. His structural analysis suggests that four sets of younger crenulations, which he relates to regional folding events, are present. The open folds with east-trending axial planes are either D_3 or D_5 folds.

The Einasleigh Metamorphics and Juntala Schist were both deformed by tight north-trending D_2 folds and refolded by open east-trending folds. This similar deformational history supports the contention that the units are part of a conformable sequence.

Subarea analysis of structural data

Domain A

Figure 26 shows plots of structural data (poles to S_0 and S_1) for subareas 1 to 7 in domain A. In each subarea the poles to S_0 define girdles, although some of the plots show large spreads. Poles to these girdles dip east or west at shallow angles, corresponding approximately with measured B_1^0 axes. The variation in plunge of B_1^0 from one subarea to another, and in some cases within a subarea (indicated by plots of S_0/S_1 intersections) is due either to weak refolding or to the D_1 folds being non-cylindrical.

Plots of poles to S_1 generally cluster about the north and south pole of the diagram, consistent with the east-west trend of the mapped axial traces of folds; the spread is probably mainly due to fanning about the fold axis rather than refolding. In subareas 1, 2, and 6 the plots of S_1 suggest that the axial planes of the folds are vertical. In subareas 3, 4, and 5, maxima for S_1 in the southern hemisphere are due to the folds being inclined or overturned with axial planes dipping north.

Figures 26(m) and (n) show plots of S_0 and S_1 for subarea 7 which is near the boundary between domains A and B. The considerable spread of poles to S_1 cannot be explained as being simply due to fanning about B_1^0, and was probably caused by later folding. The average trend of S_1 has changed from east to northeast.

Domain B

In this domain D_1 folds are refolded by D_2 folds. The rocks are Robertson River Formation (subareas 8 and 10) and its schist phase (subarea 11); subarea 9 contains Bernecker Creek Formation.

Fig. 26: Structural data domain A

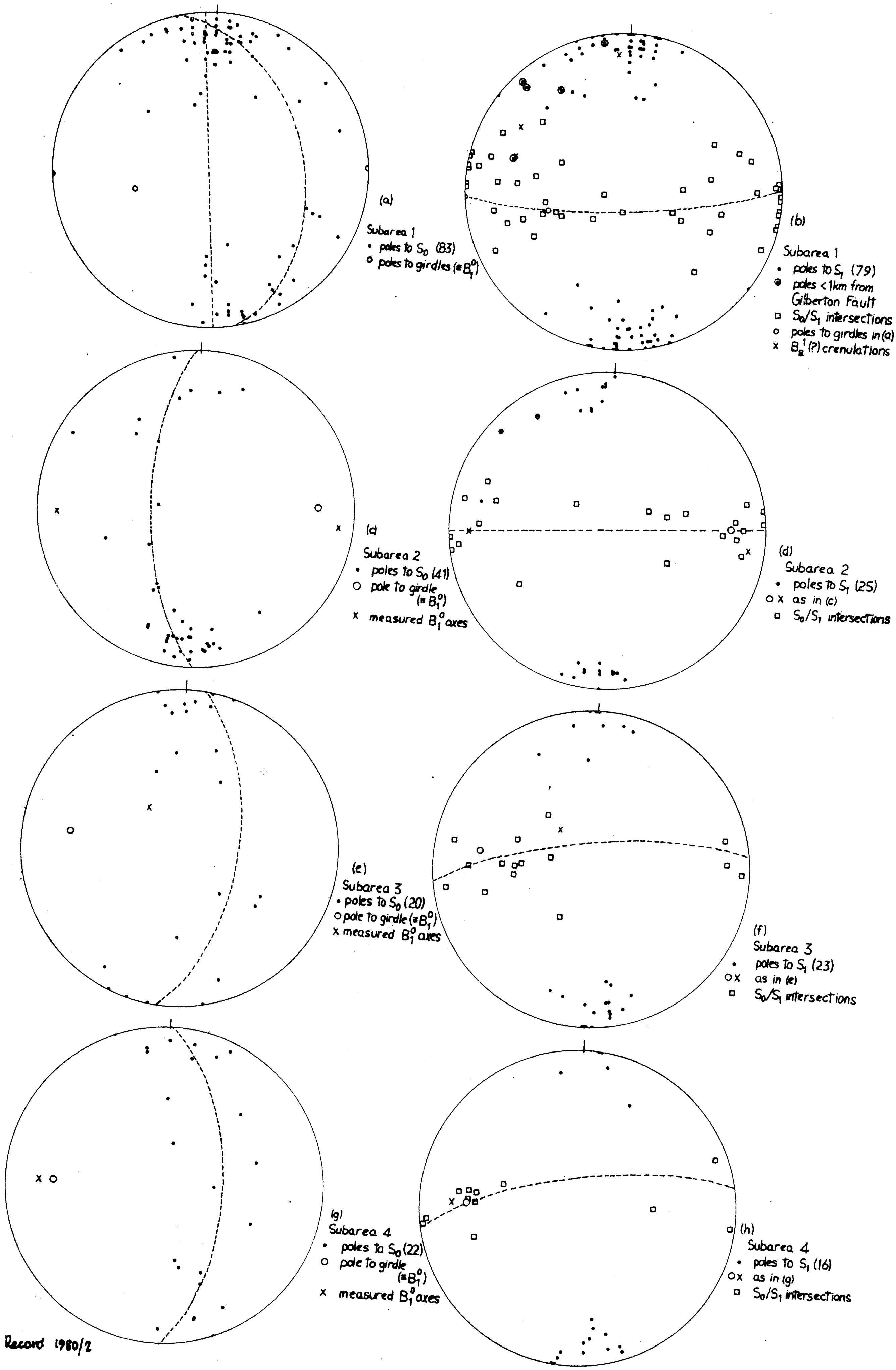
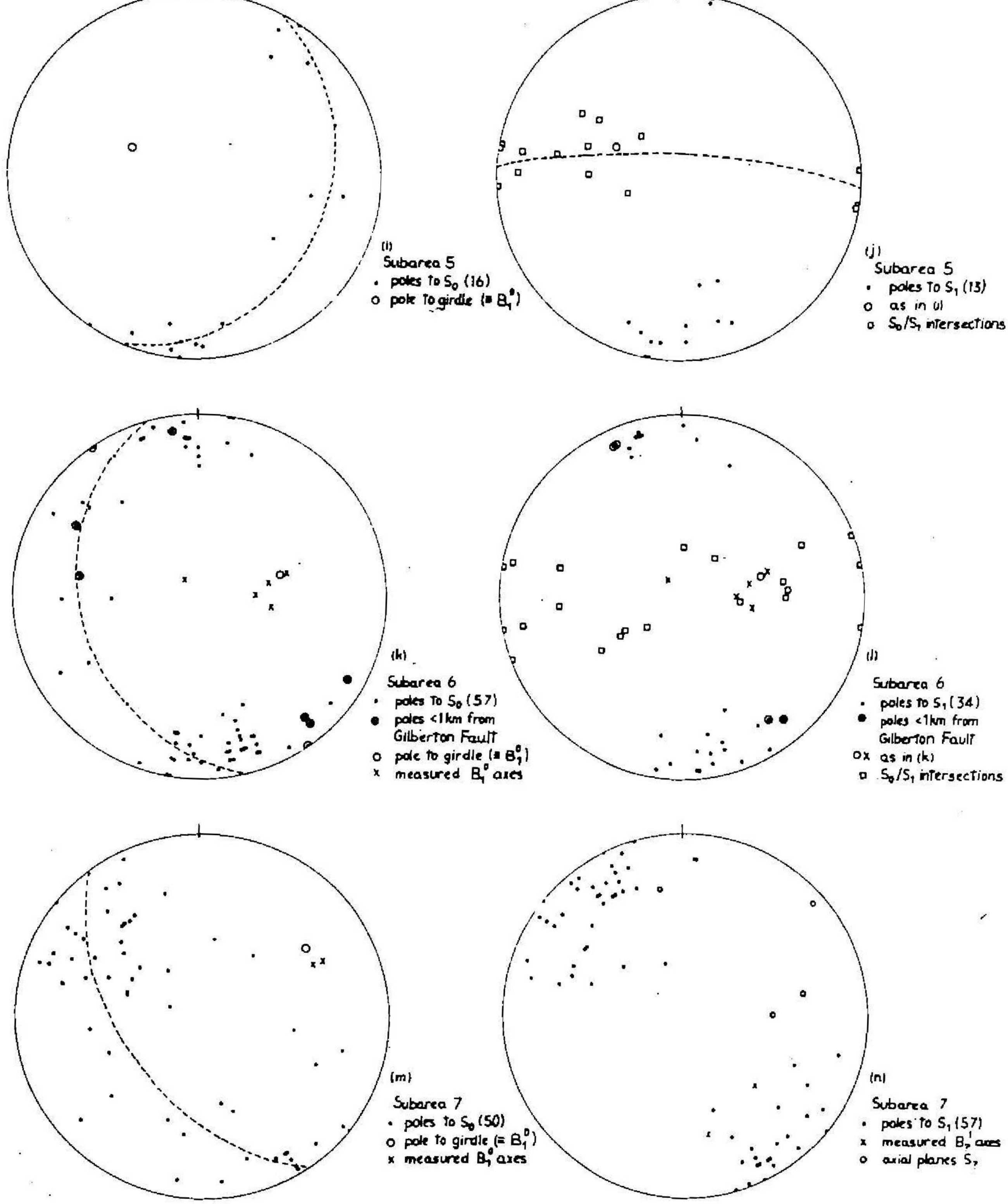


Fig. 26 continued

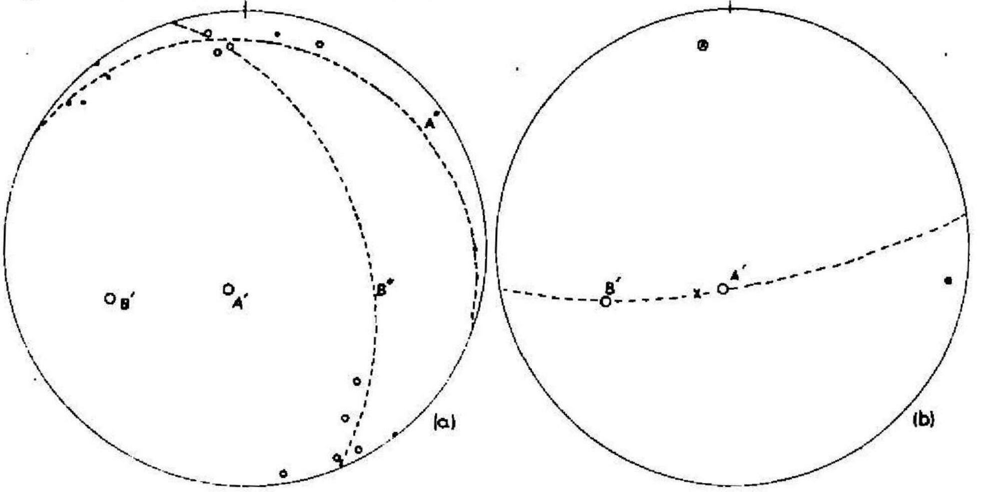


The refolding is well illustrated in subarea 10 where sills of metadolerite outline open D_2 folds; S_0 and S_1 are both folded around these structures. The constant vergence relation between S_0 and S_1 indicates that the part of subarea 10 studied lies on a single limb of a major D_1 fold, an anticline whose axial plane lies to the north and east. The large area of metadolerite west of the Gilberton Formation may represent the hinge of this fold. Poles to S_0 and S_1 are plotted in Figures 27 (d) and (e) and define single girdles in each case; the poles to these girdles are B_2^0 and B_2^1 respectively. Assuming that there has not been any subsequent refolding, a girdle drawn through measured and estimted B_2^0 and B_2^1 axes should correspond to S_2. The pole to this girdle does correspond closely with the poles of S_2 axial planes actually measured in the field; the axial plane of the D_2 folds therefore strikes east-northeast and dips steeply north. S_1 is rarely crenulated in this subarea, and consequently measurements of S_2 are difficult to obtain except as axial planes of rare minor D_2 folds.

In subarea 8, a D_2 fold is outlined on the map by the Dead Horse Metabasalt Member (Emt_1). The slaty cleavage, S_1, is folded around the hinge. The slate and phyllite in the subarea are commonly crenulated, and locally, a differentiated crenulation cleavage is developed. Data from subarea 8 are plotted in Figures 27 (a) and (b), but are inadequate to properly analyse the orientation of S_2. The mapped axial trace of the D_2 fold strikes northeast. The subarea is on the southern limb of a broad D_3 fold, the axial plane of which is just north of Cave Creek in the Forsayth 1:100 000 Sheet area.

In subarea 9, S_1 and S_0 are mostly parallel; this suggests that D_1 folding was isoclinal, or at least very tight, so that at the outcrop-scale, S_0 is transposed parallel to S_1. At GR 936861, probably near the hinge of a major D_1 fold, S_1 cuts across S_0 (as defined by thicker, more massive beds) at a high angle; in the same outcrop, however, thin laminae are tightly folded and transposed parallel to S_1. Most of the poles to S_1 from subarea 9 (Fig. 27c) plot in the northern hemisphere. This could be explained either by very tight to isoclinal folding of S_1, or by the subarea being on a single limb of a major D_2 fold, or by there being only slight folding of S_1. All three explanations could result in a single point maximum. No evidence for tight folding of S_1 was observed in the field, and no evidence for the development of S_2, either as a mineral foliation or a crenulation, was observed; the first explanation is therefore unlikely. D_3 or later folding was probably only minor.

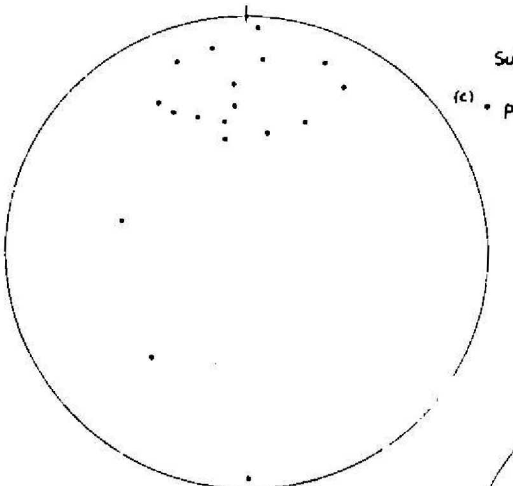
Fig. 27: Structural data domain B



Subarea 8

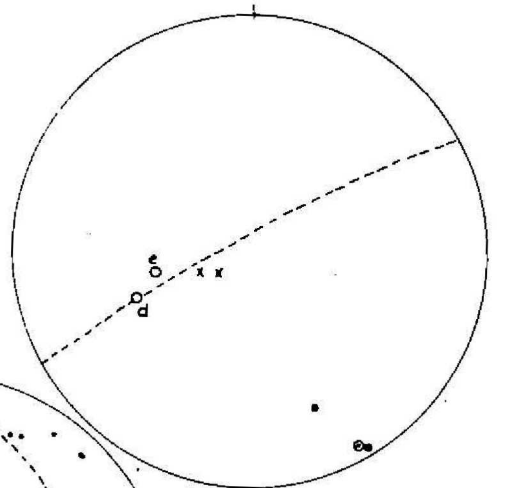
(a)
- • poles to S_0
- o poles to S_1
- O poles to girdles { A' = B_2^0, B' = B_2^1 }

(b)
- O as in (a)
- O pole to estimated S_2 (girdle)
- x measured B_2^1 axis
- • pole to measured axial plane (S_2)

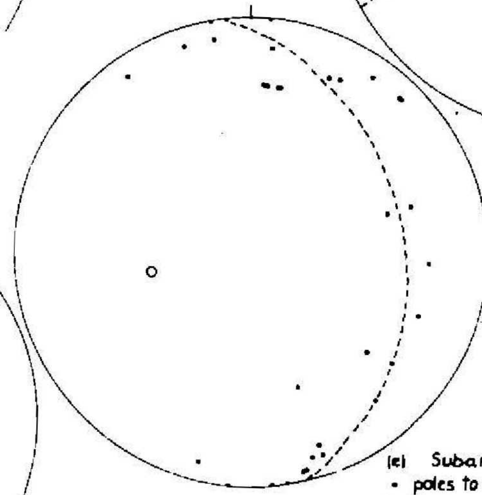


Subarea 9

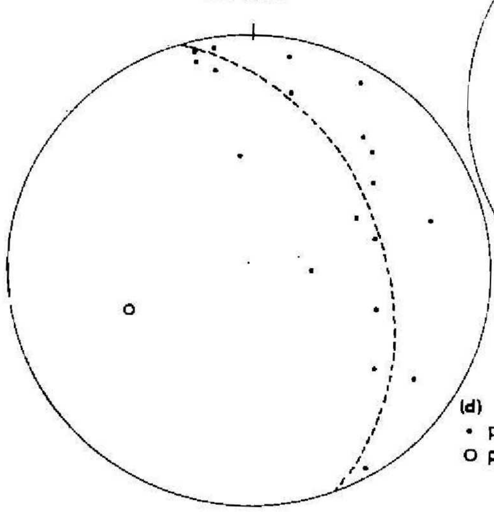
(c) • poles to S_1 (17)



(f) Subarea 10
- O poles to girdles in (d) (B_2^0) and (e) (B_2^1)
- x measured B_2^0 axes
- ⊚ pole to estimated S_2 (girdle)
- • poles to measured axial planes (S_2)

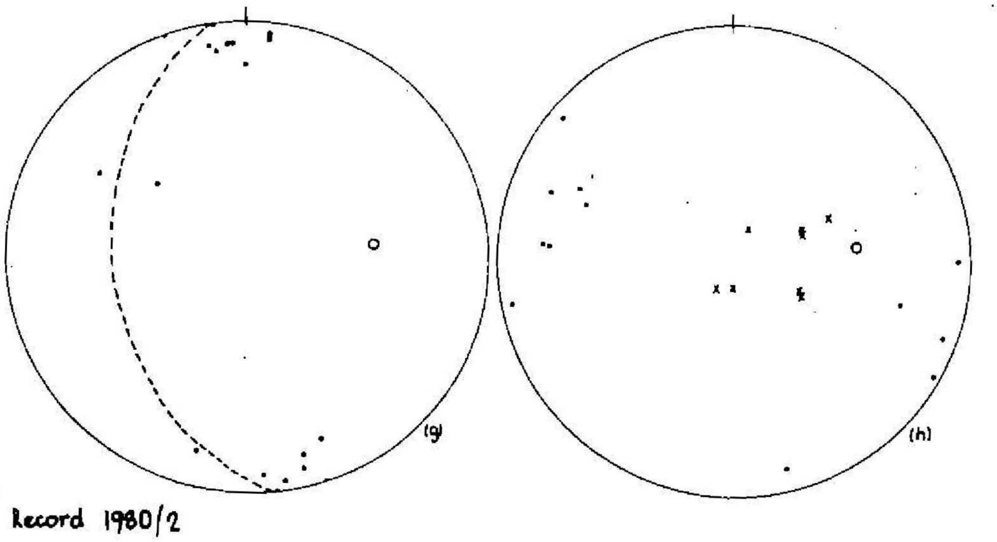


(e) Subarea 10
- • poles to S_1 (30)
- O pole to girdle (= B_2^1)



(d) Subarea 10
- • poles to S_0 (19)
- O pole to girdle (= B_2^0)

Subarea 10.



Subarea 11

(g)
- • poles to S_1 (17)
- O pole to girdle (= B_2^1)

(h)
- • poles to S_2-crenulation cleavage (12)
- x crenulations (L_2^1)
- O as in (g)

In subarea 11 also, S_0 is parallel to S_1. D_1 folds are therefore very tight or isoclinal, so that at the outcrop level, S_0 is transposed parallel to S_1. S_2 is represented mainly by a fine crenulation cleavage; locally it is parallel to the axial planes of small B_2^1 folds. At GR 062832 retrogressed andalusite porphyroblasts are parallel to these B_2^1 axes. Data from subarea 11 are plotted in Figures 27 (g) and (h). They suggest that S_1 is deformed by weak D_2 folds which have NNE-striking axial planes (S_2), and which plunge steeply east.

Domain C

Rocks in domain C include Einasleigh Metamorphics and higher-grade parts of the Robertson River and Bernecker Creek Formations. Subareas 12, 13, and 14 contain the Robertson River Formation (schist phase) and Bernecker Creek Formation (calc-silicate phase). The Einasleigh Metamorphics crop out in subareas 15, 16, and 17.

Structural data from subareas 12, 13, and 14 are plotted in Figures 28 and 29. Subarea 13 was studied in detail by Llewellyn (1974). In subarea 12 the main foliation (S_1) has been folded about axes which plot on two east-west girdles (Fig. 28a, b) suggesting subsequent refolding; this is also shows by the plot of poles to S_2, and by the spread of poles to S_1. S_2 strikes predominantly north-northeast to east-northeast (as in domain B), but some of the data extend along a girdle whose pole plunges steeply west-northwest; this is probably equivalent to the B_3^2 axis. No data are available to indicate the orientation of S_3. The axial trace of the major fold of the Robertson River Formation calc-silicate member (Emr_3) trends northeast, i.e. parallel to the predominant trend of S_2; this suggests that the fold may be a D_2 structure.

In Figure 29 the data of Llewellyn (1974) from subarea 13 are plotted. The main foliation (S_1) has a single point maximum corresponding to the single point maximum for S_2. This reflects the tight to isoclinal nature of the D_2 folds. However, the S_1 data also define a girdle, whose pole Llewellyn interpreted as the B_3^1 axis; it corresponds closely with measured B_3^1 axes. According to Llewellyn, S_2 data do not lie on a girdle because no S_2 surfaces were available for measurement in areas where D_3 folding was obvious. B_3^1 axes are constant in orientation over a wide area, suggesting that later folding was very weak.

Fig28 Structural data domain C

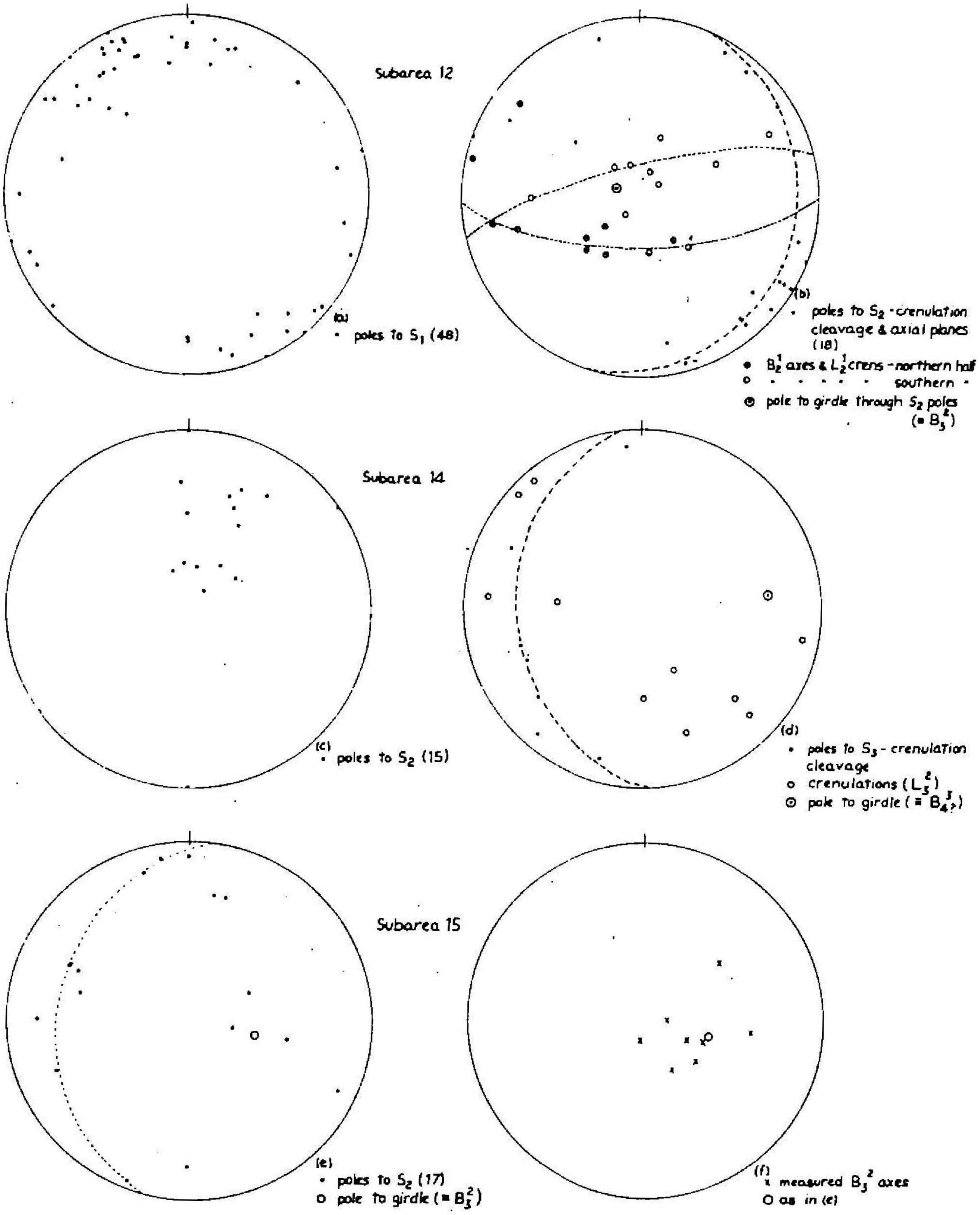
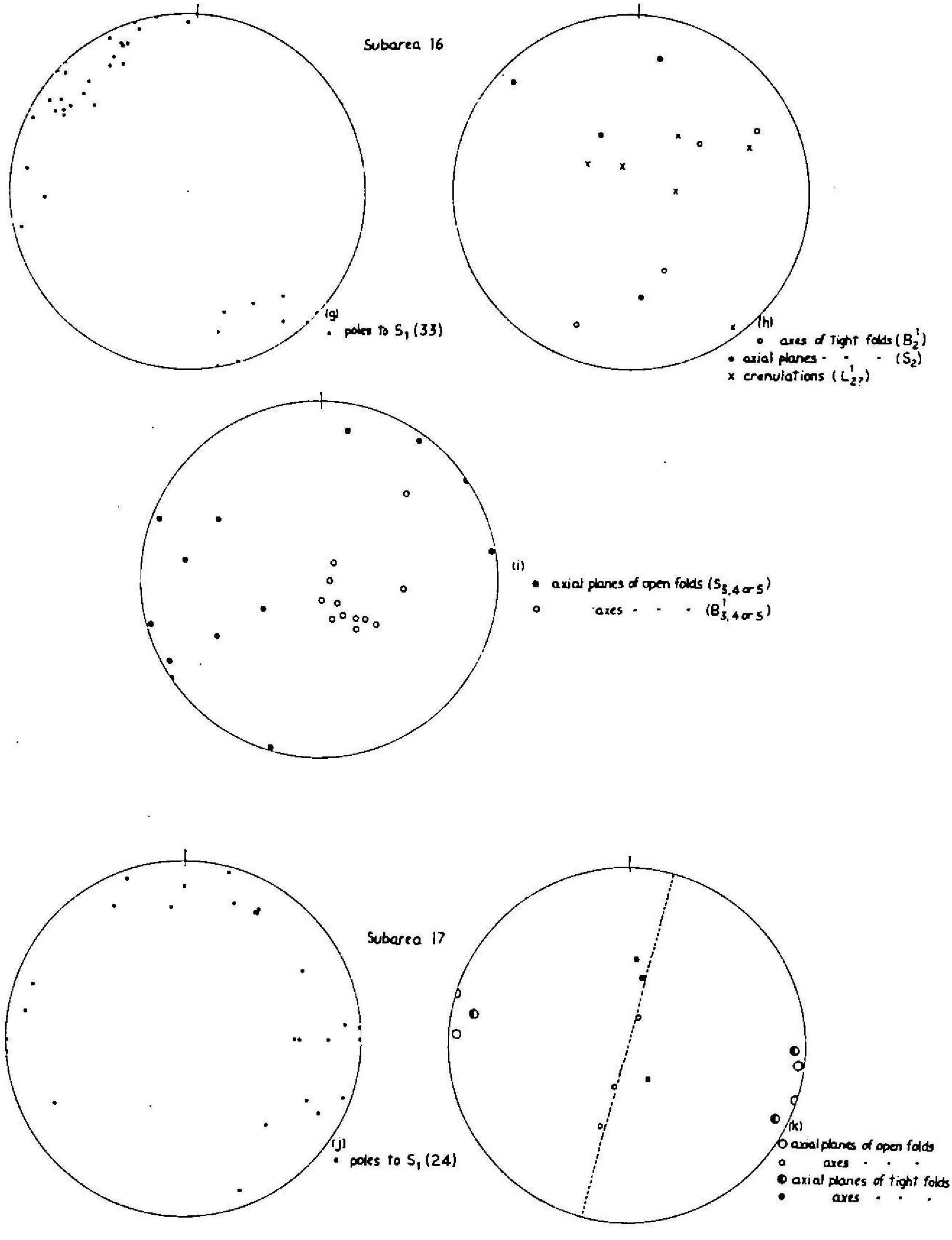


Fig.28 continued



There are insufficient data for adequate analysis of the structure of subarea 14. The dominant foliation is probably mainly S_2, either as a mineral foliation or as a tight crenulation cleavage. Locally, however, in particular along the Percy River near the Lower Percy stock camp, S_2 is only a weak crenulation cleavage; structures in this part of subarea 14 are gradational with those of domain B. Crenulations and associated crenulation cleavages developed on S_2 are due to D_3 or later folding. Poles to S_2 plot in the northern hemisphere of Figure 28(c). Subarea 14 probably lies on one limb of a major D_3 fold which has few parasitic folds associated with it; this fold, if it exists, must be much more open than those in the central part of the Forsayth Sheet area, where the D_3 folds are overturned with axial planes dipping north (Bain & others, 1976a, p. 40).

