BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1981/63

PRECAMBRIAN STRATIGRAPHY, METAMORPHISM, AND STRUCTURE
OF THE NORTH HEAD-FOREST HOME AREA,
NORTH QUEENSLAND

by

I.W. WITHNALL & D.E. MACKENZIE

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORD 1981/63

PRECAMBRIAN STRATIGRAPHY, METAMORPHISM, AND STRUCTURE OF THE NORTH HEAD-FOREST HOME AREA, NORTH QUEENSLAND

by

I.W. WITHNALL* & D.E. MACKENZIE

*Geological Survey of Queensland

CONTENTS

CONTENTS cont'd

LIST OF FIGURES

LIST OF FIGURES cont'd.

(NOTE. The 1:100 000 Geological Special Preliminary Edition maps of the North Head Region (Sheet 7560 & Part Sheet 7460) and the Forest Home Region (Sheet 7561 & Part Sheets 7461, 7562) are available for sale from BMR, PO Box 378, Canberra City, 2601).

ABSTRACT

The Proterozoic rocks of the North Head-Forest Home area, which is part of the Georgetown Inlier of northeastern Queensland, are divided into the Etheridge and Langlovale Groups.

The lowermost unit of the Etheridge Group in the area is the Robertson River Formation. The lower part of this unit consists of basic metavolcanics (Dead Horse Metabasalt Member) overlain by a cleaved mudstone sequence; the upper part of the formation is commonly carbonaceous, locally calcareous, and contains siltstone and fine sandstone, as well as mudstone. Both parts of the formation were intruded by sills of dolerite. The Townley Formation consists of fine lithic sandstone, siltstone, and mudstone which is locally carbonaceous; the rocks become more quartzose and sandy towards the top of the unit. The Heliman Formation consists of lithologies similar to those of the Townley Formation, but siliceous siltstone and fine quartzose sandstone are generally more abundant. The Candlow Formation consists of fine lithic sandstone, siltstone, and mudstone which is commonly carbonaceous and variably pyritic; two named members within the formation are the White Bull Member (similar to the Heliman Formation) and the Stockyard Creek Mudstone Member (predominantly pyritic carbonaceous mudstone). The uppermost unit of the Group is the Langdon River Mudstone which is grey and maroon laminated mudstone.

The mudstone sequence immediately overlying the Dead Horse Metabasalt Member was probably deposited in relatively deep water, but the remainder of the Etheridge Group represents predominantly shallow-water deposition. Lithic sandstone containing abundant carbonaceous (organically-bound) mudstone clasts is characteristic of the sequence; minor gypsum casts occur in the Candlow Formation.

The Langlovale Group unconformably overlies the Etheridge Group. It contains the Malacura Sandstone (mainly fluviatile sandstone) and the Yarman Formation (marine mudstone with minor sandstone intervals, possibly deposited in a pro-deltaic environment).

Metamorphism of the Etheridge Group increases in grade northeastwards from lower greenschist to upper amphibolite facies. With increasing grade the metasedimentary rocks change from slate and phyllite to schist, and the metabasalt and metadolerite grade into amphibolite. The Robertson River Formation contains the most intensely metamorphosed rocks in the area.

The Langlovale Group was hornfelsed around plutons of Esmeralda Granite; some other areas of metamorphosed rocks in this unit may be due to unexpected plutons at shallow depth.

Three main deformations (D_1, D_2, and D_3) of regionally variable intensity affected the Etheridge Group. D_1 was the most widespread event, and produced westerly to northwesterly trending folds which are tightest in the southern half of the area. Folds produced during D_2 increase in intensity to the east and have northerly trending axial planes, where the effect of D_3 is slight. D_1 and D_2 were associated with greenschist to amphibolite facies metamorphism, and produced axial plane schistosities. D_3 was strongest in the southeastern part of the area where S_2 is deformed by tight folds; it was not associated with any apparent metamorphism. Only D_2 and D_3 affected the Langlovale Group. Later events, which affected the Georgetown Inlier farther east, are difficult to recognise in the North Head-Forest Home area.

The main faults in the southern half of the area trend northwesterly, and some had a history of both lateral and vertical movement extending from the Proterozoic to the Mesozoic or Tertiary. In the northern half of the area northerly and easterly trends predominate.

INTRODUCTION

AREA OF INVESTIGATION

The North Head-Forest Home area described in this Record is bounded by latitudes 18° and 19°S and longitudes 142°56' and 143°30'E. It consists of NORTH HEAD* (7560) and FOREST HOME (7561), and a strip along the eastern edges of ESMERALDA (7460) and GILBERT RIVER (7461) (Fig. 1). The region is centred about 350 km southwest of Cairns.

Throughout this Record, references are made to geographical and other features in the 1:100 000 Geological Special Preliminary Edition maps: 'Geology of the North Head Region' (Sheet 7560 and part Sheet 7460) and 'Geology of the Forest Home Region' (Sheet 7561 and part Sheets 7461 & 7562) These maps are available for sale from the Bureau of Mineral Resources, P.O. Box 378 Canberra, ACT, 2601.

OBJECT AND METHOD OF INVESTIGATION

Investigation of the North Head-Forest Home area was part of the joint Bureau of Mineral Resources (BMR)-Geological Survey of Queensland (GSQ) Georgetown Project which commenced in 1972, and which aims primarily to refine geological knowledge and assess the mineral resource potential of the Georgetown Inlier. Geological field work was carried out in the North Head-Forest Home area between 1975 and 1978 by D.E. Mackenzie (BMR), I.W. Withnall, and E.M. Baker (both GSQ). The adjoining area, consisting of the GEORGETOWN, FORSAYTH, and GILBERTON, was mapped between 1973 and 1975 (see Oversby & others, 1978; Bain & others, 1976; Withnall & others, 1980b, respectively).

Field work in the North Head-Forest Home area consisted of about 65 man-weeks of vehicle-supported traverses, and about 6 man-weeks of helicopter-supported traverses in more inaccessible parts in the southern half of the area. In addition, a stratigraphic drilling programme near Candlow, designed to investigate the nature of the Candlow Formation and adjacent parts of the Langdon River Mudstone and Heliman Formation was carried out in 1978 (Withnall & Mackenzie, 1979). In July 1979, Withnall and J. Draper (GSQ) spent about a week in the area making a preliminary study of the depositional evironments of the Proterozoic rocks.

---

* 1:100 000 Sheet areas are referred to in this Record in capitals.

Coloured airphotos at 1:25 000 scale (flown May and October, 1972) were used for photo-interpretation, and to locate and record field data. The data were compiled at photoscale from transparent overlays, and the resulting 36 compilation sheets were reduced to 1:100 000 scale (Mackenzie & others, 1979). The reduced compilation sheets were combined with legends and references to produce the Preliminary Edition geological maps.

Annotated airphoto overlays and field notebooks are held at BMR. Thin sections (GSQ 8530 to 8720 and 8971 to 9033) and corresponding hand specimens (GSQ/R6726 to R6918 and R7115 to R7177) of Proterozoic rocks are held in the GSQ collection. Thin sections of Candlow drill core and some other outcrop samples are held by BMR (registered under numbers in the range 79300001 to 0262).

SCOPE OF THIS REPORT

This Record discusses the stratigraphy, structure, and metamorphism of the Proterozoic Etheridge and Langlovale Groups in the North Head-Forest Home area. The other rocks of the area were described briefly by Withnall & others (1980a), and Mackenzie (1980), and will be the subject of later, more detailed reports.

NOMENCLATURE AND TERMINOLOGY

Glossaries of the terms used in this Record and previous Georgetown Project reports are given by Oversby & others (1978) and Withnall & others (1980b). Most of the terms are defined as in the American Geological Institute Glossary of Geology, First Edition (Gary & others, 1972).

Sandstones (or arenites) are classified according to Crook (1960), grainsizes according to Wentworth (1922), and bedding thicknesses according to Ingram (1954). An outline of metamorphic facies nomenclature is given below under 'Metamorphism' on p 47. Structural notation follows Bell & Duncan (1978).

REGIONAL SETTING

The North Head-Forest Home area is part of the Forsayth Subprovince of the Georgetown Inlier (Fig. 2) which consists largely of multiply-deformed Proterozoic sedimentary and igneous rocks, metamorphosed to grades ranging from

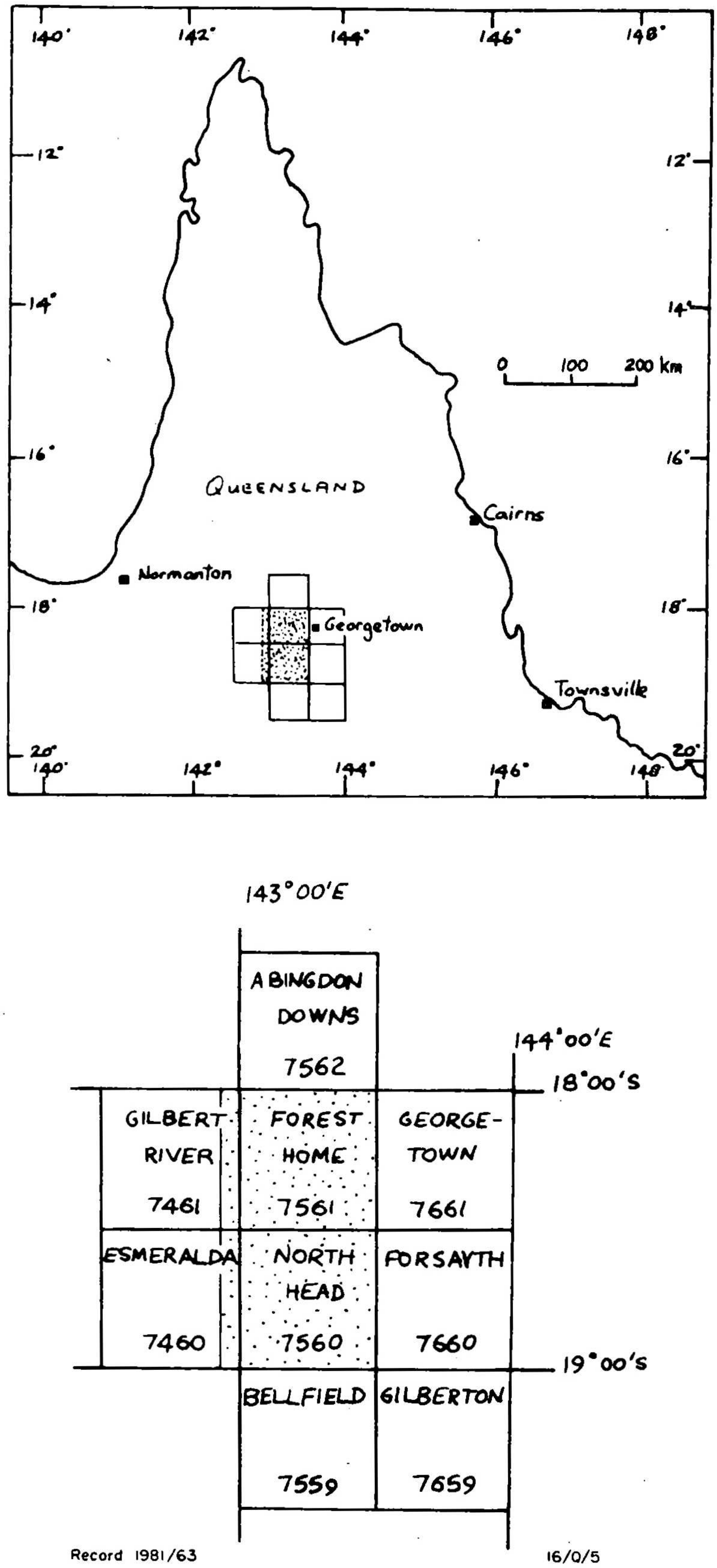


Figure 1 : Location and index to 1:100 000 sheet areas.

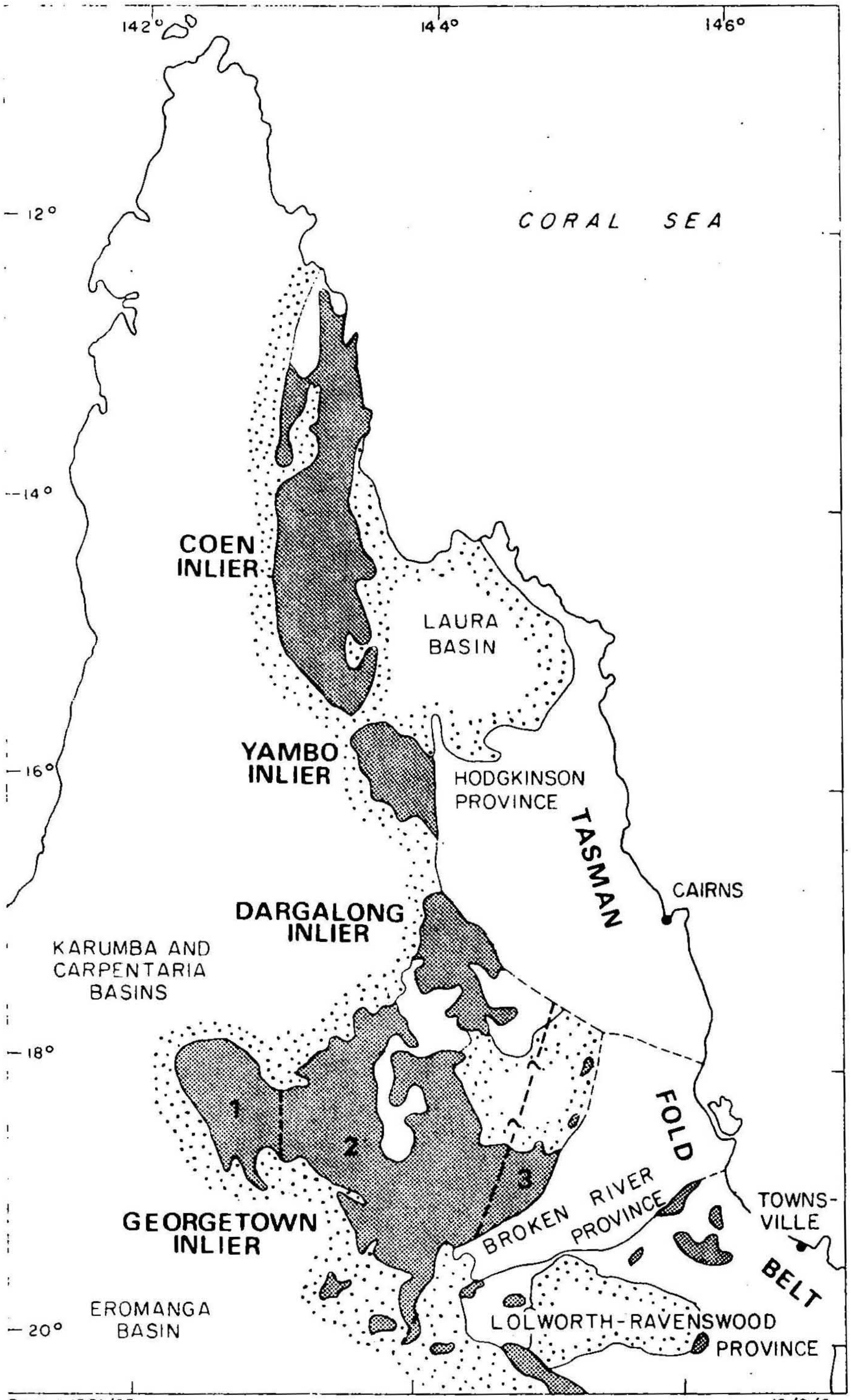


Figure 2. Distribution of Precambrian rocks in northeastern Queensland. Tectonic subprovinces in the Georgetown Inlier are 1, Croydon Subprovince; 2, Forsayth Subprovince; and 3, Greenvale Subprovince.

lower greenschist to transitional granulite facies. The Proterozoic succession in the North Head-Forest Home area is divided into the Etheridge and Langlovale Groups, which are separated by a major unconformity. The lower part of the Etheridge Group is intruded by several composite batholiths of Proterozoic to probable early Palaeozoic age. The Proterozoic Forsayth Batholith extends into the North Head-Forest Home area. Numerous small granodiorite plutons (Forest Home, Gongora, and Carnes Granodiorites) have intruded stratigraphically higher parts of the succession.

In the western part of the inlier, the Langlovale Group is unconformably overlain by and faulted against a sequence of Proterozoic acid volcanics, the Croydon Volcanics (Branch, 1966).

Remnants of an extensive late Palaeozoic continental volcanic field, characterised by rhyolitic ignimbrite and collapse structures, overlie parts of the Georgetown Inlier (Branch, 1966; Oversby & others, 1980); intrusive equivalents of these volcanics are also common. In the North Head-Forest Home area the volcanic field is represented by the Cumberland Range, Dismal Creek, and Maureen Volcanics, and by several related acid intrusive units (Mackenzie, 1980).

A thin subhorizontal sequence of Mesozoic and Cainozoic continental and marine quartzose sedimentary rocks (part of the Carpentaria, Eromanga, and Karumba Basin sequences) caps and partly surrounds the Proterozoic and Palaeozoic rocks (Needham, 1971; Smart & others, 1971).

Comprehensive descriptions of the Georgetown Inlier have been published by White (1965) and Withnall & others (1980a). The geology of the area immediately east of the North Head-Forest Home area is described in detail by Bain & others (1976), Oversby & others (1978), and Withnall & others (1980b).

STRATIGRAPHY

ETHERIDGE GROUP

Introduction

Work by the joint BMR-GSQ party in the North Head-Forest Home area (Bain & others, 1978, 1979; Mackenzie & others, 1979) has shown that the 'Etheridge Formation', defined and mapped by White (1959; 1962a; 1962b; 1965) could be subdivided into four major units. The lowermost of these included rocks that had already been shown to be the low-grade equivalents of White's Robertson River Metamorphics (Fitzgerald, 1974; Bain & others, 1976; Withnall & others, 1980a). The name 'Robertson River Formation' was consequently applied to both the low and high-grade metamorphic rocks in the lowermost part of the 'Etheridge Formation'. The other three units are, in ascending stratigraphic order, Townley, Heliman, and Candlow Formations (Mackenzie & others, 1979; Bain & others, 1978, 1979; Withnall & Mackenzie, 1980); various members, both named and unnamed, were also delineated. White's 'Etheridge Formation' was raised in status to Etheridge Group to include these formations, plus the Einasleigh and Juntala Metamorphics, the Bernecker Creek Formation, and the Langdon River Mudstone, all of which have been shown to form part of a conformable sequence (Table 1). The Bernecker Creek Formation and the Einasleigh and Juntala Metamorphics do not crop out in the North Head-Forest Home area. Withnall & Mackenzie (1980) and Withnall & others (1980a) trace in more detail the evolution of stratigraphic nomenclature of rocks in the Etheridge Group. Formal definitions for the new and revised units were published by Withnall & Mackenzie (1980).

Age

The age of the Etheridge Group is probably Middle Proterozoic; a minimum age of 1570±20 m.y. was obtained by dating the earliest deformational-metamorphic event in the Einasleigh Metamorphics (Black & others, 1979); the event also affected all the other units in the Etheridge Group, including the metamorphosed basic intrusive rocks.

Robertson River Formation

(Map symbols: Er_l, Er_u, Er_{pl}, Er, Er_q, Ed)*

Nomenclature

White (1959) used the name 'Robertson River Metamorphics' for an area of metamorphic rocks in the Robertson River area; the relationship between these rocks and the lower grade 'Etheridge Formation' to the west was not known. Work by the joint BMR-GSQ party (Bain & others, 1976; Withnall & others, 1980a) and James Cook University staff and students (Fitzgerald, 1974) showed that the 'Robertson River Metamorphics' graded into the lower part of the 'Etheridge

---

* Map symbols referred to in this Record are from the 1:100 000 Preliminary Edition geological maps of the North Head-Forest Home region.

TABLE 1. RELATIVE STRATIGRAPHIC POSITIONS OF PRECAMBRIAN UNITS IN THE NORTH HEAD-FOREST HOME AREA.

Group	Formation	Subdivision	Member		
	CROYDON VOLCANICS				
LANGLOVALE GROUP	YARMAN FORMATION				
	MALACURA SANDSTONE				
ETHERIDGE GROUP	LANGDON RIVER MUDSTONE				
	CANDLOW FORMATION	upper			
			Stockyard Creek Mudstone Member		
		middle			
			White Bull Member		
		lower			
	HELIMAN FORMATION	upper			
		middle			
		lower			
	TOWNLEY FORMATION				
	ROBERTSON RIVER FORMATION	upper		EINASLEIGH METAMORPHICS*	JUNTALA METAMORPHICS*
		lower	Tin Hill Quartzite Member		
			Dead Horse Metabasalt Member		
	BERNECKER CREEK FORMATION*				

———— Conformable contact

∿∿∿∿ Unconformable contact

━━━━ Faulted contact

* Not exposed in North Head-Forest Home area.

Formation'. Withnall & Mackenzie (1980) extended the unit to include these low-grade equivalents, and changed the name to Robertson River Formation to be consistent with units above and below in the sequence, and because ordinary stratigraphic principles can be applied to a large part of the unit.

The Formation has been informally divided into upper and lower subunits. The lower subunit includes the Dead Horse Metabasalt Member and Tin Hill Quartzite Member. The high-grade (mostly amphibolite facies) rocks are now referred to as the 'schist phase' of the Robertson River Formation.

Distribution

The Formation crops out over most of the eastern half of the North Head -Forest Home area; in places it is obscured by Phanerozoic rocks, or intruded by Proterozoic granitoids.

The lower subunit (Er_l, Er_{pl}), as presently mapped in this area, is restricted to the southeastern quadrant of NORTH HEAD. In the northern half of FOREST HOME, the Robertson River Formation had not been subdivided when the map was compiled. However, additional photo-interpretation and re-examination of field notes indicates that most of the rocks shown as undivided Robertson River Formation ('schist phase') (Er) north of the Forsayth Batholith can be assigned to the upper subunit (Er_u). Most of the metamorphic rocks forming screens between or enclosed in the granitoid plutons of the Forsayth Batholith, are probably lower Robertson River Formation (Er_l). In addition, rocks in the Cave Creek-Agate Creek area (southeastern corner of NORTH HEAD) presently shown as lower Robertson River Formation (Er_{pl}) probably include a proportion of the upper subunit. Interpretation of the structure and stratigraphy is made difficult by the patchy Mesozoic cover and rugged terrain, but markedly carbonaceous rocks which characterise the upper subunit are present in this area. A triangular area of Er_{pl} bounded on the west by the Robertson Fault and on the north by Malcolm Creek consists mainly of carbonaceous rocks, and may be part of the upper subunit.

Topography and airphoto characteristics

The Robertson River Formation has produced moderately hilly to subdued relief, the greatest relief being where Mesozoic cover has only recently been eroded. Outcrop is fair to good in most areas of moderate to strong relief. However, except for the Western Creek and Ironhurst areas, outcrop is very poor in much of FOREST HOME, particularly those areas of metamorphic rocks enclosed by the Forsayth Batholith west of the Etheridge River; this is because of the close proximity of the present surface to Mesozoic and Tertiary deep weathering surfaces.

Bedding trends have been picked out in places by differential weathering and erosion, particularly in the upper subunit (Er_{pu}). This unit is also characterised by a greyish tone on airphotos which is caused by abundant carbonaceous rocks; calc-silicate rocks give rise to reddish soils and are generally topographically subdued.

A resistant, ridge-forming unit of greenish phyllite marks the top of the lower subunit in the Stake Yard area, east of the Water Resources Commission (WRC) gauging station on the Robertson River, and in the Malcolm Creek area. Although generally less topographically prominent, the marker can be traced by airphoto interpretation into 'schist phase' Robertson River Formation. It can be used to delineate the boundary between the sub-units in the 'schist-phase', even as far north as the Ironhurst area in the northern parts of FOREST HOME and GEORGETOWN, where it occurs typically as a low, 'lancewood'(Acacia shirleyi)-covered ridge with abundant blocky outcrops of mica-quartz schist which contains characteristic biotite porphyroblasts and sparse laminations.

Type and reference sections

The type section for the Robertson River Formation is in FORSAYTH between the Forsayth-Agate Creek road (GR 653113) and a point near Tin Hill (GR 718110) (White, 1959). This section is in the 'schist phase' and probably includes metamorphosed equivalents of only the lower subunit (Er_1).

Withnall & Mackenzie (1980) nominated several reference sections for the unit. The lowermost part of the lower subunit (that below the Dead Horse Metabasalt Member) may not be exposed in NORTH HEAD and FOREST HOME (see below). Its nominated reference section is in the Percy River between GR 633788 and GR 622796 (GILBERTON and BELLFIELD respectively).

