DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1978/44

Georgetown Project Progress Report -

GEOLOGY OF THE GEORGETOWN 1:100 000 SHEET AREA (7661), NORTH QUEENSLAND; PART A

by

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

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(Please note: owing to unforeseen delays, that section of the report which deals with Proterozoic and Palaeozoic (?) granitoid rocks will be issued separately at a later date as Part B).

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SUMMARY

The Georgetown 1:100 000 Sheet area is in the central Georgetown Inlier of northeastern Queensland, about 250 km southwest of Cairns. Mid-Proterozoic(?) metamorphic rocks which have been intruded by mid-Proterozoic to Palaeozoic(?) granitoid rocks (discussed in a Record to be issued later) constitute local basement. This basement is overlain with profound unconformity by Carboniferous volcanic and associated rocks, and intruded by Carboniferous and Permian(?) hypabyssal and plutonic rocks. Discontinuous areas of Mesozoic and Cainozoic rocks also occur in the Sheet area. Mineralisation and exploration in the Sheet area are dealt with only briefly in this report; they are discussed at length by Withnall (1974; 1976; in press).

Mid-Proterozoic(?) metamorphic rocks are assigned to the Einasleigh and Robertson River Metamorphics, and Cobbold metadolerite. The Einasleigh Metamorphics are dominated by upper amphibolite facies gneiss; migmatites and basic granulites also occur locally. Four (possibly five) generations of folds have been recognised in the unit; the second period of folding and the main prograde metamorphism probably took place at essentially the same time. Most metabasites in the Einasleigh Metamorphics are believed to be of intrusive origin, although some possibly extrusive rocks occur at one locality near "Eveleigh". The depositional age of the Einasleigh Metamorphics is uncertain; it is older than about 1570 million years, the age of the first deformation, and is assumed to be Proterozoic. No unambiguously Archaean component can be recognised within the unit. Metabasites antedate the first deformation. Few mineral deposits occur in the Einasleigh Metamorphics and associated metabasites in the Sheet area. Only one important gold deposit (Overland Telegraph) has been worked in the rocks; several minor copper deposits occur in the McMillan Creek and "Talaroo" areas. Stratabound zinc mineralisation is known to occur near "Eveleigh", but it has not been worked.

The Robertson River Metamorphics are dominated by lower to upper amphibolite subfacies schist; metabasite bodies, all of which appear to be of intrusive origin, are assigned to the Cobbold metadolerite. The Robertson River Metamorphics have been folded at least four times; the main prograde metamorphism and the second generation of folds are probably

contemporaneous, as in the Einasleigh Metamorphics. Several gold deposits occur in the Robertson River Metamorphics, including the one worked at the City of Glasgow mine, the principal producer in the Georgetown Sheet area.

Available data suggest that the Einasleigh and Robertson River Metamorphics originally graded into each other; they apparently represent two different original lithofacies of essentially the same age. Metabasite in the Einasleigh Metamorphics, and the Cobbold metadolerite, are thought to represent the same suite of intrusive bodies with minor extrusive equivalents. The main prograde metamorphic event which affected both the Einasleigh and Robertson River Metamorphics probably took place under conditions similar to those which formed the Stonehavian metamorphic facies series - intermediate between those of the classic low-pressure (Abukuma and Buchan) and medium-pressure (Barrovian) series.

These basement rocks are overlain by the Carboniferous Newcastle Range and Cumbana Volcanics, which contain terrestrial sequences dominated by rhyolitic ignimbrite. The Newcastle Range Volcanics appear to have accumulated in three cauldron subsidence areas, the southernmost and northernmost two of which are connected by a partly fault-bounded linear downwarp. Two apparently separate stratigraphic sequences are included in the unit. Intrusive rhyolite and other hypabyssal rocks are closely associated with the volcanic units; in part these rocks have been intruded as cone sheets and ring dykes around the various cauldron subsidence areas. Major volcanic vents have not been located in the Sheet area.

The Palaeozoic volcanic units have been intruded by the high-level Eva Creek Microgranite, Elizabeth Creek Granite, and Yataga Granodiorite, which may be of Permian age in part. Several rock types occur within the Elizabeth Creek Granite, but it has not been possible to map them separately. Both the Elizabeth Creek Granite and Eva Creek Microgranite are hosts to tin mineralisation; in addition, it is thought that uranium-fluorine-molybdenum mineralisation is genetically related to the former unit, and could thus occur in any one of several older favourable environments in addition to fluviatile sedimentary rocks below a volcanic sequence as at the Maureen prospect.

Mesozoic and Cainozoic rocks in the Sheet area have been studied only cursorilly; they include Jurassic to Cretaceous quartzose sandstone (Gilbert River Formation), a basalt flow (which is only 19 000 years old!), calcareous tufa associated with hot springs at "Talaroo", soil and colluvium, and two types of alluvium.

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INTRODUCTION

Area of investigation

The Georgetown 1:100 000 Sheet (7661) covers an area of 2915 km^2 in the central Georgetown Inlier of northeastern Queensland (Fig. 1); it is bounded by latitudes 143°30' and 144°00' East, and by longitudes 18°00' and 18°30' South.

Purpose and scope of investigation

The Georgetown Project, which is being undertaken jointly by the Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland (GSQ), aims to refine knowledge of pre-Mesozoic rocks and their mineral deposits in the Georgetown Inlier by means of integrated geological, geophysical, and geochemical studies. The first phase of the project began in 1972 with a geological reconnaissance and geochemical orientation survey. By the end of 1976, field research in three 1:100 000 Sheet areas (Georgetown, Forsayth, and Gilberton) was essentially complete. These three Sheet areas (Fig. 1) constitute a north-south strip through the central Georgetown Inlier, and contain representatives of most of the main geological terrains which occur in the Inlier. During 1976 and 1977 field research was extended westwards into the Forest Home and North Head Sheet areas.

This report deals with geological aspects of the work undertaken in the Georgetown 1:100 000 Sheet area, the northernmost one of the three studied during the first phase of the Georgetown Project. For various reasons, a discussion of the Proterozoic granitoid rocks has been deferred; it will constitute a separate Part (B) of the report, to be released as soon as possible.

The geology of the Forsayth 1:100 000 Sheet area has already been described (Bain, Withnall, & Oversby, 1976), and similar reports dealing with the Gilberton North Head, and Forest Home Sheet areas are being prepared. All of these reports are of a preliminary nature, and should not be regarded as final or definitive in any way.

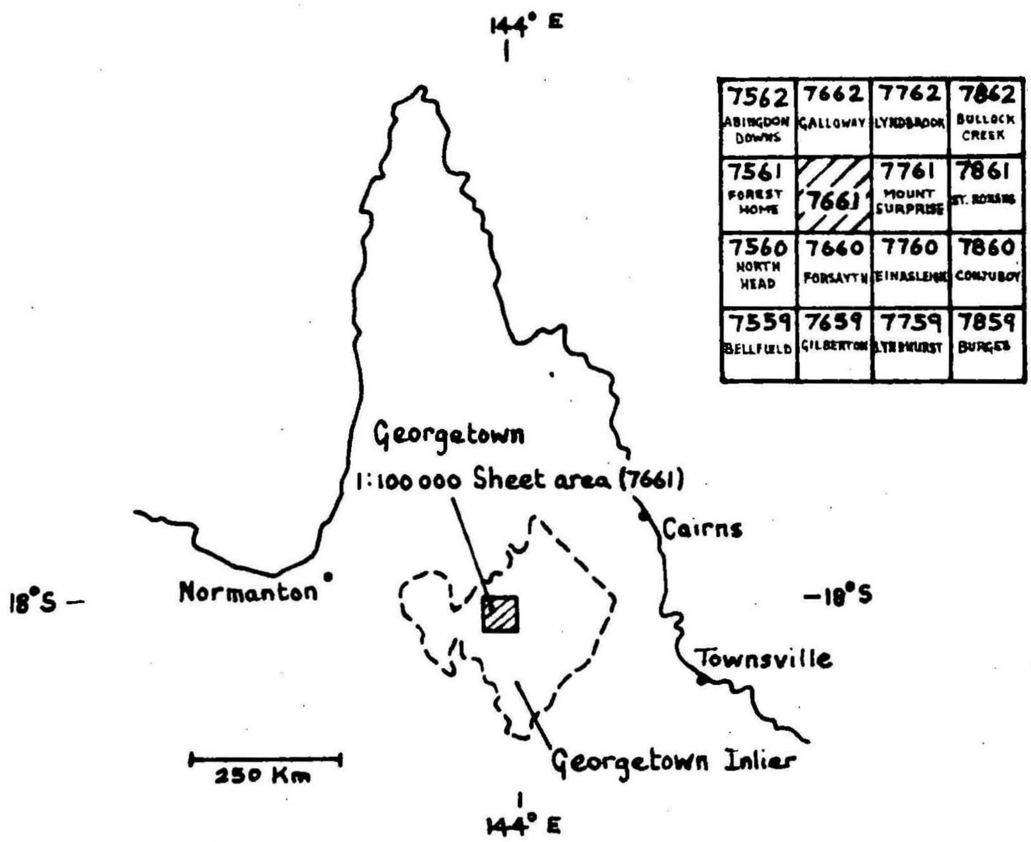

Fig. 1 Location of the Georgetown 1:100 000 Sheet (7661) area

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The Georgetown 1:100 000 Sheet area was mapped geologically mainly between mid-June and late September 1975 by Oversby, Withnall, and Bain. Some remapping of the northernmost Newcastle Range was done by Oversby in September and October 1976 (Oversby, 1977), but this work postdated compilation of the Preliminary Edition of the Georgetown 1:100 000 Geological Series map (end pocket) and results will be referred to only incidentally in this report.

Data from field research were recorded initially on transparent overlays to 1:25 000 (approx.) scale colour airphotos taken in September 1972. The overlays were combined and redrawn in the field as sixteen photo-scale compilation sheets by Peter Blythe. These sixteen compilation sheets, reduced photographically to 1:100 000 scale (cf. Bain, Oversby, & others, 1976; Oversby, 1977), formed the basis for the map. About 1800 observations were recorded during the course of the field research (many more were noted in passing, but not formally recorded); about 500 thin sections have been examined at least cursorily.

Settlement and access

Georgetown (pop. about 350) is the only significant settlement and service centre in the Sheet area. The town grew up in the early 1870s after gold was discovered in the area (Bolton, 1963, p.48; Withnall, in press); it was the administrative centre of the Etheridge Goldfield (proclaimed in 1872), and was probably named after Howard St George, the field's first Commissioner. Georgetown is currently the seat of the Etheridge Shire Council. The area outside the town is held under pastoral leases (Fig. 3); beef cattle grazing is virtually the only land use, although much of the Newcastle Range has been fenced off or is otherwise inaccessible to stock.

Georgetown is connected to Cairns (440 km by road) and its hinterland to the northeast by the sealed Gulf Developmental Road, built in the 1960s as part of the beef roads scheme, and other sealed roads forming part of the Highway 1 system (Fig. 2). Access from Mount Isa (795 km by road) and adjacent areas is by way of mainly sealed roads through Normanton and Croydon, the latter being about 150 km west of Georgetown. Subsidiary roads, only partly sealed, connect Georgetown to the Hughenden and Townsville

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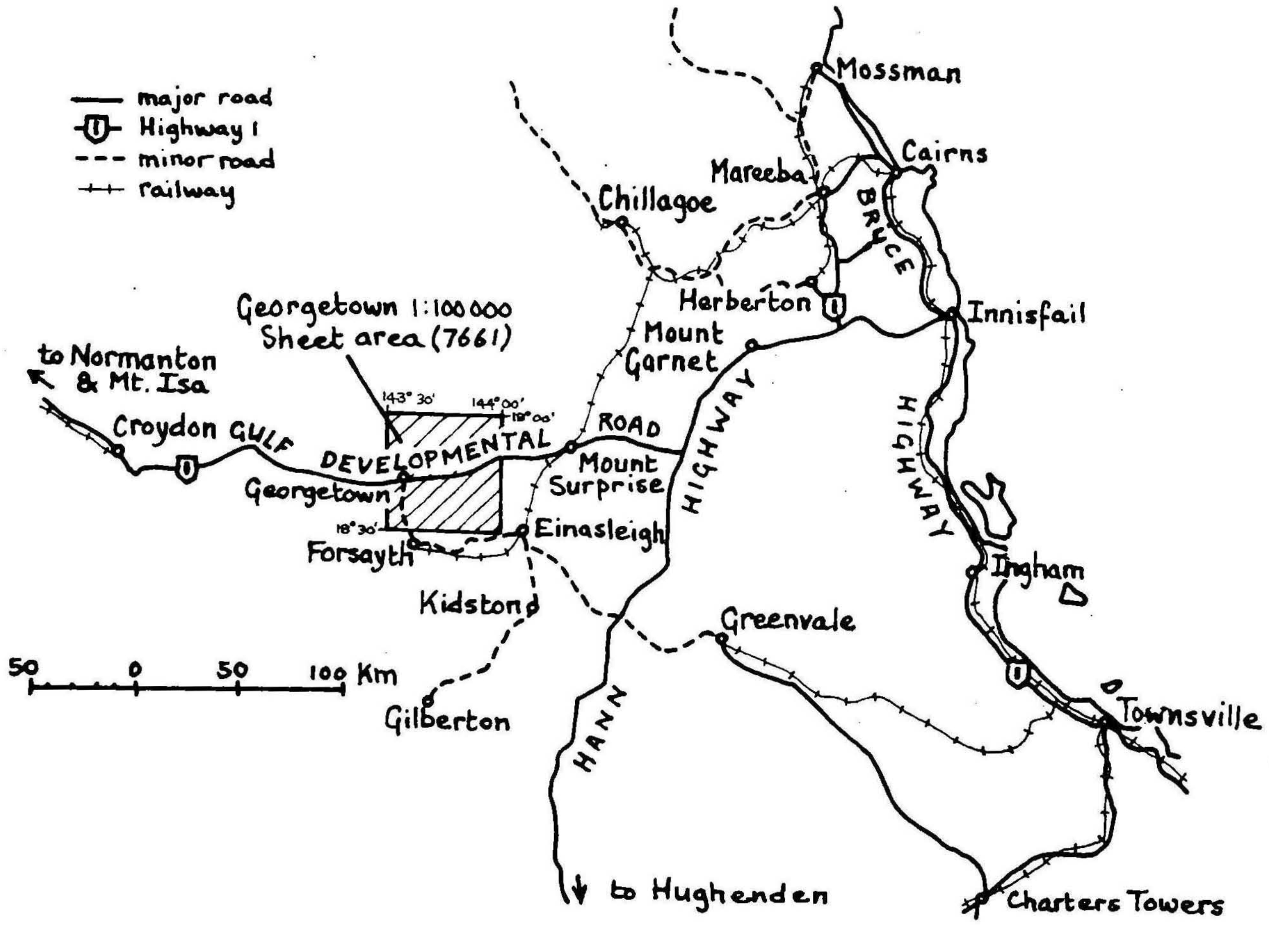

Fig. 2 Access to Georgetown Sheet area.

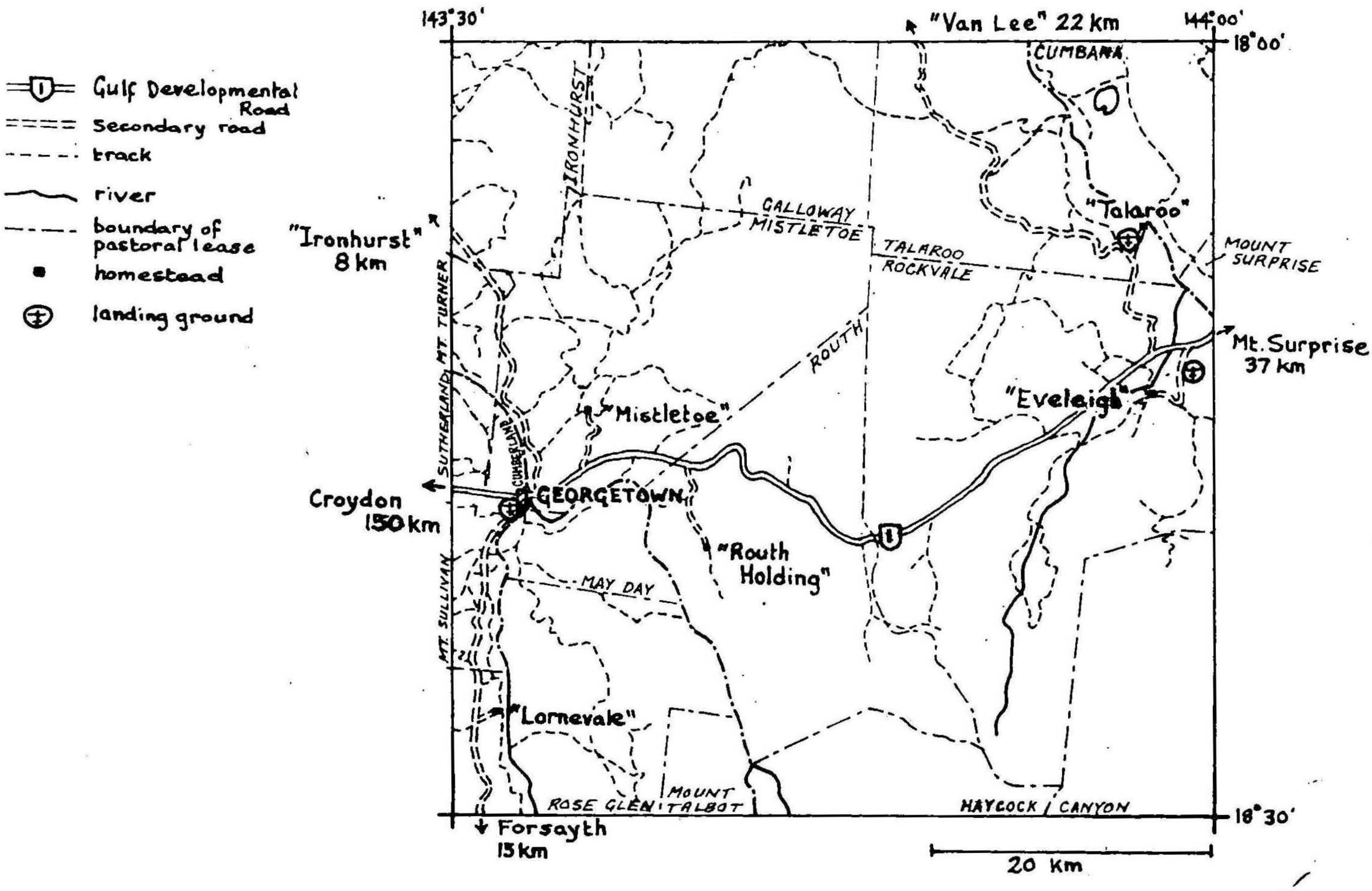

Fig. 3 Settlement and access within the Georgetown Sheet area

areas via Forsayth and Einasleigh, about 40 km to the south and 95 km to the southeast respectively (Fig. 2). Forsayth is the terminus of a narrow-guage railway from Cairns.

Bush Pilots Airways operates regularly scheduled passenger and limited freight services by light aircraft to the all-weather airstrip at Georgetown. Unsurfaced airstrips are also located adjacent to "Talaroo" and "Eveleigh".

Minor unsealed roads and tracks of variable quality are widespread to the east and west of the Newcastle Range. Movement of four-wheel drive vehicles between these routes is relatively easy during the dry season, except in local areas of excessively steep and rough terrain. The Newcastle Range constitutes a major obstacle to movement, however; within the Georgetown Sheet area it is crossed only by the Gulf Development Road and the Brodies Gap-Dagworth Bore track, and most parts cannot be reached easily except by helicopter.

Physiography

The Georgetown 1:100 000 Sheet area is in the Einasleigh Uplands physiographic province (Twidale, in Perry, 1964 pp.115-124; Twidale, 1966); it is drained by the Etheridge and Einasleigh Rivers, both of which are tributaries of the Gilbert. Elevations in the area range from less than 260 m in the northwest to more than 760 m in the southeast.

That part of the Sheet area west of the Newcastle Range is an irregularly dissected plain (Fig. 4), cut by steep-sided V-shaped valleys; bouldery granite pediments and inselbergs are common. Elevations range from less than 260 m in the northwest to 530 m at Mount Talbot (grid ref. 781548), although local relief is mostly commonly 20 to 50 m, and rarely exceeds 100 m. Similar terrain also occurs between the main Newcastle Range and the Einasleigh River, as far north as a line joining Brodies Gap and Cawana Lake, and in the embayment between the main and eastern parts of the range (Fig. 4). Elevations here range from about 340 m along the Einasleigh River opposite Cawana Lake to about 600 m in the upper reaches of McMillan Creek farther south. Local relief is greatest in the south, where it is mostly up to about 60 m but rarely more than 100 m.

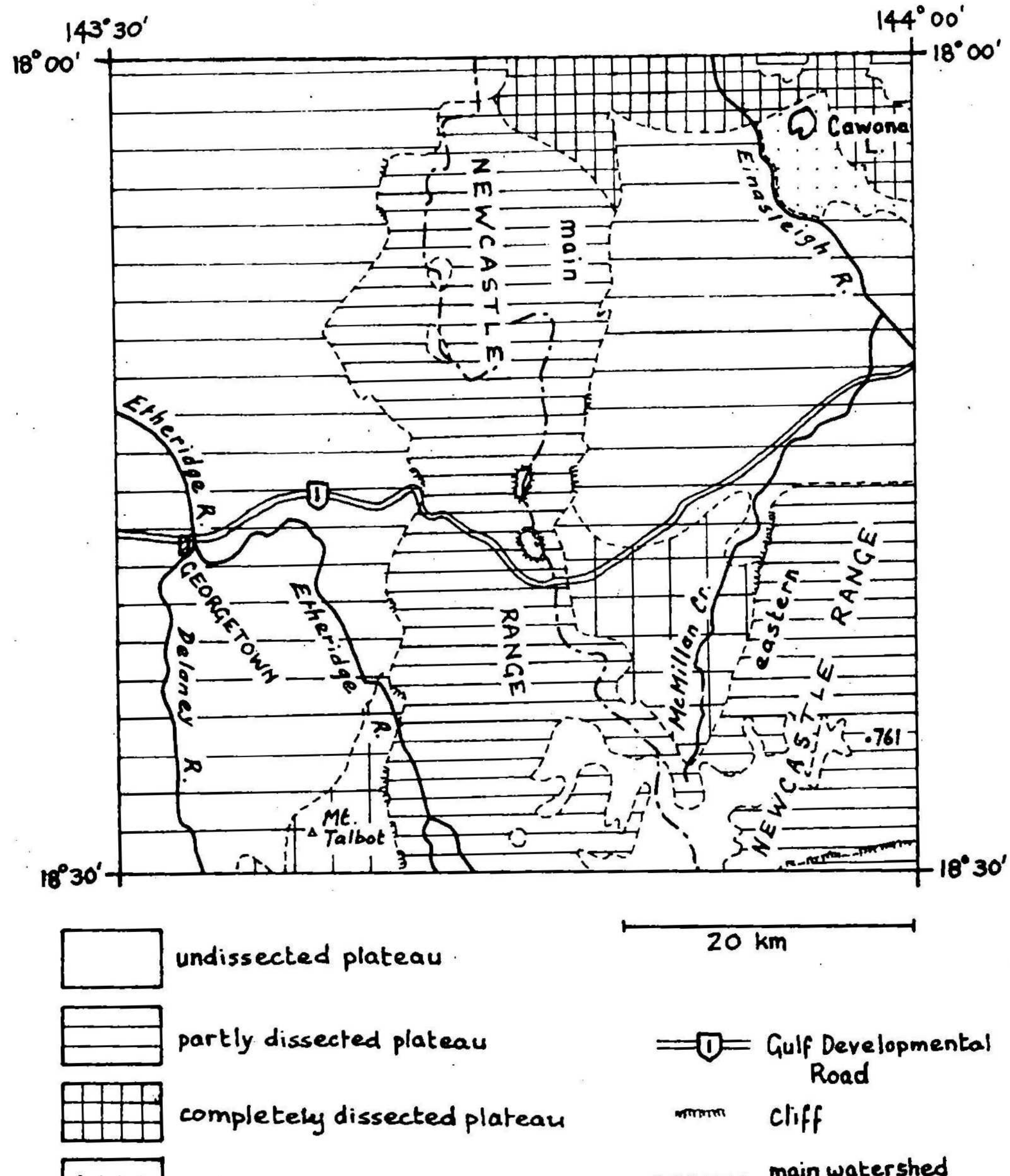

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Fig. 4 Physiography of the Georgetown Sheet area

At, and southeast of, Cawana Lake, there is a virtually undissected plain of low relief at an elevation of about 350 m (Fig. 4) which is mostly underlain by basalt. Farther north, in the northeastern corner of the Sheet area, an almost completely dissected plateau forms extremely rugged country with elevations up to 534 m (grid ref. 144026) (Fig. 4). Granite, which is conspicuous in bouldery outcrops and hills, underlies much of this area; relief of 100 m or more is relatively common. This area merges westwards into the Newcastle Range, which is an area of variable topography. Most of the range is a partly, but deeply, dissected plateau lying up to about 200 m above the average elevation of the surrounding country, although it tends to merge into adjacent terrains in the north and in the upper McMillan Creek area. Cliffs and extremely steep slopes characterise the edges of the range in many places, as well as the sides of valleys within the range. These valleys are V-shaped and commonly deeply incised; many are markedly linear. Relief of 60 to 100 m is common. The greatest elevation reached in the Georgetown 1:100 000 Sheet area, more than 760 m, is in the Newcastle Range in the southeast. Relatively small areas of virtually undissected plateau also occur on the Newcastle Range, mostly in the southern part of the Sheet area (Fig. 4); these areas are underlain by Mesozoic and Cainozoic rocks.

Climate and vegetation

The Georgetown Sheet area has a semi-arid tropical, verging on humid tropical, climate (Slatyer, in Perry, 1964, pp. 90-104); a north-western rainfall influence is predominant in most years. Average annual rainfall at Georgetown is a little more than 750 mm, most of which falls between November or December and April. Rainfall in the intervening months is mostly sporadic and local. Average temperatures at Georgetown range from a minimum of about 12^{o} in July to a maximum of about 36^{o} in November; the greatest average temperature range (about 17^{o}) occurs in August. The average 3 p.m. relative humidity ranges from a low of 21 percent in October to 47 percent in February. The climate of that part of the Sheet area to the east of the Newcastle Range is subject to an eastern rainfall influence to a slightly greater extent than is Georgetown.

Most of the Georgetown Sheet area is covered by open to moderately dense eucalypt woodland with a ground cover of various grasses. Various species of box, ironbark, and bloodwood predominate; most are from 6 to 12 m high. Paperbarks are characteristic of the major river courses and some poorly-drained areas, such as the one around Cawana Lake. Ti-trees are common in sheltered gullies and along small creeks. Several vegetation associations occur on the Newcastle Range, although areas of widely-spaced small trees and bushes of various types are most common; species diversity is locally higher than in surrounding areas. Dense stands of lancewood (*Acacia shirleyi*) are common on the range locally, especially on the Mesozoic and Cainozoic cover in the south.

Previous geological investigations

In the mid- and late 1950s the Georgetown 1:100 000 Sheet area was included in 1:250 000 scale regional geological mapping of the whole Cairns-Townsville hinterland by joint BMR-GSQ parties (White, 1965; Branch, 1966). White (1965, pp. 6-10) summarised earlier work in the region, much of which was at least partly concerned with the Georgetown Sheet area, although he did not cite the three reports by Daintree which contain the first accurate geological observations (Daintree, R., *in* Queensland Legislative Assembly, Votes and Proceedings, 1869, V.II, pp.163 + map, 165-166 + map, 167-171 + map).

Later work has tended to consider the Sheet area within the context of the regional framework erected by White and his coworkers. Reports which contain data relating in part to the Georgetown Sheet area include Richards, and others (1966), Black (1973, 1974), Sheraton (1974), and Sheraton and Labonne (1974, 1978). Geological and related work carried out by various companies in the Georgetown and adjacent 1:100 000 Sheet areas is described in many unpublished reports, summarised by Withnall (1974, 1976).

Acknowledgements

We gratefully acknowledge the assistance, both direct and indirect, provided by many of our collegues at BMR and GSQ, especially Lance Black and Alan Rossiter. Duncan Dow, Dave Blake, and Ken Walker have supervised the Georgetown Project at various times since its inception. Permanent and temporary field staff, without whom the field research in the Georgetown Sheet area in 1974 would not have been possible, were Dave Gregg (mechanic), John Dando (cook), Tom Fletcher, Alan Hoey, Ken Mitchell, Jim Pollard, and Gordon Wilson (field hands); Ken ("Tas") Armstrong handled much of the administration of a combined geological and geochemical party's camp with his customary efficiency and tact. Peter Blythe (BMR Geological Drawing Office) transferred the sometimes near-illegible doodlings on geologists' airphoto overlays to field compilation sheets; later he followed the work through to drafting of the Preliminary Edition map. Lyn Walton produced a superbly typed early draft of the report.

We are indebted to geologists of CRA Pty Ltd, who first brought the occurrence of possible pillow structures in Einasleigh Metamorphics near "Eveleigh" to our attention. Personnel of other companies active in the Georgetown area also co-operated with us to the fullest practicable extent. We have always benefited from free exchange of information with university workers active in the area - Neil McNaughton (University of Queensland), Tim Bell, John Fitzgerald, John Patrick, and Mide Rubenach (James Cook University) - whose detailed studies have complemented out more regional understanding of the metamorphic rocks. Local people in and around Georgetown, too numerous to mention individually, gave us friendship and assistance at every opportunity; we are especially grateful to all the landowners who permitted us to travel at will throughout their properties.

Annotated airphoto overlays and notebooks relating to field research in the Georgetown Sheet area are held at BMR. Field numbers assigned to observation points (and accompanying hand specimens where appropriate - see Tables in Appendix) are made up of photo run/ photo number/ point number. Thin sections have "registered numbers"; those prefixed by "7430" are in the BMR collection, whereas others prefixed by "GSQ" are held by the Geological Survey of Queensland.

MID-PROTEROZOIC? METAMORPHIC ROCKS

Einasleigh Metamorphics (Ꝑme)

Introduction

The Einasleigh Metamorphics were named and defined by White (1959c, pp. 443-444), who listed previous references. In the Georgetown 1:100 000 Sheet area the unit consists mainly of biotite gneiss, quartzite, schist, migmatite, and metabasite (amphibolite and basic granulite - see below) which are commonly cut by pegmatoid and granitoid dykes and veins. The rocks crop out in two main areas which total about 550 km^2 to the east and west of the Newcastle Range.

Low undulating topography characterises areas underlain by the Einasleigh Metamorphics; vegetation consists mainly of various types of ironbark and bloodwood, with minor Georgetown box (*Eucalyptus microneura*), and a thick ground cover of three-awn grasses (*Aristida* spp.) and spear grass (*Heteropogon contortus*). The metamorphic rocks are commonly poorly exposed, especially to the north of the Gulf Development Road on the eastern side of the Newcastle Range, where Caïnozoic soil and colluvium are widespread. However, good outcrops occur locally along the Einasleigh River, and in McMillan Creek and its tributaries.

The thickness of the Einasleigh Metamorphics is unknown because of the generally poor exposure and complex polyphase deformation which the unit has undergone.

Subunits Ꝑme$_1$ (Banded calc-granofels) and Ꝑme$_2$ (granite-gneiss and migmatite) (Bain, Withnall, & Oversby, 1976, pp. 7-9, 11-12), which were shown on the Preliminary Edition of the Forsayth 1:100 000 Geological Series map, have not been differentiated on the Georgetown map.

Lithology and petrography

(a) Biotite gneiss

Biotite gneiss is the most characteristic rock type in the Einasleigh Metamorphics. The gneiss consists of alternating leucocratic and melanocratic layers ranging from a few millimetres to several centimetres thick. One or more conspicuous foliations commonly occur; the best-developed foliation at most localities is parallel to the leucocratic and melanocratic layers. A subsidiary (younger) foliation cuts across layers locally. The layers are commonly deformed by one or two sets of folds (Fig. 5), which are locally accompanied by crenulations.

Quartz, feldspar, biotite, and sericite are the main constituents of the biotite gneiss (Table 1). Quartz and feldspar occur as subequant grains, most of which are less than 1 mm across; the grains have curved, slightly interlocking contacts and form a granoblastic mosaic. Plagioclase is the predominant feldspar; it is most commonly andesine, although more calcic varieties (up to An_{55}) occur sporadically. Minor potassium feldspar, mainly orthoclase, occurs locally as poikiloblastic grains up to 2 mm across; many grains have been partly replaced by myrmekite.

Biotite occurs as reddish brown to dark brown flakes up to 1.5 mm long; it commonly contains inclusions of zircon surrounded by pleochroic haloes. Most flakes have been at least partly altered to chloritic material. Biotite, together with sericite, defines the foliation or foliations in the gneiss. Hornblende is not known to occur in the Einasleigh Metamorphics of the Georgetown 1:100 000 Sheet area (cf. Bain, Withnall, and Oversby, 1976, p. 6).

Lenses and bands of sericite (Fig. 5) are common in the gneiss. The lenses are up to 1 cm long; bands are discontinuous and up to several millimetres thick. Some of the sericite has been recrystallised to randomly-oriented muscovite flakes up to 0.3 mm long. Muscovite also occurs as large irregular flakes cutting across foliation planes.

Sericite aggregates commonly contain cores made up of bunches of sillimanite fibres; sillimanite inclusions in muscovite flakes are also common. Most of the sillimanite fibres are less than 0.5 mm long.

Subsequant garnet porphyroblasts occur locally in the gneiss. They are up to 5 mm across, and commonly partly pseudomorphed by chlorite and sericite.

(b) Schist

Grey fine- to medium-grained schist is common in the Einasleigh Metamorphics; it is rarely as well exposed as the gneiss, although it may be the predominant rock type in some areas, particularly to the northwest

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- Table 1: Visually estimated modal compositions of gneiss, Einasleigh Metamorphics

Registered no.	Q	Kf	Pl (composition)	Bi	Chl	Ser	Mu	Ga	Sill	Acc	Remarks
74300285	45-50	0	15-20 (andesine)	20	0	0	15	0	0	zr, ap	
" 0288	30	<5	35 (An_{45})	20	0	5	5-10	0	0	zr, ap	
" 0291	30	5-10	10-15 (andesine)	25	0	25	0	0	0	zr, ap	banded
" 0295	45	5(?)	20 (andesine)	10	0	20	<1	0	trace	zr, ap	banded
" 0301	25	<1	10 (An_{55})	10	0	55	0	<1	0	zr, ap	
" 0302	65	<1	30 (An_{40-45})	3-5	0	0	<1	0	0	zr, ap	banded
" 0303	50	0	0	10	0	35	0	<1	0		5% cordierite; biotite chloritised
" 0304	65	<5	25 (An_{45})	2	0	5	0	0	0	zr, op	leucocratic band
	50	0	15	20	0	15	0	0	0		melanocratic band
" 0317	40	5	15 (An_{35})	30	0	0	5	0	5	zr, ap	biotite slightly chloritised
" 0341	50-55	<1	30 (An_{40})	<5-10	0	5	0	0	0	ap	banded
GSQ 7848	50	<5	10-15 (andesine)	2-3	10	15	2-3	<1	5	zr, ap, op	
" 7849	30	<5	5-10 (An_{45})	20	0	35	5	<1	0	zr, ap	
" 7850	45	<5	40 (An_{40})	10-15	0	0	0	0	0	zr, ap	banded
" 7851	50	<1	15 (An_{45})	20	0	15	0	0	0	zr, ap, op	well crenulated; biotite slightly chloritised
" 7852	45	10-15	30-35	5-10	0	<1	<5	<1	0	zr, ap	banded
" 7854	40	0	5	25	5	15	0	0	0		feldspar sericitised
" 7855	40	<1	30 (An_{40})	15-20	0	5	5-10	0	trace	op, zr, ap	
" 7856	5	0	5-10 (An_{35})	35	0	30	20	0	<5	zr	
" 7857	35	0	20 (andesine)	<5	10-15	15	15	0	trace	op, zr, ap	
" 7858	45	0	25 (An_{45})	5	10	<5	10-15	0	trace	op, zr, ap	poorly banded
" 7863	35-40	0	15-20 (An_{55})	15	5	20	<5	trace	0	op, zr, ap	

Table 1 (continued):

Registered no.	Georgetown 1:100 000 Sheet area: Field no.	Grid ref.
74300285	5/898/20B	785874
" 0288	6/914/11	722847
" 0291	7/1006/6B	743791
" 0295	7/1008/4	689793
" 0301	10/136/2	786659
" 0302	10/136/3B	792667
" 0303	10/136/5	788676
" 0304	10/136/6	783674
" 0317	7/1004/2	780772
" 0341	9/124/3	779708
GSQ 7848	5/878/4A	156899
" 7849	5/878/3B	165893
" 7850	6/930/3	066824
" 7851	7/990/26	092809
" 7852	10/146/6B	008675
" 7854	10/146/11A	016675
" 7855	10/146/22	019660
" 7856	10/148/28	033662
" 7857	11/166/7A	035629
" 7858	11/166/8	033633
" 7863	11/178/12	802621

Abbreviations used in Tables 1-7:

Q - quartz
Kf - K-feldspar
Pl - plagioclase
Bi - biotite
Chl - chlorite
Ser - sericite
Mu - syntectonic muscovite
Mu* - post-tectonic muscovite
Ga - garnet
Sill - sillimanite
Hbl - hornblende (colour in Z direction - bl-g - bluish-green; br - brown; br-gr - brownish-green; g - green; g-br - greenish-brown)
Di - diopside
Opx - orthopyroxene
Cumm - cummingtonite
Ep/Cz - epidote/clinozoisite
Trem/Act - tremolite/actinolite
Sp - sphene
Andal - andalusite
Staur - staurolite
C - graphite
Acc - accessory mineral/s (ap - apatite; bi - biotite; cal - calcite; chl - chlorite; cz - clinozoisite; ep/cz - epidote/clinozoisite; op - orthopyroxene; sp - sphene; zr - zircon)

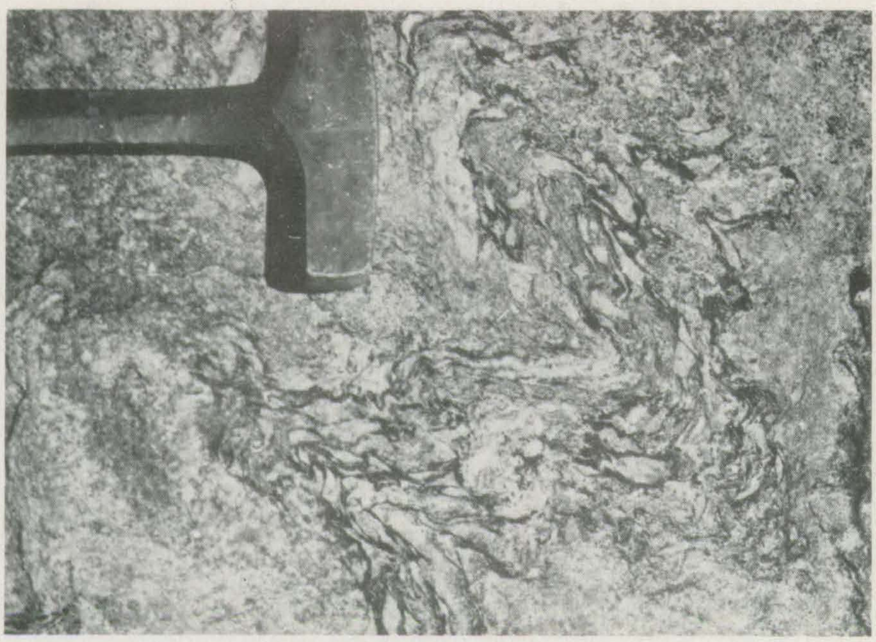

Fig. 5: Biotite bands with sericite aggregates (small lenses) in gneiss, folded by B_{II}^{III} structures, Einasleigh Metamorphics. G7/990/24 (grid ref. 086880)- McMillan Creek, 6 km west-southwest of "Eveleigh". Photo by I.W. Withnall.

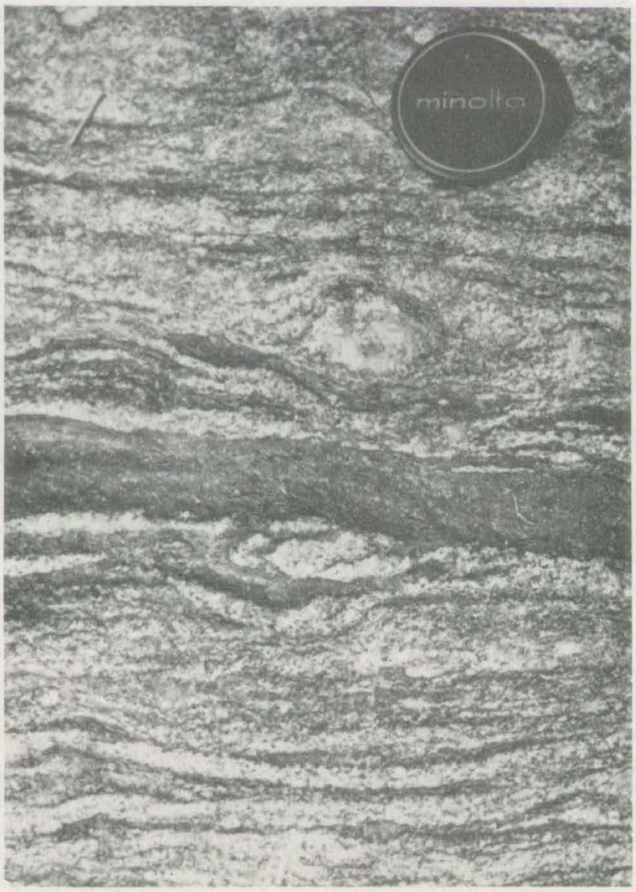

Fig. 6: Melanosomes (dark) and leucosomes (pale) in migmatite, Einasleigh Metamorphics. G2/746/2 (grid ref. 075018) - Einasleigh River, 9.5 km north-northwest of "Talaroo". Photo by I.W. Withnall.

of "Talaroo". The foliation is commonly strongly crenulated, and is axial-planar to small isoclinal folds which have locally deformed small quartz and granitoid veins.

Quartz, biotite, chlorite, and sericite are the main constituents of the schist (Table 2). Quartz grains are equant to elongate, and up to 1 mm in maximum dimension; they are locally associated with plagioclase grains of similar morphology. Biotite, which has commonly been partly (or less commonly wholly) replaced by chlorite, occurs as reddish brown flakes; most of the flakes are less than 0.5 mm long, although some up to 1.5 mm long occur locally. Sericite is more abundant than in the gneiss (above), although it has similar morphology in both rock types; bands of sericite in schist locally contain bunches of sillimanite fibres, as in the gneiss. Schistose foliation is commonly defined by parallel flakes, lenses, and bands of biotite and sercite. Garnet porphyroblasts are common in the schist.

