BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

1977/4

GEOLOGY OF THE PROSPECTOR 1:100 000 SHEET AREA (6857)
QUEENSLAND

by

I.H. Wilson, G.M. Derrick, R.M. Hill, B.A. Duff, T.A. Noon, D.J.Ellis

Record 1977/4

GEOLOGY OF THE PROSPECTOR 1:100 000 SHEET AREA (6857), QUEENSLAND

by

I.H. Wilson, G.M. Derrick, R.M. Hill, B.A. Duff, T.A. Noon, D.J. Ellis

CONTENT

(with initials of chief author(s) of a section)

Page

TABLES

FIGURES

area. The floor of the valley is underlain by Leichhardt Metamorphics and Kalkadoon Granite. The distant ridges are Surprise Creek Beds; the sharp ridge to the right is a silicified segment of the Mount Remarkable Fault. M1509/16 IHW.

Fig. 5 Dissected Early to mid-Tertiary erosion surface developed on quartzite units of the Myally Subgroup 25 km south-southwest of Julius Dam. M1507/8 IHW.

Fig. 6 Strongly crenulated acid gneiss from a large xenolith in the Kalkadoon Granite 5.7 km southwest of Mount Olive copper mine. Gneiss is probably highly altered Leichhardt Metamorphics. M1509/32 IHW.

Fig. 7 Classification of Leichhardt Metamorphics by QAP diagram.

Fig. 8 Geological sections of the Magna Lynn Metabasalt, Prospector Sheet area

Fig. 9 Large amygdales in Magna Lynn Metabasalt 3.5 km east of Mount Olive copper mine. M1537/10 IHW.

Fig. 10 Hyaloclastite? flow in Magna Lynn Metabasalt. Note that pale concentrically zoned structures are surrounded by less well defined dark concentric zones and clastic fragments. M1507/37 IHW.

Fig. 11 Round structure (vertical and horizontal sections) with an amygdaloidal basic core in hyaloclastite from Magna Lynn Metabasalt. Note the dark concentric zones to the left of main round structure. M1509/4 IHW.

Fig. 12 Sheared fragmental (fiamme?) porphyritic acid volcanic of the Argylla Formation in southeast corner of Sheet area. M1499/24 IHW.

MAP

rr

SUMMARY

The Prospector 1:100 000 Sheet area (6857) in northwestern Queensland is bounded by latitudes 20°00'S and 20°30'S and longitudes 139°30'E and 140°00'E. The city of Mount Isa lies about 25 km south of the southwestern corner of the Sheet area.

Most of the area contains good exposures of Proterozoic rocks of probable Lower Proterozoic? to Carpentarian age (1800-1400 m.y.). The oldest rocks constitute the Tewinga Group, which forms the basement to two younger sequences lying to the east and west - the eastern succession and the western succession respectively. The eastern succession contains the Mary Kathleen Group and the Mount Albert Group. The western succession contains the Haslingden Group, the Surprise Creek Beds, the 'Mammoth Formation' equivalents, and the Mount Isa Group.

The Tewinga Group comprises the Leichhardt Metamorphics, the Magna Lynn Metabasalt and the Argylla Formation. The Leichhardt Metamorphics are a metamorphosed sequence of grey porphyritic dacite and rhyodacite, fragmental acid volcanics, sediments, and fluidal rhyolite. This predominantly acid volcanic formation is overlain by a sequence of metabasalt, basic tuff, and intercalated quartzite called the Magna Lynn Metabasalt. This in turn, is overlain by pink porphyritic rhyolite and minor sediment of the Argylla Formation. The lower part of the Tewinga Group is intruded by the Kalkadoon Granite.

The Mary Kathleen Group contains the oldest rocks of the eastern succession in the Sheet area. Basal conglomerate and labile sandstone of the Ballara Quartzite unconformably overlie the Argylla Formation. The sandstone becomes more quartzose upward and grades into the Corella Formation. This formation is characterized by laminated calcareous siltstone, calcareous breccia, calc-silicate rocks, and minor quartzite, shale, and basalt. The Corella Formation is intruded by the Wonga Granite.

After slight uplift and erosion of the Mary Kathleen Group, the Mount Albert Group was deposited. The only formation

of this group exposed in the Prospector Sheet area is the Deighton Quartzite, which consists of labile and pebbly sandstone, siltstone, and quartzite.

Deposition in the western basin began with the Haslingden Group. The basal formation of this group in the west of the Sheet area is the Leander Quartzite, a thick sequence of quartzose arenite, arkose, siltstone, and minor phyllite. Small outcrops of Mount Guide Quartzite in the south of the Sheet area are equivalent to the Leander Quartzite. Both are overlain by the Eastern Creek Volcanics, which comprises three members: the basal member of metamorphosed amygdaloidal basalt and intercalated quartzite and calcareous siltstone (the Cromwell Metabaslt Member) is overlain by a persistent quartzite unit (the Lena Quartzite Member) which is in turn overlain by a metamorphosed amygdaloidal basalt sequence with abundant sedimentary intercalations (the Pickwick Metabasalt Member). The volcanics are conformably overlain by the Myally Subgroup which consists of the Alsace Quartzite (feldspathic and clayey quartzite and minor siltstone), the Bortala Formation (fine-grained sandstone and siltstone), the Whitworth Quartzite (feldspathic and micaceous quartzite), and the Lochness Formation (fine-grained ferruginous sandstone, siltstone, shale and minor rhyolite). The siltstone and rhyolitic tuff at the top of this Formation have been called the Police Creek Siltstone Member. The Haslingden Group was uplifted and gently folded before the overlying Surprise Creek Beds and Mount Isa Group were deposited.

The Surprise Creek Beds overlie the Haslingden Group and onlap the basement. They consist of a thick sequence of sandstone, conglomerate, siltstone, dolomite, orthoquartzite, shale, and phyllite, and are probably slightly older than most of the Mount Isa Group, which is represented in the west of the Sheet area by the Warrina Park Quartzite (feldspathic sandstone, conglomerate, and orthoquartzite), Moondarra Siltstone, Breakaway Shale, and Native Bee Siltstone (siltstone, slate, chert, and dolomitic siltstone).