Reference sections for other parts of the Formation are in NORTH HEAD. Sections in Slaty Creek between GR 479125 and GR 477150, and in Stake Yard Creek between GR 400192 and GR 413159, contain reference sections for that part of the lower subunit above the Dead Horse Metabasalt Member. The upper subunit reference section is along the eastern bank of the Robertson River from the WRC gauging station at GR 484233 to GR 471251.

Thickness

The thickness is difficult to determine because of the intense multiple deformation which has affected much of the unit. Withnall & Mackenzie (1980) estimated the thickness to be of the order of 3000 m.

General Lithology

The Robertson River Formation consists of the following regionally metamorphosed (greenschist to upper amphibolite facies) sedimentary and basic volcanic rocks:

Br_{pl} - mainly grey to green phyllite (± chloritoid), cleaved mudstone, shale and siltstone;

Br_{l} - white or buff to grey quartz-mica schist (± staurolite, andalusite, garnet) and minor micaceous quartzite (± calc-silicate);

Bd (Dead Horse Metabasalt Member) - metabasalt, minor sediments.

Br_{q} - (Tin Hill Quartzite Member), white, pure quartzte;

Br_{pu} - white to very dark grey, commonly carbonaceous, locally calcareous phyllite and cleaved mudstone, siltstone and fine lithic sandstone, siliceous and fine lithic sandstone, siliceous siltstone, quartzite, and impure limestone;

Br_{u} - white to dark grey (commonly graphitic) quartz-mica schist (± andalusite, cordierite), micaceous quartzite, calc-silicate rocks, minor impure marble;

Details of lithologic units

The named members of the Robertson River Formation - the Dead Horse Metabasalt Member (Bd) and Tin Hill Quartzite Member (Br_{q}) - are described under separate chapter subheadings.

Robertson River Formation - lower subunit (Br_{pl}) Rocks of the lowermost part of the subunit (below the metabasalt member) may not be exposed in NORTH HEAD and FOREST HOME. Although the structure in the Cobbold Creek-South Head area is not well understood, it appears that the rocks on both sides of the belt of metabasalt overlie it. In GILBERTON, where the lowermost part of Br_{pl} is exposed, it consists of siltstone, sub-labile sandstone (commonly calcareous with concretions), mudstone, and shale. Sedimentary structures are well preserved and include lensoid and wavy bedding, scour-and-fill, cross stratification, ripple laminae, and sandstone dykes. By contrast, such structures, apart from laminae, are rare in rocks overlying the Dead Horse Metabasalt Member in NORTH HEAD and GILBERTON. Immediately overlying the metabasalt is grey, commonly well laminated mudstone, which passes upwards into a monotonous sequence of green, poorly laminated cleaved mudstone in which chloritoid is common. The ridge-forming phyllite marking the top of the lower subunit (see above) is part of the poorly laminated sequence.

In thin section, the mudstones consist of fine-grained (less than 0.05 mm) muscovite, chlorite (and biotite where the metamorphic grade was high enough), and quartz. Quartz is generally subordinate to the phyllosilicates, which are aligned and produce the slaty cleavage; a later crenulation cleavage accompanied by different degrees of metamorphic differentiation is present in places (see below). With increasing metamorphic grade the rocks grade into schist.

Robertson River Formation - lower subunit ('schist phase') (Br_l): These rocks are predominantly quartz-mica schist and subordinate micaceous quartzite. The schist is silvery grey to buff, well foliated due to alignment of quartz and mica, and commonly crenulated. The main foliation may be S_1 or S_2, the latter usually being a crenulation cleavage; S_1 is almost obliterated in some rocks (particularly those in which there was extensive growth of porphyroblasts, during D_2 - discussed more fully below). Muscovite is the predominant mica, but minor biotite is usually present, commonly as porphyroblasts. Post-tectonic chlorite porphyroblasts occur locally.

Buff muscovite-quartz schist containing abundant large porphyroblasts of staurolite, biotite, and andalusite, and smaller garnet porphyroblasts, is a characteristic lithology in places. It is particularly abundant near the boundary with the carbonaceous schist of the upper Robertson River Formation (Br_u), between the Agate Creek road and the Robertson River in NORTH HEAD and in Daniel Creek southeast of Ironhurst homestead in FOREST HOME. Staurolite is more abundant than andalusite in the NORTH HEAD localities, whereas andalusite predominates in the Daniel Creek area. Outcrops generally contain sparse biotite-rich layers about 1 cm wide and up to 1 m apart, or lack discernable layering. The rocks are equivalents of the green chloritoid phyllite which is also poorly laminated and occupies a similar stratigraphic position; both chloritoid and staurolite crystallise from similar, relatively restricted ranges of host-rock compositions.

With decreasing mica content, the schists grade into quartzite, which generally contains some plagioclase and, in places, also contains porphyroblasts of hornblende and garnet.

Robertson River Formation - upper subunit (Br_{pu}): The upper Robertson River Formation is characterised by an abundance of highly carbonaceous or graphitic mudstone and siltstone; the rocks are commonly finely laminated, and contain alternating carbonaceous and weakly carbonaceous to non-carbonaceous laminae. The organic carbon content ranges up to 10 per cent in some rocks. Pyrite casts and limonite pseudomorphs after pyrite nodules are common. The rocks are interbedded with white to light-grey mudstone and siltstone that are generally more quartz-rich than otherwise similar rocks in the lower Robertson River Formation. The mudstone and siltstone are well cleaved, and are slaty to phyllitic; a crenulation cleavage (commonly differentiated) is present locally. Sublabile to labile sandstone is a minor component, though more common than in the lower subunit; it is fine grained, sericitic, and contains minor plagioclase. Much of the sericite is probably derived from degradation of mudclasts rather than a clay matrix; mudclasts are still visible in some rocks. Slumping and distorted bedding, and small to medium-scale trough-bounded cross-stratification are present in some of the silty and sandy beds.

Another characteristic of the upper Robertson River Formation is the presence of calcareous rocks, ranging from thin beds of relatively pure limestone to calcareous mudstone and siltstone. No stromatolites have been observed.

Relatively pure orthoquartzite occurs as rare thin beds less than a metre thick in several areas. Dark grey carbonaceous orthoquartzite crops out 3 km north-northeast of Western Creek bore and 4 km southeast of Bonneys Gully bore. The quartz is recrystallised to a fine mosaic of elongate sutured grains; however, the graphite still preserves the outlines of original grains averaging about 0.4 mm across, which indicates that the rock was a sandstone and is not a recrystallised chert. White medium to coarse orthoquartzite is interbedded with laminated carbonaceous mudstone 2 km west of the WRC gauging station on Agate Creek, probably within the upper Robertson River Formation. Brecciated quartzite in the hills flanking Dry Pocket at GR 610108 is probably orthoquartzite rather than Tin Hill Quartzite Member.

Robertson River Formation - upper subunit ('schist phase') (Br_u): The slaty and phyllitic mudstone, siltstone, and fine sandstone of the 'phyllite phase' grade into quartz-mica schist. The non-carbonaceous schists are generally coarse muscovite porphyroblasts appear; even at that grade the quartz remains relatively fine grained. In the lower amphibolite facies, andalusite (chiastolite variety) and cordierite are the main porphyroblasts, and textural relationships indicate that they formed during D_2. They are particularly well developed in the Western Creek area, and east of the Agate Creek-Robertson River junction, where andalusite porphyroblasts up to 20 cm long occur, restricted mainly to the carbonaceous lithologies.

The schists are generally well foliated, although in the Western Creek area the foliation is poorly defined. This may be due to strong overprinting of D_2 structures on those of D_1; some outcrops appear to have two poorly defined foliations. The lower mica content and coarser-grained quartz of the rocks in this area (which suggests that they were more sandy than silty) probably also influenced the development of foliation; this is discussed more fully below (pp 55-58).

The calcareous sedimentary rocks grade into calc-silicate rocks which, depending on their composition, contain various combinations of quartz, calcite, tremolite or hornblende, clinozoisite, garnet, diopside, and phlogopite. They are generally finely laminated, and in places contain concretionary structures. Minor relatively pure marble also crops out.

North of Ironhurst homestead and in areas adjacent to the Forsayth Batholith, where metamorphic grade was highest, the schists are coarse-grained and contain abundant muscovite porphyroblasts which cut across the foliation; lenticular aggregates and layers of sericite after sillimanite are also present. In GEORGETOWN (Oversby & others, 1978) these features are characteristic of upper amphibolite facies rocks. North of Ironhurst homestead, the schists grade into migmatite, which consists of alternating layers of granitoid; composed mainly of quartz and lesser plagioclase, and schist.

Relationships

The base of the Robertson River Formation is not exposed in the North Head-Forest Home area. Dolerite and gabbro sills (now metamorphosed) probably intruded the Robertson River Formation before the deposition of the conformably overlying Townley Formation.

In NORTH HEAD and FOREST HOME the Formation was later intruded by Proterozoic Aurora, Forsayth, Delaney, and Ropewalk Granites, Carnes and Gongora Granodiorites, several unnamed Proterozoic granitoid plutons, the Carboniferous Prestwood Microgranite, Mount Darcy and Mount Sircom Microgranodiorites, and numerous minor rhyolitic to dacitic intrusives. The Carboniferous Maureen, Dismal Creek, and Cumberland Range Volcanics, and various Mesozoic and Cainozoic sedimentary units, unconformably overlie the Formation.

Dead Horse Metabasalt Member

(Map Symbol Ed)

Nomenclature

Dead Horse Metabasalt Member as defined by Withnall & Mackenzie (1980) incorporates basic volcanic rocks, previously known as 'Cobbold Dolerite' (White, 1959, 1962b, 1965), in the lower part of the Robertson River Formation. The unit was first recognised in GILBERTON by Withnall & others (1980b); we have extended it to include basic volcanic rocks that crop out at the same stratigraphic level in the area between South Head homestead and the Robertson River.

Distribution

The Member crops out over about 150 km^2 between South Head homestead and the Robertson River.

Topography and airphoto characteristics

The Dead Horse Metabasalt Member crops out in area of relatively subdued relief with a trellised drainage pattern. The unit has a characteristic dark reddish brown colour on airphotos due to the red soil cover; outcrop is poor, except in larger stream channels.

Type Section

Withnall & Mackenzie (1980) nominated the type section along the Percy River between GR 682823 and GR 633813 (GILBERTON). In NORTH HEAD the best exposed sections are along the Gilbert River from GR 457045 to GR 383118, and downstream along Red Spring and Cobbold Creeks from near the yards at GR 501096 to GR 526158. The latter section corresponds to White's (1959) type area of the Cobbold Dolerite (see below).

Thickness

The Member is 300 to 1000 m thick in GILBERTON; in NORTH HEAD, thickness is difficult to estimate because the structure is not well understood, but it is likely to be similar to that in GILBERTON.

General lithology

The dominant lithology is metabasalt, which is mostly massive, although pillows, amygdales, and hyaloclastite occur locally. Coarser-grained varieties may be metadolerite sills or dykes, or parts of thick flows. Cleaved mudstone, shale, and siltstone are interbedded with the metabasalt in places.

Detailed lithology

In NORTH HEAD, the metabasalt was metamorphosed in the greenschist facies; amphibolite facies equivalents crop out in adjacent FORSAYTH. The rocks are generally dark green, fine to very fine-grained, and aphyric. They contain 25 to 50 percent albite as randomly orientated microlites 0.5 to 1 mm long, or as a fine mosaic of grains less than 0.2 mm; the matrix to the albite laths consists of various proportions of pale green acicular actinolite or hornblende (depending on the metamorphic grade), epidote/clinozoisite, chlorite, calcite, sphene, and opaque oxides. Amygdales are filled with quartz, minor epidote and/or calcite. Traces of chalcopyrite are present in the amygdales or disseminated through the rock.

The pillows generally range from 20 cm to 1 m in diameter; finer-grained, darker-coloured selvages, amygdales, and radiating cooling joints filled with silica or calcite are preserved. The hyaloclastic breccias consist of irregular fragments of metabasalt in a pale-green to white matrix of quartz, calcite, chlorite, and epidote. The clasts are up to 5 cm, but generally 1 to 5 mm long; some larger fragments show curved surfaces with finer-grained selvages indicating that they are fragments of pillows.

Origin and environment of deposition

The presence of pillows, hyaloclastites, and interbedded sedimentary rocks indicates that the Dead Horse Metabasalt Member is mainly of submarine origin. However, the underlying sediments in GILBERTON were deposited in a shallow subtidal environment, and it is possible that the thicker non-pillowed flows may have been extruded subaerially.

Unpublished chemical analyses by AMDEL (held at GSQ) of metabasalt samples indicate that they are of tholeiitic affinity, showing characteristics of both abyssal and 'island-arc' basalts; the chemical data will be presented in a separate report.

Relationships

The Dead Horse Metabasalt is a member within the lower subunit of the Robertson River Formation (Br_{pl}).

Tin Hill Quartzite Member

(Map symbol - Br_q)

Nomenclature

Withnall & Mackenzie (1980) defined this unit, which was previously mapped as an unnamed member of the 'Robertson River Metamorphics' by White (1962b) and Bain & others (1976).

Distribution and topography

The main outcrop area of the Tin Hill Quartzite Member is in FORSAYTH near the Robertson River between the Agate Creek and Robin Hood roads, where it forms a series of prominent steep ridges, including Tin Hill, from which the name is derived.

In NORTH HEAD, the unit does not form any prominent topographic feature, but has been mapped mainly on the basis of airphoto-interpretation and information from T.H. Bell (James Cook University, personal communication, 1978); it crops out between Malcolm Creek and Dry Pocket, and south of the Robertson River near the eastern edge of NORTH HEAD, but was not examined in either of these areas.

Type section, thickness, and general lithology

The type section on the southern side of Tin Hill (GR 730163, FORSAYTH). The unit is 5 to 40m thick, and consists mainly of white (locally grey) pure quartzite, with very minor lenses of mica schist.

Detailed lithology

The quartzite is very clean, and contains only traces (less than 1 percent) of muscovite and tourmaline.

In the Tin Hill area, the quartzite is massive, or shows poorly developed layering. The layers are 1 to 2 cm wide, and appear to reflect grainsize differences; the greyish layers are generally coarser (up to 0.5 mm), whereas the white layers are finer and are granulated and sheared. Darker-grey varieties appear to contain finely disseminated specular hematite. Brecciation and quartz veining, apparently associated with the deformation, are present in places.

A bed of white siliceous siltstone several metres thick within buff cleaved mudstone that crops out on the bank of the Gilbert River at GR 479030, 9 km southeast of South Head homestead may be a low-grade equivalent of the Tin Hill Quartzite Member. The rock contains over 95 percent quartz, which forms a mosaic of equant 0.01 to 0.02-mm grains, with minor muscovite and traces of zircon.

Origin

The origin of the Tin Hill Quartzite Member is uncertain. All outcrops studied are within the high-grade part of the Robertson River Formation, and recrystallisation has obscured the original texture. The preservation in the Member of some apparent primary bedding features, and its conformable nature preclude a vein quartz origin and indicate a sedimentary origin. Its occurrence within a mainly pelitic sequence is difficult to reconcile with normal quartz arenites which are generally of shallow-water or continental origin (Pettijohn & others, 1972). Most of the other quartzite units from the Etheridge Group are sublabile and contain feldspar and mica; some relatively pure quartzites are known from the upper Robertson River Formation (see above) but none of these is as thick or as laterally persistent as the Tin Hill Quartzite Member.

Thin beds of fine-grained spotted siliceous rocks of probable chemical origin occur within the Dead Horse Metabasalt Member; it is possible that the Tin Hill Quartzite Member represents a later, similar depositional event. If the outcrop in the Gilbert River is an equivalent of the Tin Hill Quartzite Member, its very fine grainsize is consistent with such an origin.

Relationships

The Tin Hill Quartzite Member is within the lower Robertson River Formation, probably stratigraphically above the Dead Horse Metabasalt Member; its position is shown incorrectly in the Reference of 'Geology of the North Head Region' 1:100 000 Geological Special Preliminary Edition.

Metamorphosed basic intrusives

(Map symbols : mdl, a)

Nomenclature

Metamorphosed basic rocks in the Georgetown Inlier were previously assigned to the 'Cobbold Dolerite' by White (1959, 1962a, 1962b, 1965); Bain & others (1976) and Oversby & others (1978) tentatively proposed changing the name to 'Cobbold Metadolerite'. However, most of the rocks in the Cobbold Creek, the type area of the unit (White, 1959), are now recognised as extrusive metabasalt, and assigned to the Dead Horse Metabasalt Member. Although minor amounts of basic intrusive rocks crop out in Cobbold Creek, we prefer to abandon usage of the name 'Cobbold Dolerite', and to assign the multitude of deformed basic intrusive rocks in the Etheridge Group to two unnamed categories, namely metadolerite (mdl) and amphibolite (a).

Distribution

Basic igneous rocks in the North Head-Forest Home area are restricted to the Robertson River Formation (both upper and lower), strongly suggesting that they were emplaced before deposition of the Townley Formation. Amphibolite is restricted to the upper amphibolite facies rocks of the northwestern corner of FOREST HOME; elsewhere, the basic rocks are classified as metadolerite. Metadolerite intrusions are particularly widespread in the upper Robertson River Formation except in the south of the area, around North Head homestead.

Topography and airphoto characteristics

The basic igneous rocks are generally distinguished by a dark red-brown to brown colour on airphotos. The intrusive rocks are generally better exposed than the Dead Horse Metabasalt Member, and commonly form prominent boulder-strewn hills.

Calc-silicate rocks and colluvium overlying metasedimentary rocks commonly have a red soil cover, and could be misidentified as metadolerite; however the brownish tint of soils on metadolerite is characteristic.

Morphology of the intrusive bodies

Most of the metamorphosed basic intrusives in the North Head-Forest Home area were emplaced as sills ranging from a few tens of metres to several hundred metres thick; no clearly discordant bodies are known. Sills southwest of Ironhurst homestead commonly contain primary igneous layering, made up of alternating hornblende and plagioclase-rich layers 1 to 10 cm wide.

General lithology

Metadolerite, metagabbro, amphibolite, and minor chlorite schist.

Detailed lithology

Metadolerite and metagabbro. These are dark-green to black, fine to coarse-grained, generally massive rocks. In the greenschist facies they consist mainly of albite, epidote, and blue-green hornblende. Towards the upper part of the greenschist facies, oligoclase is present instead of albite.

Albite (or oligoclase where present) occurs as laths 0.5 to 1.5 mm long, with cores of epidote or saussurite; epidote also forms discrete grains. Hornblende forms aggregates up to 5 mm wide of randomly orientated prisms, or discrete blastophitic crystals enclosing feldspar laths; the aggregates may result from recrystallisation of fibrous uralite or actinolite aggregates formed at an earlier, lower-grade stage of metamorphism. Chlorite, where present, occurs as small flakes less than 0.1 mm long in clusters interstitial to, and included in albite. Opaque grains are up to 0.5 mm wide, are commonly skeletal, and generally partly replaced by sphene. Minor interstitial quartz is present in some rocks; apatite is the main accessory mineral.

Where the rocks are of amphibolite facies, the plagioclase is andesine or labradorite. Relict igneous laths persist in some specimens, but the plagioclase generally forms a granoblastic mosaic, probably representing recrystallised albite-epidote aggregates formed during earlier greenschist facies metamorphism. Hornblende is similar in habit to that described above; it changes progressively from bluish green through green to brownish green as the metamorphic grade increases.

Chlorite schist. The area mapped as metadolerite along Malcolm Creek, west of the Agate Creek road, includes some outcrops of chlorite schist. The schist consists of discontinuous layers or lenses of chlorite 1 to 2 mm apart, in a matrix of albite, calcite, and quartz. Sparse plagioclase laths are preserved.

Amphibolite. These are black, fine to medium-grained rocks, commonly foliated and/or lineated, and consist of plagioclase, hornblende, and diopside. Hornblende forms generally brownish-green subequant to elongate polygonal grains, rarely more than 1.5 mm long, and commonly aligned. Plagioclase is of labradorite composition and generally forms granuloblastic grains less than 0.5 mm across. Diopside is locally present as irregular poikiloblastic grains, 1 to 2 mm across, that are slightly retrogressed to pale-green amphibole.

Relationships

As discussed above, basic intrusive rocks in the North Head-Forest Home area are restricted to the Robertson River Formation, in which they form sills which have been deformed and metamorphosed with sediments.

Origin

The metadolerite and metagabbro are low-potassium tholeiites. Although they have some chemical similarities to the Dead Horse Metabasalt Member, they have generally lower Ti and Zr contents, and lower Fe_{total}/Mg ratios. These chemical differences are shown by metadolerites in both lower and upper parts of the Robertson River Formation, and suggest that most intrusives in the lower subunit are not comagmatic with the Dead Horse Metabasalt Member.

Townley Formation

(Map symbols - Bt, Bt_s)

Nomenclature

The Townley Formation was defined by Withnall & Mackenzie (1980). Rocks comprising the unit were included in the Robertson River Formation on the original field compilation sheets (Mackenzie & others, 1979) and by Withnall & others (1980a). White (1962b, 1965) included the rocks in the 'Etheridge Formation'.

Distribution

The Townley Formation occurs in a northerly trending folded belt which extends from the Reedy Creek area (GR 300150), near North Head homestead, to near Riverview homestead (GR 310770), and east from Black Gin Creek to the Mosquito Creek silver-lead field.

Topography and airphoto characteristics

The Townley Formation is topographically more prominent than the Robertson River Formation, ranging from subdued to gently or moderately hilly. Differential weathering and erosion have picked out well-defined bedding trends, particularly east of the Gilbert River, although not as markedly as in the overlying Heliman Formation. The unit has a greyish to reddish brown colour on airphotos; a prominent carbonaceous interval (see below) is conspicuous as a dark grey band in some areas.

Type section

The 1400 m-thick type section is exposed along a tributary of Black Gin Creek from its head at GR 290466, downstream to GR 275448.

Thickness

The Formation is 400 to 1500 m thick, but in many areas, especially the Mount Clark-Mosquito Creek area, complex folding prevents determination of thickness.

General lithology

The Townley Formation consists of white to grey fine-grained sericitic or sublabile to labile sandstone, siltstone and mudstone, and minor quartzose sandstone, siliceous siltstone, and calc-silicate rocks; carbonaceous siltstone or mudstone forms a conspicuous interval in the middle of the unit. The rocks are cleaved or foliated, and grade eastwards into fine-grained schistose equivalents; they are metamorphosed in the amphibolite facies, except in the southwest of NORTH HEAD, where rocks are in the greenschist facies.

Detailed lithology

The basal part of the Townley Formation consists of white to light grey siltstone, mudstone, and fine sublabile to labile sandstone which contrast with the darker, more carbonaceous rocks of the underlying Robertson River Formation. Distinctive among these lithologies is white to light grey, laminated, moderately siliceous siltstone which is stained pink to purple along fractures and pyrite layers (pyrite is commonly preserved). The siltstone consists of quartz, plagioclase, and minor muscovite; grainsize is generally less than 0.05 mm, but in places the siltstone grades into fine sublabile sandstone. Pyrite and limonite/hematite pseudomorphs after pyrite commonly form small elongate lenses up to a few millimetres long parallel to the cleavage. Anomalous zinc values (1000 to 6000 ppm) are associated with this lithology in the type section, and in some other areas (Withnall, 1981).

Beds of laminated siliceous calc-silicate rocks are interbedded with the lower part of the Townley Formation, in at least two areas. They consist mainly of quartz and needles and rosettes of tremolite; plagioclase, muscovite and biotite are also present. At the Mount Clark South zinc prospect (GR 428343), discovered by Conzinc Riotinto Australia Exploration Pty Ltd (CRAE), the siliceous calc-silicate rocks are interbedded with white 'sericitic' siltstone which contains anomalous zinc concentrations (up to 4000 ppm). Johnston (1978) considered that the siliceous rocks are of tuffaceous origin because they contain abundant K-feldspar. Brownish altered laths, which may have been K-feldspar, along with quartz and tremolite are present in a thin section from a sample collected in one of the costeans at Mount Clark South. Similar rocks, though without obvious K-feldspar, crop out in a similar stratigraphic position in the Mount Johnstone area. In both areas the rocks are characterised by deep weathering and reddish soil cover. The rocks were probably originally dolomitic siltstone; the K-feldspar may be authigenic and was possibly derived from a tuffaceous component.

The carbonaceous, locally calcareous siltstone in the middle of the Townley Formation is generally thin-bedded, well laminated, strongly fissile, and has a characteristic blocky jointing.