(c) Quartzite

Quartzite is common in the Einasleigh Metamorphics of the Georgetown 1:100 000 Sheet area, especially in the western part of the McMillan Creek area. This relative abundance contrasts with the comparative scarcity of quartzite in the Forsayth Sheet area (Bain, Withnall, & Oversby, 1976, p. 7). A variety of quartzite which contains spots rich in calc-silicate minerals occurs locally in layers and small ellipsoidal pods up to 30 cm long surrounded by "normal" quartzite and gneiss. Quartzite grades into biotite gneiss as mica content increases.

The quartzite consists mainly of a fine- to medium-grained granoblastic to granuloblastic mosaic of subequant to equant quartz (65-80 percent) and plagioclase (15-30 percent) grains with or without minor biotite, chlorite, potassium feldspar, and muscovite. Those quartzites which contain calc-silicate minerals commonly carry more plagioclase than quartz; the main calc-silicate minerals are pale green hornblende and minor garnet.

Table 2. Visually estimated modal compositions of schist and quartzite, Einasleigh Metamorphics. See Table 1 for abbreviations used.

	Registered no.	Q	Kf	Pl (composition)	Bi	Chl	Ser	Mu	Ga	Sill	Acc	Remarks
schist	GSQ 7853	<5	1	<5	20	0	70	0	5	0	zr, op	biotite partly chloritised
	" 7464	1	0	0	0	15-20	80	0	<5	0	op	biotite chloritised
	" 7465	5	0	<1	10	20	30	30	1	5	op, zr	biotite chloritised
	" 7466	55	0	0	0	10	25	<5	5	<1	op	biotite chloritised
	" 7467	40	0	0	0	10	50	0	<5	0	op	biotite chloritised
	" 7468	10	0	<1 (An_{52})	0	20	60	0	5	5	op, ap	biotite chloritised
quartzite	74300286	80	0	0	5	0	15	0	0	0	zr, ap	granuloblastic
	" " 9292	65	15-20	20-25	1-2	0	0	0	0	0	zr	
	" " 0302	65	<1	30	3-5	0	0	<1	0	0	zr, ap	
	" " 0307	70	<5	25-30	0	1-2	0	trace	0	0	zr, op	granuloblastic
	" " 0342	60-70	10-15	20-25	2-3	0	1	0	0	0	ap	
	GSQ 7859	65-70	5(?)	25	1-2	1-2	0	<1	0	0	op, ap	
	" 7860	80	0	15-20	0	1-2	0	<1	0	0	zr, ap	
	" 7862	60	0	40 (An_{40})	1	1	0	trace	0	0	zr, ap	

Registered no.	Georgetown 1:100 000 Sheet area: Field no.	Grid ref.
GSQ 7853	10/146/6G	008675
" 7464	3/764/10	010980
" 7465	2/746/2D	076002
" 7466	2/748/2E	076002
" 7467	2/744/1	019003
" 7468	3/764/11	005998
74300286	5/898/20C	785874
" 0292	7/1006/6A	743791
" 0302	10/136/3B	792667
" 0307	10/136/7	785680
" 0342	9/124/4	778713
GSQ 7859	10/146/6A	008675
" 7860	10/146/3A	000673
" 7862	5/878/3A	165893

(d) Calc-granofels

There are only two known occurrences of calc-granofels in the Einasleigh Metamorphics of the Georgetown 1:100 000 Sheet area; they are not shown in the map. In contrast, calc-granofels is sufficiently abundant in the Forsayth Sheet area to be distinguished as a discrete subunit, Eme_2 (Bain, Withnall, & Oversby, 1976 pp. 7-8).

Massive pale-green calc-granofels crops out about 6 km northeast of "Mistletoe". The rock consists of 10 percent fine- to medium-grained granoblastic quartz, 60 percent plagioclase (An_{50}), 25 percent diopside, 5 percent hornblende, 1 to 2 percent sphene, and accessory apatite. Calc-silicate-bearing rocks, composed mainly of granular epidote with minor quartz and calcite, are reported to be host to zinc mineralisation at the prospect (35 on map) south of "Eveleigh" (Davies, 1972).

(e) Migmatite

Migmatite is common in the Einasleigh Metamorphics of the Georgetown Sheet area. The rocks show clear separation of leucocratic and melanocratic components into leucosomes and melanosomes (see Glossary) - respectively (Fig. 6), consistent with their having originated by *in situ* mobilisation of parental country rock (Palaeosome), presumably as the result of some degree of anatexis. Gneiss commonly grades into migmatite; the former rock type does not show such clear separation of leucocratic and melanocratic phases as migmatite does, although the dividing line between the two types is not sharp and can be difficult to place. Migmatite in its turn commonly grades into gneissic and schlieren-bearing leucogranitoids (Fig. 7). The gradation from gneiss through migmatite to granitoid presumably reflects increasing degrees of anatexis.

In Pinchers Creek, at grid ref. 783681, migmatite formed from slightly modified gneiss contains alternating leucogranitoid and biotite-rich layers. Increasing degrees of mobilisation and segregation of leucocratic components in the migmatite appear to have caused disruption of the melanocratic layers. The greatest amount of modification is represented by nebulite-leucograntoid (see Glossary) which contains biotite-rich schlieren. Where the same process has taken place on a larger scale, thin quartzite and amphibolite layers, quartz veins, early leucogranitoid veins,

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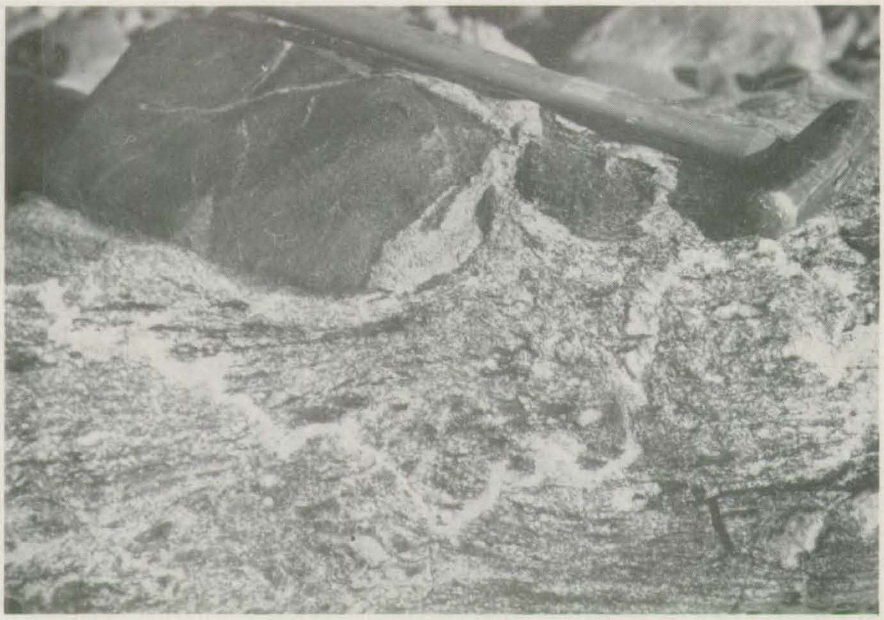

Fig. 7: Schlieren-granite with restite (amphibolite) xenoliths, feldspar augen (relics of early pegmatoid dykes ?), and later pegmatoid vein, Einasleigh Metamorphics. G2/746/5 (grid ref. 083000) - Einasleigh River, 8 km north-northwest of "Talaroo". Photo by I.W. Withnall.

Fig. 8: Biotite gneiss with leucogranitoid veins rimmed by biotite-rich selvages, Einasleigh Metamorphics. G7/1004/2 (grid ref. 770772) - west end of O'Brien Creek bridge on Gulf Developmental Road, 8 km east of Georgetown. Photo by I.W. Withnall.

and pegmatoid veins, as well as melanocratic layers, form enclaves in the resultant leucogranitoid (Fig. 7). Such rocks are agmatites, formed by diatexis (see Glossary). The various enclaves are anatectic restites, i.e. they represent refractory portions of the pre-anatectic rock assemblage. Large areas of agmatite and nebulite are exposed along the Einasleigh River, and smaller-scale (single outcrops) agmatite occurs in the McMillan Creek area, e.g. at grid ref. 008675. There are also examples of the gradation from gneiss to granite via migmatite exposed in cuttings along the Gulf Developmental Road between the O'Brien Creek bridge (grid ref. 773771) and the turnoff to "Mistletoe" (grid ref. 737768). Anatectic granites developed in and intruding Einasleigh Metamorphics will be discussed mainly in Part B of this report.

Migmatite leucosomes are mostly of trondhjemitic, tonalitic, or granodioritic composition; true granite is rare (Table 3). The leucosomes are medium-grained, equigranular, and have an allotriomorphicgranular texture; they contain 30 to 40 percent quartz, 40 to 50 percent plagioclase (mostly about An_{40}), 5 percent potassium feldspar, 2 to 20 percent (most commonly about 5 percent) biotite, and secondary muscovite and sericite. The biotite is reddish-brown and commonly partly chloritised.

Melanosomes contain about equal proportions of biotite (locally chloritised) and sericite (Table 3). The sericite has replaced original sillimanite and has locally been recrystallised to small flakes of muscovite. Secondary muscovite has also replaced sillimanite, feldspar, and biotite.

(f) Pegmatoid and granitoid veins

Pegmatoid and granitoid veins are locally widespread in the Einasleigh Metamorphics. Many of them consist of quartz and feldspar with sporadic patches of biotite, muscovite, and garnet. Most of the veins have sharp edges but are irregular in outline; they commonly pinch and swell, or are ptygamatically folded. Several generations of veins occur; some, which antedate the main foliation (S_{II} - see below) occur as enclaves in migmatite and agmatite. Other veins postdate the foliation, and have been folded in company with it.

Table 3: Visually estimated modal compositions of migmatite, Einasleigh Metamorphics. See Table 1 for abbreviations used.

Registered no.	Q	Kf	Pl (composition)	Bi	Chl	Ser	Mu	Ga	Acc	Remarks
GSQ 7869	45	<5	25 (An_{35})	15-20	0	10-15	0	0	zr, ap	biotite tonalite with schlieren
" 7870	40	<5	45 (An_{35-40})	0	5	0	5	0	zr, ap	altered trondhjemite
" 7871	30	20-25	30-35 (An_{40})	5-10	0	0	0	5	zr	garnetiferous biotite granite
" 7872	35	<5	45 (An_{40})	2	5	5	2	0	op, zr, ap	altered biotite tonalite with sericite-chlorite schlieren
" 7873	30	5-10	50	0	3-5	0	10	0	ap, ep, op	altered biotite granodiorite leucosome
	<1	0	0	30	0	65	5	0		melanosome
" 7874	40	0	40 (An_{40})	3-5	0	0	15	0	op, ap	altered granodiorite
" 7875	25	40	15	15-20	0	0	5	0	zr, ap, op	biotite granite (agmatite)
74300306	45	trace	50 (An_{40})	2-3	0	1-2	1-2	0		tonalite or trondhjemite leucosome
	0	0	0	30	0	70	0	0		melanosome

Registered no.	Georgetown 1:100 000 Sheet area	
	Field no.	Grid ref.
GSQ 7869	2/746/5	084998
" 7870	3/762/1	086986
" 7871	3/764/1	022943
" 7872	2/746/2B	076002
" 7873	10/146/24A	018666
" 7874	10/136/4	787674
" 7875	10/146/6C	008675
74300306	10/136/8	783681

Some of the pegmatoid and granitoid veins have biotite-rich selvages (Fig. 8), and are probably veinites (see Glossary), formed in situ. Many have no such selvages, however, and are evidently arterites (Glossary) which have intruded their host rocks from outside. The source/s of these arterites may have been at deeper structural levels, or in local "hot spots", where leucocratic material was mobilised during migmatisation. Although small leucogranitoid bodies are common in areas where granitoid and pegmatoid veins occur, they too were probably formed as the result of partial anatexis and do not represent the primary source/s of the arterites. The leucogranitoid veins and bodies probably formed as partial melts or metatects (see Glossary).

(g) Metabasite (Ᵽme$_3$)

Bodies of amphibolite are common in the Einasleigh Metamorphics; basic granulites also occur at a few localities. White (1962, 1965) grouped all of the metabasites of the Einasleigh Metamorphics, along with those of the Etheridge Formation and Robertson River Metamorphics, in the Cobbold Dolerite. Bain, Withnall, & Oversby (1976) changed the name informally to Cobbold metadolerite as being a more accurate reflection of the dominant lithology and, in addition, restricted application of the name to those metabasites in the Robertson River Metamorphics (and by implication, to those in the Etheridge Formation also). The restriction was believed to be desirable because of uncertainty regarding the pre-metamorphic age relationships between the Einasleigh Metamorphics and lower-grade units (Bain, Withnall, & Oversby, 1976, p. 9). That nomenclatural scheme is retained in this report.

The metabasite in the Einasleigh Metamorphics of the Georgetown 1:100 000 Sheet area occurs as bodies which range from concordant lenses less than 1 m thick to large, virtually solid, discordant masses occupying areas of up to 10 km^2. Contacts with the surrounding rocks are sharp, and the metabasites are considered to be of igneous rather than sedimentary origin. Although most of the metabasite bodies contain amphibolite which probably originated as intrusive dolerite sills and dykes, and gabbro stocks, extrusive rocks may also be represented locally. On the hillside to the northwest of the Eveleigh mine (34 on map) some of the rock in a metabasite body contains pillow-like structures (Fig. 9) which suggest an origin as

Fig. 9(a): Zoned "pillow" in amphibolite, Einasleigh Metamorphics. G7/988/20 (grid ref. 127798) - 0.5 km northwest of Eveleigh mine. Photo by I.W. Withnall.

Fig. 9(b): Overturned(?) "pillow" in amphibolite with cuspate "bottom" (above) and bulbous "top" (below), Einasleigh Metamorphics. G7/988/20 (grid ref. 127798) - 0.5 km northwest of Eveleigh mine. Photo by I.W. Withnall.

lava. The structures are ellipsoidal, 20 to 50 cm across, and some appear to have bulbous "tops" and cuspate "bottoms" which, if the structures do represent metamorphosed pillows, are overturned. Interstices between the "pillows" are filled by siliceous material or carbonate locally. Some of the structures are zoned, having a pale green diopside-rich core and dark green hornblende-rich rim; other individuals have the diopside- and hornblende-rich zones distributed more irregularly. The same metabasite body also contains an unknown proportion of amphibolite with a relatively coarse blastophitic texture, suggesting that at least some rocks of intrusive origin accompany the possible pillow lavas.

Because of its relatively high melting point, metabasite occurs as an anatectic restite in the migmatites of the Einasleigh Metamorphics. Such restites are conspicuous in outcrops along the Einasleigh River (Fig. 7).

Amphibolite in the Einasleigh Metamorphics is fine- to medium-grained and consists mainly of hornblende, plagioclase, quartz, and sporadic diopside (Table 4). The texture is most commonly granuloblastic polygonal or nematoblastic. Hornblende occurs as subequant to elongate grains, most of which are less than 1.5 mm long, with smooth straight edges. The colour of the Z direction is commonly greenish-brown or brown, although the edges of some grains are slightly bluish. The hornblende in some specimens has a blastophitic texture, with inclusions of plagioclase laths; this blastophitic hornblende is set in a matrix of finer-grained granuloblastic hornblende and plagioclase. Diopside grains are colourless, poikiloblastic, and up to 1.5 mm long. Plagioclase grains, which are commonly slightly sericitised, are subequant to equant; most are 0.5 mm or less long, although some are up to 1.5 mm. Compositions range from An_{50} to An_{80}, but most are An_{67} to An_{75}. Quartz has a similar habit to plagioclase. Garnet occurs sporadically as poikiloblastic porphyroblasts up to 5 mm across; it is most common in rocks with a relatively high quartz content. Opaque mineral grains constitute up to 5 percent of some amphibolite specimens. Accessory minerals include apatite, sphene, and alteration products such as "chlorite" and epidote.

One amphibolite specimen (registered no. GSQ7896, Table 4) from near the Eveleigh mine has a blastoporphyritic texture with randomly oriented plagioclase laths in a groundmass consisting of plagioclase and

Table 4: Visually estimated modal compositions of metabasite, Einasleigh Metamorphics. See Table 1 for abbreviations used.

Registered no.	Q	Pl (composition)	Hbl (colour)	Ol	Opx	Cumm	Trem/Act	Ga	Sp	Acc	Remarks
GSQ 7889	1	30 (An_{50})	70 (g-br)	0	0	0	0	0	0	1% op, ap	granuloblastic, well-lineated; weak early foliation
" 7890	<5	45-50 (An_{75})	<5 (br)	30	15	0	0	0	0	1-2% op, ap	granuloblastic, very poorly-foliated
" 7891	1	35 (An_{85})	25 (br)	10	20	0	0	0	0	1-2% op, ap	granuloblastic, lineated
" 7892	10-15	25-30 (An_{70})	55 (br)	0	0	0	0	0	0	5% op, bl	granuloblastic, poorly-lineated
	5	35	0	0	40	10	0	3-5	0	5% op, bl	pod
" 7893	1	35 (An_{75})	20 (br)	10	30	0	<5	0	0	3% op, bl	granuloblastic, foliated and poorly-lineated
" 7894	<1	35 (An_{65-70})	55 (br)	0	0	<5	5-10	0	0	<1% op, bl	granuloblastic, poorly-foliated
" 7895	<5	35 (An_{65-75})	55 (br)	0	0	<5	trace	0	0	2% op, ap	granuloblastic, massive
" 7896	<5	40-45 (An_{80})	55 (br)	<5	0	0	0	0	2	ep/cz	fine-grained, blastoporphyritic
" 7897	<1	40 (labradorite/bytownite)	60 (g-br)	0	0	0	0	0	trace	<1% op, ap	granuloblastic, blastophitic
" 7898	0	30 (An_{70-80})	60 (br-g)	0	0	0	0	0	0	0	granuloblastic, lepidoblastic; contains 10% biotite
" 7899	2-3	45-50 (An_{70})	50 (br-g)	0	0	0	0	0	0	1% op, chl	granuloblastic, massive
" 7900	<1	25 (An_{75})	75 (g-br)	0	0	0	0	0	0	<1% op, ap, chl	granuloblastic, well-lineated
" 7901	<5	60 (An_{70})	40 (g-br)	0	0	0	0	0	<1	ap	granuloblastic, massive
" 7902	15	25 (An_{70})	45 (br-g)	0	0	0	0	10	0	5% op, ap	granuloblastic, well-lineated
" 7903	5-10	20-25 (An_{65})	70 (g)	0	0	0	0	0	0	1-2% op	granuloblastic, blastophitic
" 7904	0	60 (An_{70})	40 (br-g)	0	0	0	0	0	0	trace op, bl, ap	granuloblastic, massive
74300289	<1	50 (An_{60})	50 (br)	0	0	0	0	0	trace	1% op, ap	granuloblastic, massive
" 0294	35	20 (An_{70})	<1 (g)	20	0	0	0	25	trace	1% op, ep/cz	granuloblastic, foliated
" 0293	<5	35-40 (An_{65})	55 (g-br)	5	0	0	0	0	0	1% op, ep	granuloblastic, well-foliated
" 0305	1	40 (An_{75})	45 (br-g)	15	0	0	0	0	0	<1% op, ap	granuloblastic, poorly-foliated
" 0315	15-20	35-40 (An_{65-70})	10 (br)	0	25	10	0	0	0	2-3% op, ap	granuloblastic, poorly-lineated
" 0316	1	30 (An_{60})	55 (br)	15	0	0	0	0	0	<1% op, ap	granuloblastic, poorly-lineated

Table 4 (continued):

Registered no.	Georgetown 1:100 000 Sheet area: Field no.	Grid ref.
GSQ 7889	3/762/2	094970
" 7890	4/864/1	997918
" 7891	5/878/4B	156899
" 7892	5/878/4C	156899
" 7893	5/878/4D	156899
" 7894	6/930/2B	067815
" 7895	6/930/2C	067815
" 7896	7/988/14B	130794
" 7897	7/988/15	131800
" 7898	10/146/6D	008675
" 7899	10/146/10	016676
" 7900	10/146/24B	019653
" 7901	10/148/33B	040682
" 7902	11/166/7C	035628
" 7903	11/166/10	035638
" 7904	9/122/13	811704
74300289	6/918/1	786862
" 0294	7/1006/8	718807
" 0293	7/1006/7	741804
" 0305	10/136/7	785680
" 0315	7/1006/10	737775
" 0316	7/1006/18	754805

hornblende grains less than 0.5 mm across. This rock is part of the assemblage which includes amphibolite with pillow-like structures, described above; it probably originated as an extrusive porphyritic basalt.

Two-pyroxene-hornblende ("basic") granulite (Table 4) occurs at grid refs. 156899 (in the Einasleigh River several hundred metres upstream from its junction with McMillan Creek), 997918 (in a tributary of Collins Creek), 067815 (on a hill to the south of the Gulf Developmental Road), and 737775 (about 4 km south of "Mistletoe"). The rocks are characterised by the presence of orthopyroxene (hypersthene, indicated by the 2V angle), which most commonly occurs as highly poikiloblastic, slightly pleochroic, grains up to 2 cm long which contain inclusions of quartz, plagioclase, hornblende, and opaque minerals. The orthopyroxene grains are locally elongate parallel to a hornblende lineation. In most specimens the orthopyroxene has been partly replaced by a colourless to pale green amphibole which rims fresh cores. At grid ref. 067815, orthopyroxene, which is a minor component of the rock at this locality, has been almost completely replaced by the amphibole. Diopside in the basic granulite has a similar habit to orthopyroxene; it is commonly colourless to very pale green, and it too has been partly altered to pale green amphibole. Hornblende is commonly brown in the Z direction. Plagioclase ranges from An_{65} to An_{85}. Cummingtonite grains up to 1.5 mm long are locally associated with orthopyroxene, which they have probably replaced. The cummingtonite grains commonly show lamellar twinning; some are conspicuously zoned and have brown hornblende cores.

Metamorphism

Mineral assemblages in the Einasleigh Metamorphics indicate that most of the rocks have been affected by at least medium to high amphibolite grade regional metamorphism (Fig. 20). Probable granulite facies rocks also occur. The numerous indications of anatexis, especially the nebulite and agmatite which probably formed at the peak of prograde metamorphism, are consistent with the inferred high metamorphic grades. Later greenschist grade metamorphic event/s also affect the rocks.

Sillimanite in the Einasleigh Metamorphics is not accompanied by primary (syntectonic) muscovite, which suggests that it formed above the stability field of the latter mineral under at least upper amphibolite grade conditions. The muscovite flakes which partly replace sillimanite in some of the Einasleigh Metamorphics rocks probably formed during the waning stage of metamorphism as conditions returned to the stability field of muscovite. In most cases the sillimanite was subsequently replaced by sericite.

The colour of hornblende in the Z direction is useful in determining which metamorphic facies various rocks belong to, even though it may be influenced to some extent by the overall TiO_2 contents of the rocks. In general, greenish-brown and brown hornblende of the type which occurs in the metabasites of the Einasleigh Metamorphics characterises the upper amphibolite subfacies and the granulite facies. Bluish rims may be formed by retrogression caused by the introduction of water.

Although diopside begins to appear in calcareous rocks at approximately the threshold of the lower amphibolite subfacies, it is not common in metabasites until the middle or upper amphibolite subfacies (depending on the bulk compositions of the rocks) (Miyashiro, 1973, p. 260). The presence of diopside in many of the Einasleigh Metamorphics metabasites is thus consistent with the rocks being in the upper amphibolite subfacies.

The presence of orthopyroxene in some metabasites indicates that they were probably metamorphosed under grade conditions. It is difficult to say whether the cummingtonite which has replaced some of the orthopyroxene formed at slightly lowered temperatures during the waning stages of the main prograde metamorphism, or at increased P_{H_2O} due to the introduction of water, or if it formed during a separate amphibolite grade event. The presence of hornblende in all of the basic granulites suggests that P_{H_2O} at the time of metamorphism was relatively high compared with conditions during formation of "dry" two-pyroxene granulites which are common in some high-grade terrains.

Granulite assemblages are not present in the "acid gneisses" (metasediments), and occur only sporadically in the metabasites. The probable reason for the first fact is that, although temperatures were high, P_{H_2O} relative to P_{load} was too high in the metasediments to allow orthopyroxene to form; as a consequence of the high P_{H_2O} many of the metasediments underwent almost complete anatexis. It may be that only in the relatively dry interiors of metabasite bodies was P_{H_2O} low enough for hornblende to break down into orthopyroxene. An objection to this theory is that the interiors of many large (several kilometres across) metabasite bodies lack orthopyroxene, whereas the basic granulite near the junction of McMillan Creek and the Einasleigh River occurs in a body only about one metre wide. A possible alternative explanation for the occurrence of orthopyroxene is suggested by the association of this small basic granulite body with migmatite - initial melts in deep-seated rocks contain large quantities of water; as such melts form they should absorb all available water from their surroundings. If water diffused out of small metabasite bodies for this reason their internal P_{H_2O} might be lowered sufficiently for orthopyroxene to form, at least locally (cf. Olsen, 1977). It is possible that temperatures in most places were below, or transitional to, those of granulite grade, and that the threshold which allowed orthopyroxene to form (provided P_{H_2O} was low enough) was crossed only very locally. The problems of granulite formation and occurrence in the Einasleigh Metamorphics, among others, are currently being studied by N. McNaughton as part of a PhD project at the University of Queensland.

Both the first and second deformations (D_1 and D_2 respectively) were accompanied by amphibolite grade metamorphisms. Judging from the fact that, in places, migmatisation apparently accompanied D_2 rather than D_1, the grade during the second deformation was somewhat higher than that during the first. The granulite grade metamorphism at Einasleigh was probably syn-D_2 (N. McNaughton, personal communication 1977). The third deformation, D_3, was probably accompanied by retrograde metamorphism. D_1, D_2, and D_3 have been dated at 1574 ± 28, 1469 ± 20, and 967 ± 28 m.y. respectively (Black, and others, in press).

Widespread alteration of biotite to chlorite, and of sillimanite to sericite, took place under the influence of greenschist grade metamorphism. The timing of this retrogression is uncertain. It could represent merely the end-point of a main prograde event if temperatures dropped slowly enough; in this case it too would be Proterozoic. However, isotopic dating indicates that a major Silurian and/or Devonian thermal event occurred in the Georgetown Inlier and on Cape York Peninsula (Richards & others, 1966; Black, 1973, personal communication 1977; Cooper, and others, 1975; Oversby, and others, 1975). The event completely reset most K-Ar ages, and partly reset Rb-Sr ages, in all older rocks; it probably caused much of the greenschist grade metamorphism, although some also probably occurred during the third (Proterozoic) deformation. Evidence from the Robertson River Metamorphism of the Forsayth 1:100 000 Sheet area (below) supports these conclusions.

Structure

The most conspicuous fabrics in the Einasleigh Metamorphics are compositional layers and foliation in gneiss and migmatite, foliation in schist, and foliation and hornblende lineation in metabasite.

The compositional layers in the gneiss and migmatite (Figs. 5, 6) probably mainly represent original stratification (S_o), which has been modified by transposition and metamorphic differentiation. The best developed foliation at most localities is parallel to these compositional layers. The main foliation in the Einasleigh Metamorphics of the Forsayth 1:100 000 Sheet area was previously thought to be the oldest (Bain, Withnall, & Oversby 1976 p. 37), but there is now evidence of an even older one (T. Bell and J. Patrick, personal communication 1976). This older foliation must thus be S_I, the main one being S_{II}, and all S-surface notations in Bain, Withnall, & Oversby (1976) should be adjusted accordingly. The main foliation in the Georgetown Sheet area is also apparently S_{II}; it probably developed at essentially the same time as the second main amphibolite grade metamorphism and anatexis.

There are several relationships which suggest that the main foliation in the Georgetown Sheet area is probably S_{II}. At grid ref. 997981 (near the junction of the Einasleigh River and McMillan Creek) small isoclinal folds, to which the main foliation is axial planar, appear to deform a foliation which is older than associated migmatites and presumably S_I. In some metabasite outcrops the main foliation is represented by a crenulation cleavage which is parallel to axial planes of isoclinal folds outlined by quartz veins. Local small "hooks" of hornblende in these rocks probably represent a tightly folded early foliation which is deformed by the crenulation cleavage. This early foliation probably represents S_I, while the crenulation cleavage is S_{II}. Foliation in schist is also locally parallel to the axial planes of isoclinal folds which deform quartz veins; this foliation is also believed to represent S_{II}. Lacking data to the contrary, it is thought that the predominant foliation throughout the Einasleigh Metamorphics in the Georgetown Sheet area most probably represents S_{II}.

Structural analyses of the Einasleigh Metamorphics have been made in several areas (Fig. 10). Not all of these areas are structural domains in the strict sense - some simply reflect concentrations of data points and are mainly separated by granitoid and volcanic rocks. The structural analyses are not definitive because the relatively small numbers of data incorporated are scattered over large, structurally complex areas. The following discussion and conclusions are thus preliminary and tentative.

Only a small number of data were collected to the west of the Newcastle Range because of the generally poor exposure. The data plotted in Figure 11 are from the area between "Mistletoe" and the Etheridge River. The best exposures are in cuttings along the Gulf Developmental Road, where at least two sets of folds occur. Folds of both sets have deformed leucogranitoid veins, as well as a foliation equated with S_{II}. Folds of one set are relatively tight, while others are very open. Some other almost isoclinal folds which deform leucogranitoid veins may be B_{I}^{II} structures. Poles to S_{II} foliation planes in the area define two girdles which probably reflects superimposition of the postulated B_{II}^{III} and B_{II}^{IV} folds. Fold axes, mostly measured from the relatively open structures, lie on an almost vertical, north-northwest-striking girdle; none plots near the poles to either of the two girdles defined by foliation planes shown in Figure 11a. The dispersion of the fold axes along a girdle reflects the superimposition of the structures on pre-existing folds, believed to be B_{II}^{III} structures. The girdle should represent the axial plane of the folds if there has been no subsequent deformation; five of the poles to axial planes shown in Figure 11b do plot near the pole to the girdle. The significance, if any, of the apparently random positions of the poles to the remaining three axial planes is not known.

Poles to the main (S_{II}) foliation planes in three subareas east of the Newcastle Range are plotted in Figure 12. The folds most commonly seen in outcrop have a very open style (Fig. 13). Relatively tight folds (Figs. 5, 14), best developed in the McMillan Creek area, are relatively

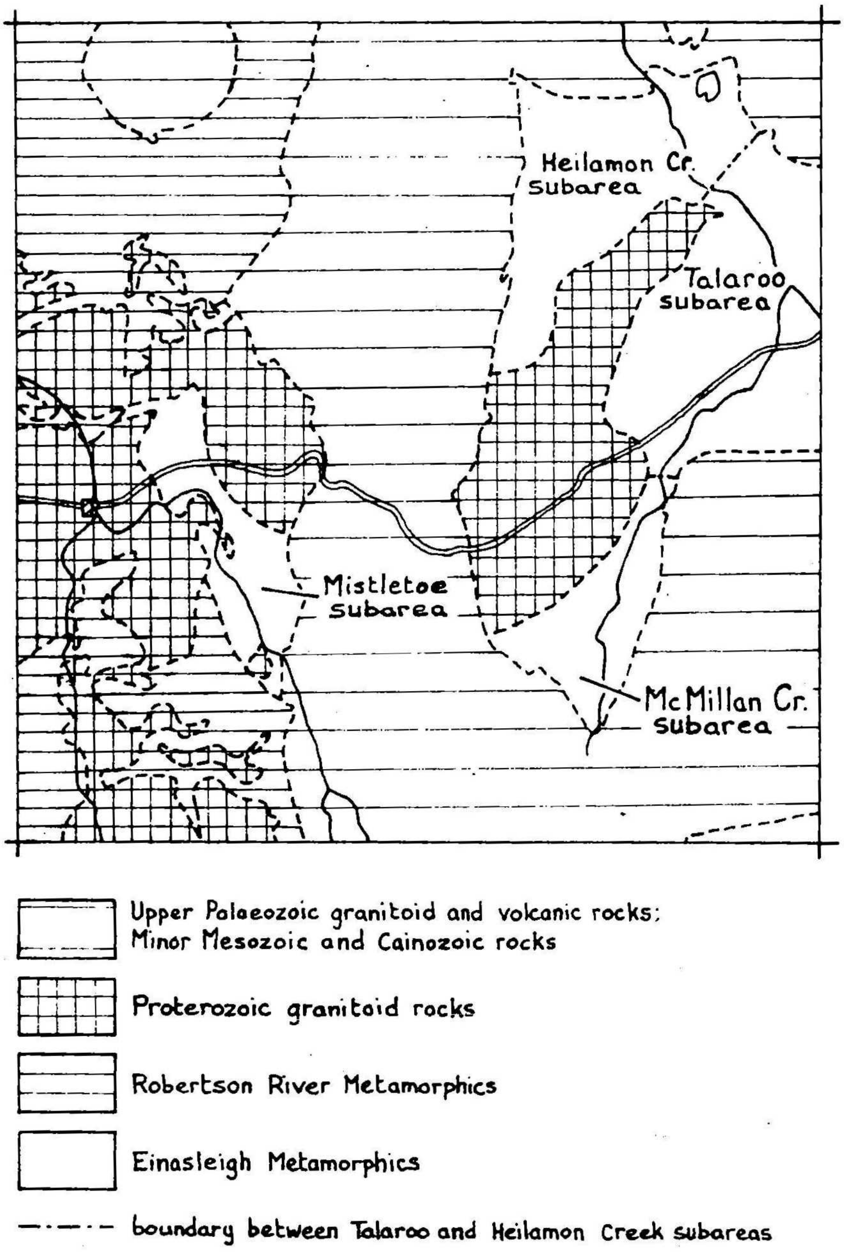

Fig. 10 Structural subareas in the Einasleigh Metamorphics

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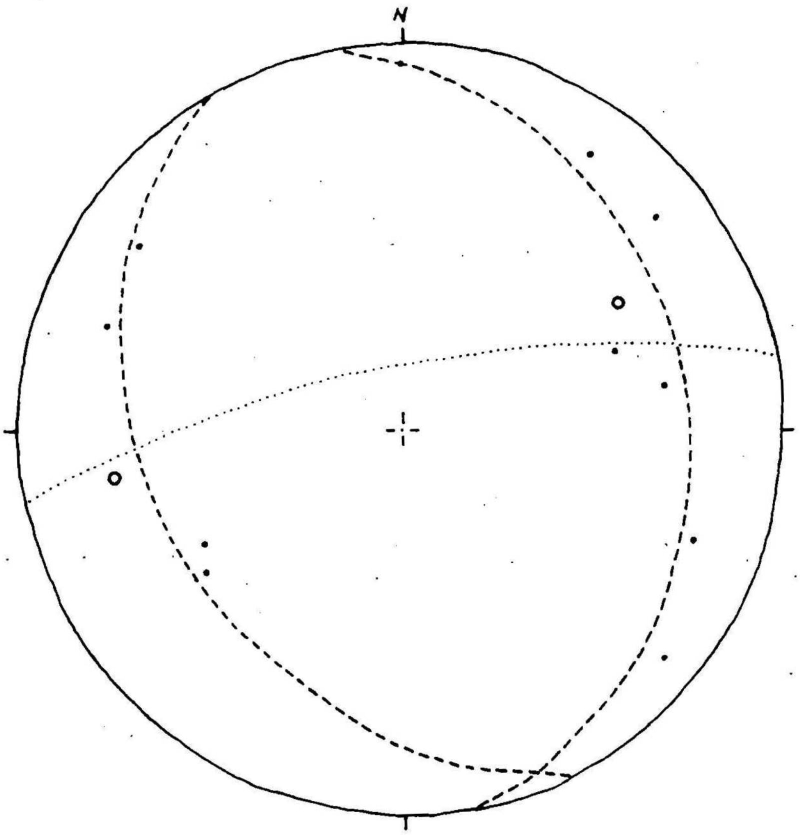
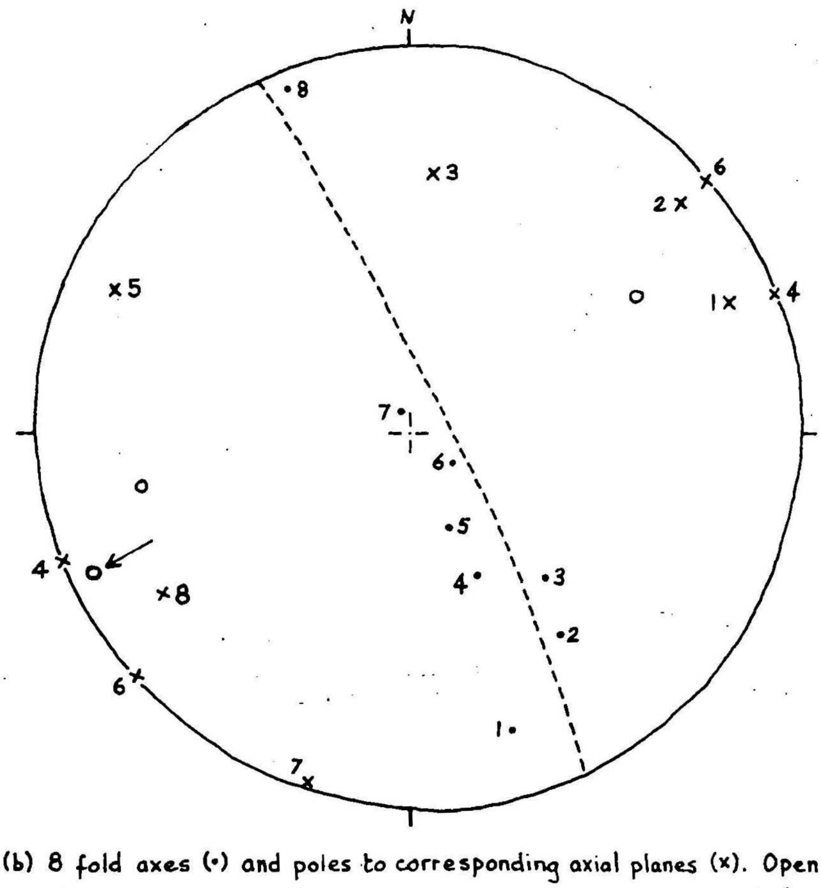
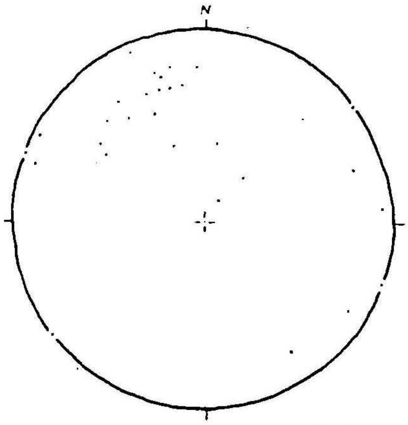


(a) Poles to 10 foliation planes (S_{II}); dotted line is girdle from Fig. 22(h)

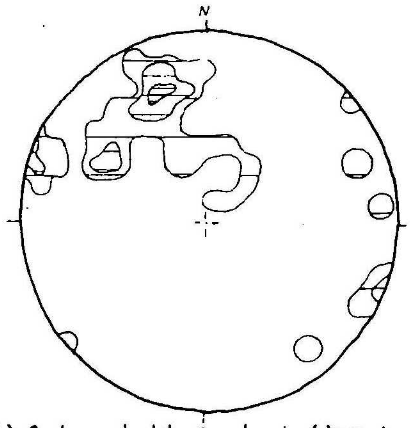


(b) 8 fold axes (•) and poles to corresponding axial planes (×). Open circles in this and succeeding figures are poles to girdles; pole to girdle through fold axes is arrowed

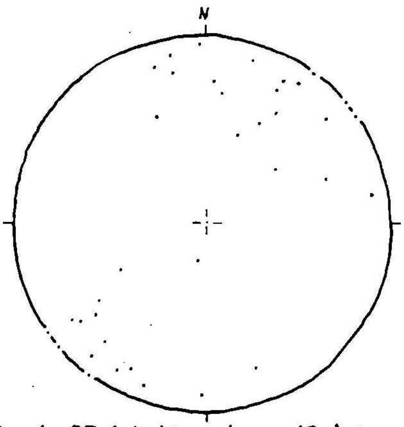
Fig. 11 Structural data from the Einasleigh Metamorphics west of the Newcastle Range (lower hemisphere equal area projection)



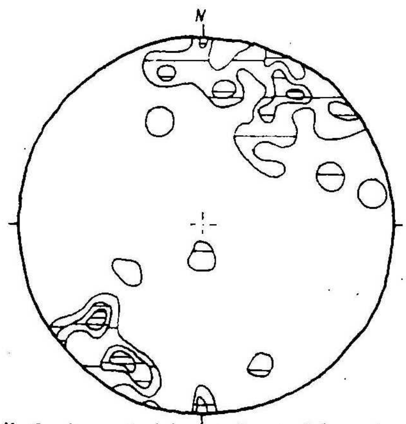
(a) Poles to 26 foliation planes (S_{II}) from the McMillan Creek subarea



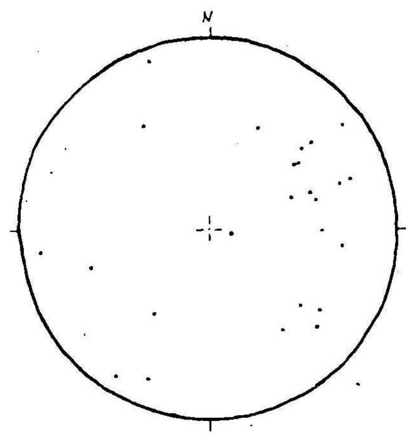
(b) Contoured plot of poles in (a); contours at 4, 8, and 15% per 1% area



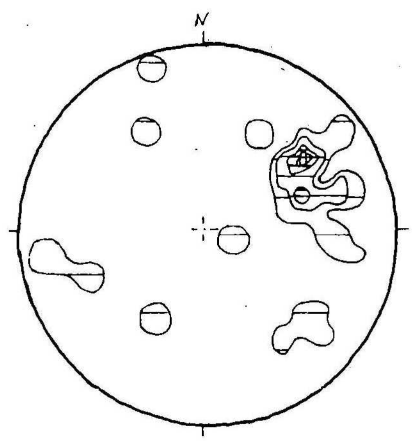
(c) Poles to 35 foliation planes (S_{II}) from the Talaroo subarea



(d) Contoured plot of poles in (c); contours at 3, 5, and 8·5% per 1% area



(e) Poles to 25 foliation planes (S_{II}) from the Heikamon Creek subarea



(f) Contoured plot of poles in (e); contours at 4, 8, 12 and 15% per 1% area

Fig. 12 Sructural data from the Einasleigh Metamorphics east of the Newcastle Range (lower hemisphere equal area projection).