Crenulations and poles to related crenulation cleavages are plotted in Figure 28(d). The poles to the crenulation cleavages (assumed to be S_3) plot on a girdle, which suggests refolding about axes plunging to the east; these axes may belong to D_4 folds, which Bell & Rubenach (personal communication), on the basis of their work in the Robertson River area, believe to be roughly coaxial with D_3 folds.

Data collected by Llewellyn (1974) from the southern part of subarea 15 (Fig. 29e, f) show a spread of poles to S_2 about a single point maximum. Poles to S_3, however, are extended into a girdle, probably due to D_4 folding. In general, S_3 trends east to northeast as do most D_3 folds in the Robertson River Formation (schist phase) in the Forsayth and Georgetown Sheet areas.

Figure 28 (e, f) shows the data collected in subarea 15 during this survey. Poles to S_2 appear to be distributed along one and possibly two girdles; and B_3 axes cluster around the pole of one of these. There are insufficient data to draw any definite conclusions as the area is large and complex.

In subarea 16, the Welfern area, poles to S_1 plot with a large spread near the primitive circle in the northwest and southeast quadrants (Fig. 28g). D_2 folds are almost isoclinal, the plot of S_1 being therefore effectively also a plot of S_2. The overall trend of the foliation is northeast and the B_2 fold axes and related crenulations plunge mainly to the northeast (Fig. 28h). In the adjacent part of the Forsayth 1:100 000 Sheet area Bain & others (1976a, pp. 39, fig. 39) found that S_1 and S_2 trended southeast and B_2 plunged southeast. This suggests that the two areas are on the opposite limbs of a major D_3 fold, the axial plane of which lies approximately along

79

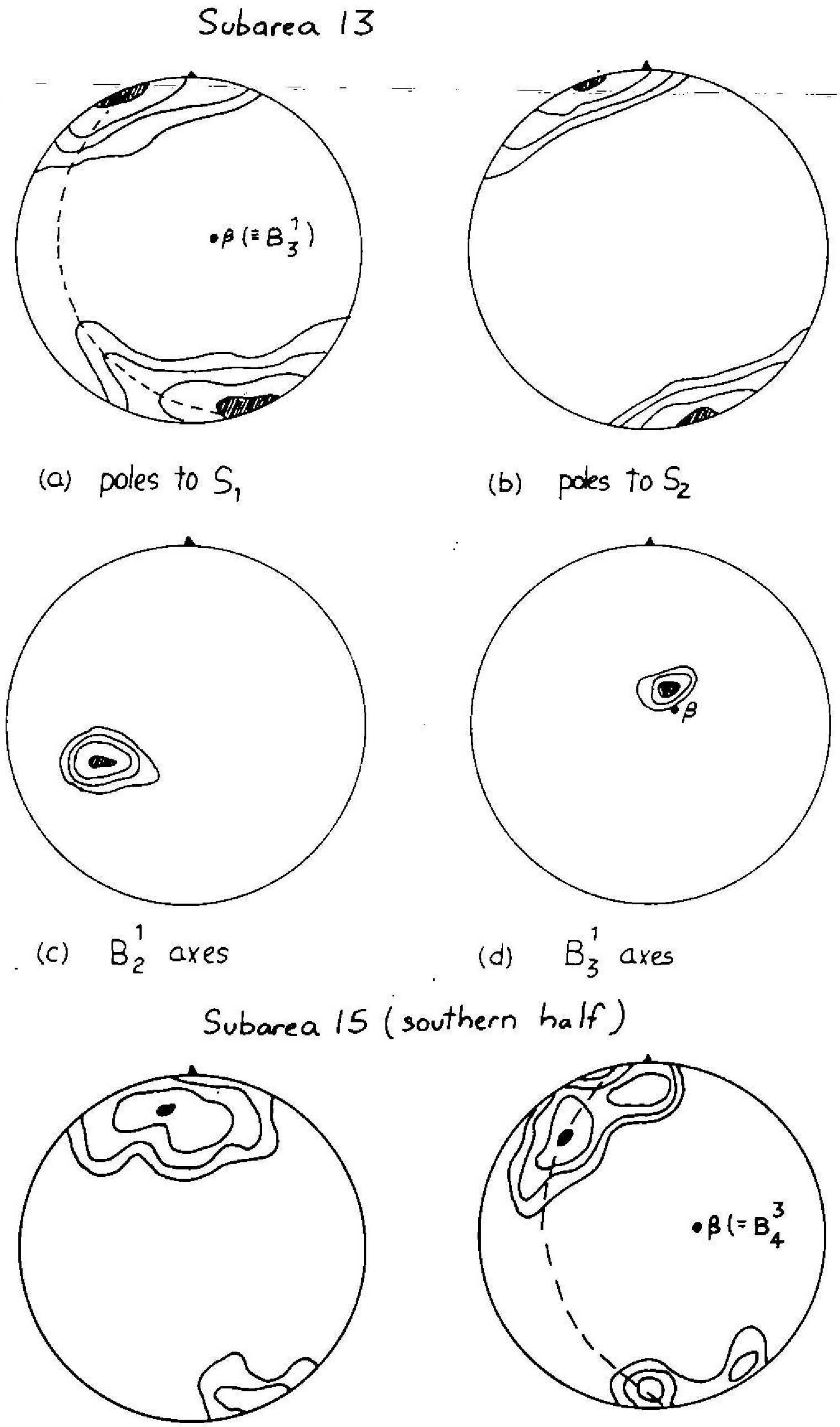


Fig. 29 Structural data from subarea 13 and part of subarea 15; after Llewellyn (1974) (number of measurements and contour intervals not known)

the sheet boundary. B_3^1/B_3^2 axes plunge steeply to the southeast (Fig. 28i) but lie on the same east-west girdle as do the B_3^1, axes in the adjacent part of the Forsayth Sheet area (Bain & others, 1976a, fig. 39d). However, poles to S_3 are scattered, the significance of which is not clear. Those plotted by Bain & others (1976a, fig. 39d) range in strike from northeast to southeast, which is consistent with the overall east-west trend of D_3 folds elsewhere (see above).

A plot of poles to foliation from subarea 17 shows a large scatter around the primitive (Fig. 28j). These were measured in the Einasleigh Metamorphics near the hinge of the major fold (D_2?) outlined by the Bernecker Creek Formation (calc-silicate phase) (Emr_3). Foliation measurements were made on the lithological layers which have a foliation (S_1?) parallel to them. Tight folds with an axial plane foliation (S_2?) cutting across the main foliation at a low angle are present; in some outcrop, however, for example GR 132905, zones of very tight folds with an axial plane mineral foliation are separated by zones in which the folds, although having the same orientation, are more open. This suggests that in subarea 17, D_2 folds are only locally isoclinal and transpositional; it probably represents a transition between subarea 12 and 16. Axes of both tight and open folds in subarea 17 plot near a vertical NNE-trending girdle, and the poles of axial planes of these folds are clustered around the pole to the girdle (Fig. 28k); this suggests that the folds belong to the same generation, the girdle probably representing S_2.

Domain D

This domain has been divided into eight subareas for analysis of data. Subareas 18 to 21, 23, and 24 contain Einasleigh Metamorphics and small leucogranitoid bodies; subarea 22 contains large areas of Proterozoic and Palaeozoic granitoids with some Einasleigh Metamorphics; subarea 25 contains Juntala Schist.

Structural data from the Einasleigh Metamorphics of domain D are plotted in Figure 30. The subareas are too large to allow detailed analysis of the structure, but the following observations and conclusions can be made.

Plots of poles to foliation measured in subareas 18 and 20 show concentrations of points in the eastern hemisphere, which indicate that the foliation in general dips to the west, and trends between northeast and northwest. As the foliation is almost isoclinally folded, this is also effectively the orientation of S_2, the axial planes of the D_2 folds; this is borne out by the plot of poles to actual axial planes of tight folds (Fig. 30b). The large spread of poles to foliation away from the ideal point maximum expected for isoclinal folding is probably due mainly to later folding. No single well defined girdle is evident, suggesting that more than one set of later folds may be responsible. Earlier (D_2) folds are not always isoclinal and this would also account for some of the spread. A similar, though less pronounced, pattern is derived from data in subarea 21. Some of the scattering there, may be due to proximity to the Gilberton Fault; the same effect is also apparent in the plot of poles to foliation from subarea 19.

In subarea 23, although poles to foliation again tend to be concentrated in the eastern hemisphere, a larger spread is apparent (Fig. 30i). Poles to foliation in subarea 24 (Fig. 30k) are concentrated in the northeast quadarant.

Fig. 30(l) is a synoptic diagram of poles to axial planes of folds in the Einasleigh Metamorphics for subareas 18, 20, and 23. Axial planes to tight folds (S_2) strike approximately north, and most dip to the west. Axial planes to the open folds strike mainly east and dip steeply; the latter probably are mainly S_3, and have the same general trend as axial planes to D_3 folds in the Einasleigh Metamorphics of the Welfern area (see domain C) and in the Robertson River Metamorphics of the Forsayth and Georgetown 1:100 000 Sheet areas.

Data from the Juntala Schist (subarea 25) are plotted in Figure 30 (m, n, and o). Poles to S_1 plot as a single maximum in the eastern hemisphere (Fig. 30 m); poles to S_2 (Fig. 30 n) plot in a similar position, demonstrating that the D_2 folds are very tight or almost isoclinal and that they are overturned with west-dipping axial planes. This is the same pattern as that in parts of the Einasleigh Metamorphics (for example, subareas 18, 20, and 21). The B_2^1 fold axes plot near a north-trending girdle whose pole plots among the poles to S_2.

In Figure 30(c) the open crenulations and poles to the associated crenulation cleavage planes are plotted. These were measured on a traverse between GR 883486 (Lyndhurst 1:100 000 Sheet area) and GR 142521 (Gilberton 1:100 000 Sheet area). The poles to the crenulation cleavage planes plot in two clusters about 45° apart. The major cluster corresponds to that of poles to S_3(?) in the Einasleigh Metamorphics (Fig. 30, l). The crenulations that correspond to the various crenulation cleavage planes are plotted in Figure 30(o). With one exception the two groups of crenuations plot separately, suggesting that the crenulations are related to separate phases of folding.

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Fig30: Structural data domain D

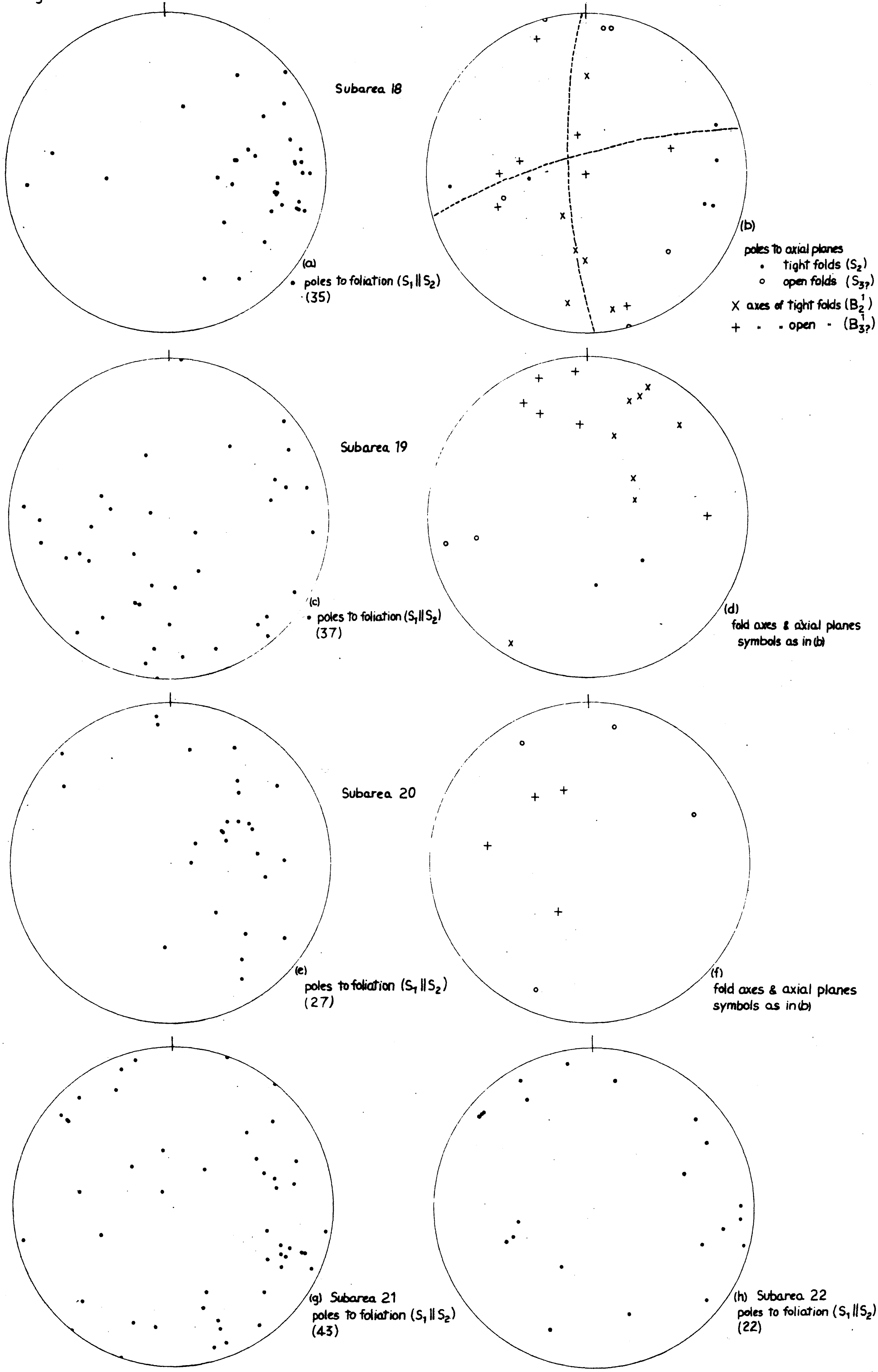
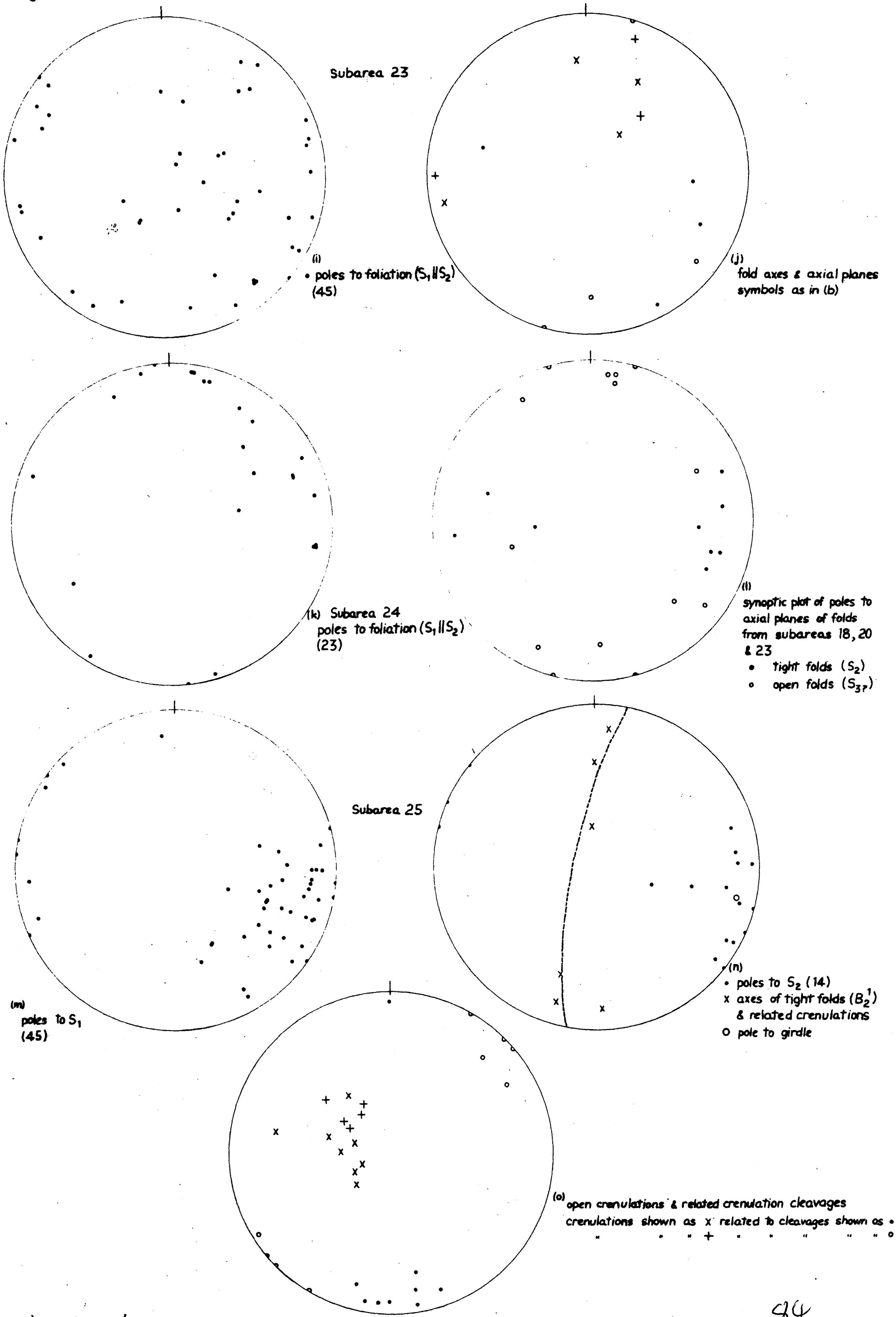


Fig 30 continued



MID TO LATE PALAEOZOIC SEDIMENTARY AND VOLCANIC ROCKS

GILBERTON FORMATION (DCg)

(White, 1959a)

Introduction

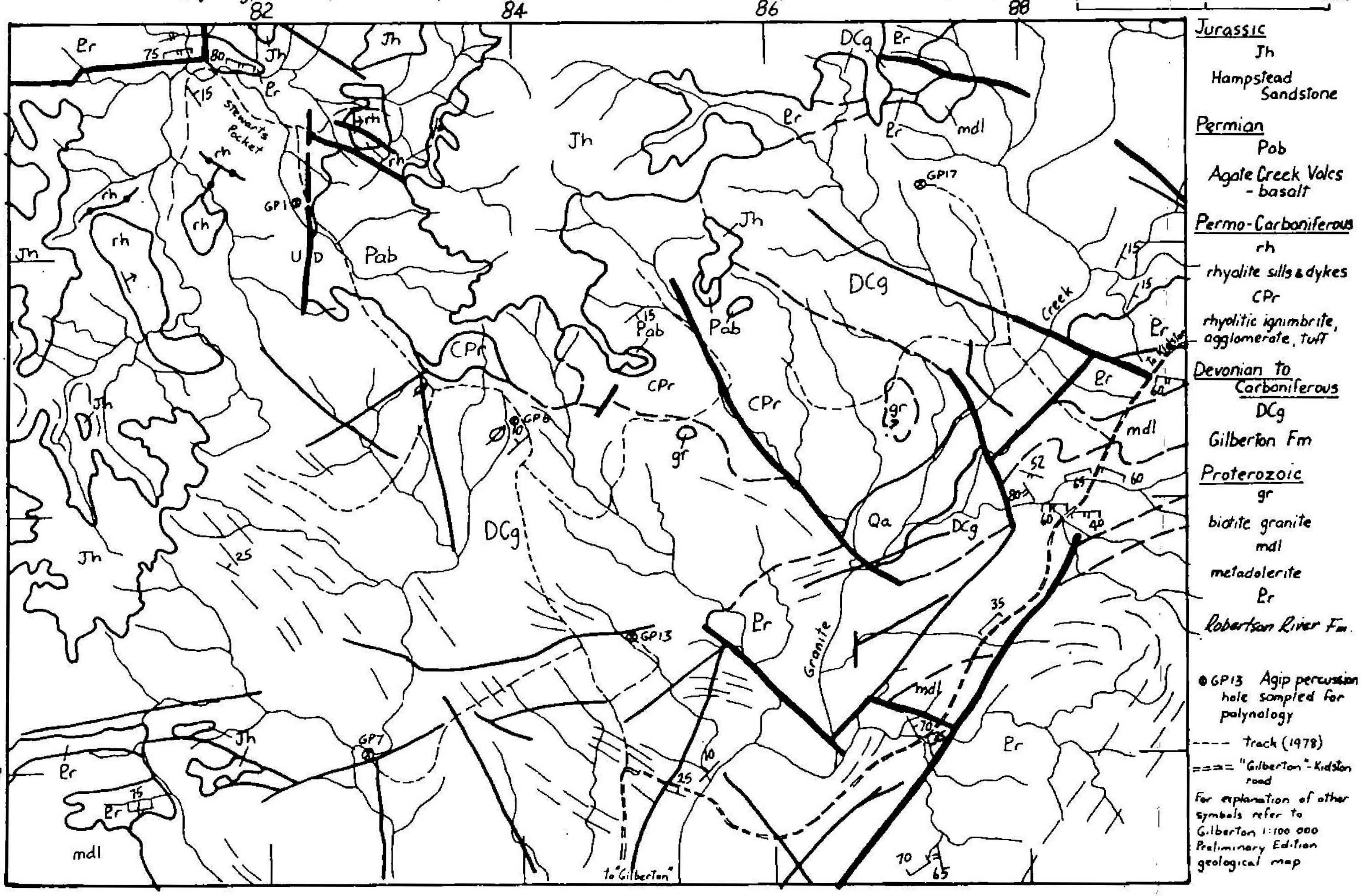
The late Devonian and/or early Carboniferous Gilberton Formation (White, 1959a, p. 33; 1965) occurs in three areas totalling about 120 km^2; all of these are north of the Gilberton Fault and were probably originally continuous. The largest area, about 115 km^2, extends from 4.5 km north to 20 km north-northeast of "Gilberton". Smaller areas occur south of the Gilbert River, opposite the former site of Gilberton township, and in the Percy River 4 km downstream from Lower Percy Stock Camp (map). Immature terrigenous clastic sedimentary rocks characterise the formation, which lies unconformably on greenschist to lower amphibolite facies Proterozoic metamorphic rocks of the Robertson River and Bernecker Creek Formations. Volcanic rocks tentatively assigned to the Agate Creek Volcanics overlie the Gilberton Formation with presumed disconformity (Fig. 31 and pp. 85, 90); no sedimentary rocks that could be unambiguously assigned to the Agate Creek Volcanics were seen. Trachy-andesite dykes and rhyolite dykes and bodies, which are probably cogenetic with the Agate Creek Volcanics, intrude the formation locally. The Gilberton Formation is well exposed along Granite Creek, but elsewhere outcrop is sporadic. The thickness of the formation is difficult to estimate; in some places it is at least 200 m.

The characteristics of clastic rocks in the Gilberton Formation were mostly estimated visually in the field. Grainsize classification is based on the Wentworth scale (Pettijohn, 1957, p. 18); sandstone nomenclature basically follows Pettijohn (1957, p. 291), although "quartzose sandstone" is used in preference to "orthoquartzite".

Stratigraphy

The gross aspect of the Gilberton Formation is that of a coarsening-upward sequence containing an unknown number of poorly-defined fining-upward cycles. Interbedded quartzose and feldspathic sandstone and siltstone locally occur in the lower part of the formation; the upper part is mainly coarse arkose and conglomerate with well-developed trough cross-bedding. The two parts of the formation grade into each other laterally and vertically, and they are

Fig 31 : Geological map of the northeastern part of the Gilberton Formation showing the distribution of Permo-Carboniferous volcanics; geology 1975 by B.S. Oversby (BMR) and 1978 by J.D. Shaw (Agip Nucleare Aust. Pty Ltd)



not differentiated on the map. The Gilberton Formation has not been sufficiently well studied to date for a formal type section to be nominated and described; in this report the original definition of White (1959a) is augmented by description of two representative sections of the unit.

One section is in the southeastern part of the main outcrop area; it extends from the base of the Gilberton Formation exposed beside the "Iona" road at and near GR 776727, northeastward across strike to the base of the Mesozoic sandstone which lies at an elevation of about 540 m. The second reference section is south of the Gilbert River, and extends from the base of the Gilberton Formation, exposed on the eastern end of Commissioners Hill at and near GR 804662, east-southeast for about 1 km to the highest(?) preserved part of the formation in the area at GR 814659.

In the northern section the contact between the Gilberton Formation and the underlying fine-grained buff and grey metaquartzite of the Robertson River Formation is exposed on hill slopes near the "Iona" road, about 3 km from the junction with the Kidston-Gilberton road. The lowermost beds of the Gilberton Formation are over-steepened and warped, but they and the contact with the Robertson River Formation are not faulted. About 8 m of interbedded coarse feldspathic sandstone, fine conglomerate, and thin to medium-bedded flaggy green and purple sandy siltstone, and siltstone with detrial muscovite and biotite, constitute the lowermost Gilberton Formation. Siltstone is locally mottled. These lowermost beds are overlain by about 200 m of coarse arkose and subsidiary coarse quartzose sandstone which locally are pebbly and cross-bedded. Leptophloeum australe was found in "ferruginous siltstone" in the lowermost beds at GR 774734 during the coarse of earlier 1:250 000 mapping (White, 1965) but no identifiable fossils were found in the area during the present work.

Elsewhere in the main outcrop area of the Gilberton Formation, siltstone interbeds occur locally in the lowermost part of the unit. About 5 km north-northeast of the above-described section purple siltstone is subordinate to medium to very coarse-grained white, pink, and green, locally pebbly and cobbly, feldspathic sandstone and arkose with conglomerate stringers and lenses. In the northeastern part of the main outcrop area beds up to about 3 m thick of purple and green siltstone are interbedded with feldspathic sandstone, arkose, and conglomerate. Farther south, at GR 873781, coarse grey to brown siltstone and fine-grained brown lithic sandstone are associated with fine to medium-grained quartz-pebble conglomerate; plant fossils occur in the finer-grained beds (pp. 78-79).

88

The exposed Gilberton Formation in the main outcrop area consists predominantly of arkose similar to that forming most of the section near the "Iona" road. The arkose is pinkish-grey to pale purple in overall aspect, poorly-sorted, medium to coarse-grained, commonly pebbly and cobbly, and contains conglomerate stringers and lenses. It commonly has a calcareous cement. Trough cross-bedding, with many troughs 1 m or more deep, is common in the arkose; some troughs contain basal conglomerate grading upwards into medium or coarse arkose. Siltstone and quartzose sandstone are rare. At GR 818804, purple calcareous siltstone or mudstone containing mudcracks crops out. The total thickness of this arkose-dominated sequence is unknown because of the lack of marker beds, presence of cross-bedding, and uncertainty regarding the configuration of the unexposed base. A thickness of about 200 m near the "Iona" road is a local minimum.