The upper part of the Townley Formation is characterised by a greater abundance of fine sublabile to labile sandstone than in the lower part; the sandstone is interbedded with grey siltstone and minor siliceous siltstone. Laminations are the main sedimentary structures; minor small to medium-scale cross-laminae are present, and slumping, distorted bedding, and sandstone dykes become more common towards the top of the unit.

Relationships

The Townley Formation overlies the Robertson River Formation and grades upwards into the more siliceous Heliman Formation.

It is intruded by Proterozoic Forsayth Granite, Carnes and Gongora Granodiorites, and by Carboniferous Prestwood Microgranite and various minor bodies of porphyritic rhyolite and dacite. The Carboniferous Cumberland Range Volcanics and Jurassic Eulo Queen Group unconformably overlie the unit.

Heliman Formation

(Map symbols - Eh_1, Eh_2, Eh_3)

Nomenclature

Withnall & Mackenzie (1980) defined the Heliman Formation, and divided it into informal subunits - lower (Eh_1), middle (Eh_2), and upper (Eh_3); it was originally mapped by White (1962b, 1965) as part of the 'Etheridge Formation'.

Distribution

The Heliman Formation is exposed virtually continuously from the southern bank of the Gilbert River near Forest Home homestead, south along Pinnacle Creek, and through much of the western half of NORTH HEAD, where it can be traced around several large-amplitude folds into the Reedy Creek area and the headwaters of the Langdon River. Two major synclinal outliers crop out to the east. One, 22 km long and 2 to 4 km wide, extends from the head of Pinnacle Creek to the Glenrowan Creek area, and the other extends for about 10 km between Mount McDonald and Mount Tabletop. Smaller synclinal outliers are in the headwaters of Pinnacle Creek, and in the lower reaches of Mosquito Creek. Patchy exposures surrounded by Mesozoic/Cainozoic cover occur north of the Gilbert River in the west of FOREST HOME.

Topography and airphoto characteristics

The Heliman Formation is topographically more prominent than the underlying Townley Formation and the overlying lowermost part of the Candlow Formation (Ec_1). The lower (Eh_1) and upper (Eh_3) parts form rounded hills and ridges on which the numerous resistant beds of siliceous siltstone or fine quartzose sandstone are conspicuous. The unit generally has a light tone (pale grey to cream) on airphotos, especially where the sparse vegetation cover is dominated by spinifex and stunted silver-leafed ironbark (Eucalyptus shirleyi). The middle part of the Heliman Formation (Ph_2) is a laterally persistent belt of subdued topography with a brownish tone on airphotos, and lacks conspicuous bedding trends.

Type section

The type section extends from the junction of the eastern and western branches of upper Black Gin Creek at GR 252464 (base) upstream along the western branch to GR 246451 (top); the upper and lower subunits in this section are each about 500 m thick and the middle subunit is about 200 m thick.

Thickness

The Formation ranges from about 800 m thick in the headwaters of Heliman Creek to about 2500 m along Black Gin Creek. However, thickness is difficult to estimate in many areas (particularly in FOREST HOME) because of complex interfering folds.

General lithology

The Heliman Formation consists of cleaved, sericitic, sublabile to labile (lithic and feldspatholithic) sandstone, sandy siltstone, and mudstone; very dark grey 'flinty' siliceous siltstone to fine sandstone constitutes 10 to 30 per cent and is characteristic of the upper (Bh_3) and lower (Bh_1) subunits, but is nearly absent in the intervening, selectively eroded middle subunit (Bh_2). The Formation has been affected by metamorphism ranging from lower greenschist to lower amphibolite grade.

Detailed lithology

The lower and upper parts of the Heliman Formation are essentially identical, and are not described separately. Resistant siliceous siltstone and fine feldspathic to lithic sublabile and quartzose sandstone in beds 0.2 m to several metres thick form the bulk of the outcrop, although they constitute only 10 to 30 per cent of the section. The rest of the section consists of poorly exposed fine sublabile to labile (lithic) sandstone, siltstone, mudstone, and minor carbonaceous mudstone or siltstone.

The siliceous rocks are dark grey to black on fresh surfaces. Weathered surfaces are generally white, and the pale tone of the Formation on aerial photographs is probably due to its extensive cover of rubble. The rocks consist of detrital and diagenetic quartz, and generally up to 25 per cent feldspar (mainly plagioclase), minor muscovite and biotite, disseminated carbon (usually less than 0.5 per cent), and irregular patches of pyrrhotite and pyrite up to 1 cm across. They are commonly slightly calcareous. Clasts of carbonaceous siliceous siltstone ranging from sand size to about 1 cm long are also common, and constitute up to 20 percent of some rocks.

The less resistant sublabile to labile sandstones that are interbedded with the siliceous rocks are not described here in detail because they are similar to those which constitute a large part of the Candlow Formation (see below). In brief, they contain quartz, feldspar, and abundant mudclasts, although in the more metamorphosed areas (upper greenschist to amphibolite facies), most of the mudclasts were recrystallised to mica and have lost their outlines. Such rocks are difficult to distinguish from metamorphosed siltstone or mudstone.

Most rocks in the Heliman Formation are internally laminated as well as being thick-bedded; distorted bedding and slumping are common, and load casts, flame structures, and small sand pillows are also present. Siliceous sand balls up to 5 mm in diameter occur in some labile sandstones in the upper subunit.

The uppermost part of the Heliman Formation (36.6 m) was intersected in GSQ Georgetown 7 drillhole (Withnall & Mackenzie, 1979). The section consists mainly of fine to very fine sublabile sandstone, mudstone, dark grey siliceous siltstone, and several beds of carbonaceous mudstone. The sequence is slightly calcareous in places, and a few very thin (up to several centimetres) impure limestone beds are present.

The middle subunit (Eh_2) consists mainly of labile sandstone, siltstone, mudstone, and only rare siliceous beds. Blocky-jointed, laminated carbonaceous siltstone and mudstone similar to those in the middle part of the Townley Formation are common.

Relationships

The Heliman Formation conformably overlies the Townley Formation, and is conformably overlain by the Candlow Formation. It is intruded by the Proterozoic Carnes and Gongora Granodiorites and Carboniferous Prestwood Microgranite and unconformably overlain by Jurassic-Cretaceous sandstones of the Eulo Queen Group and Gilbert River Formation.

Candlow Formation (Including White Bull Member and Stockyard Creek Mudstone Member)

(Map symbols - Ec_1, Ec_2, Ec_3, Ew, Es)

Nomenclature

The Candlow Formation was originally mapped as part of the 'Etheridge Formation' by White (1959, 1962b, 1965) who recognised and named the 'Stockyard Creek Siltstone Member' (now a member of the Candlow Formation). Withnall & Mackenzie (1980) formally defined the unit, redefined the 'Stockyard Creek Siltstone Member' as a member of the Candlow Formation, and recognised and defined the White Bull Member. The name 'Stockyard Creek Siltstone Member' is here changed to Stockyard Creek Mudstone Member because mudstone is now recognised to be the dominant lithology. The two named members divide the Candlow Formation into three subunits, informally referred to as lower, middle, and upper Candlow Formation (Ec_1, Ec_2, and Ec_3 respectively).

Distribution

The unit crops out as a strongly folded belt of rocks exposed from near Forest Home homestead, south to the Reedy Creek area and the headwaters of the Langdon River. A few small inliers are surrounded by Mesozoic/Cainozoic cover rocks north of Forest Home homestead. Aeromagnetic data (BMR, 1975) suggest that the Candlow Formation continues under the cover in a northwesterly direction.

Topography and Airphoto Characteristics

Apart from the two named members, the Candlow Formation generally forms very subdued to flat topography; eroded claypans, commonly bare of grass and littered with quartz pebbles, are characteristic and give the unit a light yellowish tone on the airphotos. Outcrop is sparse and commonly restricted to deep washouts and gullies. Trees are sparse and stunted, except where soil or alluvial cover is thicker.

The White Bull Member forms low ridges on which prominent beds of siliceous siltstone crop out. A cover of siliceous siltstone rubble and spinifex produces a light grey tone on the airphotos. Stunted paperbark and silver-leaf ironbark are the main trees.

The Stockyard Creek Mudstone Member generally forms prominent steep-sided ridges with a characteristic dense cover of lancewood (Acacia shirleyi) which gives the unit a dark tone on airphotos. The soil is dark grey because of the abundant carbon in the rocks.

Type and Reference Sections

The type section of the Candlow Formation is 5 km northeast of White Bull bore between GR 236389 (base) and GR 216377 (top). It includes the type section of the White Bull Member (GR 234386 to GR 232384) and a reference section for the Stockyard Creek Mudstone Member (GR 236389 to 216377). The type section of the Stockyard Creek Mudstone Member (White, 1959) is in Stockyard Creek, about 2.5 km south-southwest of Stockyard Dam between GR 28202919 (base) and GR 28252892 (top).

Drill core from GSQ Georgetown 3, 4, 5, 6, and 7 (Withnall & Mackenzie, 1979) provides reference sections of most of the Candlow Formation (Table 2); the White Bull Member was not cored. Figure 3 shows graphic logs of the drillholes.

Thickness

The overall thickness of the Candlow Formation ranges from about 1000 m in the Candlow area to about 3500 m in the Pinnacle Creek area; the type section contains about 2000 m, which includes 200 m of White Bull Member and about 150 m of Stockyard Creek Mudstone Member. Elsewhere, White Bull Member is between 100 m and 300 m thick and the Stockyard Creek Mudstone Member ranges from less than 50 m to about 300 m thick.

General lithology

Candlow Formation-lower subunit (Ec_1): light to dark grey mudstone and siltstone (carbonaceous in part); fine lithic and sublithic sandstone and minor siliceous siltstone; some rocks are calcareous, and rare thin impure limestone beds occur; gypsum casts or moulds are present in places.

White Bull Member(Ew): dark grey siliceous siltstone, grey sublithic to lithic fine sandstone, and variably carbonaceous mudstone and siltstone.

Table 2 : Stratigraphic Drillholes in the Candlow Area

Drillhole	Location*	Total Depth	Inclination Azimuth at Collar	Units Intersected
GSQ Georgetown 2R/2RA	16403335	99.15 m	45°/030°	Langdon River Mudstone
GSQ Georgetown 3	16523360	150.95 m	45°/025°	Candlow Formation (upper subunit)
GSQ Georgetown 4	16823368	213.92 m	45°/040°	Candlow Formation (upper subunit) (0 to 110 m) Stockyard Creek Mudstone Member (110 to 213.92 m)
GSQ Georgetown 5	16983385	142.07 m	45°/040°	Candlow Formation (middle subunit)
GSQ Georgetown 6	15363540	106.07 m	45°/030°	Candlow Formation (middle subunit)
GSQ Georgetown 7	16903470	181.58 m	45°/040°	Candlow Formation (lower subunit) (0 to 149 m) Heliman Formation (149 to 181.58 m)

*Metric grid reference: Northing and Easting, both to 4 significant figures.

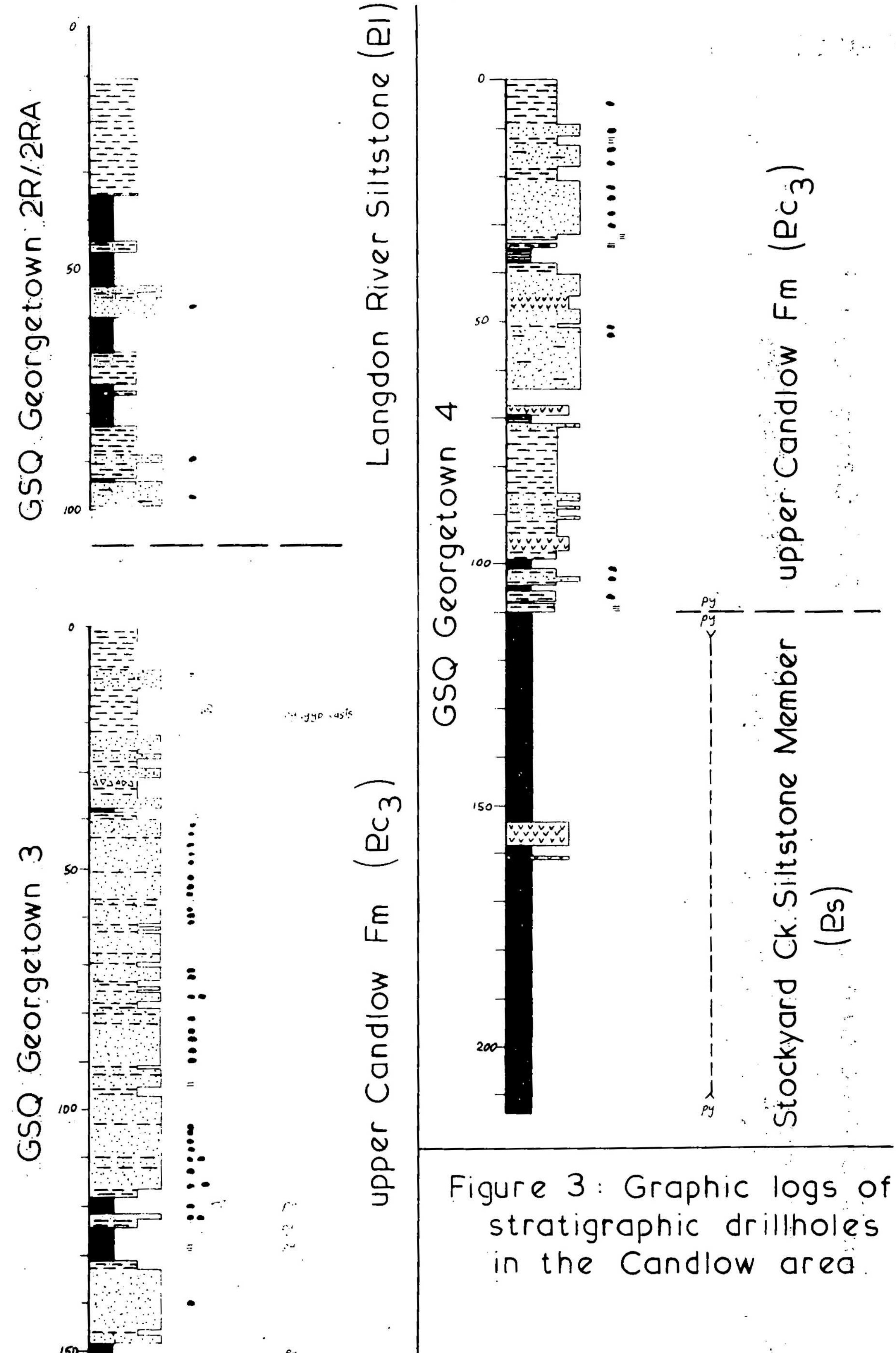
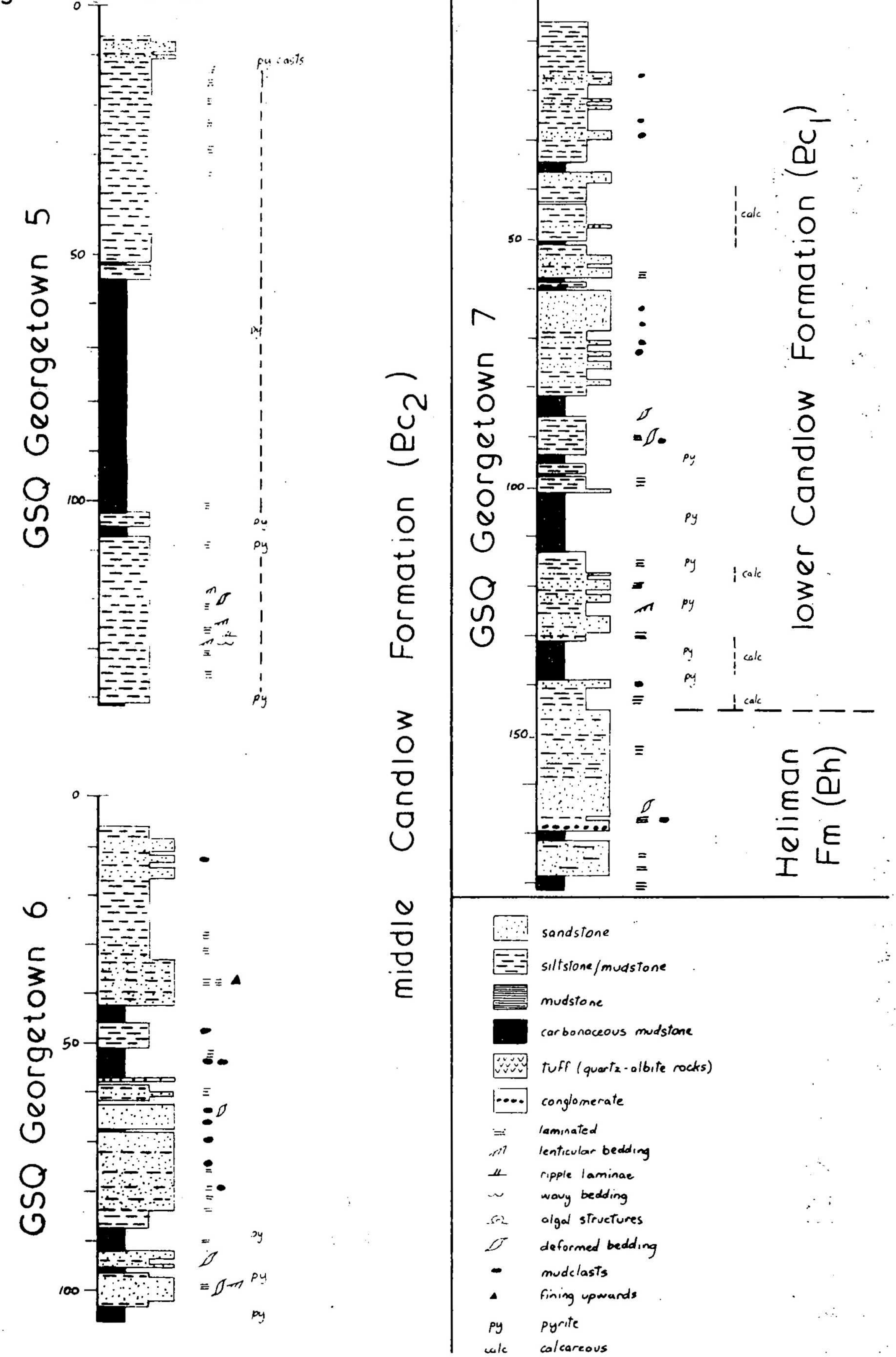


Figure 3: Graphic logs of stratigraphic drillholes in the Candlow area.

Figure 3 cont.



Candlow Formation-middle subunit (Bc_2): light grey to black variably carbonaceous and pyritic mudstone, siltstone and minor lithic sandstone; commonly purple and strongly ferruginous in outcrop; white effloresence of hydrated magnesium sulphates common on outcrops; minor calcareous rocks and impure limestone.

Stockyard Creek Mudstone Member (Bs): black, variably pyritic carbonaceous mudstone and rare tuff.

Candlow Formation-upper subunit (Bc_3): greenish grey (when fresh) fine lithic sandstone and light to dark grey carbonaceous mudstone and siltstone; some siliceous siltstone and quartz sandstone, particularly in the middle of the subunit.

The Candlow Formation was metamorphosed mainly in the greenschist facies, and all of the rocks, except for the very siliceous ones, are well cleaved.

Detailed lithology

Candlow Formation-lower subunit (Bc_1). This subunit is moderately well exposed in the type section of the Formation. The lower half of the section consists of thin-bedded and laminated siltstone and mudstone, some of which is carbonaceous, and minor fine sublithic to lithic sandstone. Iron-rich laminae and limonitic nodules (after pyrite?) up to 40 cm long occur in places, and mudclasts up to a few millimetres long are conspicuous in some siltstone and sandstone beds. Small-scale planar cross-laminae with cosets about 5 cm across, slumps, distorted laminae, and load casts occur in some beds.

About halfway up the section, some beds in a 30 to 40-m thick interval of siltstone and fine sub-lithic sandstone contain numerous randomly orientated moulds of 1 to 2 mm-long lenticular crystals (probably gypsum), that tend to be concentrated in particular layers (Fig. 4); mudclasts up to 1 cm are also present in these beds. Laminated siliceous mounds about 1 m across in a siltstone bed within this interval contain moulds up to 2 cm long (Fig. 5).

A sequence of laminated to thin-bedded grey to black, variably carbonaceous mudstone, ferruginous mudstone, very fine quartz sandstone and siliceous rocks containing over 50 per cent mudclasts crops out between the gypsiferous(?) interval and the White Bull Member. A minor occurrence of gypsum moulds is present in a siltstone bed within this section; this bed also contain ferruginous concretions up to 1 m across. Thin beds(?) of fine-grained, light to dark grey mottled laminated quartz or chert also crop out. They consist almost entirely of a fine mosaic of quartz grains (generally 0.1 to 0.5 mm wide) divided into layers by thin partings of muscovite or carbon; rare plagioclase and microcline crystals are also present. These beds may have formed by replacement of evaporite layers.

Gypsum moulds also occur along the White Bull Bore-Stockyard Dam track at GR 253332, and at GR 227344 where grey 'bedded quartz' also crops out.

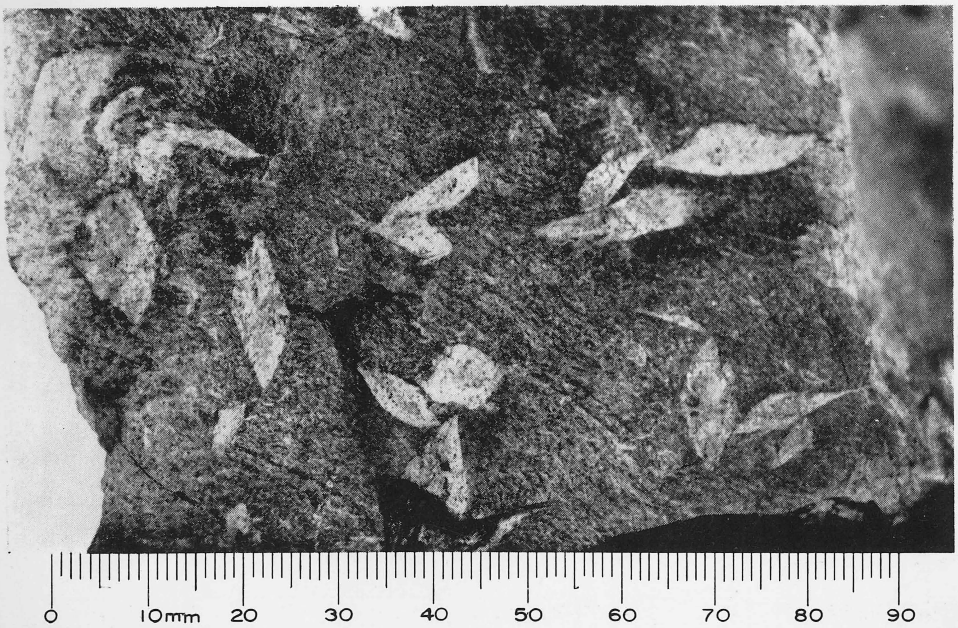
In another section, upstream from the North Head homestead-Stockyard Dam track at GR 332280, the base of the sequence consists of well-laminated black siltstone containing slumps, distorted beds, and small to medium-scale cross-laminae (trough cosets), oversteepened by slumping. An interval of calcareous purple-and-black banded siltstone is present, and is overlain by grey laminated mudstone containing discontinuous black laminae and lenses. A thick sequence of very fine lithic sandstone containing mudclasts and interbedded mudstone forms the top of the lower subunit in this area. No gypsum moulds or bedded quartz were noted.

GSQ Georgetown 7 cored 145 m of lower Candlow Formation, before intersecting the underlying Heliman Formation. The cored section consists of grey laminated siltstone and mudstone, massive carbonaceous siltstone and mudstone, fine lithic sandstone, and rare litho-feldspathic sandstone. Lithic sandstone is more abundant in the upper half of the section. The mudstone and siltstone are pyritic, but not as abundantly so as in the middle Candlow Formation. Rare lensoid and distorted laminae are present. In several intervals, which are up to 10 m thick, the rocks are calcareous, and a few thin limestone beds up to 20 cm thick were intersected. No gypsum or 'bedded quartz' was intersected, but it is possible that the hole was collared below the stratigraphic interval in which they occur; outcrop is sparse near the drillsite.