Fig. 13: Partly differentiated S_{III} crenulation cleavage (parallel to pen) cutting across S_{II} (parallel to lithological layering) and folded by probable B_{II}^{IV} structure, Einasleigh Metamorphics. G7/990/26 (grid ref. 091809) - McMillan Creek, 5.2 km west-southwest of "Eveleigh". Photo by I.W. Withnall.

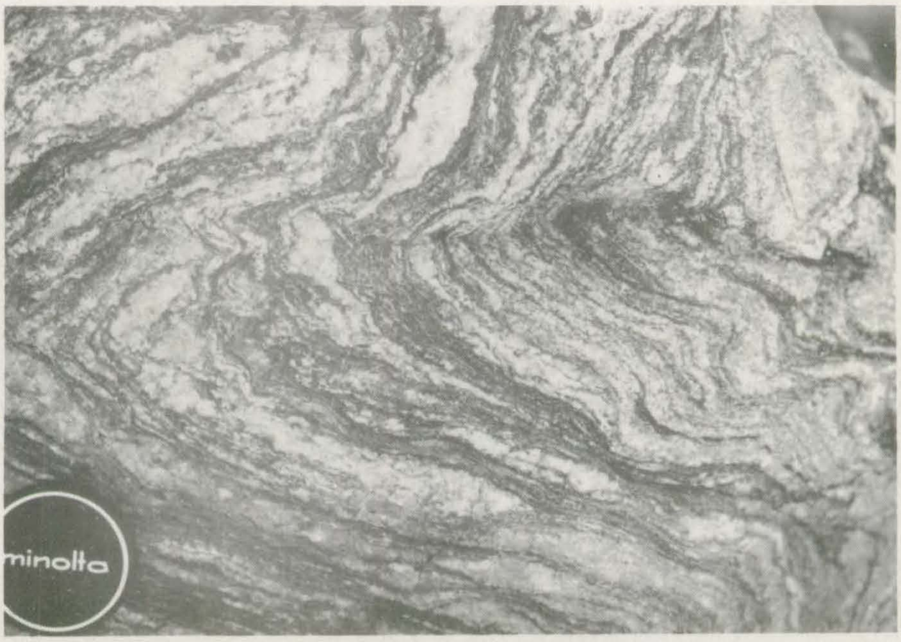


Fig. 14: Migmatite folded by B_{II}^{III} (?) structure, Einasleigh Metamorphics. G2/746/2 (grid ref. 075018) - Einasleigh River, 9.5 km north-northwest of "Talaroo". Photo by I.W. Withnall.

uncommon. These tight folds deform compositional layers and a foliation which is probably S_{II}; they are probably B_{II}^{III} structures, and a conspicuous crenulation cleavage parallel to their axial planes is thus probably S_{III}. A differentiated schistosity is locally developed in more micaceous layers; it is defined by light quartzofeldspathic and dark sericite-rich bands. The subparallel limbs of these tight folds commonly do not show up as separate maxima in plots of poles to foliation planes. In the McMillan Creek subarea, poles to S_{II} foliation planes form a single maximum in the northwestern quadrant of the stereographic projection (Fig. 12a, b), consistent with the presence of tight overturned B_{II}^{III} folds with south-southeast-dipping axial planes. The occurrence of two groups of maxima in the northeast and southwest quadrants respectively of the Talaroo area (Fig. 12c, d) suggests the presence of tight northwest-plunging folds with vertical southeast-striking axial planes. Tight overturned folds with west-southwest-dipping axial planes may be present in the Heilamon Creek subarea (Fig. 12e, f).

The poles to S_{II} foliation planes from the McMillan Creek subarea reflect the predominance of south-southeast dips; they form a similar pattern to the poles of the main foliation in the Einasleigh Metamorphics in the northern half of the Stockman Creek subarea of the Forsayth 1:100 000 Sheet area (Bain, Withnall, & Oversby, 1976, Fig. 38b, c). Vergences of mesoscopic folds in the Stockman Creek area indicate that the rocks are on the northern limb of a major synclinorium. The rocks in the McMillan Creek subarea are probably also on the northern limb of this major synclinorium which is probably a B_{II}^{IV} structure (the same as $B_{S_1}^{S_3}$ of Bain, Withnall, & Oversby, 1976). Although poles to S_{II} foliation planes in the Heilamon Creek subarea show a broad scatter, there is an indication that west-southwest dips predominate. The rocks may thus be on the overturned northwestern limb of a major B_{II}^{IV} anticlinorium whose axial trace passes somewhere between the McMillan and Heilamon Creek subareas.

The positions of the various maxima of poles to S_{II} foliation planes (which have different absolute values) in all subareas, as well as the maximum from the northern Stockman Creek area, are shown in Figure 15b. The fact that two girdles (A' and B', with corresponding poles A" and B") can be drawn through the maxima suggests an interference pattern. Whether this pattern is due to the interference of B_{II}^{III} and B_{II}^{IV} folds, or of the latter and some younger (unidentified) set (e.g. B_{II}^{V}) cannot be ascertained from the limited number of data.

Most of the fold axes measured in the Talaroo and McMillan Creek subareas plot near the girdle through poles A" and B" (Fig. 15c). Points 2, 4, 5, 7, and 8 represent axes of open folds which probably belong to the B_{II}^{IV} set. The other points belong to tighter folds with more uncertain affiliations. Axes 1 and 3, measured in the Talaroo subarea, belong to tight folds; they plot in positions where the orientations of S_{II} foliation planes (Fig. 12d) suggest that $B_{S_{II}}^{S_{III}}$ folds in this subarea should lie.

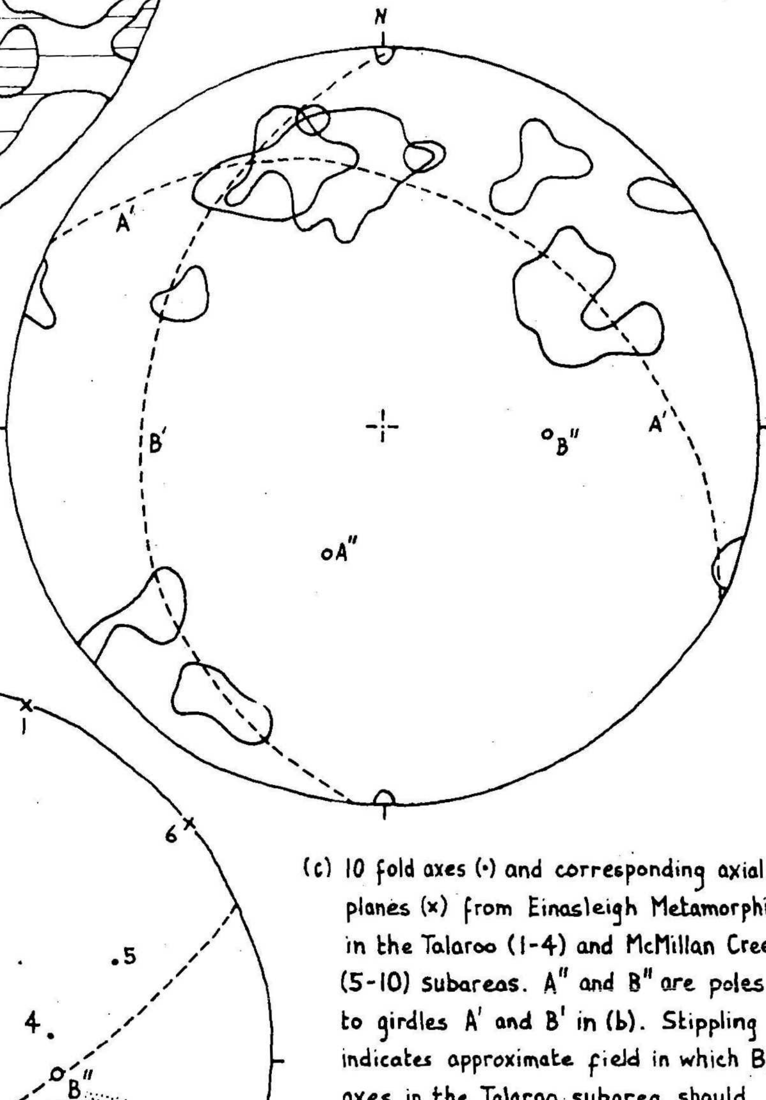
The spread of the fold axes along the girdle through A" and B" could be due to the folds having been superimposed on older fold surfaces. If this is the case, then the girdle indicates that the axial planes of B_{II}^{IV} folds strike approximately east-northeast and dip steeply south. This is consistent with the fact that measured axial planes of such folds (Fig. 15c, nos. 4, 5, 7, and 8) strike approximately northeast. Alternatively, later folding may have reoriented the axes. In any case, the axes of B_{II}^{IV} folds to the east of the Newcastle Range appear to have a different trend from that of the open folds to the west. The open folds in the latter area might actually be a later generation (B_{II}^{IV}) since they plot on a north-northwest girdle - this trend is the same as that of S_5 in the Robertson River Metamorphics (below).

In summary, the Einasleigh Metamorphics in the Georgetown 1:100 000 Sheet area show evidence of an early deformation whose structures have been almost completely obliterated by later isoclinal folds and associated foliation (S_{II}). This second deformation produced the most conspicuous structures in the rocks, and probably took place at essentially the same time as amphibolite grade regional metamorphism. At least two sets of younger structures also occur. Tight folds with associated crenulation cleavage are folded by open folds; these are believed to be B_{II}^{III} and B_{II}^{IV} or B_{II}^{V} structures respectively.

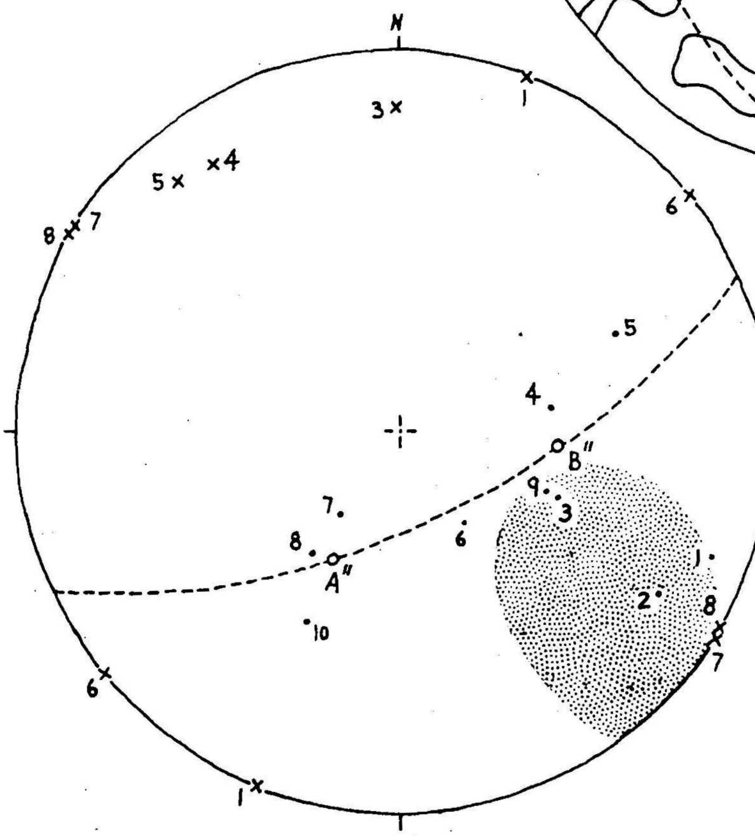
Origin and age

The Einasleigh Metamorphics represent a sequence of sedimentary, intrusive, and possible extrusive rocks which have been multiply deformed and intensely metamorphosed. The first deformation has been dated (Rb-Sr

(a) Contoured plot of 120 poles to foliation planes (S_{II}) from Einasleigh Metamorphics east of the Newcastle Range (Georgetown 1:100 000 Sheet area), and the northern Stockman Creek area (Forsayth 1:100 000 Sheet area). Contours at 0·8, 1·6, 2·5, 3·3, 5·0, 6·7, and 8·3% points per 1% total area.



(b) Plot of foliation (S_{II}) maxima from subareas in Fig. 12 and Stockman Creek area (Bain, Withnall, and Oversby, 1976, Figs 38b, c)



(c) 10 fold axes (·) and corresponding axial planes (x) from Einasleigh Metamorphics in the Talaroo (1-4) and McMillan Creek (5-10) subareas. A'' and B'' are poles to girdles A' and B' in (b). Stippling indicates approximate field in which B_2^3 axes in the Talaroo subarea should plot

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Fig. 15 Structural data from the Einasleigh Metamorphics east of the Newcastle Range; synoptic diagrams and plots of fold axes and axial planes (lower hemisphere equal area projection) total-rock) at 1574±28 m.y. (Black & others, in press), and deposition of the unit must have antedated this; it is tentatively assumed to have taken place in mid-Proterozoic time. The biotite gneiss may originally have been a laminated to thin-bedded feldspathic sand or silt with a variable proportion of clayey matrix. The quartzite may represent a more siliceous, iron-poor equivalent of the sediment which formed the gneiss, whereas schist may have been derived from more potassic clay or silt. Metabasite evidently originated mainly as basalt to dolerite sills and dykes, and gabbro stocks, although some submarine basalt lava flows may have been extruded locally.

It is assumed that there are no Archaean rocks within the Einasleigh Metamorphics. If there are, we cannot recognise or map them separately from the mid-Proterozoic(?) part of the unit on the basis of currently available data.

Mineralisation

Few mineral deposits are known to occur in the Einasleigh Metamorphics and associated metabasite of the Georgetown 1:100 000 Sheet area. The following summary of the main occurrences has been condensed from Withnall (in preparation), who gives a more complete account and bibliography.

The Overland Telegraph (No. 40 on map) is the only auriferous reef of any significance to have been worked in the Einasleigh Metamorphics. The reef was the first one worked in the Georgetown district, and yielded a recorded total of 2403 g of gold bullion from 1009 tonnes of ore between 1870 and 1913.

Most of the copper won in the Georgetown Sheet area came from the oxidised and secondarily enriched upper parts of sulphide-bearing quartz veins, stockworks, and shear zones in the Einasleigh Metamorphics. The copper-bearing deposits occur in the McMillan Creek and "Talaroo" areas, to the east of the main Newcastle Range. The greatest quantity of copper was obtained from the Questend mine (No. 93 on map), which produced 11.7 tonnes of copper (and 8843 g of silver) from 67.7 tonnes of ore (mainly malachite and azurite with minor cerargyrite). The original (pre-metamorphic) source of the copper might have been metabasite (Eme_3), although patchy radioactivity and rare fluorite associated with some deposits (such as the Questend) may provide a link with the important late Palaeozoic uranium-fluorine-molydbenum association at the Maureen prospect north of Georgetown (O'Rourke, 1975), and elsewhere in northeastern Queensland (Bain, 1977).

Some copper was also obtained from the Eveleigh mine (No. 34 on map), which was mainly a lead and silver producer. Mineralisation at this mine occurs both in quartz veins and as disseminations. The presence of disseminated mineralisation, in conjunction with an apparent lack of host rock alteration locally, suggests an original pre-metamorphic age for the mineralisation, with subsequent widespread mobilisation into fissures. The possibility that some of the metabasite near the mine might be of extrusive origin (above) introduces the possibility that at least some of the sulphide mineralisation could have had a volcanogenic origin. The occurrence of stratabound disseminated zinc mineralisation (which has not been worked) in calc-silicate-bearing metasedimentary rocks interlayered with amphibolite at a prospect (no. 35 on map) about 600 m south of the Eveleigh mine reinforces the possibility.

Robertson River Metamorphics (Ꞓmr)*, and Cobbold metadolerite (Ꞓmc)

Introduction

White (1959c, pp. 444-445) named and defined the Robertson River Metamorphics, and listed previous references. In the Georgetown 1:100 000 Sheet area the unit consists mainly of mica schist and quartzite, with local graphitic schist; it is intruded by bodies of metabasite assigned to the Cobbold metadolerite (informal variation of White's (1959c, p. 446) Cobbold Dolerite). About 400 km^2 of the western third of the Sheet area are underlain by the Robertson River Metamorphics and Cobbold metadolerite.

Low undulating topography characterises areas underlain by the two units; outcrops tend to be relatively poor. Most of the area supports open woodland dominated by Georgetown box (*Eucalyptus microneura*) accompanied by various species of ironbark and bloodwood. The ground cover consists predominantly of various three-awn grasses (*Aristida* spp.); areas with dense growths of deciduous quinine bush (*Petalostigma banksii*) occur locally.

The thickness of the Robertson River Metamorphics is not known, mainly because of the complex polyphase deformation which the unit has undergone. Sills of Cobbold metadolerite range in thickness from a few metres to almost one kilometre; thicknesses of 100 to 500 m are most common. Some of the sills probably extended for more than 10 km along strike before being folded. In the northwestern corner of the sheet area stocks of metagabbro (locally recrystallised to amphibolite) up to 3 km across occur. The Cobbold metadolerite appears to be distributed throughout the Robertson River Metamorphics, with no preference for any particular stratigraphic level.

* Field research in the Gilberton, North Head, and Forest Home Sheet areas has shown that the Robertson River Metamorphics are the schist phase of part of the lowermost Etheridge Formation (*sensu* White, 1959c). It is proposed to raise the Etheridge Formation to group status, and to define a Robertson River Formation within it, comprising both slate and schist phases. Robertson River "Metamorphics" would thus be the informal name for the schist phase of the Robertson River Formation.

Ᵽmr$_2$ (quartzite) and Ᵽmr$_3$ (banded calc-granofels), which were differentiated in the Forsayth 1:100 000 Sheet area (Bain, Withnall, & Oversby, 1976, pp. 25, 26), do not form mappable subunits in the Georgetown Sheet area.

Lithology and petrography

(a) Mica schist

Mica schist is the dominant rock type present in most outcrops of the Robertson River Metamorphics, although a high proportion of quartzite occurs in some areas. The mineralogy of the schist is variable and depends on the metamorphic facies in which any particular occurrence lies. Most primary (sedimentary) structures other than gross lithology layering in schist have been obliterated by transposition and metamorphism, although chaotic, disharmonically folded, laminae in some bands at grid ref. 679977 (Fig. 16) may reflect soft-sediment slumping.

Fine- to medium-grained biotite-muscovite-quartz schist (Table 5) of the lower amphibolite subfacies occurs in the westernmost part of the outcrop area. It is grey to greyish yellow when fresh. Muscovite predominates over biotite in the rock; both micas occur as parallel flakes up to 1.5 mm long which define the schistose foliation. This foliation is locally crenulated, and two foliations can be recognised in some outcrops. Zircon, apatite, and tourmaline are minor accessory minerals. Andalusite occurs locally as conspicuously poikiloblastic porphyroblasts up to 2 cm long; most of these porphyroblasts occur in discrete layers. Garnet and staurolite porphyroblasts, up to 3 mm and 5 mm in maximum dimension respectively, accompany the andalusite locally. Some andalusite prophyroblasts have staurolite cores. Sericite has replaced some of the andalusite. Sporadic aggregates of muscovite and biotite were probably produced by the prograde metamorphism of staurolite. Andalusite-bearing schist commonly has a conspicuous biotite-rich and poor compositional layering. Biotite-rich layers contain subequant poikiloblastic porphyroblasts of biotite between 1 and 3 mm long; some of these porphyroblasts are parallel to a locally developed second foliation defined by muscovite and elongate quartz grains. The first foliation, most commonly defined by differentiated layers

Table 5: Visually estimated modal compositions of schist, Robertson River Metamorphics. See Table 1 for abbreviations used.

Registered no.	Q	Kf	Pl	Bi	Chl	Ser	Mu	Mu*	Ga	Sill	Andal	Staur	C	Acc
74300091	50	0	0	0	20	25	0	5	trace	trace	0	0	0	0
" 0092	70	0	0	10 - 15		10-15	0	<5	0	trace	0	0	0	0
" 0095	35	0	0	0	15	45	0	5	0	0	0	0	0	0
" 0100	50	0	5-10	15	0	20	0	5	0	trace	0	0	0	0
" 0101	60	0	5-10	15-20	0	0	0	10-15 (+ser)	0	trace	0	0	0	0
" 0104	50	0	trace	5	10	30	0	5	0	0	0	0	0	0
" 0105	<5	0	0	40	0	0	55	0	0	0	0	0	0	0
" 0108	30	0	0	25	0	25	20	0	trace	0	0	0	0	0
" 0252	30	10		30	0	20	0	0	trace	5	0	0	0	0
" 0257	50	0	0	5	0	45	0	0	0	trace	0	0	0	0
" 0261	50	0	0	5	0	40	0	<5	0	<5	0	0	0	0
" 0264	65	0	5	5		20	0	5	0	trace	0	0	0	0
" 0265	15	0	0	15		45	0	25	0	0	0	0	0	0
" 0266	45	0	0	0	15-20	25	0	15-20	0	0	0	0	0	0
" 0267	50	0	0	0	15-20	20-25	0	10	0	0	0	0	0	0
" 0268	30	0	0	25	0	0	40	0	<1	0	<5	0	0	0
" 0271	70	0	0	5	0	<5	25	0	0	0	0	0	0	0
" 0272	30	0	0	15	0	0	35	0	<1	0	20	trace	0	0
" 0273	65	0	0	10	0	0	15	0	0	0	10	0	0	0
" 0274	similar to 74300273													
(well-banded schist) " 0276	80-85	0	0	1	0	0	15	0	0	0	0	0	0	<5% op
	<5	0	0	35	0	0	65	0	0	0	0	0	0	0
	5-10	0	0	25	0	15	30	0	<5	trace	30	<5	0	0
" 0277	30	0	0	20	0	15	35	0	0	0	0	0	0	0
" 0279	40	0	0	10	0	0	50	0	0	0	0	0	0	0
" 0281	60	0	<5	0	10	5-10	0	20	0	0	0	0	0	0
" 0287	45	0	0	trace	15	40	0	<5	trace	0	0	0	0	0
" 0296	60	0	0	5		35	0	<5	0	0	0	0	0	0
" 0297	45	0	15	35	0	trace	0	trace	0	5	0	0	0	0
" 0299	45	0	0	0	0	25	0	10	0	<1	0	0	0	0
" 0300	35	5	10	10	5	30	0	0	0	5	0	0	0	0
" 0309	40	<5	<5	20	0	20	0	0	1	15	0	0	0	0
" 0310	65	0	<5	1-2	10	20	0	0	0	0	0	0	0	0

Table 5 (continued):

Registered no.	Q	Kf	Pl	Bi	Chl	Ser	Mu	Mu*	Ga	Sill	Andal	Staur	C	Acc
74300312	70	10-15	<5	15	0	<1	0	1	0	0	0	0	0	0
" 0313	50	<5	15	20	0	15	0	<5	0	0	0	0	0	0
" 0318	30	0	0	20	0	40	0	10	0	trace	0	0	0	0
" 0320	60	25	5	5-10	0	0	0	5-10	0	<1	0	0	0	0
" 0323	30	0	0	0	10-15	50	0	<5	0	0	0	0	0	0
" 0326	70	20	<5	10	0	<5	0	<5	0	1	0	0	0	0
" 0327	50	<5	<5	20	0	0	0	25	0	<5	0	0	0	0
" 0331	65	trace	0	10	0	0	25	0	0	0	0	0	0	0
" 0337	25	0	0	10	0	0	65	0	0	0	0	0	0	0
" 0339	20	0	0	20	0	30 (Ser + Mu)		0	0	0	10	0	10-15	0
" 0505	65	10-15	0	0	0	5	0	<5	0	5-10	0	0	5	0
GSQ 7879	40	0	20	10-15	0	10	0	<5	0	0	0	0	0	0
" 7880	25-30	0	5-10	25	0	40	0	5	0	trace	0	0	0	0
" 7881	20	0	0	25	0	25	0	30	0	<5	0	0	0	0
" 7882	70	0	5-10	10-15	0	5-10	0	<5	0	0	0	0	0	0
" 7883	35	0	0	20	0	0	25	0	<5	0	20	0	0	0
" 7884	80-85	0	0	<1	0	0	10	0	0	0	0	0	<5	0
" 7885	30	0	10	20	0	15	0	25	0	trace	0	0	0	0
" 7886	65	0	10	15	0	0	0	5	0	5	0	0	0	0

Registered no.	Georgetown 1:100 000 Sheet area	
	Field no.	Grid ref.
74300091	3/774/8	785983
" 0092	3/774/7A	795983
" 0095	2/728/1	680026
" 0100	2/734/11B	811002
" 0101	2/734/11A	811002
" 0104	1/712/33	825048
" 0105	1/712/32B	829052
" 0108	1/712/29A	826069
" 0252	1/718/5A	696062
" 0257	1/720/4	662072
" 0261	2/728/3	655031
" 0264	3/774/4	791991
" 0265	3/776/1B	733966

Registered no.	Georgetown 1:100 000 Sheet area	
	Field no.	Grid ref.
74300266	3/776/6	747974
" 0267	3/778/1	733966
" 0268	3/778/2	699964
" 0271	3/780/1	662991
" 0273	3/780/12A	659951
" 0273	3/780/12A	659951
" 0274	3/780/12B	659951
" 0276	4/850/3B	715939
" 0277	4/850/3C	715939
" 0279	4/848/6	662948
" 0281	4/852/9	739951
" 0287	6/914/2	720866
" 0296	10/132/3	692682
" 0272	3/780/5	686974

Table 5 (continued):

Registered no.	Field no.	Grid ref.
	Georgetown 1:100 000 Sheet area	
74300297	10/132/4	696677
" 0299	10/132/16	702649
" 0300	10/136/1	779650
" 0309	10/136/13	773668
" 0310	10/136/15	768663
" 0312	11/182/7	714615
" 0313	11/182/9A	726616
" 0318	7/1006/18	754805
" 0320	7/1010/2	678799
" 0323	11/180/7	746644
" 0326	11/180/9C	754629
" 0327	11/184/1	670649
" 0331	11/184/6	666615
" 0337	11/184/16	647621
" 0339	11/184/21	633633 (Forest Home 1:100 000 Sheet area)
" 0505	13/276/1A	691534
6SQ 7879	11/178/14	801611
" 7880	11/178/15	802605
" 7881	12/408/14C	788569
" 7882	12/408/18	796608
" 7883	13/274/1	649550
" 7884	13/274/4	650534
" 7885	13/282/28	823525
" 7886	13/282/7	824538

Fig. 16: Disharmonic soft-sediment (?) folds in schist, Robertson River Metamorphics. G3/780/8 (grid ref. 679977) - spillway of dam across tributary of Mistake Creek, 20 km north-northwest of Georgetown. Photo by I.W. Withnall.

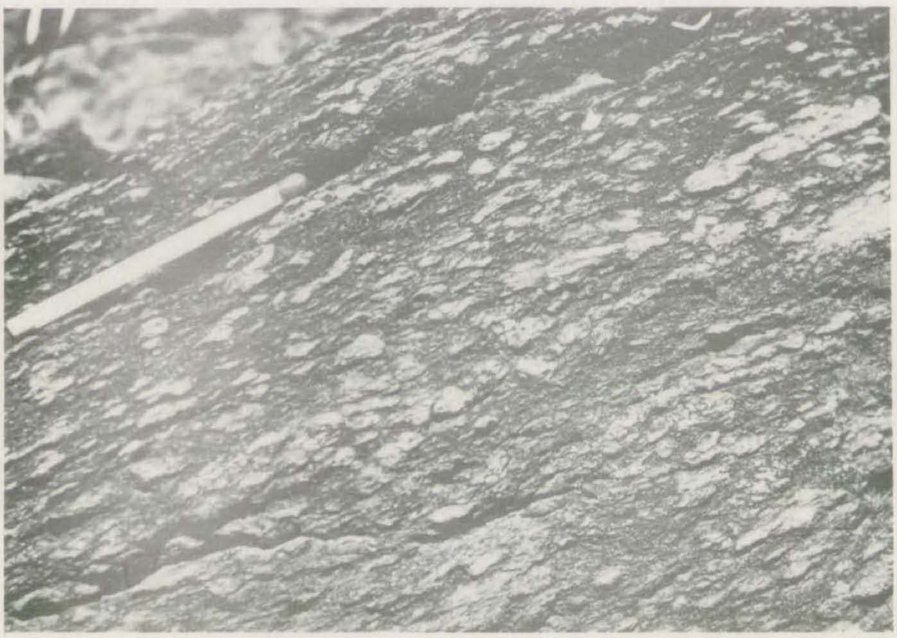

Fig. 17: Sillimanite-quartz "knots" in schist, Robertson River Metamorphics. G12/408/21 (grid ref. 787606) - tributary of Machine Creek, about 5 km southeast of Lighthouse Mountain. Photo by I.W. Withnall.

of muscovite, is parallel to compositional layering in all outcrops except those in the westernmost part of the Georgetown Sheet area, where it is cross-cutting.

Biotite-muscovite-quartz schist also occurs in the middle amphibolite subfacies, but it can only be distinguished in the absence of other rock types when it contains sillimanite accompanied by syntectonic muscovite (Table 5).

Biotite-sericite-quartz schist, with sporadic chlorite, muscovite, plagioclase, sillimanite, and garnet (Table 5), characterises the upper amphibolite subfacies. This schist is widespread in the Robertson River Metamorphics, to the east of that in the lower and middle amphibolite subfacies (cf. Fig. 20). The feldspar content of the schist is commonly low, although plagioclase increases markedly to the southeast of Georgetown. Sporadic microcline and orthoclase have been replaced by myrmekite locally. Biotite and lenticular sericite aggregates commonly define the main foliation; traces of a subsidiary (older) foliation are preserved locally. Biotite occurs as reddish brown flakes up to 2 mm long, which have been partly or wholly chloritised locally. Most sericite occurs as lenticular aggregates between 1 and 10 mm long; it evidently formed from sillimanite which occurs as cores in some of the aggregates. Irregular muscovite flakes between 0.5 and 3 mm long are commonly associated with the sericite aggregates, partly rimming many of them. Most of the muscovite flakes cut across the foliation and commonly contain sillimanite inclusions. These inclusions are made up of fine needles up to 0.5 mm long in fasciculate bundles. In the headwaters of Talbot and Machine Creeks sillimanite also occurs in aggregates with quartz (Fig. 17). The aggregates are up to 1 cm long, and are sheathed (and partly pseudomorphed) by muscovite. Subidioblastic grains, up to 1 mm across, of garnet occur in the rock locally.

(b) Graphitic schist

Graphitic schist occurs only in the southwestern corner of the Sheet area where it has been locally intruded by Forsayth Granite in which it occurs as roof pendants. The rock is dark grey to black, and commonly has basically the same mineralogy as associated mica schist, although it is much finer-grained. Graphite almost invariably constitutes much less than

5 percent of the schist, although up to 10 percent occurs locally (Table 5). Minute specks of graphite less than 0.05 mm across are dispersed along quartz grain boundaries or included in muscovite and andalusite. Andalusite (var. chiastolite) porphyroblasts up to 3 cm long and 5 mm across are common in the very fine-grained graphitic schist exposed to the west of Sandy Creek, in the southwestern part of the Georgetown 1:100 000 Sheet area. Farther east the andalusite has been replaced by sericite lenses.

(c) Quartzite

Quartzite layers range in thickness from less than one centimetre to several metres. Both bounding surfaces of the layers are commonly sharp, although quartzite locally grades into mica schist. Those parts of the Robertson River Metamorphics which contain a high proportion of quartzite have been differentiated as a separate subunit, Pmr_1, on the map. Most of the quartzite is grey and fine-grained, and commonly contains quartz and feldspar with minor muscovite, biotite, sericite, or sillimanite (Table 6), depending on the metamorphic facies. The average grainsize is less than 0.5 mm. Quartz occurs as a granoblastic mosaic of subequant to elongate grains. Elongate quartz and parallel mica flakes define a weak foliation; the rock grades into mica schist with an increase in the mica content. Quartzite commonly contains more feldspar than adjacent schist; most of the feldspar is plagioclase.

Quartzite which contains calc-silicate minerals occurs locally in the Robertson River Metamorphics. The rock consists mainly of quartz and plagioclase (commonly andesine or labradorite) accompanied by up to 10 percent hornblende and up to 2 percent sphene (Table 6). Grains average less than 0.3 mm across. Clinozoisite and tremolite occur rather than plagioclase and hornblende in equivalent lower amphibolite grade rocks.

White pure quartzite (Pmr_2), like that in the Tin Hill area of the Forsayth 1:100 000 Sheet area (Bain, Withnall, & Oversby, 1976, p. 25) is rare; the only known occurrence is at grid ref. 783945, 3.5 km northwest of Fiery House outstation (registered no. 74300284, Table 6).

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Table 6: Visually estimated modal compositions of quartzite, Robertson River Metamorphics. See Table 1 for abbreviations used.

Registered no.	Q	Kf	Pl (composition)	Mu	Ser	Bi	Chl	Hbl	Sill	Acc
74300260	60	0	30 (An_{65-70})	0	0	0	0	5-10	0	sp, zr, ap
" 0278	65	0	30	1-2	0	0	1-2	0	0	ap, sp, cal, cz
" 0284	95-100	0	0	0	<5	0	0	0	0	
" 0329	70	0	25	0	0	0	0	5-10	0	sp, ap, op, cz
" 0322	70	25	<5	0	0	2-5	0	0	0	zr, ap
" 0335	75	0	20	5	0	0	0	0	0	ap, sp
" 0308	65	10-15	20-25	0	0	2-3	0	0	0	zr, ap
GSQ 7877	70-75	0	20-25	1-2	1-2	5	0	0	0	zr, ap
" 7878	65-70	0	25-30	1-2	0	5	0	0	trace	zr, ap
74300336	60; plus 40% clinozoisite and 1-2% tremolite; Acc sp, ap									

Registered no.	Georgetown 1:100 000 Sheet area: Field no.	Grid ref.
74300260	2/734/38	799017
" 0278	4/848/2A	665940
" 0284	4/854/9	783945
" 0329	11/184/38	679639
" 0322	10/134/10	732659
" 0335	11/184/12	655604
" 0308	10/136/12	772676
GSQ 7877	12/408/7	805588
" 7878	12/408/19	793607
74300336	11/184/14C	651628

(d) Metabasite (Cobbold metadolerite)

The smaller metabasite bodies in the Robertson River Metamorphics of the Georgetown 1:100 000 Sheet area consist mainly of foliated or lineated medium-grained amphibolite. Larger bodies are mostly massive or poorly lineated; they consist of granuloblastic amphibolite in areas affected by high-grade metamorphism. Amphibolite locally retains ophitic textures characteristic of intrusive dolerite and gabbro. Metadolerite and metagabbro with well preserved igneous textures occur in areas affected by lower-grade metamorphism, such as that to the west of the Delaney River in the southwestern part of the Georgetown Sheet area. Some of the metabasite bodies in the northwestern part of the Sheet area contain probable primary igneous layers (Fig. 18); alternating hornblende- and plagioclase-rich layers up to 30 cm thick occur in a small stock and a sill at grid refs. 697073 and 824076 respectively. No pillows, amygdales, or textures suggestive of an extrusive origin are known to occur in metabasite in the Georgetown Sheet area, and on this basis it is assumed that most, if not all, of the rocks have an intrusive origin. Foliation in metabasite bodies, where present, is invariably parallel to that in the enclosing Robertson River Metamorphics, indicating that the rocks have been deformed together.

The metadolerite and metagabbro are medium- to coarse-grained dark green to greenish black rocks, and consist mainly of plagioclase and hornblende (Table 7). Plagioclase occurs as randomly oriented laths 0.2 to 1.5 mm long with embayed margins and small patches which have recrystallised to microgranular mosaics in the rocks which have well-preserved igneous textures (mostly in the lower or middle amphibolite facies). Hornblende has two main modes of occurrence: (i) as pale green "stumpy" to subequant grains and prisms up to 3 mm long lying between the plagioclase laths (intersertal texture), and as slender prisms within the plagioclase; (ii) as subequant crystals up to 1 cm long enclosing randomly oriented plagioclase laths (blastophitic texture). In both modes of occurrence the main hornblende grains contain inclusions of small idioblastic hornblende crystals which have different crystallographic orientations to that of the host. Some hornblende in rocks whose plagioclase has recrystallised has a blastophitic habit, and the rocks have retained an igneous appearance. Rocks which do not retain igneous textures contain plagioclase (calcic andesine to

Table 7: Visually estimated modal compositions of Metabasites, Cobbold Metadolerite. See Table 1 for abbreviations used.

Registered no.	Q	Pl (composition)	Hbl (colour)	Cumm	Di	Ga	Ep/Cz	Sp	Acc	Remarks
74300090	trace	25–30	70–75 (br–g)	0	0	0	0	0	1% op	massive
" 0096	35	15	50 (bl–g)	0	0	0	0	<1	1% op	weak foliation
" 0097	0	0	60 (bl–g)	0	0	0	35	5	0	altered by Yataga Granodiorite; weak foliation
" 0102	5–10	50–55(labradorite)	40 (br–g)	0	0	0	0	<1	<1% op,ap	blastophitic, massive
" 0103	<5	10–15(labradorite)	85 (bl–g)	0	0	0	0	0	1–2% op	weak lineation
" 0106	<1	75 (An_{70})	20 (g)	0	0	0	0	trace	0	massive leucogabbro with some primary (?) augite
" 0107	<1	25(labradorite)	70 (bl–g)	0	0	0	0	<1	<1% op	massive; some primary (?) augite
" 0109	<1	5	85 (g)	0	0	0	0	0	2% op	5–10% actinolite; weak foliation
" 0253	<5	25–30 (An_{60})	65 (br–g)	0	5	0	0	<1	<1% op	granuloblastic, massive
" 0254	<5	65–70 (An_{60})	30 (br–g)	0	0	0	0	trace	trace op	massive granuloblastic leucogabbro
" 0255	<1	40 (An_{55-60})	60 (g–br)	0	0	0	0	0	1% op	granuloblastic; very weak lineation
" 0256	trace	15	85 (g–br)	0	0	0	0	0	<1% op	well foliated
" 0258	20	40 (An_{45-50})	40 (br–g)	0	0	0	trace	trace	ap	foliated
" 0259	<5	25	70–75 (g)	0	trace	0	0	0	<1% op, ap	massive
" 0262	<5	45–50 (An_{60})	50 (br–g)	0	0	0	0	<1	0	weak layering and foliation
" 0263	<1	10 (An_{55-60})	90 (br–g)	0	0	0	0	0	<1% op	blastophitic, massive
" 0269	<5	20–25 (An_{45})	70–75 (bl–g)	0	0	0	0	0	1–2% op,ap	massive
" 0270	1	30–35 (An_{40})	60–65 (bl–g)	0	0	0	0	trace	<5% op, ap	sheared or foliated
" 0275	10–15	30–35	45–50 (bl–g)	0	5–10	0	0	1–2	ap	weak foliation
" 0280	<5	20	75 (g–br)	0	0	0	0	0	1–2% op	granuloblastic; weakly lineated
" 0283	1	45 (An_{45-50})	55 (br–g)	0	0	0	0	0	1% op	granuloblastic; strongly lineated and foliated
" 0311	10	20 (An_{65-70})	60–65 (br–g)	5–10	0	trace	0	0	1–2% op,ap,bi	
" 0314	0	<5	70 (bl–g)	0	0	0	1–2	trace	ap	25% microcline; K-metasomatised
" 0319	<5	35–40 (An_{65})	60 (g–br)	0	0	0	0	0	1% op	fine-grained; weak lineation
" 0325	10–15	15–20 (An_{60})	70 (g)	0	0	0	0	0	1–2% op, ap	granuloblastic; weakly lineated
" 0328	0	40 (An_{65})	60 (g)	0	0	0	0	0	<1% op, ap	well-preserved gabbroic texture- blastophitic Hbl and Pl laths
" 0333	<1	40 (An_{65-45})	60 (g)	0	0	0	0	1	0	as for 74300328; subophitic
" 0338	trace	35 (An_{67})	65 (g)	0	0	0	0	0	1–2% op, ap	well-preserved gabbroic texture - intersertal
" 0340	<1	40 (An_{65-70})	60 (br)	0	<5	0	0	0	<1% op, ap	granuloblastic, massive
GSQ 7887	trace	50 (An_{55})	50 (g)	0	0	0	trace	0	<1% op, ap	as for 74300328
" 7888	10	55	35 (g)	0	0	0	trace	<1	1% op, ap	granuloblastic; weakly lineated

74300330 fine actinolite in a very fine matrix of tremolite; strongly foliated. Sheared metabasite

" 0332 epidote up to 4 mm across in a very fine matrix of tremolite, chlorite, and sericite. Altered massive metabasite

" 0334 actinolite up to 3 mm across in a very fine matrix of tremolite, actinolite, chlorite, and albite. Altered massive metabasite.

Table 7 (continued):

Registered no.	Georgetown 1:100 000 Sheet area	
	Field no.	Grid ref.
74300090	2/730/10	698027
" 0096	2/730/1B	721002
" 0097	2/730/1A	721002
" 0102	2/734/11A	811002
" 0103	2/734/10	826015
" 0106	1/712/30B	824076
" 0107	1/712/30A	824076
" 0109	1/714/7	798063
" 0253	1/718/10A	697074
" 0254	1/718/10B	697074
" 0255	1/718/9	682062
" 0256	1/720/1	671059
" 0258	1/720/5	673070
" 0259	2/732/2	760003
" 0262	2/728/4	657032
" 0263	3/774/2A	796962
" 0269	3/778/7	710968
" 0270	3/778/11	698985
" 0275	4/850/1	704920
" 0280	4/852/7	749918
" 0283	4/854/7	774937
" 0311	11/178/4	778632
" 0314	11/182/10	807637
" 0319	7/1010/7	651798
" 0325	11/180/9B	754629
" 0328	11/184/3A	679639
" 0333	11/184/8	664612
" 0338	11/184/18	641620
" 0340	9/124/1	757698
GSQ 7887	11/184/13	656608
" 7888	12/408/17	793603
74300330	11/184/4A	668636
" 0332	11/184/7	665612
" 0334	11/184/9	660609

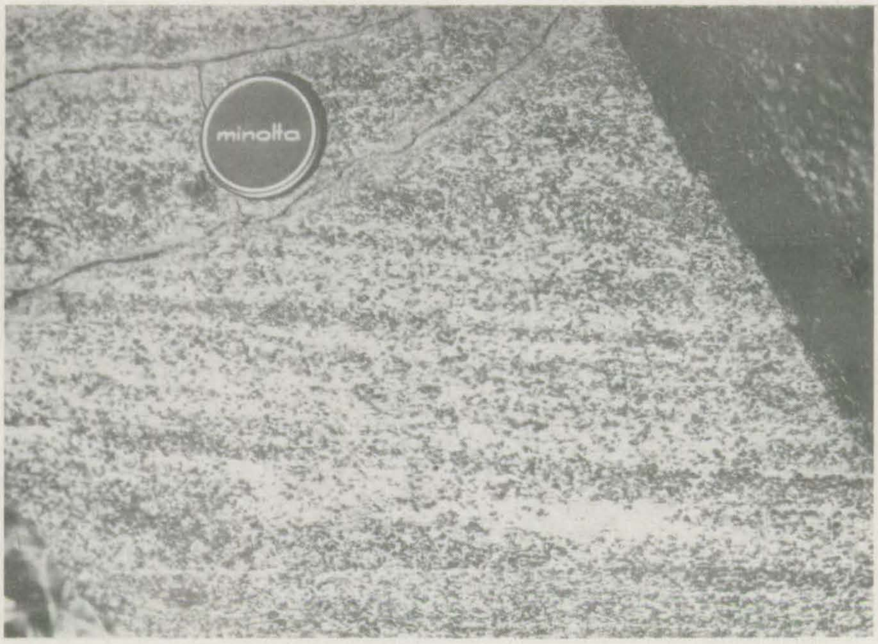

Fig. 18: Alternating hornblende and plagioclase-rich layers in amphibolite which probably represent primary igneous layering, Cobbold Metadolerite. GI/718/10 (grid ref. 697073) - about 1 km northeast of Spring Creek crossing on Ironhurst-Dagworth track. Photo by I.W. Withnall.