After sedimentation, the region was deformed and metamorphosed. Folding about meridional axes occurred and a north-trending cleavage developed, accompanied by dolerite intrusion. With progressive deformation, inhomogeneous strain resulted in a characteristic basin-and-dome style of folding with fold axes plunging north and south. The folds are fragmented by north-trending reverse faults and later east-trending normal faults. The final major deformation involved conjugate strike-slip faulting. The folding and early faulting was accompanied by greenschist facies and, in some areas, amphibolite facies metamorphism. Minor dolerite intrusions succeeded the metamorphism.

Gold, copper, silver, and tungsten have been produced in small quantities from the Sheet area. The gold was produced from quartz reefs, veins, and alluvial deposits, and as a by-product of copper mining. Copper occurs as disseminations in the basic volcanic rocks and some of the metasediments, but the economic concentrations are in siliceous shear zones in the Leichhardt Metamorphics, the Argylla Formation, and the Corella Formation. Most copper production has been from secondary enriched ore. Silver has been produced as a byproduct of the copper mining. The tungsten (scheelite) was extracted from a quartz and calcite lode in hornblende schist. Minor occurrences of uranium are known in the Eastern Creek Volcanics.

INTRODUCTION

Location

The Prospector 1:100 000 Sheet area (6857) is in northwest Queensland between latitudes 20°00'S and 20°30'S, and longitudes 139°30'E and 140°00'E (Fig. 1). It forms part of the Cloncurry 1:250 000 Sheet area, SF 54-2. The southwest corner of the Prospector Sheet area is 25 km north of Mount Isa, which is about 1970 km from Brisbane by road. Four kilometres east of the northeastern corner of the Sheet area is Kajabbi, a railway terminus 100 km northwest of Cloncurry and 877 km from the port of Townsville.

Object

This report presents the results of detailed reconnaissance geological mapping by the Bureau of Mineral Resources (BMR) and Geological Survey of Queensland (GSQ) from June to October, 1973. Reports on the geology of the 1:100 000 Sheet areas to the south, i.e., Cloncurry (7056), Marraba (6956), Mary Kathleen (6856), and Mount Isa (6756) have already been completed (Glikson & Derrick, 1970; Derrick et al., 1971, in press; Hill et al., 1975). Reports on the geology of the adjoining Kennedy Gap (6757) and Quamby (6957) Sheet areas are currently being prepared.

The aims of the survey were to:

(1) prepare a map at 1:100 000 scale of the Precambrian geology;
(2) reassess the stratigraphy, structure, petrology, economic geology, and geological history of the region;
(3) undertake a geochemical examination of selected rock units;
(4) prepare a detailed report of the geology.

Access

Access within the Sheet area is restricted by rugged north-south ranges. The main access is afforded by the formed gravel Mount Isa/Kajabbi road, which traverses the middle and northeastern parts of the Sheet area. It connects with a road to the Julius Dam near the middle of the Sheet area, and with an abandoned ore-haulage road to the mining town of Gunpowder, 70 km to the northwest. Rough tracks provide access to numerous mines in the eastern part of the Sheet area. The main access in the western part of the Sheet area is the Julius Dam/Mount Isa pipeline road.

Landing grounds have been constructed near Gereta homestead and Mount Cuthbert in the north, and 10 km east of the Julius Dam near the middle of the Sheet area.

Population and industry

There are no permanent townships in the Sheet area; however, at the time of mapping, a construction camp at the Julius Dam site housed several hundred people. The Gereta homestead and several operating copper mines accommodate the permanent population of less than 40 people.

Cattle-raising and mining are the only significant industries in the area. Coolullah, Gereta, Calton Hills and West Leichhardt stations lease most of the Sheet area for grazing. At the time of the survey, copper was being mined at several localities by the Fisher family, Angeli Mining Co. Pty Ltd, U. Marchiolo, and L. Graziano.

Climate

The area has a semi-arid tropical climate, with warm to hot summers and warm to cool dry winters. It lies between the 400 mm and 500 mm rainfall isohyets, which trend northwest;