White Bull Member (Ew). This unit is similar to the lower and upper subunits of the Heliman Formation. The dominant lithology in outcrop is medium to thick-bedded dark-grey laminated siliceous siltstone; the laminae are distorted or slumped in places. As in the Heliman Formation, the poorly exposed parts of the White Bull Member consist of fine sublithic to lithic sandstone, and variably carbonaceous siltstone and mudstone.

Candlow Formation-midde subunit (Ec_2). In the type section, as in most areas, the middle subunit is the most poorly exposed. Black carbonaceous mudstone and grey laminated siltstone crop out near the base. Above this, yellow to brown mudstone containing ironstone nodules crops out; similar rocks occur near GSQ Georgetown 6. Overlying these rocks is a poorly exposed white to pale grey siltstone or mudstone with pink ferruginous laminae. A large part of the middle of the type section is not exposed; rubble of purple ironstone or ferruginised mudstone is abundant. Medium to thick-bedded laminated ferruginous siltstone, and poorly exposed purple to grey mudstone covered with white

Figure 4: Randomly orientated moulds after gypsum in fine-grained sub-lithic sandstone from the lower Candlow Formation type section (GR 235388)



Record 1981/63 16/Q/8

Figure 5: Large moulds after gypsum in siltstone from the lower Candlow Formation type section (GR 235387)

efflorescence crop out above this section. These rocks are overlain in turn by a 15 m-thick bed of purple-yellow laminated siltstone or fine lithic sandstone which contains pyritic laminae (now mostly weathered). Above this bed, exposed in gullies and shallow washouts, are white, purple, grey, and black mudstone, locally covered in white effloresence, and containing thin laminae and spots of limonite (after pyrite).

In other areas, buff to grey mudstone, with red and purple ferruginous laminae, crops out most commonly. Pebbles of ferruginised mudstone and ironstone which commonly litter the surface reflect the pyritic nature of the unit, which commonly has a more reddish tone on airphotos than the other subunits.

GSQ Georgetown 6 intersected the lower part of the subunit, immediately above the White Bull Member. The section consists of fine to very fine lithic sandstone (containing thin siltstone beds), grey siltstone and shale or mudstone, and dark grey carbonaceous mudstone. The siltstone is laminated in part, and the laminae are locally distorted.

GSQ Georgetown 5 intersected the much finer-grained upper half of the subunit immediately below the Stockyard Creek Mudstone Member. Grey laminated mudstone and siltstone, and black carbonaceous mudstone make up the bulk of the interval. Very minor lithic sandstone occurs near the top of the hole, and a few thin limestone beds were intersected towards the bottom. The mudstone and siltstone are laminated, with sporadic lensoid and wavy bedding, and rare distorted bedding; the carbonaceous mudstone is massive. Pyrite occurs throughout the section, commonly as small cubic crystals with well developed quartz pressure fringes, but also as disseminated, extremely small grains (much less than 0.01 mm), and associated with carbon along the cleavage planes.

The white hydrated magnesium sulphate efflorescence common on outcrops of middle Candlow Formation was originally thought to indicate that the rocks were dolomitic (Bain & others, 1979; Mackenzie, 1979; legend on preliminary edition maps). However, all carbonate layers in the drill core are low-Mg calcite, and no trace of dolomite or high-Mg calcite has been found. The efflorescence was probably the result of reaction between chlorite and groundwater containing sulphuric acid derived from the breakdown of the abundant pyrite in the middle subunit; chlorite weathers readily under moderately acid conditions (Weaver & Pollard, 1973, p 92), and, in this instance, the Mg-rich brucite layer would be removed as magnesium sulphate. X-ray diffraction and petrographic studies on drill core indicate that chlorite is common in mudstones in the lower half of GSQ Georgetown 5, whereas in other intervals in the Candlow Formation, chlorite is very minor or absent; quartz, muscovite, and plagioclase are generally the main constituents. Chemical analyses of core samples show that Mg content is generally 0.5 to 1 percent, compared with 1 to 2 percent in the chlorite-rich interval.

Stockyard Creek Mudstone Member (Es). This unit consists almost entirely of black or dark grey cleaved carbonaceous mudstone and siltstone. Apart from thin pyritic layers, the rocks are not conspicuously bedded or laminated, although in some areas such, as at GR 240655 (FOREST HOME), weathering has resulted in a subtle fine lamination being clearly visible in hand specimen.

Cubic pyrite moulds up to 1 or 2 cm across are common in outcrop; in core from GSQ Georgetown 4, pyrite also occurs as finely disseminated grains streaked out along the cleavage planes, small ellipsoidal aggregates (up to 2 mm), discordant veins, and concordant layers which are finely laminated locally. Much of the pyrite is probably remobilised or authigenic, but some of the small grains may have been framboids, and some of the layers may have been syngenetic beds. Traces of pyrrhotite and covellite occur in some rocks, and bladed crystals of arsenopyrite about 0.1 mm long occur in some pyrite layers, included in the pyrite or the matrix.

North of White Bull Bore, the Candlow Formation, in particular the middle subunit and Stockyard Creek Mudstone Member, is characterised by a line of magnetic anomalies (BMR, 1975). These anomalies are probably due to part of the pyrite having been converted to pyrrhotite at higher metamorphic grades. The rarity of pyrrhotite in the drill core from the Candlow area is consistent with the lack of magnetic response over the unit in that area and to the south.

X-ray diffraction and thin section studies indicate that the rocks consist of quartz and muscovite, in approximately equal proportions, and carbon; minor plagioclase occurs in a few samples. The carbon content is generally more than 3 per cent and ranges up to 10 per cent by weight; carbon in GSQ Georgetown 4 is amorphous.

The massive appearance and topographic prominence of the Stockyard Creek Mudstone Member contrasts with carbonaceous rocks elsewhere in the Candlow Formation, and in the Robertson River, Townley, and Heliman Formations; these rocks consist of finely alternating mudstone/siltstone and carbonaceous/non-carbonaceous layers. However, the lack of lamination in the Stockyard Creek Mudstone Member may be more apparent than real. All rocks containing more than 1 or 2 per cent carbon tend to be jet-black, and fine-scale variations in carbon content and mud/silt ratios would be disguised, even in thin section. The resistant nature of the Member may be partly, if not wholly due to its massive nature and lack of bedding-plane partings.

Interbedded with carbonaceous mudstone in GSQ Georgetown 4 are two beds (4 m and 0.7 m thick) of white to cream, fine-grained rocks that consist predominantly of randomly orientated albite laths 0.1 to 0.5 mm long, interstitial quartz, muscovite, and rare siderite veins. The origin of these rocks is uncertain; their unusual mineralogy, particularly when contrasted with the highly carbonaceous sedimentary rocks with which they occur, suggests that they may be tuffaceous. Rocks with a similar composition were intersected by GSQ Georgetown 4 in the upper subunit, but no such rocks have been recognised in outcrop of the Candlow Formation.

Candlow Formation-upper subunit (Pc_3). The uppermost part of the Candlow Formation consists of light to dark grey, commonly carbonaceous mudstone and siltstone, fine lithic sandstone, and lesser siliceous siltstone and quartz sandstone. Most of these rocks are variably pyritic.

Medium-bedded siliceous siltstone and sandstone are common in the middle of the subunit. In the type section, they contain abundant flattened mudclasts which range from less than 1 mm to several centimetres long, and are interbedded with less siliceous carbonaceous siltstone and lithic sandstone. The siliceous rocks are overlain by thin ferruginous beds, and siltstone which contains large limonite nodules up to 2 m across. The siliceous interval does not have sufficient thickness or lateral persistence to form a distinct, mappable unit like the White Bull Member.

Sections of the upper subunit were intersected in GSQ Georgetown 3 and 4. In GSQ Georgetown 4, the upper subunit overlies Stockyard Creek Mudstone Member with a gradational contact. The lower 40 m of the subunit consists of grey mudstone and siltstone, and lithic sandstone beds up to 2.5 m thick; carbonaceous mudstone occurs in the lowermost 10 m. Lithic sandstone is dominant in the upper 70 m of the hole.

Three 1 to 2 m-thick beds of quartzo-feldspathic rock, coarser than, but otherwise similar to that in the Stockyard Creek Mudstone Member, were encountered in drill core from the upper subunit. In thin section, these rocks contain turbid, euhedral plagioclase laths up to 1 mm long, which are rimmed by clear albite in optical continuity with the core; the matrix is a fine myrmekitic or micrographic intergrowth of quartz and albite(?) with undulatory extinction. Aggregates 0.5 to 1 mm across of interlocking quartz grains, and very minor muscovite, chlorite, and biotite are also present. The rock may have been a crystal tuff or lava, in which the glassy groundmass devitrified and recrystallised to form the micrographic intergrowths.

The section intersected by GSQ Georgetown 3 is stratigraphically higher than that in GSQ Georgetown 4, and consists predominantly of lithic sandstone which contains numerous mudclasts, interbedded with minor siltstone and mudstone. Siliceous siltstone is relatively common, and this section may be equivalent to the siliceous interval in the type section. The lowermost 30 m of the section contains three intervals of carbonaceous mudstone between 2 and 8 m thick. At 17.6 m, a 40cm intersection of pale grey, moderately siliceous siltstone contains fine contorted laminae which might represent algal mats; small pseudomorphs after gypsum(?) are present in some layers. This is the only occurrence of possible algal structures so far observed in the Etheridge Group.

Petrography of the Lithic Sandstone. The lithic sandstones that constitute a large part of the Candlow Formation (and also the Heliman, and parts of the Townley and Robertson River Formations) are poorly sorted and consist of clasts of mudstone in a very fine sandy to silty matrix.

Mudstone clasts constitute up to 70 per cent of the rocks and range from silt-size (less than 0.05 mm) to over 1 cm long, but are generally less than 2 mm long. They consist of fine-grained muscovite and quartz, and are flattened parallel to the cleavage. Some are carbonaceous, and these are the most conspicuous in hand specimen; they are also generally the largest, possibly because the organic-rich muds were more cohesive than those without such a binding. Where the mudclasts are particularly abundant, they coalesce and become diffuse in outline so that the rocks are difficult to distinguish from mudstone, particularly in hand specimen; in such rocks, only the presence of scattered carbonaceous clasts may indicate the original sandy nature of the rock. In deeply weathered and oxidised outcrops, the lithic sandstones are particularly difficult to identify. Where the units have been affected by more intense metamorphism, phyllite and schist derived from lithic sandstone become indistinguishable from those derived from mudstone and siltstone.

The smaller clasts are difficult to distinguish from the matrix, which consists of quartz, feldspar (mainly plagioclase), fine metamorphic muscovite, and rare detrital muscovite. In many rocks, the matrix is composed mainly of silt or very small sand grains, and little metamorphic muscovite (clay derived material). Where muscovite in the matrix is more abundant, it may be partly derived from breakdown of mudclasts during compaction, diagenesis, and metamorphism.

Traces of detrital zircon and authigenic tourmaline are generally present.

Relationships

The Candlow Formation conformably overlies the Heliman Formation, and is conformably overlain by the Langdon River Mudstone. The Proterozoic Malacura Sandstone unconformably overlies part of the Candlow Formation in the headwaters of the Langdon River.

The Formation is intruded and contact metamorphosed by Proterozoic Forest Home Granodiorite and Esmeralda Granite and unconformably overlain by Mesozoic Eulo Queen Group and Gilbert River Formation. It is capped by a Tertiary deep-weathering profile, and locally blanketed by ferruginised Tertiary valley fill, colluvium, or fanglomerate.

Langdon River Mudstone
(Map symbol - El)

Nomenclature

The 'Langdon River Formation' as originally defined by White (1959) included rocks that unconformably overlie the upper part of the 'Etheridge Formation'. Withnall & Mackenzie (1980) redefined the unit to include only that part of White's unit below the unconformity. The name was changed to 'Langdon River Siltstone' because the unit consists predominantly of pelitic rocks; it is here changed to Langdon River Mudstone, because mudstone is now recognised as the dominant lithology. Rocks above the unconformity are assigned to the Langlovale Group.

Distribution

The unit crops out as a tightly folded belt of rocks in the western portions of FOREST HOME and NORTH HEAD, and along the eastern edges of GILBERT RIVER and ESMERALDA.

Topography and airphoto characteristics

The Langdon River Mudstone produces a characteristic dense drainage pattern, in places partly rectilinear due to strike-ridge control, and rounded but steep hills of uniform size and height. The topographic prominence of the unit, in spite of its pelitic nature, is probably due to its lithologic homogeneity and lack of parting along bedding planes. Vegetation cover ranges from dense *Acacia* forest to open mixed forest.

Type section

White's (1959) type area of the 'Langdon River Formation' was 'along the track between Forest Home and Candlow Dam, along the eastern side of the valley of the Langdon River'. Withnall & Mackenzie (1980) restricted the type section to that part of the track between GR 119329 (base) and GR 114339 (synclinal hinge), because White's type area included rocks now recognised as Malacura Sandstone.

Better exposures of the same stratigraphic interval, about 0.5 km to the east in Candlow Creek (between GR 127330 and GR 127339), were designated as a reference section.

Thickness

The exposed thickness ranges from 800 m in the type area to 1400 m or more in the southeast of FOREST HOME. The unit is truncated at the top by an angular unconformity, so that its original thickness is unknown.

General lithology

The Langdon River Mudstone consists predominantly of well cleaved, grey (variably carbonaceous) to maroon laminated mudstone and siltstone; rare lithic sandstone and sandy siltstone are present. A discontinuous layer of highly carbonaceous mudstone occurs at the base.

Detailed lithology

The reference section in Candlow Creek consists predominantly of thin to medium-bedded mudstone with characteristic alternating grey and maroon bands. Thin siltstone beds containing planar cross-laminae, possible lensoid bedding, boudinage-like pull-apart structures, and load casts are present, particularly near the base of the unit. A thick, intensely convoluted bed of grey micaceous siltstone crops out near the top of the reference section; it may be stratigraphically equivalent to a 100 m-thick ridge-forming unit of brown micaceous siltstone displaying convolute bedding which crops out near Walkers Dam (GR 146452).

The maroon layers in the Langdon River Mudstone range from thin laminae to medium beds and commonly contain pyrite casts. Bleaching of the dark grey layers to white (adjacent to joints) and pink weathered pyritic layers is common; outcrops on hillsides are generally also pale grey to white because of oxidation of carbon, and the carbonaceous nature of the rocks is best observed in deep creek sections.

At stratigraphic levels higher than the reference section, the unit tends to be more massive and consists predominantly of maroon mudstone.

An interval of black, highly carbonaceous mudstone occurs at the base of the Langdon River Mudstone; it is discontinuous and restricted mainly to hinge zones, where it may have been tectonically thickened. The rocks are generally massive, and resemble the Stockyard Creek Mudstone Member, but thin red or purple mudstone bands occur in places. GSQ Georgetown 2R/2RA intersected a sequence near the base of the Langdon River Mudstone which consists of carbonaceous mudstone (commonly brecciated with a strongly contorted cleavage) interbedded with maroon mudstone and lithic sandstone; the lithic sandstone contains mud clasts, up to several millimetres long, in a silty matrix.

Areas of andalusite hornfels are common in the western part of the outcrop area, around exposed or inferred near-surface intrusions of Forest Home Granodiorite and Esmeralda Granite. The andalusite crystals are generally 0.1 to 1 cm long, and their abundance reflects the strongly pelitic nature of the Langdon River Mudstone.

Relationships

The Langdon River Mudstone is the uppermost formation of the Etheridge Group. It conformably overlies the Candlow Formation and is overlain unconformably by the Proterozoic Malacura Sandstone. The Proterozoic Forest Home Granodiorite and Esmeralda Granite have intruded and contact-metamorphosed the unit.

The Mesozoic Eulo Queen Group and Gilbert River Formation and Tertiary Bulimba Formation and ferruginised valley fill, colluvium, and fanglomerate overlie the unit unconformity.

Environment of deposition of the Etheridge Group

Introduction

Although the stratigraphy of the Etheridge Group is now well known, only preliminary studies to determine the environments of deposition have been undertaken. During the original mapping (Mackenzie & others, 1979), no systematic studies were made of the sedimentary structures, and their vertical and lateral distribution, and relationships with rock types.

A preliminary study was carried out by J. Draper (GSQ) and I. Withnall in July, 1979. The work involved examination of one or two complete vertical sections and some isolated localities in each of the constituent formations of the Etheridge Group. Only preliminary ideas are presented here, because a complete analysis of the data has not yet been made; the results will be reported more fully in a separate report. A wide range of sedimentary structures are present in the rocks, and the area could provide rewarding detailed sedimentological studies using the stratigraphic framework now available.

The environments are discussed here as a separate section (rather than under the descriptions of individual units) to avoid unnecessary repetition. Similar rocks and structures are present in several units, in particular in the interval from the upper part of the Townley Formation to the top of the Candlow Formation.

Preliminary interpretation and discussion of environment

The part of the lower Robertson River Formation below the Dead Horse Metabasalt Member probably does not crop out in the North Head-Forest Home area; it is thought to represent a shallow subtidal to intertidal depositional environment. The presence of pillows, hyaloclastites, and interbedded sedimentary rocks indicate that the Dead Horse Metabasalt Member was at least in part submarine. The shallow-water character of the underlying sediments introduces the possibility that the volcanic pile might have built up sufficiently for some of the thicker, non-pillowed flows to have been extruded subaerially.

Overlying the metabasalt are fine-grained rocks (mostly mudstone and siltstone) that are commonly finely laminated, but contain few other structures, and grade upwards into massive unbedded mudstone. This part of the sequence appears to have been deposited in deeper, quieter water than the rocks which preceded the metabasalt extrusion. The Tin Hill Quartzite Member occurs in this part of the sequence, but its origin is uncertain; a possible origin as a chemical sediment is discussed above (p 15). The deepening water and the extrusion of tholeiitic basalt may reflect accelerated thinning and subsidence of the underlying crust.

In the upper Robertson River Formation, the abundance of siltstone and mudstone, which are commonly carbonaceous and laminated, suggests continuation of deep subtidal conditions during deposition of this unit. Internal slumping and contortion of bedding are common, and indicate that the sediments were deposited rapidly and retained a high water content. Fine sandstone containing mudclasts and small-scale trough cross-bedding are present towards the top of the unit and may reflect the shallowing evident in the overlying units.

The basal Townley Formation consists predominantly of non-carbonaceous silty to fine sandy rocks, and may represent progradation of shallower water sediments. The sequence from the middle of the Townley Formation to the top of the Candlow Formation consists of alternating variably carbonaceous mudstone, siltstone, siliceous siltstone and lithic sandstone. Different proportions of these basic lithologies characterise the various units. A feature of the sequence is the fine grainsize of the sediment supplied to the basin; in fact this characterises all the Etheridge Group above the Dead Horse Metabasalt Member. The sandy rocks are actually composed of mudclasts in a silty matrix (see p 32) and sand-sized quartz or feldspar grains are not abundant; the primary sediment supply was therefore mainly clay and silt.

Lithic (mudclast) sandstone occurs abundantly in the upper Townley Formation, Heliman Formation, White Bull Member, and parts of the upper Candlow Formation. These sandstones are probably shallow-water deposits; mud and silt deposited during quiet intervals were reworked by strong currents and/or wave action. The mud was relatively cohesive, and tended to form mudclasts in contrast to the silt, which was generally redeposited as matrix to the mudclasts. The sandy units locally contain interbeds on siliceous siltstone, some of which contains silt clasts; the silt clasts are almost invariably carbonaceous, suggesting that their cohesiveness may have been due to an algal binding. Algal or bacterial mats could have developed on, and binded the surface of silt deposits in the shallow-water conditions that prevailed.

Slumping and distorted bedding attest to the rapid deposition of the sandy units; these structures, together with sandstone dykes, are particularly common in the upper Townley Formation.

Short periods of intertidal to supratidal conditions are indicated by the presence of gypsum moulds and of possible stromatolites in parts of the lower and upper Candlow Formation respectively.

Quieter or slightly deeper-water conditions may have prevailed periodically such as during the deposition of the mudstones of the middle Heliman Formation, the upper half of the middle Candlow Formation, the Stockyard

Creek Mudstone Member, and the Langdon River Mudstone. Pyritic carbonaceous mudstone characterises all but the first of these intervals, and mudclast sandstones are absent. It is uncertain whether the units represent deposition under truly euxinic conditions, or whether they simply reflect a richer supply of organic matter relative to detrital material than in other mudstone intervals in the Etheridge Group. Rapid burial or a zero Eh surface near the sediment/water interface could preserve the organic matter. Alternatively, the carbonaceous intervals could represent shallow water, favouring an abundance of in situ algae and bacteria, which bound the sediments and made them resistent to reworking.

The relationship between the area of deposition of these sediments and the palaeo-shoreline is uncertain. The lithological uniformity and continuity of thin units over a large distance (more than 100 km allowing for shortening by folding) suggests that uniform sedimentary environments existed over extensive areas. Such environmental uniformity might be expected in an open-sea environment, but may be difficult to reconcile with a near-shore region where barriers, lagoons, and distributary channels would give rise to a greater lateral heterogeneity of facies. There is little evidence of scouring or channel development in the upper Etheridge Group. The lack of terrigenous sand might also suggest an environment far removed from a shoreline. However, it is possible that the rivers for some reason carried mainly silt and clay. A copious supply of silt and clay relative to sand could have resulted in insignificant development of barriers. Tidal currents would therefore be little restricted and tend to move over the region as a broad uniform flow with little tendency to form channels. Such a situation occurs at present in the Colorado River delta in the Gulf of California (Thompson, 1968, 1975). Strong tidal currents and storm surges moving over the shallow tidal flats could rework algal bound silt and mud to form the mudclast sandstones. The carbonaceous, predominantly muddy units could represent deposition in slightly deeper water farther offshore.

In an open-sea environment, the various lithologies would reflect fluctuations in water depth due to variations in rates of subsidence and sedimentation, or to sea level changes. Shoaling would bring the sediments within the influence of storm waves, wind-driven currents etc., resulting in reworking as described above; extreme shoaling may have brought about local emergence. The type of situation envisaged is similar to that in an epeiric sea. Restricted circulation could result in hypersaline conditions favourable for the formation of evaporites in emergent areas, and in density stratification leading to euxinic conditions favourable for the deposition of black shales in deeper water.

There is little evidence at present to indicate the orientation of the shoreline and configuration of the basin in which the sediments were deposited. A general north-south continuity of facies is apparent, but it is not known whether they are time-transgressive facies parallel to a north-trending shoreline, or whether they are time-conformable and the north-south distribution is due solely to the general westward plunge of the folds. Time-conformable facies would more likely be the result of deposition in open-sea conditions.

LANGLOVALE GROUP

Introduction

As noted above, our field work has shown the existence of a major unconformity within the 'Langdon River Formation' as mapped by White (1962b, 1965). Predominantly pelitic rocks below the unconformity are assigned to the Langdon River Mudstone; the rocks above the unconformity, including some in the upper Langdon River catchment area previously mapped as 'Etheridge Formation', have been divided into two units, the Malacura Sandstone and Yarman Formation. Withnall & Mackenzie (1980) defined the two units, and excluded them from the Etheridge Group, but did not assign them to any other group. It is now considered that erection of a group to incorporate the two units is warranted. The name 'Langlovale Group' and its definition have been approved by the Queensland Stratigraphic Nomenclature Subcommittee, and will be published in due course.

The underlying Etheridge Group was strongly deformed and metamorphosed by an event dated at 1570 $\pm$ 20 m.y. (Black & others, 1979), which does not affect, and hence predates, the Langlovale Group. The first folding event that appears to have affected the Langlovale Group is correlated with an event in the Robertson River Formation in the western edge of FORSAYTH dated at 1469 $\pm$ 20 m.y. (Black & others, 1979). The unconformably overlying Croydon Volcanics give an imprecise Rb-Sr whole-rock date of 1429 $\pm$ 75 m.y. (Black, 1973); a more precise Rb-Sr muscovite age of 1475 m.y. was determined by Black (1973) for the Esmeralda Granite, which is comagmatic with the Croydon Volcanics, and intrudes the Langlovale Group. The Langlovale Group is therefore mid-Proterozoic in age (probably between 1470 and 1570 m.y)

Malacura Sandstone

(Map symbol Bm)

Nomenclature

Withnall & Mackenzie (1980) defined the Malacura Sandstone, which was formerly included in the 'Langdon River Formation' (White, 1959, 1962b, 1965; see Introduction, p 39).

Distribution

The Malacura Sandstone is exposed along most of the valley of the Langdon River, most extensively in the western upper reaches of the river; small outliers crop out north of the Gilbert River, near Forest Home homestead.