Fig. 19: $B_1^{\,2}$ structure folding S_o (and parallel S_1) in schist; note transposition of relatively ductile layers parallel to axial plane of fold (right), and buckling of less ductile layers (left), Robertson River Metamorphics. G3/780/12 (grid ref. 659951) - Daniel Creek, 0.5 km downstream from junction with Home Creek. Photo by I.W. Withnall.

labradorite) which commonly occurs as a granoblastic mosaic of equant to subequant, rarely zoned, grains commonly less than 0.5 mm across. Ragged subidioblastic, randomly oriented, hornblende prisms from 0.1 to 3 mm long commonly occur in clusters up to 7 mm across.

Hornblende occurs in amphibolite as subidioblastic prismatic grains up to 2 mm long. Some rocks contain mainly randomly oriented hornblende grains, others are markedly nematoblastic and differentiated into thin plagioclase- and hornblende-rich layers. Hornblende locally cuts across the foliation. Plagioclase is less abundant than hornblende in most of the rocks (Table 7). It forms an interstitial mosaic of subequant grains commonly less than 0.3 mm across. Quartz, where present, has a similar habit to the plagioclase. Granuloblastic amphibolite is especially common in large bodies affected by upper amphibolite metamorphism. Hornblende in these rocks occurs as polygonal, slightly elongate, locally poorly aligned, grains 0.1 to 3 mm across which are associated with smaller granuloblastic plagioclase and quartz grains. Garnet porphyroblasts up to 1 cm across occur rarely. Cummingtonite occurs locally as aggregates (up to 7 mm across) of poikiloblastic grains between 0.2 and 2 mm across. Diopside is a minor constituent of some amphibolite in the upper amphibolite subfacies; it occurs as colourless poikiloblastic grains up to 1 mm across.

Although the metabasite bodies at grid refs. 697074 and 824076 contain preserved igneous layers, the rocks themselves are amphibolites, being almost devoid of relict igneous textures. The leucocratic layers are made up of clusters of hornblende grains up to 1 cm across set in a granuloblastic matrix of plagioclase (averaging 0.1 to 0.3 mm across) with minor hornblende. Some larger plagioclase laths, which are partly aligned, probably constitute a relict igneous texture. The darker bands consist of normal granuloblastic hornblende and plagioclase.

Opaque minerals and/or sphene, and accessory apatite, are common in all types of metabasite.

Metamorphism

The mineralogy of the Robertson River Metamorphics of Cobbold metadolerite indicates that they range from the lower to the upper amphibolite subfacies from west to east. Figure 20 shows diagnostic mineral assemblages and inferred isograds. The isograds relate to the peak of prograde

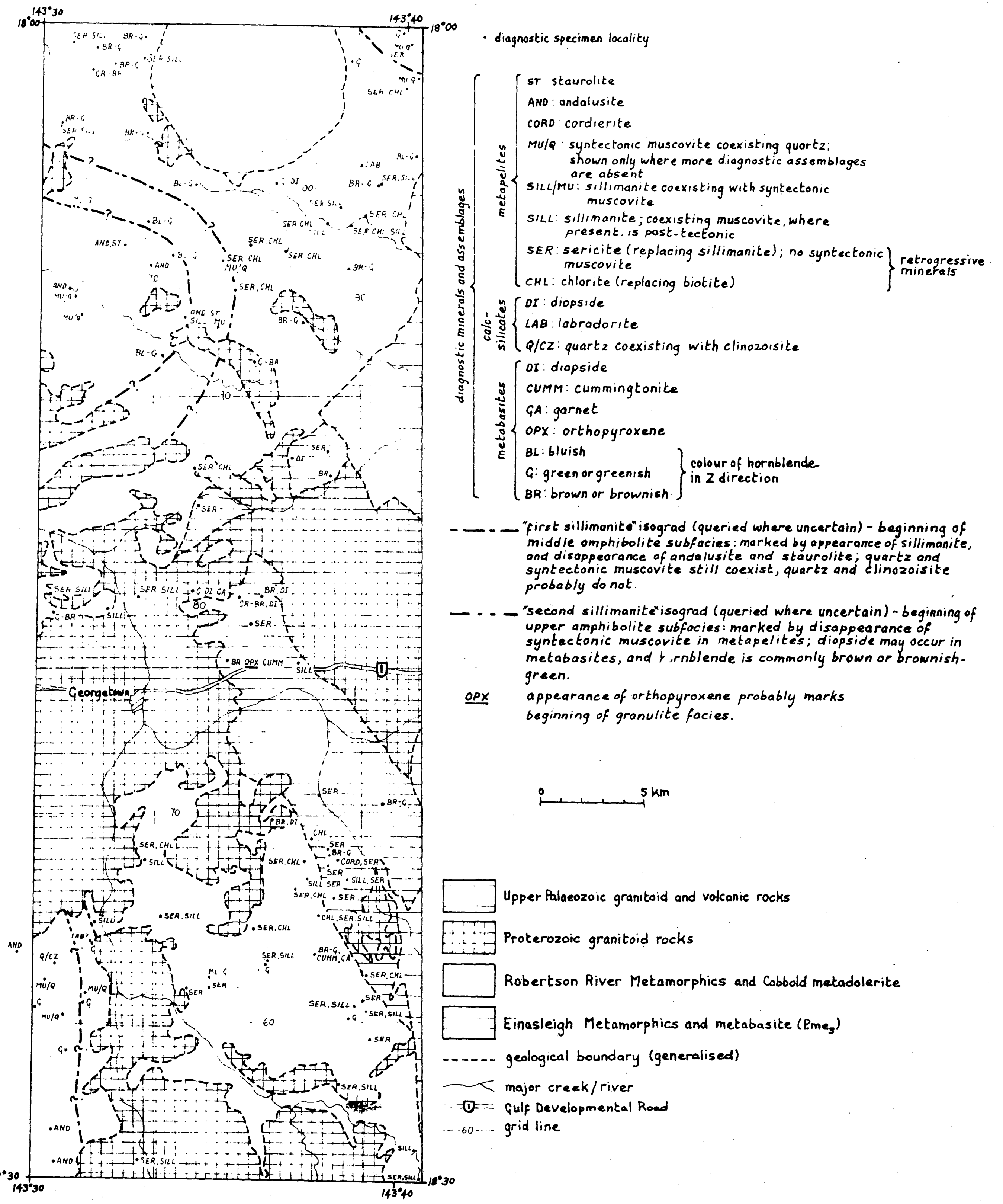

Fig. 20 Diagnostic metamorphic mineral assemblages and inferred isograds in the Robertson River and Einasleigh Metamorphics, and associated metabasites, west of the Newcastle Range in the Georgetown 1:100 000 Sheet area.

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metamorphism, although many rocks contain minerals formed at lower temperatures, either during the waning stages of the main metamorphism or during a later greenschist grade event. The isograds relate to the second of two prograde events; this metamorphism caused widespread overprinting of an older one, whose grades are thus impossible to ascertain accurately.

The presence of andalusite and staurolite in metapelite (mica schist), and of bluish green (colour in the Z direction) hornblende in metabasite (Cobbold metadolerite), is indicative of the lower amphibolite subfacies. In general, the colour of hornblende in the Z direction changes from bluish green or green in rocks of the lower amphibolite subfacies to brownish green or brown in the upper subfacies because of a decrease in the H_2O content and Fe^{3+}/Fe^{2+} ratio, and an increase in TiO_2 (Miyashiro, 1973, p. 255). The colour can be affected by several variables which are independent of temperature (such as the overall TiO_2 content of the rock), and is susceptible to retrogression; however, on the whole it is a valuable guide to the metamorphic facies, especially taken in conjunction with metapelite mineral assemblages. Clinozoisite and quartz coexist in calc-silicate-bearing rocks of the lower amphibolite subfacies; this, and other relationships, suggest that metamorphism in the central Georgetown Inlier took place at pressures intermediate between those which operated during formation of the classic Abukuma and Barrovian facies series (cf. Bain, Withnall, & Oversby, 1976, pp. 34-35), as discussed further below.

The position of the inferred "first sillimanite" isograd is coincident with the appearance of middle amphibolite subfacies rocks, defined on the breakdown of andalusite and the appearance of sillimanite; quartz, syntectonic muscovite, and sillimanite coexist, while andalusite and staurolite are absent. Quartz and clinozoisite probably do not coexist in the calc-silicate-bearing rocks of this subfacies. In many rocks, staurolite apparently broke down to muscovite and biotite before the isograd was reached. Of the metapelites examined, only a few now contain sillimanite (although retrogression of sillimanite during a later greenschist grade metamorphism (below) may have been responsible for the small patches of sericite which occur in some specimens); consequently they cannot definitely be assigned to the middle amphibolite subfacies by themselves. At grid ref. 715939 the presence of andalusite accompanied by traces of sillimanite suggests that the rock was metamorphosed under conditions close to the "first sillimanite" isograd. Metabasite in the middle amphibolite subfacies contains green hornblende.

Rocks of the middle amphibolite subfacies in the Georgetown 1:100 000 Sheet area occur in an outcrop belt which is apparently only about 3 km wide in contrast to 12 km in the Forsayth Sheet area (Bain, Withnall, & Oversby 1976, fig. 28).

At temperatures above those of middle amphibolite grade, syntectonic muscovite becomes unstable in the presence of quartz, and they react to form sillimanite and potassium feldspar. The reaction begins at the "second sillimanite" isograd, which is coincident with the start of the upper amphibolite subfacies. The place of syntectonic muscovite is taken in these rocks by sericite lenses which have partly or wholly replaced sillimanite. The lenses are rimmed by post-tectonic muscovite with sillimanite inclusions; the rims probably formed during the waning stages of metamorphism as temperatures fell back into the stability field of muscovite. Most metabasite in the upper amphibolite subfacies contains brownish green hornblende and sporadic diopside; the latter mineral does not occur in lower-grade rocks in the Sheet area.

Well-preserved igneous textures in some metabasite bodies in the lower and middle amphibolite subfacies could be due to a rapid local temperature rise during prograde metamorphism. If, as metamorphism proceeded, the metabasite was initially subjected to greenschist grade conditions for an appreciable length of time, plagioclase laths would break down to aggregates of albite and epidote, while clinopyroxene would be altered to aggregates of fibrous actinolite or uralite. Subsequently, as the temperature rose further and amphibolite grades were reached, albite and epidote would recrystallise to a granular mosaic of plagioclase, and fibrous actinolite would recrystallise as prismatic hornblende. Destruction of igneous textures would be enhanced by shearing or the development of stress-induced fabrics such as foliation during metamorphism. However, if the temperature were to rise quickly enough, amphibolite grade conditions might be reached before the primary minerals had an opportunity to equilibrate to their greenschist grade equivalents. In such a case pyroxene would be replaced directly by hornblende with no intervening uralite stage, and plagioclase would remain unchanged, with primary laths being preserved. Local minor development of granular plagioclase and blastophitic hornblende with included smaller hornblende prisms might reflect an intermediate stage in which slight alteration took place during a relatively short-lived greenschist grade interval.

Primary textures might also be preserved if metabasite was introduced and crystallised during the amphibolite grade metamorphism, but structural considerations (below) suggest that this was not the case in the Georgetown Sheet area.

Metabasite minerals tend to assume a granoblastic polygonal texture when recrystallised under the effects of conditions above those of middle amphibolite grade; most igneous textures are consequently destroyed. Blastophitic hornblende - large hornblende grains with inclusions of plagioclase laths - in a finer-grained, commonly foliated or lineated, matrix of hornblende and plagioclase, is commonly the only relict igneous texture which persists under upper amphibolite grade conditions. Metabasite of extrusive origin could be blastoporphyritic, with the fine groundmass of the precursor lava. Such rocks occur in the Einasleigh Metamorphics near "Eveleigh" (above), but none are known to be present in the Robertson River Metamorphics.

Total-rock Rb-Sr and Ar^{40}/Ar^{39} dating of rocks in the Robertson River Metamorphics of the Forsayth 1:100 000 Sheet area indicates that amphibolite grade metamorphism which probably accompanied the second deformation took place 1469±20 m.y. ago (Black & others, in press).

Like the Einasleigh Metamorphics and associated metabasite bodies (above), the Robertson River Metamorphics and Cobbold metadolerite in the Georgetown 1:100 000 Sheet area have been affected by an extensive greenschist grade regional metamorphism (presumably the same one in both cases) which postdated the main amphibolite grade one associated with the second deformation. The effects of this retrogression are partly obvious in rocks of the upper amphibolite subfacies, where biotite and sillimanite have been altered to chlorite and sericite respectively. There has been some alteration of andalusite to sericite in rocks of the other subfacies. As noted above, the greenschist facies minerals are thought to have been produced by a discrete low-grade thermal event, rather than during the last stage of the Proterozoic amphibolite grade metamorphism. This interpretation is supported by the fact that the greenschist-grade event affected the Robertson River Metamorphics and Cobbold metadolerite in the Forsayth Sheet area only slightly (as indicated by the rarity of reset isotopic "ages" and retrograde greenschist facies rocks) (Bain, Withnall, & Oversby, 1976, pp. 27, 33), while the effects of the main prograde event are equally as conspicuous there as in the Georgetown Sheet area.

Structure

The structure of the Robertson River Metamorphics and Cobbold metadolerite in the Georgetown 1:100 000 Sheet area is better understood than that of the Einasleigh Metamorphics and associated metabasite. The most conspicuous fabrics in the rocks are foliation and compositional layers in schist (Fig. 19) and original bedding in schist/quartzite assemblages where the relatively resistant quartzite layers define the bedding. Compositional layers in schist are defined by concentrations of particular minerals such as biotite. Some of the layers have probably been produced by metamorphic differentiation and growth of, for instance, biotite porphyroblasts along foliation planes. However, layers up to 5 cm thick in well-laminated schist are probably primary. Some small disharmonic folds at grid ref. 679977 (Fig. 16) may have formed by soft-sediment deformation.

At least four generations of folds have deformed the Robertson River Metamorphics and Cobbold metadolerite in the Georgetown 1:100 000 Sheet area; in comparison, five generations have been recognised in the Forsayth Sheet area (Fitzgerald, 1974; Bain, Withnall, & Oversby, 1976).

The first-generation folds are tight to isoclinal; they are associated with a schistosity (S_1), which is well preserved only in the extreme western part of the outcrop area, e.g. in rocks of lower amphibolite subfacies in Daniel Creek and west of the Delaney River. The foliation, which is defined by muscovite flakes, is either parallel to (Fig. 19), or cuts across, original bedding (S_o).

A second-generation foliation (S_2) is the most conspicuous one present in most outcrops; it is associated with folds which are also tight to isoclinal (Fig. 19). This second phase of deformation probably took place at the same time as the main prograde metamorphism, as indicated by various mineral textures and relationships. In the areas where the S_1 foliation is well preserved, S_2 is represented by a locally-developed crenulation cleavage along which some differentiation has taken place by dissolution of silica, or by layers of muscovite which cut across S_o and S_1 surfaces (Fig. 19). Farther east S_2 is most commonly parallel to S_o, and S_1 occurs only as local relics represented by biotite flakes which occur between, and are commonly oriented at a high angle to, the layers of biotite which define S_2. Helicitic inclusions in some andalusite grains (lower amphibolite subfacies rocks) are parallel or subparallel to the biotite layers; suggesting that andalusite is essentially syn-S_2 and reinforcing the correlation of the second deformation with the main prograde metamorphism.

The main foliation (S_2) has been overprinted by at least two younger sets of folds which are locally clearly delineated by trend lines. Figures 22, 23, and 24 show plots of data from the major structural elements in six subareas (Fig. 21). Subareas 1, 2, and 4 enclose single major B_2^3 folds outlined by trend lines. The folds are relatively open, with east-striking axial traces and wavelengths of from 3 to 8 km. In contrast, B_2^3 folds in the central-west Forsayth 1:100 000 Sheet area are much tighter, and overturned (Bain, Withnall, & Oversby, 1976, p. 40), although they become more open southwards. The remainder of the area for which structural data are available has been subdivided into subareas 3, 4, and 6 (Fig. 21).

At least two girdles can be fitted to the data points from most of the Subareas (1, 2, 3, and 4), indicating that more than one set of folds is present (assuming that the folds are approximately cylindrical). The poles to the girdles represent the axes of B_2^3 folds; they are distributed along an east-striking girdle (Fig. 22h), suggesting refolding of the B_2^3 structures. Alternatively, if the B_2^3 folds are not approximately cylindrical, the girdle may simply represent S_3, the effect of later folding being negligable. Crenulations in subarea 1 (Fig. 22c), and the axes of mesoscopic folds in subarea 2 (Fig. 22f), plot close to the east-striking girdle, suggesting that the data relate to $B_{S_2}^3$ folds. Crenulations in subarea 2 Fig. 22f) are probably related to younger (B_2^4) folds, however, as indicated by the fact that they plot well away from the girdle.

Data from subareas 5 and 6 define only one girdle. Poles to the main foliation (S_2) in subarea 6 (Fig. 23c) show considerable scatter; poles from the eastern half of the subarea (6a) define a girdle better when plotted alone. The poles to the various girdles do not lie near the girdle through the S_2 poles in Figure 22h (see Fig. 23h). Data points from crenulations in subarea 6 (Fig. 23e) show a fairly high scatter, although they are concentrated in the southeastern quadrant of the stereogram (Figs. 23e, g) around the pole to the girdle through the S_2 poles in Figure 22h. This suggests that the crenulations are probably parallel to the axes of B_2^3 folds.

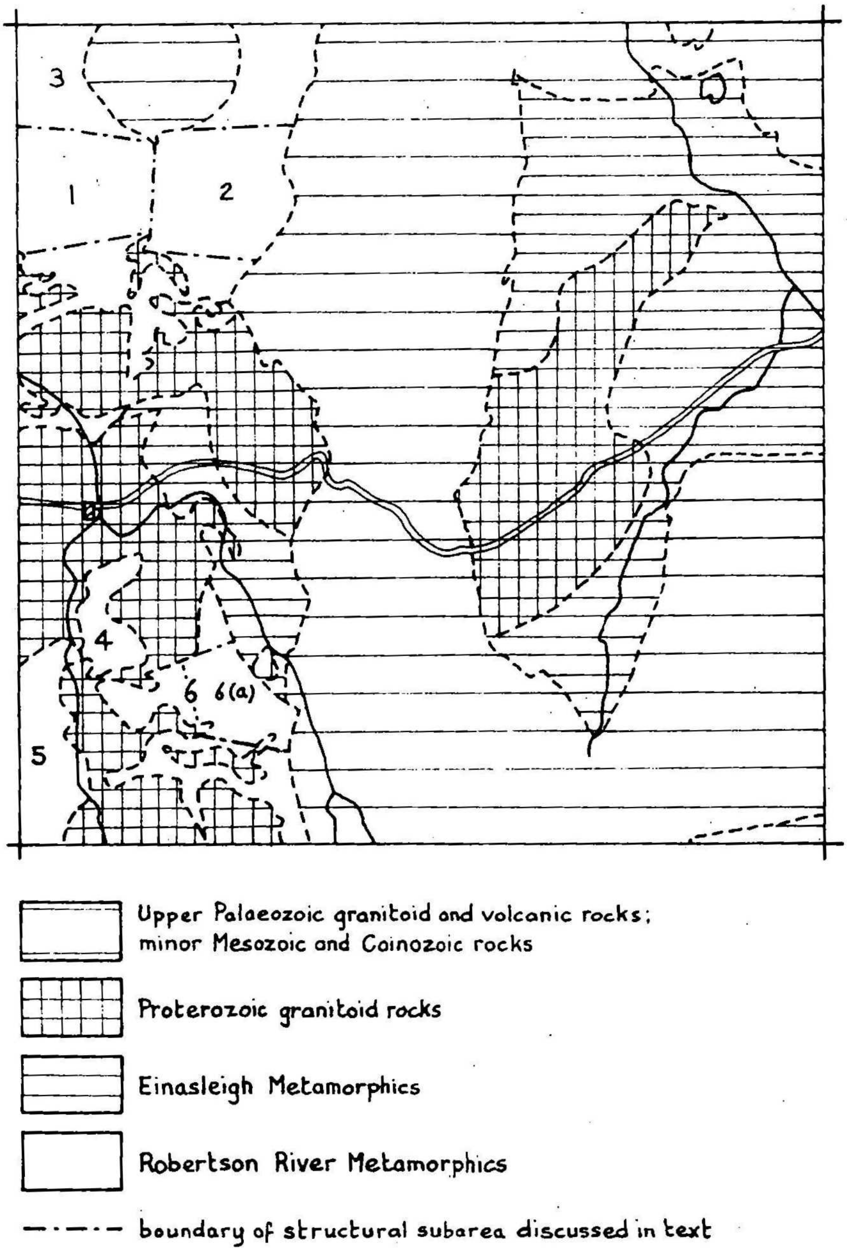

Fig. 21 Structural subareas in the Robertson River Metamorphics

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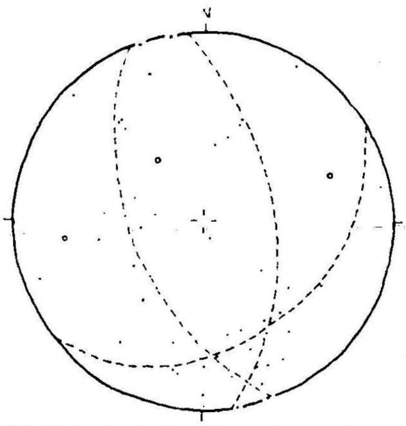
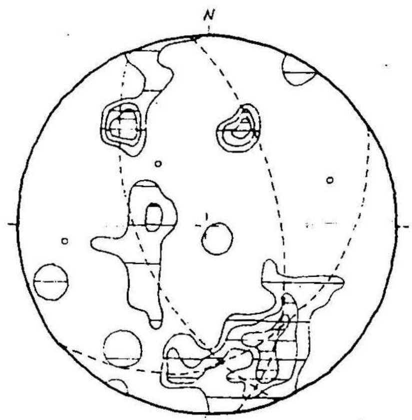
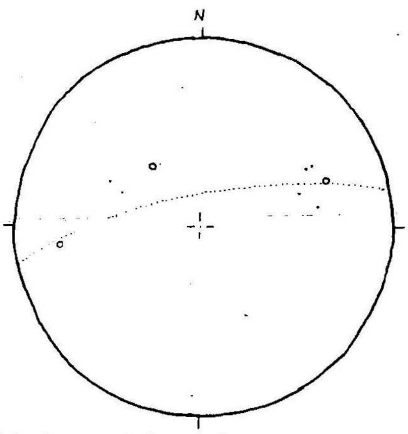


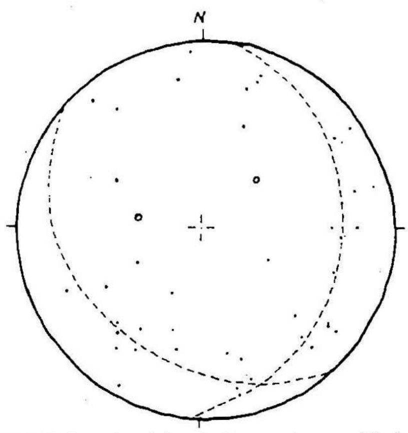
(a) Poles to 40 foliation planes (S_2) from subarea 1



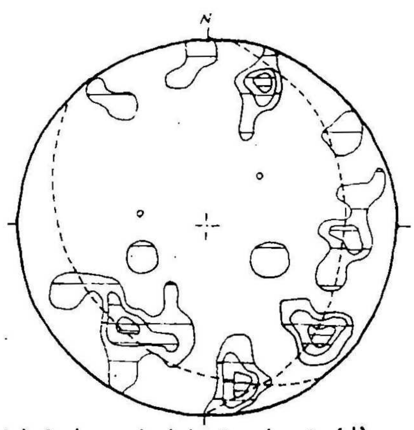
(b) Contoured plot of poles in (a), contours at 2·5, 5, and 7·5% per 1% area



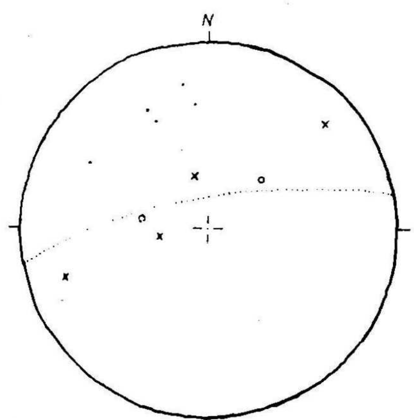
(c) 6 crenulations from subarea 1. Dotted line is girdle from (h)



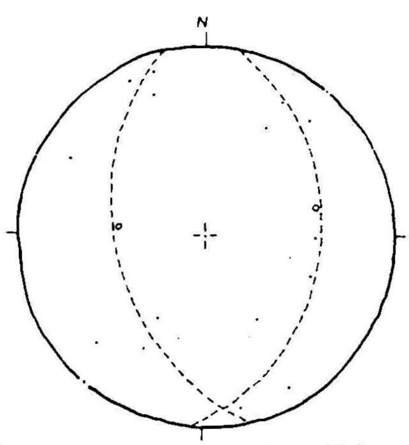
(d) Poles to 41 foliation planes (S_2) from subarea 2



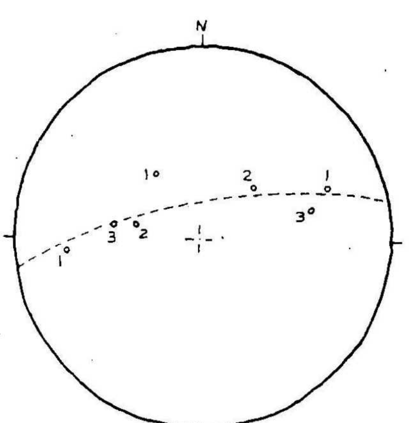
(e) Contoured plot of poles in (d); contours at 2·5, 5, and 7·5% per 1% area



(f) 6 crenulations (·) and 4 fold crests (x) from subarea 2. Dotted line is girdle from (h)

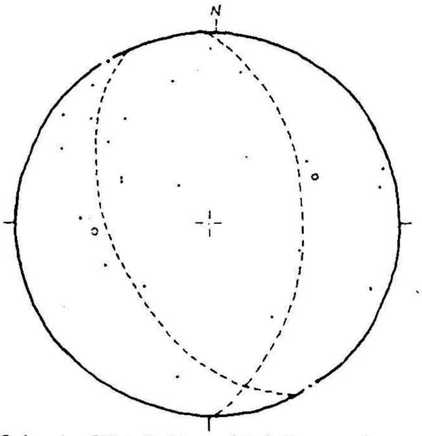


(g) Poles to 15 foliation planes (S_2) from subarea 3

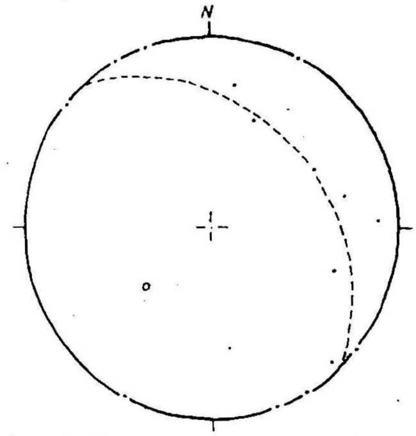


(h) Poles to girdles in (a), (d), and (g); numbers refer to subareas

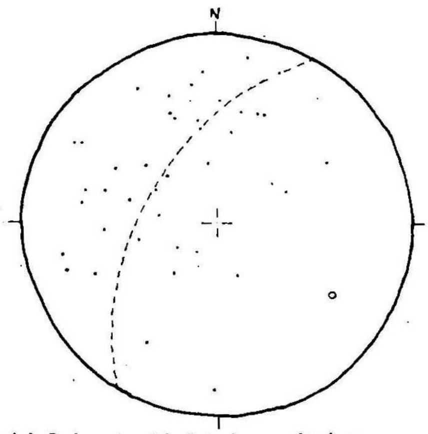
Fig. 22 Structural data from the Robertson River Metamorphics in subareas 1, 2, and 3 (lower hemisphere equal area projection)



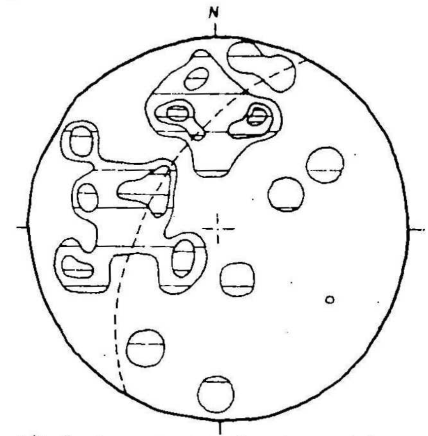
(a) Poles to 22 foliations (S_2) from subarea 4



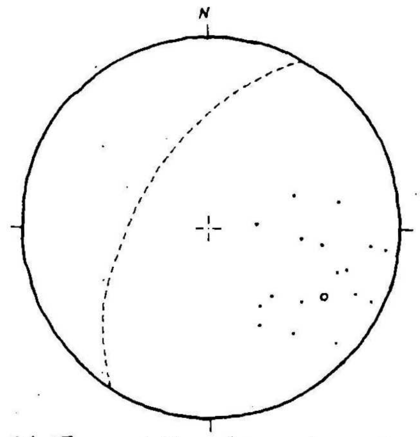
(b) Poles to 10 foliations (S_2) from subarea 5



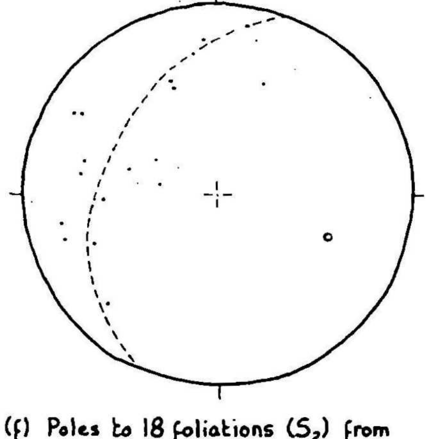
(c) Poles to 41 foliations (S_2) from subarea 6



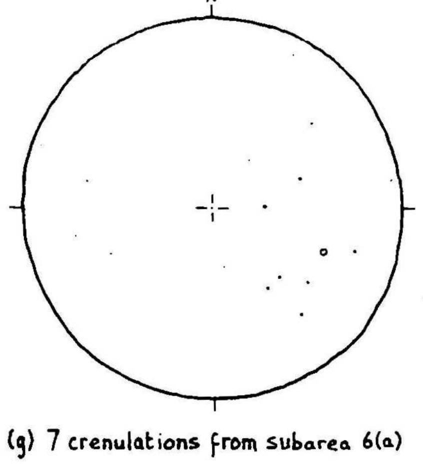
(d) Contoured plot of poles in (c); contours at 2·5, 5, and 7·5% per 1% area



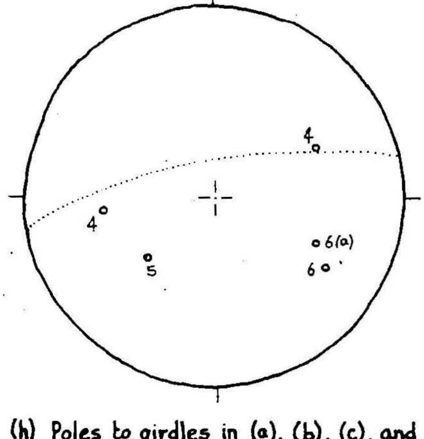
(e) 17 crenulations from subarea 6



(f) Poles to 18 foliations (S_2) from subarea 6(a)

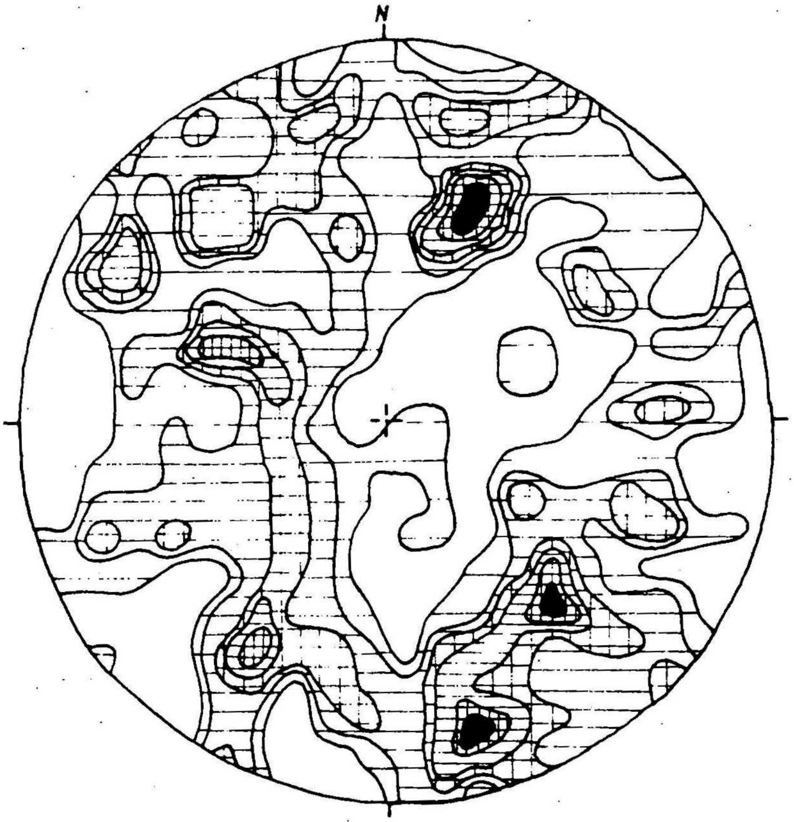


(g) 7 crenulations from subarea 6(a)

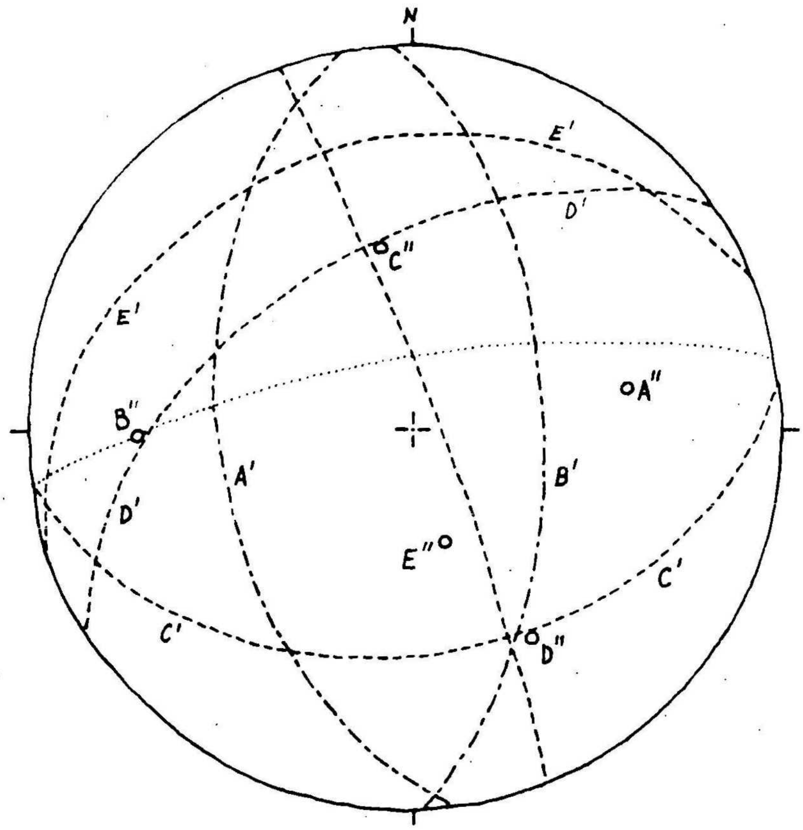


(h) Poles to girdles in (a), (b), (c), and (f); numbers refer to subareas. Dotted line is girdle from Fig. 22(h)

Fig. 23 Structural data from the Robertson River Metamorphics in subareas 4, 5, 6, and 6 (a) (lower hemispere equal area projection).



(a) Contoured plot of poles to 175 foliation planes (S_2) from the whole outcrop area of Robertson River Metamorphics in the Georgetown 1:100 000 Sheet area. Contours at 0·6, 1·1, 1·7, 2·3, 2·8, and 3·4 % per 1% total area.



(b) Girdles through maxima in (a). A' and B' reflect B_2^3 folds; C', D', and E' probably reflect later B_2^4(?) folds. Dotted line is girdle from Fig. 22h.

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Fig. 24 Structural data from the Robertson River Metamorphics: composite plots (lower hemisphere equal area projection)

Poles to S_2 from throughout the outcrop area of Robertson River Metamorphics and Cobbold metadolerite in the Georgetown 1:100 000 Sheet area (Fig. 20a) indicate that B_2^3 folds are more open than they are in the Forsayth Sheet area (Bain, Withnall, & Oversby, 1976, Fig. 45a). In the latter area most of the S_2 foliation poles plot in the southern half of the stereogram. Five girdles fit the maxima in Figure 24 a (Fig. 24b). Girdles A' and B' probably reflect B_2^3 folds; their respective poles (A" and B") are close to the girdle through the S_2 poles in Figure 22h. Other girdles (C', D', and E') may represent B_2^5 folds; their poles (C", D", and E") lie on an almost vertical, north-northwest-striking, girdle (F') which represents the axial plane, S_4, of the fourth generation of folds seen in the field. Small structures with north-striking axial planes and wavelengths of less than 1 km are locally outlined by trend lines. Such folds are better developed in the Forsayth Sheet area, where they are gentle structures with north-striking axial planes and wavelengths of up to 8 km; subsidiary folds with wavelengths of a few hundred metres also occur. These folds have been shown to belong to a fifth generation (T. Bell, personal communication 1977), and are the ones which reorient S_3 on a regional scale (Fitzgerald, 1974). Another generation of folds which Fitzgerald (1974) considered to reorient S_3 only on a subarea scale are roughly coaxial with the B_2^3 folds described above (T. Bell, personal communication 1977), and are fourth generation. We clearly recognise only the larger of the two fold sets, probably because the subareas (Fig. 21) are much larger than Fitzgerald's. However, the distinctive pattern of data points in subarea 6 might, if it is significant at all, reflects interference by the smaller of the two fold sets.

Large tight folds delineated by metabasite sills in the south-western and northern parts of the outcrop area of uncertain affiliations. The folds in metadolerite to the north of Daniel Creek may be B_o^2 structures. The tight fold outlined by metadolerite to the northwest of "Lornevale" is probably a B_o^1 structure overprinted by B_o^2 ones.

Origin and age

The Robertson River Metamorphics apparently originated as a sequence of mud and slightly calcareous quartzose silt with minor feldspathic sand. The Cobbold metadolerite represents intrusive dolerite and gabbro sills, dykes, and plugs; no volcanic component is known.

The original (depositional) age of the Robertson River Metamorphics is not known. We assume that the first deformation and metamorphism took place in the Robertson River Metamorphics at the same time as the ones in the Einasleigh Metamorphics (below), i.e. about 1570 m.y. ago (Black, & others, in press). The Cobbold metadolerite bodies apparently intruded the Robertson River Metamorphics before this time in the southwestern part of the Sheet area, and we assume that this was the case elsewhere. The units are thus at least about 1570 m.y. old; we tentatively assign a mid-Proterozoic age to them.

Mineralisation

Although most of the gold-bearing reefs in the Georgetown 1:100 000 Sheet area occur in various phases of the Forsayth Granite, there are also a number in the Robertson River metamorphics and Cobbold metadolerite, especially close to the edges of the granite. The following summary of the main occurrences is condensed from Withnall (in press).

The principal gold-producer in the Sheet area, the City of Glasgow mine (No. 110 on map) worked an east-southeast-striking reef in the Robertson River Metamorphics. During the first two of three main periods of activity (1879-1902 and 1909-1910), 2326 tonnes of ore yielded 7333 g of gold bullion. An additional 715 g gold, 4283 g silver, and 4 tonnes of lead were produced between 1937 and 1953. Primary (unoxidised) ore evidently contained pyrite with subordinate galena. Several other relatively less productive reefs cutting Robertson River Metamorphics in the vicinity of the City of Glasgow mine have also been worked.

Some of the reefs exploited by the Lighthouse group of mines (Nos. 125-131 on map) are in the Robertson River Metamorphics, as are the ones at the Lord Nelson (No. 139) and surrounding mines. The Stockman mine (No. 146), 4.5 km south-southwest of the Lord Nelson, produced gold, lead, and copper from a reef which was probably in schist. The reef at the Dairymaid mine (No. 148) cuts Cobbold metadolerite; it consists mainly of barren "milky" quartz, but sporadic patches of "specimen" gold occurred in it.

Conditions of metamorphism of the Einasleigh and Robertson River Metamorphics and associated metabasites

Bain, Withnall, & Oversby, (1976, pp. 34-35) noted that the pressure during metamorphism of the Robertson River Metamorphics and Cobbold metadolerite was probably intermediate between that of the classic low-pressure (Abukuma and Buchan) and medium-pressure (Barrovian) facies series. Further work in the Forsayth, Georgetown, and Gilberton 1:100 000 Sheet areas has confirmed this.

A feature indicative of low-pressure metamorphism in the various sheet areas is the presence of andalusite and cordierite* in the metapelites. Other features more characteristic of medium pressures include the persistence of clinozoisite/epidote well into the amphibolite facies, the presence of garnet in lower amphibolite subfacies metabasites (Bain, Withnall, & Oversby 1976, p. 34), and coexisting albite and hornblende in greenschist facies metabasites of the Gilberton 1:100 000 Sheet area. Detailed studies of the isograd and facies reactions in the Robertson River Metamorphics of the Forsayth 1:100 000 Sheet area indicate similarities to those in the Stonehaven area of Scotland (Bell & others, 1977). Harte (1975) assigned the Stonehaven rocks to a facies series, the Stonehaven, intermediate in pressure between the Buchan and Barrovian series.