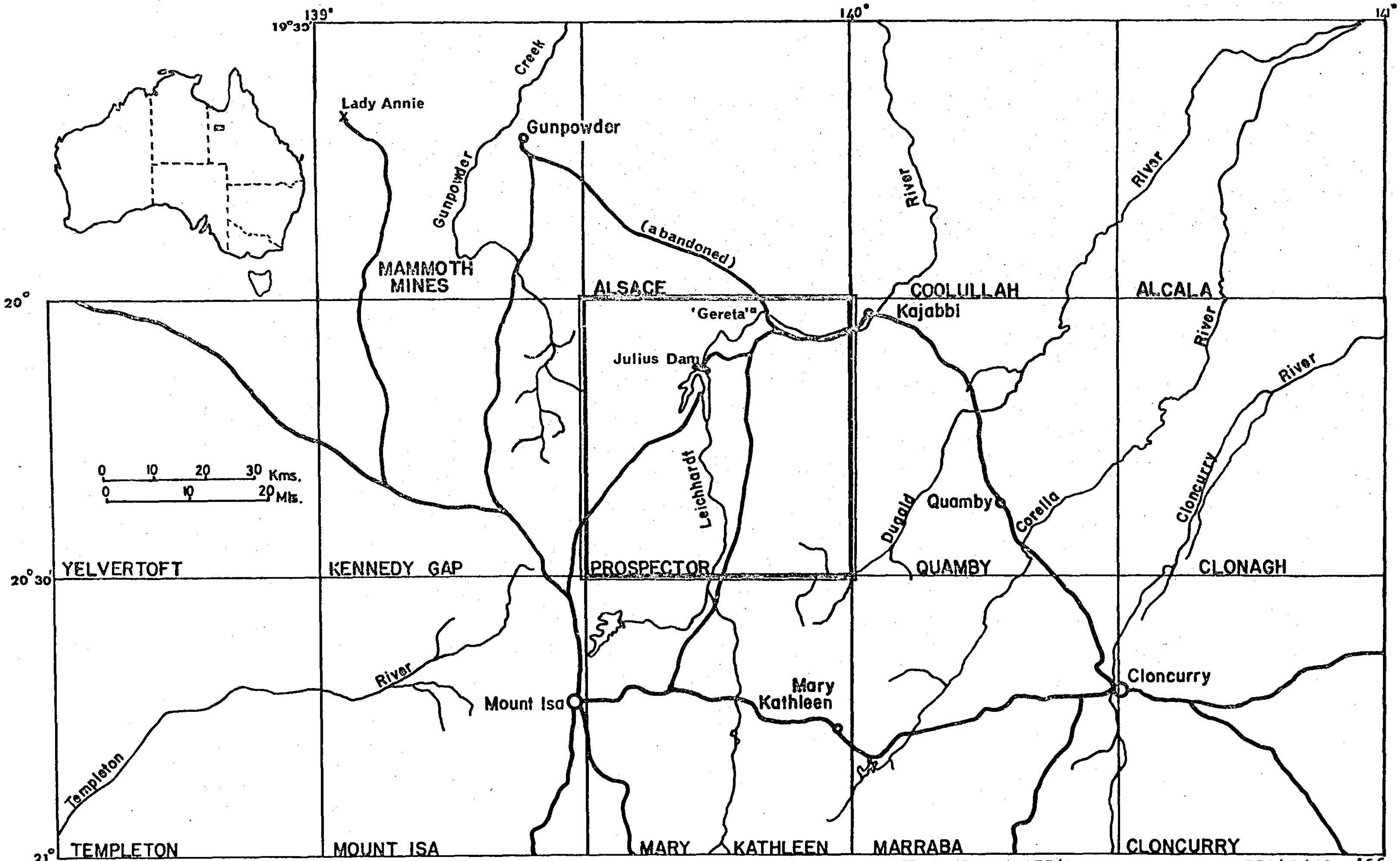


Fig.1 LOCATION MAP PROSPECTOR 1:100 000 SHEET AREA Record 1977/4 F54/A2/168 A.E.G.

rainfall increases to the northeast and falls mainly between November and March. Most rainfall results from isolated storms yielding 20 to 50 mm; however, some general rain accompanies the weak monsoonal activity during the summer. Minor falls of up to 5 mm occur in the winter months.

Temperatures during summer are high, with monthly average maxima ranging from 32 to 39°C and average minima ranging from 20 to 25°C. In winter the monthly average maxima range from 25 to 32°C and the average minima range from 11 to 20°C. Relative humidity is low, often being below 10 percent. The summer average is about 40 percent and the winter average is about 25 percent. A detailed account of the climate of the area is given by Slatyer (1964).

Vegetation

An account of the vegetation of the area is given by Perry & Lazarides (1964). They note the well developed stratification of vegetation into a tree layer and a grass layer, each of which is classified into communities on the basis of its prominent species. The Isa highland sparse low woodland and the Western spinifex, which are generally found together, are the dominant communities in the Prospector Sheet area. The species of the Isa highland sparse low woodland community are *Eucalyptus brevifolia* (snappy gum), *E. terninalis* (bloodwood), *E. argillacea* (western box), *E. pruinosa* (silverleaf box), *E. papuana* (ghost gum), *Acacia* spp. and *Cassia* spp. The species of the Western spinifex community are *Triodia pungens* (soft spinifex), *T. burkensis*, *T. molesta* (hard spinifex) and *T. longiceps*. Species of trees that occur in communities mainly restricted to watercourses include *Acacia cambagei* (gidyea), *Hakea lorea* (corkwood), *Bauhinia cunninghamii* (bean tree), *Eucalyptus camaldulensis* (river red gum), and *Melaleuca leucadendron* (paper bark). *Grevillea striata* (beefwood) and *G. wickhamii* grow on some ridges. The arid short grass community (*Aristida arenaria*, or kerosene grass, and *Euneapogon* spp.) occurs in small patches occupying valleys throughout the Sheet area, but is moderately abundant in the west on the undulating plains underlain by basic rocks. It forms the understorey for the sporadic arid sparse low woodland community which contains Acacia estrophiolata (ironwood), A. victoriae, Atalaya hemiglauca (whitewood), Hakea lorea (corkwood), Ventilago viminalis (vine tree), Grevillea striata (beefwood), Ehretica saligna (soapwood), Carissa lanceolata (konkerberry), Capparis spp., Cassia spp., and Acacia spp.

Water resources

Most of the creeks and rivers of the Sheet area contain surface water only during and for a few weeks after the main wet season. Large permanent waterholes are restricted to the Leichhardt River, Surprise Creek, Paroo Creek, and Police Creek. Minor rockholes are generally inaccessible, being located in the rugged quartzite ridges. A few earth dams or bores supplement the natural surface water storage. The Julius Dam, on the Leichhardt River immediately below its confluence with Paroo Creek, will be used to augment the Mount Isa town water supply.

Previous Literature

A comprehensive history of geological work in the whole of the Precambrian belt of northwest Queensland before 1960 has been compiled by Carter, Brooks, & Walker (1961, pp. 25-30 and 259-275). Where this work is relevant to the Prospector Sheet area, it is listed at the back of the Record in the bibliography, which also contains relevant works up to 1976. The available aerial photographs, photomosaics, and maps for the Sheet area are listed in Table 1.

Present investigation

This report presents the results of mapping by a team of 6 geologists, four from BMR (G.M.D., R.M.H., B.A.D., D.J.E.) and two from GSQ (I.H.W., T.A.N.). Vehicle traverses were made

19

TABLE 1. PHOTOGRAPHIC AND CARTOGRAPHIC COVERAGE,
PROSPECTOR SHEET AREA

(a) Photographic coverage of whole sheet area

(1)	1950	1:50 000	K17	flown by RAAF for Division of National Mapping
(2)	1966	1:85 000	RC9	flown by Adastra for Division of National Mapping
(3)	1970	1:50 000		flown by Adastra for Lands Department, Queensland
(4)	1971	1:25 000 (colour)		flown by Civil Aerial Surveys for Division of National Mapping
(5)	Mosaics of (1) and (2) available from Division of National Mapping			

(b) SLAR Imagery at 1:100 000 flown by Goodyear-Aerospace for the former Department of National Development covers the southern part of the Sheet area.