Topography and airphoto characteristics

The unit generally forms very subdued topography, except where it is hornfelsed, and has a medium cover of low scrub. It is characterised on airphotos by prominent trend lines and pale yellowish-brown to reddish-brown tones.

Type section

The type section is along an unnamed tributary of the upper Langdon River between GR 093228 and GR 084218, and thence along a small tributary of that stream to GR 077214 (ESMERALDA).

Thickness

The formation is 1300 to 1450 m thick in the general area of the type section; the thickness in the north is unknown because the top and base of the formation are obscured, and the structure is uncertain.

General lithology

The Malacura Sandstone is composed of fine to very coarse, commonly micaceous, lithofeldspathic and feldspatholithic sandstone and sandy siltstone; dark grey siltstone or mudstone is also present in the south, but rocks finer than sandstone appear to be scarce in the north.

Detailed lithology

The lowermost 100 m of the type section consists of medium to very thick-bedded, medium to coarse feldspathic sublabile sandstone, and feldspathic and lithic sandstones. Angular to rounded mudclasts, and fragments of Etheridge Group rocks are present, and large detrital mica flakes are common. Sedimentary structures include planar and cross-laminae (small to medium-scale trough cosets), current lineations, load casts, small-scale ripples, and rill-like marks.

The remainder of the section consists of thinner-bedded, mainly finer sandstone, and contains an upwardly increasing proportion of siltstone and mudstone. The mudstone and siltstone are commonly dark grey or black (carbonaceous), and are pyritic in places. Thick-bedded, very coarse sandstone is present locally. The most common rock type is poorly sorted lithofeldspathic sandstone, which contains angular to subrounded clasts of quartz, feldspar (mainly plagioclase), siliceous siltstone, minor mudstone, and detrital muscovite and biotite; the coarse sandstones also contain microcline and metaquartzite clasts. The sandstones are rarely cemented, and appear to have been lithified mainly by compaction. Sedimentary structures include planar and cross-laminae, load casts, thickening and thinning of sandstone beds, linguoid and undulatory ripple-marks, lensoid and wavy bedding, and large (generally 0.5 to 5 cm, and locally up to 10 cm) angular and rounded mudclasts. The mudclasts are commonly concentrated in thin beds. Cross-laminae are present as cosets, and are of small to medium scale, with trough-bounded bases. Some beds near the top of the unit are massive at the base, become increasingly well laminated upwards, and are capped by ripple marks. Many of the mudclast-bearing sandstone beds have erosive bases. The few measurements taken indicate current flow to the north.

The Malacura Sandstone in the northern part of the area consists predominantly of fine to medium, poorly sorted feldspatholithic and lithic sandstones similar to those in the type area; a calcareous cement was observed in a few localities, but generally the rocks have no obvious cement. Most specimens examined in thin section contain abundant metamorphic biotite, as well as detrital mica; the metamorphic biotite forms small (0.01 to 0.02 mm) randomly orientated flakes that rim and replace lithic clasts and some feldspar. Some of these specimens were collected near exposed bodies of Esmeralda Granite, but it is possible that much of the northern outcrop area is underlain at shallow depth by Esmeralda Granite and possibly Forest Home Granodiorite. Detrital mica, lying parallel to the bedding, is so abundant locally that the rocks have a schistose appearance. Mudstone is apparently less common in the north, but this may be a function of the poor outcrop and possible selective erosion of the relatively soft mudstone.

Provenance and depositional environment

The poor sorting and range of grainsizes, and the abundance of coarse detrital mica, feldspar, and lithic fragments in the sandstones indicate a high degree of immaturity and a relative proximity to source. The presence of mudclast conglomerates and erosive contacts indicates channel activity; fluvial processes appear to have been important, particularly in the lower part of the unit.

In the uppermost part, the dominance of lensoid and wavy bedding, and the greater mudstone content of the upper part of the formation suggest shallow subtidal, lower energy, marine conditions, and deepening water.

The abundant siliceous siltstone clasts suggests that the Etheridge Group was a source for some of the sediment. However, the abundant quartz, plagioclase, detrital mica, and, locally, microcline and metaquartzite, indicate that a plutonic/metamorphic terrain was also an important source. Most of the granitoids now exposed to the east were not emplaced until during or after D_2, that is, after the deposition of the Langlovale Group, so it is possible that the source was in older rocks to the south or west, under the Eromanga Basin sediments. High-grade metamorphic rocks (possibly metamorphosed acid volcanics) were intersected in the bottom of the Lily Bore near Prospect homestead, south of Croydon (Ford, Bacon, & Davis Inc., 1972); the exposed Etheridge Group rocks decrease in metamorphic grade westwards, so these high-grade rocks may represent older basement terrain, uplifted and rejuvenated during D_1.

Relationships and age

The Malacura Sandstone unconformably overlies the Candlow Formation and Langdon River Mudstone of the Etheridge Group, and is conformably overlain by the Yarman Formation. The Proterozoic Croydon Volcanics, the Mesozoic Eulo Queen Group and Gilbert River Formation, and various Cainozoic sediments overlie the unit unconformably. It is intruded by the Esmeralda Granite.

Its age is probably Middle Proterozoic, as discussed under 'Introduction' (p 39).

Yarman Formation
(Map symbol Ey)

Nomenclature

Withnall & Mackenzie (1980) defined the Yarman Formation, which was formerly included in the 'Etheridge Formation'and 'Langdon River Formation' (White, 1959, 1962b, 1965; see Introduction, p 39).

Distribution

The Yarman Formation is exposed in a roughly triangular area in the upper Langdon River catchment area, with extremitites at GR 056237, GR 077227 and GR 167189 (ESMERALDA), and in a small area near Langlovale outstation, centred on GR 075542 (GILBERT RIVER).

Topography and airphoto characteristics

The Yarman Formation is characterised by steep but rounded hills, generally with sporadic, prominently outcropping sandstone beds. It displays a red-brown tone on the airphotos, and has a stunted vegetation cover.

Type section and thickness

The type section is along an unnamed tributary of the upper Langdon River, southeast of Snake Creek, between GR 066234 and GR 056219 (ESMERALDA). This section is at least 1800 m thick, but the top is not exposed.

General lithology

The Yarman Formation consists mainly of dark grey, laminated, thin-bedded or massive mudstone, siltstone, and shale, which generally weather to maroon or reddish brown; fine to medium micaceous sublithic and feldspatholithic sandstone in beds generally less than 1 m thick are distributed through the unit, and amount to between 5 and 10 percent of its total thickness.

Detailed lithology

The basal part of the Yarman Formation overlying the type section of the Malacura Sandstone consists of about 300 m of maroon mudstone containing groups of two or three thin, fine micaceous sandstone beds; the upper parts of the sandstone beds contain planar laminations overlain by ripple cross-laminae, and have poorly preserved ripple marks on their upper surfaces.

Above this sequence, sandstone beds become progressively thicker, and the quantity of interbedded mudstone becomes progressively less. Associated with the thickening of sandstone beds is an increase in the importance of ripple cross-laminae, which generally occupy the whole bed, and sole markings such as flute marks, lineations, and transverse scour marks become more evident; palaeocurrent directions indicated by these structures are to the north. Minor slump folds are present, but no grading or change in grainsize with varying bed thickness has been observed in the sandstone beds. The sequence is about 300 m thick.

The sandy sequence is overlain by about 200 m of maroon mudstone which contains rare, thin sandy beds. Another sandy sequence similar to that described above overlies the mudstone, and is overlain in turn by massive maroon mudstone. The upper part of the formation is obscured by poor outcrop and Mesozoic cover.

The type section of the Yarman Formation consists of dark grey to maroon (weathered) mudstone, siltstone, and shale, coarser laminated or cross-laminated siltstone, and cross-laminated or, less commonly, massive fine sublithic sandstone. Two or three sandstone beds are commonly grouped together, separated by siltstone or mudstone, and they tend to be thicker (up to 1 m) and more numerous in the middle 700 m of the section; the sandstone is commonly micaceous, and has a characteristic salt-and-pepper texture when weathered. Specimens of typical sandstone from the type section are fine-grained, well sorted, matrix-poor, and quartzose. They consist of subangular to subrounded quartz grains (80-85%), fragments of fine-grained sericitic and/or quartzose rocks (about 10%), grains of amorphous hydrated(?) iron oxides (3%), small amounts of muscovite, plagioclase, and sericitic matrix, and a trace of zircon. Siltstone is more common in the lowermost 300 m of the section, and is generally finely interbedded with mudstone, sandstone, and shale. A typical siltstone from the lower part of the sequence consists largely of subangular quartz fragments (80%) and muscovite flakes (5%), with minor shale and quartzose mudstone clasts, iron oxides (after pyrite?), and rare plagioclase and tourmaline. The uppermost 200 m of the section consists of mudstone and lesser siltstone.

Environment of deposition

The Yarman Formation as a whole appears to have been the result of mainly quiet water deposition, disturbed by progradation of at least two sandy intervals and occasional minor influxes of sand. The sequence superficially resembles a classic distal turbidite, with progradation of more proximal deposits. Characteristics of distal turbidites found in the thinner sandstone beds of the Yarman Formation are : (a) the generally thin nature and lack of amalgamation of the sandstone beds; (b) common laminations and ripples; (c) parallel-sided regular beds; (d) fine grainsize; (e) lack of scours and channels; and (f) well-developed mudstone layers. The thinner sandstone beds commonly contain planar laminae which pass upwards into ripple cross-laminae; these are the B and C diversions of the Bouma Sequence (Bouma, 1962), and are characteristic of more distal environments (Walker, 1967). Thus, apart from the thicker sandstone intervals, the Yarman Formation resembles marine shales with intercalations of distal turbidites.

If the intervals of thicker sandstone beds represent more proximal turbidite deposits, the beds should contain flute marks or other scour features on their bases, and internal structures indicating higher energy than in the distal deposits; the A, B, and C (or at least B and C) divisions of the Bouma Sequences should be present. In the Yarman Formation, although the thicker beds have scour marks at their bases, ripple cross-laminae are the only internal structures (division C of the Bouma Sequence), and are similar to types attributed to ocean-current reworking of turbidites by Walker (1967). The progradation therefore seems to be related to non-turbidity current activity.

Some of the features of the Yarman Formation could have been produced in a prodeltaic environment; the occasional thin sandstone beds could represent delta-derived sand deposited in marine muds by either normal currents, turbidity currents, or a combination of these. As the delta prograded, the sandstone beds would become thicker and current(flood?)-deposited sandstone more common. Switching of delta lobes would produce a return to open marine conditions, and the deposition of mudstone.

Sandstone in the Yarman Formation is generally finer-grained and more mature than that in the Malacura Sandstone, but the same types of clasts are present. Remarks made concerning the provenance of the Malacura Sandstone therefore probably also apply to sandstone in the Yarman Formation.

Relationships and age

The Yarman Formation conformably overlies the Malacura Sandstone, and is unconformably overlain by the Proterozoic Croydon Volcanics and Mesozoic Eulo Queen Group. It is intruded by rhyolite plugs and dykes related to the Croydon Volcanics. The age is probably Middle Proterozoic (as discussed on p.39).

CROYDON VOLCANICS

The Croydon Volcanics crop out along the western edge of the North Head-Forest Home area where they are faulted against or unconformably overlie the Langlovale Group and Etheridge Group. They were not examined in detail during this survey, and consequently no detailed description is given here.

The unit consists predominantly of rhyolitic ignimbrite, with some dacitic ignimbrite, rhyolitic to dacitic lava and agglomerate, and minor intermediate to basic volcanics. It was previously described by Branch (1966) and Sheraton & Labonne (1978). The Esmeralda Granite intrudes the Croydon Volcanics and is thought to be comagmatic with them.

In 1980, a joint BMR-GSQ party mapped ESMERALDA, GILBERT RIVER, and CROYDON. As a result, the Croydon Volcanics have been subdivided into seven main units, and the Esmeralda Granite into eight main units, all of which will be given formation status. Brief descriptions of the volcanic units are given by Mackenzie (*in* Oversby & others, 1981).

An imprecise Rb-Sr whole-rock age of 1429 ± 75 m.y. for the Croydon Volcanics was obtained by Black (1973).

METAMORPHISM

ETHERIDGE GROUP

Introduction

Winkler (1974) proposed four divisions of metamorphism: very low, low, medium, and high-grade. However, the facies terms 'greenschist' and 'amphibolite' (Turner & Verhoogen, 1960; Winkler, 1967) are still widely used in the literature; we use these terms subdivided into upper and lower greenschist, and upper, middle, and lower amphibolite facies to be consistent with earlier reports on the Georgetown region (Bain & others, 1976; Oversby & others, 1978; Withnall & others, 1980b). The boundaries of the five subdivisions, which are based on the appearance or disappearance of certain key minerals, are not always easily located. Therefore, three major categories are used in the following discussion: greenschist facies, lower to middle amphibolite facies, and upper amphibolite facies. These, in fact, correspond to Winkler's low, medium, and high-grade zones. Figure 6 shows the distribution of the metamorphic zones in the North Head-Forest Home area.

Greenschist facies

The rocks of this zone can be divided into lower and upper parts by the biotite isograd (Fig. 6). The most common metasedimentary assemblage in the lower greenschist facies is quartz+muscovite+chlorite. Basic igneous rocks of this facies contain various proportions of actinolite, chlorite, albite, epidote, calcite, sphene and opaque oxides; the two most common assemblages are actinolite+albite+epidote or chlorite+calicite+albite.

Lower greenschist facies rocks are restricted to the southern part of NORTH HEAD. The appearance of syn-D_1 biotite in the metasedimentary rocks (the biotite isograd), coincides approximately with the appearance of hornblende in metabasic rocks, and is at a higher grade than in some other terrains. This is probably due to the absence of K-feldspar; the reaction of chlorite with phengitic muscovite to produce biotite takes place at a higher temperature than that between chlorite and K-feldspar. Withnall & others (1980b) suggested that the biotite isograd in GILBERTON is slightly above the hornblende isograd. However, this suggestion was based on few data, and for the purposes of this reconnaissance study, the two isograds are assumed to be approximately coincident (see Fig. 6).

At somewhat higher grades, oligoclase replaces albite in the metabasic rocks; epidote and chlorite persist in these rocks until the beginning of the amphibolite facies, where the plagioclase is of andesine composition.

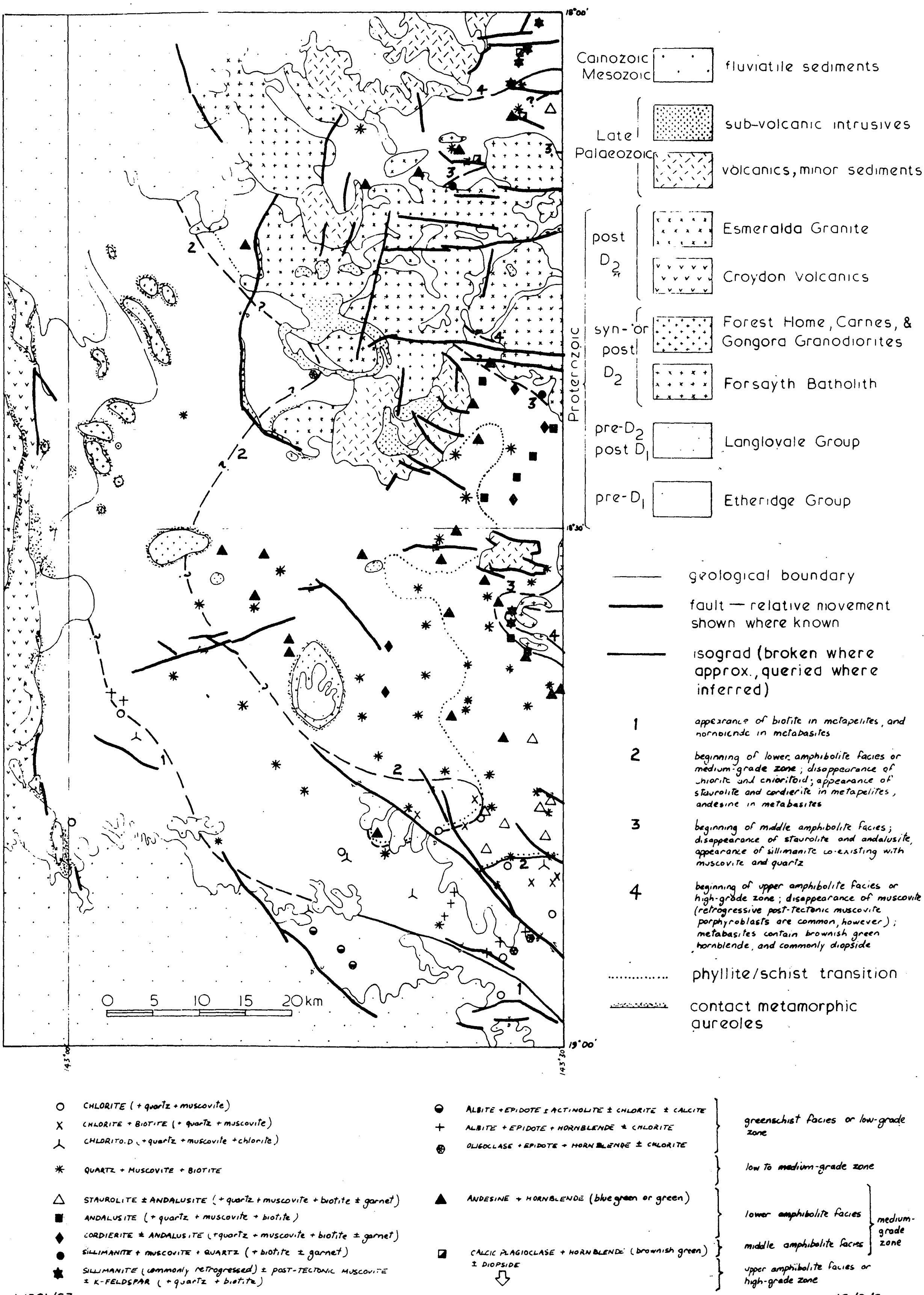
The foliation in most of the metasedimentary rocks in the area in which the biotite isograd lies is S_1; the isograd therefore indicates the extent of the biotite zone during D_1. S_2 is generally not developed, or, at best, is a differentiated crenulation cleavage with little or no growth of syn-D_2 minerals. Consequently, we do not know if the extent of the syn-D_2 biotite zone is significantly different from that of D_1.

Chloritoid occurs in rocks of both the lower and upper greenschist facies; however, its occurrence is restricted mainly to a narrow stratigraphic zone near the top of the lower Robertson River Formation. It has also been identified in the Langdon River Mudstone. These rocks presumably fulfil the peculiar bulk rock composition requirements of chloritoid, namely high Al_2O_3 combined with high FeO/MgO. Chloritoid postdates the main foliation, S_1, but whether it formed pre or syn-D_2 is uncertain.

As noted above (p 30), the Candlow Formation, in particular the middle subunit and Stockyard Creek Mudstone Member, which are the most pyritic parts, is characterised by a line of magnetic anomalies following the strike of the unit northwards from about White Bull Bore (BMR, 1975). This is possibly due to conversion of some of the pyrite to pyrrhotite with a rise in metamorphic grade. South of White Bull Bore, the unit has little magnetic response, which is consistent with an almost total absence of pyrrhotite in drill core from the Candlow area. The increase in magnetic intensity occurs just above the biotite isograd. Carpenter (1974) reported that in the Barrovian-type metamorphic rocks of the Blue Ridge province of Tennessee and North Carolina, pyrite gives way to pyrrhotite just below the biotite isograd. Pyrrhotite is the most common sulphide in the Heliman Formation; it is uncertain whether this is the result of metamorphic modification of pyrite, or whether pyrrhotite is the primary sulphide in these rocks.

Lower to middle amphibolite facies

The lower and middle amphibolite facies can generally be separated by the sillimanite isograd; however, as this isograd is difficult to locate in the North Head-Forest Home area (see below), the rocks are assigned to a single zone.



Record 1981/63 16/Q/9

Figure 6 : Metamorphic mineral assemblages and isograds in the North Head—Forest Home area.

Lower amphibolite facies metasedimentary rocks can be identified by the presence of porphyroblastic staurolite and andalusite. Cordierite is also present, but, because it also occurs in higher-grade rocks, it is diagnostic of the amphibolite facies in general, rather than just the lower part. Staurolite is mostly restricted to the same stratigraphic level as chloritoid, and in some rocks may have formed by the breakdown of chloritoid. Chloritoid and staurolite have not been observed together, so the presence of chloritoid is taken to indicate the greenschist facies.

Staurolite, andalusite, and cordierite form porphyroblasts in metasedimentary rocks, and in most cases are clearly syn-D_2; muscovite and biotite also grew in these rocks during this event. Syn-D_1 minerals in the metasedimentary rocks at this grade are quartz, muscovite, and biotite, which are not particularly diagnostic of grade. Therefore, the boundary of the amphibolite facies during D_1 (or during D_2 in rocks lacking porphyroblastic minerals) is difficult to place. The absence of syntectonic chlorite may be taken as a guide, but it is not very reliable; if chlorite is present with biotite, it could be either prograde, or a retrogression product of biotite.

In the metabasic rocks, the appearance of andesine and the absence of epidote and chlorite mark the beginning of the amphibolite facies. However, in this area the basic rocks, particularly the metadolerite and metagabbro, rarely develop a tectonic fabric at low to medium grades, so it is not known when the hornblende formed in relation to the deformation. The greenschist/amphibolite boundary based on metabasic assemblages could therefore be either syn-D_1 or syn-D_2.

Calc-silicate rocks formed at this grade contain tremolite, diopside and garnet. Clinozoisite coexisting with quartz also persists well into the amphibolite facies.

Middle amphibolite facies rocks are difficult to identify. Staurolite and andalusite are not present, but because their presence is compositionally controlled, their absence need not be indicative of grade. Sillimanite (or its alteration products) coexisting with muscovite is indicative of middle amphibolite facies rocks, but it is rarely observed in the North Head-Forest Home region; this may be because the rocks are not sufficiently aluminous. In Sheet areas to the east, sillimanite is usually inconspicous and difficult to identify in hand specimen, and the sillimanite zone appears to be relatively narrow. In the metabasic rocks, hornblende changes colour progressively with increasing grade, from blue-green to green in the medium-grade zone, and finally to olive or brownish green in higher-grade rocks. Diopside is apparently restricted to upper amphibolite facies metabasic rocks in GEORGETOWN (Oversby & others, 1978). However, in the Forest Home-North Head region, diopside occurs in metadolerite associated with middle amphibolite facies metapelites; its presence is probably controlled by bulk rock composition as well as by metamorphic grade.

The boundary between the 'phyllite facies' and 'schist facies' of the metasedimentary rocks is above the greenschist/amphibolite facies boundary. The phyllite/schist boundary in most areas is actually a transition zone ranging from less than a kilometre wide in the Malcolm Creek area to several kilometres wide. The precise distinction between phyllite and fine schist is rather subjective, and the position of the boundary between them is subject to individual interpretation; it is further complicated by the fact that abundant carbon appears to inhibit recrystallisation, so that carbonaceous phyllite may be interbedded with non-carbonaceous schist. For this reason, the phyllite/schist boundary north of Malcolm Creek coincides with the boundary between the non-carbonaceous lower subunit and carbonaceous upper subunit of the Robertson River Formation. The phyllite/schist boundary therefore reflects different metamorphic grades in different rock types. Because the boundary passes mainly through rocks in which the dominant foliation is S_1, it mostly reflects the metamorphic grade during D_1; the main exception is in the area east of the Agate and Cobbold Creeks/Robertson River junctions where S_1 is commonly completely obliterated by overprinting of an S_2 schistosity.

Upper amphibolite facies

The upper amphibolite facies metasedimentary rocks are recognised by the absence of syn-tectonic muscovite; muscovite has reacted with quartz to form sillimanite and K-feldspar. However, in most rocks the reaction appears to have subsequently reversed, and muscovite has formed retrogressively as large porphyroblasts cutting across the foliation.

Hornblende in the metabasic rocks of this grade is olive or brownish green, and plagioclase is of labradorite composition.

Figure 6 shows that upper amphibolite facies rocks are restricted to the Ironhurst area, and around Mount Glenrowan. Metamorphic screens within the Forsayth Batholith in the Mount Turner area are probably also of this grade; abundant muscovite is present in these rocks, some of it at least being retrogressive after sillimanite. Migmatite is present locally in the Ironhurst area.

Isograds

Tentative isograds and metamorphic facies boundaries are shown in Figure 6. Some of the difficulties in determining the positions of the isograds have been outlined above. Additional problems include lack of rocks of suitable composition, and unavailability of material for petrographic study because of deep weathering or inadequeate sampling.