In an attempt to establish a petrogenetic grid for elucidating the conditions of metamorphism of the Robertson River and Einasleigh Metamorphics, experimental equilibrium curves and stability fields of various minerals in pelitic rocks, as well as relevant minimum melting curves, have been plotted (Figs. 25 and 26). Figure 25 incorporates more recent data than the comparable one in Bain, Withnall, & Oversby (1976, Fig. 29).

The main problems encountered in establishing and using such a petrogenetic grid are caused by the major uncertainty in placing phase boundaries of the Al_2SiO_5 polymorphs, despite exhaustive studies by numerous laboratories. To illustrate this, triple points and phase boundaries from

*Coexisting andalusite and kyanite previously identified in one rock, from the Forsayth Sheet area (Bain, Withnall, & Oversby, 1976, pp. 22, 31) are now known to be cordierite and andalusite respectively. M. Rubenach (personal communication 1977) has also found cordierite in the Robertson River Metamorphics of the Forsayth Sheet area.

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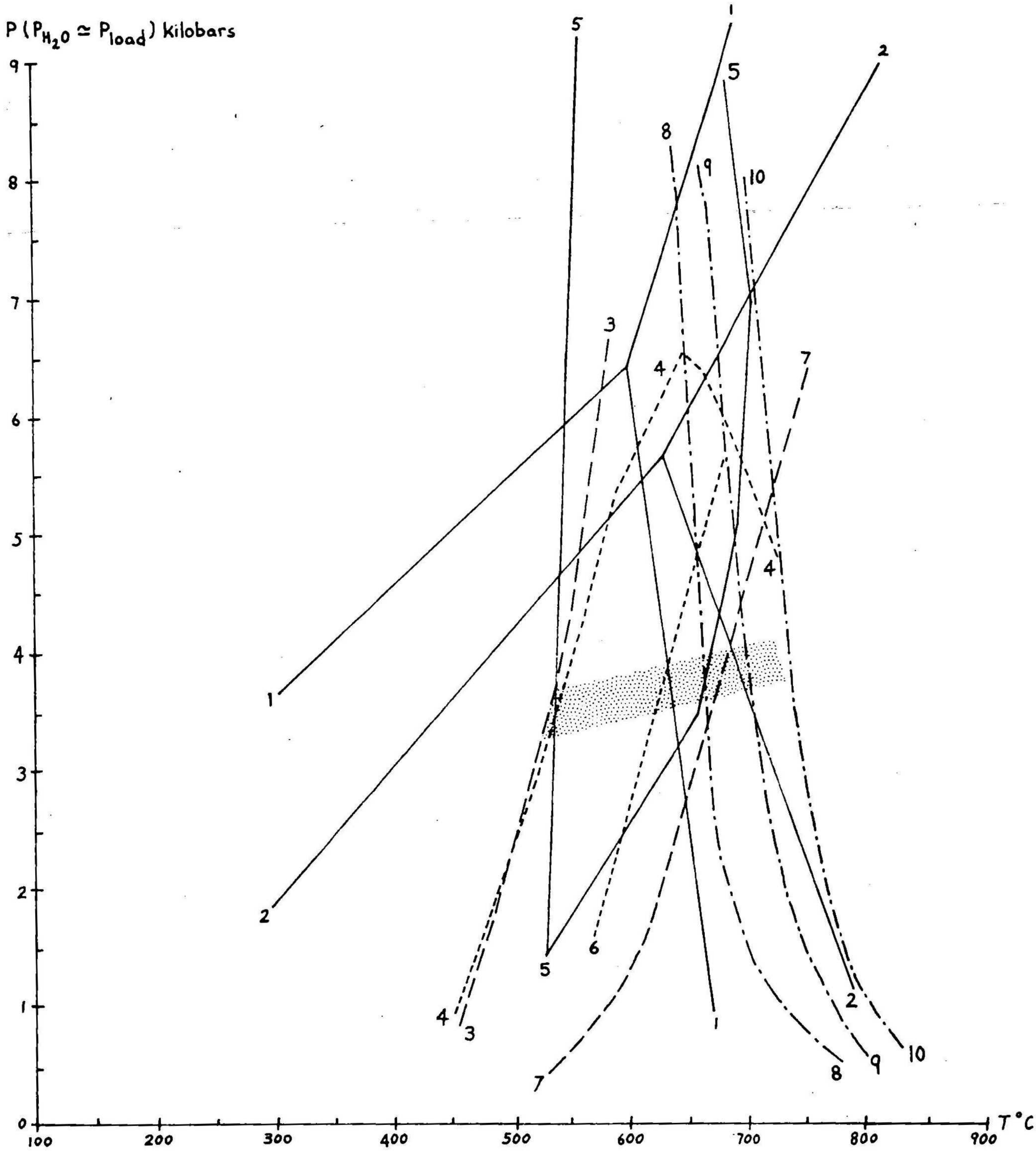


1 Al_2SiO_5 phase boundaries after Althaus (1967, 1969)

2 Al_2SiO_5 phase boundaries after Richardson, and others (1969)

3 Formation of staurolite: chlorite + muscovite = staurolite + biotite + quartz + H_2O (Hoscheck, 1969)

4 Stability field of Mg-cordierite ± muscovite + quartz (Seifert, 1970)

5 Stability field of staurolite + quartz (Richardson, 1968; Ganguly, 1972)

6 Breakdown of staurolite: staurolite + muscovite + quartz = Al_2SiO_5 + biotite + H_2O (Hoscheck, 1969)

7 Breakdown of muscovite: muscovite + quartz = Al_2SiO_5 + K-feldspar + H_2O (Althaus, and others, 1970)

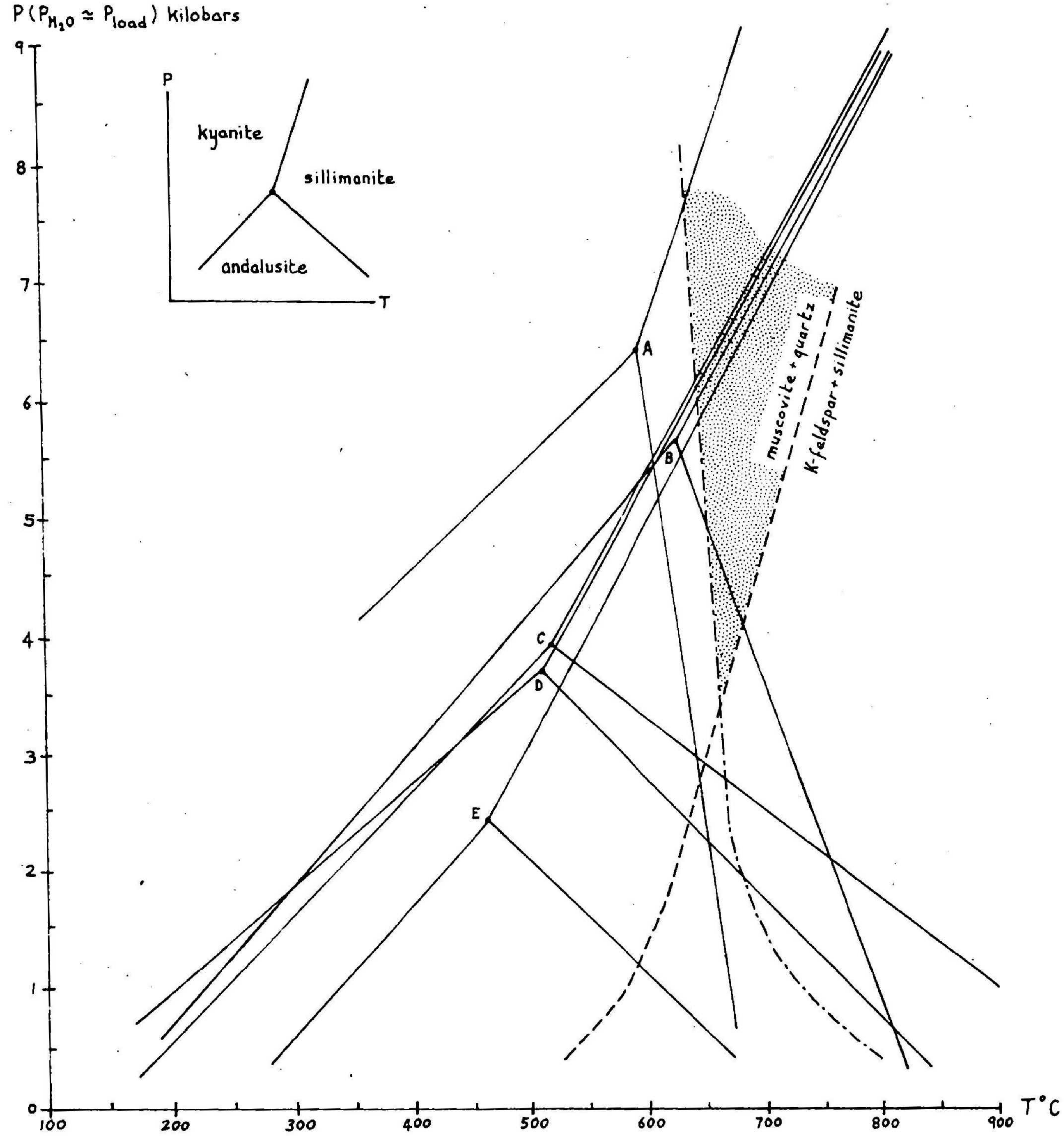
8 Minimum melting curve of "granite" (Luth, and others, 1964)

9 Melting curve of albite + quartz + H_2O (Thompson, 1974)

10 Melting curve of sanidine + quartz + H_2O (Shaw, 1963)

Stippling indicates suggested pressure-temperature field during metamorphism of Einasleigh and Robertson River Metamorphics

Fig. 25 Equilibrium curves and stability fields for diagnostic metamorphic minerals in pelitic rocks.



Triple points and phase boundaries: A after Althaus (1967, 1969)
B after Richardson, and others (1969)
C after Newton (1966)
D after Holdaway (1971)
E after Fyfe and Turner (1966)

— — — — Breakdown of muscovite (Althaus, and others, 1970)

—·—·· Minimum melting curve of "granite"

Stippling indicates field of muscovite "granite"

Fig. 26 Triple points and phase boundaries of $Al_2 SiO_5$ polymorphs, and field of muscovite "granite" five sources are shown in Figure 26. Harte (1975) used the results of Richardson & others (1969). Winkler (1974) used the triple points of both Richardson & others (1969) and Althaus (1967, 1969); he preferred Althau's andalusite/sillimanite boundary for low-pressure conditions because the boundaries of Richardson & others (1969), Newton (1966), and to some extent Holdaway (1971) require sillimanite to form only at temperatures well above the melting points of most metasediments. This requirement is obviously in conflict with observations in many contact metamorphic aureoles.

One of the most useful facies-determining reactions is that causing the disappearance of staurolite, which apparently occurs at or just below the "first sillimanite" isograd. The staurolite-breakdown curve of Hoscheck (1969) is preferred over the stability limit of staurolite and quartz (Richardson, 1968; Ganguly, 1972); the latter is applicable only to muscovite-free rocks and much higher temperatures than the staurolite breakdown curve. The andalusite/sillimanite boundary of Richardson & others (1969), and the staurolite breakdown curve, suggest that conditions of 5 kilobars pressure and 650^{o}C existed at or just below the "first sillimanite" isograd. By comparison, the preferred andalusite/sillimanite boundary of Althaus (1967, 1969) indicates a pressure of 3.5 kilobars and a temperature of 630^{o}C.

Taking a pressure of 3.5 kilobars, the lower amphibolite subfacies (marked by the appearance of staurolite) begins at about 525^{o}C; the middle amphibolite subfacies (marked by the appearance of sillimanite - the "first sillimanite" isograd) begins at about 630^{o}C; and the upper amphibolite subfacies (marked by the decomposition of muscovite - the "second sillimanite" isograd) begins at about 670^{o}C. At 5 kilobars the corresponding temperatures would be increased to 550^{o}, 650^{o}, and 700^{o}C respectively.

At 3.5 kilobars the minimum melting point of the granite system is crossed just before the "second sillimanite" isograd, although most rocks in the Georgetown 1:100 000 Sheet area apparently did not actually begin to melt until well above the isograd. This is because the melting curve for schist in the Robertson River Metamorphics is that of sanidine + quartz + H_2O, and the appropriate curve for gneiss in the Einasleigh Metamorphics is plagioclase (albite) + quartz + H_2O; both of these curves lie at higher temperatures than the "granite" curve. Some rocks in the Robertson River Metamorphics contain minor plagioclase, and some of the Einasleigh Metamorphics contain minor potassium feldspar. Partial melting of such rocks would probably begin close to the "second sillimanite" isograd. The leucogranitoid veins which are common in rocks above this isograd probably mostly, or wholly, originated through partial melting (metatexis) of such rocks.

At 5 kilobars the minimum melting curve of "granite" is close to the "first sillimanite" isograd (as shown by Richardson & others, 1969), and the melting point of albite + quartz + H_2O is well below the "second sillimanite" isograd. In such a case most of the metasedimentary rocks in the Robertson River and Einasleigh Metamorphics would have melted before the "second sillimanite" isograd was reached. That this did not happen confirms that the curve of Althaus (1967, 1969) is probably more valid than that of Richardson & others (1969) in general terms. Actually, the true situation may lie somewhere between the two curves; the occurrence of primary muscovite in some of the anatectic granitoids and pegmatoids (to be described in Part B of this report) requires the pressure to have been above 3.5 kilobars (Fig. 26). At lower pressures the "granite" liquidus is crossed above the stability field of muscovite, and only secondary muscovite can form. Muscovite-bearing granitoid and pegmatoid veins and dykes are abundant in rocks from above the "first sillimanite" isograd (especially in the Forsayth 1:100 000 Sheet area - Bain, Withnall, & Oversby, 1976, fig. 28). Such high mobility of the melts at this grade suggests that the "first sillimanite" isograd may be close to the minimum melting point of "granite", as would be the case in a situation somewhere between the two positions of the andalusite/sillimanite boundary.

As noted above, the metamorphic rocks contain similar mineral assemblages to those in the Stonehaven area of Scotland. Harte (1975) estimated that the pressure during the Stonehavian metamorphism ranged from 4.5 to 5.5 kilobars, with a pressure-temperature gradient of about $100^{o}C$ per kilobar. This is about 1 to 1.5 kilobars higher than the pressures we have estimated (above) because Harte's petrogenetic grid employed the Al_2SiO_5 phase boundaries of Richardson & others (1969) rather than Althaus's (1967, 1969).

Granulite formation cannot be represented in Figure 25 because the figure deals with a situation in which P_{load} approximately equals P_{H_2O}. Granulite facies minerals, in particular orthopyroxene, only form when P_{H_2O} is much lower than P_{load}. Widespread anatexis in the gneiss, such as that which occurred along the Einasleigh River, probably took place at $700^{o}C$ and P_{load} of about 4 kilobars; for orthopyroxene to form in preference to

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cummingtonite in metabasites at this temperature, P_{H_2O} in the metabasites must have been no higher than 1 kilobar (Winkler, 1974, p. 253). It is consequently necessary to explain the occurrence of orthopyroxene in the Einasleigh Metamorphics by invoking a theory that the bodies were "dry" and impermeable to water from the surrounding metasedimentary rocks at least locally.

Relationships between Einasleigh and Robertson River Metamorphics and associated metabasites

Introduction

The uncertainty regarding the relationships (both present and original) between the Einasleigh and Robertson River Metamorphics (and associated metabasites) represents a major problem throughout the central Georgetown Inlier.

White (1965) hypothesised that the Einasleigh Metamorphics were of possible Archaean age, and formed part of a basement on which the supposedly younger (Proterozoic) Etheridge Formation and other low-grade units were deposited unconformably. The Robertson River Metamorphics were also thought to be of Proterozoic age, although they were tentatively considered to represent a portion of the basement which had been thrust over the low-grade units. Oversby & others (1975), dealing with essentially the same data as White (1965), concluded that the various metamorphic rock units more probably constitute a single Proterozoic assemblage. Bain, Withnall, & Oversby (1976, pp. 15-20) discussed the several known and possible relationships in the light of field research in the Forsayth 1:100 000 Sheet area, concluding that the Etheridge Formation and Robertson River Metamorphics represent different metamorphic facies of a single original lithofacies, and that the Einasleigh Metamorphics represent a different original lithofacies which might be either of the same age or somewhat older. All units were thought to be most probably of the same general, probably Proterozoic, age, thus supporting the conclusion of Oversby & others (1975). However, Bain, Withnall, & Oversby (1976) did not explicitly dismiss the possibility that part, or all, of the Einasleigh Metamorphics could be Archaean.

Field relationships

The Einasleigh and Robertson River Metamorphics are in contact to the west of the Newcastle Range. However, exposures are poor in critical areas and the position of the contact is not known precisely. The present nature of the contact (i.e. whether structural or stratigraphic) is also not known. The presence of plagioclase-rich biotite gneiss in the Einasleigh Metamorphics is the main feature serving to distinguish the unit from the Robertson River Metamorphics because upper amphibolite facies schist, quartzite, and metabasite are essentially identical in both units. Most of the schist in the Robertson River Metamorphics contains only sparse plagioclase, although there is an increase in the plagioclase content locally towards the contact with the Einasleigh Metamorphics. This increase presumably reflects an original gradation from clayey to more feldspar-rich sandy sediments, suggesting either that the Robertson River and Einasleigh Metamorphics originally graded laterally or vertically into each other, or that the former unit overlay the latter unconformably and contained detrital plagioclase derived from it. There is no definite evidence than an unconformity ever existed between the Einasleigh and Robertson River Metamorphics, although any signs of, for instance, basal conglomerate or angular discordance would probably have been largely obliterated during the various isoclinal folding and metamorphic events which both units have been subjected to.

The simplest interpretation of the poor field data available is that the Einasleigh and Robertson River Metamorphics were originally two separate lithofacies which graded into each other, at least in part.

Metamorphic relationships

The Robertson River Metamorphics contain evidence for a progressive easterly increase in grade during the main prograde metamorphism. The easternmost Robertson River Metamorphics are in the upper amphibolite subfacies, as are most of the Einasleigh Metamorphics.

These facts suggest that the two units were metamorphosed by the same prograde events, implying that they were in their present relative positions at least by the time that the events occurred. Both units have also been affected by a greenschist grade metamorphism, believed to be probably of Silurian and/or Devonian age.

Structural relationships

The small number of available structural data makes comparisons between the Einasleigh and Robertson River Metamorphics difficult. The first-, second-, third-, and fifth generation structures in the Robertson River Metamorphics of the Georgetown 1:100 000 Sheet area correlate well with those in the Forsayth Sheet area, although in the former area the third-generation B_2^3 folds are more open than in the former. Fourth-generation (B_2^4) folds were not definitely recognised in the Georgetown Sheet area, probably because of inadequate data. West of the Newcastle Range the Einasleigh Metamorphics have similar patterns and sequences of folds. There are close similarities between structures in the Einasleigh Metamorphics east of the Newcastle Range in the Georgetown 1:100 900 Sheet area and those in the same unit in the Stockman Creek area (Forsayth 1:100 000 Sheet area).

The B_{II}^{III} folds in the Einasleigh Metamorphics east of the Newcastle Range are much tighter than those in the metamorphics to the west of the range. This is not a major problem because variations in fold style from one area to another are to be expected; B_2^3 folds in the Robertson River Metamorphics show major variations in style between the Forsayth and Georgetown Sheet areas, as noted above.

The youngest event shown by our structural analysis to have affected the Einasleigh Metamorphics produced east-northeast-trending folds, in contrast to the north-northwest-trending folds produced by the youngest event in the Robertson River Metamorphics. This disparity can be explained easily (although more detailed studies would be needed to provide definite confirmation) because the east-northeast-trending folds in the Einasleigh Metamorphics are probably B_{II}^{IV} structures; fourth-generation folds were not detected in the structural analysis of the Robertson River Metamorphics because such folds are roughly coaxial with B_2^3 folds, and may be similar in style. East of the Newcastle Range, where the B_{II}^{III} folds are much tighter, the more open B_{II}^{IV} folds can be distinguished from them.

Inadequate data may explain why mesoscopic fifth-generation (B_{II}^{V}) folds have not been recognised in the Einasleigh Metamorphics east of the Newcastle Range. They were not recognised in the Stockman Creek area either, but a fifth period of folding is required to fully explain the structures there and in the Einasleigh area (T.H. Bell, personal communication 1977).

On structural grounds therefore, S_1, S_2, S_3, S_4, and S_5 in the Robertson River Metamorphics can be correlated with S_I, S_{II}, S_{III}, S_{IV}, and S_V respectively in the Einasleigh Metamorphics. There is thus no reason to suppose that the Einasleigh and Robertson River Metamorphics are not of the same age, at least on structural grounds.

Results of Rb-Sr dating of metamorphic and structural events (Black & others, in press) suggest that at Einasleigh the third deformation occurred at 967 ± 28 m.y., about 500 m.y. later than the second deformation in the Robertson River Metamorphics (1469 ± 20 m.y.). This supports the correlation of S_{III} with S_3 rather than with S_2; the latter correlation might be expected if the Einasleigh Metamorphics were significantly older and had undergone a detectable deformation before the Robertson River Metamorphics were deposited.

Conclusions

Although the main inference reached above - that the Einasleigh and Robertson River Metamorphics are of essentially of the same original age - is tentative, it is supported by relationships between the various metamorphic rock units in the Gilberton 1:100 000 Sheet area. Field research in that Sheet area in 1975 showed that the Einasleigh Metamorphics and lower-grade units are probably all of the same age and originally graded laterally into each other. They have all been subjected to essentially the same deformational and metamorphic events.

We cannot definitely exclude the possibility, albeit apparently remote, that rocks of Archaean age occur without the Einasleigh Metamorphics. However, the existence of any such rocks could only be revealed by much more detailed field research than we have been able to undertake.

UPPER PALAEOZOIC VOLCANIC AND ASSOCIATED ROCKS

Newcastle Range Volcanics (Cn)

Introduction

The mid-Carboniferous Newcastle Range Volcanics are one of several Upper Palaeozoic units dominated by subaerial volcanic rocks - mainly calc-alkaline (Sheraton & Labonne, 1978) rhyolitic ignimbrite and lava - which occur commonly throughout northeastern Queensland. These units may once have coalesced and covered most, if not all, of the region; faulting, warping, and erosion have separated them however, and each has been given a different stratigraphic name, mainly because of this separation and the attendant difficulty of correlating the units.

The Newcastle Range Volcanics occur in the Newcastle Range, a dissected plateau (see Introduction) which occupies an area about 2000 km^2 in the Forsayth, Georgetown, Galloway, and Mount Surprise 1:100 000 Sheet areas. White (1959a, p. 36) named the unit, and nominated Shrimp Creek, in the Mount Surprise Sheet area about 7 km north-northwest of Einasleigh, as the type area. Branch (1966, pp. 22-23) correlated rocks throughout the whole Newcastle Range with ones in three informal subunits which he recognised in the Shrimp Creek area; he hypothesised that the Newcastle Range Volcanics had originally accumulated in two cauldron subsidence areas. Bain, Withnall, & Oversby (1976, pp. 56, 58) concluded that most of the rocks in the main* Newcastle Range sequence could not be correlated with ones in the eastern* part of the range.

The stratigraphy and structure of the Newcastle Range Volcanics shown in the Preliminary Edition of the Georgetown 1:100 000 Geological Sheet area are based on data obtained mainly during the 1974 field season. Additional work, including mapping in the Galloway Sheet area, remapping in the northernmost Georgetown Sheet area, and collection of many additional rock specimens in conjunction with a systematic geochemical survey of the

*In this report, "main Newcastle Range" refers to the north-trending part of the range in the Georgetown Sheet area which forms the watershed between the Etheridge and Einasleigh River basins. The "eastern Newcastle Range" is that part between the Einasleigh River and McMillan Creek, in the southeastern part of the sheet area. Use of these terms conforms with that of Branch (1966) and Bain, Withnall, & Oversby (1976).

Georgetown Sheet area, was done in the Newcastle Range during the 1976 field season (Oversby, 1977). Preliminary results from this later work indicate that some additions and corrections to the map are necessary; the nature and scope of these changes will be indicated as far as possible in appropriate parts of the following text.

The total preserved thicknesses of the main and eastern range sequences of Newcastle Range Volcanics in the Georgetown 1:100 000 Sheet area are about 1850 m and 1200 m respectively.

Lithology and petrography

Rhyolitic ignimbrite (see Glossary) is dominant in the Newcastle Range Volcanics; the ignimbritic nature of the rock is indicated by the sporadic occurrence of relict vitroclastic texture and eutaxitic foliation (Fig. 27). Rhyolitic lava (Fig. 28), and dacitic ignimbrite and lava, are common locally in the unit, but andesitic lava is relatively rare and invariable occurs in a stratigraphically low position. Poorly sorted, unstratified or only crudely stratified, agglomerate and airfall tuff occur sporadically throughout the main and eastern range sequences. Reworking of the latter by local streams at the time of its deposition converted it into relatively better sorted and stratified volcaniclastic sedimentary rocks (Fig. 32). Epiclastic sedimentary rocks (Fig. 31) occur commonly between the Proterozoic basement and the volcanic rock sequences.

(a) Rhyolitic ignimbrite

Numerous rhyolitic ignimbrite cooling units (Smith, 1960, p. 812) occur in the Newcastle Range Volcanics; some of them apparently contain a single flow, but most are probably made up of two or more flows which cannot be differentiated clearly without more detailed data than have been collected during the present work.

Rhyolitic ignimbrite is mainly shades of buff, pink, purple, grey, or green. Some rhyolitic ignimbrite in the eastern Newcastle Range is aphyric, but the rock is more commonly porphyritic, and different varieties contain from 25 to 50 percent phenocrysts up to about 4 mm in maximum dimension. Individual varieties of rhyolitic ignimbrite are

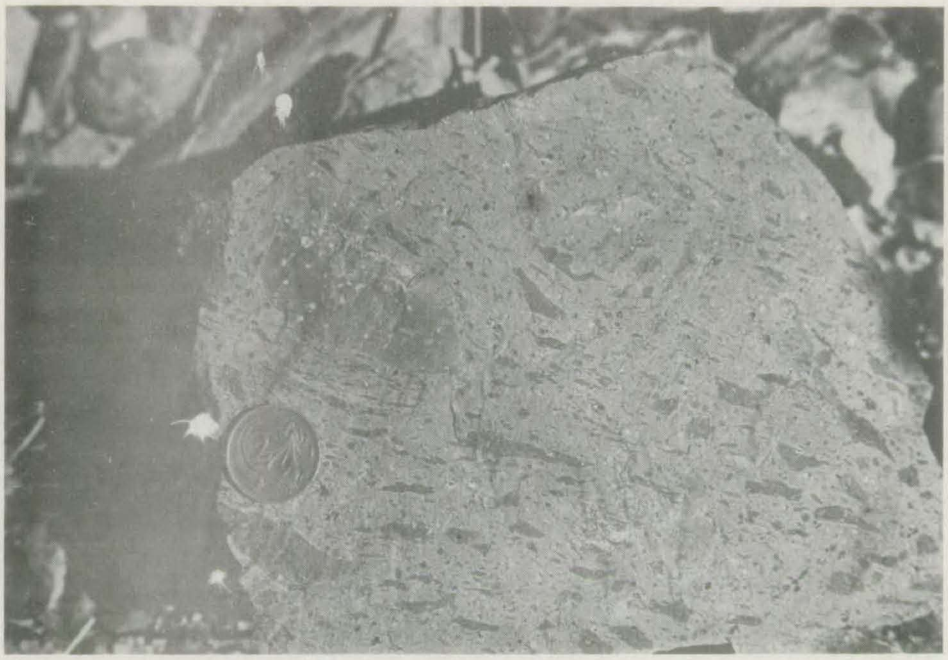

Fig. 27: Rhyolitic ignimbrite with well-developed eutaxtitic texture in the uppermost part of unit Cn_{IV} (distal equivalent of Cn_{Vb}?), main Newcastle Range sequence. G8/1028/1 (grid ref. 868755) - Rough Creek bridge on Gulf Developmental Road. Photo by R.J. Bultitude.

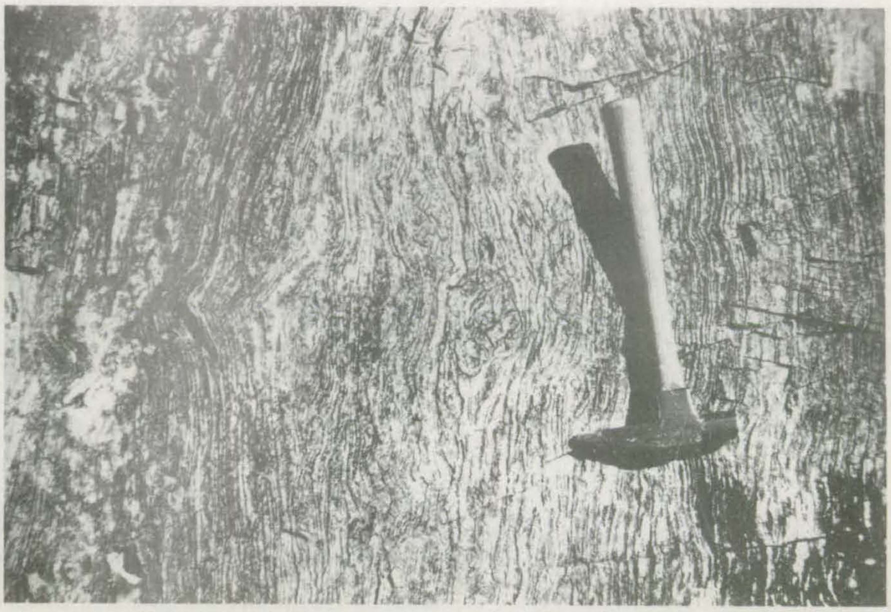

Fig. 28: Rhyolitic (?) lava with well-developed flow bands in unit Cn_{IV}, main Newcastle Range sequence. G10/144/19 (grid ref. 957653) - 4 km south-southwest of Kungaree Dam. Photo by B.S. Oversby.

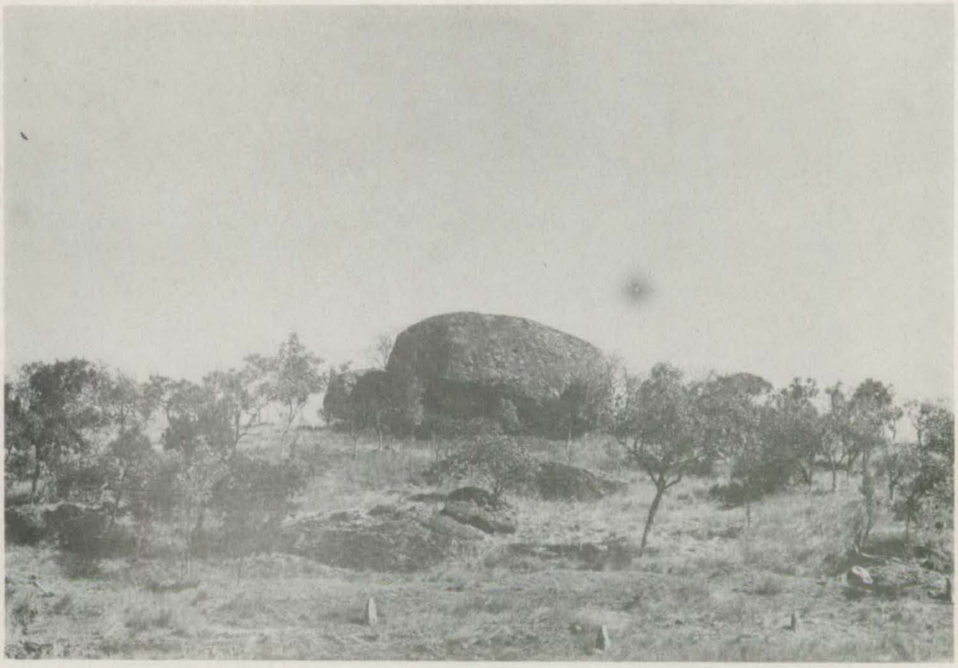

Fig. 29: Turtle Rock - boulders weathered from a lens of dactitic agglomerate in unit Cn_{III}, main Newcastle Range sequence. G8/1028/8 (grid ref. 904736). Photo by R.J. Bultitude.

Fig. 30: Breccia dyke containing subrounded clasts of Proterozoic Talbot Creek Granodiorite in a rhyolitic matrix. G11/176/20 (grid ref. 818604) - western side of main Newcastle Range 7 km north-northeast of Mount Talbot. Photo by B.S. Oversby.

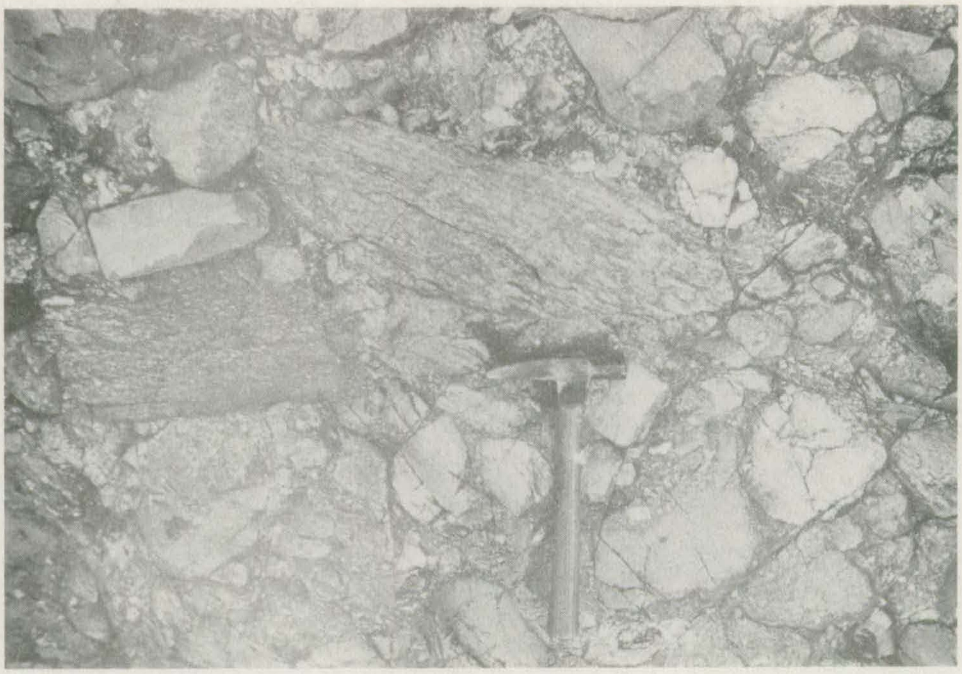

Fig. 31: Poorly-sorted epiclastic conglomerate in the lowermost part of the eastern Newcastle Range sequence; angular to subrounded clasts have been derived from local Einasleigh Metamorphics. G8/1036/11 (grid ref. 073750) - McMillan Creek 10 km southwest of "Eveleigh".

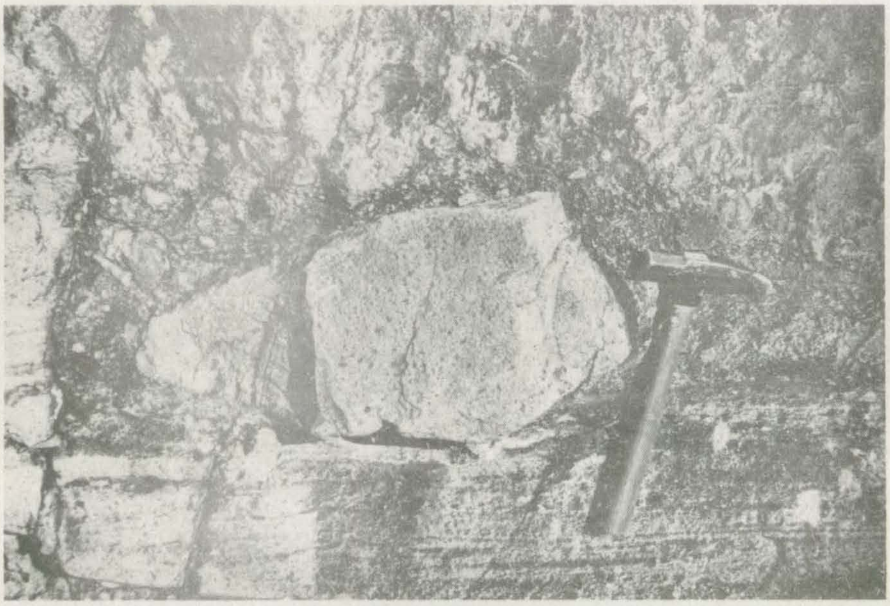

Fig. 32: Cross-laminated coarse volcaniclastic sandstone overlain by poorly-sorted conglomerate in an interbed within unit Cn_{III}, main Newcastle Range sequence. The beds at the extreme left have been displayed by a minor fault. G10/138/3 (grid ref. 838687) - 4 km south-southeast of "Routh Holding".

assigned to appropriate units on the bases of associated rock types, relative proportions of different phenocryst minerals (where present), phenocryst size, and gross colour.

Most porphyritic rhyolitic ignimbrite contains quartz, alkali feldspar, and plagioclase phenocrysts; these are accompanied in some varieties by phenocrysts of biotite or hornblende, or both (or their chloritic pseudomorphs). One variety, which may not be of rhyolitic composition strictly speaking, contain 1 to 5 percent alkali feldspar and plagioclase, but only rare quartz, phenocrysts up to about 1 mm across; its chemical composition is not known. Accessory apatite and opaque minerals are characteristic of all varieties of rhyolitic ignimbrite. Most phenocrysts are subhedral; quartz, and to a lesser extent feldspar, phenocrysts are corroded and embayed, and commonly cracked or broken. Alkali feldspar and plagioclase both occur as phenocrysts; the former is commonly microperthitic. The plagioclase is of uncertain composition; extinction angles of albite twins suggest that it is either albite or oligoclase-andesine (Bain, Withnall, & Oversby, 1976, p. 57, stated explicitly that it is oligoclase-andesine in the Forsayth Sheet area, but albite may also occur there). All feldspar phenocrysts are cloudy, and most contain variable proportions of recognisable secondary clay minerals, "sericite", epidote, silica, and hematite; they are white, pink, or "orange". No high-temperature feldspars have yet been identified during our work (contrast Branch, 1966, p. 23). Biotite and hornblende phenocrysts, where present, are up to 4 mm long. Porphyritic rhyolitic ignimbrite also locally contains up to about 50 percent (most commonly less) lithic fragments up to about 2 cm across; most of these fragments are cognate (autoliths), although exotic metamorphic, granitoid, and volcanic xenoliths occur rarely.

Aphyric ignimbrite, and the groundmass of porphyritic ignimbrite, consist of microcrystalline quartz and cloudy feldspar; textures are like those produced by the devitrification and recrystallisation of glass (cf. Lambert, 1974, p. 34; Lofgren, 1971), and pseudomorphs of individual shards and pumice fragments (Fig. 27) are preserved sporadically. The pseudomorphs define a eutaxitic foliation (Glossary) in most of the rocks in which they are preserved; the foliation occurs because the original shards and pumice fragments from which the pseudomorphs formed were flattened and fused together. Such features are diagnostic of ignimbrite (Ross & Smith, 1961, pp. 33-35; Lambert, 1974, pp. 23-34.

The ubiquitous mild alteration of groundmass and phenocryst feldspar in rhyolitic ignimbrite was presumably brought about by hydration and devitrification of original glass, and by inversion of high-temperature feldspars. Rhyolitic ignimbrite has locally been altered almost completely to clay minerals ("kaolinised") or silica, or both; even quartz phenocrysts have been reconstituted in some of these rocks. Such intense local alteration was probably caused by fluids associated with fumerole activity.

(b) Dacitic ignimbrite

Dacitic ignimbrite in the Newcastle Range Volcanics is green, purple, or buff, and contains about 25 percent alkali feldspar and andesine (?) phenocrysts, rare quartz phenocrysts, and 5 to 10 percent chloritic pseudomorphs of hornblende(?) phenocrysts and aggregates. In all other respects, including alteration, the rock is essentially identical to porphyritic rhyolitic ignimbrite, discussed above. Chemically, this dacitic ignimbrite is close to quartz trachyandesite (Sheraton & Labonne, 1978).

(c) Rhyolitic(?) and dacitic lava

All of the known rhyolitic(?) lava in the Newcastle Range Volcanics is mineralogically identical to the variety of ignimbrite of doubtful rhyolitic composition which contains alkali feldspar and plagioclase, but only rare quartz, phenocrysts, described above. The groundmass of the lava is invariably completely recrystallised, but it is distinguished from ignimbrite by the presence of flow bands (Fig. 28) which, even when contorted, are distinctly more continuous than the streaks, wisps, and lenses which define eutaxitic foliation (rock which has a completely recrystallised groundmass, no flow bands or eutaxitic foliation, and which does not grade laterally into lava, is assumed to be ignimbrite). Flow bands in lava commonly dip at high angles and are folded disharmonically; flow-banded and auto-brecciated varieties of lava locally grade into each other.

Most dacitic lava is mineralogically and chemically (Sheraton & Labonne, 1978) identical to ignimbrite of the same composition, described above. The lava is distinctive in either being flow-banded or in containing subparallel groundmass microphenocrysts. Lava which contains rare quartz and feldspar phenocrysts in a groundmass of subparallel microphenocrysts and devitrified glass is thought to be dacitic, although it has not been chemically analysed; the rock is rare.

Like rhyolitic ignimbrite, rhyolitic and dacitic lava have invariably been at least partly altered; they have also been almost completely "kaolinised" or silicified (or both) locally.

(d) Andesitic lava

Two varieties of andesitic lava, aphyric and porphyritic (annotated Cna_I and Cna_{II} respectively), occur in the Newcastle Range Volcanics. Both varieties most commonly form thin and discontinuous intercalations among other volcanic rocks, although they are also present as fairly thick sequences in the northwestern part of the main range (Georgetown and Galloway Sheet areas). Porphyritic andesitic lava also forms the matrix of small volumes of rhyolitic agglomerate at a few localities.

Aphyric andesitic lava is dark green and consists of subparallel plagioclase laths less than 1 mm long, smaller interstitial augite grains, and rare quartz xenocrysts up to 2 mm across, in a mesostasis of devitrified glass or quartzofeldspathic residuum. The porphyritic variety is similar, except in that it contains about 50 percent slightly cloudy andesine to labradorite phenocrysts up to 2 cm long. Both varieties of andesitic lava locally contain secondary clay minerals, sericite, epidote, and carbonate but neither has been so intensely altered as have more acid rocks at some localities. Pigeonite and biotite-bearing andesite noted by Branch (1966, p. 22) in the Galloway 1:100 000 Sheet area has not been found in the Georgetown Sheet area.

Amygdales containing quartz, carbonate, chlorite, and rare chalcopyrite occur locally in the uppermost parts of andesite flows; they are relatively most common in the prophyritic variety.