(c) LANDSAT-1 images (available from Division of National Mapping)

1027 - 00123
1116 - 00073
1117 - 00132
1152 - 00073
1189 - 00131
1207 - 00133
1296 - 00074
1386 - 00064
1405 - 00120
1422 - 00060

(d) LANDSAT-2 images

2039 - 28555
2059 - 00012

(e) Maps of Sheet area

(1)	1961	1:250 000 topographic map SF 54-2 (Cloncurry)	Division of National Mapping
(2)	1972	1:100 000 topographic map 6857 (Prospector)	Division of National Mapping
(3)	current	1:100 000 Mining Lease Atlas Map 6857 (Prospector),	Mines Department, Queensland
(4)	current	1:250 000 Mining Lease Atlas Map SF 54-2 (Cloncurry),	Mines Department, Queensland
(5)	current	1:1 000 000 Block Identification Map, Series B, (Cloncurry),	Mines Department, Queensland
(6)	current	1:2 534 400 Authority to Prospect (Minerals) Map of Queensland,	Mines Department, Queensland

where possible, and extensive foot traverses covered the area in an irregular grid with spacings generally less than 2 km.

1:25 000 colour aerial photographs were used in the detailed reconnaissance mapping. 1:50 000 and 1:85 000 black-and-white photographs were used for navigation and the detection of large-scale structures. Photomosaics, side-looking radar imagery, and multispectral scanner imagery from the Earth Resources Technology Satellite (ERTS-1) were also examined. The geological overlays were compiled by M.R. Little using Division of National Mapping 1:100 000 topographic bases enlarged to photoscale.

The authors examined over 500 thin sections, and D.J.E. did some mineragraphy. Swift Automatic Point Counters were used to estimate modal compositions from counts of 1000 to 2000 points for about 100 specimens. Other modal analyses were estimated by comparison with percentage area charts. Igneous rocks were classified according to Streckeisen (1967), and sedimentary rocks were classified according to Crook (1960) and Folk (1968). Metamorphic rock terminology follows Winkler (1967) and Joplin (1968b).

Concurrent investigations

A suite of volcanic and granitic rocks was collected from the Sheet area and adjoining areas by Dr R.W. Page and various members of the mapping team for Rb/Sr dating. The results of this study will be presented by Page.

Volcanic rocks from the Leichhardt Metamorphics, the Magna Lynn Metabasalt and the Argylla Formation were collected for major and trace element geochemistry. These data are currently being assessed (Wilson, 1976).

During 1973 the BMR Airborne Geophysical Section carried out aeromagnetic and scintillometer surveys of the

Cloncurry 1:250 000 Sheet area on east-west lines 1.5 km apart at a flying height of 150 m, and a detailed survey of the Prospector 1:100 000 Sheet area on east-west lines 500 m apart at a flying height of 80 m (Tucker, 1975).

GEOMORPHOLOGY

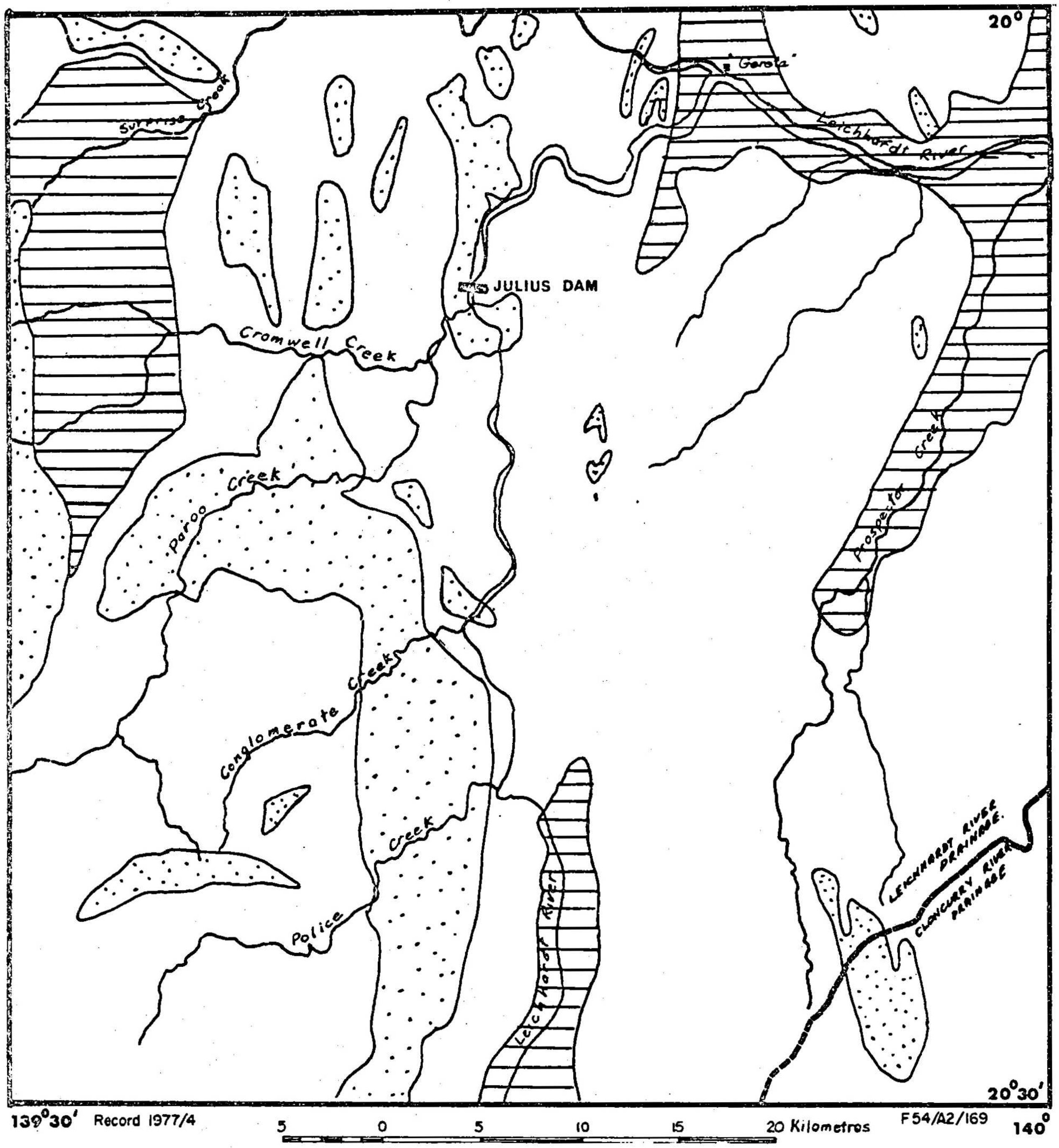
The Sheet area falls within the southwest part of the Leichhardt-Gilbert area, of which the geomorphology is described by Twidale (1964, 1966). He recognized three physiographic divisions, of which two are represented in the Sheet area (Fig. 2). These are the Isa Highlands and the Carpentaria and Inland Plains.