The second representative section contains about 150 m of interbedded mid-brown, olive-green, and purple lithic sandstone and subordinate siltstone overlain by at least 20 m of mid-brown, grey, and purple, lithic and feldspathic sandstone and arkose with conglomerate stringers, lenses, and interbeds. The section rests unconformably on basic metavolcanic (Dead Horse Metabasalt Member) and metasedimentary rocks of the Robertson River Formation at an elevation of about 580 to 600 m at the eastern end of Commissioners Hill. Sandstone in the lower 150 m of the Gilberton Formation is mostly fine to medium-grained, although coarse, poorly-sorted pebbly and cobbly varieties are also common. At least some of the sandstones are medium-bedded; beds contain crude horizontal stratification or low-angle tabular cross-bedding internally. Interbedded siltstone contains sporadic stringers of granule to pebble-sized clasts. Rocks in the upper 20 m of the formation are most commonly medium to coarse-grained; scattered pebbles and cobbles, and local conglomerate lenses, are common. The rocks are probably cross-bedded, although this is not evident in most outcrops because of their limited extent. Thicker conglomerate lenses and interbeds do not crop out but their existence is indicated by veneers of loose pebbles and cobbles of vein quartz.

Elsewhere in the southern outcrop area, as in the main area to the north, the lowermost, siltstone-bearing part of the Gilberton Formation appears to be no more than about 10 m thick; the fine sandstone and siltstone beds probably interfinger with and grade laterally into the arkose-dominated part. Leptophloeum australe and other fossils (pp. 78-79) occur in the lowermost part of the formation in the southern outcrop area, as they do farther north; specimens have been obtained from GR 805662, 819665, and 814653, both during 1:250 000 reconnaissance mapping (White, 1965) and during the present work.

The small, partly fault-bounded, outlier of lower Gilberton Formation in the Percy River contains interbedded purple siltstone and coarse feldspathic sandstone lying unconformably on Bernecker Creek Formation.

Provenance and depositional environment

Quartz and lithic fragments constitute the main clastics in the lower sandstone-siltstone assemblage of the Gilberton Formation. The larger quartz fragments (pebbles and cobbles) appear to have come from veins. Lithic fragments are metaquartzite, phyllite, "sericite" schist and metadolerite, similar to rocks in the Robertson River Formation. Granitoid clasts and feldspar grains occur sporadically and detrital muscovite and biotite are locally common. No clasts of amphibolite facies metamorphic rocks like those in the Einasleigh Metamorphics are known to occur in the southern outcrop area, even in Gilberton Formation close (less than 1 km) to Einasleigh Metamorphics southeast of the Gilberton Fault.

Quartz clasts are also common in the arkose, although generally subordinate to clasts of metamorphic and granitoid rocks. The suite of metamorphic rock clasts in the arkose is similar to that noted above, with the addition of mica schist in some areas. High-grade metamorphic rock clasts are known to occur only in the northeastern part of the main outcrop area. Granitoid clasts include white and pink foliated and unfoliated muscovite leucogranite of Digger Creek type, and pink equigranular and porphyritic biotite granite (of Robin Hood Granodiorite and Mount Hogan Granite). At GR 826803 a conglomerate contains pebbles and cobbles of rhyolite; these rhyolite clasts contain graphite, a feature characteristic of the Proterozoic Croydon Volcanics from which the clasts are presumed to be derived. The feldspathic material in the arkose is mostly pink and of sand to small pebble size; it presumably is derived from granitoids. Clastic biotite is virtually ubiquitous in the arkose; clastic muscovite is common locally.

Clasts are angular to well-rounded and display variable sphericity; there is commonly considerable variation in roundness among adjacent clasts, and among clasts of the same rock type.

The types of clastic material present in the Gilberton Formation indicate derivation from geologically heterogeneous source areas underlain mainly by low-grade metamorphic rocks intruded by granitoid bodies and quartz veins. The variable roundness and sphericity of clasts suggest that they were transported from sources located at varying distances from the present outcrop areas. Apparently no material was derived from the Einasleigh Metamorphics on the southeastern side of the Gilberton Fault; this may suggest that source areas lay only to the north or west, or that the Einasleigh Metamorphics were faulted into their present position after deposition of the Gilberton Formation. Lower-grade rocks may have been exposed in this area before faulting. Systematic cross-bedding measurements to indicate the direction of transport of clastic material were not made during the present work. However, according to Lemon (1973) cross-bedding in Gilberton Formation exposed in Granite Creek indicate sediment transport from the northwest and southwest. The clasts of probable Croydon Volcanics also indicate that at least some sediment was derived from the west.

The Gilberton Formation evidently accumulated in a series of interconnected depressions which were subsequently disrupted by high-angle faults, and partly exhumed. Outcrops of biotite granite of unknown age at GR 871808 and 852807 represent an east-trending Palaeozoic ridge in the basement. Palaeotopography and relief adjacent to the present outcrop areas of the Gilberton Formation were probably broadly comparable to those existing at present.

No detailed sedimentological studies of the Gilberton Formation have been made, but the unit is simular to fluvial sequences (e.g. Allen, 1974); a lacustrine origin (White, 1965) is most improbable. The large area of coarse and poorly-sorted trough cross-bedded material, paucity of fine-grained interbeds, lack of well-defined fining-upward cyclothems, and hypothesised local topography and relief, all suggest that deposition of the Gilberton Formation sediments took place in the proximal region of a braided stream system (Gilbert & Asquith, 1976; Rust, 1972; Smith, 1970). A high proportion of sediments in such an environment accumulate in longitudinal bars in which the coarser material most commonly has a crude horizontal stratification. Tabular and trough cross-bedding occur in the finer portions of the sediment on top, and in front, of bars and in interbar channels. The apparent relative rarity of tabular cross-bedding and horizontal stratification in the Gilberton Formation, which should be relatively more common in a proximal braided stream accumulation, might be a function of outcrop and observation point distribution, or it might be due to those sedimentary structures having been destroyed by continual migration of interbar channels. In any case, it is considered that the bulk of the evidence favours the interpretation that the Gilberton Formation sediments were deposited in a proximal braided stream system; the distal equivalents may be preserved farther east as part of the Bundock Creek Formation (White, 1965).

The gross coarsening-upward nature of the Gilberton Formation, and the increasingly common occurrence of detrital feldspar and biotite, suggest that erosion in the source area/s, stream size, channel mobility, and sediment load, all increased markedly soon after the start of sedimentation. These increases could have been caused by one or more of several factors such as uplift in the source area/s, significant increase in rainfall and runoff, and enlargement of catchment area.

The preserved areas of Gilberton Formation probably represent only a small segment of an originally more extensive fluvial system draining the south-central Georgetown Inlier during late Devonian and/or early Carboniferous time. The so-called "Gilberton Basin "(White, 1961) is thus only an accidental remnant which has been preserved because of the vagaries of subsequent deformation and erosion.

Palaeontology and age

Plant and fish fossils have been found in siltstones and associated rocks low in the Gilberton Formation at GR 774734 and 873781 (main outcrop area), and 805662, 814653, and 819665 (southern outcrop area). The first and fourth localities were found during the previous 1:250 000 mapping (White, 1965). The position of White's locality GD 1 is uncertain; it may correspond to the one at GR 805662, which has apparently been known for many years (Jack, 1890 MS map; T. Michellmore, pers. comm. 1975). Plant fossils also reported at additional localities in the main outcrop area by Lemon (1973) and J.D. Shaw (personal communication, 1978).

Leptophloeum australe is the dominant element of the flora, as noted by previous workers; it is represented by specimens up to 30 cm long showing several decortication levels. Specimens of the leafy terminal shoots of L. australe are rare. The flora also contains fragments assigned to Sphenophyllum tenerrimum, Archaeocalamites radiatus, Barinophyton (?), and various unidentified stems (N. Morris, pers. comm. 1976). The identification of S. tenerrimum represents only the second record of the genus in Australia. Leptophloeum definitely occurs in Devonian (Frasnian) rocks, and less definitely in Carboniferous (Tournaisian) ones also; Sphenophyllum ranges from Upper Devonian to Permian rocks, and Archaeocalamites is generally regarded as a Carboniferous (Tournaisian to Namurian) genus (Banks & others, 1967).

Hills (1935) described an Antiarchan (Placoderm) fish plate from the Gilberton Formation. Several plates, scales, a fragment of spine, and an otolith were collected during the present work, but they are unidentifiable (A. Ritchie, pers. comm. 1976). Antiarchs are known only from Devonian (Eifelian to Famennian) rocks (Andrews & others, 1967).

Poorly preserved lepidodendroid remains collected higher in the sequence at GR 838806 and 832809 in 1978 are superficially similar to some in the early Carboniferous Cumberland Range Volcanics.

Samples of carbonaceous siltstone from percussion holes drilled by AGIP Nucleare Pty Ltd were collected for palynology in 1978. Samples from two of the holes contain Retispora lepidophyta (C.B. Foster, pers. comm. 1979). This is the first record of this species in eastern Australia. It is regarded as a pre-eminent palynostratigraphic index on a global scale (see Playford, 1976) and ranges from latest Famennian to earliest Tournaisian.

Although there is some discrepancy between the ages indicated by the various fossils, the balance of the evidence suggests that the lowermost part of the Gilberton Formation is of late Devonian (Famennian) age; higher, unfossiliferous, parts of the unit could be early Carboniferous.

Structure

The Gilberton Formation is cut and locally oversteepened by high-angle faults, some of which have been intruded by rhyolite dykes; such faults form the southern and eastern edges of the main outcrop area. Rocks in the lowermost part of the formation are also locally oversteepened adjacent to palaeo- hill-slopes developed on the underlying Proterozoic rocks. The oversteepening probably resulted from compaction and draping on the slopes. However, most of the Gilberton Formation is undeformed, although the presence of consistently eastward dips suggests tilting in that direction.

Mineralisation

No mineral deposits are known to have been worked in the Gilberton Formation. However, the provenance area of the formation may have included outcropping gold-bearing quartz reefs at Gilberton, and possibly Mount Hogan, depending on the age of these deposits, and the rocks could contain clastic gold or auriferous quartz clasts.

Nine bulk rock samples from the Gilberton Formation in the southern outcrop area were analysed for gold by AMDEL using fire assay and atomic absorption spectrography. The samples were selected randomly; no attempt was made to identify and selectively collect from channel-bottom material. Gold contents (Table 1) range from less than 0.005 ppm to 0.03 ppm (detection limit 0.004 ppm); these values are comparable to those obtained from conglomerates and sandstones in unmineralised areas elsewhere (Jones, 1969).

Scintillometer (Austral SG-1) counts in the Gilberton Formation range from 15 to 45 counts/second, averaging about 27 counts/second. An airborne radiometric survey by Union Corporation (Australia) Pty Ltd in 1973 revealed only low-order uranium anomalies (Lemon, 1973).

TABLE 1: Fire assay-AAS analyses for gold, Gilberton Formation (analyses by AMDEL 1976, Report AN 1191/77)

Sample No.	Grid ref.	Lithology*	Au (ppm)**
301585	812648	1, 2	0.005
" 1586)	814653	(1	0.005
" 1587)		3	0.015
" 1588)	805662	(2	0.005
" 1589)		(3	0.03
" 1590	814659	3, 2	0.005
" 1591	817662	4	0.005
" 1592)	806653	(2	0.005
" 1593)		(3	0.005

* 1-coarse arkose; 2-conglomerate; 3-coarse sandstone; 4-medium to coarse sandstone

** detection limit 0.004 ppm

BUTLERS VOLCANICS (CBu)
(White, 1959a; Branch, 1966)

Introduction

The Butlers Volcanics, consisting mainly of rhyolitic ignimbrite of probable Carboniferous age, crop out over about 3 km^2 in the northeast corner of the Gilberton 1:100 000 Sheet area; the unit covers an area of about 30 km^2 in the adjacent Lyndhurst Sheet area. The name was derived from Butlers

Knob (144°04'E and 19°02'S) about 8 km northeast of Ballynure homestead. The original name for the unit was the Butlers Igneous Complex (White, 1959a; 1962a, b, c; 1965) and it was interpreted to be an inclined sheet of granite intruding a rhyolite-porphyry "hood". Branch (1966) later re-interpreted the geology and restricted the name to the volcanics in the complex, and correlated the granite with the Lochaber Granite.

Branch (1966) considered the Butlers Volcanics to be a downfaulted block, forming part of the Lochaber Ring Complex, an oval-shaped structure measuring 23 km by 30 km, centred about 16 km south of Kidston. Microgranite bodies (mg) were interpreted as occupying the ring-fault forming the western boundary of the complex. Branch also believed the mylonite zone (p. 132) to be part of the ring-fault system; we consider the mylonite zone to be an older structure, although it may have been re-activated during the formation of the complex.

Stratigraphy

Most of the Butlers Volcanics crop out in the adjacent sheet area, and were not examined. Two sub-units were distinguished in the Gilberton Sheet area. The lowermost (CPu_1) consists of purple rhyolitic ignimbrite containing 30 to 40 percent phenocrysts, 0.2 to 2.0 mm across, of quartz, sanidine, plagioclase, and minor chlorite; lithic clasts (less than 10 percent) are mainly ignimbrite and subordinate metamorphic fragments; the groundmass (50 to 60 percent) consists of brownish cryptocrystalline devitrified glass with a eutaxitic texture.

The western contact of CPu_1 with the basement is faulted and marked by a steeply dipping rhyolite dyke. The southern boundary may be a stratigraphic unconformity but was not examined. A thickness of at least 30 m is exposed.

Sub-unit CPu_2 overlies CPu_1, and consists of pink rhyolitic ignimbrite containing 60 percent phenocrysts, 0.1 to 3.0 mm across, of beta-quartz, plagioclase (An_{30}), alkali feldspar, and minor chlorite and altered hornblende; greenish flattened lithic fragments (10 to 20 percent), up to 4 cm long, consist of porphyritic dacite and rhyolite, some of which is epidotised; the groundmass (20 to 30 percent) consists of brownish cryptocrystalline devitrified glass with vague outlines of intensely flattened shards. The subunit is about 70 m thick.

Although CPu_2 overlies CPu_1 in the section we examined, farther north CPu_2 appears to be directly in contact with the basement; this contact is possibly faulted.

Overlying CPu_2, just east of the Sheet area, is a thick cliff-forming subunit which appears (by photo-interpretation) to be the main constituent of the Butlers Volcanics. This subunit contains the 190 m thick "reference" section described by Branch (1966, p. 80).

Age

The Butlers Volcanics have not been dated isotopically but they are almost certainly Carboniferous or Permian. A Carboniferous age is the more likely because the unit is similar to the Newcastle Range Volcanics which give a Rb-Sr whole-rock age of about 330 m.y. (Oversby & others, in press); like the eastern Newcastle Range sequence, the Butlers Volcanics in the Einasleigh and Lyndhurst Sheet areas are intruded by a stock of microgranite or granite.

AGATE CREEK VOLCANICS (Pa)
(White, 1959a; Branch, 1966)

Introduction

The Agate Creek Volcanics, of Permian age (White, 1959a, 1965; Branch, 1966), are among the youngest of many late Palaeozoic units in northeastern Queensland dominated by continental volcanic rocks that perhaps once coalesced and blanketed the region. Most of the late Palaeozoic volcanics are calc-alkaline (Sheraton & Labonne, 1978) rhyolitic ignimbrite; the Agate Creek Volcanics are distinctive in that ignimbrite is rare, while basic rocks are common.

The Agate Creek Volcanics crop out mainly within and around a northwest-elongated ovoid topographic depression ("Agate Pocket") which is drained by the upper reaches of Agate Creek in the northwestern corner of the Gilberton 1:100 000 Sheet area and the adjacent part of the Forsayth 1:100 000 Sheet area. The main outcrop area is about 70 km^2. Small outliers of rocks assigned to the unit also occur farther north in the Forsayth Sheet area (Bain & others, 1976a, pp. 63-64), and there is an outlier of (probable) Agate Creek Volcanics overlying the Devonian-Carboniferous Gilberton Formation about 4 km southeast of the Percy River (Gilberton 1:100 000 Sheet area) (Fig. 31).

White (1959, pp. 26-27) named the Agate Creek Volcanics after Agate Creek, which was nominated as the general type area; no type section was given. Branch (1966, pp. 62-65) mapped all but the southern corner of the main outcrop area in "Agate Pocket" in moderate detail, and described a composite stratigraphic section. He inferred that the Agate Creek Volcanics had accumulated in a shallow, perhaps fault-bounded, basin; later (1969, Table 2) he stated that the basin was due to cauldron subsidence. Bain & others (1976a, pp. 63-64) briefly described the occurrences of Agate Creek Volcanics in the Forsayth 1:100 000 Sheet area.

Map units and stratigraphy

Bain & others (1976a) subdivided the Agate Creek Volcanics in the Forsayth Sheet 1:100 000 Sheet area into three informal subunits, namely Pas (conglomerate and sandstone), Pa (rhyolitic ignimbrite(?) and agglomerate), and Pab ("basaltic" lava). Essentially the same system of subdivision has been extended into the Gilberton Sheet area with the addition of Pat (tuff and agglomerate), Par (rhyolitic lava), rhyolitic ignimbrite (not shown on the 1:100 000 Scale Prelim. map), and intrusive rocks, although some deficiencies have become apparent in it (see below). Further revision is required before stratigraphic nomenclature can be formalised.

(1) Subunit Pas (confined to Forsayth 1:100 000 Sheet area)

Probable fluviatile conglomerate and sandstone containing epiclastic material derived from subjacent granitic and metamorphic rocks (subunit Pas), occur in the lowermost part of the Agate Creek Volcanics in an outlier about 4 km north of the northern edge of the Gilberton 1:100 000 Sheet area. The subunit also crops out (in the same stratigraphic position) at the northwestern end of "Agate Pocket", where it is up to about 10 m thick and contains local interbeds of fine, sporadically fossiliferous, vitric tuff (like that in subunit Pat) and medium to coarse lithic-crystal tuff (probably related to agglomerate in the overlying unit, Paa).

(2) Subunit Paa

This subunit consists of extrusive agglomerate (possibly at least partly non-welded ignimbrite) and airfall tuff; it lies on subunit Pas, or (more commonly) on an irregular surface of Proterozoic rocks (mainly Robin Hood Granodiorite). The top of the subunit is also irregular, apparently because of penecontemporaneous faulting and possibly erosion. The maximum exposed thickness is about 200 m at the northwestern end of the main outcrop area in the Forsayth 1:100 000 Sheet area. Paa thins irregularly southeastwards along the northeastern edge of the Agate Creek Volcanics in the Gilberton Sheet area, and disappears near Big Hope Mine (No. 3 on map, GR 775937). It is not known along the southwestern edge of the Agate Creek Volcanics.

Agglomerate is poorly to moderately well sorted, commonly purple, less commonly grey, buff, greenish grey or buff, and pink. Clasts are angular to subrounded, mostly up to 1 cm across and rarely to 10 cm; groundmass is tuffaceous. Most of the clasts are fine to medium-grained aphyric "felsite" (possibly tuff); some are flowbanded porphyritic rhyolite, biotite schist, and leucogranitoid. Quartz and feldspar fragments and crystals up to about 2 mm across occur sporadically in the groundmass.

Some rare thin, laterally discontinuous flows of buff and purple porphyritic rhyolitic lava and welded ignimbrite(?) are present in the upper part of the subunit, at the northwestern end of the main outcrop area; they are too small to show on the map.

The presence of schist and leucogranitoid fragments, and the subunit's overrall distribution and thickness variations, suggest a source area or areas in the Robertson River Formation (schist phase) to the north of "Agate Pocket". One source area might have been "Dry Pocket" which straddles the Forsayth-North Head 1:100 000 Sheet area boundary about 20 km north-northwest of "Agate Pocket".

(3) Subunit Pab

All basic rocks (mostly lava but some high-level intrusives) in the Agate Creek Volcanics of the Forsayth and Gilberton 1:100 000 Sheet areas have been assigned to this subunit. Work completed after the Gilberton Preliminary map was issued indicates that the lavas might belong to two stratigraphically separate sequences.

Pab overlies subunit Paa along the northern edge of the main outcrop area, but locally lies directly on Robin Hood Granodiorite. It is overlain by flowbanded rhyolitic lava of subunit Par. Pab is absent at the northwestern end of the main outcrop area, where rhyolitic lava lies directly on agglomerate; it cannot be traced beyond GR 975722 (Forsayth 1:100 000 Sheet area). The sequence thickens irregularly southeastwards along strike and oversteps agglomerate of subunit Paa near Big Hope mine to lie directly on Robin Hood Granodiorite. Its maximum thickness (at least 300 m) is at the southeastern end of the main outcrop area where it is partly covered by Jurassic Hampstead Sandstone.

Basic lava in this northeastern sequence is mid to dark greyish green when fresh, and pale green or purplish brown when weathered. It is commonly splintery, and cut by closely-spaced concordant (i.e. parallel to tops and bottoms of flows) fractures. Calcite and agate-filled amygdales, flow bands and streaks, and flow-foot and flow-top breccias occur locally. A basal flow-foot breccia at GR 805913 (Gilberton 1:100 000 Sheet area) contains angular fragments of fine vitric tuff (like that in subunit Pat) and poorly banded rhyolitic lava up to 3.5 cm across.

These rocks appear to be andesite or basalt. Their mineralogy is commonly difficult to ascertain because of the very fine grainsize and alteration. They locally contain about 1% phenocrysts and crystal aggregates of plagioclase (at least partly labradorite) and clinopyroxene up to about 1 mm in maximum dimension. Some of the feldspar phenocrysts are zoned and corroded. Corroded quartz xenocrysts occur rarely. The groundmass has a trachytic to subtrachytic texture, and consists of feldspar laths (mainly or wholly plagioclase), altered clinopyroxene(?) grains, and opaque grains. At least 30 m of similar andesite or basalt with sporadic agate-filled amygdales, tentatively assigned to subunit Pab, crop out in an isolated outlier at the head of "Stewart's Pocket" about 4 km southeast of the Percy River. These rocks dip shallowly to the southwest and lie with presumed unconformity on arkose and associated fluviatile sedimentary rocks of the Gilberton Formation or are underlain by rhyolite, ignimbrite, agglomerate, and tuff (Fig. 31). They are overlain unconformably by Jurassic Hampstead Sandstone.

Basic lavas that may constitute a separate sequence from the one discussed above but are also assigned to subunit Pab crop out extensively in "Agate Pocket", and host all the well-known agate deposits ("Black Soil, "Crystal Hill", "Bald Hill" etc). These lavas lie unconformably on Robin Hood Granodiorite along the southwestern edge of the main outcrop area, but the base of the sequence is not exposed elsewhere; they have an exposed thickness of between 200 and 400 m (excluding intercalated rocks assigned to subunit CPat). The relations of these basic lavas to other subunits in the Agate Creek Volcanics, other than CPat, are not clear; they apparently underlie rhyolitic lava in subunit CPar although the contact is now faulted. They may be laterally equivalent to the sequence of andesitic or basaltic lavas along the northwestern edge of the main outcrop area, even though of different appearance and considerably greater thickness.

The basic rocks of unequivocally extrusive origin assigned to subunit CPab in Agate Pocket contain up to about 3% plagioclase (andesine to labradorite) and sporadic orthopyroxene phenocrysts and aggregates up to about 2 mm across. Plagioclase phenocrysts are commonly zoned and corroded, and have rims of microgranular quartz; orthopyroxene is fresh and there are some rare olivine phenocrysts and corroded quartz xenocrysts. The groundmass has a trachytic to subtrachytic texture, and consists of plagioclase(?) laths and needles, and opaque grains and "dust". Agate-filled amygdales occur at the tops of many flows; they range in maximum dimension from a few millimetres to 20 cm or more. Flow-foot and flow-top breccias occur locally.

Only one chemical analysis of these rocks is known to exist (Sheraton & Labonne, 1978); it is of an altered amygdaloidal "andesite", (from near GR 720937, Gilberton Sheet area) and cannot be considered representative.

Subunit CPab is now known to incorporate high-level intrusive basic rocks ("Augite-andesite" of Branch, 1966) which are not distinguished separately on the Gilberton and Forsayth maps, as well as rocks which could be either intrusive or extrusive. These rocks are described below.

(4) Subunit CPat

Subunit CPat is characterised by thin-bedded and laminated, locally fossiliferous, fine-grained vitric tuff with subordinate medium to coarse crystal tuff and fine to medium agglomerate. Rocks assigned to the subunit crop out mainly in the central part of the main outcrop area, where they are interbedded with basic lavas of subunit CPab (above). The maximum preserved thickness - about 220 m - is between Spring and Agate Creeks where basic lava is intercalated high in the sequence. Farther north, to the northeast of Agate Creek opposite the mouth of Spring Creek, there are three discontinuous tongues of CPat between 30 and 100 m thick, within subunit CPab. Rocks assigned to subunit CPat also occur in isolated outcrops at various stratigraphic levels and/or in fault slices along and adjacent to Agate Creek.

Vitric tuff is the most abundant and characteristic rock type in subunit Ρat: it is mainly buff, or green and grey locally. The vitric tuff is composed of silt-sized glass particles, undeformed and unworn shard fragments, and a minor proportion of quartz and feldspar crystal fragments; wisps of "carbonaceous" material occur locally. The finest-grained varieties of the tuff ("porcellanite" and "ribbonstone") are siliceous, hard and compact, and have a splintery to subconchoidal fracture. Some laminae in "ribbonstone" are crudely graded upwards from coarser to finer; such normally graded laminae have sharp bases with small load and flame structures. However, other laminae show reverse grading (coarsening upwards), and many are not graded at all. Some small soft-sediment faults and minor slumps can be seen in places.

The main exposures of subunit Ρat are described separately (below) because each shows some unique features and relationships.

(a) The thickest and most continuous section (between Agate and Spring Creeks) overlies basic lava of subunit Ρab. The sequence appears to contain a disconformity about 200 m from its base. Up to 100(?) m of basic lava rests locally on the disconformity surface, and in turn is overlain unconformably by at least another 20 m or so of tuff. Relationships in the area have been further complicated by the intrusion of an irregular body of porphyritic microdiorite (mdi - p. 93).

(b) Northeast of the junction of Agate and Spring Creeks several interbeds of Pat in basic lavas are presumably tongues of the more continuous section (a) described above. The two largest interbeds of Ρat are in the uppermostpreserved part of the section. The lower of these (bed 4) is at least 100 m thick in the northwestern part of its outcrop area; it thins over a relatively short distance (0.5 km) eastwards and southeastwards to about 10-15 m, a thickness which is maintained throughout the rest of the outcrop area. This tuff interbed is separated from the uppermost one by about 30 m of basic lava; only about 10 m of the uppermost tuff bed (5) is exposed below the present erosion surface. About 120 m (assuming no intervening faults) below the lower ofthe two interbeds of Ρat, discussed above, are two (beds 2 & 3) more: they are discontinuous, up to about 10 m thick, and separated by about 10 m of basic lava. An isolated outcrop (GR 735953) of a bed (1) of medium-grained vitric-crystal tuff, 5 m thick (Ρat) occurs at a stratigraphically lower level (again, assuming no major intervening faults). This tuff consists of alternating poorly-defined layers containing about 10% and 3% crystals respectively. There is a similar isolated outcrop at about the same stratigraphic level at GR 723962. No "ribbonstone" is known to occur in any of these interbeds.

The base of the lower of the two well-developed interbeds in the uppermost part of the section is tentatively correlated with the base of section (a); the vertical mismatch of this basal plane across Agate Creek is believed to be due to a concealed high-angle fault.

(c) Immediately south of the mouth of Spring Creek subunit Ꞓat is mainly agglomerate and coarse tuff with minor interbedded fine to medium tuff. The agglomerate is poorly sorted, most commonly buff, locally greyish or greenish buff, and contains angular subrounded clasts of banded and spherulitic porphyritic rhyolite, pumice, and fine siliceous tuff, in a matrix of fine particles of devitrified glass. Clasts are most commonly up to about 2 cm across (the largest seen was about 50 cm across). No clasts of granitoid or metamorphic rocks are known to occur, which distinguishes these rocks from superficially similar ones in subunit Ꞓaa (above). The agglomerate and tuff are locally stratified; airphoto interpretation suggests that large-scale cross-stratification may occur.