The position of the biotite isograd in the western part of NORTH HEAD is now well known. Few diagnostic specimens were collected from the low-grade side of the isograd. Metadolerite between the Carnes and Gongora Granodiorite plutons contains andesine and hornblende (indicative of the amphibolite facies); however, because no metadolerite crops out farther west, and the metasedimentary rocks there contain non-diagnostic assemblages, the precise westward limit of the amphibolite facies is not known. The tentative limit shown in Figure 6 is based on the degree of recrystallisation in the metasedimentary rocks compared with that in rocks in areas where the boundary position is well controlled.

Few specimens from the western part of FOREST HOME were collected and studied petrographically, but any specimens from this area would be unlikely to contain diagnostic minerals. The limit of the amphibolite facies is inferred mainly from the position of the phyllite/schist transition; a metadolerite sample collected from southeast of Prestwood homestead at GR 382692 is probably transitional between the greenschist and amphibolite facies.

Relationships between metamorphism and granitoid emplacement

In the Glenrowan area, the extent of upper amphibolite facies rocks seems to be closely related to the distribution of the Ropewalk Granite, and the relatively narrow zone of middle amphibolite facies rocks compared with that in FORSAYTH (Bain & others, 1976, figure 28) indicates a steeper geothermal gradient. These two facts suggest that the grade of metamorphism has been influenced by the intrusion of the Ropewalk Granite. Furthermore, the phyllite/schist boundary swings westward in the Mount McDonald area, parallel to the upper amphibolite facies boundary. As the phyllite/schist boundary is based on the size of minerals defining S_1, it suggests that the upper amphibolite facies boundary and the Ropewalk Granite are both related to D_1.

The largest granite bodies of the Forsayth Batholith are restricted to the medium and high-grade areas, and there is a general increase in grade towards the batholith. However, in detail the batholith cuts across isograds, and in the western part of the batholith the country rocks are probably transitional between greenschist and amphibolite facies; a narrow contact aureole flanks the batholith in the area north of Green Hills outstation. The Forsayth Granite also appears to cut across D_2 folds outlined by metadolerite. These facts are consistent with a late or post-D_2 age of emplacement of the granitoids; it is possible, however, that the granitoids were generated at a deeper level in the crust during metamorphism accompanying D_1 or D_2.

Plutons of Gongora, Carnes, and Forest Home Granodiorites are all surrounded by distinct contact aureoles. The aureoles around Forest Home Granodiorite plutons contain mostly fine-grained andalusite hornfels. However, an increase in the size of the syn-tectonic micas in the aureole of the Carnes Granodiorite suggests that this pluton may have been emplaced syn-tectonically, probably during either D_2 or late D_1. The three granodiorite units are petrographically similar, and may be similar in age; they are not foliated, and some plutons truncate D_1 folds.

Contact aureoles containing andalusite hornfels also surround the Esmeralda Granite where it intrudes Etheridge and Langlovale Group rocks. The granite also intrudes Croydon Volcanics, which unconformably overlies the Langlovale Group. These relationships, together with the isotopic ages (Black, 1973) suggest that the Esmeralda Granite was emplaced after D_2, probably about 1450 m.y.

Pressure-temperature conditions

Pressure conditions during metamorphism were intermediate between those in the classic low-pressure (Abukuma/Buchan) and medium-pressure (Barrovian) facies series. The persistence of clinozoisite coexisting with quartz well into the amphibolite facies, the presence of garnet in lower amphibolite facies metabasic rocks, and the presence of albite rather than oligoclase in metabasic rocks in which actinolite has changed to hornblende, are features of medium-pressure metamorphic terrains. However, the existence of andalusite and cordierite is characteristic of low-pressure terrains. Detailed studies of the metamorphic rocks in the area around Malcolm Creek and Tin Hill by Rubenach & others (1977; personal communication), indicate that the isograd reactions and zonal sequences are similar to those in the Stonehaven area of Scotland; Harte (1975) proposed a separate facies series, the Stonehavian, which was intermediate in pressure between the Buchan and Barrovian facies series.

It was suggested by Withnall & others (1980a), that the relative abundance of cordierite and absence of staurolite in the Western Creek area reflected a Buchan rather than Stonehavian type of metamorphism. However, we now consider that bulk rock composition is the main factor that controls the formation of staurolite or cordierite. The rocks in the Western Creek area are stratigraphically higher within the Robertson River Formation, and are compositionally distinct from those to the south in the Malcolm Creek/Tin Hill area. Staurolite also occurs in some rocks in the Ironhurst area farther to the north.

Oversby & others (1978) suggested temperatures of 525°C to 670°C and pressures between 3 and 4 kilobars for the beginning of the lower and upper amphibolite facies respectively.

Retrogressive metamorphism

Rocks in the northeastern corner of FOREST HOME have been affected by a low-grade retrogressive metamorphism, which had extensive effects in the adjacent GEORGETOWN area (Oversby & others, 1978, p 16, 31). Biotite and sillimanite were pseudomorphed by chlorite and by aggregates of fine-grained muscovite respectively; no new mineral fabrics were produced. Oversby & others (1978, p 16) related the retrogression to a major Silurian to Devonian thermal event which at least partially reset most K/Ar and Rb/Sr mineral ages in the Georgetown Inlier and Cape York Peninsula (Richards & others, 1966; Black, 1973; Cooper & others, 1975). We have found no additional evidence to refute this interpretation, although it is possible that some retrogression may have occurred during the D_3 event at about 1000 m.y. (Black & others, 1979).

Crosscutting chlorite flakes and local retrogression of cordierite that occur in the Western Creek area, and in places in the eastern part of NORTH HEAD were produced after the peak of the D_2 metamorphic event, or possibly during D_3 or D_4.

LANGLOVALE GROUP

The Langlovale Group has been hornfelsed by the Esmeralda Granite. An area of metamorphosed rocks between Langlovale outstation and Blackfellow yards (GR 095427) is not associated with exposed granite, but an intrusive body may be present at shallow depth.

The presence of randomly orientated biotite flakes that have replaced lithic clasts and rimmed some feldspar grains is the most common metamorphic effect recognised in the Langlovale Group. Andalusite occurs in some hornfelsed mudstone, and a granoblastic texture is developed close to contacts with granite plutons.

STRUCTURE

FOLDING

Etheridge Group

The outcrop area of the Etheridge Group has been divided into eleven structural domains for the purpose of the following discussion (Fig. 7), each domain being characterised by a particular style, orientation, or complexity of folding. However, the boundaries are arbitary, and gradations occur from one domain to another.

First generation folding (Fig. 7)

The structurally simplest areas are the Candlow and Carnes domains in the west. The structure in both domains is dominated by large westward-plunging F_1 folds which have wavelengths of between 4 and 12 km. The folds are tight, and locally overturned, with dips of strata on the fold limbs of between 70° and vertical. A well-developed axial-plane slaty cleavage is present. The axial-plane traces trend approximately westward in the Candlow domain, but the trend changes to northwest in the Carnes domain. The reason for this change of trend is not known; it may reflect a 'megafold' related to one of the later folding episodes (perhaps D_2 or D_3), or it may simply be due to an inhomogeneous stress field or a change in the direction of stress during D_1. The bending of F_1 axial-plane traces in the western part of the Candlow domain is due to later open folding (probably D_2); a north-trending crenulation cleavage is locally developed parallel to the axial plane of these younger folds.

The Townley domain, contains a large area of Townley Formation exposed in a relatively open F_1 synclinorium about 15 km wide. Numerous tight, easterly or westerly plunging parasitic folds with wavelengths of less than 1 km occur on the limbs of this structure. The small wavelength of F_1 folds in

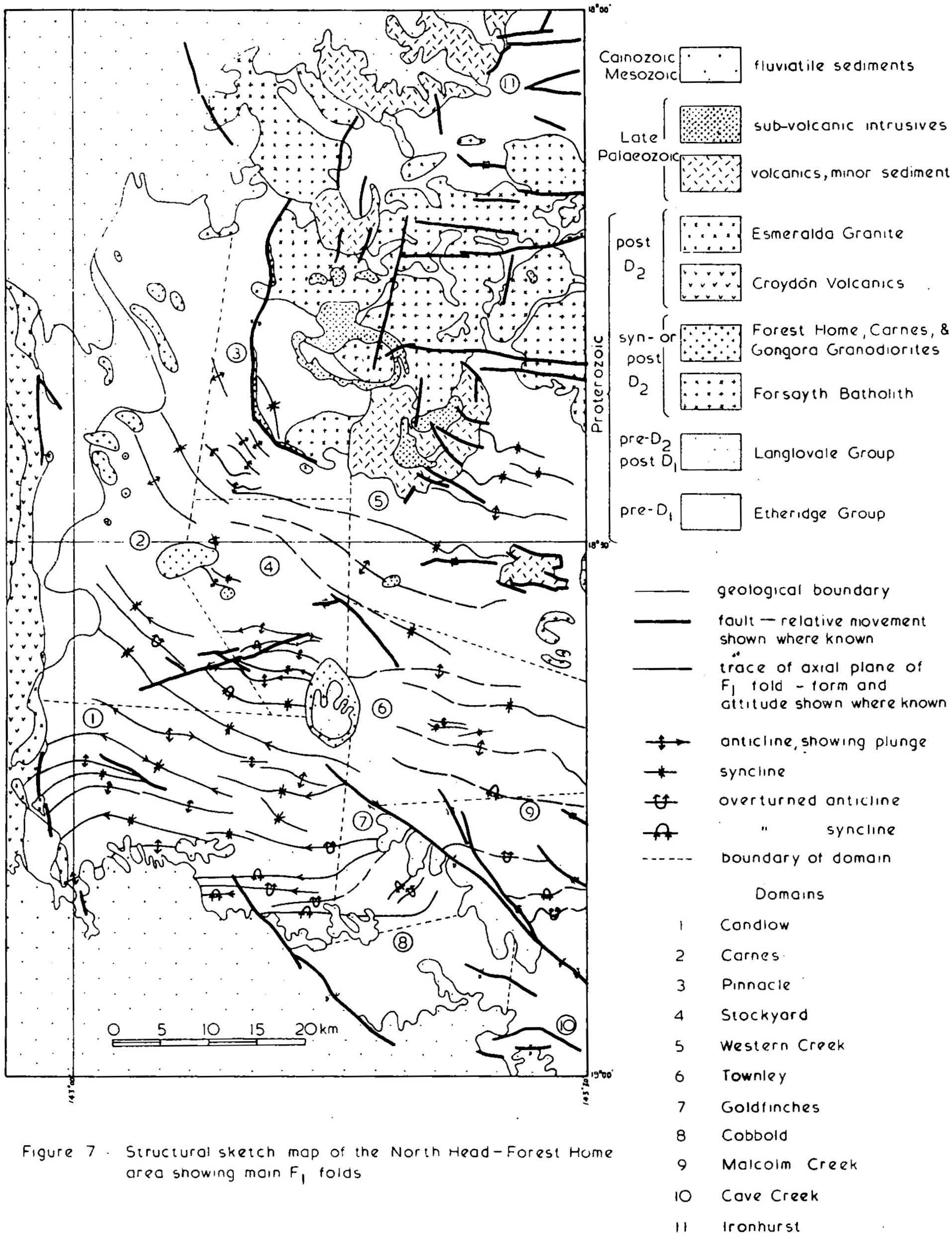


Figure 7 · Structural sketch map of the North Head – Forest Home area showing main F_1 folds this area is probably the result of contrasting competence of relatively thin alternating siliceous and non-siliceous layers that comprise the Townley Formation. Similarly, the Heliman Formation in the central western part of the Candlow domain is folded into a series of folds that have wavelengths of a kilometre or less. The Candlow Formation and Langdon River Mudstone do not contain lithologies with such contrasting competencies, and formed longer wavelength folds. This effect can be observed at outcrop scale locally in the Townley domain: beds containing laminated rocks are internally tightly folded and transposed, whereas the enveloping surfaces and adjacent more massive beds show no small-scale folding; a slaty cleavage parallel to the axial planes of small folds indicates that they are tectonic in origin and not due to soft-sediment deformation.

In the southern half of the Candlow domain and in Goldfinches domain the F_1 folds are overturned and the axial planes dip north. S_1 also dips predominantly north in the southern half of the Townley domain and adjacent part of the Malcolm Creek domain (see Fig. 16). Most of the Cobbold Creek domain in the south is occupied by a strongly overturned anticline, with an axial plane that dips north at between 10° and 40° (see poles to S_1 in Fig. 13); the rocks exposed in the domain are on the upper subhorizontal limb of the fold, on which open F_2 or F_3 folds are superimposed. Farther south in GILBERTON and BELLFIELD (Withnall & others, 1980b), the axial planes of F_1 folds again become steeper.

F_1 folds also appear to become more open and broad in the northern half of the area. In the Western Creek domain, tight F_2 folds are superimposed on more open F_1 folds. The Stockyard domain also contains a relatively open F_1 fold on which F_3, and probably some F_2 folds are superimposed. The lack of intricate interference structures in the Ironhurst domain suggests that the tight F_2 folds there are superimposed on only one limb of an F_1 fold that has a wavelength of at least 20 km (see below).

The axial-plane foliation associated with F_1 folds (S_1) ranges from a simple slaty cleavage to a schistosity depending on the metamorphic grade; the slaty cleavage is either domainal or non-domainal. The domainal cleavage consists of thin films or layers of phyllosilicates alternating with quartz-rich layers up to 0.2 mm wide that contain randomly orientated phyllosilicate flakes; in the carbonaceous rocks, carbon particles are concentrated along the phyllosilicate layers. In rocks with a non-domainal cleavage, the phyllosilicate flakes are parallel but uniformly distributed. Rocks which are either very rich in phyllosilicates or very quartzose tend to have a non-domainal cleavage, and schists are non-domainal.

Although the general plunge of F_1 folds is between 20° and 50° to the west, local reversals of plunge are common. Evidence for this can be seen in the Heliman and Townley Formations where trend-lines of resistant lithologies outline basin-and-dome structures on aerial photographs. Even where trend-lines are absent, cleavage-bedding relationships may indicate local plunge reversals; in the vicinity of the stratigraphic drillholes near Candlow (see Table 2), cleavage-bedding relationships consistently indicate the presence of an eastward-plunging fold, although regionally the folds plunge gently to the west (see Fig. 11). Plunge reversals are most common in the Townley domain where the numerous tight parasitic folds and cleavage-bedding intersections plunge both east and west (see Fig. 14). The overall plunge of the synclinorium is to the west at less than 5°.

Second generation folding (Fig. 8)

Some of the plunge reversal of F_1 folds may be due to inhomogeneous strain along the fold axes, but much of it, particularly in the Townley domain, is probably due to refolding during the D_2 event. In the Western Creek and Pinnacle Creek domains, intricate interfering fold patterns are developed by superimposition of northerly to northeasterly trending F_2 folds on westerly to northwesterly plunging F_1 folds (see Fig. 10). The F_2 folds have wavelengths of only 1 km or less, in contrast to the F_1 folds which have wavelengths of 4 to 8 km. A change in strike of axial-plane traces of overturned F_1 folds, from east in the Candlow domain to northeast in the adjacent Goldfinches domain, is probably due to refolding, but intricate interference patterns were not produced because both F_1 limbs dip in the same direction.

The F_2 folds of the Western Creek domain appear to die out southwards into the Townley domain as they pass from Robertson River Formation into Townley and Heliman Formations (see Fig. 10). This is because the rocks in the last two formations were already folded into relatively tight, short-wavelength structure as outlined above. F_2 folds are present in the Townley domain, but their main effect on the outcrop pattern is to produce basin-and-dome interference patterns elongated east-west rather than north-south.

The intensity of F_2 folding increases to the east (Fig. 8) and is generally accompanied by the development of an S_2 foliation. The nature of S_2 depends on the intensity of folding, lithology, and metamorphic grade. Where F_2 folds are weak and metamorphic grade is low, S_2 is generally a

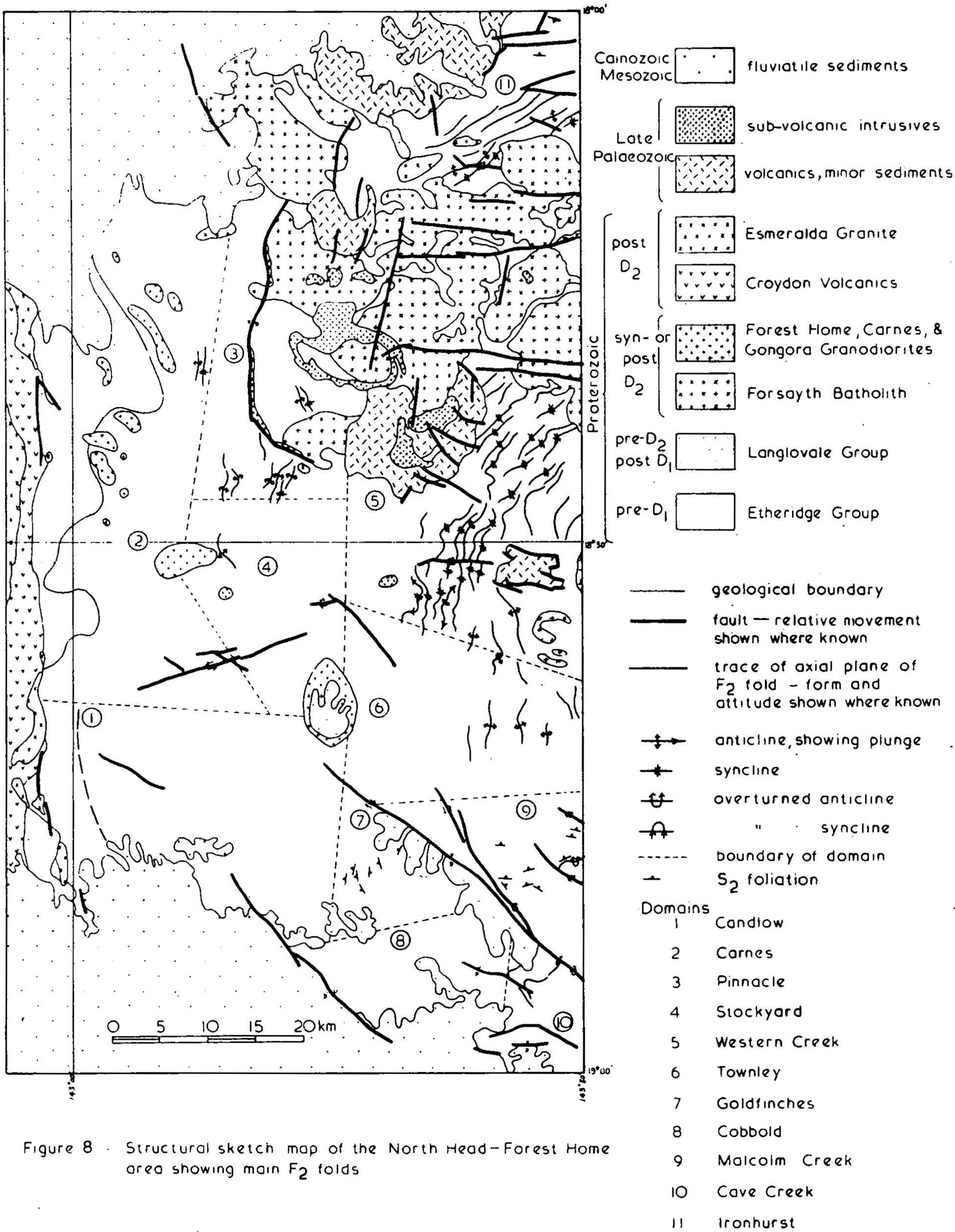


Figure 8 · Structural sketch map of the North Head-Forest Home area showing main F_2 folds simple, open crenulation cleavage. With an increase in strain, the crenulation cleavage became stronger, and differentiation into quartz-rich and mica-rich domains occurred. S_2 is strongest in the Malcolm Creek domain. In extreme cases, S_1 may be so strongly overprinted by S_2 that it is unrecognisable even in thin section. Commonly, however, S_1 micas can be seen in the quartz-rich domains between mica-rich domains in which micas are aligned in S_2. Inclusion trails in porphyroblasts preserve the earlier foliation locally, even though only the later schistosity is present in the matrix.

The control of lithology on development of S_2 is well demonstrated by outcrops of specimens consisting of alternating micaceous and quartzose beds or laminae. For example, the quartzose layers may contain only one foliation S_1, perhaps weakly crenulated, whereas in the adjacent, more micaceous layers a strongly differentiated crenulation cleavage (S_2) with entirely different orientation may obscure S_1.

Local variations in strain also caused different degrees of S_2 development in apparently similar rock types; for example, in Stake Yard Creek at GR 402190 (Goldfinches domain) outcrops of phyllitic mudstone in an area less than 50 m wide show a complete range from slightly crenulated S_1 to strongly differentiated S_2.

In the Western Creek domain, where F_1 and F_2 folds are superimposed, the foliations are commonly poorly defined. This may be due to a combination of several factors. Many of the rocks of the upper Robertson River Formation in that area were originally fine sublabile to labile sandstone; mica is less abundant and the quartz grains are larger than in the metapelites. Strain in the area during D_1 was probably not as high as elsewhere; the quartz grains are not as flattened, and the F_1 folds are not as tight as those to the south. The mica flakes, which are smaller than the quartz grains, lie along the quartz grain boundaries, and are therefore only subparallel to each other. Because the S_1 foliation was weak, and the rocks therefore lacked semi-continuous mica-rich surfaces or layers, development of crenulations during D_2 was inhibited. Any syn-D_2 micas that formed tended also to be small and their orientation to becontrolled by grain boundaries. Outcrops in the Western Creek domain therefore commonly lack any well-defined foliation apart from one or two vague parting directions; micas in some thin sections have an almost random orientation. Nevertheless, the more pelitic rocks in the Western Creek area do contain well-developed foliations; S_2, in particular, is commonly present as a differentiated crenulation cleavage.

In the Ironhurst domain, the structure is dominated by tight northeasterly trending folds with wavelengths of about 1 km. Their orientation and style suggest that they are F_2 structures. However, no intricate interference patterns are present; as noted above, this could occur if the only F_1 structure present was one limb of a very open structure with a wavelength in excess of 20 km. In many parts of the domain, only S_2 (?) is developed, although in the lower Robertson River Formation in Daniel Creek, southeast of Ironhurst homestead, two foliations can be recognised; S_1 is a schistosity, and S_2. ranges from a differentiated crenulation cleavage to a schistosity.

Third generation folding (Fig. 9)

Third generation folds (F_3) are strongest in the Malcolm Creek domain. In that domain, and in the adjacent part of FORSAYTH, F_3 folds are tight and overturned, with axial planes that dip about 40° to 50° to the north. As a result of this tight F_3 folding, poles to S_2 are confined to the southern hemisphere in Figure 16. The main fabric associated with F_3 folds is a crenulation cleavage which is generally not differentiated. West of the Malcolm Creek domain, for example in and around grid square 4826, open F_3 folds have folded the axial plane cleavage and sub-horizontal or gently-dipping limbs of overturned F_1 folds. However, where the F_1 folds are more upright, it is difficult to differentiate between F_1 and F_3 folds because their axial traces have a similar orientation. An easterly striking crenulation cleavage superimposed on S_1 in some places indicates that F_3 folding has occurred, at least on a macroscopic scale, even if larger-scale folds are difficult to recognise. In the Townley domain, some of the parasitic folds are probably F_3 structures; in the hinge zone of the synclinorium, superimposed F_1 and F_3 folds result in local gentle dips of the slaty cleavage.

In the Western Creek area (Fig. 10), F_3 folds are open structures, but are readily recognisable because they fold the north to northeast-striking axial planes of the F_2 folds, which are in turn overprinted on F_1 structures. The spread of poles to S_2 in the Western Creek domain (Fig. 15) results from the F_3 folds. On the limbs of the northwesterly trending F_1 folds in the Carnes domain, open folds which have westerly trending axial plane traces deform both S_0 and S_1. Some of the easterly and westerly plunging folds outlined by metadolerite in the Stockyard domain are also probably F_3 folds superimposed on a relatively open northwesterly trending F_1 fold. More detailed work would be needed to determine whether some of the west to west-northwesterly plunging folds near the southern edge of Carnes domain are F_3 folds or parasitic folds on the major F_1 structures.