Isa Highlands

The Isa Highlands occupy more than 90 percent of the Sheet area; they are divided by Twidale into immaturely dissected plateaux and high plains, and maturely dissected hill country. The immaturely dissected plateaux and high plains range in elevation from 360 to 500 m, and consist of rugged planated quartzite ridges and plateaux dissected by narrow steep-sided valleys. The maturely dissected hill country ranges from about 250 to about 400 m and is underlain by more easily eroded shale, siltstone, carbonate, granite, acid and basic volcanics, and metamorphics (Fig. 3). Sharp ridges coincide with resistant strata, and low bouldery hills have formed over granite and volcanics.

Carpentaria and Inland Plains

The Carpentaria and Inland Plains are plains of erosion with an average elevation of 160 to 250 m. Typical terrain consists of isolated granite and volcanic hills and tors in flat to gently undulating sand plains (Fig. 4).



PHYSIOGRAPHIC DIVISIONS	GEOMORPHOLOGICAL UNITS
ISA HIGHLANDS	Immaturely dissected plateaux, ridges and high plains
	Maturely dissected hill country
CARPENTARIA AND INLAND PLAINS	Plains of erosion

Drainage Divide

FIG 2 . Physiographic and Geomorphological Sketch Map, Prospector 1:100 000 Sheet area.

Fig. 3.
The Isa Highlands, represented by rugged ridges of Ballara Quartzite and maturely dissected (black) hills of Corella Formation in the valley to the right; south-east corner of Prospector Sheet area. M1499/13 IHW.

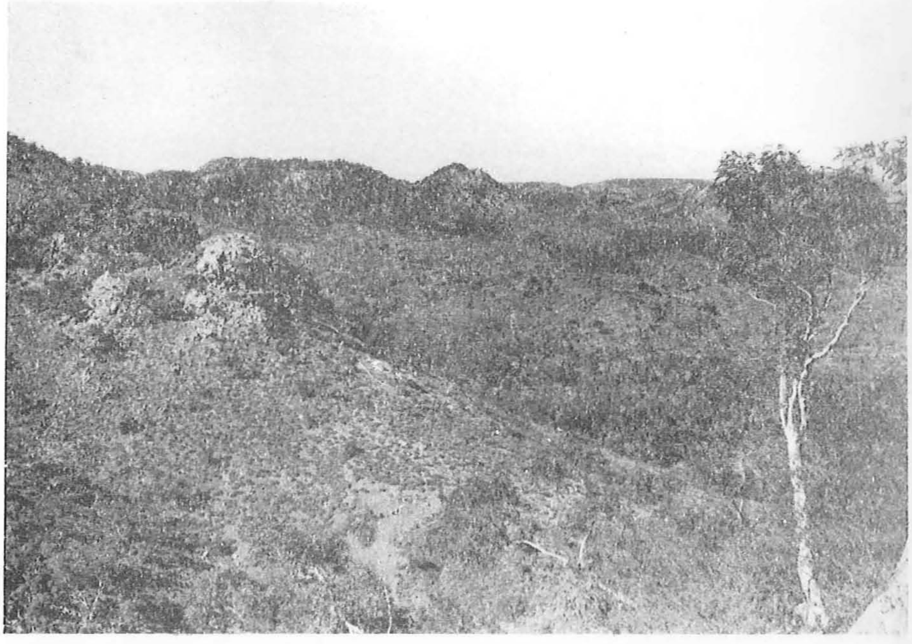


Fig. 4.
Leichhardt River valley, part of the Carpentaria and Inland Plains physiographic division, viewed from the east in the southern part of the Sheet area. The floor of the valley is underlain by Leichhardt Metamorphics and Kalkadoon Granite. The distant ridges are Surprise Creek Beds; the sharp ridge to the right is a silicified segment of the Mount Remarkable Fault. M1509/16 IHW.