These rocks grade imperceptibly into intrusive agglomerate and tuff (ag), which in turn grade into small irregular bodies of intrusive flow-banded rhyolite not shown on the map. The whole assemblage appears to be overlain by the basic lavas that underlie the tuff in section (a) (above). The contact between this section (c), including the associated intrusive agglomerate and rhyolite, and the basic lavas is extremely irregular, and it is thought that the former rocks accumulated as a pyroclastic cone and fan/s around a local vent area; the cone and fan/s were evidently partly eroded before the younger basic lavas flowed around and over them. To what extent this vent contributed material, either directly or by reworking, to stratigraphically higher sections of subunit Ꞓat is not known.

A lens of agglomerate about 1 m thick between Robin Hood Granodiorite and basic lava at GR 692938, about 3 km west-northwest of the mouth of Spring Creek, is too small to show on the map. This agglomerate contains subrounded clasts, up to 30 cm across, of porphyritic rhyolitic ignimbrite and lava(?) (with some small quartz and pale brown feldspar phenocrysts) set in a matrix of coarse lithic-crystal tuff. It may represent the oldest preserved material derived from the vent at the mouth of Spring Creek.

(d) Laminated and thin bedded, light and dark grey fossiliferous "ribbonstone" about 2 m thick crops out on the southwestern side of Agate Creek immediately northwest of the confluence of Agate and Spring Creeks; it is gently warped, locally intensely fractured and brecciated, and overlain by basic lava. "Ribbonstone" also crops out along Agate Creek at GR 710939, 709943, 703951, 698957, 695964, and possibly near 712947 (Gilberton 1:100 000 Sheet area). The outcrops at the Agate Creek-Spring Creek confluence and at GR 710939 are probably part of the same beds. About 100 m southwest and southeast of the former locality two small outcrops of Robin Hood Granodiorite are surrounded by the basic lava that overlies the "ribbonstone". These outcrops are apparently pinnacles of basement, rather than megaclasts within the Agate Creek Volcanics or float from outcrops farther southwest, suggesting that there is only a thin veneer of basic lava in the area with interbedded (or underlying) "ribbonstone" lenses. The sporadic occurrences of "ribbonstone" in subunit Pas at the northwestern end of the main outcrop area (Forsayth 1:100 000 Sheet area) are also close to the base of the Agate Creek Volcanics, and the fine tuff clasts in basal flow-foot breccia at GR 805913 (Gilberton 1:100 000 Sheet area) must have been torn from a bed or lens at the base of the unit. The "ribbonstones" at GR 698957, and possibly at about 712947, appear to be at a somewhat higher stratigraphic level; they are underlain and overlain by basic lavas. The other outcrops along Agate Creek could be in fault slices.

Subunit Pat thus contains beds at different stratigraphic levels throughout most of the Agate Creek Volcanics. The pyroclastic material constituting the rocks is believed to have been at least partly derived from a vent near the confluence of Spring and Agate Creeks. The finest fraction of erupted material was widely dispersed and settled slowly from the eruptive column; at least some of it fell into still water (presumably a lake or lakes) where differential settling resulted in graded bedding characteristic of the "ribbonstone". Leaves and other plant fragments were occasionally swept into the water and incorporated into the sediments.

(5) Subunit Par

This subunit consists of flow-banded rhyolitic lava at least 250 m thick that unconformably overlies subunit Paa, and the northeastern sequence of subunit Pab, at the northwestern end and along the northeastern edge of the main outcrop area of Agate Creek Volcanics. It apparently also overlies the basic lavas of subunit Pab in the central part of Agate Pocket.

The rhyolitic lava is buff, pink or purple, and contains up to about 3% corroded anhedral quartz and subsidiary "kaolinised" and "sericitised" subhedral perthitic alkali feldspar phenocrysts up to about 2 mm across in a microcrystalline quartzofeldspathic groundmass. Most of the groundmass feldspar is "kaolinised". Flow bands are ubiquitous. Spherulites are common; some with central stellate or irregular jasper and agate-filled cavities ("thunder eggs") occur at GR 767930 (1 km southwest of Big Hope mine) at GR 768894 (0.8 km east-northeast of "Banyan Spring"), and at GR 743949 (head of "Black Soil"); other localities are continually being discovered.

(6) Rhyolitic ignimbrite

Rhyolitic ignimbrite, in the central part of the main outcrop area of Gilberton Formation (Fig. 31) and here included in the Agate Creek Volcanics, represents a different eruptive style and possibly originated from a distant source. The full extent of this subunit was not recognised until 1978 when AGIP Nucleare Pty Ltd undertook uranium exploration in the Gilberton Formation. The ignimbrite was examined late in the 1978 field season by Withnall in company with Mr J. Shaw of AGIP.

The ignimbrite has a similar photo-pattern and outcrop appearance to the Gilberton Formation. It is grey or buff to purple and contains up to 50 percent angular to corroded and embayed quartz chips, phenocrysts, and aggregates of quartz up to 5 mm in maximum dimension; feldspar and about 1 percent biotite phenocrysts about 1 mm long, and rare muscovite, are also present. Lithic clasts include rhyolite and pumice as well as granite, amphibolite, vein quartz, quartzite, and cleaved siltstone from the basement. The groundmass contains slightly deformed shard pseudomorphs indicating original slight to moderate welding.

Interbedded with the ignimbrite are agglomerate, thin rhyolite flows, and finely laminated water-laid tuff ("ribbonstone"). The acid volcanics strike northeast and dip about 15° to the southeast. They are partly fault bounded. A percussion hole drilled by AGIP at GR 841818 intersected 80 m of volcanics before reaching the underlying Gilberton Formation; the total thickness in this area is probably about 200 m. The acid volcanics are overlain by basaltic or andesitic flows (locally containing agate) and appear to thin westwards towards the Stewarts Pocket area where the basalt directly overlies the Gilberton Formation. This suggests that the relationship may be unconformable; the acid volcanics could be significantly older than the basalt, and possibly in part distal equivalents of the Carboniferous Newcastle Range Volcanics, or extrusive rocks like the Butlers Volcanics erupted from the Bagstowe/Lochaber ring structures.

Rhyolitic ignimbrite also occurs in the Agate Pocket area, but is rare. All known occurrences are at or near the northwestern end of the main outcrop area in the Forsayth 1:100 000 Sheet area. Buff ignimbrite, which contains 30 percent quartz and orange feldspar (not examined in thin section) up to 2 mm across, crops out among agglomerate of subunit Paa at GR 708981 and 708982; these outcrops apparently represent a single thin interbed or lens. Outliers of similar grey ignimbrite overlie Robin Hood Granodiorite about 1 km north, beyond the edge of the main outcrop area.

Palaeontology and age

Fine tuff and "ribbonstone" of subunit Pat (or similar rocks in subunit Pas) contain plant fossils, some of which were collected from three localities during 1:250 000 scale reconnaissance mapping in the late 1950s (GR 725943, 703951, and 698971(?), Gilberton 1:100 000 Sheet area). They were figured and discussed by M.E. White (in D.A. White, 1965, pp. 161-163, plates 5-7). During the present work comparable fossils were found in similar rocks at GR 706976 (Forsayth 1:100 000 Sheet area), 736947, 720936, 724925, 742917, and 744922 (Gilberton 1:100 000 Sheet area); and in greatest abundance and variety at locality GR 720936.

The flora is probably Early Permian, being dominated by Gangamopteris cyclopteroides, Neoggerathiopsis hislopi, and Glossopteris spp. (M.E. White, in White, 1965).

Structure

The main outcrop area of Agate Creek Volcanics coincides with an ovoid structural basin slightly more than 14 km long from northwest to southeast, and up to 6 km wide; other outcrops are in locally fault-bounded outliers. High-angle faults (partly occupied by intrusive rhyolite) disrupt the northwestern end of the main outcrop area, but peripheral faults are rare elsewhere. The exposed edges of the Agate Creek Volcanics dip at up to 30° towards the central part of the main outcrop area, which is also disrupted by several high-angle faults. A major concealed high-angle fault (northeast side down) probably underlies alluvium (Qa) along Agate Creek. As noted above, subunits Pab and Par are mainly in fault contact along the northeastern edge of Agate Pocket.

A detailed gravity traverse was run across Agate Pocket in 1978 between GR 697935 and 736972 approximately. Preliminary interpretation of the data suggests that the shallow basinal form of the sequence is maintained at depth, no major underlying subsidiary structures such as cauldrons or grabens being present. Subunit Par probably has a "root" of intrusive rhyolite.

Intrusive rocks

Rhyolite, intrusive agglomerate, basalt, and trachyandesite-microdiorite intrude the Agate Creek Volcanics, as well as the Gilberton Formation and Proterozoic rocks in the vicinity of Agate Pocket.

Intrusive rhyolite is essentially the same as the extrusive rhyolite in subunit Ear described above: it occurs in dykes and irregular bodies which locally contain xenoliths of wallrock. Intrusive rhyolite (not shown on the map) on the northwestern side of Spring Creek near its junction with Agate Creek is locally intensely fractured and brecciated; it grades laterally into coarse intrusive tuff and fine agglomerate which contain comminuted intrusive rhyolite. These rocks in turn grade into and/or intrude agglomerate and tuff assigned to subunit Eat (above).

Anastomosing "basalt" dykes and associated plugs cut rocks of subunits Eas and Eaa in the lower part of the Agate Creek Volcanics at the northwestern end of the main outcrop area; they do not appear to cut overlying rhyolitic lava of subunit Ear. The rocks were mapped by Branch (1966) as intrusive "augite andesite". The rocks are dark green and compact; they weather by exfoliation ("onionskin weathering") into rounded cobbles. Randomly oriented subhedral plagioclase (close to An_{50}) laths are intergrown with subhedral to anhedral crystals and aggregates of orthopyroxene and subordinate clinopyroxene. Plagioclase and pyroxene also occur as microphenocrysts in some of the rocks. Subhedral to anhedral olivine crystals also occur, but are common only in coarser-grained rocks. A mesostasis is represented by interstitial feldspar, subsidiary quartz, and chloritic material; interstitial calcite occurs rarely. Discordant opaque needles and grains are common. The dykes and plugs have chilled margins which locally contain agate-filled amygdales and xenoliths of wallrock. The mineralogy of these rocks, and the single available chemical analysis of a specimen from GR 704978 (Forsayth 1:100 000 Sheet area) given in Branch (1966, table 4), suggest that they have continental tholeiitic affinities.

Similar rocks crop out in the narrow northwest-trending valley between GR 710972 and 720964, 3 and 4 km northwest of the junction of Agate and Spring Creeks (most of this valley is in the Gilberton 1:100 000 Sheet area), farther southeast in Agate Pocket (GR 724957), and at GR 792914 and 808897 (Gilberton 1:100 000 Sheet area), about 4 and 1.5 km respectively northwest of the Percy River. Currently available field data make it impossible to say whether these occurrences represent the central, coarser, parts of lava flows, or whether they are intrusive bodies emplaced at shallow depth.

Discontinuous "basalt" (bs) dykes up to 6 m wide cut the Gilberton Formation at GR 844752, 837758, 856763, and 841758 (Gilberton 1:100 000 Sheet area). These rocks are green or brownish-green, slightly altered, and locally amygdaloidal; they are composed of randomly oriented orthoclase and plagioclase (andesine?) laths, and chlorite pseudomorphs after pyroxene(?). Up to 1% phenocrysts of plagioclase (some with corroded cores), and aggregates of plagioclase and chlorite pseudomorphs, occur locally. Interstitial opaque grains are common. Corroded quartz xenocrysts occur rarely. These rocks appear to be trachyandesites, and are probably related to the microdiorite that intrudes the Agate Creek Volcanics in Agate Pocket (below).

An irregular body of altered microdiorite (mdi) about 1 km^2 in surface area, has intruded and partly domed the Agate Creek Volcanics between Agate and Spring Creeks. The rock consists of euhedral to subhedral prisms and laths of orthoclase, plagioclase (andesine), and clinopyroxene up to 8 mm long in a groundmass of smaller interpenetrating feldspar crystals. Opaque grains and needles are common. Its photo pattern is indistinguishable from that of unit Pab.

PLUTONIC ROCKS

INTRODUCTION

The plutonic rocks of the Gilberton 1:100 000 Sheet area range in age from mid-Proterozoic to Carboniferous. They form part of three composite batholiths and several smaller isolated plutons, as well as numerous dykes, veins, and small bodies (many of which are too small to show on the 1:100 000 scale map), in the Einasleigh Metamorphics.

The three batholiths were named the Robin Hood, Glenmore and Copperfield Batholiths by Withnall & others (in press). The first consists of the Siluro-Devonian or late Proterozoic Robin Hood Granodiorite and Mid-Proterozoic Digger Creek Granite. In the Glenmore Batholith, the main unis are the mid-Proterozoic Sawpit Granodiorite, Loafers Granodiorite, late Proterozoic or Silurian-Devonian Anning Granite and Dumbano Granite, and Carboniferous Culba Granodiorite; in addition the high-level, Carboniferous Bagstowe Ring Complex

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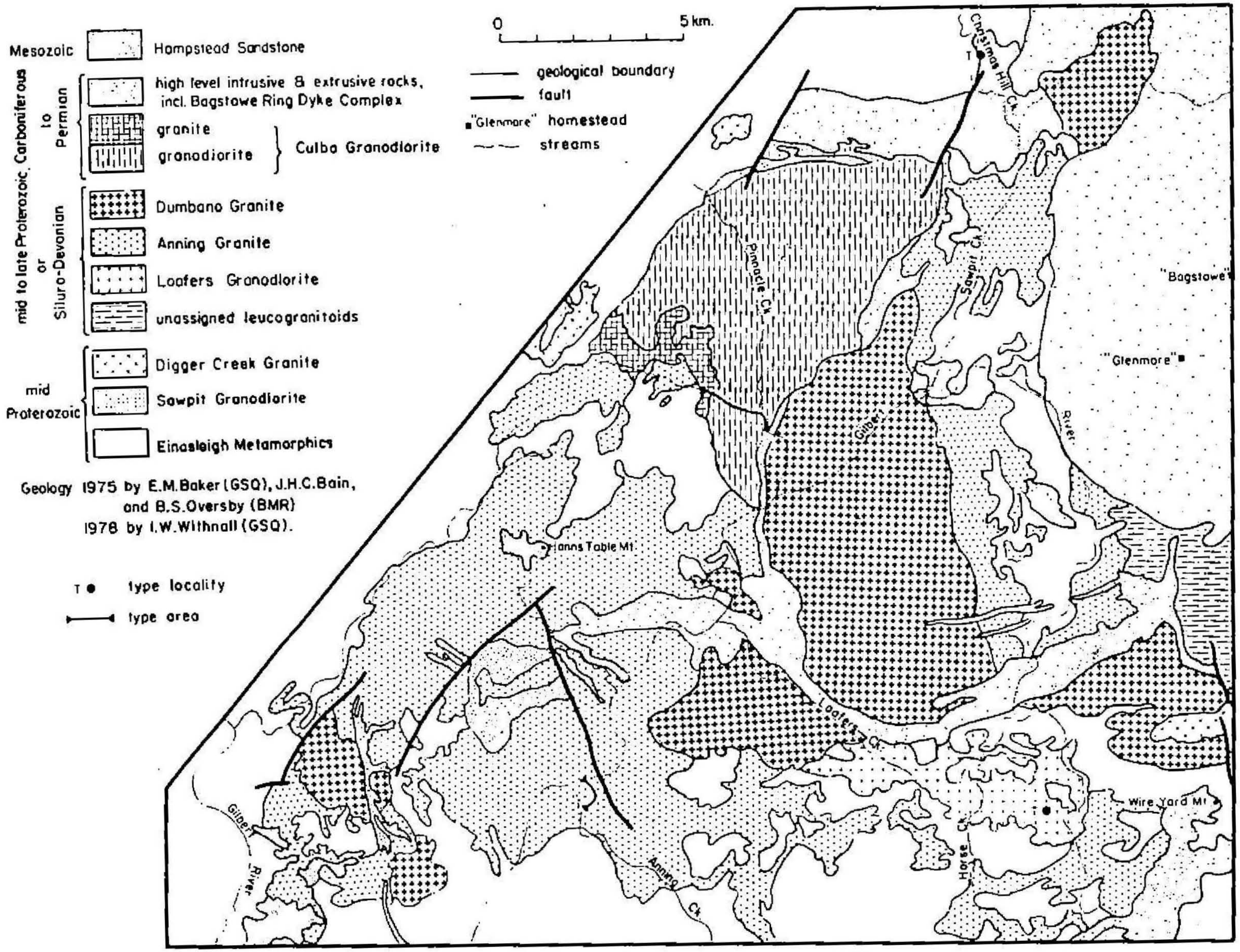


FIG. 32 GEOLOGY OF THE GLENMORE BATHOLITH

occurs within the confines of the Glenmore Batholith, and includes some fine-grained granitoids. In the northeastern corner of the Sheet area, granodiorite and trondhjemite, assigned tentatively to the Oak River Granodiorite, are part of the Copperfield Batholith.

The isolated plutons contain the mid-Proterozoic Welfern Granite and late Proterozoic Mount Hogan Granite, both north of the Gilberton Fault, and Carboniferous Purkin Granite (two plutons), which overlaps the southern margin of the Sheet area.

Some of the numerous small granitoid bodies intruding the metamorphic rocks have been mapped as Digger Creek Granite, but many are unassigned; the latter may include equivalents of Sawpit Granodiorite, Anning Granite, and Digger Creek Granite.

Geological boundaries within the Glenmore Batholith on the 1:100 000 scale Preliminary edition map have been revised following additional fieldwork in 1978. The revised boundaries are shown in Figure 32. In particular the Anning Granite now includes large areas shown previously as Dumbano Granite and Culba Granodiorite.

WELFERN GRANITE (Pmn)
(new name)

Introduction

The Welfern Granite crops out in an area of about 10 km^2 in the northeast corner of the Sheet area as an elongate intrusion 7.5 km long and 2 to 3 km wide; a large roof pendant of metamorphic rocks gives the intrusion an annular shape. Several small apophyses and numerous dykes and veins of Welfern Granite are also exposed in the nearby Einasleigh Metamorphics. The name is derived from Welfern Holding on which most of the unit crops out; Welfern homestead is at GR 096946.

The type area is along the Kidston-Gilberton road between GR 102935 and 094907 (Gilberton 1:100 000 Sheet area); the metamorphic roof pendant is exposed along part of this section (between 097927 and 092915).

White (1962c, 1965) previously assigned the rocks to Dumbano Granite.

In areas of low relief the granite can be distinguished from the Einasleigh Metamorphics on aerial photographs by its slightly lighter coloured photo-pattern, and by tor-like hills where relief is greater; however, in general the photo-pattern is not as distinctive as that of some of the other granitic units.

A distinctive feature of the unit is its relatively high radiometric background of 90 to 120 counts/second (Austral SG-1 scintillometer). Some leucogranite and pegmatite veins cutting metamorphic rocks in the vicinity of the intrusion have a similar high background, and are probably derived from the Welfern Granite. Most other granitoid units in the Sheet area (with the exception of the Mount Hogan Granite) have radiometric backgrounds of less than 50 counts/second.

Lithology and petrography

The Welfern Granite is pink, equigranular to slightly porphyritic, medium-grained biotite granite; it is generally foliated.

Two specimens (76300312 and 318) were examined in thin section. The texture is allotriomorphic granular. Quartz (30 to 35 percent) forms strained subequant to elongate, partly aligned grains. Microcline (30 to 40 percent) occurs as subequant anhedral perthitic grains 1 to 5 mm across; sparse megacrysts up to 1 cm are also present, and they contain inclusions of quartz, plagioclase, and biotite. Myrmekite locally partly replaces microcline. Plagioclase (25 to 30 percent) consists of slightly sericitised subequant to subelongate grains of oligoclase (An_{25} approx.) up to 2 mm long. A mortar texture is developed around some of the quartz and feldspar grains. Biotite (2 to 5 percent) forms dark brown or greenish brown subparallel flakes, 0.1 to 2.0 mm long, commonly containing pleochroic haloes. Minor secondary muscovite (less than 1 percent) is associated with biotite. Accessory minerals present are sphene, apatite, zircon, and metamict allanite.

Descriptions of two specimens (70571164 and 1165) collected from northwest of Ballynure homestead and identified as "Dumbano Granite" by Sheraton & Labonne (1974) correspond closely with that given above except that 1164 contains accessory garnet. These specimens are probably also of Welfern Granite even though the location given plots outside the area of Welfern Granite mapped by us.

Geochemistry and petrogenesis

The Welfern Granite (samples 70571164 and 1165, Sheraton & Labonne 1978) has higher Rb and K/Ba, lower K/Rb and much lower Ba/Rb than the Dumbano Granite and leucogranite samples; Rb/Sr is slightly higher than for most Dumbano Granite specimens but lower than in the leucogranites. In addition the Welfern Granite has lower Na_2O and generally higher K_2O. Thorium is high (71 and 49 ppm, c.f. averages of 7 ppm in the Dumbano Granite and 22 ppm in the leucogranites) and one sample contains 15 ppm U. Two specimens (75300312 and 318) analysed by the Queensland Government Chemical Laboratory contained 45 and 41 ppm Th respectively, but less than 10 ppm U. The high Th is probably responsible for high radiometric background.

Relations and age

The Welfern Granite intrudes the Einasleigh Metamorphics and is overlain by the Jurassic Eulo Queen Group. The unit has not yet been isotopically dated. The granite is well foliated, suggesting that it was emplaced syntectonically with one of the main periods of deformation. Foliations range in strike between 008° and 090°. In adjacent metamorphic rocks the foliation has a similar trend caused by tight to isoclinal D_2 folds, so it is likely that the Welfern Granite is syn-D_2, and that the variation in strike of the foliation is due to deformation by D_3. The foliation would be expected to strike consistently east if the granite was syn-D_3.

If the Welfern Granite was emplaced during D_2, its age is about 1500 m.y. - i.e. mid-Proterozoic.

OAK RIVER GRANODIORITE (Pmo)
(Withnall & others, 1976b)

Introduction

The Oak River Granodiorite as defined by Withnall & others (1976b) crops out in the southeastern corner of the Forsayth 1:100 000 Sheet area. It consists of locally foliated biotite granodiorite, commonly containing K-feldspar megacrysts; subordinate foliated hornblende-biotite tonalite in the extreme southeast was also included in the unit. The unit is believed to extend eastwards towards Kidston and "Carpentaria Downs" in the Einasleigh 1:100 000 Sheet area, where Sheraton & Labonne (1974, 1978) described similar rocks.

In the northeastern corner of the Gilberton Sheet area, rocks mapped in an area of about 11 km^2 north of the Gilberton Fault around Ballynure homestead have tentatively been assigned to the Oak River Granodiorite. They were originally mapped as Dumbano Granite by White (1962c, 1965).

The granodiorite crops out poorly because it is deeply weathered and partly covered by alluvium. It can be recognised on the aerial photographs by its tone, which is lighter than that of the metamorphic rocks.

The radiometric background of the granodiorite ranges from 15 to 25 counts/second (Austral SG-1 scintillometer).

Lithology and petrography

The outcrops examined in the Gilberton 1:100 000 Sheet area consist of foliated white or grey, equigranular to porphyritic, medium-grained biotite granodiorite and tonalite. Two specimens (75300316 and 317) were examined in thin section.

75300316 is an equigranular, medium-grained biotite tonalite with an hypidiomorphic granular texture. Quartz (25 to 30 percent) forms strongly strained, partly aligned grains 1 to 5 mm long with suture boundaries. The plagioclase (65 to 70 percent) is andesine (An_{40}) and occurs as partly aligned laths 1 to 4 mm long; twin lamellae are slightly deformed. Biotite flakes (5 percent) are generally parallel to the foliation. Chlorite (1 to 2 percent) and traces of secondary muscovite replace some of the biotite. Accessory zircon, allanite, apatite, and opaques are present.

75300317 is a granodiorite containing 10 to 15 percent pink microcline megacrysts up to 4 cm long; the groundmass is similar to that of 316 except that the plagioclase is oligoclase (An_{25}) and the biotite is completely chloritised. The hand specimen contains minor garnet, which was not seen in thin section.

Sheraton & Labonne (1974) described three specimens of "trondhjemite" (i.e. leucocratic tonalite) from north-northeast of "Ballynure" to the east of the Butlers Volcanics. Their petrographic descriptions of the specimens (70571166, 1167, and 1168) correspond closely with that of 75300316 above, and the rocks presumably come from the same unit.

The small area of Oak River Granodiorite at the northern edge of the Sheet area probably consists of hornblende-biotite tonalite like that described by Bain & others (1976a) in the Forsayth Sheet area and by Sheraton & Labonne (1974) near Kidston.

111

Geochemistry and petrogenesis

No samples of Oak River Granodiorite from either the Gilberton or the Forsayth Sheet areas have been analysed. However, in the Lyndhurst & Einasleigh 1:100 000 Sheet areas, "trondhjemites" (70571166, 1167 and 1168) that are similar to Oak River Granodiorite in the Gilberton Sheet area, were shown by Sheraton & Labonne (1978) to be chemically, as well as petrographically, distinct from the Dumbano Granite. They have higher CaO, Sr, and Mg/Li, and lower K_2O, Y, K/Rb, K/Ba, and Rb/Sr than the Dumbano Granite.

Four other samples analysed by Sheraton (1974) are possibly Oak River Granodiorite. They are 68590100 and 70571169 (both hornblende-biotite tonalite), and 70571170 and 1192 (biotite granodiorite). Of these 70571192 is strongly mylonitised. The two tonalite samples have similar geochemistry but the granodiorites differ from them in some respects, particularly in having lower Mg/Li, K/Ba, CaO, and MnO and higher K/Rb. The "trondhjemites" have higher Na_2O and lower K_2O, Y, Rb, MnO, Sr, Mg/Li, and K/Ba than the tonalites, and higher CaO and lower K_2O, Y, Rb and K/Rb than the granodiorites.

The significance of the geochemical differences between the three rock types is uncertain because there are too few data to define trends, and it is not certain that the samples are representative. The three types may be unrelated petrogenetically.

Relations and age

The Oak River Granodiorite intrudes the Einasleigh Metamorphics; it is overlain by the Carboniferous(?) Butlers Volcanics and intruded by microgranite that is probably related to the Carboniferous Lochaber Ring Complex.

The northeast trend of the foliation in the Granodiorite is similar to that of tight to isolinal D_2 folds in the Einasleigh Metamorphics. Therefore the Oak River Granodiorite is probably syn-D_2 or older, i.e. about 1500 m.y. old - mid-Proterozoic. Bain & others (1976a) came to a similar conclusion for the hornblende-biotite tonalite phase in the Forsayth Sheet area. In that area the Oak River Granodiorite is intruded by Digger Creek Granite and biotite leucogranite.

112

SAWPIT GRANODIORITE (Pms)
(new name)

Introduction

Foliated biotite granodiorite that crops out in an area of about 15 km^2 south of the Gilberton Fault, mainly in the Headwaters of Sawpit Creek (also known as Styx River), is called Sawpit Granodiorite. The type locality is on Christmas Hill (or Duffer) Creek at GR 088778, about 7.5 km west-northwest of Bagstowe homestead. Other excellent exposures occur in the Gilbert River at GR 073686, near its junction with Sawpit Creek.

The unit crops out poorly, and may actually be numerous small bodies rather than the larger masses represented on the map. Roof pendants of metamorphic rocks are common within the granodiorite. South of the Bagstowe Ring Complex there are many small bodies of foliated biotite granodiorite, similar to that in the type area, which are too small to show on the 1:100 000 scale map. One body which was large enough to be mapped is at GR 121515 in the Gilbert River.

Scintillometer readings (Austral SG-1) on outcrops range from 45 to 55 counts/second.

Lithology and field relations

The Sawpit Granodiorite consists of white to grey, generally fine to medium-grained, foliated biotite granodiorite, tonalite, and quartz diorite. At the type locality (Figs. 33 and 34) the granodiorite is well foliated, and commonly contains long thin (1 cm wide and over 5 m long) biotite-rich bands or layers as well as wider (up to 10 cm), more leucocratic, layers and streaks; the margins of the leucocratic layers are not sharply defined, and they merge into less leucocratic granodiorite. Discordant leucocratic granodiorite veins are also common, cutting across the layering in the granodiorite and the xenoliths of biotite gneiss which are common at the type locality. The xenoliths contain tight D_2 folds, which also deform the layers in the granodiorite and the discordant veins. An axial plane foliation is present locally in the folded veins.