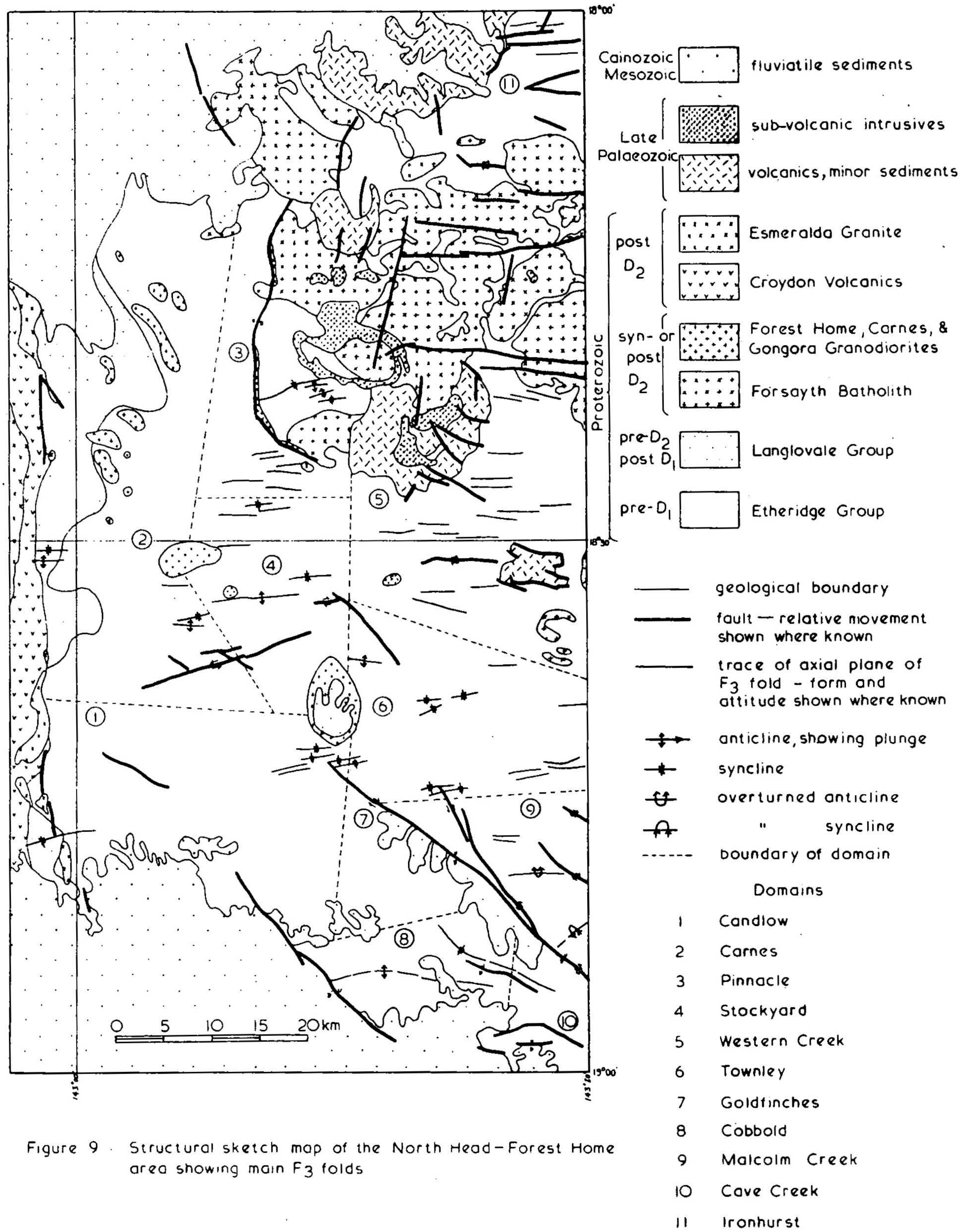
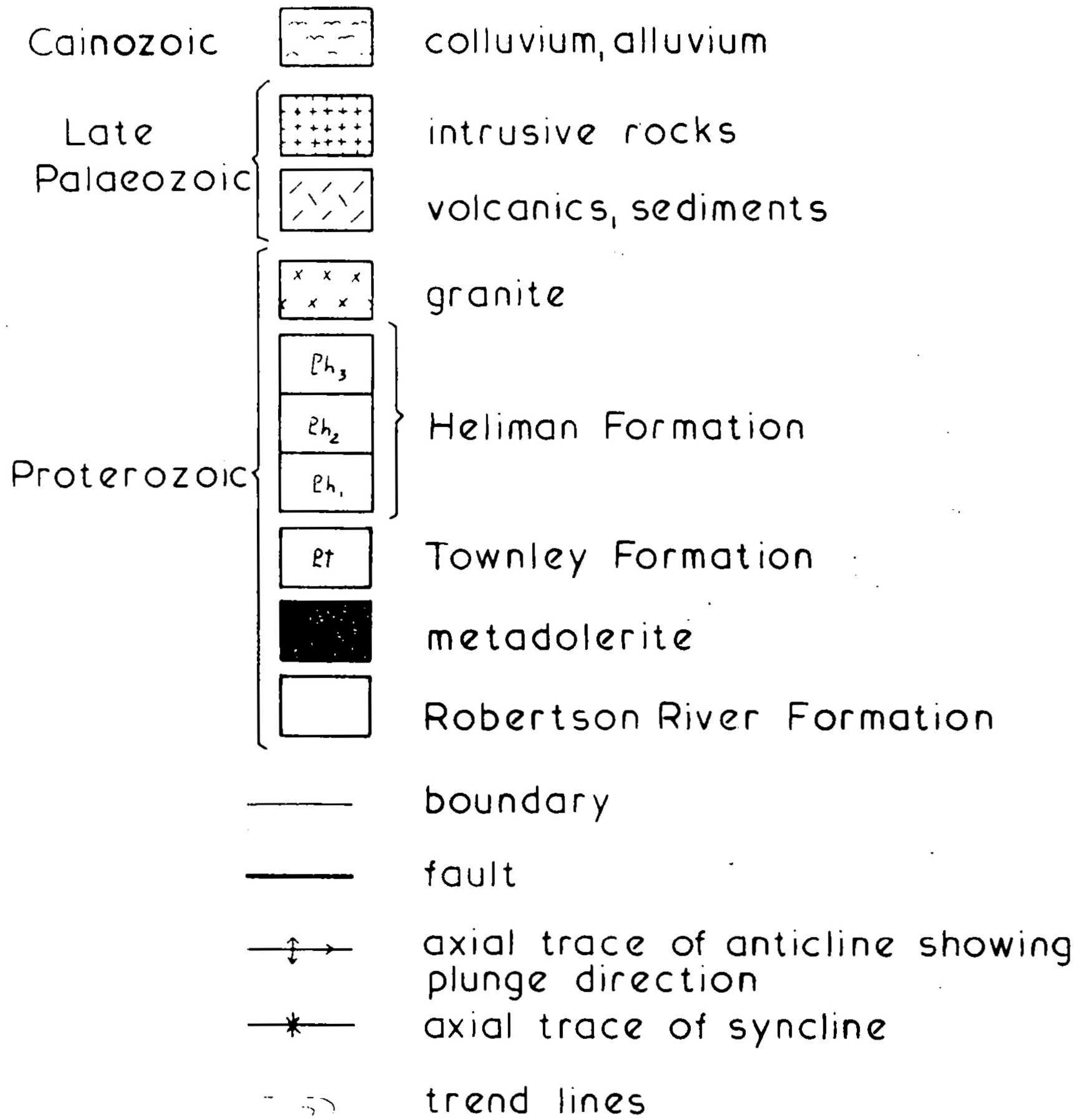


Figure 9. Structural sketch map of the North Head–Forest Home area showing main F_3 folds

Record 1981/63 Sheet 1 of 2 16/Q/13

Figure 10: Geology of the Western Creek domain showing interference fold patterns.



Record 1981/63 Sheet 2 of 2 16/Q/13

Fig 10 cont. Reference for fig 10

The intricate interference pattern in the Pinnacle domain is produced by interference of northwesterly trending F_1, north to northeasterly trending F_2, and easterly trending F_3 folds.

Later folding

Detailed work has been carried out in the Malcolm Creek domain, and adjacent parts of FORSAYTH by Fitzgerald (1974), and subsequently by T. H. Bell and M.J. Rubenach (JCUNQ)(Rubenach & others, 1977). Their studies indicate that the rocks were deformed by several later events. The D_4 event produced open, approximately northerly trending folds. Broad, very open post-D_3 folds with northerly trending axial-plane traces in FORSAYTH can probably be correlated with the D_4 event. In the North Head-Forest Home area, these folds can only be recognised in the Malcolm Creek domain, where metadolerite sills and the upper/lower Robertson River Formation boundary are deformed by folds of similar orientation and style.

Evidence for post-D_4 events is based on detailed studies of lineations by Bell and Rubenach; no larger-scale structures have been recognised. Folds of post-D_3 events, if present, are all likely to be very open structures, and could not be distinguished from open folds produced by earlier events.

Langlovale Group

The Langlovale Group was deposited unconformably on the Etheridge Group after folding by the D_1 event. The unconformable relationship is most clearly seen in the area southeast of the Snake Creek mine (near GR 080240), where westerly striking units of the Candlow Formation and Langdon River Mudstone are truncated by the northwesterly striking Langlovale Group.

Two episodes of folding are evident in the Langlovale Group. The first event produced westerly dips of between 60° and 80°, and is correlated with D_2 in the Etheridge Group. Only the eastern limb of a northerly-trending syncline is exposed. A weak, northerly trending crenulation cleavage was locally produced in phyllitic mudstone in the western part of the Etheridge Group. However, no well-developed axial-plane foliation occurs in the Langlovale Group, except for a weak fracture cleavage in some mudstone in the

Yarman Formation. Widely spaced kink bands (resembling ripple marks) that occur in coarse, micaceous sandstone in the Malacura Sandstone at GR 098683 on the Langlovale road may be related to this event.

The most obvious folds in the Langlovale Group are open structures with easterly trending axial-plane traces, and wavelengths of 2 to 10 km; they may correlate with F_3 in the Etheridge Group. The eastern edge of the Croydon Volcanics, which is probably a fault, truncates these folds south of the Snake Creek mine. Because the Croydon Volcanics are about 1450 m.y. old and D_3 has been dated at about 1000 m.y., the marginal fault may not be related to synvolcanic cauldron subsidence, but rather to a difference in competence across the fault .

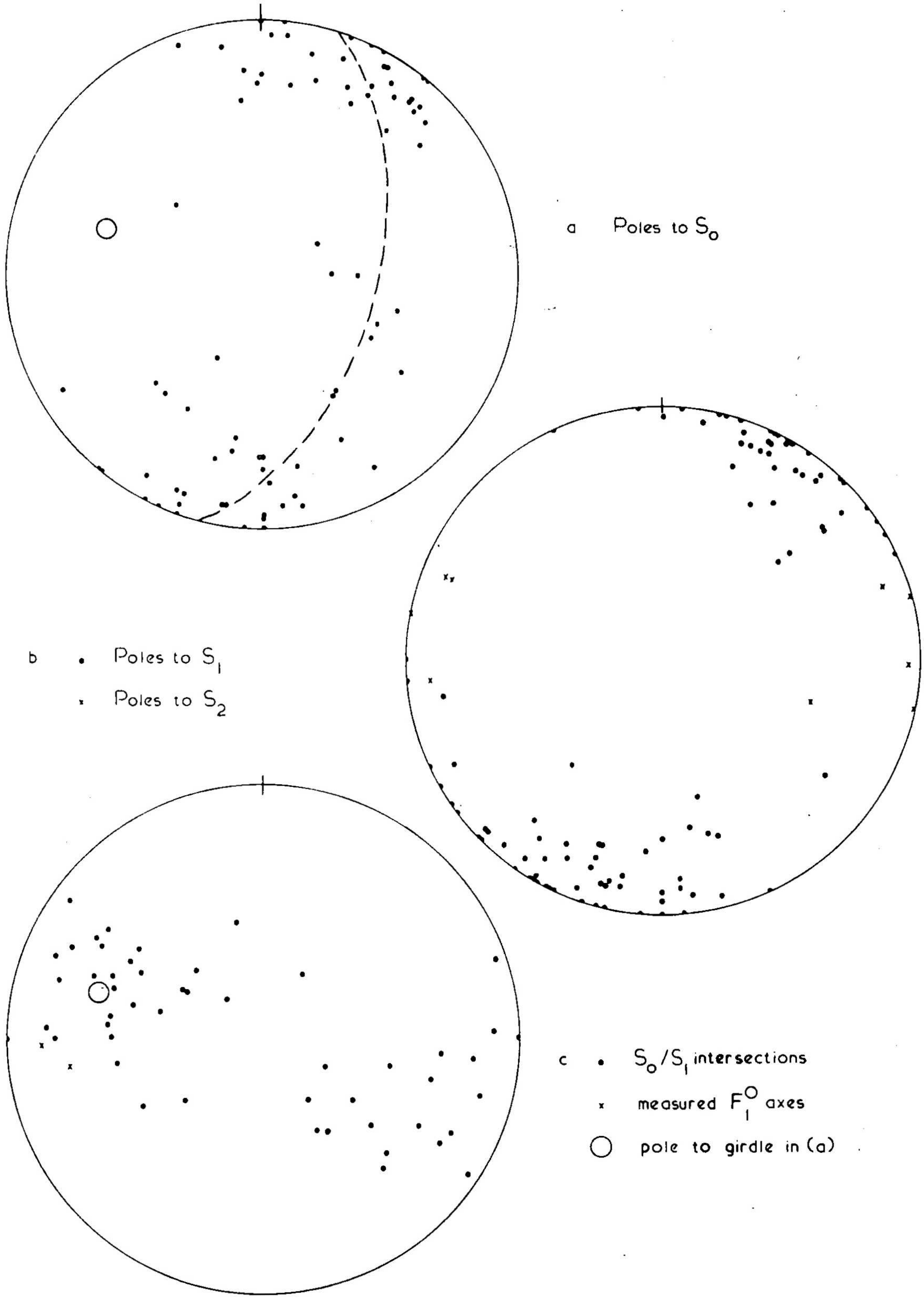
Absolute Ages of Deformation Events and their Relationships to Metamorphism

The first three deformation events coincided with metamorphic events, and have been dated by Rb-Sr whole-rock and mineral age techniques (Black & others, 1979). Specimens were collected from localities displaying a dominant foliation unaffected by subsequent events. The derived Rb-Sr whole-rock ages were considered to date the deformation represented by the foliation. Consistent ages for structurally identified foliations were obtained over a wide area.

D_1 was associated with greenschist to amphibolite facies metamorphism, and has been dated at 1570 $\pm$ 20 m.y. D_2 was associated with metamorphism of similar grade in the North Head-Forest Home area, but farther east the grade reached granulite facies in places; D_2 has been dated at 1469 $\pm$ 20 m.y. Metamorphism accompanying D_1 and D_2 may represent either two separate events, or a single sustained event lasting at least 100 m.y.

D_3, dated at 967 $\pm$ 28 m.y., was accompanied by greenschist-facies metamorphism in the Einasleigh area (in FORSAYTH). However, there are no apparent direct effects of syn-D_3 metamorphism in the North Head-Forest Home area, although some of the retrogression in the Ironhurst area could be due to this event.

D_4 is correlated with the event that produced a slaty cleavage in the Hodgkinson and Broken River Provinces (to the northeast and southeast of the Georgetown Inlier respectively), probably in the Devonian (Bell, 1980).



Record 1981/63 16/Q/14

Figure 11 : Structural data – Candlow domain

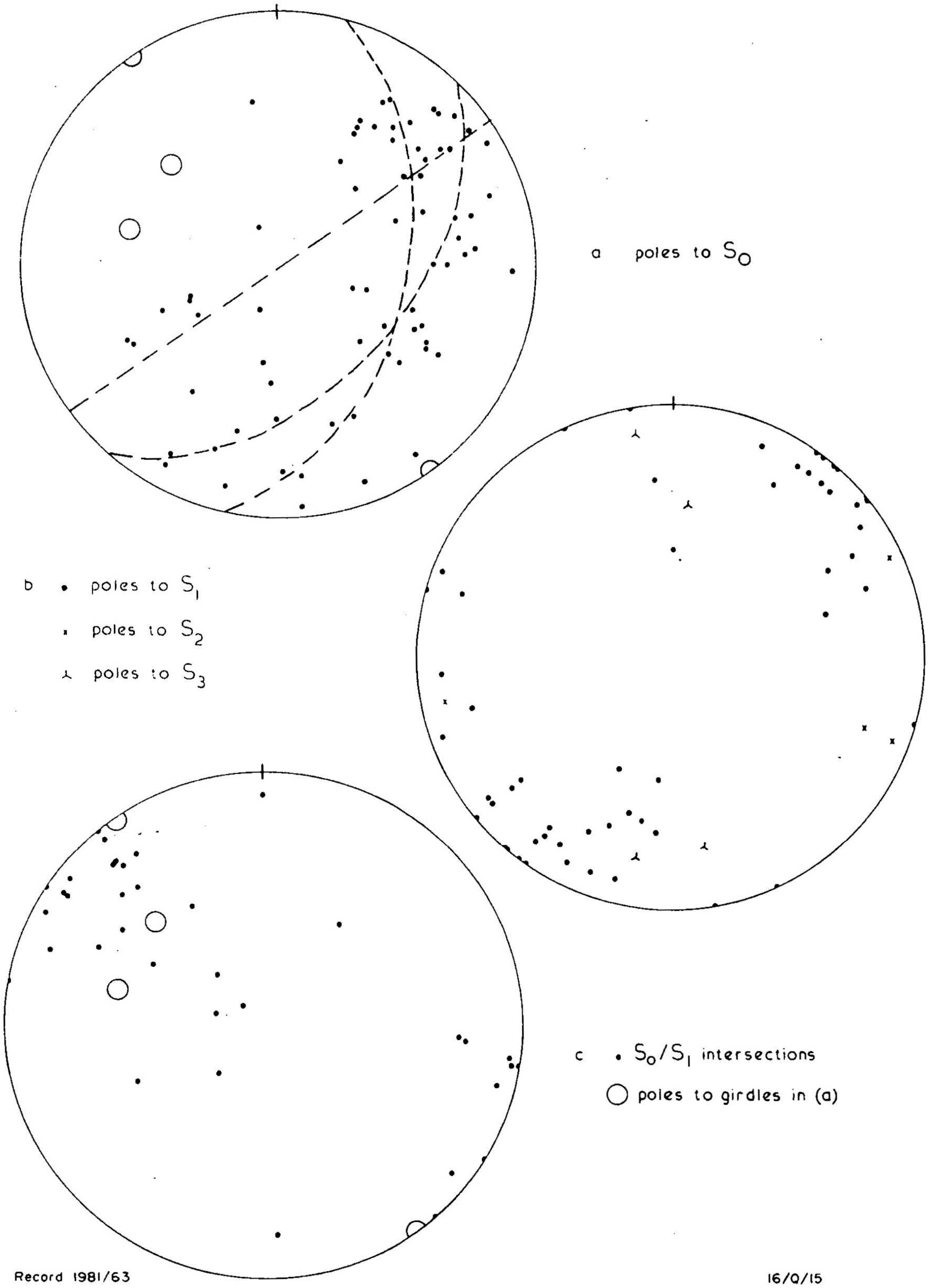
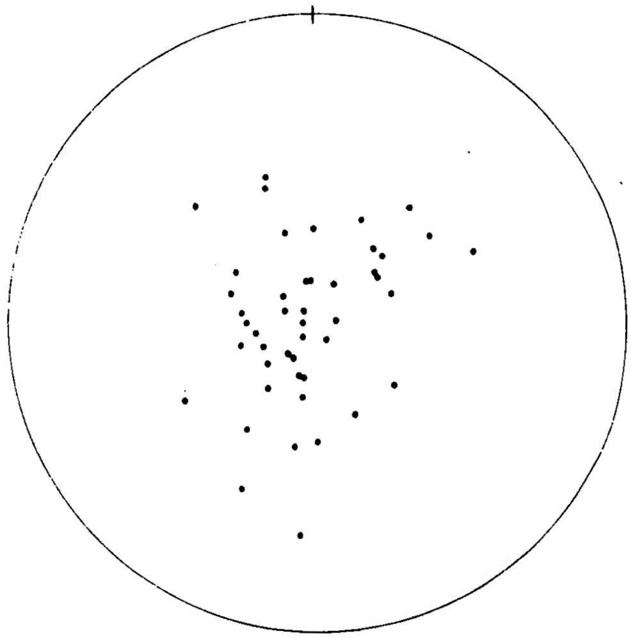
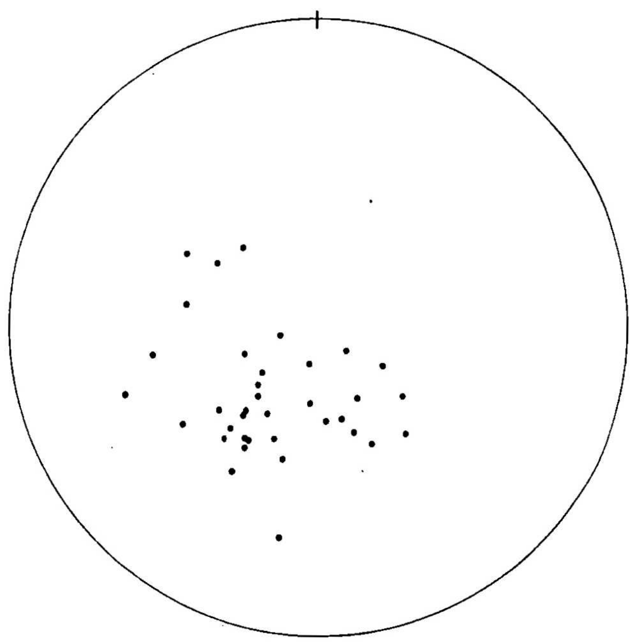


Figure 12 : Structural data – southern half of Carnes domain.



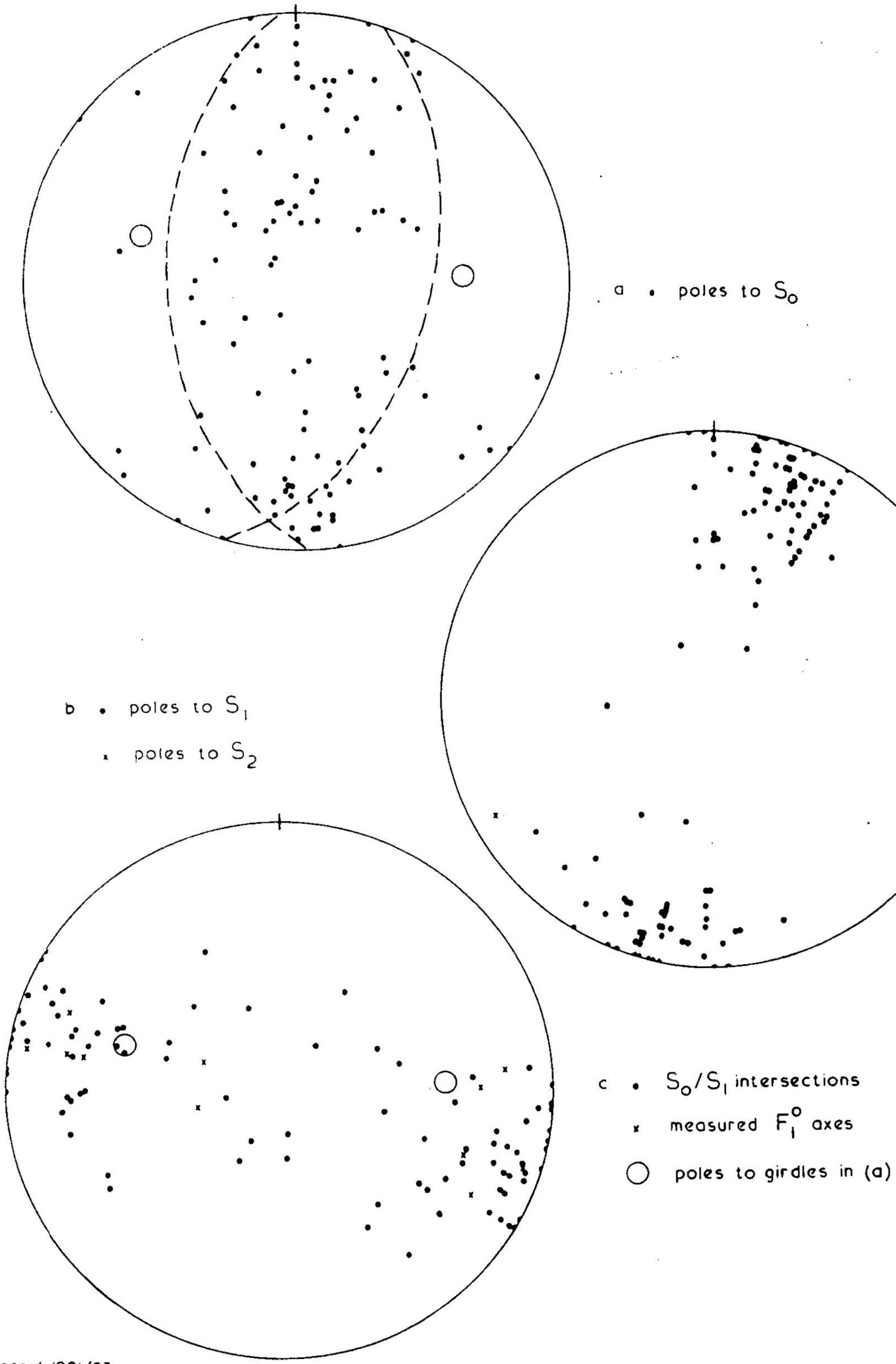
a poles to S_0



b poles to S_1

Record 1981/63 16/Q/16

Figure 13 : Structural data — Cobbold domain.