(e) Airfall agglomerate and tuff

Lenses of agglomerate occur locally in the Newcastle Range Volcanics of the Georgetown 1:100 000 Sheet area. Most of the lenses are associated with rhyolitic and dacitic lava and contain angular to (rarely) rounded cognate clasts (autoliths) up to about 50 cm across. Xenoliths of metamorphic, granitoid, and exotic volcanic rocks are relatively rare. Only a few of the lenses are large enough to show on the map.

Tuff lenses and interbeds occur sporadically throughout the Newcastle Range Volcanics; most of them are interbedded with rhyolitic lava, but none is sufficiently large to show separately on the map. The tuff is apparently mainly of rhyolitic composition, commonly pale green or buff, and it contains fragments of quartz and feldspar crystals, lithic fragments, and devitrified glass shards and dust. Scattered angular to rounded pebble-sized clasts of volcanic rock (mainly rhyolitic lava and ignimbrite, and "felsite") occur in the tuff at some localities.

Airfall tuff is distinguished from volcaniclastic sedimentary rock (Fig. 32), into which it grades locally, by its greater content of poorly sorted and angular material, its less regular stratification, and by the fact that it locally grades laterally into agglomerate. The dividing line between tuff and sedimentary rock is rather arbitrary, however, and it is commonly impossible to assign an individual specimen or outcrop to one or the other with any confidence. Much of the volcaniclastic sedimentary rock shown on the map might not have been appreciably reworked, and might have been better annotated "volcaniclastic sedimentary rock and/or airfall tuff".

(f) Volcaniclastic and epiclastic sedimentary rocks

Rock which is classed as volcaniclastic siltstone, sandstone, and conglomerate by the criteria noted above is annotated Cns_b; it occurs in interbeds and lenses, many of which are large enough to be shown on the map. The rock is commonly pale green or purple.

Epiclastic sedimentary rock of fluvial origin (annotated Cns_a) occurs sporadically between the Proterozoic basement and the lowermost volcanic or volcaniclastic sedimentary rocks. Poorly sorted, medium to thickbedded purple, pink, green, grey, buff, and brown siltstone, arkose, lithic and feldspathic sandstone, and conglomerate (Fig. 31) all occur; sandstone and arkose are commonly pebbly. The rock types are distributed unsystematically with respect to each other, and have not been distinguished individually. The rocks mainly contain angular to subrounded clastic material derived from subjacent metamorphic and granitoid basement, although a minor proportion of volcanic clasts occur locally. The rocks locally grade upwards into volcaniclastic sedimentary rocks as the volcanic component increases. Thin limestone interbeds and lenses occur at a few localities; some of these may be lacustrine, while others probably represent calcrete.

Stratigraphy and map units

The stratigraphy of the Newcastle Range Volcanics in the Forsayth 1:100 000 Sheet area has been described by Bain, Withnall, & Oversby (1976, pp. 58-61). In that area, most of the units in the main part of the range cannot be correlated with those in the eastern range; the same is true in the Georgetown Sheet area. Eastern range units are thus given arabic numeral subscripts in order to distinguish them from ones in the main range, which have roman subscripts. The units in each sequence are basically numbered in ascending stratigraphic order. However, sedimentary rocks and andesitic lavas are distinguished on the basis of lithology rather than stratigraphic position because they underlie, or occur as intercalations within several different units. This system will eventually be rationalised by naming and defining the main units as formations, thus raising the Newcastle Range Volcanics to group status.

Most thicknesses of units given below are only rough estimates because it is commonly impossible to measure or calculate accurate thicknesses owing to the lack of internal markers in units, the paucity of reliable dip measurements, and uncertainty about subsurface positions of the bottoms and tops of units.

(1) Main Newcastle Range sequence

(1a) Epiclastic sedimentary rocks (Cns_a)

About 75 m of epiclastic sedimentary rocks lie between the Proterozoic basement and the volcanic rock-dominated sequence in the main Newcastle Range to the north of Dagworth Bore (grid ref. 851060), on the western side of the range. The sedimentary rocks extend into the Galloway Sheet area. An unknown thickness of similar rocks is now also known to occupy the fault-bounded block annotated Cn_{Vb}?, due east of the bore.

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Epiclastic sedimentary rocks also crop out sporadically in a series of fault-bounded blocks and slices on the western side of the range for 9.5 km south of Dagworth Bore; they are 75 m thick to the north of Galah Creek and at least 50 m thick 2 km farther south. The rocks apparently persist as far south as grid ref. 836641, on the eastern side of the Etheridge River. At that locality epiclastic sedimentary rocks are overlapped by porphyritic rhyolitic ignimbrite of unit Cn_{II} which lies directly on Proterozoic basement rocks. The sedimentary rocks reappear along the western edge of the main range about 3 km south of the southern edge of the Georgetown Sheet area; they also occur in an embayment on the southwestern side of Stony Etheridge Creek, in the southernmost Georgetown and northernmost Forsayth Sheet areas.

On the eastern side of the main range about 50 m of epiclastic sedimentary rocks are well exposed in gullies for 5 km south of grid ref. 962871. A few discontinuous porphyritic rhyolitic ignimbrite flows from 0.3 to 1 m thick are interbedded with the sedimentary rocks. The sedimentary rocks die out and are overlapped by rhyolitic ignimbrite and lava of unit Cn_{IV} at grid ref. 962671. About 6.5 km farther north the sedimentary rocks reappear, and apparently persist (although locally cut out by faults) to Brodies Gap. Epiclastic sedimentary rocks also apparently die out in the area of the Gulf Developmental Road; they are only about 10 m thick at grid ref. 945774, 4 km north of the road, and are absent 1 km south of it where prophyritic rhyolitic ignimbrite of unit Cn_{II} lies on White Springs Granodiorite.

No interbeds or lenses of epiclastic sedimentary rocks are known to occur within the volcanic-rock-dominated part of the main range sequence in the Georgetown, Forsayth, or Galloway 1:100 000 Sheet areas (the interbed shown on the enclosed map as occurring between 1 and 2 km southeast of Goolie Dam, in the north, actually consists of volcaniclastic sedimentary rocks - Oversby, 1977). This suggests that no topographically high areas, such as caldera rims, containing exposed Proterozoic rocks existed during the span of time in which volcanic rocks accumulated (contrast e.g. Lambert, 1974).

(1b) Andesitic lava (Cna_I, Cna_{II})

Two sequences of andesitic lava overlie epiclastic sedimentary rocks to the north of Dagworth Bore. The lower sequence is about 120 m thick and consists mainly of aphyric andesite (Cna_I); about 200 m of porphyritic andesite (Cna_{II}) characterises the upper sequence. The two sequences are separated by about 80 m of purple porphyritic rhyolite ignimbrite annotated Cn_{IV} on the map; it would probably be more correct to assign it to unit Cn_V (below). Thin flows of aphyric andesitic lava also occur intercalated among dacitic(?) lavas in the lowermost part (subunit a) of unit Cn_V; it would actually have been more logical to include this subunit with the andesite succession, either as part of the aphyric sequence or as a separate one as has been done by Oversby (1977) (see also below).

About 2 km north of the Georgetown Sheet area's edge, in the Galloway 1:100 000 Sheet area, the lower aphyric andesite sequence is cut out by an east-striking high-angle fault which appears to be only slightly younger than the andesite. South of the Brodies Gap-Dagworth Bore track aphyric andesitic lava occurs in several fault-bounded blocks and slices on the western side of the range; only the largest of these are shown on the map. The only other known occurrences are at grid refs. 967905 (upper Collins Creek), 968881 (2.5 km farther south), and 858957 (2 km west of upper Cattle Creek). The lava at the first locality is about 5 m thick, partly carbonatised, and contains calcite-filled amygdales and poorly-defined pillow-like structures. Amygdaloidal andesite also occurs at the third locality; it probably belongs to unit Cn_{Va} (as currently constituted). The andesite which crops out at the second locality contains less than 1 percent quartz xenocrysts (?) up to 4 mm across.

The upper sequence of porphyritic andesitic lava also occurs in the Galloway 1:100 000 Sheet area; it is thinner and crops out less commonly to the east of Cattle Creek than to the west. South of Dagworth Bore, in the Georgetown Sheet area, the sequence occurs in a fault-bounded block drained by Dagworth Creek, and thin (1 to about 10 m) distal representatives of one or more flows which are thought to be approximately isochronous occur at grid refs. 839022, 833991, 833966 (4, 7.1, and 10 km south of Dagworth Bore respectively), 958905 (upper Collins Creek), and 929707 (2 km south of the Gulf Developmental Road). At grid refs. 839022, 833991, and 833966 the andesite is about 100 m above the base of unit Cn_{IV}; at the second and third of these localities it constitutes the matrix of small volumes of more extensive autolithic agglomerate (not differentiated on the map). The andesite is also within unit Cn_{IV} in upper Collins Creek, but it is in the upper half of unit Cn_{III} at grid ref. 929707.

The relationships noted above suggest that the lower part of unit Cn_{IV} is of the same age as the aphyric andesitic lava sequence, and that units Cn_{IV} and Cn_{III} grade laterally into each other, at least in part (see also below).

(1c) <u>Unit Cn_{I}</u>

Unit Cn_{I}, the lowest one in the volcanic rock-dominated part of the main range sequence in the Forsayth 1:100 000 Sheet area (Bain, Withnall, & Oversby, 1976, p. 59), may be represented in the Georgetown Sheet area by airfall crystal-lithic-vitric tuff and agglomerate which crops out about 6 km south-southwest of "Lornevale" (grid ref. 676583). The outcrop area (about 0.3 km^2) is about 18 km west of the main Newcastle Range, and straddles the boundary between the Georgetown and Forsayth Sheet areas. No other occurrences of unit Cn_{I} are known in the Georgetown Sheet area.

(1d) <u>Unit Cn_{II}</u>

Unit Cn_{II} overlies unit Cn_{I} in the Forsayth Sheet area, where it contains six subunits and is up to about 200 m thick (Bain, Withnall, & Oversby, 1976, pp. 59-60). Only two of the subunits, b and d, have been mapped in the Georgetown Sheet area (although examination of rocks collected during 1976 suggests that subunit e might also crop out). Unit Cn_{II} occurs mainly in the southern part of the main range, and subunits b and d appear to grade laterally into each other. Subunit Cn_{IIb} is characterised by up to 150 m of purple and buff porphyritic rhyolitic ignimbrite containing about 25 percent quartz, alkali feldspar, and plagioclase phenocrysts up to about 2mm across. Subunit Cn_{IId} contains similar rocks, but phenocrysts are up to 4 mm across. Both subunits lie directly on Proterozoic basement rocks, except where epiclastic sedimentary rocks are interposed, and are overlain either by unit Cn_{III} or (north of the Gulf Developmental Road) by unit Cn_{IV}.

Subunit Cn_{IIb} probably consists of a single cooling unit made up of two or more flows; it is best exposed on the eastern side of the main range, although it is cut out locally by high-grade faults between grid ref. 964875 and the upper reaches of Spear Creek. The greatest thickness of the unit in the Georgetown Sheet area is about 3.5 km southwest of Barneys Knob Mill (grid ref. 975808). North of this area the subunit thins progressively and intertongues with subunit Cn_{IV} (below); it dies out at grid ref. 964874. The subunit also thins south of the area of maximum thickness; it is about 30 m thick opposite Jimmys Bore (grid ref. 959713), and that thickness is probably maintained to the point where the subunit is cut out by high-angle faults about 3 km southwest of Kungaree Dam (grid ref. 976685).

The only known outcrops of rock assigned to subunit Cn_{IIb} on the western side of the range are in a relatively small area about 1 km south of Big Spring (grid ref. 835698). The rocks in this area are actually intermediate in type between those of subunits Cn_{IIb} and Cn_{IId}, a majority of their phenocrysts being about 3 mm across. Subunit Cn_{IIb} evidently dies out between the outcrop area to the south of Big Spring and Sisters Creek, a distance of 12 km; epiclastic sedimentary rocks lying on White Springs Granodiorite are overlain directly by rocks in unit Cn_{IV} (below) at the last locality.

Subunit Cn_{IId} occurs throughout the southern quarter of the main Newcastle Range in the Georgetown Sheet area. The subunit is 30 m thick between Spear Creek and the Etheridge River, on the western side of the range. It is difficult to estimate the maximum thickness of the subunit farther south for the reasons discussed above; it is at least 100 m thick, however.

(1e) Unit Cn_{III}

Unit Cn_{III} is restricted to the main Newcastle Range in the Georgetown 1:100 000 Sheet area; it crops out from 3 km north to 10 km south of the Gulf Developmental Road and contains up to 150 m of dacitic ignimbrite and lava flows with minor airfall pyroclastic and volcaniclastic sedimentary rocks, a single andesitic lava flow, and rare porphyritic rhyolitic ignimbrite flows.

The unit is thickest along the central east-west axis of its outcrop area, roughly between Big Spring and the eastern edge of the range opposite Kungaree Dam; the top of the unit forms a very irregular surface, reflecting original topography of the lava pile, and penecontemporaneous faulting. The outcrop area is bounded about 5 km south of this axis by a series of high-angle faults. North of the axis the unit loses its identity at grid ref. 964875; it may grade laterally into part of unit Cn_{IV} (below); unit Cn_{III} is also overlain by rocks currently put in the upper part of unit Cn_{IV}.

Agglomerate (Cn_{IIIa}) occurs in lenses throughout the unit; the largest lens is at Turtle Rock (grid ref. 904736), (Fig. 29), on the southern side of the Gulf Developmental Road (map). A 30 m-thick interbed of cross-bedded green lithic and feldspathic volcaniclastic sandstone and conglomerate (Fig. 32) occurs about 50 m above the base of the unit on the western side of the range to the south of Big Spring. A few porphyritic rhyolitic ignimbrite flows up to about 2 m thick occur near the top of the unit in the same area. A porphyritic andesitic lava flow (Cna_{II}) occurs within unit Cn_{III} at grid ref. 929707 (above).

Intrusive dacite and microgranodiorite may be widespread in the outcrop area of unit Cn_{III}, although none is shown on the map. Further thin-section examination is required to evaluate this possibility.

(1f) <u>Unit Cn_{IV}</u>

Unit Cn_{IV}, as defined for the purposes of this report, is up to 450 m thick and has the largest outcrop area of any unit in the main range of the Georgetown 1:100 000 Sheet area. It occurs from about 8 km south of the Gulf Developmental Road to the northern edge of the Sheet area; for most of that distance the unit occupies virtually the whole width of the range (from 8.5 to nearly 20 km) and lies directly on Proterozoic basement, or on epiclastic sedimentary rocks. Rocks currently assigned to unit Cn_{IV} are rare in the Galloway 1:100 000 Sheet area; they do not occur in the Forsayth Sheet area.

The most common and distinctive rocks in unit Cn_{IV} are grey and buff porphyritic rhyolitic(?) ignimbrite and lava (Fig. 28) which contain 1 to 5 percent alkali feldspar and plagioclase, but only rare quartz, phenocrysts (above). These rocks are locally intensely "kaolinised". A single flow of buff and purple porphyritic rhyolitic ignimbrite with conspicuous eutaxitic foliation (Fig. 27) constitutes the uppermost part of the unit in the Gulf Developmental Road area; this flow may be a distal equivalent of subunit Cn_{Vb} farther north. Porphyritic rhyolitic ignimbrite assigned to unit Cn_{IV} also occurs to the north of Dagworth Bore and extends into the Galloway Sheet area. Agglomerate, airfall tuff, volcaniclastic sedimentary rocks, and dacitic(?) and andesitic lava also occur in unit Cn_{IV}.

Any formal definition of unit Cn_{IV} will eventually be based on the occurrence of rhyolitic(?) ignimbrite and lava; porphyritic rhyolitic ignimbrite, like that which occurs in the Gulf Developmental Road area and to the north of Dagworth Bore, will thus be excluded from the unit.

Unit Cn_{IV} attains its maximum preserved thickness of about 450 m in the northern part of its outcrop area. The ignimbrite north of Dagworth Bore which is currently assigned to the unit is about 80 m thick. South of the upper reaches of Fiery Creek the uppermost part of unit Cn_{IV} has been eroded away so that its original thickness in about half of the outcrop area is not known; it was certainly more than 100 m, however (this thickness includes about 50 m of the porphyritic rhyolitic ignimbrite flow which occurs at the top of the unit in the Gulf Developmental Road area).

Agglomerate and airfall tuff lenses are relatively common in unit Cn_{IV}, but they have not been differentiated on the map because most of them are small and their boundaries cannot be seen on airphotos. Airfall tuff locally grades into volcaniclastic sedimentary rocks, which occur in several discontinuous interbeds within unit Cn_{IV}. About 200 m of such sedimentary rocks occur in the uppermost part of unit Cn_{IV} 3 km south of Dagworth Bore; they interfinger with volcanic rocks farther south, and are only about 30 m thick at grid ref. 854952. On the eastern side of the range the lower half of unit Cn_{IV} locally contains two interbeds of volcaniclastic sedimentary rocks. The lowest interbed is about 120 m above the base of the unit; it is up to about 30 m thick, and crops out between a high-angle fault at grid ref. 945814, and grid ref. 965875 where it dies out. Another interbed occurs at approximately the same stratigraphic level about 3 km south of Brodies Gap. A stratigraphically higher interbed, up to 80 m thick, occurs about 100 m farther up in unit Cn_{IV} between high-angle faults 4.5 km west-northwest and 8.5 km northwest of Barneys Knob Mill. A 10 m-thick segment of (probably) the same interbed also crops out between high-angle faults about 4 km north of Collins Creek.

A single dark grey dacitic(?) lava flow about 30 m thick, annotated Cn_{IVa} on the map, crops out between grid refs. 789897 and 795878, 3 km south-southwest of Fiery House outstation. Andesitic lava flows in unit Cn_{IV} crop out at several localities (above).

Intensely "kaolinised" rocks in unit Cn_{IV} (annotated Cn_{IVk} on the map) occur on the southern side of O'Brien Creek, 6 km north-northeast of Fiery House (at this locality the alteration may also have affected intrusive porphyritic rhyolite), and possibly 3 km south of Turtle Rock. These altered rocks will be discussed further below.

(1g) Unit Cn_V

Three subunits are recognised within unit Cn_V locally. The unit consists mainly of porphyritic rhyolitic ignimbrite with relatively rare andesitic and dacitic(?) lava, volcaniclastic sedimentary rocks, airfall tuff, and agglomerate: it is widespread in the northern half of the Georgetown 1:100 000 Sheet area and in adjacent parts of the Galloway Sheet area, but it does not occur in the Forsayth Sheet area. Unit Cn_V has a maximum thickness of about 650 m in the first of these areas, and overlies unit Cn_{IV} throughout it.

The lower subunit, Cn_{Va}, is characterised by up to 150 m of purple and green dacitic (or trachyandesitic) lava which contains 1 to 3 percent quartz, alkali feldspar, and plagioclase phenocrysts about 2 mm across; several aphyric andesitic lava flows are interbedded with dacite or trachyandesite locally. Subunit Cn_{Va} does not contain any rhyolitic lava or ignimbrite (contrary to what is stated in the map key); these rocks are now known to be intrusive rhyolite and microgranite in concordant and near-concordant cone sheets (Oversby, 1977). Subunit Cn_{Va} crops out 4 km northeast of Dagworth Bore, from where it extends into the Galloway Sheet area. It also occurs at grid ref. 850045, 2 km south of the bore; it thins southwards from there to grid ref. 854022, where it dies out. A poorly exposed aphyric andesitic lava flow at grid ref. 858957 (2 km west of upper Cattle Creek) may be a distal representative of subunit Cn_{Va}.

The rocks constituting subunit Cn_{Va} are more closely affiliated with those in the underlying andesitic lava succession to the north of Dagworth Bore than they are with the porphyritic rhyolitic ignimbrite characteristic of the remainder of unit Cn_V. The rocks in the subunit will thus probably not be included in unit Cn_V when that unit is formally defined; rather, they will probably be included in the same unit as the other andesites (cf. Oversby, 1977).

The overlying subunit, Cn_{Vb}, consists of about 450 m of purple and (rarely) buff porphyritic rhyolitic ignimbrite which contains 30 percent quartz, alkali feldspar, and plagioclase phenocrysts between 1 and 4 mm across. This subunit crops out in the largest area of the three in the Georgetown Sheet area, and contains at least two cooling units made up of an unknown number of flows. It is also widespread in the Galloway 1:100 000 Sheet area.

Subunit Cn_{Vc} is probably a single cooling unit made up of several flows; it is characterised by grey, purple, and buff porphyritic rhyolitic ignimbrite which contains 25 to 40 percent quartz, alkali feldspar, and plagioclase phenocrysts about 1 mm across. About 200 m of subunit Cn_{Vc} are preserved to the south of the Brodies Gap-Dagworth Bore track.

Unit Cn_V has not been divided into subunits in that part of the Georgetown 1:100 000 Sheet area north of the Brodies Gap-Dagworth Bore track, except in the western part of the range as noted above. Most of the rocks in the undivided part of the unit are like those in subunit Cn_{Vc} (above), although there are also several intercalations of subunit Cn_{Vb}-type ignimbrite (as well as numerous concordant and near-concordant sheets of rhyolite and microgranite not shown on the map). The proportions of subunit Cn_{Vb}-type rocks increases northwards in the Galloway Sheet area (Oversby, 1977). Many of these rocks contain autoliths, which increase in quantity and size northwards. The sequence in the extreme northernmost Newcastle Range consists mainly of interbedded Cn_{Vb}-type ignimbrite, which commonly contains large autoliths, and agglomerate which contains clasts of purple porphyritic rhyolitic ignimbrite up to at least 3 m across; these are probably "lag-fall" deposits (Wright & Walker, 1977). The preliminary interpretation of the relationships is that the source area of all ignimbrite flows and associated agglomerates in unit Cn_V was in the north, and that ignimbrite characteristic of subunit Cn_{Vc} is a distal equivalent of that in subunit Cn_{Vb}. The contact between the two subunits is thus envisaged to be a discordant interfingering facies boundary on a regional scale, even though it happens to be concordant where preserved in the Georgetown Sheet area.

An interbed of volcaniclastic sedimentary rock about 30 m thick occurs between subunits Cn_{Vb} and Cn_{Vc} in the Georgetown Sheet area. This interbed is now known to occur throughout the area in which the contact between the two subunits is exposed, rather than only in the west as shown on the map (Oversby, 1977). Another volcaniclastic sedimentary rock interbed, incorrectly annotated Cns_a on the map, also occurs among high-angle faults between 1 and 2 km southeast of Goolie Dam; the interbed is apparently overlain by Cn_{Vb}-type ignimbrite. Volcaniclastic sedimentary rocks are also now known to crop out within subunit Cn_{Vb} at grid ref. 874961, in the upper Cattle Creek area, while airfall tuff and agglomerate which occur at grid ref. 932018, 1.5 km southwest of Brodies Gap, may be in the same stratigraphic position.

Intensely "kaolinised" and silicified rocks in unit Cn_V (annotated Cn_{Vk} and Cn_{Vbk} on the map) occur 3 km southeast of Goolie Dam, 5 km south of Brodies Gap, and possibly 10 km south-southwest of Brodies Gap. These altered rocks will be discussed further below.

(2) Eastern Newcastle Range sequence

(2a) Epiclastic sedimentary rocks (Cns_a)

Epiclastic sedimentary rocks in the eastern Newcastle Range sequence of the Georgetown 1:100 000 Sheet area lie between the Proterozoic basement and lowermost volcanic rocks, as they do in the main range sequence (above). The main occurrences of these rocks are in the area where the Fish Hole Branch of McMillan Creek debouches from the range, about 12 km south-southwest of Eveleigh mine (No. 34 on map), and between 5 and 8 km southwest of the mine, where McMillan Creek cuts into the foot of the range. Epiclastic sedimentary rocks also occur at the easternmost edge of the Georgetown Sheet area 4 km east-southeast of the Eveleigh mine. They extend into the Mount Surprise Sheet area, where they are almost continuously exposed below volcanic rocks along the front of the range to the west of the Einasleigh River (Oversby, 1977).

In the area of debouchment of Fish Hole Branch at least 40 m of epiclastic sedimentary rocks evidently accumulated in a shallow palaeotopographic depression. The rocks occur for 1 km south of the basin, but they are less than 30 m thick. The contact between the epiclastic sedimentary rocks and the basement is exposed in the bed and banks of Fish Hole Branch at and around grid ref. 073695; the contact shows local relief of several metres.

A second basin filled by epiclastic sedimentary rocks occupies an area of almost 2 km^2 between about 6 and 9.5 km southwest of the Eveleigh mine. At least 100 m of sedimentary rocks occur in the basin, whose southern edge coincides with a west-southwest-striking high-angle fault. The fault has not displaced the superjacent volcanic rocks; this fact, and the presence of conglomerate (Fig. 31) containing boulders up to at least 2 m across adjacent to the fault, suggest that a fault scarp existed at the time of accumulation of the sedimentary rocks. The scarp probably limited the southward extent of the sedimentary rocks; none is known to occur between this basin and the one farther south. Epiclastic sedimentary rocks occur north of the basin, but are no more than about 30 m thick and persist for only 1 km before being cut out by high-angle faults.

Interbeds of sedimentary rocks in the volcanic rock-dominated part of the eastern range sequence in both the Georgetown and Mount Surprise Sheet areas are mostly volcaniclastic (below); they rarely contain epiclastic muscovite (and perhaps other unidentified epiclastic material) which is invariably fine-grained. These facts suggest that only a few local exposures of Proterozoic rocks remained in the area when the main volcanism took place, as in the main range (above).

(2b) Andesitic lava (Cna_1)

Only aphyric andesitic lava occurs in the eastern Newcastle Range. No thick successions of andesite flows, like the one which is present in the northwestern part of the main range, occur; instead, flows are thin and laterally impersistent. The andesite flows invariably occupy a stratigraphically low position.

One 30 m-thick flow 6.5 km southwest of the Eveleigh mine is exposed for a strike length of about 500 m and lies between epiclastic sedimentary rocks and the base of unit Cn_{2a}. Between 1 and 2.5 km farther north is another flow, also about 30 m thick; it is interbedded with ignimbrite in the lowermost part of unit Cn_{2a}. A similar flow at the foot of the range nearby apparently lies directly on Einasleigh Metamorphics.

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Aphyric andesitic lave flows which are too small to show on the map are known to occur in a fault zone at grid ref. 072687, between epiclastic sedimentary rocks and the base of unit Cn_{2b} at grid ref. 074695, and possibly near the top of unit Cn_{2a} at grid ref. 098763. None of these flows is more than 10 m thick.

(2c) Unit Cn_1

Unit Cn_1 is up to 100 m thick; it occurs only along the northern edge of the eastern Newcastle Range, opposite the Eveleigh mine. The unit extends into the Mount Surprise Sheet area, but it apparently does not persist beyond about 2 km southeast of the edge of the sheet area (Oversby, 1977).

Buff to (rarely) grey porphyritic rhyolite containing about 40 percent quartz, alkali feldspar, and plagioclase phenocrysts up to 1 cm across characterises unit Cn_1. The rock has a relatively coarse, microgranitic groundmass which is locally streaky but which does not contain a clear eutaxitic foliation. Virtually identical rock occurs nearby in a dyke and small stock which intrude Newcastle Range Volcanics and Einasleith Metamorphics. In view of this it is now thought that the unit actually represents a low-angle, near-concordant dyke which has intruded along the zone of weakness formed by the contact between epiclastic sedimentary rocks and unit Cn_{2a}, and is not part of the stratigraphic sequence.

(2d) Unit Cn_2

One major and two minor subunits are distinguished in unit Cn_2. The unit consists mainly of porphyritic rhyolitic ignimbrite containing quartz, alkali feldspar, and plagioclase phenocrysts; it is widespread in the northern part of the eastern Newcastle Range of the Georgetown 1:100 000 Sheet area, and in the Mount Surprise Sheet area (Oversby, 1977). South of the Fish Hole Branch of McMillan Creek unit Cn_2 is about 100 m thick; it thickens northwards to about 500 m opposite Eveleigh mine, and maintains this thickness throughout its outcrop area in the Mount Surprise Sheet area. At most localities the unit unconformably overlies Proterozoic basement rocks, except where epiclastic sedimentary rocks intervene, and is conformably overlain by rocks of unit Cn_3 (below).

Subunit Cn_{2a} is characterised by several flows and cooling units of buff, purple, and grey porphyritic rhyolitic ingimbrite which contains about 25 percent phenocrysts up to 2 mm across. It is the most widespread subunit of unit Cn_2 in both the Georgetown and Mount Surprise Sheet areas, constituting almost all of the unit opposite the Eveleigh mine. Subunit Cn_{2a} thins and grades laterally into subunit Cn_{2b} (below) to the south of the mine.

Buff and purple rhyolitic ignimbrite which contains 1 percent quartz and/or feldspar (alkali feldspar and plagioclase) phenocrysts is characteristic of subunit Cn_{2b}. Similar rock probably also occurs in concordant and near-concordant dykes and has been included in the unit; it is not differentiated on the map because its distribution has not been fully worked out. The whole thickness (100 m) of unit Cn_2 in the southernmost part of its outcrop area is made up of subunit b, although the subunit reaches its maximum thickness of 300 m about 7 km southwest of the Eveleigh mine where it lies between subunits Cn_{2a} and Cn_{2c}, or between the latter and unit Cn_3. North of this area subunit Cn_{2b} thins again to about 50 m at the eastern edge of the Georgetown Sheet area. In the area of debouchment of the Fish Hole Branch of McMillan Creek subunit Cn_{2b} consists of two indivisible parts which underlie and overlie unit Cn_3.

Crystal-lithic-vitric tuff beds with minor agglomerate lenses make up subunit Cn_{2c}; the tuff is probably partly of airfall origin and partly represents distal nonwelded ignimbrite. The subunit attains its maximum thickness, approximately 100 m, about 5 km southwest of Eveleigh mine. Northwards and southwards subunit Cn_{2c} dies out by intertonguing with subunits Cn_{2a} and Cn_{2b} respectively.

Several interbeds of volcaniclastic sedimentary rock up to about 60 m thick (most commonly not more than about 30 m) occur within unit Cn_2 in the northern part of the eastern range. Most of these interbeds are within subunit Cn_{2b}, but one occurs at the top of subunit Cn_{2a} about 5.5 km south-southeast of Eveleigh mine. Volcaniclastic sedimentary rock interbeds are more common in unit Cn_2 of the Mount Surprise Sheet area (Oversby, 1977).

Thin aphyric andesitic lava flows also occur locally within unit Cn_2 (above).

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(2e) Unit Cn_3

Unit Cn_3 crops out north of grid ref. 073687 in the Georgetown 1:100 000 Sheet area, and is exposed continuously northwards and eastwards into the Mount Surprise Sheet area except where it has been cut out locally by high-angle faults and the Eva Creek Microgranite (below). The unit contains buff and grey aphyric rhyolitic ignimbrite which locally contains a very faint eutaxitic foliation and conspicuous columnar joints. The ignimbrite apparently constitutes a single cooling unit made up of several flows.

At grid ref. 073687 unit Cn_3 is 30 m thick and is both underlain and overlain by rocks currently assigned to unit Cn_{2b}; about 0.6 km farther south unit Cn_{2b} lies directly on epiclastic sedimentary rocks, unit Cn_3 having apparently died out. North of grid ref. 073687 unit Cn_3 thickens to 100 m and is overlain by unit Cn_4. It is also overlain by unit Cn_4 in the Mount Surprise area (Oversby, 1977), where it changes in thickness from 50 to 160 m from south to north.

(2f) Unit Cn_4

Unit Cn_4 is probably the most extensive one in the eastern Newcastle Range; it occurs throughout much of the northern part of the range in the Georgetown 1:100 000 Sheet area and extends eastwards and southwards into the Mount Surprise Sheet area. It is also present in that part of the eastern range which is within the northernmost Forsayth Sheet area (Bain, Withnall, & Oversby, 1976, p. 61). However, at least the northern part of the outcrop area of Cn_4 shown on the map is now known to consist of intrusive microgranite (mg_1).

At least 50 m of buff to purple porphyritic rhyolite ignimbrite which contains 40 percent quartz, alkali feldspar, and plagioclase phenocrysts up to 4 mm across characterises the unit. The ignimbrite apparently constitutes a single cooling unit. Unit Cn_4 overlies unit Cn_3 with apparent conformity at most locations; it is overlain by unit Cn_6 except in the southwestern part of the range where unit Cn_5 is locally interposed.

A sequence of about 100 m of volcaniclastic sedimentary rock occurs above the ignimbrite of unit Cn_4 in the southwestern part of the outcrop area. This sequence is overlapped and cut out by unit Cn_6 in the upper reaches of the Fish Hole Branch of McMillan Creek. Southwards the volcaniclastic sedimentary rock abuts the dyke-filled range-front fault.

(2g) Unit Cn_5

Unit Cn_5 is restricted to the southwestern part of the eastern Newcastle Range in the Georgetown 1:100 000 Sheet area, and is characterised by at least 60 m of purple and buff porphyritic rhyolitic lava and ignimbrite which contain 10 percent quartz, alkali feldspar, and plagioclase phenocrysts up to between 5 mm and 1 cm across. Outcrops of the unit commonly have a rubbly aspect, and a large volume of the rocks has been intensely brecciated at and around grid ref. 053628.

Unit Cn_5 is separated from ignimbrite in unit Cn_4 by a sequence of volcaniclastic sedimentary rock (above); the base of the unit is apparently conformable with stratification within the sedimentary rock sequence. Unit Cn_4 is overlain discordantly by unit Cn_6.

(2h) Unit Cn_6

The uppermost unit in the eastern sequence of the Newcastle Range Volcanics, Cn_6, crops out in the southern half of the range in the Georgetown 1:100 000 Sheet area. It extends for about 1 km eastwards into the Mount Surprise Sheet area, and also occurs in that part of the eastern range which is within the Forsayth Sheet area (Bain, Withnall, & Oversby, 1976, p. 61) . It is the only unit in the eastern range sequence which has been recognised (albeit tentatively) in the main range.

Grey and (rarely) buff porphyritic rhyolitic ignimbrite which contains about 50 percent quartz, alkali feldspar, and plagioclase phenocrysts up to 4 mm across, and 1 percent partly to wholly chloritised hornblende and biotite phenocrysts up to 2 mm long, characterises unit Cn_6. The ignimbrite apparently constitutes a single cooling unit and is at least 200 m thick.

Unit Cn_6 overlies volcaniclastic sedimentary rocks between units Cn_4 and Cn_5, and rocks within the latter unit, discordantly; it is not so obviously discordant in relation to ignimbrite in unit Cn_4. The discordance may be either an unconformity, or the result of low-angle faulting at the base of unit Cn_6, or a combination of both (see also below).

Age and source

White (1959) and Branch (1966) inferred that the Newcastle Range Volcanics were probably of Late Palaeozoic (more specifically Carboniferous) age by analogy with similar units elsewhere in northeastern Queensland known (from fossil evidence) to be of that general age, and from the fact that the unit is intruded by Elizabeth Creek Granite and rocks equated with it. Isotopic data were tentatively taken to indicate an Early Devonian age, however (Richards & others, 1966, p. 26).

More recently, samples from units Cn_{III} and Cn_{IV}, and from dykes associated with the main Newcastle Range (including localities 31 to 37 on map), have given a total-rock Rb-Sr age of 318 $\pm$ 21 million years while samples from the eastern range sequence (including localities 19 and 20 on map) have given an age of 316 $\pm$ 21 million years (Black, 1974, p. 41). These ages (Late Carboniferous) are not statistically different. Data yielded by additional samples from both sequences in the Georgetown (map), Forsayth, Galloway, and Mount Surprise Sheet areas have not yet been fully evaluated; it remains to be seen whether the main and eastern range sequences of the Newcastle Range Volcanics will give meaningfully different isotopic ages or not.

A single fragment of a plant stem from volcaniclastic sedimentary rock below the volcanic-rock-dominated part of the main range sequence near Fish Hole in the Forsayth 1:100 000 Sheet area was found by one of us (I.W.W.) in 1975. The fossil has been tentatively identified as *Lepidodendropsis? pacifica* (Jongmans), and also suggests that the rocks are of Late Carboniferous age (N. Morris, personal communication 1976). Unidentifiable plant fragments have also been found in the same general area by geologists of Urangesellschaft Australia Pty Ltd (W.E. Schindlemayr, personal communication 1974).

The magma which formed most of the Newcastle Range Volcanics and other Upper Palaeozoic acid igneous rocks in northeastern Queensland was probably generated by partial anatexis of dry, Rb-poor, metasedimentary rocks in the lower crust (Sheraton & Labonne, 1978). The anatexis may have been caused by the introduction of basic melt into the lower crust, most of which crystallised before higher levels were reached, although some was extruded as andesite. No major vents associated with the Newcastle Range Volcanics are exposed in the Georgetown 1:100 000 Sheet area, although a few small ones (Fig. 30) are known. Some of the dykes and other intrusive bodies of rhyolite and microgranite (including the Eva Creek Microgranite), which are described in more detail below, might have been emplaced into vent areas and destroyed evidence for their prior existence. Alternatively, such major vent areas might still be concealed beneath the volcanic rocks. "Lag-fall" deposits (Wright & Walker, 1977) in subunit Cn_{Vb} of the Galloway 1:100 000 Sheet area (see above) suggest that the source of at least that subunit was in the north.

Structure

Branch (1966, pp. 16-20) considered that large shallow synclines and basins were the most common structures in the Newcastle Range, apart from faults; smaller-scale, tighter folds were thought to be rare. His interpretation of the available data was that the main and eastern parts of the Newcastle Range occupy the sites of two complete cauldron subsidence areas of Late Palaeozoic age within which the Newcastle Range Volcanics accumulated. The eastern range cauldron was tentatively inferred to be a composite structure which had undergone three periods of subsidence.

Bain, Withnall, & Oversby (1976, p. 66) described the structure of the Newcastle Range Volcanics in the Forsayth 1:100 000 Sheet area, and agreed with Branch that the structure of the unit there was that of a large basin. However, they concluded that there was probably no well-defined cauldron of the type which Branch evidently envisaged, but rather an area of subsidence which was both spatially and temporally relatively diffuse. However, it must be noted that Branch's pioneering application of the cauldron subsidence concept to these rocks is in no way invalidated, and is believed to be essentially correct.

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In the Georgetown Sheet area the main range sequence of Newcastle Range Volcanics are preserved in what appears to have been a north-trending, partly fault-bounded, downwarp (perhaps best thought of as a shallow rift valley only locally bounded by inward-facing escarpments). This downwarp merges southwards into the more nearly circular, mostly fault-bounded, structure which is present in the Forsayth Sheet area, and which is here informally named the "Wirra cauldron". The downwarp also merges northwards across the Brodies Gap-Dagworth Bore fault zone into an ellipsoidal, partly fault and cone-sheet-bounded structure in the Galloway Sheet area - the "Namarrong cauldron". The eastern range sequence is preserved in a fault and ring-dyke-bounded trapezoidal area - the "Eveleigh cauldron". Thus, we recognise three main cauldron subsidence areas within which Newcastle Range Volcanics accumulated, as well as a downwarped and partly rifted isthmus between two of them. These various structures evidently overlapped and intergraded, both spatially and temporally, at least in part; they may have been within a wider area of structural disturbance extending from the Delaney Fault to the Mount Nigger dyke (Mount Surprise 1:100 000 Sheet area - Oversby, 1977) and Cumbana volcanics, east of the Einasleigh River.

Regional Bouguer gravity data, supplemented by two detailed gravity traverses across the Newcastle Range in 1975, indicate that the area of the Newcastle Range Volcanics is spatially coincident with a gravity low in gross terms. Within this low are two discrete minima which coincide with the eastern "Eveleigh cauldron" and the northeastern "Wirra cauldron". The structures cannot be modelled realistically, however, because there is evidently no significant density contrast between volcanic and associated rocks and basement rocks (D. Wilson, personal communication 1975).

The various subsidence areas in which the Newcastle Range Volcanics accumulated were apparently active to different degrees at different times. Their evolution remains to be fully worked out, but, judging from the relative volumes of ignimbrite present in various units, the "Wirra cauldron" probably underwent its main subsidence during extrusion of units Cn_{II} and Cn_6?, the "Eveleigh cauldron" during extrusion of units Cn_4 and Cn_6, the "Namarrang cauldron" during extrusion of Cn_V, and the remainder of the main Newcastle Range subsided gradually and progressively during extrusion of units Cn_{II} (in the south) and Cn_V (in the north). Periods of uplift of the various structures, perhaps reflecting magmatic insurgence, are also suggested by inward-dipping faults, ring dykes, and cone sheets, and by the distribution

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of certain units. The intrusion of microgranite and microgranodiorite bodies into the volcanic pile at various times might have caused resurgent doming (Smith & Bailey, 1968) locally.

(a) Folds

Rhyolitic and dacitic lava in the Newcastle Range Volcanics of the Georgetown 1:100 000 Sheet area commonly contain flow bands which are complexly and disharmonically folded. Epiclastic sedimentary rocks have locally been drag-folded adjacent to high-angle faults; the most intensely folded rocks of this type known crop out in a small fault-bounded inlier in O'Brien Creek, 5 km north of the Gulf Developmental Road.

The volcanic and associated rocks in both parts of the Newcastle Range rarely dip at more than about 20 degrees except where they abut high-angle faults, however. The gross structure of the main range is that of a shallow north-trending syncline whose hinge occurs in the centre of the range. The limbs of the syncline most commonly dip at between 5 and 15 degrees; the hinge plunges north between 1 and 3 degrees in the northern third of the range, but it is apparently horizontal to the south of the Gulf Developmental Road.

Branch (1966, p. 18) thought that a suite of relatively complex structures occurred on the eastern side of the main range in the vicinity of the Gulf Developmental Road. In that area, steep dips away from the front of the range reflect oversteepening by high-angle range-front faults, and an elongate dome has been formed by superimposition of this phase of oversteepening on a second one produced by west-striking faults. Flow-folds in lava have been partly involved in both phases of oversteepening, and very high "false" dips (up to 80 degrees) have thus been produced locally. A syncline, and anticlinal cross folds at the southeastern edge of the dome, which were identified by Branch on the basis of photo-interpretation, do not appear to exist.

The base of the Newcastle Range Volcanics on the western side of the main range lies at an elevation of about 340 m 6.5 km south of Dagworth Bore, at about 440 m between Sisters and O'Brien Creeks, and at about 380 m between the western side of the Etheridge River and the southern edge of the Georgetown Sheet area. The rocks tentatively assigned to unit Cn_I in the southwestern corner of the Georgetown Sheet area also lie at an elevation of about 380 m. On the eastern side of the main range the base of the sequence is at about 370 m 3 km southeast of Brodies Gap, at about 380 m 3 km north of Collins Creek, at about 420 m 6 km south of Collins Creek, at about 380 m 4 km north of the Gulf Developmental Road, and at about 520 m 3 km south of the road. Epiclastic sedimentary rocks in the Newcastle Range Volcanics thin and die out in sympathy with the rise in elevation of the base of the sequence, suggesting that the variations in elevation primarily reflect the prevolcanics palaeotopography.