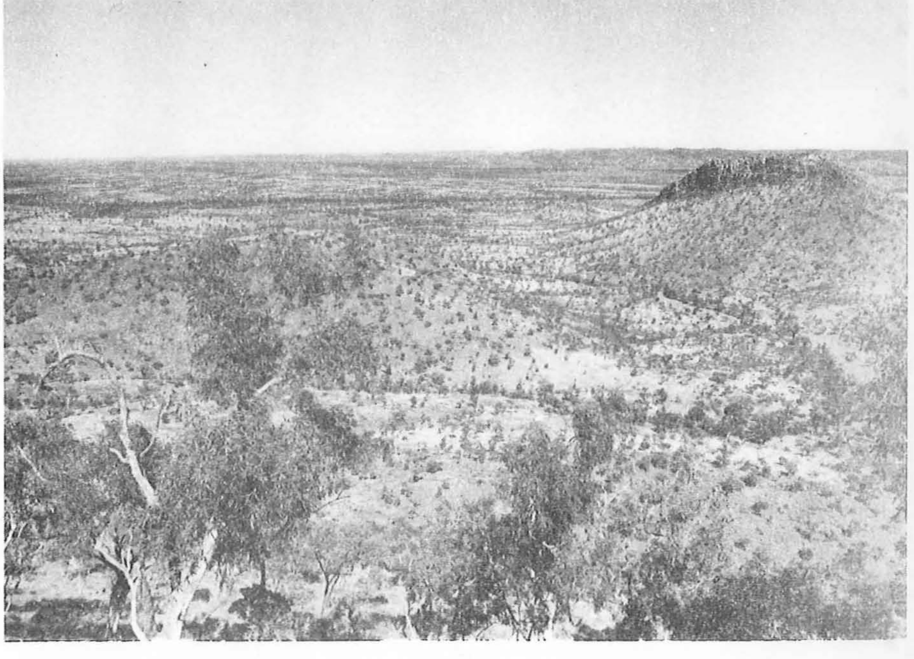
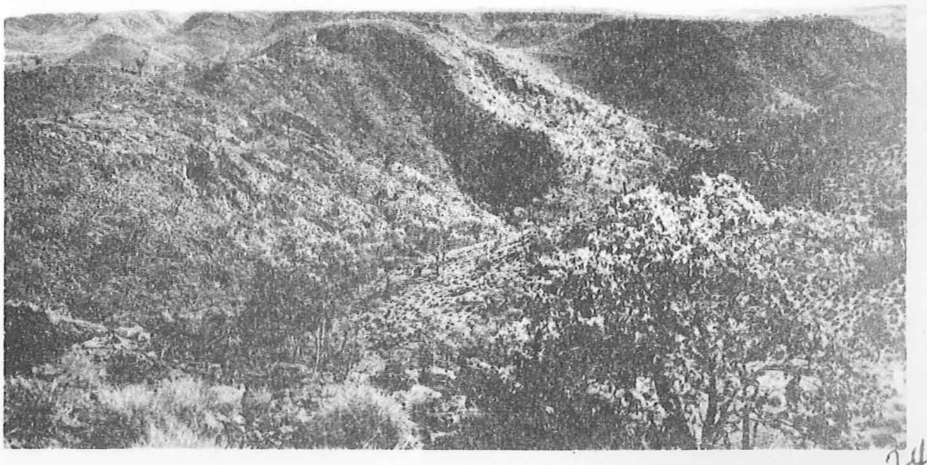


Fig. 5.
Dissected Early to mid-Tertiary erosion surface developed on quartzite units of the Myally Subgroup 25 km south-southwest of Julius Dam. M1507/8 IHW.



Erosion surfaces

Three erosion surfaces are recognized by Twidale (1964):

(a) the pre-mid-Mesozoic surface
(b) the Early to mid-Tertiary surface
(c) the late Tertiary-Quaternary surface

These are all believed to have been peneplains, and all contribute in some measure to the present configuration of the land surface; the prominent Early to mid-Tertiary surface is best illustrated by the planated surface developed on steeply dipping quartzites (Fig. 5).

Land systems

These are described fully by Perry (1964). Those which occur in the Prospector Sheet area are the Kuridala, Argylla, and Quamby land systems.

Drainage

A major drainage divide trends northeast across the southeast corner of the Sheet area; it separates the Cloncurry River drainage to the southeast from the Leichhardt River drainage to the northwest.

Most of the major streams are superimposed, and cut across the regional 'grain' of the country. The Leichhardt River, in a stretch between Glenroy and Gereta, consists of deeply entrenched meanders cutting across resistant quartzite ridges; Cromwell and Paroo Creeks also meander across resistant quartzites. Twidale (1964) believes these streams originated on the planated Early to mid-Tertiary land surface. Minor tributary streams are subsequent, being controlled by structure and lithology.

LOWER PROTEROZOIC? TO CARPENTARIAN STRATIGRAPHY

Introduction

The Precambrian rocks of the Prospector Sheet area form part of the Cloncurry Complex, which Carter et al. (1961, p. 58) redefined to include all rocks in northwestern Queensland older than the Upper Proterozoic. Brown, Campbell, & Crook (1968) considered that there was a 'Nullaginian?' basement exposed to the west of Mount Isa (the Yaringa Metamorphics), and that except for minor Adelaidean? basins the remaining Precambrian rocks in the Mount Isa/Cloncurry region were Carpentarian and formed in the Mount Isa Geosyncline. The geosyncline began with volcanism that formed a median ridge which separated the geosyncline into eastern and western troughs. These three divisions of Brown et al. (1968) correspond to the 'tectonic welt', Eastern Geosynclinal Belt, and Western Geosynclinal Basin of Carter et al. (1961). In the Prospector Sheet area the rocks that formed in these environments are called the Kalkadoon-Leichhardt basement succession, the eastern succession, and the western succession respectively.

The Kalkadoon-Leichhardt basement succession consists mainly of metamorphosed acid volcanic and plutonic rocks and minor basic volcanics and sedimentary rocks. The basement forms a north-northeast-trending belt up to 18 km wide that extends from the middle of the southern Sheet area boundary to the north-east corner of the Sheet. It is also exposed as folded or faulted inliers in the western succession near the middle of the Sheet area, and in the eastern succession near the eastern margin of the Sheet area.

The eastern succession occupies most of the eastern quarter of the Sheet area, and is a predominantly metasedimentary sequence containing sandstone, calcareous siltstone, and minor limestone and basic metavolcanics.

The western succession occupies the western half of the Sheet area, and consists of basic metavolcanics, sandstone, siltstone, shale, dolomitic rocks, and minor conglomerate.

Stratigraphic nomenclature in the Sheet area generally follows that of Carter et al. (1961). Groups have been erected on the basis of new stratigraphic data on the regional significance of unconformities, and several new formations and members have been defined. The following alterations to the nomenclature of Carter et al. (1961) have been made. Those alterations asterisked have been made since the Prospector 1:100 000 Preliminary Edition map was printed.

(a) Magna Lynn Metabasalt is a new formation in the basement succession (Derrick, Wilson, & Hill, 1976a).

(b) The Argylla Formation is now mainly acid volcanics; it has been redefined to exclude a conglomerate-quartzite sequence which unconformably overlies the acid volcanics (Derrick et al., 1976a).

(c) The conglomerate-quartzite sequence in (b) is now considered to be the northern continuation of the Ballara Quartzite, and has been divided into two informal members (Derrick et al., 1976a, 1977a).

(d) The Corella Formation has been divided into three informal members (Derrick et al., 1977a).