Record 1981/63

16/0/17

Figure 14 : Structural data – Townley domain.

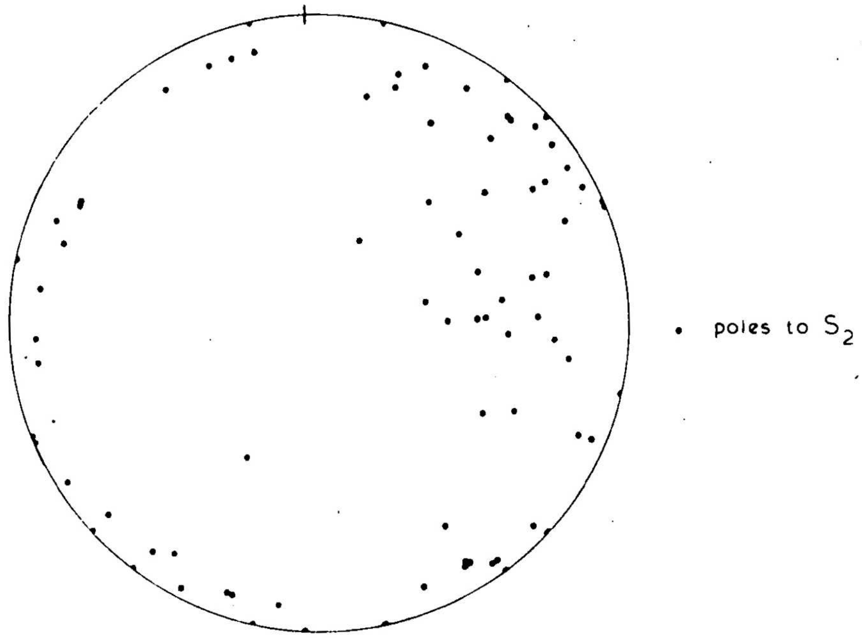
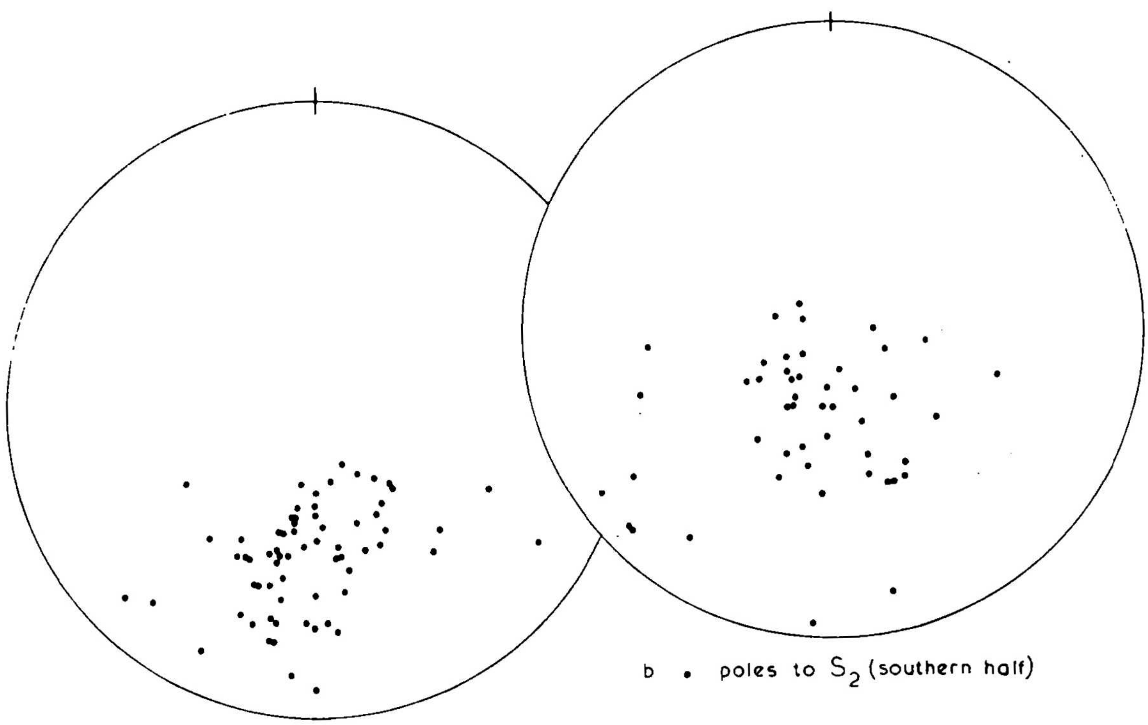


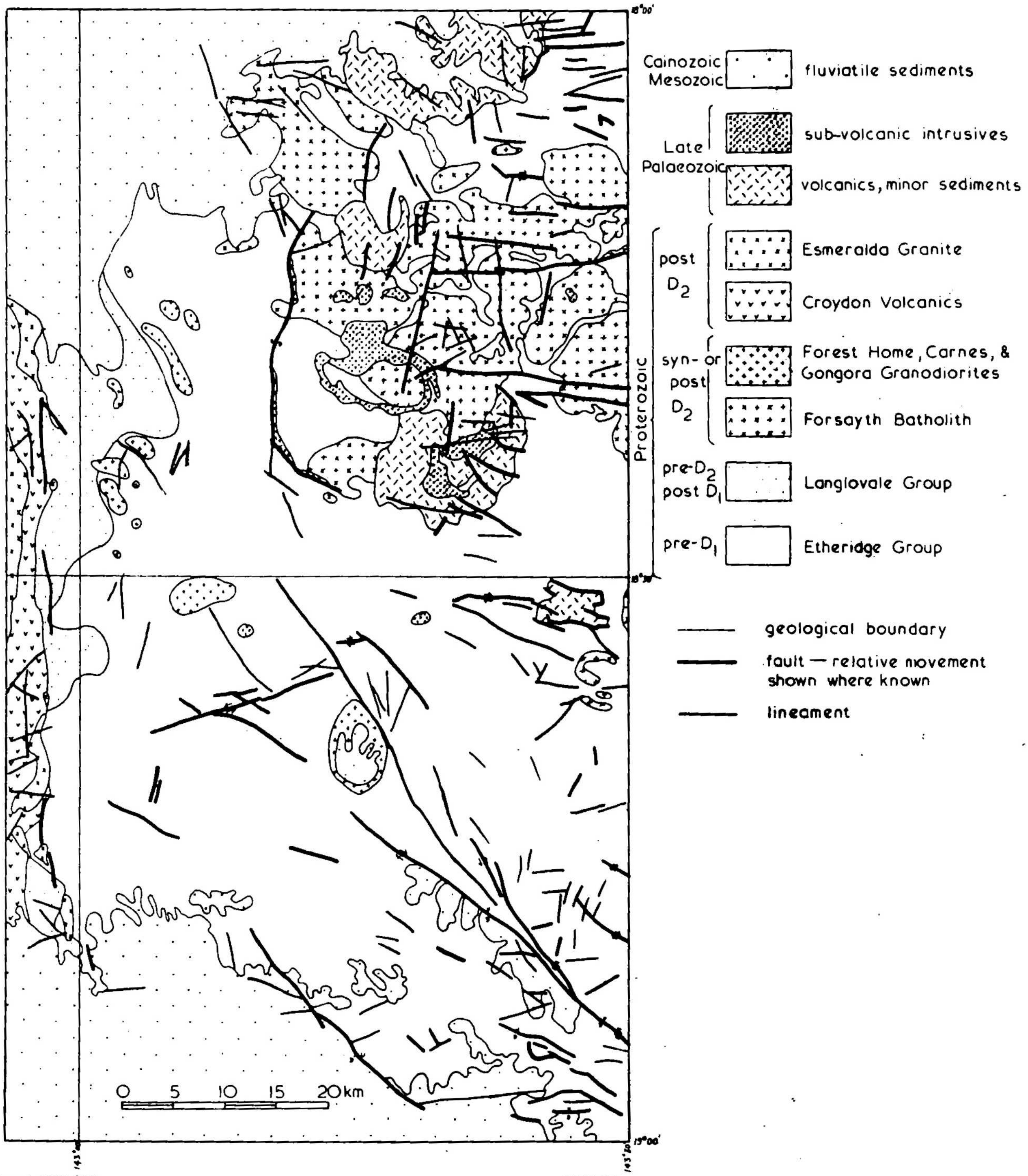
Figure 15 : Structural data – Western Creek domain



Record 1981/63

16/Q/18

Figure 16 : Structural data – Malcolm Creek domain.



Record 1981/63

16/Q/19

Figure 17 : Main faults and lineaments – North Head – Forest Home area

This event may correspond with a thermal event at about 380 to 385 m.y. that reset many K-Ar and Rb-Sr ages, and possibly caused much of the retrogressive metamorphism in the Georgetown Inlier.

Folds and slaty cleavage produced by the Devonian event trend approximately north in the Hodgkinson and northern Broken River Provinces; in the southern Broken River Province the trend changes to southeasterly, suggesting that the Broken River Province was deformed by a large fold with an approximately easterly trending axial plane. Bell (1980) named this postulated structure the 'Big Bend Megafold', and correlated it with D_5 in the Georgetown Inlier. He considered it to be a mid-Carboniferous event. D_6 may correlate with a Triassic event which folded sediments in the northern part of the Bowen Basin.

FAULTS

In the southern part of the North Head-Forest Home area, the major faults strike northwest (Fig. 17) whereas the less important faults strike east-northeast or west-northwest.

The Robertson Fault is a major structure which has a complex movement history. Near the point where the fault divides into two parts, in the Robertson River about 2 km south of the Malcolm Creek junction, the main fault and its eastern branch have sinistral displacements of about 5 km. Movement on the western branch was dextral, and a displacement of 2 to 3 km is indicated near where the North Head road crosses the Robertson River. In addition to this lateral movement, structural contours of the base of the Jurassic Hampstead Sandstone indicate vertical, western block down movement of up to 150 m on the western branch and the main fault. Lateral movement on the two branches dies out south of the Gongora Granodiorite pluton. However, the structural contours indicate post-Mesozoic warping and faulting along a diffuse northwestward continuation of the structure, corresponding in part with a lineament on LANDSAT imagery passing just to the west of Mount Clark. Northwest of the Georgetown Inlier, the structure forms the western margin of the Gilbert-Mitchell trough of the Karumba Basin, although the sense of movement in that area is reversed. Needham (1971) and Doutch & others (1972) suggested that most of the vertical movement on the Robertson Fault occurred in the Pliocene. Minor adjustment in the Pleistocene caused Cobbold Creek, a tributary of the Robertson River, to change its course and carve a narrow gorge through a large outlier of Hampstead Sandstone.

A southward extension of the Robertson Fault in GILBERTON appears to have formed a line of weakness along which intermediate and acid volcanism and intrusive activity were localised in the late Palaeozoic. However, no lateral or vertical movement is evident in this area.

Between 25 and 50 m of vertical displacement occurred on another prominent northwesterly trending fault to the southwest of North Head homestead, but no lateral movement is apparent.

The other faults in the area caused lateral displacement of up to 1 km, but generally less than 300 m. Some minor post-Mesozoic movement is indicated on faults in the southeastern corner of the area.

An entirely different fault pattern is evident in Proterozoic rocks in the northern half of the North Head-Forest Home area. The area is dominated by easterly striking faults or lineaments, and some which strike north. No consistent pattern of movement is evident, and much of the apparent lateral displacement is probably vertical displacement of gently dipping intrusive contacts. Late Palaeozoic basic or intermediate intrusive rocks were emplaced along many of the faults. A similar rectangular fault pattern occurs in the Proterozoic rocks west of the Newcastle Range in adjacent GEORGETOWN.

Faults in and around the Carboniferous igneous rocks are probably related to cauldron subsidence; they are probably at least in part re-activated basement structures.

ACKNOWLEDGEMENTS

Part of the fieldwork on which this Record is based was carried out by E.M. Baker (ex-GSQ). In particular, he mapped the western part of the area in which the Candlow Formation, Langdon River Mudstone, and Langlovale Group crop out. Most of the ideas on the depositional environments were contributed by J.J. Draper (GSQ). Fruitful discussions have been held at various times with J.H.C. Bain and Dr B.S. Oversby (BMR).

Geologists of mining companies, in particular P. Onley, W.H. Johnston, and I. Johnson of CRA Exploration Pty Ltd, and R.J. Marjoribanks and G.L. Rolfe of Anaconda Australia Inc., participated in a free exchange of information. Maps made available to us by CRA and Anaconda were of considerable value in the early stages of our mapping. The detailed studies of T.H. Bell, M.J. Rubenach, and J.D. Fitzgerald (James Cook University) on the structure and metamorphism of the Robertson River Formation have complemented our regional coverage.

Permanent and temporary field staff who assisted with the field work were J.T. Pollard, K.H. Ellingsen, R. Wills, C. Jollife, L. Culpepper, S.P. Lang, J.R. Pye, A.T. Hoey and I.R. Chandler. P.L. Blythe (BMR Geological Drawing Office) transferred the data from airphoto overlays to field compilation sheets.

Finally, the hospitality and ready assistance of the local land-holders is gratefully acknowledged.

REFERENCES

BAIN, J.H.C., WITHNALL, I.W., & OVERSBY, B.S., 1976 - Geology of the Forsayth 1:100 000 Sheet area (7660), north Queensland. Bureau of Mineral Resources, Australia, Record 1976/4 (unpublished).

BAIN, J.H.C., MACKENZIE, D.E., & WITHNALL, I.W., 1978 - Georgetown Project. In, Geological Branch Summary of Activities, 1977. Bureau of Mineral Resources, Australia, Report 208, 171-179.

BAIN, J.H.C., MACKENZIE, D.E., OVERSBY, B.S., & WITHNALL, I.W., 1979 - Georgetown Project. In, Geological Branch Summary of Activities, 1978. Bureau of Mineral Resources, Australia, Report 212 (Microform MF 81), 140-152.

BELL, T.H., 1980 - The deformation history of northeastern Queensland - a new framework. In, Henderson, R.A., & Stephenson, P.J. (Editors) - THE GEOLOGY AND GEOPHYSICS OF NORTHEASTERN AUSTRALIA. Geological Society of Australia Incorporated, Queensland Division, Brisbane, 307-313.

BELL, T.H., & DUNCAN, A., 1978 - A rationalised and unified shorthand terminology for lineations and fold axes in tectonics. Tectonophysics, 47, T1-T5.

BLACK, L.P., 1973 - Tables of isotopic ages from the Georgetown Inlier, north Queensland. Bureau of Mineral Resources, Australia, Record 1973/50 (unpublished).

BLACK, L.P., BELL, T.H., RUBENACH, M.J., & WITHNALL, I.W., 1979 - Geochronology of discrete structural-metamorphic events in a multiply deformed Precambrian terrain. Tectonophysics, 54, 103-137.

BOUMA, A.H., 1962: SEDIMENTOLOGY OF SOME FLYSCH DEPOSITS. A GRAPHIC APPROACH TO FACIES INTERPRETATION. Elsevier, Amsterdam.

BRANCH, C.D., 1966 - Volcanic cauldrons, ring complexes, and associated granites of the Georgetown Inlier, Queensland. Bureau of Mineral Resources, Australia, Bulletin 76.

BMR, 1975 - Georgetown, Forsayth, North Head, Forest Home, Esmeralda, Gilbert River, Queensland - 1:100 000 Preliminary Total Magnetic Intensity Series, Sheets 7460, 7461, 7560, 7561, 7660, 7661. Bureau of Mineral Resources, Australia.

CARPENTER, R.H., 1974 - Pyrrhotite isograd in southeastern Tennessee and southwestern North Carolina. Geological Society of America Bulletin, 85, 451-456.

COOPER, J.A., WEBB, A.W., & WHITAKER, W.G., 1975 - Isotopic measurements in the Cape York Peninsula area, north Queensland. Journal of the Geological Society of Australia, 22, 285-310.

CROOK, K.A.W., 1960 - Classification of arenites. American Journal of Science, 258, 419-428.

DOUTCH, H.F., SMART, J., GRIMES, K.G., NEEDHAM, R.S., & SIMPSON, C.J., 1972 - Progress report on the geology of the central Carpentaria Basin. Bureau of Mineral Resources, Australia, Record 1972/64 (unpublished).

FITZGERALD, J.D., 1974 - The structure of the Robertson River Metamorphics, Robin Hood Station, Forsayth region, Queensland. B.Sc. (Honours) Thesis, James Cook University of North Queensland. (unpublished).

FORD, BACON & DAVIS INC., 1972 - Progress report on Authorities to Prospect 940M, 952M, 953M and 954M, Croydon area, Queensland. Unpublished report held by Queensland Department of Mines (CR 3960).

GARY, M., McAFEE, R., & WOLF, C.L., (Editors), 1972 - GLOSSARY OF GEOLOGY. American Geological Institute, Washington.

HARTE, B., 1975 - Determination of a pelite petrogenetic grid for the eastern Scottish Dalradian. Carnegie Institution of Washington Yearbook, 74, 438-446.

INGRAM, R.L., 1954 - Terminology for the thickness of stratification and parting units in sedimentary rocks. Geological Society of America, Bulletin, 65 937 938.

JOHNSTON, W.H., 1978 - Annual report for 1977 and final report, Stockyard Creek A. to P. 1613M. CRA Exploration Pty Ltd. Unpublished report held by Queensland Department of Mines (CR 6599).

MACKENZIE, D.E., 1979 - Revised Proterozoic stratigraphy and economic potential of the western Georgetown Inlier, north Queensland. In, Abstracts of the 8th BMR Symposium, Canberra, 1-2 May 1979. Bureau of Mineral Resources, Australia Report 217 (Microform MF 105), 22.

MACKENZIE, D.E., 1980 - New and redefined igneous rock units in the Forest Home-North Head region, Georgetown Inlier, north Queensland. Queensland Government Mining Journal, 81, 208-214.

MACKENZIE, D.E., WITHNALL, I.W., & BAKER, E.M., 1979 - Forest Home, North Head and parts of Gilbert River and Esmeralda 1:100 000 Geological Sheets, Catalogue of preliminary field data compilation sheets. Bureau of Mineral Resources, Australia, Record 1979/12 (unpublished).

NEEDHAM, R.S., 1971 - Mesozoic stratigraphy and structure of the Georgetown 1:250 000 Sheet area, Queensland. Bureau of Mineral Resources, Australia, Record 1971/100 (unpublished).

OVERSBY, B.S., WITHNALL, I.W., BAKER, E.M., & BAIN, J.H.C., 1978 - Geology of the Georgetown 1:100 000 Sheet area (7661), north Queensland; part A. Bureau of Mineral Resources, Australia, Record 1978/44 (unpublished).

OVERSBY, B.S., BLACK, L.P., & SHERATON, J.W., 1980 - Late Palaeozoic continental volcanism in northeastern Australia. In, Henderson, R.A., & Stephenson, P.J., (Editors) - THE GEOLOGY & GEOPHYSICS OF NORTHEASTERN AUSTRALIA. Geological Society of Australia Incorporated, Queensland Division, Brisbane, 247-268.

OVERSBY, B.S., MACKENZIE, D.E., & WITHNALL, I.W., 1981 - Georgetown Project. In, Geological Branch Summary of Activities, 1980. Bureau of Mineral Resources, Australia, Report, 230.

PETTIJOHN, F.J., POTTER, P.E., & SIEVER, R., 1972 - SAND AND SANDSTONE. Springer-Verlag, New York.

RICHARDS, J.R., WHITE, D.A., WEBB, A.W., & BRANCH, C.D., 1966 - Isotopic ages of acid igneous rocks in the Cairns hinterland, north Queensland. Bureau of Mineral Resources, Australia, Bulletin, 88.

RUBENACH, M.J., BELL, T.H., & FITZGERALD, J.D., 1977 - The significance of textures from the Robertson River Metamorphics, north Queensland. Abstracts of the 2nd Australian Geological Convention, Monash University, Melbourne. Geological Society of Australia Incorporated, 72.

SHERATON, J.W., & LABONNE, B., 1978 Petrology and geochemistry of acid igneous rocks from northeast Queensland. Bureau of Mineral Resources, Australia, Bulletin, 169.

SMART, J., INGRAM, J.A., DOUTCH, H.F., & GRIMES, K.G., 1971 - Recent mapping of the Carpentaria Basin - new stratigraphic names. Queensland Government Mining Journal, 72, 3-8.

THOMPSON, R.W., 1968 - Tidal flat sedimentation on the Colorado River delta, northwestern Gulf of California. Geological Society of America, Memoir, 107.

THOMPSON, R.W., 1975 - Tidal flat sediments of the Colorado River delta, northwestern Gulf of California. In Ginsburg, R.N., (Editor) - TIDAL DEPOSITS, Springer-Verlag, Berlin, Heidelberg, New York, 57-65.

TURNER, F.J., & VERHOOGEN, J., 1960 - IGNEOUS AND METAMORPHIC PETROLOGY. McGraw-Hill, New York, (second edition).

WALKER, R.G., 1967 - Turbidite sedimentary structures and their relationship to proximal and distal depositional environments. Journal of Sedimentary Petrology, 37, 25-43.

WEAVER, C.E., & POLLARD, L.D., 1973 - THE CHEMISTRY OF CLAY MINERALS: DEVELOPMENTS IN SEDIMENTOLOGY 15. Elsevier, Amsterdam, London, New York.

WENTWORTH, C.K., 1922 - A scale of grade and class terms for clastic sediments. Journal of Geology, 30, 377-392.

WHITE, D.A., 1959 - New stratigraphic names in north Queensland geology. Queensland Government Mining Journal, 60, 442-447.

WHITE, D.A., 1962a - Gilberton, Queensland - 1:250 000 Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SE/54-16.

WHITE, D.A., 1962b - Georgetown, Queensland - 1:250 000 Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SE/54-12.

WHITE, D.A., 1965 - The geology of the Georgetown/Clarke River area, Queensland. Bureau of Mineral Resources, Australia, Bulletin, 71.

WINKLER, H.G.F., 1967 - PETROGENESIS OF METAMORPHIC ROCKS. Springer-Verlag, New York, (revised second edition).

WINKLER, H.G.F., 1974 - PETROGENESIS OF METAMORPHIC ROCKS). Springer-Verlag, New York, (third edition).

WITHNALL, I.W., 1981 - Investigation of possible stratabound lead-zinc mineralisation in the Robertson River Formation and Townley Formation, Georgetown area, Queensland. Geological Survey of Queensland, Record 1981/22 (unpublished).

WITHNALL, I.W., & MACKENZIE, D.E., 1979 - Stratigraphic drilling in the Candlow area, Georgetown Inlier - preliminary report and drill logs. Geological Survey of Queensland, Record 1979/37 (unpublished).

WITHNALL, I.W., BAIN, J.H.C., & RUBENACH, M.H., 1980a - The Precambrian geology of northwestern Australia. In, Henderson, R.A., & Stephenson, P.J., (Editors) - THE GEOLOGY AND GEOPHYSICS OF NORTHEASTERN AUSTRALIA. Geological Society of Australia Incorporated, Queensland Division, Brisbane, 109-127.

WITHNALL, I.W., OVERSBY, B.S., BAIN, J.H.C., & BAKER, E.M., 1980b - Geology of the Gilberton 1:100 000 Sheet area (7659), north Queensland: data record. Bureau of Mineral Resources, Australia, Record 1980/2 (unpublished).

WITHNALL, I.W., & MACKENZIE, D.E., 1980 - New and revised stratigraphic units in the Proterozoic Georgetown Inlier, north Queensland. Queensland Government Mining Journal, 81, 28-43.