The eastern part of the Newcastle Range is structurally similar to the main range in that it consists of a shallow syncline whose limbs commonly dip between 10 and 15 degrees except where they have been over-steepened by high-angle faults. The hinge of the syncline most commonly plunges south-southwest at between 2 and 5 degrees, although it is apparently horizontal locally. The Newcastle Range Volcanics have not been obviously domed by the Eva Creek Microgranite.

The base of the eastern range sequence lies at en elevation of about 420 m in the easternmost part of the Georgetown 1:100 000 Sheet area, at about the same elevation 5.5 km southwest of Eveleigh mine, at about 500 m 8 km southwest of the mine, and at about 540 m 2 km south-southwest of the Fish Hole Branch of McMillan Creek. These variations probably mainly reflect the influence of high-angle faults which are oblique to the range front and which have displaced the volcanic and associated rocks.

In the Mount Surprise Sheet area the base of the eastern Newcastle Range Volcanics sequence lies at an elevation of between about 385 and 430 m; the variations are partly due to the effects of faults.

(b) Faults

Linear and curvilinear faults occur sporadically along and parallel to the fronts of the main and eastern parts of the Newcastle Range in the Georgetown 1:100 000 Sheet area. The two parts of the range are by no means bounded by single, continuous range-front faults, however, and in many places there are no faults at all. There is no evidence to suggest that major strike-slip took place along any of the faults, except perhaps in the Dagworth Bore area (below).

Faults, which have commonly been filled by rholite (rh) and microgranite (mg_1) dykes, along the western and eastern fronts of the main Newcastle Range strike northwest, north-northeast, and/or northeast; they commonly change direction along strike and cut the volcanic and associated rock sequence locally. Fault planes are rarely well exposed, but their trace on the ground indicates that all faults dip at high angles (45 degrees or more); most dykes dip at similarly high angles and presumably reflect the orientation of the fractures along which they were emplaced. The range-front faults and associated dykes exposed in cuttings along the Gulf Developmental Road on the eastern side of the main range (grid ref. 942733) dip at about 75 degrees to the west; those on the opposite side of the range (at and near grid ref. 846768) (Fig. 33) dip at 45 to 60 degrees to the east. Most of the visible fault planes show evidence for two or more phases of movement, mostly in the form of sequentially crosscutting and faulted sets of dykes.

It is rarely possible to calculate displacements on individual faults because only a few of them cut markers such as contacts or thin units within the Newcastle Range Volcanics. Apparent displacement of contacts between basement rock units cannot be used to estimate absolute displacement because the variations in direction and amount of dip of these contacts are rarely known sufficiently well. The range-front fault which occurs between Big Spring (grid ref. 835698) and Spear Creek (grid ref. 830672) probably has a displacement of about 45 m, the eastern side having moved down relative to the western side. The fault along the western front of the range between grid refs. 846833 (0.5 km southeast of O'Brien Creek) and 816850 (2 km southeast of Quartz Blow Creek) has displaced Newcastle Range Volcanics in the northeast down about 40 m against the Proterozoic White Springs Granodiorite. None of the faults farther north which bound small blocks and slices of Newcastle Range Volcanics between 5.5 km north-northeast of Fiery House outstation (grid ref. 801919) and Dagworth Bore can be inferred to have a displacement of more than about 20 m.

No faults or dykes occur along the eastern front of the main Newcastle Range between grid refs. 958845 and 971941, although the volcanic and associated rocks dip west at up to 15 degrees. This absence of faults, and the fact that only a few small dykes occur to the east of that part of the range in the Georgetown Sheet area, suggest that the Newcastle Range Volcanics which presumably originally occurred throughout the area to the

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east of the range were not cut, let alone bounded, eastwards by any major faults. The relatively high dips along the range front suggest, however, that the site of the range was an area of downwarping, either during the time that the Newcastle Range Volcanics accumulated or afterwards. Similarly, there are no faults or dykes along the western front of the range between grid ref. 826599 and the southern edge of the Georgetown Sheet area, an area in which the Newcastle Range Volcanics appear to be horizontal (suggesting that downwarping has been minor). West of the range front there are a few small dykes, but the closest major structure is the Delaney Fault, 15 km away. The Delaney Fault, which contains small dykes and stocks of rhyolite, microgranite, and diorite locally in the Forsayth 1:100 000 Sheet area, and which has undergone no major detectable movement (Bain, Withnall, & Oversby, 1976, p. 67), may mark the western limit of faults genetically related to subsidence in the area of the main Newcastle Range. There are no outliers of Newcastle Range Volcanics in elevated areas (e.g. Mount Talbot - 530 m) between the range front and the occurrence of Cn_I(?) in the southwestern corner of the Georgetown Sheet area, possibly because these areas were palaeotopographic highs.

Three roughly west-striking fault zones cut across the main Newcastle Range in the Georgetown 1:100 000 Sheet area. These zones are irregular, being made up of segments of west, northwest, and southwest-striking faults. The southernmost zone is about 12 km south of the Gulf Developmental Road; it extends from the Etheridge River to the head of Spear Creek, and has brought units Cn_{IId} (in the south) and Cn_{III} (in the north) into contact with each other. The amount of throw has been about 60 m (north side down relative to south side). A similar fault zone crosses the range in the area occupied by the Gulf Developmental Road; in general terms it has brought unit Cn_{III}, in the south, into contact with the uppermost part of unit Cn_{IV}, indicating that the northern side of the zone has moved down about 40 m relative to the southern side. The zone is now known to be more complex than shown on the map. The northernmost and most complex of these west-trending fault zones is the one between Brodies Gap and Dagworth Bore. The western end of this zone consists of numerous blocks and slices bounded by relatively short faults, and by segments of faults which strike into the zone from the north and south. The zone is represented by a single high-angle fault through Brodies Gap on the eastern side of the range. The central part of

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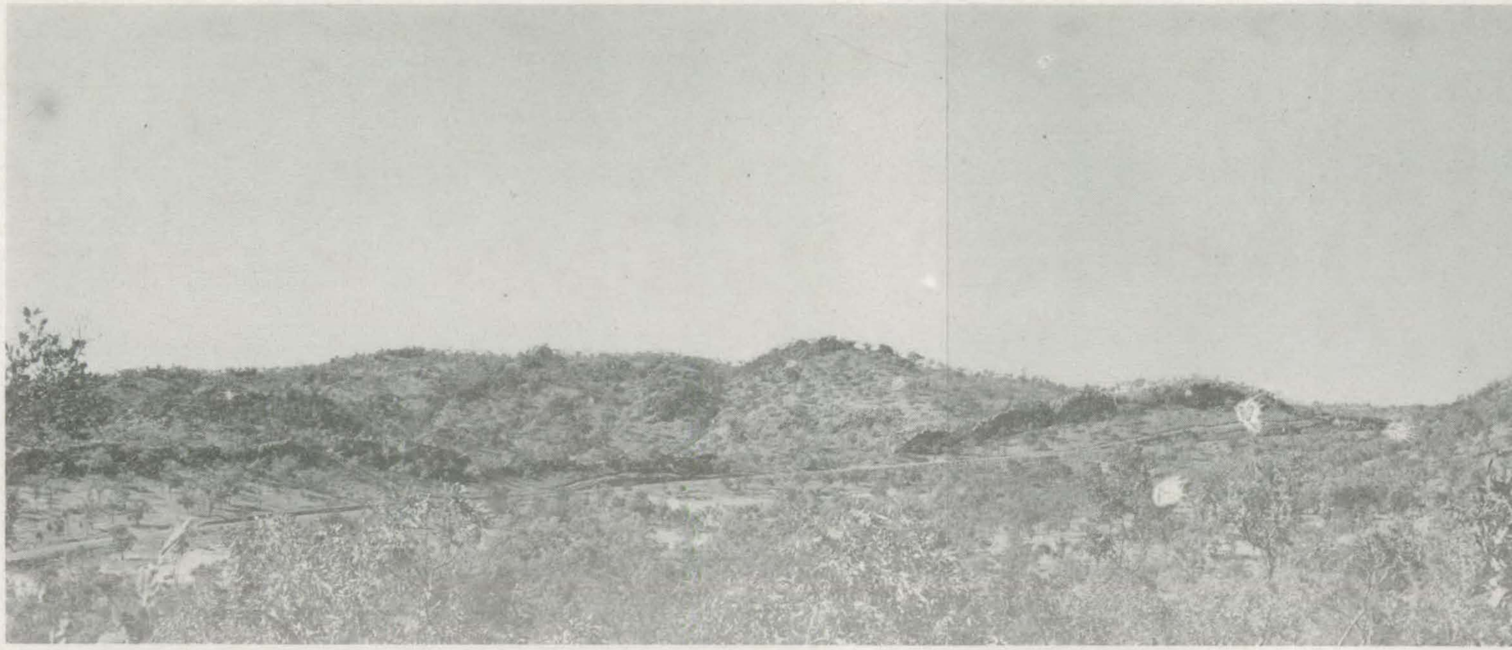

Fig. 33: Rhyolite dyke partly coincident with the present range-front fault on the western side of the main Newcastle Range. Proterozoic White Springs Granodiorite underlies the area between the dyke and near edge of the photo, and a strip of country (not visible) on the far side of the left half of the dyke; dacitic rocks of main Newcastle Range unit Cn_{III} crop out in the bluffs and cliffs beyond the dyke. The Gulf Developmental Road runs parallel to the dyke. View to the southeast from grid ref. 841775. Photo by A.J. Stewart.

the fault zone has been intruded by north-dipping rhyolite and microgranite cone sheets, not shown on the map (Oversby, 1977). The nature and magnitude of displacements in the Brodies Gap-Dagworth Bore fault zone are not known because of the zone's complexity, and because of stratigraphic changes across it. The most notable stratigraphic changes are, from south to north, the considerable increase in thickness of andesitic lava sequences, and the thinning of rocks currently assigned to unit Cn_{IV} (in actual fact the unit may be completely absent immediately north of the fault zone). These stratigraphic changes suggest that at least the western end of the fault zone was either active at the time that the Newcastle Range Volcanics accumulated, or that there has been a significant component of strike-slip movement along it resulting in juxta-position of rocks from two areas which had undergone different degrees of subsidence. Neither of these explanations is completely satisfactory, however, because no syndepositional breccias are known to occur adjacent to the fault zone (although the most complex part of the zone might be a depositional rather than a tectonic megabreccia), and the interlocking nature of the fault-bounded blocks and slices in the zone would have tended to inhibit strike-slip movement along it.

Like the main Newcastle Range, the eastern part of the range is bounded locally by linear and curvilinear high-angle faults. Several such faults, some of which have been filled by microgranite, occur along the western front of the range, and also separate it from the main range in the upper reaches of McMillan Creek. Single faults occur along the northern and southern fronts of the range. The fault bounding the northern front and probably dips at about 75 degrees to the south opposite the Eveleigh zinc prospect (35 on map), as indicated by reconstructions made from Minad's EVDH21 diamond drillhole data given in Davies (1971) (Fig. 34). The unconformity between the Newcastle Range Volcanics and Proterozoic basement rocks is exposed along most of the eastern front of the range in the Mount Surprise Sheet area (Oversby, 1977); the volcanic and associated rocks presumably originally extended at least as far east as the series of dykes which occurs near the Einasleigh River, up to 2 km from the range front, as suggested by Branch (1966, p. 18). Individual dykes in this series cut the Newcastle Range Volcanics locally, and extend southwards to form the eastern edge of the supposed early ring structure centred 8 km northwest of Einasleigh. (Branch, 1966, p. 19).

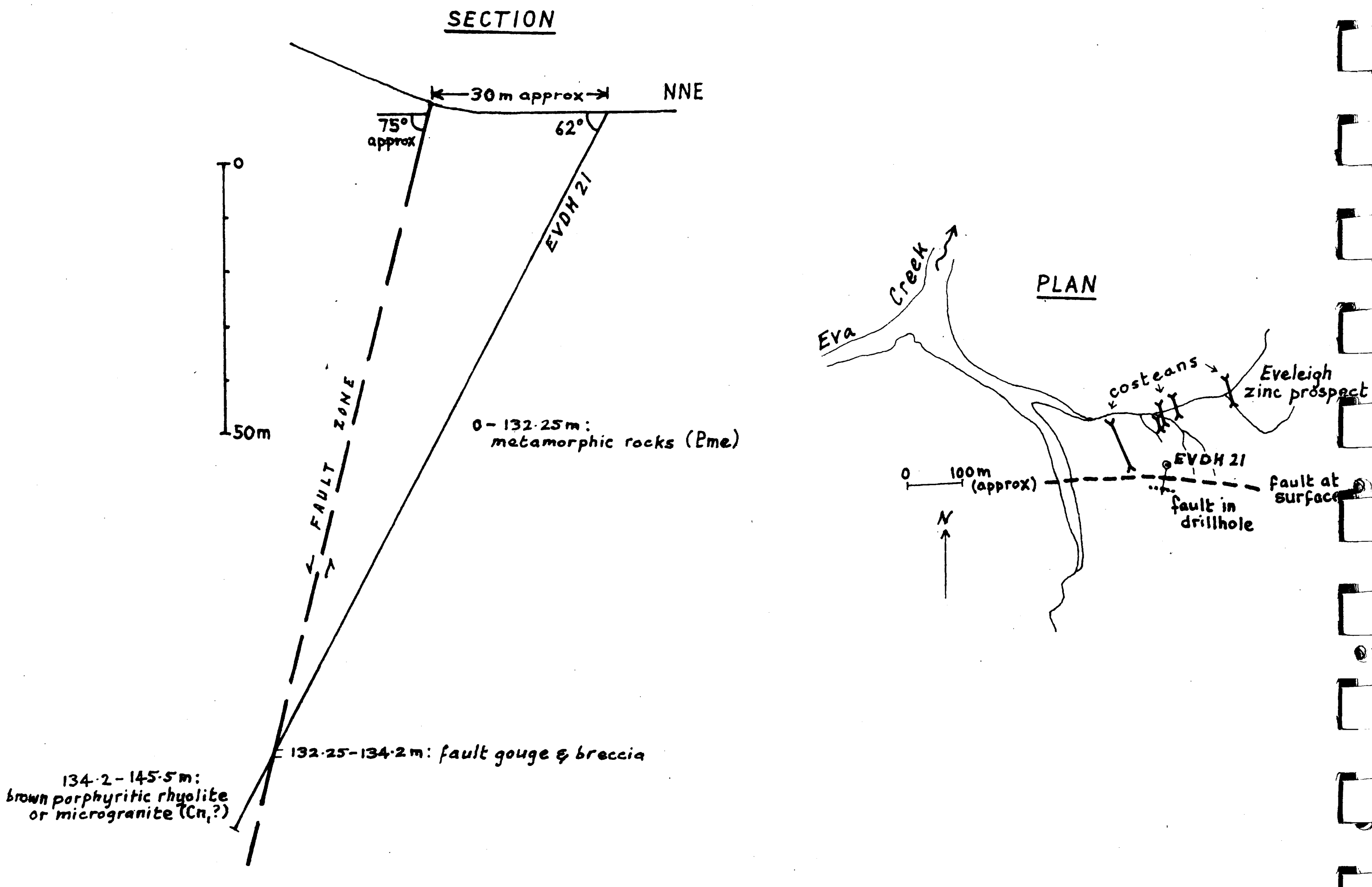

Fig. 34 The northern boudary fault of the eastern Newcastle Range opposite Eveleigh zinc prospect. Reconstructed from data in Davies (1971)

The southernmost range-front fault on the western side of the eastern Newcastle Range has been filled by a microgranite dyke; the dip-slip component and throw on the original fault may have been at least 200 m greater near the head of McMillan Creek than at grid ref. 056657, 7 km farther north, but the total throw is unknown because the fault does not now cut the Newcastle Range Volcanics internally. The fault between the Fish Hole Branch of McMillan Creek and grid ref. 074731 is inferred to have a throw of about 240 m; the one between grid refs. 080755 and 076771 has a throw of about 210 m. A few other faults cut the Newcastle Range Volcanics, but none of them is known to have a throw of more than about 50 m. There are no major west-striking fault zones in the eastern Newcastle Range.

A short west-striking high-angle fault which occurs about 9.5 km southwest of Eveleigh mine was apparently responsible for the existence of a scarp at the time that epiclastic sedimentary rocks below the volcanic-rock-dominated part of the eastern Newcastle Range sequence were accumulating (above). The throw on the fault is not known, however.

Swarms of linear and curvilinear rhyolite (rh), microgranite (mg_1), and andesite (ad) dykes occur in basement rocks to the west of the main Newcastle Range, and between the main and eastern parts of the range, in the Georgetown 1:100 000 Sheet area; the dyke rocks are discussed in more detail below. The dykes were presumably emplaced into tension fractures, none of which appears to have displaced the Proterozoic rocks which they cut to any detectable extent. In this respect the fractures are similar to the Delaney Fault. The reason for the evident localisation of the original fracture swarms is not known.

(c) Joints and lineaments

Ignimbrites in both sequences of the Newcastle Range Volcanics in the Georgetown 1:100 000 Sheet area commonly contain columnar joints which are perpendicular to the tops and bottoms of flows and cooling units. Such joints are especially well developed in the porphyritic rhyolitic ignimbrite at the top of unit Cn_{IV} at many localities in the upper reaches of Kitchen Creek, to the south of the Gulf Developmental Road, and in unit Cn_3 in the Mount Surprise Sheet area. Rhyolite dykes commonly also contain columnar joints which are perpendicular to their margins.

Many lineaments, defined by drainage segments, topographic lows and (rarely) highs, and colour variations, occur in both parts of the range in the Georgetown Sheet area. Most of these lineaments appear to be major joint zones along which no displacement has taken place, although a few are known to be faults with displacements of less than 10 m (some may also be occupied by dykes). Some high-angle faults die out and become lineaments along strike. Strikes of the lineaments are variable, although most commonly either west-northwest to northwest or roughly north. The lineaments are probably due to regional extension caused by gently post-volcanic flexing which rejuvenated appropriately oriented basement fractures and propagated them upwards through the relatively brittle Newcastle Range Volcanics. Local intrusion of magma into well-defined fractures caused dykes to be formed. Individual lineaments are most conspicuous in relatively homogeneous units such as Cn_6. An area of about 30 km^2 in the main range about 10 km north of the Gulf Developmental Road is anomalously free of lineaments for some reason; perhaps it is underlain by a rigid intrusive body at fairly shallow depth.

Mineralisation

Very few mineral occurrences of potential economic interest are known to occur in the Newcastle Range Volcanics, and none of them has been worked. The Mountain King, Flying Fox, or Low's mine (No. 36 on map) is now known to occur in Eva Creek Microgranite rather than volcanic rocks; it will be discussed below.

Laura Jean (No. 65 on map) is a small fluorite prospect at grid ref. 942734, on the eastern side of the main Newcastle Range about 25 km east of Georgetown. Mineralisation is exposed in a cutting on the northern side of the Gulf Developmental Road; it occurs in brecciated dacitic lava and microgranite within a fault and dyke zone which has evidently had a fairly complex history (Bain, 1977; Withnall, in press). Chloritised and fluoritised breccia in the cutting is moderately radioactive, and contains 112 to 155 ppm uranium in association with thorium, molybdenum, lead, copper, and zinc; tin has not been detected. Mineralisation evidently does not extend far in any direction. The fluoritised breccia probably represents a channelway for mineralising hydrothermal fluids similar to those which formed the Maureen prospect to the north-northwest of Georgetown (O'Rourke, 1975; Bain, 1977). This suggests that important uranium deposits could occur in suitable stratigraphic or structural sites anywhere in the Newcastle Range Volcanics.

Chalcopyrite occurs in amygdaloidal porphyritic andesitic lava (Cna_{II}) at grid ref. 834991, and in similar rocks to the northeast of Dagworth Bore. The chalcopyrite partly to wholly fills amygdales up to 0.75 mm diameter; larger amygdales do not appear to contain the mineral, although iron oxide stains which occur at the edges of some might have been derived from small specks of original chalcopyrite. Chalcopyrite never constitutes more than a portion of one percent of rocks in which it occurs; analyses indicate that andesite with visible chalcopyrite in amygdales contains up to 150 ppm copper, compared to 32 to 70 ppm in similar rocks which contain no visible chalcopyrite (Withnall, in press). Films of chalcopyrite also coat joints in aphyric andesitic lava (Cna_{I}) to the northeast of Dagworth Bore, and malachite occurs locally in epiclastic sedimentary and volcanic rocks.

Intensely "kaolinised" and/or silicified rocks in the Newcastle Range Volcanics, which may represent fumarole pipes, are not known to be mineralised.

Cumbana volcanics (Cc)

Introduction

White (1959b, 1962), and Branch (1966) applied the name "Cumbana Rhyolite Porphyry" to rocks which we assign to the Cumbana volcanics in the belief that they represented a chilled hood of Elizabeth Creek Granite. However, our mapping in the Georgetown 1:100 000 Sheet area indicates that the "Cumbana Rhyolite Porphyry" actually consists of a stratigraphic sequence of volcanic rocks, mainly ignimbrite. Consequently the name has been changed informally so as to reflect the nature of the unit more accurately; this informal name will eventually be formalised, and the unit defined (probably) as a formation.

The Cumbana volcanics crop out in an area of about 30 km^2 in the northeastern corner of the Georgetown Sheet area, where there are two main subunits. The rocks extend for about 7 km eastwards in the adjacent Mount Surprise Sheet area; we have not studied them there, but photo-interpretation suggests that the sequence is identical to that farther west. Physiographically, the area underlain by Cumba volcanics is a rugged, almost completely dissected, plateau, similar to the northern part of the main Newcastle Range (Fig. 4).

About 500 m of Cumbana volcanics are exposed in the Georgetown Sheet area. The top of the unit has been weathered away, and the base is not exposed; the unit presumably lies unconformably on Proterozoic Einasleigh Metamorphics. Microgranite (mg_1), Elizabeth Creek Granite (Ce), and probably near-Concordant rhyolite dykes (not shown on the map) intrude the Cumbana volcanics.

Lithology and petrography

Porphyritic rhyolitic ignimbrite is dominant in the Cumbana volcanics; agglomerate and volcaniclastic sedimentary rocks are minor constituents of the unit. The rocks are identical in all essential respects to their counterparts in the Newcastle Range Volcanics, described above, and so need not be discussed further.

Stratigraphy and map units

(a) Subunit Cc_I

The lowest exposed subunit in the Cumbana volcanics, Cc_I, crops out between Simons Gap and the eastern edge of the Georgetown Sheet area; it extends into the Mount Surprise Sheet area. The subunit is at least about 400 m thick, and is characterised by buff to purple porphyritic rhyolitic ignimbrite flows. Several varieties of ignimbrite occur; they contain from 10 to 50 percent quartz, alkali feldspar, and plagioclase phenocrysts between less than 0.5 and about 2 mm across.

Autoclastic agglomerate (Cc_{Ia}) is relatively rare in the subunit; the only occurrence extensive enough to show on the map is in an apparent lens at the top of subunit Cc_I in the middle reaches of Friendly Creek. About 30 m of buff siliceous volcaniclastic sandstone and conglomerate occur 100 m below the top of unit Cc_I in the southern part of its outcrop area. Similar rocks occur in a 10(?) m-thick interbed about 200 m below the top of the unit between 2 and 6 km to the northwest. A single thin (10 m?) aphyric andesitic lava flow (Cca_I) crops out between grid refs. 156997 and 175998, close to the top of the unit.

(b) Subunit Cc_{II}

Subunit Cc_{II} overlies Cc_I in the central part of the Cumbana volcanics' outcrop area, and extends into the Mount Surprise Sheet area. About 100 m of the subunit has been preserved; it consists of buff to brown porphyritic rhyolitic ignimbrite containing 40 percent quartz, alkali feldspar, and plagioclase phenocrysts between 1 and 3 mm across. The igimbrite apparently constitutes a single cooling unit, and may be a single flow.

Age and source

Even though the Cumbana volcanics have not yielded any fossils or been isotopically dated, it is believed that they are probably laterally equivalent to unit Cn_V (described above) of the Newcastle Range Volcanics in the Galloway 1:100 000 Sheet area. This correlation is supported by the presence of similar rocks in both units, and by the short distance (5 km) between their closest outcrops. The correlation implies that the Cumbana volcanics are of Late Carboniferous age, and originated from a source area in the northernmost part of the main Newcastle Range.

Structure

The structure of the Cumbana volcanics is a shallow, northwest striking syncline. The southern limb of the fold dips at about 10 degrees; most of the northern limb has been engulfed by Elizabeth Creek Granite and destroyed. The syncline is bounded in the south and west by an elongate microgranite (mg_1) body and a presumed curvilinear high-angle fault or dyke system which has been covered by Undara basalt and superficial Cainozoic rocks. This presumed fault or dyke system may have been the continuation of a dyke system along the eastern side of the Einasleigh River in the Galloway 1:100 000 Sheet area (Oversby, 1977). An east-southeast-striking high-angle fault, which is probably part of the main bounding fault system, cuts the Cumbana volcanics in the southern part of the outcrop area; the amount of displacement on the fault (north side down) is not known. About 20 m of dip-slip movement (east side down) has taken place on a second, north-northwest-striking, high-angle fault which cuts the unit.

The Cumbana Volcanics have probably been preserved because they occurred in a small ellipsoidal cauldron-like area within the wider downwarp which included the sites of the main and eastern parts of the Newcastle Range. It is difficult to say whether subsidence of this local cauldron-like area took place during the time that the unit was accumulating, or whether it took place afterwards; the presence of a relatively thick ignimbrite cooling unit (Cc_{II} suggests that at least some subsidence took place during accumulation of the unit, possibly in an eastern apophyse of the "Namarrang cauldron", or in a small independent structure.

Mineralisation

No mineral deposits of potential economic interest are known to occur in the Cumbana volcanics, although the unit may contain uranium mineralisation of the type present in the Newcastle Range Volcanics (above) and at the Maureen prospect near Georgetown (Bain, 1977; O'Rourke, 1975).

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Eva Creek Microgranite (Cv)

Introduction

The Eva Creek Microgranite was named by Withnall & others (1976, p. 3) from Eva Creek, a north-northwestward-flowing tribuatry of McMillan Creek in the west-central part of the Georgetown 1:100 000 Sheet area. The type area extends along an old track between grid refs. 157749 and 130759. The rocks were previously assigned to the Elizabeth Creek Granite (White, 1965; Branch, 1966; Bain & others, 1975), although they are well away from occurrences of "typical" Elizabeth Creek Granite, as well as being of different lithology.

The main occurrence of Eva Creek Microgranite is in an area of about 11 km^2 in the northern part of the eastern Newcastle Range. There is a second smaller (about 0.75 km^2) area about 2.5 km southwest of the main one, and a third area of a few hundred square metres (not shown on the map) about 5 km south-southwest of "Eveleigh". Porphyritic granophyre in a small boss at grid ref. 07779, 7 km west-southwest of "Eveleigh", is also assigned to the unit.

Rocks similar to those in the Eva Creek Microgranite also occur in the central part of the "Wirra cauldron" (above) in the Forsayth 1:100 000 Sheet area (these rocks are annotated as mg_4 on the Preliminary Edition map of that area) (Bain, Withnall & Oversby, 1976, p. 65), and at Mount Adler in the Mount Surprise 1:100 000 Sheet area (Oversby, 1977).

In the Georgetown Sheet area the Eva Creek Microgranite intrudes and has thermally metamorphosed units Cn_2, Cn_3, and Cn_4 of the eastern Newcastle Range Volcanics sequence; it is not known whether or not it ever intruded unit Cn_6, although rocks tentatively assigned to that unit in the Forsayth Sheet area are intruded by mg_4. The granophyre to the west-south-west of "Eveleigh" has been emplaced into Einasleigh Metamorphics. The detectable thermal metamorphic aureole of the main body of Eva Creek Micro-granite is only about 30 m wide.

Lithology and petrography

The rock type most characteristic of the Eva Creek Microgranite is leucocratic grey and pink, buff-weathering, porphyritic microgranite. The rock contains up to about 20 percent rounded quartz crystals and aggregates between 1 mm and 1 cm across, up to about 35 percent feldspar phenocrysts between 1 mm and 1.5 cm long, and up to 15 percent (more commonly about 3 percent) biotite crystals and aggregates up to 2.5 mm long. The microgranite locally grades into fine-grained porphyritic granite with increase in the size of groundmass crystals. Aplite and greisen occur locally.

Alkali feldspar is orthoclase microperthite and makes up from about 25 to about 70 percent of the rocks; it is almost invariably turbid because of finely divided "sericite" and clay minerals. The alkali feldspar has three main modes of occurrence: (i) as subhedral to anhedral phenocryst and aggregates up to 1.5 cm in maximum dimension; some of the aggregates also contain subhedral plagioclase, anhedral quartz and subhedral biotite crystals which are apparently primary constituents and have not crystallised from the groundmass; (ii) overgrowths on phenocrysts and aggregates; (iii) anhedral interstitial groundmass crystals.

Plagioclase (mainly oligoclase with subordinate andesine) makes up between 3 and 20 percent of the rocks; it is also commonly altered, especially in cores, and is locally zoned. Like alkali feldspar, it occurs as phenocrysts up to about 4 mm long, and in aggregates, both of which have overgrowths. The phenocrysts are euhedral to subhedral. Plagioclase also occurs as mainly subhedral groundmass crystals.

Quartz makes up from about 22 to about 60 percent of the rocks. It occurs as phenocrysts which are rounded, locally embayed, single crystals and aggregates of crystals. Single crystals are 1 to 2 mm across, aggregates are up to 1 cm across. Phenocrysts and aggregates have overgrowths of later quartz. Groundmass quartz occurs as roughly equidimensional, partly interstitial crystals in the finest-grained groundmasses; with increasing grainsize the crystals become more irregular and markedly interstitial.

Biotite constitutes up to 15 percent of the rocks, most commonly about 3 percent. It occurs as pleochroic (dark brown or green to pale yellow-brown) anhedral to subhedral, partly interstitial, crystals and aggregates; it is locally chloritised, and commonly contains pleochroic haloes.

Fine-grained pink aplite occurs in diffuse veins and patches in the Eva Creek Microgranite locally; it consists of segregations of the rock's groundmass components (anhedral to subhedral plagioclase, anhedral alkali feldspar, and quartz) with a few scattered phenocrysts.

The above rocks contain accessory opaque minerals, apatite, allanite, zircon, and muscovite.

Quartz-rich greisen occurs locally in the Eva Creek Microgranite, mostly in the southern part of the outcrop area. The greisen occurs as more-or-less vertical "dykes" and subelliptical pipe-like bodies with irregular apophyses. The "dykes" are up to 10 m wide and from 100 to 400 m long; the longest ones strike roughly northeast, parallel to a major set of joints. In hand specimen the greisen is pale to dark grey, vitreous, and commonly contains irregular patches of pale yellowish or greyish green very fine-grained micaceous material and vugs, mostly 2 mm or less across, which are lined with small quartz crystals. Areas of greisen have locally recrystallised to massive vuggy quartz which has been partly remobilised into veinlets. In thin section the greisen is medium-grained and consists of about 70 percent irregular anhedral quartz grains up to 3 mm in maximum dimension which have slightly undulose extinction. Interstitial masses of felted fine-grained "sericite" make up the remaining 30 percent of the rock except where up to 3 percent molybdenite and rare cassiterite(?) occur in interstices. Zircon occurs in accessory amounts. The vugs seen in hand specimens are probably interstitial areas from which the sericite has been weathered. Greisen in the area of the Hammer and Mary prospects is reported to contain some muscovite (Wright & Hatcher, 1972). Microgranite grades into these greisen bodies at least locally, suggesting that the greisens have been formed by alteration of microgranite along major joints.

Greisen is commonly associated with zoned quartz-feldspar "chlorite" and quartz veins, stringers, and lenses which contain cassiterite, galena, pyrite, fluorite, bismuthinite(?), and topaz(?). The "chloritic" part of these intrusions might include appreciable amounts of green-stained sericite. The intrusions locally cut microgranite, which is reddened and "chloritised" adjacent to them.

The granophyre at grid ref. 07779 is a porous grey rock with about 5 percent anhedral, subangular to rounded, clear quartz phenocrysts, and about 1 percent subhedral phenocrysts of turbid orthoclase microperthite, up to 4 mm in maximum dimension. The matrix of the rock consists of graphically intergrown quartz and alkali feldspar. About 1 percent biotite occurs as subhedral crystals up to 1 mm long; the biotite is pleochroic from dark to pale brown and contains pleochroic haloes around minute zircon(?) inclusions. About 2 percent of chlorite occurs as interstital rosettes. Muscovite makes up about 3 percent of the rock; it occurs as scattered euhedral to anhedral crystals which locally coalesce into felted masses, and locally with chlorite in interstitial rosettes. The non-interstitial muscovite has replaced alkali feldspar and biotite.

The granophyre probably represents a very high-level, more acid, partially greisenised, equivalent of the Eva Creek Microgranite which occurs in the main outcrop area. Such rock probably also occurred at the apex of the main Eva Creek Microgranite body originally, but has been removed by erosion.

Branch (1966, Table 8, No. 10) presented a single analysis of Eva Creek Microgranite from the eastern Newcastle Range. The rock is calc-alkaline and similar to Elizabeth Creek Granite (c.f. Sheraton, 1974), although the silica content is rather lower than it is in the latter unit. Like the Elizabeth Creek Granite, the Eva Creek Microgranite probably crystallised at a high-level from dry, highly fractionated magma which had been generated by melting of Rb-poor lower crustal material.

Relationships and age

The Eva Creek Microgranite intrudes part of the eastern range sequence of the Newcastle Range Volcanics; it is thus younger than about 316 million years (Black, 1974). The broad similarities of the unit in petrography, chemistry, and setting to the Elizabeth Creek Granite suggest that the two units are of the same general age, i.e. early to late Carboniferous.

Specimens (23 to 27 on Map) of Eva Creek Microgranite from the Georgetown 1:100 000 Sheet area are being dated by the total-rock Rb-Sr method, but results are not yet available.

Mineralisation

Relatively minor occurrences of cassiterite in the Eva Creek Microgranite of the Georgetown 1:100 000 Sheet area were worked on a small scale in the 1930s and 40s; alluvial tin has also been won from the same area. Most of the cassiterite occurs with rare pyrite and galena in zoned quartz-feldspar-"chloritite"-fluorite veins, stringers, and lenses within, or close to, bodies of quartz-rich greisen which contain up to about 3 percent interstitial molybdenite locally. The main producing tin mine was Della's Find (No. 66 on map), where 6 tonnes of ore yielded 1 tonne of concentrates containing about 74 percent cassiterite (Withnall, in press).

Copper mineralisation (chalcopyrite, chalcocite, azurite, and malachite) also occurs in greisenised Eva Creek Microgranite at Furber's mine (No. 68 on map), and in sheared and quartz-veined microgranite at the Mountain King mine (No. 36 on map). The latter mine is situated at grid ref. 113780, not 114770 as shown on the map. Furber's mine has yielded 4.3 tonnes of copper and 361 g of silver; the Mountain King produced about 12 tonnes of copper with minor silver and gold (Withnall, in press).

Soil over visibly mineralised greisen zones was sampled by us in 1974, and several anomalous concentrations of tin and molybdenum were detected. These anomalous concentrations coincided with high values of tungsten, bismuth, and arsenic in one of the greisens (Withnall, in press).

Mineralisation in the Eva Creek Microgranite is too low-grade and patchy to have any significant economic potential in the foreseeable future, although the possible existence of rich ore-bearing pipes of the type worked at Wolfram Camp (Plimer, 1974) cannot be ruled out. Workable alluvial cassiterite may also occur in Cainozoic sand and gravel to the west of "Eveleigh" (A.G. Rossiter, personal communication, 1977). The various mineral assemblages which occur in the Eva Creek Microgranite suggest that there may be a genetic link between at least some copper deposits and the fluorine-uranium-molybdenum association elsewhere in the Georgetown 1:100 000 Sheet area (Bain, 1977; O'Rourke, 1975).

Intrusive(?) volcanic breccia (ag)

Volcanic breccia which is believed to fill an intrusive pipe crops out in an area of about 0.5 km^2 on the western side of Cattle Creek, about 3 km southeast of Goolie Dam. The area of breccia is almost completely surrounded by intrusive rhyolite (Oversby, 1977) rather than rocks of unit Cn_V as shown on the map. Angular to subrounded clasts of aphyric andesite and subsidiary rhyolite up to about 25 cm across occur in the breccia; the clasts are set in a tuffaceous matrix. Irregular areas and stringers of tuff occur locally in the breccia.

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Probable intrusive breccia also crops out in an area of about 0.25 km^2 6 km north-northeast of Theiss Dam (grid ref. 788775), to the west of the main Newcastle Range. This breccia contains angular rhyolite(?) clasts up to about 3 cm across, and subangular to rounded clasts of White Springs Granodiorite up to 75 cm across, in a tuffaceous matrix. The breccia has been intruded by dykes of rhyolite. An area of similar breccia, too small to show on the map, is associated with rhyolite dykes at grid ref. 818604, near the Einasleigh River.

These breccias are believed to represent minor vent sources of some of the airfall tuff and agglomerate in the Newcastle Range Volcanics.

Intrusive rhyolite (rh)

Dykes and irregular intrusive bodies of several varieties of buff, pink, red, and green rhyolite, some of which evidently originated as ignimbrite, are also common within and adjacent to the Newcastle Range in the Georgetown and adjoining 1:100 000 Sheet areas. No attempt has been made to distinguish the various rhyolites, mainly because the number of rocks examined represents only a small fraction of the total exposed.

Some of the rhyolite is aphyric, but most is mineralogically similar to microgranite and contains some proportion of quartz and/or feldspar (alkali feldspar and plagioclase) phenocrysts, which are commonly up to about 2 mm across. The groundmass is microgranular and quartzofeldspathic, and ranges from aphanitic to finely saccharoidal; it locally contains spots, wisps, and patches of chloritic material. Flow bands are common. Some dykes consist of marginal rhyolite and central microgranite; the two rock types grade into each other and were evidently introduced by a continuous process of intrusion (such dykes are designated rhyolite or microgranite on the map according to their predominant rock type).

Rhyolite in a few of the dykes examined has a vitroclastic texture, suggesting that it originated as intrusive ignmibrite. The real abundance of such intrusive ignimbrite is unknown because of the small number of dykes examined in detail.

Most of the intrusive rhyolite in the Georgetown Sheet area occurs in a swarm of west-northwest and north-striking high-angle dykes to the west of the main Newcastle Range between Quartz Blow Creek and the Etheridge River. The large irregular body of rhyolite shown on the map as being cut across by the Etheridge River actually consists of many closely-spaced anastomosing dykes which cannot be shown individually. A swarm of west-northwest and north-striking rhyolite dykes also occurs between the main and eastern parts of the Newcastle Range. The two swarms do not seem to join up across the range (although rhyolite dykes cutting volcanic rocks are commonly not distinctive on the airphotos); rather, individual dykes die out or change strike to become subparallel to, or part of, the range-front system, which commonly consists of rhyolite as well as microgranite dykes. Irregular intrusive rhyolite bodies occur within the main range in the uppermost reaches of Cattle Creek, and numerous closely-spaced, near-concordant dykes are now known to occur in the Brodies Gap-Dagworth Bore track area, and farther north (Oversby, 1977).

The age of most of the intrusive rhyolite in the Georgetown Sheet area is broadly the same as that of the microgranite (above). Both rock types were apparently emplaced recurrently during a late stage of the accumulation of the volcanic and associated rocks, but it is impossible to be more precise than that about their age. Intrusive ignimbrite was presumably emplaced while volcanism was taking place, although it is not known exactly when because individual dykes cannot be correlated with particular stratigraphic units.

Total-rock Rb-Sr data derived from several specimens of intrusive rhyolite (70571200, 70571208, 70571214(?), 70571215, 70571219) have been used in deriving the Late Carboniferous age for the Newcastle Range Volcanics (Black, 1974, pp. 41-42). Additional specimens are currently being dated, although it seems likely that they and the volcanic rocks will not give statistically different ages.

Unnamed microgranite and microgranodiorite (mg)

Introduction

Two mappable variaties of unnamed microgranite, and one of microgranodiorite, occur in dykes and irregular intrusive bodies within and adjacent to the Newcastle Range in the Georgetown 1:100 000 Sheet area; the rocks are also common in the Forsayth, Mount Surprise, Galloway, and Einasleigh Sheet areas (Bain, Withnall, & Oversby, 1976; Oversby, 1977).

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At least two dykes in the Georgetown Sheet area which were originally thought to be andesite (and are so annotated on the map) are now known to contain microgranodiorite, and so will be discussed here.

Branch (1966) did not differentiate between any of the above rocks and intrusive "rhyodacite" (intrusive rhyolite of this report).

Lithology and petrography

(a) Microgranite (mg_1 and mg_2)

Of the four varieties of "microgranite" (actually microgranodiorite in one case, as noted below) mapped in the Forsayth 1:100 000 Sheet area, two of them (mg_1 and mg_2) were differentiated on the basis of having different percentages of quartz and feldspar phenocrysts (Bain, Withnall, & Oversby, 1976); the distinction is probably not a particularly meaningful or useful one, but it is retained here for the sake of conformity.

The most common of the two microgranite varieties in the Georgetown Sheet area is mg_1; it is characterised by about 25 ($\pm$10) percent quartz, alkali feldspar, and plagioclase feldspar phenocrysts between 5 mm and 1 cm in maximum dimension, in a microgranular quartzofeldspathic groundmass. Up to 1 percent partly to wholly chloritised hornblende phenocrysts, mostly 5 mm or less long, occur sporadically. Accessory apatite and opaque minerals are common. The rock is characteristically pink to red, although grey gm_1 occurs at a few localities. Most quartz phenocrysts are corroded and embayed; alkali feldspar is commonly microperthitic. The composition of the plagioclase is uncertain; it could be either albite or oligoclase-andesine (probably the latter). All feldspar phenocrysts are more or less cloudy, and white, pink, or orange; many contain recognisable secondary clay minerals, "sericite", epidote, silica, and hematite, although they are rarely so intensely altered as similar phenocrysts in porphyritic rhyolitic ignimbrite (above). The mineralogical similarities between mg_1 and porphyritic rhyolitic ignimbrite suggest that the two are chemically similar and were derived from magma of the same type.

There are several minor variations within the main mg_1 type, involving colour of the rock and feldspar phenocrysts, sizes (average, maximum, and minimum) of different phenocrysts, and presence or absence of hornblende, some of which reflect different intrusive phases. No attempt has been made to distinguish most of the minor varieties separately because they have no obviously systematic distribution or, in most instances, evident genetic significance.

One probable minor variety of mg_1 which has been distinguished is designated mg_2 (no age relationship implied); it occurs only in the central part of the main Newcastle Range of the southernmost Georgetown Sheet area, and in the adjoining part of the Forsayth Sheet area. The distinctive feature of this variety is that it contains only 3 percent quartz and feldspar phenocrysts; in other respects it is identical to mg_1 as defined above.