113

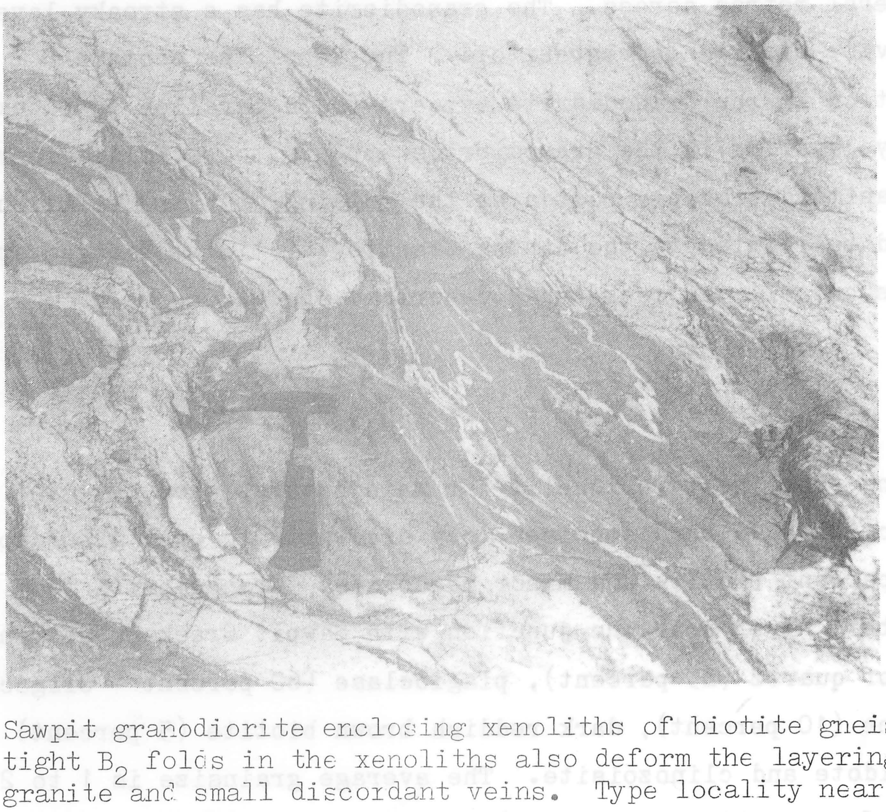


Fig 33: Sawpit granodiorite enclosing xenoliths of biotite gneiss - tight B_2 folds in the xenoliths also deform the layering in the granite and small discordant veins. Type locality near Christmas Hill Creek at GR 088778.

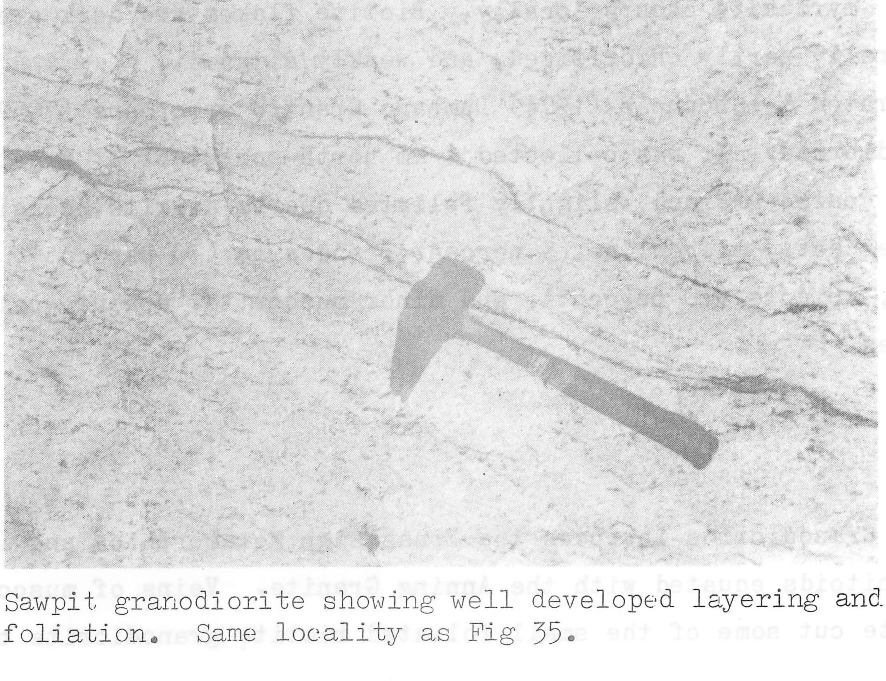


Fig 34: Sawpit granodiorite showing well developed layering and foliation. Same locality as Fig 35.

The outcrop in the Gilbert River near its junction with Sawpit Creek consists of grey foliated biotite granodiorite containing abundant calc-silicate xenoliths up to several metres across. The granodiorite has a streaky layering and is cut by muscovite-biotite leucogranitoid. The xenoliths contain D_2 folds and the foliation in the granodiorite appears to be parallel to D_2 axial planes; the streaky layering in the granodiorite appears to be folded in rare cases. The leucogranitoid probably postdates the folding, but the relation is not clear; it could be related to the Anning Granite (p. 110). Younger aplitic veins and pegmatoids cut all the rock types described above.

Petrography

No specimens from the type locality or main outcrop area have yet been examined in thin section. In hand specimen they are white to grey granodiorite with up to about 5 percent biotite and minor muscovite. Granodiorite from the outcrops in the Gilbert River near the junction with Sawpit Creek (specimen 75300191) consists of quartz (25 percent), plagioclase (60 percent - oligoclase/andesine), microcline (10 percent), dark reddish brown biotite (5 percent) and minor primary(?) epidote and clinozoisite. The average grainsize is 1 to 2 mm. Specimens collected from smaller bodies to the south of the Bagstowe Ring Complex (75300199, 265, 303, 305) are essentially similar, consisting of quartz (25 to 40 percent), plagioclase (45 to 60 percent) microcline (10 to 20 percent), biotite (4 to 5 percent) secondary muscovite (1 percent), and accessory epidote, allanite, sphene, zircon, and opaques. The quartz forms elongate grains with undulose extinction. Plagioclase shows slight normal and oscillatory zoning; myrmekite occurs locally. Biotite flakes are dark greenish brown, and are generally partly chloritised, and weakly aligned.

One of Sheraton & Labonne's (1974) Dumbano Granite specimens (70571162) may be Sawpit Granodiorite. It was collected 4 km north-northwest of Bagstowe homestead, and is a coarse-grained, slightly foliated quartz diorite, consisting of quartz (5 to 6 percent), microcline (5 percent), andesine (70 percent), biotite (8 percent), epidote (10 percent), and minor muscovite, sphene, calcite, allanite, and opaques.

Relations and age

The Sawpit Granodiorite intrudes the Einasleigh Metamorphics and is cut by biotite leucogranitoids equated with the Anning Granite. Veins of muscovite granite and pegmatite cut some of the small foliated biotite granodiorite bodies south of the Bagstowe Ring Complex, e.g. at GR 121515 in the Gilbert River; these veins are equated with the Digger Creek Granite. The Dumbano Granite is inferred to intrude the Sawpit Granodiorite, although no contacts are exposed. Several phases of the Bagstowe Ring Complex intrude the unit.

At the type locality the Sawpit Granodiorite is strongly foliated and folded by D_2 folds, indicating that the unit is syn- or pre-D_2 in age, i.e. mid-Proterozoic (1470 to 1570 m.y.).

DIGGER CREEK GRANITE (Pmd)
(Withnall & others, 1976b)

Introduction

Leucocratic muscovite granite, aplite, and pegmatite, which intrude the Robertson River Formation (schist phase), Einasleigh Metamorphics, and Juntala Schist in the Gilberton Sheet area, have been equated with the Digger Creek Granite. This unit was defined by Withnall & others (1976b) to embrace muscovite granite and pegmatite in the southern and central parts of the Forsayth 1:100 000 Sheet area, which are continuous into the Gilbert Sheet area. Muscovite granite also crops out south of the Gilberton Fault, particularly in the Six Mile Creek area, north of the Glenmore Batholith, and in the southeast corner of the Sheet area.

Although the Digger Creek Granite has tended to become a "catch-all" term for any body of muscovite leucogranite, most of the rocks mapped within the unit are probably roughly contemporaneous and syn-D_2. However, work by Rubenach and Bell (pers. comm.) in the Forsayth Sheet area, and A. Duncan (pers. comm.) near "Werrington", suggests that the muscovite granites and pegmatites may range in age from syn-D_1 to post-D_2; care should therefore be taken in assigning relative ages to other intrusive rock units on the basis of their relations to muscovite granite.

The muscovite granite and pegmatite bodies range from small veins to plutons many square kilometres in area. Roof pendants and screens of metamorphic rocks are common, and many bodies shown on the map may be networks of pegmatite and granite dykes and veins in metamorphic rocks. Although the muscovite granite and pegmatite crop out poorly, outcrop of the enclosing metamorphics is generally worse, and this tends to give a false impression of the abundance and size of the granite/pegmatite bodies. The granite and pegmatite weather to a sandy soil with abundant quartz pebbles, exhibiting a light colour on the airphotos.

Scintillometer (Austral SG-1) readings on outcrops of Digger Creek Granite range from 25 to 40 counts/second.

Lithology and petrography

The Digger Creek Granite consists of white to light grey, cream, and pink muscovite granite, varying in grainsize from aplitic to pegmatitic, commonly within the same outcrop. The rocks are locally foliated. The pegmatite occurs both as segregations within the granite, and as dykes and veins within the metamorphic rocks.

In the Percyville area, the Digger Creek Granite (specimens 70571124, 25, 28; 75300286, 321) is cream to pink, and consists of quartz (30 to 35 percent), slightly perthitic microcline (40 to 45 percent), plagioclase (10 to 30 percent - oligoclase/andesine), and muscovite (1 to 3 percent). Myrmekite is common between plagioclase and microcline grains. Quartz is usually granulated, particularly along grain boundaries. Traces of chloritised biotite, partly replaced by muscovite, are present in some specimens. Garnet is a common accessory mineral; other accessory minerals include sphene, apatite, zircon, and opaques.

Some specimens collected from areas mapped as Digger Creek Granite south of the Gilberton Fault, contain up to several percent biotite; muscovite present in these specimens is mostly secondary, replacing biotite and plagioclase. These specimens (75300091, 095, 119, and 305) could be variants of the Digger Creek Granite, but it is also possible that phases of some other unit, such as Anning Granite, are mixed in with the Digger Creek Granite; the other specimens collected in the area (Table 1 in Appendix B) are similar to those in the Percyville area.

Much of the muscovite in the Digger Creek Granite is probably primary; however, it is often difficult to distinguish between primary and secondary muscovite, except where the muscovite flakes obviously replace other minerals. Secondary muscovite is present in the other leucogranites (e.g. Anning Granite), and even in the Dumbano Granite. Rocks in which secondary muscovite is abundant could easily be assigned to the Digger Creek Granite by mistake if not examined in thin section.

Geochemistry and petrogenesis

Sheraton (1974) and Sheraton & Labonne (1978) presented geochemical data for some specimens of Digger Creek Granite (68900416, 018A & B, 70571124, 25, 28) although in that study, the rocks were included with the petrographically and chemically different Robin Hood Granodiorite. Not enough data are available to compare other leucogranites with the Digger Creek Granite.

Some specimens contain greater than 1 percent normative corundum which, considered with the field relation and petrography, indicates that the unit is an S-type granite, i.e. derived by anatexis of sedimentary rocks. At Percyville, in fact, muscovite granite and pegmatite appear to have formed in situ during the metamorphism (see below).

Relations and age

In the Percyville area, the Digger Creek Granite intrudes the Robertson River Formation (schist phase) and Einasleigh Metamorphics, and is intruded by the Robin Hood Granodiorite. At the junction of Blakos Creek and the Percy River, concordant muscovite granite and pegmatite layers appear to have formed in situ by migmatisation of the enclosing gneiss and schist; the felsic melt was also mobilised into discordant muscovite granite veins. The relations suggest that the veins formed synchronously with the locally dominant foliation, S_2. Larger masses of muscovite granite and pegmatite probably formed at about the same time as the smaller veins, by mobilisation of similar granitic material from greater depth. This has been confirmed by Rb-Sr dating (Black & others, 1979). Samples of Digger Creek Granite at Percyville yielded a Rb-Sr total-rock age of 1460 $\pm$ 40 m.y., and a muscovite age of 1505 m.y. Both ages are in general accord with each other, and with estimates of the age of D_2 in the metamorphics at Percyville and elsewhere. The age of the Digger Creek Granite is thus mid-Proterozoic.

South of the Gilberton Fault, muscovite granite intrudes the Einasleigh Metamorphics and Juntala Schist, and is locally cut by veins of biotite leucogranite, which may be related to the Anning Granite. Veins of muscovite granite intrude the Sawpit Granodiorite.

LOAFERS GRANODIORITE (Pmlf)
(new name)

Introduction

The Loafers Granodiorite is a hornblende-biotite granodiorite named after Loafers Creek, which joins the Gilbert River at GR 014626 and has its headwaters about 0.5 km south of Mount Rous. The type area is northwest along the track to "Glenmore" for about 1 km from the yards on the Gilbert River at GR 107566.

The granodiorite crops out as a small irregular body (about 10 km^2) mainly in the headwaters of Loafers Creek. Smaller bodies of hornblende granodiorite and granite associated with calc-silicate gneiss between Gorge Creek and the main outcrop area have been labelled Loafers Granodiorite on the Gilberton 1:100 000 Preliminary Edition map, but are now regarded as unassigned leucogranitoid. The Loafers Granodiorite has the typical light-coloured photo-pattern of the leucogranitoids, and crops out poorly.

Scintillometer (Austral SG-1) readings on outcrop are generally 20 to 25 counts/second.

Lithology and petrography

The Loafers Granodiorite is mainly a grey to pinkish grey, weakly foliated to non-foliated, medium-grained equigranular to slightly porphyritic hornblende-biotite granodiorite; locally it grades into granite.

In thin section the rocks are mainly allotriomorphic granular. Quartz grains (20 to 35 percent) commonly show sutured margins, inclusion trails, and undulose extinction. Alkali feldspar (15 to 55 percent) is dominantly microcline; the grains are commonly perthitic and contain inclusions of plagioclase, biotite, and hornblende. Plagioclase (20 to 60 percent) ranges in composition from An_{25} to An_{40}; grains show cryptic normal and oscillatory zoning, and contain inclusions of biotite and hornblende. Myrmekite intergrowths between plagioclase and microcline are common; rarely microcline partly replaces plagioclase. Blue-green hornblende and green or brown biotite together constitute between 4 and 6 percent of the rock. Accessory minerals include euhedral sphene, euhedral zoned allanite, garnet, zircon, and opaques.

Petrogenesis

The Loafers Granodiorite contains hornblende, a characteristic feature of 'I-type' granitoids (Chappel & White, 1974), but as the unit intrudes diopside-hornblende gneiss and hornblende-biotite gneiss (calc-silicate subunit Ƥme$_1$ of the Einasleigh Metamorphics) the hornblende grains may be metamorphic restites and the granodiorite may have formed by anatexis of the gneiss, i.e. it may be an 'S-type' granitoid.

Relations and age

The Loafers Granodiorite cuts white leucogranite veins and the main foliation (S_1 parallel to S_2) in the Einasleigh Metamorphics; it may therefore be post-D_2 in age. Its relation to the other granitoids is not known.

The Loafers Granodiorite is shown on the map as mid-Proterozoic, but a late Proterozoic or Silurian-Devonian age like the Anning and Dumbano Granites is also possible; it could also be late Palaeozoic because it shows some similarities to the Culba Granodiorite. It has not yet been sampled for isotopic age determination.

ANNING GRANITE (ƤSDg in part)
(new name)

Introduction

On the Gilberton 1:100 000 Preliminary Edition geological map the name Anning Granite is assigned to numerous bodies of leucogranitoid intruding the Einasleigh Metamorphics south of the Gilberton Fault and around the edge of the Dumbano Granite in the Glenmore Batholith. The name Anning Granite is now restricted to those larger areas of biotite leucogranite in or near the Glenmore Batholith (see Fig. 32). The other leucogranitoids are now put in an "unassigned" category and are described separately in this report (see pp. 110-112). Remapping of the Glenmore Batholith in 1978 showed that white to pink equigranular biotite leucogranite is a major constituent of the Glenmore Batholith and is present in much of the area shown on the Preliminary map as Dumbano Granite and Culba Granodiorite.

The name of the unit is derived from Anning Creek, which joins the Gilbert River at GR 976584. The type area is in Anning Creek for about 1 km upstream from its junction with the Gilbert River.

The unit crops out in two main areas totalling about 150 km^2. The largest area occupies the western third of the Glenmore Batholith and extends along its southern margin; the smaller area flanks the batholith on its eastern side. The Anning Granite is the most extensive unit within the batholith.

Outcrop of the unit is generally good, particularly around Hanns Table Mount and near Anning Creek, but except in the major streams it crops out poorly in the eastern area. Outcrop in critical areas, such as the contact with the Dumbano Granite, is extremely poor.

The Anning Granite weathers to a whitish sandy soil, and has a cream to white photo-pattern in most areas. West of Hanns Table Mount relief is greater and the granite has a darker photo-pattern that is less easily distinguished from that of the metamorphic rocks.

Roof pendants and xenoliths are restricted to contact zones in the larger western outcrop area, but are abundant in the southern extension and in the eastern outcrop area of the granite. Smaller bodies of leucogranite surrounding the Anning Granite may represent apophyses from subcropping extensions of the main masses.

Scintillometer readings (Austral SG-1) on outcrops range from 20 to 50 counts/second.

Lithology and petrography

Most of the western outcrop area consists of cream to pink, equigranular, medium-grained biotite leucogranite. A weak foliation is present locally but in general the rock appears massive. In thin section it consists of strained quartz (20 to 40 percent), plagioclase (10 to 40 percent - oligoclase/andesine), K-feldspar (45 to 70 percent - mostly microcline), reddish brown (commonly chloritised) biotite (trace to about 1 percent) and secondary muscovite (less than 1 percent). Many feldspar grains are slightly sericitised, and epidote and clinozoisite are commonly present as alteration products; myrmekitic intergrowths commonly replace the K-feldspar. Accessory minerals are garnet, zircon, sphene, apatite, and opaques. Discontinuous veins and stringers of aplite and pegmatite are common in places. Xenoliths of metamorphic rocks are relatively rare except near contacts; in the type area xenoliths of an older foliated biotite granitoid (Sawpit Granodiorite?) are present.

In the Bar Creek area, to the east of Hanns Table Mount, the Anning Granite contains minor hornblende as well as biotite. The hornblende commonly occurs where abundant xenoliths of calc-silicate gneiss are present, particularly near contacts with the Einasleigh Metamorphics. Larger roof pendants are also common in this area. The gneiss contains hornblende and clinopyroxene. Some small parts of the granite contain diffuse bands, which possibly represent assimilated metamorphics. Generally, however, xenoliths have sharply defined margins. The hornblende is blue-green, generally less than 1 mm long, strongly poikilitic, and partly replaced by biotite; locally irregular ragged crystals from 5 to 20 mm long occur, particularly in coarse-grained to pegmatitic phases. The hornblende may be derived from assimilation of calc-silicate gneiss, or it may be a restite if the granite itself was derived from anatexis of rocks containing hornblende.

The eastern outcrop area contains similar rocks to the larger western area, except that they are almost invariably white to cream rather than pink in hand specimen. They are medium-grained equigranular leucogranites containing biotite and secondary muscovite; aplitic and pegmatitic varieties are common.

Geochemistry

Only three of the samples examined and analysed by Sheraton & Labonne (1974) and Sheraton (1974) possibly belong to the Anning Granite. They are all leucogranites and were identified by those authors as Dumbano Granite. Two of the samples (70571129 and 1157) collected from near Bagstowe homestead may be from part of the Bagstowe Ring Complex. Only 70570031 (from 17.5 km southwest of Glenmore homestead) can be recognised as the Anning Granite with any certainty. Although the Anning Granite specimen plots with Dumbano Granite samples on some of the variation diagrams, there are some marked differences: Rb, Rb/Sr, K/Ba, and Ca/Sr are all higher whereas CaO, Ba, Sr, Mg/Li, and Ba/Rb are lower in the Anning Granite sample. However, one sample from such a large unit cannot be considered representative, and no conclusions can be drawn about genetic relations (if any) between the Dumbano Granite and Anning Granite.

The Glenmore (Anning Granite?) sample is corundum-normative whereas both Bagstowe samples are diopside-normative (I-type granites), which supports the conclusion that the latter may be part of the Bagstowe Ring Dyke Complex.

122

Relations and age

The Anning Granite intrudes the Einasleigh Metamorphics, and is intruded by the Carboniferous(?) Culba Granodiorite and various members of the Bagstowe Ring Dyke Complex. The relations to the Digger Creek Granite and Dumbano Granite are not known. The Dumbano Granite and Anning Granite are in contact but exposure in the contact zone is lacking; it is difficult to map the boundary between the two granites accurately, let alone determine relationships. The two units have identical photo-patterns and resemble each other in the deeply weathered exposures in banks of streams. The presence of sparse K-feldspar megacrysts and generally more biotite in the Dumbano Granite serve to distinguish the units. The position of the boundary as mapped is very uncertain; thus although the shape of the regional contact suggests that the Dumbano Granite may be younger, little reliance can be put on this.

The Anning Granite is generally massive or weakly foliated. Leucogranite exposed in the Gilbert River at GR 073686 intrudes Sawpit Granodiorite, and appears to postdate D_2 folds in the xenoliths and roof pendants; this leucogranite is equated with the Anning Granite, which suggests that the unit is at least younger than 1470 m.y.. It may have been emplaced syntectonically with D_3 (i.e. about 970 m.y. - the same age as the Mount Hogan Granite and possibly Robin Hood Granodiorite), so accounting for the local weak foliation. However, an even younger age (Silurian-Devonian - syn-D_4) is not ruled out.

No samples of the unit have yet been collected for isotopic age determination. Until such time the Anning Granite must be regarded as being of mid to late Proterozoic or Silurian-Devonian age.

UNASSIGNED LEUCOGRANITOIDS (gr, ESDg in part)

Introduction

The Einasleigh Metamorphics south of the Gilberton Fault are intruded by countless bodies of leucogranitoid ranging in size from many square kilometres to small veins. They are mostly granite (rather than granodiorite) and range from biotite leucogranite through biotite-muscovite leucogranite to muscovite granite; many contain no mica at all. On the Gilberton 1:100 000 Preliminary Edition geological map the leucogranitoids are divided into three main categories. Those areas of predominantly muscovite granite are equated with the Digger Creek Granite and are described separately (see pp. 103-105).

Others, predominantly biotite leucogranite, were grouped into a single map unit (PSDg) equated with the Anning Granite. However, mapping in 1978 showed that a large part of the Glenmore Batholith (including much of the area shown as Dumbano granite on the map) consists of white to pink biotite leucogranite. The name Anning Granite is now applied only to these rocks in and near the Glenmore Batholith as shown in Figure 32. All other leucogranitoids originally assigned to "PSDg" are now left as unassigned, because they probably include rocks with a range of ages and relationships. They are grouped with the third category on the map ("gr"), which includes bodies of leucogranite which could not be put into either the Digger Creek Granite or "PSDg" categories; such bodies are in areas where both muscovite and biotite leucogranites are present, or where field data were inadequate to determine the category to which the mainly photo-interpreted bodies should be assigned.

All the map bodies contain abundant roof pendants and screens of metamorphic rocks. In fact many leucogranitoids shown as single bodies on the map are actually areas of abundant leucogranite dykes and veins cutting the metamorphic rocks. Similarly, large areas of the Einasleigh Metamorphics are cut by abundant unmapped leucogranitoid dykes and veins. Xenoliths of metamorphic rocks are abundant, and many of them are composite, containing veins of older leucogranitoid phases.

The largest single outcrop area of unassigned leucogranitoid is west of Six Mile (or Perryvale) homestead; this area was formerly mapped as Dumbano Granite by White (1962c).

The leucogranitoids generally crop out poorly and weather to a whitish sandy soil. The photo-pattern is typically mottled white and reddish brown because of the metamorphic enclaves.

Scintillometer readings (Austral SG-1) on outcrops range from 18 to 85 counts/second, but are mostly less than 40 counts/second.

Lithology and petrography

The leucogranitoids are extremely variable in appearance. They are white, cream or pink, medium-grained to pegmatitic (and locally aplitic), and weakly to strongly foliated. They may be agmatitic (with numerous angular to rounded and partly digested xenoliths), nebulitic (streaky, like the Sawpit Granodiorite), or massive.

In thin section, the quartz (20 to 40 percent) is strongly strained, fractured, and locally elongate. Plagioclase (10 to 60 percent) is oligoclase or andesine, with weak normal or oscillatory zoning; it is commonly partly sericitised. K-feldspar (20 to 70 percent) is mostly microcline containing string and patch perthites and inclusions of biotite and plagioclase; myrmekitic intergrowths locally replace microcline adjacent to plagioclase grains. Biotite rarely exceeds 1 percent and is commonly absent; it is greenish to reddish brown, generally partly chloritised and contains zircon inclusions. Secondary muscovite (up to 1 percent) is common. Hornblende and diopside occur locally, particularly where the leucogranitoids intrude calc-silicate gneiss; such granitoids may have been derived by anatexis of the gneiss, the hornblende and diopside grains possibly being metamorphic restites. Accessories include zircon, apatite, epidote, and opaques.

Relations and age

The leucogranitoids intrude the Einasleigh Metamorphics. Crosscutting relationships indicate that they were probably emplaced in several different stages. Some were possibly derived *in situ* by partial melting of the enclosing metamorphic rocks or have migrated only a short distance from their source. Others may have been derived at greater depths, or are related to one or more of the following: Sawpit Granodiorite, Anning Granite, and Digger Creek Granite.

Many of the leucogranitoids are foliated, suggesting that they were emplaced syntectonically, during D_1 or D_2. They are thus mid-Proterozoic in age (1470 to 1570 m.y.). A Silurian-Devonian age for some of the leucogranitoids is possible, particularly if the Dumbano Granite and Anning Granite eventually prove to be of that age.

MOUNT HOGAN GRANITE (Puh)
(new name)

Introduction

The Mount Hogan Granite occurs in a roughly semicircular pluton of biotite granite, 7 km in diameter and about 30 km^2 in outcrop area. The unit derives its name from Mount Hogan homestead at GR 967791 (Gilberton 1:100 000 Sheet area); the old Mount Hogan group of gold mines also lie within the granite. The type area is about 2.5 km southwest of Mount Hogan homestead, and about 1.5 km north of the main Mount Hogan gold mines.

The granite crops out in an area of low relief; the metamorphic rocks to the south, east, and west form more rugged hills and ridges, although there is not such a marked contrast in topography to the north. Around the southern and eastern margins of the intrusion alteration zones form prominent hills which include Mount Moran and Mount Hogan. Outcrop is generally poor, and the granite weathers to a light coloured, coarse, easily-eroded sandy soil.

The Mount Hogan Granite is characterised by a high radiometric background. Scintillometer (Austral SG-1) readings on outcrops range from 90 to 170 counts/second (average 140 counts/second). Altered granite does not appear to have a significantly different background, except in the vicinity of the Mount Hogan gold mines, where uranium mineralisation has been found (O'Rourke & Bennel, 1977); the background there is in the range 150 to 250 counts/second, and "hot spots" on some dumps give readings of up to 2500 counts/second. In the northern part of the pluton, some leucogranite dykes have higher backgrounds than the host granite (150 to 220 counts/second - average 200 counts/second).

Lithology and petrography

The Mount Hogan Granite is a reddish brown to grey, non-foliated, coarse, even-grained to slightly porphyritic biotite granite. It consists of quartz (30 to 40 percent), microcline (30 to 50 percent), plagioclase (15 to 30 percent), biotite (up to 5 percent) and accessory epidote, metamict allanite, sphene, zircon, apatite, and opaques. Plagioclase forms anhedral laths (1.0 to 5 mm) and is generally at least partly sericitised; where unaltered, it is zoned oligoclase. Microcline (1 to 10 mm) is perthitic, and contains inclusions of biotite and plagioclase; it is rarely sericitised, but is locally slightly turbid. Both feldspars are commonly pink in hand specimen because of minor alteration. Quartz grains (2 to 5 mm) are strongly strained and have highly sutured margins.