(e) The Deighton Quartzite has been divided into five informal members.

(f) The Eastern Creek Volcanics have been divided into three formal members, the Cromwell Metabasalt Member, the Lena Quartzite Member and the Pickwick Metabasalt Member, which are based on the four subdivisions suggested by Robinson (1968; see Derrick et al., 1976b).

(g) The Myally Beds have been redefined as the Myally Subgroup*, consisting of four formations and one member (Derrick et al., 1976b). The formations proposed are (from youngest to oldest).

Lochness Formation* including the Police Creek Siltstone Member*,
Whitworth Quartzite*,
Bortala Formation*, and
Alsace Quartzite*.

(h) The Surprise Creek Beds have been divided into two parallel, equivalent sequences: a shelf sequence and a trough sequence, consisting of 9 and 12 informal members respectively.

(i) The Mount Isa Shale has been redefined as the Mount Isa Group (c.f. Bennett, 1965; Smith, 1969), incorporating the Warrina Park Quartzite (Derrick, 1974; Derrick et al., 1976c, in press) as the basal formation. This unit was previously called the 'quartzite marker' in the Myally Beds (Bennett, 1965).

(j) The other groups proposed, and the formations represented in the Prospector Sheet area, are: the Haslingden Group, consisting of the Mount Guide Quartzite, the Eastern Creek Volcanics, and the Myally Subgroup and their equivalents; the Tewinga Group, consisting of the Leichhardt Metamorphics, the Magna Lynn Metabasalt, and the Argylla Formation; the Mary Kathleen Group, consisting of the Ballara Quartzite and the Corella Formation; and the Mount Albert Group consisting of the Deighton Quartzite. (Derrick et al., 1976a, b, 1977a, b)

The rocks of the Cloncurry Complex were designated Lower Proterozoic by Carter et al. (1961, p. 129) on evidence provided by a monazite lead-uranium age of 1000-1200 million years (Nier, Thompson & Murphey, 1941; and Holmes & Smales, 1948); the presence of colonial stromatolites; Lower Cambrian fossils in rocks unconformably overlying the Kalkadoon Granite;

TABLE 2. SUMMARY OF PROTEROZOIC STRATIGRAPHY, PROSPECTOR 1:100 000 SHEET AREA

A. KALKADOON-LEICHHARDT BASEMENT.

Group		Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
			do	-	dolerite, metadolerite, amphibolite	intrudes all basement rocks	various ages
	Kalkadoon Granite	undivided	Pgk	-	coarse to medium granite, granodiorite, leucogranite, aplite, gneiss	intrudes Leichhardt Metamorphics; possibly older than Magna Lynn Metabasalt and Argylla Formation;	
	Kalkadoon Granite		Pgk$_2$		coarse to medium muscovite granite, aplite	intrudes granodiorite	
TEWINGA GROUP	Argylla Formation	undivided	Pea	600-1200	porphyritic rhyolite to dacite, tuff, porphyry, andesite, schist, minor metasediment	conformably overlies Magna Lynn Metabasalt; unconformably or disconformably overlain by Ballara Quartzite; intruded by Wonga Granite	
TEWINGA GROUP	Argylla Formation		Pea$_b$	100	metabasalt, minor metasediment	intercalated in porphyritic rhyolite and dacite	mapped only near Mt Razorback
TEWINGA GROUP	Argylla Formation	"porphyry"	h		porphyritic xenolithic microgranite	intrudes Leichhardt Metamorphics and Magna Lynn Metabasalt	mapped only in southeast Sheet area
TEWINGA GROUP	Magna Lynn Metabasalt	undivided	Pem	100-700	metabasalt, amygdaloidal metabasalt, flow-top breccia, amphibolite, agglomerate, minor metasediment	conformably or disconformably overlies Leichhardt Metamorphics; conformably overlain by Argylla Formation	may be younger than Kalkadoon Granite
TEWINGA GROUP	Magna Lynn Metabasalt		Pem$_q$	1-10$^+$	quartzite, metasiltstone	intercalated with basaltic flows	only thicker sequences shown by stipple on map
TEWINGA GROUP	Leichhardt Metamorphics	undivided	Pel	2000$^+$	porphyritic tuffaceous rhyolite, rhyodacite and dacite, andesite, minor agglomerate, minor metasediment	overlain conformably or disconformably by Magna Lynn Metabasalt; intruded by Kalkadoon Granite	oldest rocks known in Sheet area
TEWINGA GROUP	Leichhardt Metamorphics		Pel$_b$	40	amygdaloidal dolerite	intrudes porphyritic volcanics	mapped only near Lillimay mine

B. EASTERN SUCCESSION

Group		Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
			do	-	dolerite, metadolerite, amphibolite	intrudes all units except Deighton Quartzite	various ages
	Wonga Granite	undivided	Pgw	-	foliated coarse porphyritic granite, diorite, granodiorite, leucogranite, gneiss, aplite, pegmatite	intrudes Argylla Formation and probably Corella Formation	a polyphase intrusive of various ages
	Wonga Granite		Pgw$_1$		foliated porphyritic biotite granite, mega-porphyritic foliated granite, gneissic granite		
	Wonga Granite		Pgw$_2$		foliated biotite granite, leucogranite, pegmatite, aplite		