Much of the microgranite in the Georgetown Sheet area occurs in dykes and other intrusive bodies which have intruded along the high-angle faults which bound the present outcrop areas of Newcastle Range Volcanics and Cumbana volcanics. These range-front intrusions are locally composite, although in no instance has the order of emplacement of the different microgranites been established because actual contacts between them are rarely exposed.

Microgranite also occurs in dykes and large irregular bodies which have intruded the various sequences of volcanic and associated rocks. One such irregular body, which contains both mg_1 and the only known occurrences of mg_2, extends from the main Newcastle Range in the northern part of the Forsayth Sheet area into the southernmost Georgetown Sheet area. Recent (1976) field research has also demonstrated that much of what is shown on the map as the northwestern part of unit Cn_4's outcrop area in the eastern Newcastle Range actually consists of one or more large bodies of mg_1. In addition, mg-type rocks assigned to unit Cn_1 are probably also intrusive, as noted above. Microgranite (mg_1) dykes are more common along the west-striking fault zone in the area of the main Newcastle Range crossed by the Gulf Developmental Road than indicated on the map.

(b) Microgranodiorite (mg_3)

A third variety of "microgranite" which was recognised in the Forsayth Sheet area, mg_3 (Bain, Withnall, & Oversby, 1976, p. 65) is now thought to be microgranodiorite by analogy with mineralogically similar dacite lava and ignimbrite in unit Cn_{III} (above). The rock is green, purple, and buff (commonly mottled), and contains about 25 percent plagioclase (andesine?) and alkali feldspar phenocrysts between 5 mm and 1 cm across, and 5 to 10 percent completely chloritised hornblende(?) phenocrysts up to about 3 mm across, in a microgranular groundmass of clear quartz and cloudy feldspar. Quartz phenocrysts are rare, and mostly less than 3 mm across. All feldspar phenocrysts are altered to about the same extent as those in dacitic rocks of unit Cn_{III} (above). The close similarities and spatial relationships between mg_3 and extrusive dacite of unit Cn_{III} suggest that they were both derived from essentially the same magma. Intrusive microgranodiorite (and dacite) may be more common within the outcrop area of unit Cn_{III} than is shown on the map.

Microgranodiorite occurs with intrusive andesite in a swarm of west-northwest and more northerly-striking dykes between Jimmys Bore and Kungaree Dam, to the east of the main Newcastle Range. The rocks were all originally thought to be andesites (ad) on the basis of hand-specimen identification, and are annotated as such on the map. However, the north-northwest-striking dykes exposed between grid refs. 951712 and 956686 consists of aphyric, finely saccharoidal, pink and green speckled microgranodiorite. The rock contains unoriented laths of cloudy alkali feldspar (mainly orthoclase) and plagioclase, clear interstitial quartz, secondary epidote and chloritic aggregates, and opaque needles and grains; the dyke appears to be cut by a southwest-striking rhyolite dyke. Similar microgranodiorite may be relatively common in the dyke swarm, but andesite and microgranodiorite in dykes tend to have similar photo patterns, and only two of the dykes have been sampled. Microgranodiorite may also occur in the west-northwest and west-southwest-striking dykes, annotated as andesite, which crop out about 1 km south of the junction of Thornborough Creek and the Einasleigh River, to the west of the main Newcastle Range. Another microgranodiorite dyke which has been incorrectly designated as andesite crops out between grid refs. 027801 and 041776, and similar rocks may occur in unsampled dykes nearby.

Large intrusive bodies of microgranodiorite cut the Newcastle Range Volcanics in the southern half of the main range of the Georgetown and Forsayth 1:100 000 Sheet areas. The spatial distribution of these bodies coincided with the present distribution of unit Cn_{III} and its possible original southward extension.

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Relationships and age

None of the microgranites in the Georgetown Sheet area is unambiguously older than any of the volcanic and associated rock sequences, and many are demonstrably younger. Intrusion by many, if not all, of these rocks to their present structural level is thus believed to postdate extrusion of the presently preserved Newcastle Range Volcanics and Cumbana volcanics. Intrusion may have been in part concurrent with extrusion of younger parts of the sequences which have been weathered away, although the presence of hornblende phenocrysts in some microgranite and in unit Cn_6 suggests that the two might have some direct genetic link. Relationships between a body of microgranite (mg_1) and unit Cn_6 in the Forsayth Sheet area suggest that at least one intrusion antedated extrusion of the unit, however (Bain, Withnall, & Oversby, 1976, p. 65). Microgranite was undoubtably emplaced recurrently, but the precise times of these emplacements cannot yet be worked out in any greater detail than has been outlined above.

If the correlation suggested above between microgranodiorite and unit Cn_{III} in the main Newcastle Range is correct, then the two are of essentially the same age. This implies that the microgranodiorite is older than the presently exposed microgranite in gross terms (if the general age of the microgranite has been correctly interpreted above).

Total-rock Rb-Sr isotopic ages of these rocks are currently being determined, but final data are not available at the time of writing.

Miscellaneous intrusive rocks

Of the andesite dykes shown on the map, only three are now definitely known to contain andesite; others consist of microgranodiorite (above), or could be either microgranodiorite or andesite because they have not been sampled, and both rock types have a similar photo pattern. Partly to wholly uralitised dolerite occurs in dykes at grid refs. 781729 and 033635.

Aphyric augite andesite, which is similar to, and presumably comagmatic with, aphyric andesitic lava (above), occurs in a low-angle dyke at grid ref. 815766, to the west of the main Newcastle Range, and aphyric microdiorite occurs in a steeply-dipping dyke which crops out between grid refs. 987811 and 979792, on the eastern side of White Springs Creek. A third andesite dyke, which is too small to show on the map, crops out at grid ref. 948710, about 1 km west-southwest of Jimmys Bore. The rock in this dyke contains slender subparallel feldspar laths and about 5 percent augite microphenocrysts. All of the rocks are fairly fresh.

Biotite lamprophyre occurs in a small plug annotated "do?" on the map at grid ref. 745670, and presumably also in other nearby plugs annotated similarly. The rock consists of phenocrysts and aggregates of partly uralitised clinopyroxene up to 2.5 mm in maximum dimension and biotite up to 1 mm long, in a groundmass of randomly oriented plagioclase laths, uralite, biotite, and opaques. The groundmass plagioclase is normally zoned from An_{40} to An_{70}. Hornblende lamprophyre occurs at grid ref. 040682, apparently in the east-southeast extension of a dyke annotated "ad" on the map. The rock contains 40 percent euhedral plagioclase phenocrysts between 0.1 and 0.5 mm long which show oscillatory zoning from cores of approximately An_{40} to albite rims, and 25 percent euhedral hornblende up to 2.5 mm long. The groundmass (35 percent) consists of very fine-grained plagioclase with minor amphibole and quartz(?).

A dyke which is too small to show on the map forms part of the range-front system on the western side of the main Newcastle Range, and is exposed in a cutting along the Gulf Developmental Road at grid ref. 846768. The dyke contains a green aphyric rock which consists of radiating needles of chlorite and actinolite(?), silicified and carbonatised feldspar, interstitial quartz, and opaque needles and grains; the rock might be an altered andesite or quartz-microdiorite. This dyke postdates an adjacent porphyritic rhyolite dyke. Similar rock occurs in a 1 m-wide dyke at the Laura Jean prospect on the eastern side of the range; the dyke appears to be younger than adjacent prophyritic microgranite and mineralised dacite-microgranite breccia (Bain, 1977; Withnall, in press).

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UPPER PALAEOZOIC PLUTONIC ROCKS

Elizabeth Creek Granite (Ce)

Introduction

The Elizabeth Creek Granite was named by White (1959b, p. 26) from Elizabeth Creek in the northwestern corner of the Mount Surprise Sheet area. The type area of the unit is opposite "Cumbana" (grid ref. 859041, Mount Surprise 1:100 000 Sheet area), which is 4 km east of the edge of the Georgetown Sheet area. The Elizabeth Creek Granite was inferred to be of late Palaeozoic age. Branch (1966, pp. 97-102) described the unit comprehensively and applied the name to numerous separate intrusive bodies in the Mount Surprise-Herberton-Mount Garnet district, a total area of more than 5000 km^2. In doing this he incorporated a variety of rock types into the unit in addition to the characteristic homogeneous salmon-pink leucocratic granite with 1 to 5 percent biotite. Blake (1972) restudied the Elizabeth Creek Granite in the Herberton-Mount Garnet area and restricted its lithological variation by separating the Hales Siding Granite and an unnamed granite from it. However, the several varieties of Elizabeth Creek Granite in the type area have never been studied in detail or adequately defined.

In the Georgetown 1:100 000 Sheet area the Elizabeth Creek Granite crops out in an area of about 60 km^2 in the northeast. This outcrop area is continuous with the type area farther east. The Elizabeth Creek Granite intruded and has thermally metamorphosed the Einasleigh Metamorphics, the Newcastle Range Volcanics of the main range sequence, and the Cumbana Volcanics; the thermal aureole of the granite is commonly about 200 m wide (it locally has a much greater apparent width in the Galloway Sheet area where the top of the granite dips at a low angle beneath the Newcastle Range Volcanics). The Elizabeth Creek Granite is overlain unconformably by the Undaral basalt and superficial Cainozoic deposits (soil, alluvium, etc).

Lithology and petrography

The Elizabeth Creek Granite in the Georgetown 1:100 000 Sheet area contains a variety of rock types which commonly grade into each other, are not systematically distributed, and do not have distinctive airphoto patterns. For these reasons they have not been mapped separately.

The most common suite of rock types contains all gradations from porphyritic microgranite, through fine-grained porphyritic granite, to medium or coarse-grained more-or-less equigranular granite. Porphyritic rocks contain up to about 40 percent phenocrysts. All members of the suite have several mineralogical and textural features in common - they all contain alkali feldspar, plagioclase, and distinctive rounded to subangular quartz grains and aggregates. All rocks contain 1 to 5 percent biotite crystals and aggregates, and are commonly pink (rarely white) and leucocratic.

Alkali feldspar is orthoclase microperthite, and constitutes from 20 to 60 percent of the rocks; it is invariably turbid because of finely divided "sericite" and clay minerals. Alkali feldspar has three main modes of occurrence - in porphyritic rocks it occurs as (i) subhedral phenocrysts up to about 3 mm long, and as (ii) anhedral interstitial crystals in the groundmass; rocks which tend towards an equigranular texture do so primarily because of progressive increase in the size of groundmass crystals with parallel but lesser increase in the size of phenocrysts so that the sizes of the various components converge. In such equigranular rocks alkali feldspar also occurs as (iii) overgrowths containing plagioclase and quartz inclusion, in optical continuity with original phenocrysts, resulting in anhedral crystals up to about 6 mm in maximum dimension in the medium to coarse-grained granites. Alkali feldspar phenocrysts locally occur as ragged cores and patches within plagioclase phenocrysts. Graphic intergrowths of alkali feldspar and quartz are common in the groundmass of some rocks.

Plagioclase (mainly oligoclase with andesine locally) and quartz similarly also have three modes of occurrence; they each constitute up to about 35 percent of the rocks. Plagioclase is less altered than alkali feldspar, and phenocrysts and groundmass crystals are mostly subhedral to euhedral, even in the medium to coarse-grained granites. They show normal and oscillatory zoning locally. Plagioclase phenocrysts in porphyritic rocks are about 3 mm long. Rounded anhedral grains and aggregates of quartz in porphyritic rocks are up to about 4 mm across; they become progressively larger and more irregular as the groundmass grainsize increases because of the formation of overgrowths. A few of the quartz phenocrysts have undulose extinction. Groundmass quartz is invariably anhedral and interstitial, like alkali feldspar.

Biotite occurs as pleochroic (dark brown or green to pale yellowish-brown) crystals about 1 mm long; in microgranites it is partly euhedral and partly anhedral-interstitial. In the coarser rocks it is invariably anhedral and interstitial. Biotite commonly contains pleochroic haloes around minute zircon (?) inclusions; it is locally replaced by chloritic material.

Fine-grained pink aplite occurs in diffuse veins and patches in the Elizabeth Creek Granite locally. It consists of segregations of the groundmass component (anhedral to subhedral plagioclase, anhedral alkali feldspar and quartz) of the coarser-grained rocks; alkali feldspar and quartz occur locally as micrographic intergrowths.

The above rocks contain accessory amounts of opaque minerals, apatite, sphene, and allanite, as well as rare tourmaline(?), epidote, interstitial carbonate, and biotite pseudomorphs after amphibole.

Mesocratic grey porphyritic fine-grained granite, which is apparently older than the rocks described above, is also common in the Elizabeth Creek Granite of the Georgetown 1:100 000 Sheet area. The rock contains up to about 20 percent white feldspar and quartz phenocrysts. Feldspar phenocrysts are anhedral to subhedral orthoclase microperthite up to 5 cm long, and euhedral to subhedral oligoclase of similar size. Quartz occurs as rounded anhedral grains and aggregates. All phenocrysts have thin overgrowth shells. The groundmass of the rocks contains small (0.2 mm) euhedral plagioclase crystals with altered cores of alkali feldspar(?) enclosed in anhedral interstitial poikilitic grains of quartz and alkali feldspar up to 2 mm in maximum dimension. The rocks contain 10 to 15 percent brown, rarely green, biotite as euhedral to subhedral crystals which are partly interstitial. About 1 percent of the biotite occurs as crystals 0.5 to 1 mm long, but most of it is 0.1 mm long.

Xenoliths and roof pendants are rare in the Elizabeth Creek Granite of the Georgetown 1:100 000 Sheet area. A large granite-veined roof pendant of dark green aphyric andesite, like that in unit Cna_I of the main Newcastle Range Volcanics sequence, crops out in an area of about 0.25 km^2 6.5 km northeast of Brodies Gap. Airphoto interpretation suggests that a similar roof pendant crops out in a smaller area 2 km farther west. Small dark-coloured xenoliths occur in porphyritic microgranite at grid ref. 084044.

Branch (1966, Table 8) presented analyses of rocks assigned to the Elizabeth Creek Granite; one specimen (No. 11) was from near Brodies Gap, and another (No. 4) was from the type area. Sheraton & Labonne (1978) considered the chemistry of the unit in more detail; their specimens 68590023 and 68590102 were also from near Brodies Gap and "Cumbana" respectively, while 68590109 was from 14½ km north of Mount Surprise. In essence, the rocks are of calcalkaline composition, and contain more than 75 percent of silica. Trace element abundances indicate that they crystallised from high-level, highly fractionated magma which was probably not differentiated from a more basic parent but rather was derived from anatexis of rubidium-poor lower crustal material. The magma was relatively dry, a characteristic which enabled it to ascend to the relatively high crustal levels at which the rocks are now exposed.

Relationships and age

The Elizabeth Creek Granite is younger than the Newcastle Range Volcanics of the main range sequence. A preliminary total-rock Rb-Sr "age" of about 320 m.y. has been derived from part of this sequence (Black, 1974, p. 41).

Early isotopic work in the Elizabeth Creek Granite, mainly on K-Ar from biotite separates, by Richards & others (1966) suggested that the unit as then constituted included rocks ranging in age from late Carboniferous to early Permian; biotite from the type area indicated an age of about 300 m.y. (late Carboniferous). Subsequent work, summarised by Black (1974, pp. 8-16), indicates that rocks included in the Elizabeth Creek Granite were emplaced over a period of at least 30 million years during early and late Carboniferous time. A specimen from the type area is currently being dated by the total-rock Rb-Sr method, but results are not yet to hand; however, since the unit has not been restudied in the type area it is uncertain what relationships the rock type represented by the specimen has to other varieties of the Elizabeth Creek Granite in the vicinity. Samples of Elizabeth Creek Granite from the Georgetown 1:100 000 Sheet area (Nos. 7, 8, and 9 on the map) have not yet been fully processed for total-rock Rb-Sr dating.

Mineralisation

The Elizabeth Creek Granite in the Georgetown 1:100 000 Sheet area is poorly mineralised, an unusual occurrence for what is one of the main ore-bearing units throughout northeastern Queensland. Lode cassiterite has been worked at the Ruby mine (No. 3 on map), and alluvial cassiterite at Pascoe's Camp (No. 1 on map); the production at both localities is not known. Two small copper prospects (Nos. 2 and 4 on map) also occur in the Sheet area. Gem-quality topaz and aquamarine occur in alluvium derived from Elizabeth Creek Granite in the northwestern part of the Mount Surprise Sheet area, but no occurrences are known to us in the Georgetown Sheet area.

Yataga Granodiorite (Py)

Introduction

The Yataga Granodiorite occurs as a circular pluton about 9 km in diameter near the northwestern corner of the Georgetown 1:100 000 Sheet area and in the adjacent part of the Galloway Sheet area. The unit was named by Withnall & others (1976, p. 3) from the parish of Yataga, in which the pluton occurs; the type area is along the Ironhurst-Dagworth track between grid refs. 706071 and 727079 (Georgetown 1:100 000 Sheet area). The Yataga Granodiorite underlies an area of relatively low relief with numerous bouldery outcrops and a few tors and low hills, mainly in the central part of the outcrop area.

The Yataga Granodiorite pluton is surrounded by a contact metamorphic aureole up to 500 m wide. Robertson River Metamorphics and Proterozoic granitoid rocks in the innermost part of the aureole have been converted to biotite-sillimanite-cordierite hornfels. In the outer part of the aureole sericite aggregates pseudomorphing sillimanite in the schist have been recrystallised to muscovite, and hornblende in Cobbold metadolerite has been partly converted to actinolite.

Bain & others (1975) informally referred to the pluton as the "Dambo Complex", but the name was rejected by Withnall & others (1976) as being unsuitable.

Lithology and petrography

Two varieties of Yataga Granodiorite have been differentiated as separate subunits. The main one of these, Py_1, occupies a peripheral position and consists of dark grey, medium-grained equigranular to (rarely) slightly porphyritic, hornblende-biotite granodiorite and tonalite. It has been intruded in the south-central part of the pluton by one large and two small irregularly-shaped bodies of grey to pink, fine to medium-grained equigranular to (most commonly) porphyritic, biotite and hornblende-biotite granite and granodiorite assigned to subunit Py_2. Numerous unmapped veins of pink aplite, and some greisen veins and dykes, occur in both subunits of the Yataga Granodiorite.

Rocks in both subunits of the Yataga Granodiorite have a hypidiomorphic-granular texture and consist mainly of short euhedral to subhedral plagioclase laths with variable amounts of interstitial anhedral quartz and orthoclase. Phenocrysts, where present, are plagioclase and subsidiary quartz.

Plagioclase crystals contain cores of andesine to labradorite and albite to oligoclase rims; normal and oscillatory zones with one or more compositional breaks are characteristic. Crystallisation of plagioclase throughout most of subunit Py_1 was evidently interrupted and recommenced at a composition of about An_{20}; a similar interruption and recommencement of growth in subunit Py_2 took place at a composition of An_{16-20}.

Quartz in the Yataga Granodiorite commonly shows undulose extinction and contains streaks and trails of "dust" which probably represent annealed fractures. Orthoclase is commonly mirocperthitic. Pale brown to olive green hornblende and biotite are commonly intergrown; much of the biotite has probably replaced hornblende. Hypersthene, commonly partly or wholly replaced by hornblende, occurs locally in rocks of subunit Py_1 as discrete euhedral to subhedral crystals, and as small inclusions in plagioclase. The hypersthene is probably primary; country rocks in the contact aureole of the Yata Granodiorite belong to the pyroxene hornfels facies, indicating that the pluton was emplaced at a high temperature.

Accessory minerals throughout the Yataga Granodiorite include allanite, topaz(?), tourmaline(?), zircon, and opaques.

Hornblende was probably replacing hypersthene in rocks of subunit Py_1 during the time that plagioclase crystallised; crystallisation of biotite, and its replacement of hornblende, took place later. Quartz and orthoclase crystallised last in all rocks.

Relationships and age

The Yataga Granodiorite has intruded and metamorphosed the mid-Proterozoic(?) rocks of the Robertson River Metamorphics, Cobbold metadolerite, and Mistletoe Granite (to be described in Part B of this report). A K-Ar biotite age of 262 m.y. (Permian) has been obtained from subunit Py_1 by the University of Queensland for GSQ; total-rock Rb-Sr data are not yet available.

Plutonic rocks of Carboniferous and Permian age with similar mineralogy to the Yataga Granodiorite are common throughout northeastern Queensland; these include the Bakersville and Kalunga Granodiorites, the Almaden Granite, and several varieties of the Herbert River Granite (Sheraton & Labonne, in 1978). If the Yataga Granodiorite is of Permian age, as seems likely, it must have intruded, and been insulated by, a relatively thick sequence of Newcastle Range Volcanics which have since been eroded away, unless the base of the volcanics was locally at a very much higher level than it now is in nearby parts of the Newcastle Range.

Mineralisation

The Yataga Granodiorite contains only a few small copper deposits (e.g. No. 5 on map). The main one of these occurs at the Dambo prospect, which is situated just north of the boundary of the Georgetown 1:100 000 Sheet area near the Ironhurst-Dagworth track. Minor malachite at this prospect occurs in veinlets within zones of sericitised granodiorite up to 5 m wide (Smart & Bain, 1977; Withnall, in press).

Greisens, like the one at grid ref. 744011, do not appear to be mineralised.

MESOZOIC AND CAINOZOIC ROCKS

Mesozoic rocks (M)

Stratigraphy

Mesozoic rocks are relatively rare in the Georgetown 1:100 000 Sheet area; most of them occur on the Newcastle Range in the southern part of the sheet area. They have only been examined briefly during the present work, and are not subdivided on the map. The following summary is taken from Needham (1971).

Most of the Mesozoic rocks in the Georgetown Sheet area have been assigned to the Lower Cretaceous Coffin Hill Member, the upper one of two in the Gilbert River Formation (Fig. 35); up to about 12 m of the member occur locally, but its stratigraphic top is not preserved. The Coffin Hill Member is characterised by fine- to coarse-grained quartzose sandstone with interbeds of mottled purple siltstone; the sandstone is commonly ferruginous and glauconitic, and locally cross-bedded. The lower part of the Coffin Hill Member is interpreted as having been deposited in an estuarine to paralic environment, but the presence of marine fossils in higher beds is indicative of a shallow marine environment. Maccoyella sp. indet. has been obtained from the member at the head of Tabletop Creek on the eastern side of the main Newcastle Range about 2 km north of the Gulf Developmental Road.

The lower member of the Gilbert River Formation, the upper Jurassic to lower Cretaceous Yappar Member, underlies the Coffin Hill Member only locally in the Georgetown Sheet area, probably because the Newcastle Range was a topographic high at the time of deposition (Fig. 35). Fine-, medium- and coarse-grained quartzose sandstone, which is locally clayey or ferruginous and cross-bedded, characterises this member which is up to about 15 m thick; sporadic siltstone interbeds also occur. The rocks were probably deposited in a fluviatile or estuarine environment.

Most of the top of the Newcastle Range is close to the base of the Mesozoic sequence, and small areas of deeply-weathered volcanic rocks on the Newcastle Range to the north of the Gulf Developmental Road were probably originally overlain by Mesozoic rocks which have only just been eroded away; the areas are not differentiated from the Newcastle Range Volcanics.

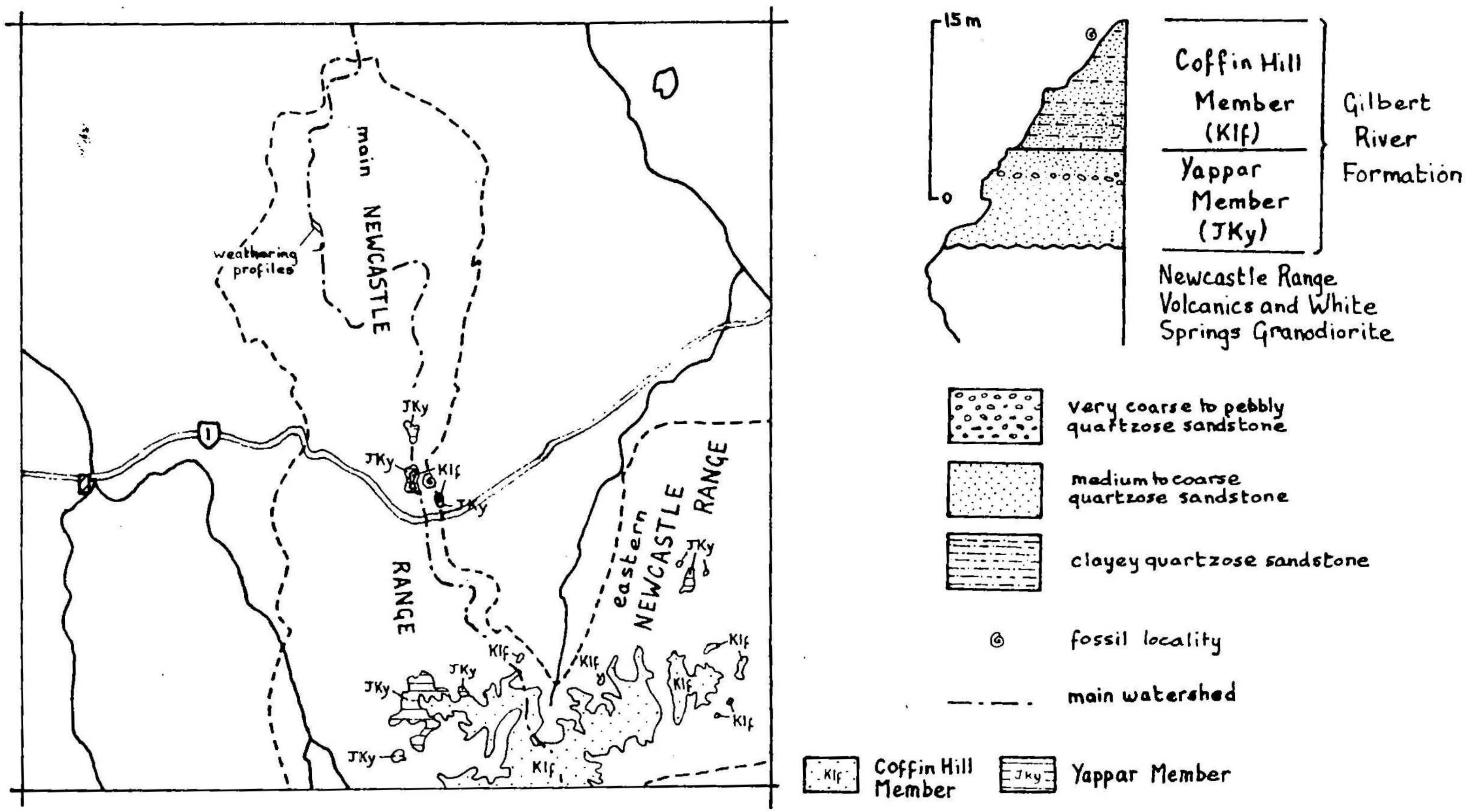

Fig.35 Mesozoic rocks in the Georgetown 1:100 000 Sheet area. Modified from Needham (1971)

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Structure

The few available data indicate that the Mesozoic rocks in the Georgetown 1:100 000 Sheet area dip to the northwest at less than $\frac{1}{2}^{o}$; they have not been appreciably folded or faulted. This situation contrasts with that in the Forsayth Sheet area (probably because of the more extensive development of Mesozoic rocks) where the Mesozoic sequence is cut by several high-angle faults (Bain, Withnall, & Oversby, 1976, p. 68).

Soil and colluvium (Czs)

The Einasleigh Metamorphics are partly blanketed to the east of the Newcastle Range by a dissected veneer of Cainozoic sand, silt, clay, and minor gravel up to several metres thick. The material was probably mainly derived by outwash from the Newcastle Range, and may contain workable alluvial cassiterite locally (Withnall, in press). It probably once covered virtually the whole of the area immediately to the east of the range, but erosion has resulted in most of it being restricted to interfluvial ridges. This transported material is lighter in colour than the thinner *in situ* soil developed on the underlying metamorphic rocks; the latter has a distinctive mottled red and brown pattern on airphoto. Metamorphic rocks are commonly deeply weathered beneath the Cainozoic veneer.

Similar outwash deposits probably also overlie much of the White Springs Granodiorite east of the Newcastle Range, although they are not delineated on the map because they have a similar photo pattern to the ubiquitous sandy soil developed on the granodiorite.

Cainozoic outwash deposits and soil cover most of the areas of contact between the Elizabeth Creek Granite, Cumbana volcanics, and Undara basalt, in the northeastern corner of the Georgetown Sheet area. Much of the older portion of this material probably originally accumulated in a large shallow lake ponded up on the northeastern side of the Undara basalt flow. The present Cawana Lake, which is surrounded by a swampy flood-prone plain, is probably the remnant of this large lake. Outwash material is presumably still being shed from the Jorgensen Range and other high parts of the area.

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Undara basalt (Qu)

The Undara basalt (informal name of Best, 1960) consists of several lava flows which cover an area of about 1000 km^2 of the McBride volcanic province in the eastern Georgetown Inlier. The basalt was extruded from the Undara crater, in the St Ronans 1:100 000 Sheet area (Best, 1960; Griffin & McDougall, 1975). In the Georgetown Sheet area the distal part of one 160 km-long flow occupies the Einasleigh River valley. The basalt was given only cursory examination during the present work; more detailed discussions can be found in Best (1960), Griffin & McDougall (1975), and Stephenson & Griffin (1976).

The flow in the Georgetown Sheet area consists of dark greenish-grey olivine basalt of hawaiitic composition (Stephenson & Griffin, 1976, pp. 48, 49); it is probably not more than about 20 m thick. The upper part of the flow is vesicular and scoriaceous; many of the vesicles are partly or wholly filled by a white zeolite(?) of undetermined type.

Undara basalt east of the Georgetown Sheet area has given K-Ar isotopic ages indicating that it erupted during Pleistocene time, about 19 000 years ago (Griffin & McDougall, 1975, p. 392).

Calcareous tufa (Qt)

A small deposit of calcareous tufa (travertine) occurs at the Talaroo (or Ambo) hot springs (grid ref. 132940), about 500 m north of "Talaroo" homestead. The springs were reported by the mailman the previous year (Jack, 1891, p. 5).

The calcareous tufa occurs in a low asymmetrical mound about 50 m across from northwest to southeast; a broad dome about 4 m high occurs on the eastern half of the mound. The mound and dome are terraced and contain one spring-fed pool and four smaller springs (Fig. 36); water flows from the pool and three of the springs. The pool is about 7.5 m long, 5 m wide, and from 1 to 2 m deep; a moderate stream of water issues from it, and is also fed by gravity through an iron pipe to a ram pump which forces it up to the nearby homestead. The largest spring is at the top of the dome; it is about 1 m across and a small quantity of water flows from it. The other

Fig. 36(a): Terraced mound and dome of calcareous tufa, Talaroo hot springs; view from the south. Photo by I.W. Withnall.

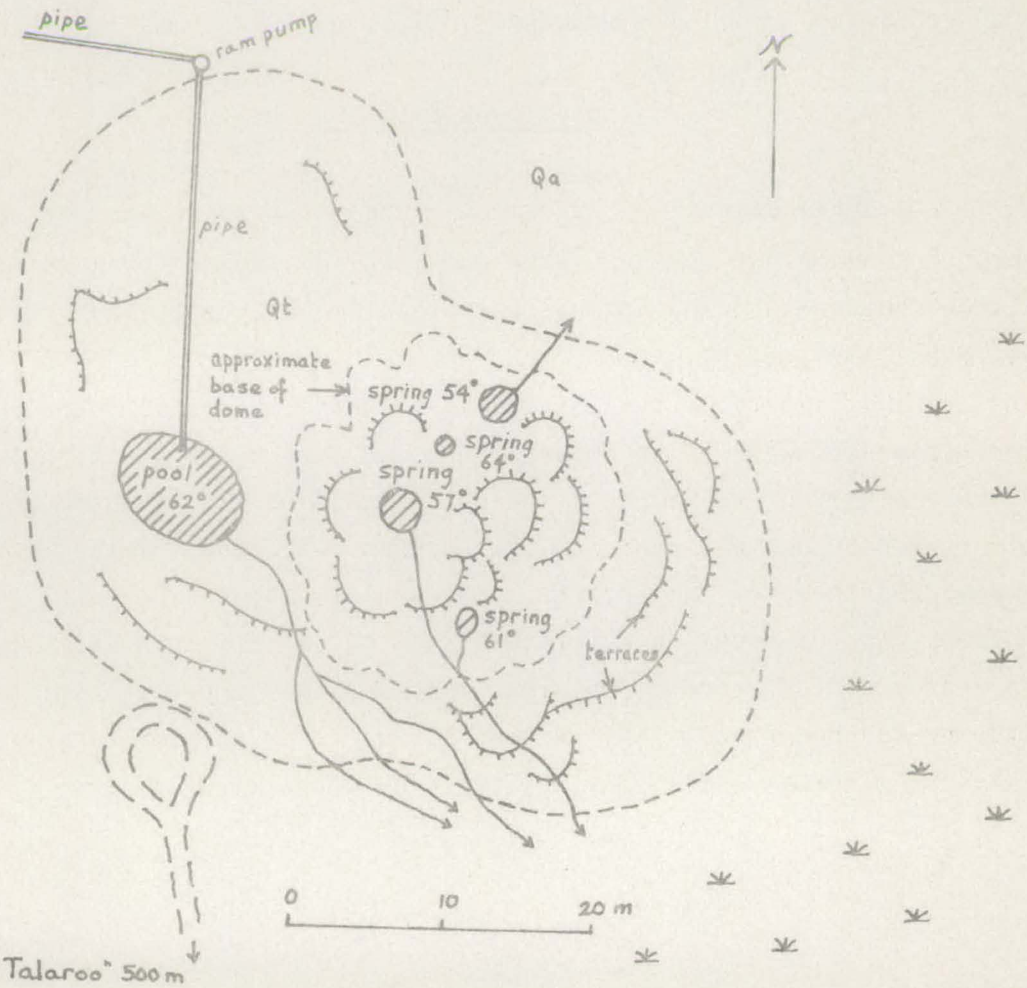

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Fig. 36(b): Sketch map of Talaroo hot springs. Modified from a field sketch by I.W. Withnall.

smaller springs are on the flanks of the dome. Tufa over which water is presently flowing (but not that within and rimming the pool and springs) is strongly "ironstained".

The water temperature in the pool and various springs ranged from 54^{o} to 64^{o} at the time of our observations (6/9/75); gas bubbles rose through the water from time to time, and there was a very faint hydrogen-sulphide-like odour. The slightly cooled water had a neutral taste. Jack (1891, p. 6) described the taste of the cooled water as "indescribably nasty"; he also noted a distinct smell of hydrogen sulphide and an occasional whiff of sulphur. These comparisons suggest that the water formerly contained more dissolved hydrogen sulphide gas than at present. An old analysis (Jack, 1891, p. 6) showed that the water contained mainly sodium and potassium chlorides accompanied by carbonates and some sulphuric acid and hydrogen sulphide. An analysis of water collected by us showed the main cations to be sodium (244 mg/L) and calcium (21 mg/L), and the main antions to be chloride (228 mg/L) and bicarbonate (197 mg/L); the pH was 8 and the sulphate content was 84 mg/L (AMDEL Report AN 1213/75, unpublished).

The hot springs are presumably a vestige of the Pleistocene volcanism, as suggested by Jack (1891). The calcareous tufa might have begun to accumulate during Pleistocene time, but at present most of it appears to be distintigrating and is probably actively accumulating only in the pool and springs. The supposed explosion and sound like rushing steam reported in 1871 suggest that a geyser might once have been active at the site, although no subsequent activity is known to have taken place. Jack (and we!) refrained from adding soap to the water in an attempt to trigger geysering.

Alluvium (Qa and Qh)

Deposits of alluvial silt, sand, and gravel occur in the main river channels and in most creeks; only the more extensive deposits are shown on the map. The main stream channels are partly or wholly filled by material which is transported during each wet season (Qh); partly stabilised material (Qa), which is not all moved even during exceptionally wet seasons, occurs sporadically in banks and islands. Part of the latter material might be of Pleistocene age.

These fluvial deposits have not been studied during the present work; they are at least superficially identical to those described by Williams (1971) from the ephemeral streams of central Australia.

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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 facies:

a metamorphic facies; used in this report as defined by Winkler (1967), who originally divided the facies into three subfacies which correspond to the lower, middle, and upper amphibolite subfacies of this report. More recently, Winkler (1974) proposed replacing "facies" and "subfacies" by grade-related terms; we have not adopted this proposal because it has apparently not gained wide acceptance, and because we have already used the facies/subfacies scheme in discussing the geology of the Forsayth Sheet area (Bain, Withnall, & Oversby, 1976). See also metamorphic facies.

Anatexis:

a general term denoting some degree of melting of pre-existing rocks. See also metatexis, diatexis; cf. migmatite.

Arterite:

a migmatite formed by closely-spaced subparallel injections of magma into pre-existing rocks. See also migmatite; cf. venite.

Autolith:

a xenolith in a genetically related igneous rock.

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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 used loosely for the structural block which has subsided. See also resurgent cauldron.

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. Cooling units have characteristic zonal patterns of welding and devitrification/recrystallisation. See also ignimbrite.

Diatexis:

extensive, but not complete, melting of pre-existing rock. Diatexis involves both mobile and more refractory components. See also anatexis; cf. metatexis, migmatite.

Epiclastic sedimentary rock:

siltstone, sandstone, and conglomerate made up of fragments derived mainly from pre-existing basement rocks. Epiclastic sedimentary rock grades into volcaniclastic sedimentary rock locally. See also volcaniclastic sedimentary rock.

Eutaxitic texture/foliation:

used in this report for a poorly-defined foliation in ignimbrite defined by parallel to subparallel wisps, streaks, and lenses made up of megascopically visible pseudomorphs of flattened shards and pumice. See also ignimbrite.

Felsite:

general term for a fine-grained, aphyric or porphyritic, dominantly quartzofeldspathic, igneous rock of obscure origin.

Folds:

in this report folds are differentiated on the basis of the youngest generation of S-surfaces which they have deformed, in conjunction with the generation of surfaces which is geometrically (and genetically) related to the relevant fold/s; e.g. a B_I^{III} fold deforms S_I and is related to S_{III} - it is a third-generation structure (in the Einasleigh Metamorphics, as indicated by the use of Roman subscripts). See also S-surface.

Granite:

the term is used in this report as recommended by the I.U.G.S. Subcommission on the Systematics of Igneous Rocks (Neues Jahrbuch fur Mineralogie, Monats hefte, 1973, 4, 149-164), i.e. expanded to include adamellite. Volcanic and hypabyssal rock nomenclature is consistent with that for plutonic rocks; rhyolite is expanded to include rhyodacite, and microgranite includes micro-adamellite. 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 rock of plutonic aspect 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.

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Granulite facies:

see metamorphic facies.

Greenschist facies:

see metamorphic Facies.

Ignimbrite:

used in this report in essentially the same sense as "ash-flow 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. See also cooling unit, eutaxitic texture/foliation, lag-fall deposit; cf. airfall tuff.

Isograd:

"a line on a map joining points at which metamorphism proceeded at similar values of pressure and temperature as indicated by rocks belonging to the same metamorphic facies" (A.G.I. Glossary of Geology, 1972, p. 375). The terms "first sillimanite" and "second sillimanite" isograd indicate those isograds defined by the appearance of sillimanite (with disappearance of andalusite and staurolite), and the disappearance of syntectonic muscovite respectively. The "first sillimanite" isograd marks the beginning of the middle amphibolite subfacies, and the "second sillimanite" isograd marks the beginning of the upper amphibolite subfacies. See also amphibolite facies, metamorphic facies.

Lag-fall deposit:

a deposit which accumulates at and near the source/s of ignimbrite eruptions. It contains a significant proportion of material which is too coarse and heavy to be transported far by the ignimbrite flows. See also ignimbrite.

Leucogranite:

see granite.

Leucogranitoid:

see granitoid.

Leucosome:

the light-coloured (leucocratic) part of a migmatite, commonly rich in quartz and feldspar. Leucosomes in venites commonly have rims which are rich in mafic minerals, and which constitute part or all of the adjacent melanosomes. See also melanosome, migmatite.

Lower amphibolite subfacies:

see amphibolite facies.

Melanosome:

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

Metabasite:

a collective term for basic rocks 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 relicts of their original textures (metabasalt, metadolerite, and metagabbro), as well as ones which have been altered to the extent that their origins are obscure (amphibolite, and basic granulite).

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" (A.G.I. 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; cf. metamorphic facies series.

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 the different types of metamorphism and metamorphic facies" (A.G.I. Glossary of Geology, 1972, p. 446). Cf. metamorphic facies.

Metatect:

see metatexis.

Metatexis:

Partial, selective, or differential melting of low-melting-point components (commonly quartz and feldspar) or pre-existing rocks to produce (among other things) a metatect - the fluid or more mobile part of a migmatite. See also anatexis, migmatite; cf. diatexis.

Microgranite:

see granite.

Middle amphibolite subfacies:

see amphibolite facies.

Migmatite:

"a megascopically composite rock consisting of two or more petrographically different parts, one of which is the 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, arterite, leucosome, melanosome, nebulite, palaeosome, restite, venite; cf. anatexis.

M-vergence:

see vergence.

Nebulite:

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

Palaeosome:

the relatively unaltered and immobile country or parental rock/s from which a migmatite has formed. See also migmatite.

Pegmatoid:

a rock of igneous aspect with the coarse to very coarse grainsize of pegmatite, but without graphic intergrowths, or granitic composition, or both. The term is used in this report particularly for relatively leucocratic and coarse-grained dykes and veins cutting gneiss and migmatite. Cf. granitoid.

Restite:

the relatively immobile part of a migmatite, commonly made up of refractory minerals. Restites include melanosomes, various palaeosome xenoliths, schlieren, etc. See also melanosome, migmatite, palaeosome, schlieren.

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Resurgent cauldron:

a cauldron subsidence area which has been uplifted after subsidence, commonly in the form of a centrally located structural/topographic dome. See also cauldron subsidence area.

Rhyolite:

see granite.

Schlieren:

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

S-surface:

one of a set of geometrically (and genetically) related parallel or sub-parallel closely-spaced planes pervading a body of rock. S-surfaces referred to in this report include original stratification (designated S), and foliations of several generations (designated S_I etc. in the Einasleigh Metamorphics, and S_1 etc. in the Robertson River Metamorphics. Roman and Arabic subscripts are used in this report to differentiate structurally-imposed S-surfaces in the two metamorphic units which are not necessarily directly equivalent). See also folds.

S-vergence:

see vergence.

Upper amphibolite subfacies:

see amphibolite facies.

Venite:

a migmatite formed in situ as a result of melting and partial mobilisation of the low melting-point components (commonly quartz and feldspar) of pre-existing rocks. See also migmatite; cf. arterite.

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 is a valuable aid in locating major fold hinges, especially in areas of poor exposure.

Volcaniclastic sedimentary rock:

siltstone, sandstone, and conglomerate made up of fragments derived mainly directly 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 and more regularly stratified. See also airfall tuff; cf. epiclastic sedimentary rock.

Z-vergence:

see vergence.