In the northern part of the pluton, pink, fine to medium-grained leucogranite to aplite crops out as dykes cutting the coarser biotite granite. This rock also occurs in the contact zone, where it may represent a chilled margin. The leucogranite consists of quartz (30 percent), microcline (45 to 50 percent), sericitised plagioclase (15 to 20 percent), biotite (less than 1 percent), and accessory zircon, sphene, and opaques. The grainsize averages about 1 mm, but some microcline grains are up to 5 mm. Secondary muscovite (less than 1 percent) forms irregular flakes up to 1.5 mm long, replacing plagioclase and biotite. Irregular epidote and quartz aggregates up to 2 mm wide are scattered through the rock.

Pegmatite segregations occur locally in biotite granite of the northern part of the pluton. Xenoliths are virtually absent from the Mount Hogan Granite.

Zones of intense chlorite-sericite alteration dipping shallowly outwards have been mapped around the eastern and southern margins of the granite. These zones host thin quartz veins containing the main gold-silver-uranium mineralisation described by O'Rourke & Bennel (1977). In the main mineralised area, these zones dip from 3° to 40° southwest, but generally from 15° to 20°. The zones are mainly between 6 and 15 m thick, but locally are up to 30 m. Narrower subparallel zones occur between the main ones.

The main alteration is to sericite or chlorite; it is locally very intense. The sericite is pale green and is difficult to distinguish from chlorite in hand specimen. All gradations from sericite alteration, through chlorite and epidote alteration, to unaltered granite have been observed.

Sericitised granite (specimen 75300082) contains quartz (40 percent), turbid but otherwise unaltered microcline (40 percent), and sericite (20 percent). The last occurs as aggregates of flakes (0.05 to 0.5 mm long), probably mainly replacing plagioclase; larger muscovite flakes (0.5 to 1 mm long), containing inclusions of zircon, opaques and iron oxides, probably replace biotite flakes.

Abundant discontinuous en echelon quartz veins and veinlets 0.2 to 0.6 cm wide are present within, and are parallel to, the alteration zones; the alteration was probably associated with the emplacement of these veins. Minor copper, lead, zinc, silver, gold, and uranium mineralisation occurs with the quartz-veined alteration zones; the highest-grade mineralisation accompanies the most intense alteration. Northeast of Mount Hogan homestead, however, the granite is intensely altered, but apparently unmineralised except for minor pyrite.

Geochemistry

No complete chemical analyses of the Mount Hogan Granite are available.

Three samples of the Mount Hogan Granite, submitted to the Queensland Government Chemical Laboratory for U and Th analysis, gave the following results:

BMR Reg. No.		U (ppm)	(ppm) Th
75300049	grey unaltered biotite granite	10	56
75300066	pink, fine-grained leucogranite	16	61
75300082	sericitised granite	13	37

The values are high compared with the average granites (4.7 and 17 ppm respectively) of Turekian & Wedepohl (1961) and Taylor (1964), and account for the high radiometric background. They are also higher than the average U and Th contents of most components of the Forsayth Batholith, 6 and 30 ppm respectively (Sheraton & Labonne, 1978; Sheraton, 1974).

Relations and age

The Mount Hogan Granite intrudes the Robertson River Formation and its higher-grade metamorphic equivalents, the schist phase, as well as basic sills within the metamorphics. It also intrudes the calc-silicate rocks of the Bernecker Creek Formation. The main contact effects appear to be "spotting" of the phyllite and schist, through the growth of chlorite porphyroblasts; Llewellyn (1974) attributed hornblende porphyroblasts in the calc-silicate rocks to contact metamorphism by the granite. The granite is intruded by dykes of rhyolite and andesite or dolerite; a fault which displaces the southern contact is intruded by microdiorite.

Folds outlined by metadolerite sills in the Robertson River Formation, are truncated by the Mount Hogan Granite. These folds are thought to be second-generation structures, the granite thus probably being post-D_2, or at the very earliest, late syn-D_2. Preliminary Rb-Sr data (L.P. Black, pers. comm., 1977) are insufficient to define a precise isochron, but indicate that the granite is almost certainly Proterozoic, and possibly about 1000 m.y. old (roughly the age of D_3), i.e. late Proterozoic.

DUMBANO GRANITE (SDd)

(White, 1959b)

Introduction

As defined by White (1959b), the Dumbano Granite is dominantly a medium-grained, grey biotite granite with pink K-feldspar megacrysts. This lithology occurs at the type locality on Middle Creek, 15 km west of Lyndhurst

128

homestead in the Lyndhurst 1:100 000 Sheet area. Therefore, other rock types present in the area previously mapped as Dumbano Granite in the Gilberton 1:100 000 Sheet area are assigned to separate units, including the Sawpit Granodiorite, Welfern Granite, Oak River Granodiorite, Digger Creek Granite, Loafers Granodiorite, Anning Granite, and Culba Granodiorite; various leucogranitoids, here not assigned to any specific units, were also previously mapped as Dumbano Granite.

As explained on pages 95 and 107 a large part of the area shown as Dumbano Granite on the Gilberton 1:100 000 Preliminary Edition geological map is now assigned to the Anning Granite as a result of more recent work. As now mapped (Fig. 32), the Dumbano Granite in the Gilberton Sheet area crops out mainly in a large triangular body 60 km^2 in area, in the middle of the Glenmore Batholith. Three smaller areas occur (a) on the western edge of the batholith along the track between Red Bar Yards and Gilberton Homestead (2 km^2); (b) in the southeast, near Castle Hill (8 km^2); and (c) in the northeast in the headwaters of Sawpit Creek near Bagstowe homestead (5 km^2). The Dumbano Granite constitutes about one-sixth of the exposed Glenmore Batholith, in the Sheet area.

The granite forms low relief, and is poorly exposed; outcrop is limited to scattered boulders and deeply weathered exposures in banks of streams. Like most of the granitoids it weathers to a whitish sandy soil, and has a uniform light-coloured photo-pattern.

Scintillometer readings (Austral SG-1) on outcrops range from 35 to 50 counts/second.

Lithology and petrography

The granite is typically a light grey medium-grained leucocratic granite with pink equant megacrysts of alkali feldspar up to 3 cm across. The granite is cut by pink pegmatitic segregations containing sporadic biotite which grade laterally into the porphyritic granite. Pink aplite veins are also present.

In thin section, the texture of the porphyritic granite is allotriomorphic granular. Quartz (15-50%) shows undulose extinction, inclusion trails, and fracturing. Alkali feldspar (20-50%) forms anhedral crystals of slightly perthitic microcline, or less commonly, orthoclase. Grains commonly show string perthite, and contain inclusions of quartz, plagioclase, and biotite. Some megacrysts contain concentrically arranged zones of quartz inclusions. Plagioclase (20-50%) is oligoclase, or zoned oligoclase-andesine, which is commonly sericitised or saussuritised, particularly in the cores of crystals. Myrmekitic intergrowths between plagioclase and alkali feldspar are common. Biotite (up to 20%) forms dark brown flakes, but is commonly chloritised. Muscovite, where present, is secondary, replacing biotite and plagioclase. Accessories include opaques, sphene, and allanite.

Sheraton & Labonne (1974) described three specimens of porphyritic biotite granite (70571132, 1138, 1139) from the area now mapped as Dumbano Granite in the Gilberton 1:100 000 Sheet area.

Geochemistry

Sheraton (1974) analysed 19 samples he identified as "Dumbano Granite". Of these, only eight are now thought to be Dumbano Granite, and only three are from the Gilberton Sheet area (70571132, 1138, 1139). Five samples from near "Oak Park" and "Lyndhurst" in the Lyndhurst Sheet area are probably also true Dumbano Granite. All eight samples are similar geochemically. Many of the generalisations made by Sheraton & Labonne (1978) concerning the geochemistry are now invalid, e.g. the wide variation they noted in many trace elements. However, as noted by them Zr, La, Ce, Th, U, and particularly Li and Cu, are low compared with values in the average granites of Turkekian & Wedepohl (1961) and Taylor (1964); other elements are close to average.

All but one of the Dumbano Granite samples are corundum-normative, some containing more than 1 percent. By the criteria of Chappell & White (1974) and Hine & others (1978), they are thus probably S-types (derived from sedimentary materials), although the high Na_2O (greater than 3.2 percent) relative to K_2O is supposed to be more indicative of I-types. However, in the granitoids of the Georgetown Inlier, high Na_2O is probably a consequence of more sodic metasedimentary parent rocks, than those in the southern Tasman Orogenic Zone, studied by Chappel & White. The parent rocks of the Georgetown granitoids may have included plagioclase-rich biotite gneiss and calc-silicate gneiss, as well as schist. Those in the southern Tasman Orogenic Zone were probably mainly metapelites, and hence less sodic.

Relations and age

The Dumbano Granite intrudes the Einasleigh Metamorphics, and is intruded by the Carboniferous? Culba Granodiorite and various phases of the Bagstowe Ring Dyke Complex.

The Dumbano Granite is rarely and weakly foliated. Therefore, it probably postdates the strongest tectonic events, D_1 and D_2. The Sawpit Granodiorite, Digger Creek Granite, and some of the unassigned leucogranitoids are definitely known to be pre- or syn-D_2. A body of muscovite granite 2 km^2 in area occurs within Dumbano Granite in the Castle Hill area; no contacts are exposed, but the muscovite granite (equated with the Digger Creek Granite) may be a large roof pendant.

As discussed above the relation between the Dumbano Granite and Anning Granite is not known. Veins of fine-grained leucogranite that intrude Dumbano Granite are probably late-stage differentiates of the granite, although they could possibly be related to the Anning Granite, if the latter is younger. The Dumbano Granite and Anning Granite are similar in appearance, the main differences being the presence of K-feldspar megacrysts and more biotite in the former. Therefore, they may belong to the same petrogenetic suite. Further geochemical studies and isotopic dating are needed to investigate this possibility.

Dating of biotite from the Dumbano Granite by the K-Ar method (Richards & others, 1966) indicated a Devonian age (380 $\pm$ 8 m.y.); Rb-Sr mineral ages on the same samples (Black, 1973) are slightly older (400 and 417 m.y.). However, a widespread tectonic event (D_4) in the Devonian may have caused resetting, and these ages must be regarded as minimum. A late Proterozoic age (e.g. syn-D_3 - about 1000 m.y.), the age of the Mount Hogan Granite, and possibly of the Robin Hood Granodiorite, is a possibility. Samples collected for Rb-Sr total-rock dating are still being processed.

Until further results are forthcoming the Dumbano Granite must be regarded as late Proterozoic or Silurian-Devonian in age.

ROBIN HOOD GRANODIORITE (SDr)

(White, 1959; Withnall & others, 1976b)

Introduction

The Robin Hood Granodiorite (Robin Hood Granite of White, 1959b; renamed and redefined by Withnall & others, 1976b) is a hornblende-biotite granodiorite which crops out in the northern part of the Gilberton 1:100 000 Sheet area between Percyvale homestead and Agate Creek. The unit extends into the Forsayth 1:100 000 Sheet area. Total outcrop area is about 300 km^2, of which about 100 km^2 is in the Gilberton Sheet area. Embayments of metamorphic rocks, Digger Creek Granite, and rhyolite divide the outcrop area in the

(3)

Gilberton Sheet area into three parts. A fourth, smaller area of Robin Hood Granodiorite crops out west of the Permian Agate Creek Volcanics.

The topography is subdued; the granodiorite is well-jointed, and some low hills are boulder-covered. Residual sand containing abundant distinctive pea-sized quartz grains is indicative of underlying Robin Hood Granodiorite in deeply weathered areas. This relatively coarse sandy soil is commonly deeply and intricately gullied, particularly on slopes beneath Mesozoic sandstone cappings.

Scintillometer (SG-1) readings on outcrops average 40 counts/second (range 35 to 45 cents/second).

Lithology and petrography

The Robin Hood Granodiorite is a non-foliated medium-grained hornblende-biotite granodiorite containing characteristic round quartz aggregates (not strictly phenocrysts) 0.5 to 1.0 cm in diameter. The unit is remarkably uniform in lithology, although the colour ranges from pink to grey, depending on the degree of alteration of plagioclase.

No specimens from the Gilberton Sheet area were examined in thin section during this survey, but Sheraton & Labonne (1974) described one specimen (70571126) from near Percyville. It contained quartz (25 percent) turbid microcline (20-25 percent), zoned andesine (45-50 percent), hornblende (2 percent), biotite (4 percent), magnetite (1 percent), and accessory fluorite, sphene allanite, apatite, and epidote. It is essentially the same as specimens from the Forsayth Sheet area, described by Sheraton & Labonne (1974) and Bain & others (1976a). Most of the quartz occurs as subrounded aggregates (5-10 mm in diameter) made up of small grains with highly sutured boundaries and undulose extinction. The plagioclase (1-5 mm) is commonly intensely sericitised, accounting for the pink colour of some parts of the unit. Microcline (1-3 mm) is commonly unaltered. Much of the hornblende (0.5-2 mm) is pseudomorphed by biotite, chlorite, and epidote. The biotite (0.5 to 2 mm) is also partly chloritised and epidotised, and some flakes are bent.

The granodiorite is locally cut by penetrative microshears and fractures, which impart a foliated appearance to the rocks. These shears and fractures are commonly sericitised and chloritised. More intense quartz-sericite alteration is associated with some of the mineralised shears, and quartz-filled fractures in the Percyville area.

No pegmatite or aplite dykes or veins have been observed in the Robin Hood Granodiorite. Xenoliths are rare, those present being mainly dark, fine-grained aggregates of biotite, hornblende, opaques, and minor quartz.

Geochemistry and petrogenesis

Sheraton (1974) and Sheraton & Labonne (1978) presented geochemical data for three specimens of Robin Hood Granodiorite. They noted that the Robin Hood Granodiorite samples were geochemically similar to granodiorite from the Georgetown 1:100 000 Sheet area (originally mapped as Forsayth Granite, and now mapped as Proterozoic White Springs Granodiorite). The main differences are slightly higher K_2O/Na_2O and considerably higher Cu (averaging 16 ppm) in the Robin Hood Granodiorite.

The presence of hornblende and mafic xenoliths, as well as normative diopside in one sample, suggests that the Robin Hood Granodiorite is an I-type granitoid (Chappell & White, 1974).

Relations and age

The age of the Robin Hood Granodiorite is indefinite. It intrudes the Proterozoic Einasleigh and Robertson River Formation (schist phase) and Digger Creek Granite, and is intruded by late Palaeozoic rhyolite and dolerite dykes; it is overlain by the Permian Agate Creek Volcanics, and (in the Forsayth Sheet area) by the Carboniferous Newcastle Range Volcanics. Pebbles of Robin Hood Granodiorite have been observed in the late Devonian to early Carboniferous Gilberton Formation. These relationships indicate that the age of the granodiorite may be anywhere between the mid-Proterozoic (post-D_2) and the mid to late Devonian. White (1965) and Richards & others (1966) regarded the Robin Hood Granodiorite as Precambrian. However, the only specimen which yielded a Precambrian age was a muscovite pegmatite, now equated with the Digger Creek Granite. The other specimen dated by Richards & others (1966) from near "Robin Hood", was true Robin Hood Granodiorite; it yielded a K-Ar biotite age of 380 m.y.. Black (1973) obtained a Rb-Sr biotite age of 426 m.y. (late Silurian) on the same specimen. Because these are only mineral ages, and susceptible to resetting, they must be regarded as minimum ages. The Silurian to Devonian "thermal event" thought to have accompanied D_4 (Black & others, 1979) may have reset the ages. However, it could be significant that Rb-Sr biotite ages in the schist phase of the Robertson River Formation of the "Robin Hood" area (Bull

133

Creek and Stars Well localities of Black & others, 1979) were not reset by the D_4 event; this indicates that any metamorphism associated with D_4 was not strong enough to reset Rb-Sr biotite ages, and therefore that the biotite age of the Robin Hood Granodiorite may be close to the true age.

Attempts to date the Robin Hood Granodiorite by Rb-Sr total-rock dating have been unsuccessful (Black, pers. comm, 1977). The samples are remarkably uniform in composition, and have insufficient spread in Rb and Sr to define an isochron. A sample has been collected for zircon-dating.

At present the unit is shown on the maps as Silurian-Devonian, but it may yet prove to be Proterozoic, perhaps equivalent in age to the Mount Hogan Granite (possibly about 1000 m.y.).

CULBA GRANODIORITE (€u)
(new name)

Introduction

The Culba Granodiorite forms an irregular pluton in the northern part of the Glenmore Batholith, 12 km west of Glenmore homestead; it abuts the northwestern section of the Mount Rous Ring Dyke. The intrusion is 9 km long from north to south, and 5 km wide in the north, tapering southwards. The total outcrop area is about 35 km^2.

The name is derived from the Parish of Culba. The type area is upstream along Pinnacle Creek and one of its tributaries from GR 027678 upstream to 008690.

The area shown as Culba Granodiorite on the Gilberton 1:100 000 Preliminary Edition geological map includes some Anning Granite and Einasleigh Metamorphics. Figure 32 shows the extent of the Culba Granodiorite more accurately.

The granodiorite forms low relief but is moderately well exposed, cropping out as isolated boulders in colluvium and as small scattered tors. It has a relatively dark-coloured photo-pattern similar to that of the metamorphics. Fine-grained biotite granite which crops out over about 2 km^2 on the southwestern margin of the unit is better exposed and has a lighter-coloured photo-pattern.

Scintillometer (Austral SG-1) readings on outcrops range from 45 to 75 counts per second.

Lithology and petrography

Two varieties of the Culba Granodiorite have been mapped as shown in Figure 32. The oldest and most widespread variety is a grey, fine to medium-grained equigranular hornblende-biotite granodiorite (map symbol $€u_1$). The subunit is non-foliated and relatively melanocratic, and contains rounded xenoliths of dark, hornblende-rich, slightly porphyritic microdiorite or micro-tonalite. In thin section the texture of the granodiorite is predominantly hypidiomorphic granular. Euhedral to subhedral green to brown hornblende and dark brown biotite together make up 5 to 10 percent of the rock. Orthoclase (10 to 40 percent) is interstitial to the euhedral or subhedral plagioclase, and generally has replacement string perthite; primary exsolution perthites are locally present. No microcline was observed. The plagioclase (30 to 65 percent) ranges from oligoclase to andesine, and shows strong normal and oscillatory zoning; it is generally partly sericitised. Interstital quartz (10 to 30 percent) is commonly graphically intergrown with orthoclase and shows undulose extinction. Accessories include opaques, euhedral zoned allanite, euhedral sphene, and apatite.

The younger variety (map symbol $€u_2$) crops out on the southwestern margin of the pluton. It consists of greyish pink, fine to medium-grained, equigranular biotite granite: it is generally finer-grained than the grano-diorite. Locally it contains xenoliths of the granodiorite phase, and apophyses of it extend into the granodiorite. Only one specimen has been examined in thin section (75300252); it was collected from GR 008682 just outside the main outcrop area, from an apophysis intruding the Einasleigh Metamorphics. It consists of quartz (20 percent), orthoclase (50 percent), oligoclase (25 percent), and biotite (3 percent).

Relations and age

The Culba Granodiorite intrudes the Einasleigh Metamorphics and Anning Granite. It may intrude the Dumbano Granite at depth, but the exposed contact is a ring-fault occupied by the Mount Rous Ring Dyke. The ring dyke, and porphyritic rhyolite dykes and cone-sheets which intrude the granodiorite, are part of the Bagstowe Ring Dyke Complex.

The Culba Granodiorite is thought to be Carboniferous in age, because of its massive, unfoliated character and petrographic similarities to some other late Palaeozoic plutonic rocks in northeast Queensland. It is older than 325 m.y., the age of the Mount Rous Ring Dyke (Richards & others, 1966).

PURKIN GRANITE (€p)
(new name)

Introduction

The Purkin Granite occurs in two plutons which crop out along the southern edge of the Gilberton 1:100 000 Sheet area, and into the adjacent Hampstead, Lyndhurst, and Chudleigh Park :100 000 Sheet areas. The western pluton is roughly circular, with a diameter of 10 to 12 km and an exposed area of about 100 km^2; the eastern pluton is more irregular in outline, and has an outcrop area of about 300 km^2.

The name is derived from the Parish of Purkin, County of Percy (Lands Department 4-Mile Cadastral Series). Smart (1973) used the name Purkin Igneous Complex for part of the western pluton, but did not formally define the unit; the complex was mapped as an annular intrusion of Carboniferous to Permian "granite(?)" around a central core interpreted as older Dumbano Granite.

Our work has shown that the whole "complex" is relatively uniform, and does not have a core of older granite. The name is accordingly changed to Purkin Granite, and extended to include the eastern intrusion which Smart (1973) mapped as unnamed Upper Palaeozoic granite.

The Purkin Granite forms rugged boulder-covered hills up to 150 m high. Outcrop is good, particularly in the larger streams; the best exposures are in Goat Gorge, where the Gilbert River cuts through the eastern pluton; this section is designated as the type area.

Branch (1966, p. 99) equated rocks, here assigned to Purkin Granite, with the Elizabeth Creek Granite, which they resemble. However, the Purkin Granite is 180 km from the type area of the Elizabeth Creek Granite, and temporal and genetic relations between the two are uncertain.

Lithology and petrography

The Purkin Granite consists of grey to pink, medium to very coarse-grained biotite leucogranite, subordinate grey porphyritic biotite microgranite with sparse pink K-feldspar phenocrysts, and minor pink aplite. The porphyritic microgranite is less common in the western pluton than the eastern one, but otherwise there are few differences between the two plutons.

Like the Welfern and Mount Hogan Granites this unit has a high radiometric background (70 to 130, average 85 counts/second); the highest values, those over 100 counts/second, are mostly in the central part of the western body.

Only three specimens of the granite in the map area have been examined in thin section. The coarse and medium to coarse-grained biotite leucogranites are mineralogically similar except for slight differences in the porportions of plagioclase and alkali feldspar. Quartz shows marked evidence of strain (undulose extinction and deformation lamellae). Other minerals are less deformed but mostly altered - some partially, some totally. Orthoclase is more abundant than microcline; it is also perthitic and more heavily clouded than the other feldspars. Plagioclase is the least clouded but the cores of most grains are partly sericitised. Biotite is pale yellow to dark brown and green-brown, and contains numerous small zircon inclusions and pleochroic haloes. Some biotite grains and parts of grains are chloritised, the chlorite locally having prussian blue pleochroism and bundles and latticeworks of rutile(?) needles. Accessory minerals include opaques (ilmenite?) sphene, rutile, zircon (some large zoned crystals), and rare purple fluorite. Coarse muscovite locally replaces biotite and plagioclase. Quartz and feldspar boundaries are commonly strongly sutured.

The porphyritic microgranite contains small (2-5 mm) quartz and feldspar phenocrysts and large (10 mm) pink K-feldspar phenocrysts; it also has slightly more plagioclase (mostly as small euhedral crystals) than the coarse leucogranite. The mineralogy and degree of alteration and deformation are otherwise very much like those of the leucogranite.

Richards & others (1966; p. 37) briefly described a similar specimen (GA 544) from the northeastern edge of the eastern pluton in the Chudleigh Park 1:100 000 Sheet area (16 km west of Black Braes homestead).

Relations and age

The Purkin Granite intrudes the Proterozoic Einasleigh Metamorphics, Juntala Schist, and various Proterozoic or early Palaeozoic leucogranitoids; it is overlain by sedimentary rocks of the late Jurassic Eulo Queen Group. Isotopic dating of the specimen from the eastern pluton 16 km west of "Black Braes" gave a K-Ar biotite age of 305 m.y., i.e. late Carboniferous (Richards & others, 1966).

LATE PALAEOZOIC HYPABYSSAL ROCKS

BAGSTOWE RING DYKE COMPLEX

(White 1959a; Branch, 1966)

Introduction

The Bagstowe Ring Dyke Complex is roughly centred on Glenmore and Bagstowe homesteads; it covers an elliptical area of about 340 km^2 with axes of 16 km and 25 km; the longer axis trends northeast. The complex extends into the adjacent Lyndhurst 1:100 000 Sheet area.

Branch (1959; 1966, pp. 68-79) gave the first comprehensive description of the complex, which he interpreted as representing a deeply eroded cauldron subsidence structure. That part of the complex lying within the Gilberton Sheet area was remapped by us in more detail in 1975; although some details are changed, the overall geology and interpretation are essentially the same as those of Branch. The following text provides only a brief summary and some discussion on points of difference with Branch (1966). A more comprehensive report will be given when the remainder of the complex is examined in 1979.

Twenty-nine samples from the Bagstowe Complex were studied petrographically and geochemically by Sheraton (1974) and Sheraton & Labonne (1974; 1978).

Lithology and structure

The Bagstowe Ring Dyke Complex comprises many overlapping ring structures which become younger towards the northeast, several dyke swarms, and some residual volcanics.

The earliest formed dyke is the Castle Hill Dyke (€Pb$_1$), a pink to brown porphyritic rhyolite that is not part of any obvious ring structure. It is older than the Mount Rous Ring Dyke, which intersects it at right angles.

The oldest ring structure, at the southwestern end of the group, contains the Mount Rous Ring Dyke (€Pb$_4$ - a biotite-hornblende microgranodiorite), an older grey flow-banded aphyric rhyolite (€Pb$_2$), and a green polymict breccia (€Pb$_3$) containing clasts of €Pb$_2$; the last two occur along the southern part of the inner side of the structure. Farther south an arcuate intrusion of porphyritic microgranite extending about 6.5 km southwest from Wire Yard Mountain is erroneously shown as unit €Pb$_4$ on the 1977 Preliminary Edition map.

The central ring structure consists of several sets of ring dykes and cone sheets which may be related to separate subsidiary centres of intrusion (Branch, 1966).

The earliest phase in the central structure consists of a series of concentric ring dykes of grey porphyritic rhyolite (inner ring dykes - €Pb$_8$) and their brecciated equivalents (€Pb$_9$); these are the "grey ring dykes" (A to F) of Branch (1966). Although Branch (1966, plate 42) depicted discrete dykes and labelled and described them separately his map is largely schematic. The elongate crescentic country rock screens between dykes A to F are apparently mostly conjectural. Some screens do exist but most are more irregularly shaped. The boundary criteria for the individual inner ring dykes - the shape, location and orientation of granite screens, elongate breccia zones, younger aphyric pink rhyolite dykes - and systematic lithological variations within €Pb$_8$ strongly suggest that €Pb$_8$ consists of numerous adjacent and overlapping ring dykes. However, they provide insufficient control for meaningful subdivision of €Pb$_8$, and none of the possible interpretations result in boundaries coincident with those on Plate 42 of Branch (1966). Unit €Pb$_8$ may include much extrusive ignimbrite.

Intrusion of augite-hornblende-quartz andesite (€Pb$_{10}$) magma followed the emplacement of the inner ring dykes; the rock forms an arcuate body 5 km long and about 1 km wide along the outer western margin of the inner ring dykes; similar but smaller dykes occur outside the central part of the complex.

The Four Mile Creek Stock, a hornblende-biotite microgranite, which Branch (1966) interpreted as being the next youngest part of the complex, does not crop out in the Gilberton 1:100 000 Sheet area.

The "east-west ring dyke" of Branch (1966) is a pink hornblende-biotite microgranite (€Pb$_{12}$) forming the northwestern and eastern boundaries of the central complex. Branch interpreted it as intruding the "pink ring dykes", but it could be older.

Dykes of brown porphyritic rhyolite (€Pb$_{13}$ - Branch's "pink ring dykes") form a continuous zone of concentric dykes around the southern and western margins of the central structure.

Several swarms of cone sheets (€Pb$_{15}$) occur to the west of the central ring structure. They dip 45° to 60° towards the centre of the complex, and are probably younger than the "pink ring dykes".

The youngest parts of the Bagstowe Ring Dyke Complex are the Northeast Stock and its associated Central Ring Dykes (€Pb$_{14}$), which together constitute the central part of the ring complex. Only the Central Ring Dyke crops out in the Gilberton Sheet area; it consists of pink leucocratic biotite microgranite. Branch (1966, plate 42) showed this dyke as fault bounded, but both inner and outer contacts are highly irregular (sutured) intrusive contacts and there are no boundary faults. Other outcrops of €Pb$_{14}$ in the mostly alluvium-covered area around Bagstowe homestead may be parts of separate related dykes or apophyses of the main dyke.

Northwest of the ring complex is a 10 km^2 area which Branch interpreted as a volcanic neck. However, rocks here are more likely to be remnants of the extrusive rocks associated with the complex. Brown rhyolitic ignimbrite (€Pb$_5$) is overlain by green rhyolitic breccia and fine extrusive agglomerate (€Pb$_7$). The near-horizontal volcanics are intruded by porphyritic hornblende microgranite (€Pb$_{11}$), dykes of augite-hornblende-quartz andesite (€Pb$_{10}$), and the "pink ring dykes" (€Pb$_{13}$). Ignimbrite equated with €Pb$_7$ crops out on Wire Yard Mountain (Grid square 1457) to the south of the Bagstowe Ring Dykes Complex; these rocks are probably also extrusives, although an intrusive origin is not ruled out.

Isolated outcrops of hornblende-biotite microdiorite(?) (hdi) occur in the centre of the complex near Glenmore and Bagstowe homesteads. The relationship of these rocks to other members of the Bagstowe Ring Dykes Complex is uncertain.

Relations and age

The Bagstowe Ring Dyke Complex intrudes the Einasleigh Metamorphics, Sawpit Granodiorite, Anning Granite, Dumbano Granite, and Culba Granodiorite.

Richards & others (1966) dated a specimen from the Mount Rous Ring Dyke; it yielded a K-Ar hornblende age of 325 m.y., i.e. Late Carboniferous. The Mount Rous Ring Dyke is one of the oldest parts of the complex; it is possible that the youngest parts of the complex may be Permian.

MISCELLANEOUS INTRUSIVE ROCKS

Rhyolite

Rhyolite dykes and plugs or bosses are common throughout most of the Sheet area. Some of the dykes form conspicuous swarms. A dyke swarm extends south-southeast for about 20 km from near the Homeward Bound gold mine. West of the Bagstowe Ring Complex, swarms of dykes intrude the Glenmore Batholith; the dykes are generally cream, pink, or brown, and are commonly aphanitic, containing only sparse quartz phenocrysts. Some are gently dipping or flat-lying and may be cone sheets, possibly related to those in the Bagstowe Ring Dyke Complex.

South of Mount Hogan are two bosses or large plugs of rhyolite. The largest is roughly elliptical, 4.5 km long and 2 km wide. An apophysis from its southern edge extends as an irregular dyke for about 5 km to the southwest, partly intruding the Gilberton Fault and another (younger) fault which offsets the former.

Gently dipping rhyolite sheets in the Stewarts Pocket area are probably sills, intruding the Gilberton Formation.

Dacite or trachyandesite

These are most common in the Glenmore Batholith west of the Bagstowe complex. They trend northwest to north-northwest and form conspicuous brownish lineaments on the airphotos. The rocks have a greenish grey groundmass and contain hornblende, pink feldspar, and sparse quartz phenocrysts.

Andesite or dolerite

Green to black aphanitic rocks, possibly andesite or dolerite, also form dykes in many parts of the area and intrude most of the pre-Mesozoic rock units. Two specimens (7530031 and 075) were examined in thin section. They are both black and relatively fresh; in thin section they have a subophitic texture consisting of normally zoned laths of plagioclase (50 to 55 percent - An_{45} to An_{70}), augite (25 to 40 percent), hypersthene (2 to 15 percent), and hornblende (5 percent); the hornblende generally rims the augite, which is also partly replaced by pale green amphibolite (uralite). Many of the greenish dyke rocks probably represent more completely uralitised equivalents of dolerite.

Microgranite

Intrusions of microgranite (mg) are not common outside the Bagstowe Ring Dyke Complex. In the northeast corner of the Sheet area several elongate masses of microgranite (one of which forms Black Mountain - grid square 1386) occupy a ring-fault forming the western boundary of the Lochaber Ring Complex. The microgranite is pink with about 20 percent quartz and feldspar phenocrysts.

Microgranite dykes intruding the main phase of the Culba Granodiorite (Єu_1), are probably related to its pink marginal phase (Єu_2) dykes; a small body of pink biotite microgranite between Hann Mountain and the Gilbert River may have the same origin.

Microdiorite and monzonite

Microdiorite also occurs as dykes commonly intruding along faults. The rocks are generally greenish and fine to medium-grained; a specimen (75300084) from the north-trending fault cutting the Mount Hogan Granite is a quartz micro-diorite consisting of quartz (10 percent), normally zoned andesine (45 percent), and hornblende (10 percent) forming optically continuous rims around uralite cores (35 percent); the last probably replace clinopyroxene. An area shown on the map as "do?" intruding Digger Creek Granite (grid square 7651) appears to be a hornblende monzonite. In thin section (75300203) it contains quartz (5 to 10 percent), microcline (30 to 35 percent), turbid altered plagioclase (35 to 40 percent), hornblende (20 percent), and chlorite (5 percent); the chlorite is associated with the hornblende and may replace biotite. The affinities of this rock are not known; Oversby & others (1976) described a similar rock from the Woolgar Gorge, south of the Gilberton 1:100 000 Sheet area.

Breccia

The small plug of flow-banded rhyolite at Black Knob, 4.5 km NNW of "Gilberton" (grid square 7971), appears to have been emplaced into an irregular body (plug?) of breccia (bx - map and Fig. 5) which contains angular fragments of Bernecker Creek Formation up to about 7 cm in maximum dimension. Similar breccia occurs in a sinuous dyke-like body south of, and possibly connected at depth to, that at Black Knob. A second dyke-like breccia body occurs between 2.5 and 5 km west of Black Knob. Breccia at these localities contains minor interstitial tuffaceous(?) material with "kaolinised" feldspar fragments, and is locally intensely ironstained. It has evidently not been subjected to prolonged gas streaming, which would have produced rounded clasts. It may have been produced by an intense phreatomogmatic explosion at shallow depth, which occurred when the ascending Black Knob rhyolite came into contact with goundwater.

PRE-MESOZOIC FAULTING

(new name)

Gilberton Fault

The largest fault in the Gilberton 1:100 000 Sheet area is the Gilberton Fault, a northeast-trending structure which extends for about 55 km across the central part of the Sheet area. The fault juxtaposes uniformly high-grade strongly deformed Einasleigh Metamorphics on the southern side of the fault against lower-grade Robertson River Formation and its schist phase to the north (Fig. 36). Only in the northeastern corner of the Sheet area are rocks of similar grade juxtaposed. The metamorphic rocks on the northern side are in general less deformed; along the fault southwest from "Gilberton" they show the effects of only one major deformation in contrast to the three recognised south of the fault. As all the metamorphic rocks are believed to be of the same metamorphic age (Black & others, 1979) it is likely that extensive movement has taken place along the Gilberton Fault.

The low-grade Robertson River Formation could be underlain at depth by rocks of a grade comparable to those south of the fault, and vertical movement could have juxtaposed the low and high-grade rocks; however, effects of the second and third deformations in the high-grade rocks south of the fault would be expected to be much stronger in the lower-grade overlying rocks than they actually are. Therefore vertical movement without some lateral component is unlikely.

Extensive transcurrent movement (with a vertical component to explain the "bowing" in the structure south-southeast of Gilberton) is thought most likely. The southern block has probably moved at least 50 km from the northeast, the calc-silicate rocks in the Six Mile Creek area being related to those near "Ballynure", or if movement was greater still, to those near "Carpentaria Downs" in the Einasleigh 1:100 000 Sheet area.

White (1962a, b) did not recognise the Gilberton Fault northeast of where it occurs in the Gilberton Sheet area; this was possibly due to lack of lithological contrast between juxtaposed rocks and also poor outcrop in the Einasleigh-Copperfield plain. The southeastern edge of the plain between The Lynd and Carpentaria Downs homesteads may in fact be controlled by the fault.

Effects of transcurrent movement on structural trends have not been examined in detail. There appears to have been little or no dragging against the fault in the northern block; the change from easterly to northeasterly trends along the fault near Gilberton implies movement in the opposite direction to that postulated above, but is more likely due to deformation prior to the movement on the fault. An abrupt change from easterly to northeasterly trends occurs north and east of Gilberton well away from the fault.

The Gilberton Fault has been observed in outcrop at only three localities (GR 117853, 734580, and 803634). At GR 117853 a 20 to 30 cm wide zone of fault gouge dips about 70° southeast. Deformation therefore appears to have been of a brittle nature at least in the final stages of movement. The leucogranite in the hanging wall, however, has a mylonitic foliation parallel to the fault defined by flattened quartz and feldspar grains; this indicates that some ductile deformation took place in the southern block probably prior to the main movement. In some places the fault zone appears to be much wider. For example, where the track south from Mount Hogan crosses the fault, a zone of shearing and fracturing about 100 m wide contains blocks of metadolerite, phyllite, granite, and gneiss; rhyolite dykes intruding along the fault zone have been sheared, indicating that minor adjustment took place at least into late Palaeozoic time.

The precise age of the main movement on the fault is unknown. In the Six Mile area, rocks south of the fault were deformed by at least three major events, whereas those to the north were affected by only one, thus indicating that movement was post-D_3 (ca 1000 m.y.), i.e. late Proterozoic or younger. South of Gilberton homestead, the small area of Gilberton Formation contains no high-grade metamorphic or ganitic clasts, even though it crops out less than a kilometre north of the fault and the Einasleigh Metamorphics cropping out south of the fault. This may indicate that movement occurred subsequent to the deposition of the Gilberton Formation, i.e. early Carboniferous; however, deposition of Gilberton Formation material by a river system flowing entirely from the north or west (see p. 77) could also explain the absence of Einasleigh Metamorphics clasts in the unit.

Rhyolite dykes of Carboniferous or Permian age have intruded along the fault, which, when projected to the northeast, is truncated by the Carboniferous Lochaber Granite. The main movement therefore occurred between the late Proterozoic and Carboniferous.

Other faults

Other faults show two main trends - northwest and north-northeast - and several minor ones. Transcurrent movement on the northwest-trending faults is mostly dextral whereas on the NNE-trending ones it is sinistral. The two main directions probably thus define a conjugate set formed by a principal stress direction orientated north-northwest/south-southeast, possibly during D_3 and D_4 time. Later vertical movement has also occurred on some of these fault, locally affecting Jurassic rocks. The long axis of the "basin" preserving the Agate Creek Volcanics follows a northwesterly trend, suggesting that they either erupted along a line of fissures trending in that direction and/or that downwarping took place along a northwesterly line of weakness.

The reefs in the Gilberton goldfield are predominantly north-striking gash veins arranged <u>en echelon</u> along several ENE-trending and ESE-trending lines. These lines could be second-order shear directions to the major conjugate set.

East-trending faults also occur locally, for example bounding the Gilberton Formation. These are parallel to the strike of the bedding in the metamorphics in the western part of the area.

Northeasterly lineament trends are also common, particularly south of the Gilberton Fault which itself strikes northeast. The various centres of the Bagstowe Ring Dyke Complex lie on a northeasterly trend.

Mylonite zones

Mylonite zones in the northeast corner of the Sheet area near "Ballynure" and in the southeast in the headwaters of the Gilbert River strike north-northeast. Intense mylonitisation occurs over widths of less than 100 m in each of the zones, but a strong foliation is developed in the adjacent granitoid and metamorphic rocks, and probably extends for as much as half a kilometre on either side of the main zone. Specimen 75300029 from the mylonite zone near "Ballynure" is a mylonitised granodiorite with a well-developed tectonic fabric defined by the elongation of quartz and by parallel alignment of mica and chlorite. A mortar texture has developed around the quartz grains. Plagioclase is almost completely replaced by epidote and sericite, and biotite is chloritised. The direction of movement on the mylonite zones, if any, is not known. The zones have the same trend as, and are probably related to, the much larger Balcooma and Stawell River mylonite zones in the eastern part of the

Georgetown Inlier (Oversby & others, 1976; Withnall & others, in press). The age, origin, and tectonic significance of these large mylonite zones are not yet known.

MESOZOIC SEDIMENTARY ROCKS

Late Jurassic to Cretaceous rocks, mainly quartzose sandstone, previously covered most, if not all, of the Sheet area before Pliocene uplift and subsequent erosion. Remnants of the Mesozoic rocks are preserved in dissected plateaux and mesas in the western and southern parts of the Sheet area. Isolated mesas also occur farther east. The rocks were described in detail by Doutch & others (1970), Smart & others (1971), and Smart (1973).

The most extensive unit is the Hampstead Sandstone (Jh), consisting mainly of quartzose sandstone and conglomerate; large-scale cross-bedding is a characteristic feature of this unit. The Loth Formation (Jul) overlies the Hampstead Sandstone conformably and consists dominantly of clayey sandstone, as well as minor siltstone; differential weathering and erosion have produced marked topographic breaks at the base and top of the unit, so that (where present) it characteristically forms a prominent spinifex-covered bench between the cliff-forming Hampstead Sandstone and Gilbert River Formation. The Loth Formation is now restricted mainly to the south, along the edge of the Gilberton Plateau. The Hampstead Sandstone and Loth Formation together constitute the Eulo Queen Group (Jue). In the mesas west of Welfern homestead, where the Mesozoic sequence is relatively thin, the Hampstead Sandstone and Loth Formation are mapped as undivided Eulo Queen Group; this area is probably close to the depositional margin of the Mesozoic sequence.

The Gilbert River Formation (JKg), consisting mainly of quartzose sandstone and conglomerate, conformably overlies the Loth Formation. It occurs mainly in the Gilberton Plateau but also caps the mesas west of Welfern homestead.

CAINOZOIC SEDIMENTS

In the southwest corner of the Sheet area, on the edge of the Gilberton Plateau, remnants of an ancient drainage system are preserved (Doutch & others, 1970). Within the old valleys of this system, patches of reddish deposits can be seen on aerial photographs. The deposits were not examined in the field, but are probably old valley-fill, consisting of partly lithified sand and soil. They are annotated "Ts" on the Gilberton 1:100 000 Preliminary Edition geological map; the unit may correspond to the "duricrust" (Td) unit of Smart (1973).

Capping the Gilberton Plateau, and overlying the valley-fill deposits, are unconsolidated sand, silt, and soil (Ꞓzs), which are grouped with similar deposits capping some of the other small plateaux. The sediments are partly colluvial and partly outwash. Small fans of colluvium overlying the Agate Creek Volcanics have also been mapped as Ꞓzs, but are probably younger than the sediments capping the plateaux.

The other Cainozoic units are: Qa - sand, gravel, and silt (inactive floodplain deposits); and Qha - mainly sand and gravel (active stream-bed alluvium).

CAINOZOIC EARTH MOVEMENTS

Uplift of the eastern margins of the Eromanga and Carpentaria Basins occurred in the early Pliocene (Doutch & others, 1970; Smart, 1973), and subsequent erosion exposed the underlying basement rocks, thereby producing the Georgetown Inlier. This uplift was a combination of tilting, warping, and block-faulting. Drainage systems, which developed to the north of what is now the Gilberton Plateau, became deeply incised as uplift proceeded. Uplift was episodic, and these ancient drainage systems were disrupted at least twice.

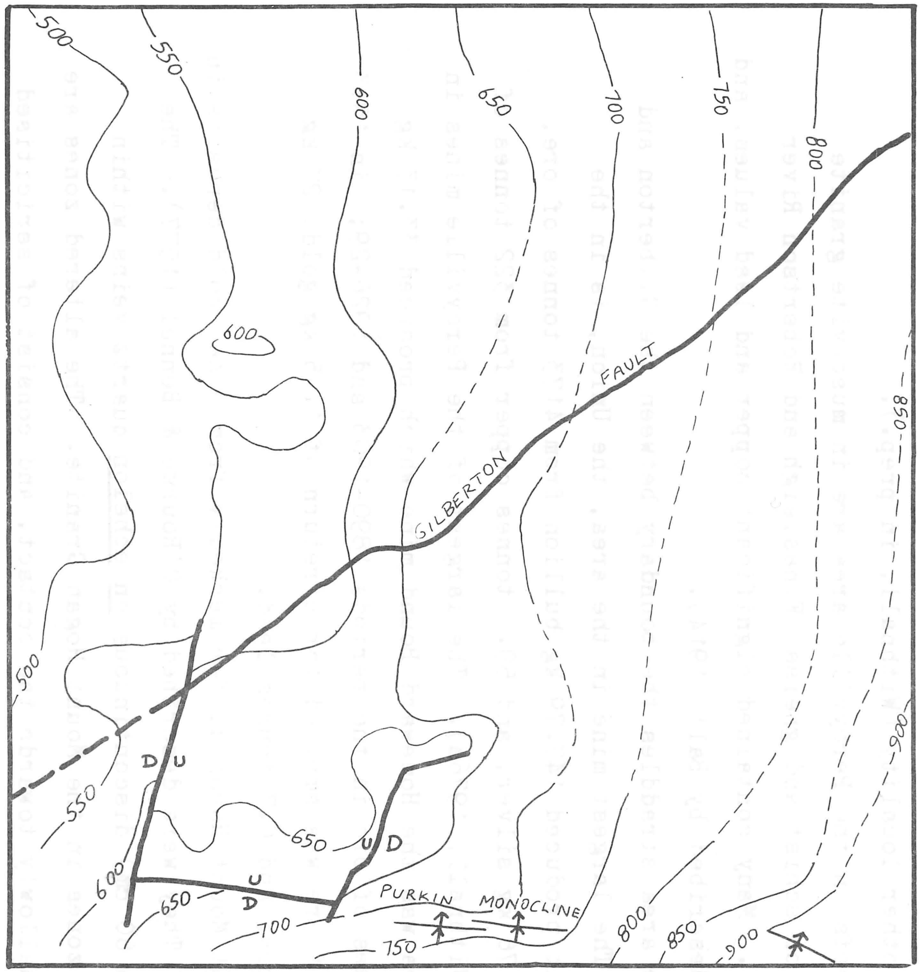
Structural contours on the base of the Eulo Queen Group are shown in Figure 35; they illustrate tilting of the Mesozoic sequence, the block faulting, and the doming of the northeastern side of the Gilberton Plateau, in what Doutch & others (1970), and Smart (1973), refer to as the Juntala Dome.

ECONOMIC GEOLOGY

The geology of the mines and mineral deposits will be reported in detail by Withnall (in prep.). A brief summary only will be given here. Bain & Withnall (in press) also discuss aspects of mineralisation in the Gilberton area as part of a review of the mineral deposits of the whole Georgetown region.

Gold-silver

Gold was produced from vein and alluvial deposits in three main centres - Gilberton, Percyville, and Mount Hogan - mostly between 1869 and 1881. Most production, estimated by Withnall (in prep.) to be between 4000 and 5000 kg,



—600— structural contours (in metres) - broken where inferred

——— fault ; D = down, U = up indicate relative movement

—↟— monocline

Fig 35: Structural contours on the base of the Hampstead Sandstone showing post-Mesozoic uplift, warping & faulting

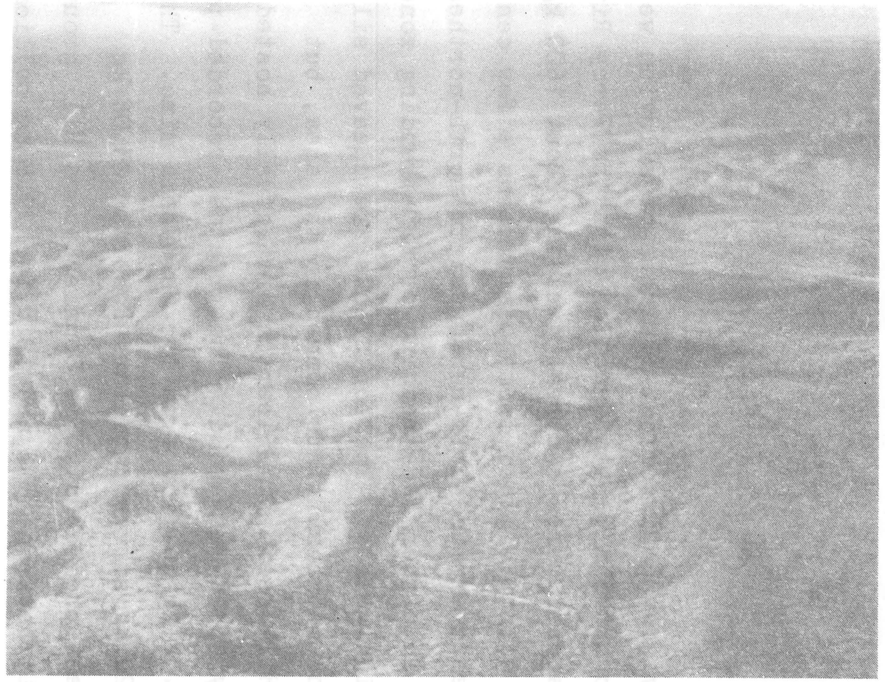


Fig 36: Aerial view, looking northeast along the Gilberton Fault. The fault separates Einasleigh Metamorphics (relatively subdued relief) from Robertson River Formation (hilly terrain). Mica Schist Creek is in the foreground. Negative M2000/19A.

came from alluvial sources mainly around Gilberton. Patches of alluvium were worked along the Gilbert River downstream to its junction with the Percy River.

Reefs were also worked at all three centres, yielding about 1600 kg gold bullion. At Gilberton, the gold was mined from quartz veins a few centimetres to 0.5 m wide. All the reefs strike north-northwest to north-northeast and most are arranged _en echelon_ in either ENE-trending or ESE-trending zones, suggesting that they occupy tension gashes. The host rocks are cleaved siltstone and shale. Metadolerite and metabasalt are common in the area, but probably only the Commissioners Hill reefs at Gilberton are actually hosted by basic rocks. None of the reefs yielded much gold. The greatest recorded production from a single reef was 30.32 kg bullion from the Caledonia mine. The Limonite (26.13 kg gold and 184.20 kg silver) and Lord Roberts (23.06 kg bullion)mines were the next largest producers. The Commissioners Hill group of deposits was worked intermittently between 1871 and 1916 for 79.8 kg bullion.

All the gold mined was in the free state, and occurred in phenomenally rich patches in otherwise almost barren quartz; for example, a 2-tonne parcel from the Joseph Morris mine yielded almost 3 kg bullion. Pyrite is probably the main sulphide in the Gilberton reefs, although few, if any, reefs were worked below the oxidised zone. Tellurides were found at the Lord Roberts mine (Ball, 1914) and at least one other locality (Withnall, in prep.).

Most of the reefs in the Percyville area are in muscovite granite (Digger Creek Granite) or schist and gneiss (Einasleigh and Robertson River Formation schist phase). Many contained significant copper and lead values, and the largest ones were described by Ball (1914).

The Percyville area straddles the boundary between the Gilberton and Forsayth Sheet areas. The largest mine in the area, the Union, is in the Forsayth Sheet area; it produced 147.79 kg bullion from 4173 tonnes of ore, and 61.41 kg gold, 256.76 kg silver, and 59.7 tonnes copper from 322 tonnes of ore and concentrates (Withnall, 1976a). The largest of the Percyville mines in the Gilberton Sheet area was the Homeward Bound mine which produced 33.13 kg bullion from 189.0 tonnes of ore in the periods 1890-1903 and 1926-29; in 1913 and 1934, 34.7 tonnes of ore was smelted for a return of 1.45 kg gold, 27 kg silver, 0.7 tonnes copper, and 0.7 tonnes lead.

The deposits at Mount Hogan differ markedly from other gold deposits in the Georgetown region. They were described by O'Rourke & Bennel (1977). The lodes are thin (2 mm to 60 cm) discontinuous _en echelon_ quartz veins within hydrothermally altered zones in the Mount Hogan Granite. The altered zones are 6 to 30 m thick, dip shallowly towards the contact, and consist of sericitised and chloritised granite that grades into comparatively unaltered granite. Gold and silver are mostly within vuggy white quartz veins and are generally associated with pyrite and base metal sulphides; other accessory minerals, not everywhere present, are molybdenite, purple fluorite, and various uranium minerals (see below). Gold is also disseminated in the altered wall-rocks. A drilling program by Central Coast Exploration NL (O'Rourke & Bennel, 1977) established inferred and indicated "reserves" of primary and oxidised "ore" of about 137 000 tonnes containing 5.5 g/t gold and about 9 g/t silver.

Mount Hogan was worked in the periods 1871-73, 1876-77, and 1885-1910. Few returns are available for the first period. Total recorded production was 341.22 kg bullion from 7016.8 tonnes of ore.

Mount Moran is an isolated gold occurrence in the Bellfield Sheet area a few hundred metres west of the Gilberton Sheet area. Three reefs were worked; these occurred in phyllite interbedded with metabasalt flows of the Dead Horse Metabasalt Member. Production for the period 1922-36 was 32.29 kg bullion from 1251.8 tonnes of ore.

The only important mineral deposits south of the Gilberton Fault are at Christmas Hill. On Christmas Hill itself numerous quartz veinlets occur in strongly sericitised granite and gneiss (Einasleigh Metamorphics) intruded by slightly altered rhyolite dykes. Most of the production, however, came from a larger reef, the Susan, on the southwestern flank of the hill. Between 1885 and 1895, 201.2 tonnes of ore yielding 27.44 kg bullion was mined from the reef. Christmas Hill was described by Marks (1911) who noted that the deposits were similar to those at Kidston.

Silver-lead

Silver-lead fissure deposits occur in a belt around the western and southern margins of the Percyville ara, outside the main area of gold-silver-copper mineralisation. This may reflect a regional zonation pattern. Granitoids and metamorphic rocks host the deposits. The richest, the Big Hope and Big Surprise, are near Cave Creek and were worked in the late 1960s (Sawers, 1966). About 90 kg silver and 0.8 tonnes lead were produced from 16.7 tonnes of hand-picked ore; the ore consisted of galena and cerargyrite in quartz veins hosted by Robin Hood Granodiorite.

South and west of Gilberton in the Robertson River Formation, several small silver-lead deposits were worked in the late 1940s and early 1950s. The Alcade produced 43.0 tonnes lead and 39.27 kg silver from 57.7 tonnes of hand-picked galena ore. The Hells Doorway produced 55.9 tonnes lead and 55.74 kg silver from 86.1 tonnes of ore. The host rocks are phyllitic siltstone and metabasalt.

Copper

The main copper deposit in the area is at Ortona, where a group of fifteen small en echelon quartz lodes, in a composite northwest-trending metadolerite-'quartz diorite' dyke (see p. 43) were worked. The lodes are confined to the dyke and strike east-northeast. The total production is difficult to estimate, but about 450 tonnes copper and at least 700 kg silver were produced from over 2000 tonnes of ore between 1899 and 1956. The ore, mostly from the zone of oxidation and secondary enrichment, consisted of malachite, azurite, chalcocite, cuprite, and some relict primary sulphides such as chalcopyrite and pyrite.

Copper was also mined at the Eight Mile and Twelve Mile Groups. These are small fissure deposits in metadolerite and metasedimentary rocks. The Eight Mile Group is within the Bernecker Creek Formation and the Twelve Mile is in the Robertson River Formation. Copper is associated with the gold deposits in the Percyville area.

Bismuth-tantalum-tungsten-tin

Bismuth, tantalum, and tungsten are associated with pegmatites in the Robertson River Formation (schist phase) and in alluvial concentrations at Dividend Gully (Ball, 1914) and the Eight Mile scheelite mines (Jensen, 1919; Morton, 1945). The Eight Mile deposits produced about 7 tonnes of scheelite concentrate and 0.44 tonnes of bismutite in 1918-20 and 1937.

No tin has been worked in the Sheet area but the Purkin Granite is potentially tin-bearing; it contains some wolfram deposits at Bismuth Creek in the adjacent Lyndhurst 1:100 000 Sheet area.

Uranium

Anomalously high uranium values are present in the Mount Hogan gold deposits and about 10 km^2 of the surrounding granite. Uranium occurs in a variety of situations; O'Rourke & Bennel (1977) noted torbernite in rhyolite and altered granite, pitchblende and phosphuranylite in quartz veins, uranium in black fluorite associated with basemetal sulphides in a quartz vein, a strongly radioactive basalt dyke, and radioactive zones in altered granite, some of which contain uraninite. Uraninite has been found at a depth of 125 m, where it is thought to be of primary hydrothermal origin. Grades encountered were of the order of 0.02 to 0.10% U_3O_8 over widths of 1 to 3.5 m.

Mullock from the deepest levels of some of the Percyville gold mines, such as the Boomerang, has anomalously high levels of radioactivity.

The Gilberton Formation has been considered a favourable host for uranium by several companies. It is prospective for deposits of both the Maureen and sedimentary types. An airborne radiometric survey by Union Corporation (Australia) Pty Ltd revealed only low-order uranium anomalies (Lemon, 1973). However, at the time of writing, the formation was being examined in detail by AGIP Nucleare (Australia) Pty Ltd, in a joint venture with Central Coast Exploration NL.

Agate

Agate forms amygdales and veins in basalt in the Agate Creek Volcanics, and attracts many hundreds of fossickers to the area each year. The amygdales are ovate in shape and 1 to 15 cm across.

"Thunder eggs" containing infillings of agate, chalcedony, and quartz crystals are obtained from rhyolite flows in the Agate Creek Volcanics.

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APPENDIX I

GLOSSARY OF SOME TERMS USED IN THIS REPORT

Agmatite:

A migmatite which has a breccia-like structure with relatively sharply defined "clasts". See also migmatite; cf. nebulite.

Airfall tuff:

A tuff which has been deposited by settling through air from an eruptive column or cloud. See Also volcaniclastic sedimentary rock; cf. ignimbrite.

Amphibolite:

Metamorphic rock consisting essentially of plagioclase and amphibole. The texture may be nematoblastic (aligned prisms or rod-like grains of amphibole), granoblastic (mosaic of irregular grains), or granuloblastic (mosaic of polygonal grains with smooth intergranular boundaries). Ortho-amphibolite is an amphibolite derived from igneous rocks in which the original texture is largely obliterated. Para-amphibolite is an amphibolite derived from sedimentary rocks with the composition of dolomitic shale or marl. In this report "amphibolite" is used without a prefix to mean ortho-amphibolite unless otherwise specified. Where the rocks are thought to be of sedimentary origin, the prefix "para-" is used.

Amphibolite facies:

A metamorphic facies; used in this report as defined by Winkler (1967), who originally divided the facies into three subfacies which correspond with the lower, middle, and upper subdivisions of the amphibolite facies used in this report. More recently, Winkler (1974) proposed replacing "facies" and "subfacies" by grade-related terms. We have already used the subfacies/facies scheme in discussing the geology of the Forsayth and Georgetown Sheet areas (Bain & others, 1976a; Oversby & others, 1978), and it is mostly followed in this report; the only exception is in the section discussing the schist phase of the Robertson River Formation; where lower and middle amphibolite facies rocks cannot be distinguished they are described as "medium-grade" and the upper amphibolite facies ones are "high-grade". See also metamorphic facies.

Anatexis:

A general term denoting some degree of melting of pre-existing rocks.

Cauldron subsidence area:

A depression, caldera, or rift overlying a commonly cylindrical block of crust which has formed the roof of, and subsided into, an eviscerated magma chamber. Also loosely used for the structural block which has subsided. This usage follows that of Branch (1966); Oversby & others (in press) recognised first and second-order "volcanic subsidence structures" which correspond to different types of cauldron subsidence areas.

Cooling unit:

An ignimbrite unit which has cooled as a single entity. It may consist of a single flow, or be made up of two or more flows deposited within a short period of time so that previously-deposited material was not appreciably cooled.

Felsite:

General term for a fine-grained aphyric or porphyritic, dominantly quartzo-feldspathic igneous rock of obscure origin.

Epicalstic sedimentary rock:

Siltstone, sandstone, and conglomerate made up of fragments derived mainly from pre-existing basement rocks; cf. volcaniclastic sedimentary rocks.

Folds:

See structural notation

Granite:

The term is used in this report as recommended by the IUGS Subcommission on the Systematics of Igneous Rocks (Neues Jahrbuch fur Mineralogie, Monats hefte, 1973, 4, 149-164; Geotimes, 18(10), 26-30), in that it is expanded to include adamellite. Volcanic and hypabyssal nomenclature is consistent with that for plutonic rocks; rhyolite is expanded to include rhyodacite and microgranite includes microadamellite. A leucogranite is a pale (white, grey or pink) granite, with mafic minerals rare or absent; cf. granitoid.

Granitoid:

General term embracing any light to medium-coloured plutonic rock which contains essential quartz accompanied by feldspar; mafic minerals are subsidiary to absent. A leucogranitoid is a pale (white, grey, or pink) granitoid, with mafic minerals rare or absent. See also pegmatoid; cf. granite.

Granulite facies:

See metamorphic facies

Greenschist facies:

See metamorphic facies

Igneous rock classification

As recommended by the IUGS Subcommission on the Systematics of Igneous rocks (Neues Jarbuch fur Mineralogie, Monats hefte, 1973, 4, 149-164; Geotimes, 1973, 18(10), 26-30; Streckeisen, 1967, 1976); volcanic and hypabyssal rock nomenclature is consistent with that for plutonic rocks. See also granite.

Ignimbrite

Used in this report in essentially the same sense as "ash-fall tuff" of Ross & Smith (1961), but it may incorporate significant quantities of material coarser than ash. Ignimbrite units show characteristic vertical and lateral zonal patterns of welding and devitrification/recrystallisation.

Isograd:

A line joining points at which metamorphism proceeded at similar values of pressure and temperature as indicated by rocks belonging to the same metamorphic facies.

Leuco-:

Prefix applied to plutonic rock names where mafic minerals are sparse or absent (generally less than 5 percent). See granite and granitoid.

Leucosome:

The light-coloured (leucocratic) part of a migmatite, commonly rich in quartz and feldspar. Commonly associated with a mafic-rich selvedge or Melanosome. See migmatite.

Melanosome:

The dark-coloured (melanocratic) part of a migmatite, rich in mafic minerals. See also migmatite; cf. leucosome.

Metabasite:

A collective term for basic roccks of any origin (volcanic, hypabyssal, or plutonic) which have had their original textures, or mineralogy, or both, modified by metamorphism. In this report the term embraces rocks which retain relict textures (metabasalt, metadolerite, and metagabbro), as well as ones which have been altered to the extent that their origins are obscure. See also amphibolite.

Metamorphic facies:

"All the rocks of any chemical composition and varying mineralogical composition that have reached chemical equilibrium during metamorphism within the limits of a certain pressure-temperature range characterised by the stability of specific index minerals" (American Geological Institute Glossary of Geology, 1972, p. 446). The facies referred to in this report (greenschist, amphibolite, and granulite) are those defined by Winkler (1967). See also amphibolite facies, isograd.

Metamorphic facies series:

"A group of metamorphic facies characteristic of an individual area or terrane and represented by a curve or group of curves in a pressure-temperature diagram illustrating the range of different types of metamorphism and metamorphic facies" (American Geological Institute, Glossary of Geology, 1972, p. 446).

Microgranite:

Rock with a granitic composition and a fine-grained (less than 1 mm) allotriomorphic granular texture. See also granite.

Migmatite:

"A megascopically composite rock consisting of two or more petrographically different parts, one of which is country rock, generally in a more or less metamorphic stage, the other is of pegmatitic, aplitic, granitic or generally plutonic appearance" (Mehnert, 1968, p. 230). See also agmatite, leucosome, melanosome, nebulite, restite; cf. anatexis.

Nebulite:

A migmatite which contains schlieren and ghost-like relics of pre-existing rocks. See also migmatite, schlieren; cf. agmatite.

Phyllitic siltstone & shale

The terms "siltstone" and "shale" (usually prefixed by the adjective "phyllitic") are commonly used in this report to describe low-grade metasediments of the Robertson River and Bernecker Creek Formations; although the argillaceous component of these rocks has been recrystallised, the silty or shaley nature can generally still be determined in thin section. The term "argillite" is not appropriate as it generally implies a lack of any structure (bedding fissility, laminations, or cleavage); most of the rocks in the Bernecker Creek and Robertson River Formations posses one or more of these features. Where recrystallisation is more advanced the rocks are simply termed "phyllite".

Palaeosome:

The relatively unaltered and immobile country or parental rock(s) from which a migmatite has formed. See also migmatite.

Rhyolite:

See granite.

Schlieren:

Lenticular to irregular streaks or masses with diffuse boundaries in igneous and metamorphic rocks. Schlieren commonly consist of biotite, sillimanite (generally altered to sericite), and other melanocratic refractory minerals, in a more mobile and leucocratic groundmass; they may represent segregation, disrupted melanosomes, or almost completely assimilated xenoliths. See also restite.

S-surface:

One of a set of geometrically and genetically related, parallel or subparallel closely spaced planes pervading a body of rock. S-surfaces referred to in this report include original stratification (designated S_0) and foliations or axial planes of several generations (designated S_1, S_2...etc). See also structural notation.

Structural notation:

Follows Bell & Duncan (1978) except that B rather than F is retained for fold axes. Axial planes of folds, and axial plane foliations (cleavage, schistosity, etc.), produced by subsequent folding events or deformations, D_1, D_2, D_3...D_n, are designated S_1, S_2, S_3...S_n. Fold axes are designated B_n^x where subscript n refers to the folding event and superscript x refers to the generation of the S-surface deformed by the fold. Thus B_1^0 refers to a first-generation fold which deforms original stratification S_o; B_3^1 refers to a third-generation fold deforming S_1. The notation differs from those used in Bain & others (1976a) and Oversby & others (1976) which were based on that used by Turner & Weiss (1963). Oversby & others used Roman numerals for the Einasleigh Metamorphics and Arabic for the Robertson River metamorphics; this is no longer necessary because we are now able to equate the structures in the different units.

Vergence:

The systematic variation in asymmetry of minor folds across a major fold. Minor folds have S, Z, or M-vergences as defined by their shape when viewed down their hinges. Vergence, together with cleavage/bedding relationship, is a valuable aid in locating major fold hinges, especially in areas of poor exposure.

Vitric tuff:

A tuff that consists predominantly of volcanic glass fragments.

Volcaniclastic sedimentary rocks:

Siltstone, sandstone, and conglomerate made up of fragments derived mainly from contemporaneous volcanic sources. The rocks locally grade into airfall tuff from which they are distinguished somewhat arbitrarily for the purposes of this report by being relatively better-sorted, more regularly stratified and locally cross-bedded. See also airfall tuff; cf. epiclastic sedimentary rocks.

APPENDIX II

TABLE OF METAMORPHIC ROCKS EXAMINED PETROGRAPHICALLY

The following is a table of metamorphic rock specimens from the Gilberton 1:100 000 Sheet area or closely adjacent parts of the Lyndhurst Sheet area. Registered numbers prefixed by 7530 are of specimens in the BMR collection, those prefixed by GSQ are in the GSQ collection. Locations are given as metric grid references on the Gilberton 1:100 000 Sheet, or where prefixed by (L), on the Lyndhurst 1:100 000 Sheet area.

Einasleigh Metamorphics

Registered No.	Filed No.	Location	Name
7530 0001	1/46/5A	133944	biotite gneiss
0002	1/46/3	122952	" "
0003	1/48/11	078938	diopsite-hornblende gneiss
0004	1/48/9	096941	hornblende-biotite-epidote gneiss
0005	1/48/13A	074938	hornblende gneiss
0006	2/32/2A	018895	biotite gneiss
0007	1/48/6	095936	hornblende gneiss
0008	2/30/4	004896	scapolite-hornblende-diopside gneiss
0010	1/48/1B	090918	scapolite-diopside-hornblende fneiss or para-amphibolite
0011	1/48/13B	074938	biotite gneiss
0014	2/34/6	081896	hornblende-diopside-clinozoisite rock
0016	2/32/2B	018895	hornblende-clinozoisite gneiss
0021	2/36/18A	115900	biotite gneiss
0022	2/36/9A	132905	" "
0023	2/36/9C	"	hornblende gneiss
0027	2/36/19	113900	" "
0036	3/90/14	115850	quartz-muscovite schist
0037	3/90/22B	106852	biotite gneiss
0068	6/20/1B	938712	microcline-diopside marble
0071	7/50/1A	014949	hornblende gneiss/para-amphibolite
0074	7/50/3C	944700	biotite gneiss
0077	7/50/3D	"	biotite-muscovite schist

168

Einasleigh Metamorphics (continued)

Registered No.	Field No.	Location	Name
7530 0089	10/70/2D	762551	clinozoisite-hornblende gneiss
0097	8/18/4	881626	biotite gneiss
0099	8/20/8	869641	diopside-hornblende-microcline granofels
0102	10/70/34	764598	biotite gneiss
0104	10/70/3	755539	diopside-garnet-quartz-plagioclase granofels
0106	10/70/6	762552	hornblende-epidote-diopside gneiss
0108	11/30/22	739545	impure quartzite
0112	12/66/2AA	951462	hornblende-diopside gneiss
0114	11/30/10	760513	diopside-plagioclase granofels
0117	11/30/24	740540	hornblende-quartz-epidote granofels
0118	11/38/3	956531	clinozoisite-diopside gneiss
0124	12/68/15	918477	hornblende gneiss
0126	11/30/11	759515	hornblende-diopside-microcline-quartz granofels
0132	9/86/16	978610	hornblende gneiss
0202	12/74/4	769500	plagioclase-garnet-quartz granofels
0214	11/46/10A	142521	biotite-muscovite-quartz schist
0331	2/30/6	003897	biotite gneiss
0345	8/18/9	909647	" "
0351	11/46/10B	142521	quartzite & quartz-mica schist
0353	5/14/1	010758	chlorite-quartz-muscovite schist

Juntala Schist

7530 0219	11/48/9	(L)866511	chloritoid-garnet-quartz mica schist
0344	11/48/3	(L)873507	graphitic sericite-quartz schist
0346	11/48/8	(L)868509	quartz-mica schist
0350	11/48/2	(L)875506	graphitic quartz-mica schist

169

Registered No.	Field No.	Location	Name

<u>Robertson River Formation</u> (schist phase)

0018	3/90/4C	087855	biotite-plagioclase-muscovite-quartz schist
0019	3/90/6B	097856	biotite-muscovite-quartz schist
0034	3/92/4B	065848	muscovite-biotite-quartz schist
0040	3/90/18	110858	biotite-quartz-plagioclase schist
0041	3/92/8B	061849	quartz-sericite schist
0051	3/96/3	971856	quartz-sericite-biotite-muscovite schist
0052	3/96/6	954867	quartz-muscovite schist
0053	4/30/3A	058804	biotite-quartz-muscovite schist
0056	4/30/5B	073819	" " " "
0057	4/30/13	062832	quartz-mica schist with retrogressed andalusite
0059	3/98/5A	938863	quartz-sericite schist
0060	4/30/5A	073819	garnetiferous quartz-mica schist
0062	3/98/14B	944838	biotite-muscovite-sericite-quartz schist
0063	4/30/3B	058804	muscovite-biotite-quartz schist
0083	4/36/2C	928829	plagioclase-quartz-mica schist
0333	2/22/45	830904	biotite-quartz-muscovite schist
0336	2/30/8B	005877	micaceous quartzite
0337	2/30/8A	005877	quartz-biotite-muscovite schist
0338	2/24/12A	833906	biotite-muscovite-quartz schist
0352	5/14/13	001785	" " " "

<u>Bernecker Creek Formation</u> (calc-silicate phase)

0013	2/34/7	075890	scapolite-diopside-hornblende-K-feldspar rock
0020	3/90/3	084879	quartz-clinozoisite-K-feldspar-hornblende rock
0026	2/36/22A	106896	hornblende-diopside gneiss

170

Registered No.	Field No.	Location	Name

<u>Bernecker Creek Formation</u> (continued)

0032	3/92/16	044852	clinozoisite-diopside-K-feldspar granofels
0035	3/92/13B	064864	hornblende-diopside-plagioclase-k-feldspar rock
0039	3/90/16	115857	garnet-hornblende-diopside gneiss
0043	3/94/2	024852	calcite-scapolite-plagioclase-biotite-quartz rock
0045	3/94/5A	012861	calcite-K-feldspar-diopside-quartz-rock
0046	4/36/2A	928829	calcite-K-feldspar-epidote-plagioclase-biotite-quartz rock
0048	3/94/7	012869	epidote-hornblende gneiss
0050	3/94/5C	012861	scapolite-tremolite-calcite-epidote-K-feldspar quartz rock
0054	3/98/9B	933856	biotite-calcite-epidote-quartz schist
0055	3/98/6	937861	impure marble
0061	3/98/8	934857	calcite-biotite-epidote-quartz-K-feldspar rock
0064	3/96/5	959864	epidote-calcite-scapolite-diopside-plagioclase rock
0065	3/98/9A	933856	calcareous micaceous quartzite
0069	3/94/11	607857	scapolite-hornblende-biotite-K-feldspar rock
0343	3/00/3B	897869	quartz-epidote-biotite-plagioclase-K-feldspar rock
7530 0128	7/42/15	742698	calcareous shale
0133	7/42/11	732692	fine calcareous feldspathic quartz sandstone
0211	5/00/13	662762	laminated calcareous siltstone
0363	5/00/8A	684781	impure limestone

171

Bernecker Creek Formation (low grade)

Registered No.	Field No.	Location	Name
0364	5/98/4	641771	calcareous siltstone
0365	5/02/5C	708771	" "
0366	5/02/5B	"	calcareous feldspathic quartz sandstone
0373	3/02/1	882879	calcareous siltstone
0376	3/02/9	809857	cleaved shale or siltstone
0378	5/00/1D	728763	calcareous siltstone
GSQ 7911/ R 6315	Gi2D	636781	fine calcareous feldspathic quartz sandstone

Robertson River Formation (low grade)

Registered No.	Field No.	Location	Name
7530 0067	6/20/2	928715	cleaved siltstone
0072	5/10/11	905774	laminated slightly calcareous siltstone
0073	5/10/7	908769	phyllite
0085	5/10/9A	906770	slightly calcareous siltstone
0087	5/10/14A	919767	laminated quartzite with calc-silicate
0101	8/22/9	799631	feldspathic quartz sandstone
0152	6/22/12	894753	calcareous quartz sandstone
0156	7/44/19	847677	calcareous feldspathic quartz sandstone
0207	7/40/17	680693	"chert"
0209	8/28/14	658670	cleaved shale
0210	5/14/6	010769	phyllite or quartz-sericite schist
0212	2/16/1	773886	phyllite or slate with chloritoid
0213	1/66/4D	667937	crenulated phyllite with chloritoid
0215	9/84/6	722597	phyllitic shale
0314	1/66/9	777976	laminated carbonaceous slate
0320	2/18/19	711897	strongly crenulated phyllite
0326	8/24/13	757640	calcareous siltstone or shale
0328	8/24/11	758645	fine calcaceous feldspathic quartz sandstone

Robertson River Formation (low grade)

Registered No.	Field No.	Location	Name
0335	8/24/7	751656	quartz phyllite
0349	9/84/2	727592	phyllite
0355	5/98/8	632784	laminated slate
0367	3/06/1	702839	laminated shale or slate
0369	5/02/2	717764	laminated siltstone
0372	9/86/19	748624	cleaved laminated shale/siltstone
0379	6/30/1B	675729	crenulated phyllite with chloritoid
0424	6/22/2	863721	sericitic sandstone
0430	6/22/8A	885736	phyllite
0432	6/24/11	840730	cleaved shale
GSQ 7905/ R 6309	Gi3	709700	laminated carbonaceous shale
GSQ 7906/ R 6310	Gi4A	708670	intraformational breccia
GSQ 7907/ R 6311	Gi4C	"	fine sericitic lithic-quartz sandstone
GSQ 7908/ R 6312	Gi5	"	fine calcareous quartz sandstone
GSQ 7909 R 6313	Gi4E	"	fine sericitic quartz sandstone
GSQ 7910/ R 6314	Gi4B	"	" " " "

Dead Horse Metabasalt Member

7530 0123	7/40/4A	713667	amygdaloidal basalt
0127	7/40/4B	"	metabasalt
0217	4/48/3B	632815	carbonatised foliated metabasalt
0218	4/48/8	636844	" " "
0313	4/44/9	730813	metabasalt
0319	1/66/6	668934	carbonatised metabasalt

173

Registered No.	Field No.	Location	Name

Dead Horse Metabasalt Member

0324	2/18/20	711884	amygdaloidal metabasalt
0325	8/24/15	755635	metabasalt
0329	8/24/5	742661	epidotised metabasalt
0340	9/84/1	733585	metabasalt
0342	8/26/8	693652	silicified metabasalt
0348	9/84/11A	731611	quartz-calcite-albite-chlorite schist
0374	8/24/16	751634	amygdaloidal metabasalt
0374	6/30/6	664720	metabasalt
0380	8/20/18B	830662	hyaloclastite
0381	8/20/18A	830662	metabasalt

Metadolerite/metagabbro

7530 0033	3/92/3	066854	metadolerite
0038	3/92/13A	064864	"
0070	3/90/4D	087855	"
0076	6/20/3	925716	"
0081	5/12/5	963765	"
0086	5/10/3	927763	metagabbro
0094	8/22/3B	806642	metagabbro
0100	9/86/9	757602	metadolerite
0105	10/70/23	736582	"
0131	7/44/12	767721	albite "granite" or "quartz-diorite"
0155	5/08/24	894761	metagabbro
0126	4/48/5	633821	metadolerite
0322	4/46/1	696824	metagabbro
0323	5/98/11	636792	metadolerite
0327	8/24/12	759641	"
0339	9/84/7	722599	metagabbro
0341	8/26/6	696649	metadolerite
0347	5/14/16	944793	metagabbro

Registered No.	Field No.	Location	Name
0354	4/44/	730817	metagabbro
0360	5/98/1C	656761	metadolerite
0361	5/98/3	645765	"
0368	5/02/6C	723796	metagabbro
0370	7/38/2	645708	metadolerite
0371	3/02/8A	811857	"
0377	5/300/4B	697788	metagabbro
0422	6/22/9	889738	metadolerite

Amphibolite

0009	1/48/7	095937	amphibolite
0024	2/36/22B	016897	"
0025	2/36/17	119900	"
0088	7/50/2	935701	"
0116	12/68/1	634780	biotite-albite "granite" or "quartz diorite"
0359	5/98/6A	636832	amphibolite

APPENDIX III

TABLE OF PLUTONIC ROCK SPECIMENS EXAMINED PETROGRAPHICALLY

The following is a table of specimens of plutonic rocks from the Gilberton 1:100 000 Sheet area or closely adjacent parts of the adjoining Lyndhurst Sheet area. Registered numbers of specimens collected during this survey are prefixed by 7530. Those whose registered numbers are prefixed by 7057 were collected and described by Sheraton & Labonne (1974). Locations are given as metric grid references on the Gilberton 1:100 000 Sheet; grid references prefixed by (L) are on the Lyndhurst 1:100 000 Sheet.

Thin sections of these specimens are held at the BMR.

Registered No.	Field No.	Location	Name
"Oak River Granodiorite"			
75300316	2/36/10	154893	foliated biotite tonalite
0317	2/36/5	140912	porphyritic biotite granodiorite
70571166	-	-	trondhjemite
70571167	-	-	"
70571168	-	-	"
Welfern Granite			
75300312	2/34/3A	094915	biotite granite
0318	1/48/5	088951	" "
70571164	-	-	" "
70571165	-	-	" "
Sawpit Granodiorite			
75300191	7/56/9E	073686	epidote-biotite granodiorite
0199	6/14/1A	083715	biotite granodiorite
0265	10/54/38	106543	" "
0269	10/58/15	0375790	biotite granite
0303	11/44/1	121513	biotite granodiorite
0305	11/44/2	122510	" "
70571162	-	-	biotite quartz-diorite

APPENDIX III: CONT.

Registered No.	Field No.	Location	Name
Digger Creek Granite			
75300091	8/20/7	868646	biotite leucogranite
0093	10/70/2B	770551	muscovite granite
0095	9/90/2	895617	biotite leucogranite
0119	11/30/9	761506	" "
0180	10/54/9A	116551	muscovite granite
0181	9/02/18B	143600	" "
0182	9/02/22	(L)860603	" "
0186	10/54/13B	106568	garnet-chlorite-muscovite granite
0286	1/54/5A	919952	muscovite granite
0304	9/02/36	144597	biotite-muscovite granite
0308	11/44/12	091506	biotite-muscovite granite
0321	2/36/12	128904	muscovite granite
70571124	-	-	" "
70571125	-	-	" "
70571128	-	-	" "
Loafers Granodiorite			
75300247	10/56/2	095571	hornblende granodiorite
0248	10/56/1	099572	altered biotite-hornblende granite
0253	10/54/13A	106568	hornblende granodiorite
0254	9/98/1	067579	" "
0258	10/56/14	088584	biotite-hornblende granodiorite
0261	10/56/10	102569	" " "
0296	9/96/12	031580	" " "
0297	10/58/16	036536	hornblende granodiorite

APPENDIX III: CONT.

Registered No.	Field No.	Location	Name
0090	9/92/4	901584	biotite leucogranite
0176	10/60/7	004598	leucogranite
0183	7/54/22	033676	biotite leucogranite
0189	8/14/11	980629	hornblende-biotite leucogranite
0195	6/14/1B	084715	biotite leucogranite
0198	7/56/9B	073687	leucogranite
0221	9/94/2	977594	biotite leucogranite
0222	8/14/7A	009645	hornblende leucogranite
0224	7/56/4	095698	altered leucogranite
0226	9/96/10	004587	biotite leucogranite
0228	8/12/15	025657	biotite leucogranite
0229	8/14/2	007662	biotite leucogranite
0234	8/16/4	933649	chloritised biotite granite
0239	8/12/2	017661	hornblende-biotite leucogranite
0241	8/14/21	007662	biotite leucogranite
0245	8/14/16	000643	hornblende leucogranite
0246	9/96/3	011592	altered biotite leucogranite
0263	8/14/15	995636	biotite leucogranite
0269	10/58/15	037570	" "
0289	8/16/7	931627	" "
70571131	-	-	" "

<u>Unnassigned leucogranitoids</u>

75300092	8/22/10	800630	biotite leucogranodiorite
0109	10/70/29	729576	biotite granodiorite
0110	11/38/14C	932499	biotite leucogranite
0113	11/39/14A	"	leucogranite
0115	11/38/14B	"	biotite leucogranodiorite
0121	12/68/14	896466	biotite leucogranite
0125	12/68/11	917458	" "
0178	9/96/8	008586	leucogranite
0179	10/60/6	005582	biotite leucogranite

APPENDIX III: CONT.

Registered No.	Field No.	Location	Name
Unassigned leucogranitoids			
0187	9/02/18A	143600	biotite leucogranite
0200	9/00/35	095591	biotite granodiorite
0223	10/56/4	074574	biotite leucogranite
0230	9/00/34	089600	diopside leucogranite
0238	8/16/12	937652	garnet-biotite leucogranite
0244	7/56/9C	073686	hornblende-chlorite leucogranite
Dumbano Granite			
0184	9/96/6	013612	slightly porphyritic biotite granite
0190	7/54/5	032662	" " " "
0192	8/12/6B	029655	" " " "
0242	7/54/21	034676	" " " "
0291	9/02/37	145591	" " " "
70571132	-	-	" " " "
70571138	-	-	" " " "
70571139	-	-	" " " "
Mount Hogan Granite			
75300049	4/34/2	982831	biotite granite
0066	4/34/1	978834	fine biotite leucogranite
0082	5/12/7A	960770	sericitised granite
0137	4/36/5	923804	" "
0157	4/36/12	914807	biotite granite

179

APPENDIX III: CONT.

Registered No.	Field No.	Location	Name
75300193	8/12/6A	013652	hornblende-biotite tonalite
0194	7/54/19A	995684	" " "
0220	8/16/1	950663	hornblende-biotite granodiorite
0225	6/16/16	030715	" " "
0227	6/16/11	038731	" " "
0231	6/16/15	031719	" " "
0232	6/16/14	031722	" " "
0233	6/16/13	031727	" " "
0236	6/16/17	027712	hornblende-biotite granite
0237	6/16/13	031727	biotite granite
0240	8/16/1	950663	" "
0243	8/12/3B	020655	biotite granodiorite
0249	6/16/12	028729	hornblende-biotite granodiorite
0251	7/52/1	980690	hornblende-biotite granite
0252	7/54/17A	008682	biotite granite
0255	6/16/16	041725	hornblende-biotite granodiorite
0256	6/14/16	056720	" " "
0257	8/12/1	021662	" " "
0262	7/54/15	018678	hornblende-biotite granodiorite
0290	6/14/5	070740	biotite granite
0298	6/16/8	006727	hornblende-biotite tonalite