TABLE 2 (contd). SUMMARY OF PROTEROZOIC STRATIGRAPHY, PROSPECTOR 1:100 000 SHEET AREA

B. EASTERN SUCCESSION (continued)

Group	Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
MOUNT ALBERT GROUP	Deighton Quartzite	Ᵽpd$_5$	200+	lithic medium to coarse sandstone	conformably overlies Ᵽpd$_4$	
		Ᵽpd$_4$	100	grey siltstone	conformably overlies Ᵽpd$_3$	
		Ᵽpd$_3$	60	cream fine sandstone	conformably overlies Ᵽpd$_2$	
		Ᵽpd$_2$	150	laminated, grey, slightly calcareous siltstone	conformably overlies Ᵽpd$_1$	
		Ᵽpd$_1$	400	buff fine feldspathic sandstone, quartzite; rare pebbles	disconformably overlies Corella Formation	
MARY KATHLEEN GROUP	Corella Formation undivided	Ᵽkc	-	laminated calcareous siltstone, limestone, calcareous scapolite granofels, sandstone, quartzite, amphibolite, shale	conformably overlies Ballara Quartzite; disconformably overlain by Deighton Quartzite; intruded by Wonga Granite	
		Ᵽkc$_3$	600	laminated calcareous siltstone, limestone, calcareous scapolite granofels, minor metabasalt	conformably overlies Ᵽkc$_2$	
		Ᵽkc$_{3q}$	120	quartzite	lens in Ᵽkc$_3$	shown by stipple on map
		Ᵽkc$_{3r}$	-	calcareous breccia, sheared limestone	irregular, highly deformed zones	
		Ᵽkc$_2$	100	quartzite, metasiltstone, scapolitic siltstone	conformably overlain by Ᵽkc$_3$; conformably overlies Ᵽkc$_1$	
		Ᵽkc$_1$	300-1000	laminated calcareous siltstone, limestone, shale, calcareous, scapolitic granofels	conformably overlies Ballara Quartzite	a gradational contact with the Balara Quartzite
	Ballara Quartzite undivided	Ᵽkb	300-500	quartzite, micaceous quartzite, minor pebble beds	unconformably or disconformably overlies Argylla Formation; conformably overlain by Corella Formation	
		Ᵽkb$_2$	300-500	quartzite, micaceous quartzite	conformably overlies Ᵽkb$_1$	
		Ᵽkb$_{2t}$	0-200	laminated siltstone, minor shale	lens in Ᵽkb$_2$	only mapped in south
		Ᵽkb$_{2l}$	0-200	limestone, ferruginous siltstone	lens in Ᵽkb$_2$	only mapped in southeast
		Ᵽkb$_1$	0-300	arkose, grit, cobble and boulder conglomerate	unconformably overlies Argylla Formation; conformably overlain by Ᵽkb$_2$	lenticular

TABLE 2 (contd). SUMMARY OF PROTEROZOIC STRATIGRAPHY, PROSPECTOR 1:100 000 SHEET AREA

C. WESTERN SUCCESSION

Group	Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
		do	-	dolerite, metadolerite, amphibolite	intrudes all units except Surprise Creek Beds and rare in Mount Isa Group	various ages
Surprise Creek Beds	undivided	Ꝑr	-			equivalent to lower Mount Isa Group
		Ꝑr$_{H}$	275+	grey pyritic and dolomitic siltstone	conformable on Ꝑr$_{G}$	
		Ꝑr$_{G}$	200	grey shale and siltstone	" " Ꝑr$_{F}$	
		Ꝑr$_{F}$	300	laminated red and grey siltstone, shale, dolomitic siltstone	" " Ꝑr$_{E}$	
		Ꝑr$_{E}$	200	feldspathic and quartzose sandstone and quartzite, conglomerate, siltstone	" " Ꝑr$_{D}$	
		Ꝑr$_{D}$	280-350	siltstone, shale, flaggy fine sandstone	" " Ꝑr$_{C}$	shown by screen on map
		Ꝑr$_{C}$	25-80	feldspathic quartzite, green-grey siltstone	" " Ꝑr$_{B}$	
		Ꝑr$_{B}$	56-140	grey-buff siltstone, laminated sandstone	" " Ꝑr$_{A}$	
		Ꝑr$_{A}$	75-300	feldspathic quartzite, cobble & boulder conglomerate	locally unconformable on Ꝑr$_{Z}$ and Ꝑr$_{M}$	shown by screen on map
		Ꝑr$_{M}$	200-500	conglomerate, arkosic grit, feldspathic quartzite, shale and siltstone	unconformable on Ꝑea, Ꝑgk; unconformably overlain by Ꝑr$_{A}$	includes units Ꝑr$_{W}$, Ꝑr$_{X}$, Ꝑr$_{Y}$, Ꝑr$_{Z}$
		Ꝑr$_{Z}$	120	feldspathic sandstone, marl, siltstone, limestone	conformable on Ꝑr$_{Y}$	
		Ꝑr$_{Y}$	85-115	feldspathic quartzite, sandstone, pebbly sandstone, minor shale and siltstone	" " Ꝑr$_{X}$	shown by screen on map
		Ꝑr$_{X}$	170-200	feldspathic sandstone, shale, siltstone	" " Ꝑr$_{W}$	
		Ꝑr$_{W}$	315-435	arkosic grit, feldspathic quartzite, grey siltstone	unconformable on Ꝑea, Ꝑgk	shown by screen on map, possibly equivalent to Ballara Quartzite
		Ꝑr$_{8}$	70+	feldspathic quartzite	conformable on Ꝑr$_{7}$	
		Ꝑr$_{7}$	90	ferruginous siltstone & shale, minor grit, pebbly greywacke, feldspathic quartzite	" " Ꝑr$_{6}$	
		Ꝑr$_{6}$	80	ferruginous quartzite, conglomerate grit, siltstone	" " Ꝑr$_{5}$	
		Ꝑr$_{5}$	190	fine ferruginous sandstone, pale green shale, siltstone, phyllite	" " Ꝑr$_{4}$	

TABLE 2 (continued). SUMMARY OF PROTEROZOIC STRATIGRAPHY, PROSPECTOR 1:100 000 SHEET AREA

C. WESTERN SUCCESSION (continued)

Group	Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
Surprise Creek Beds (contd)		Er_4	380-530	brown conglomeratic sandstone, minor shale & siltstone	conformable and disconformable on Er_3	shown by screen on map. Base of Er_4 marks regional unconformity.
		Er_3	80-190	purple-grey shale, siltstone, calcareous siltstone, micaceous sandstone, limestone, dolomite	conformable on Er_2	
		Er_2	250-750	feldspathic quartzite, orthoquartzite, minor siltstone	" " Er_1	
		Er_1	120-525	ferruginous feldspathic sandstone, quartzose and stromatolitic dolomite, oolitic siltstone, dolarenite	" " Er_0	
		Er_0	100?-540	ferruginous sandstone, feldspathic quartzite, shale, arkosic grit	conformable or disconformable on Ehm_4 or Ehm_5	
MOUNT ISA GROUP	Native Bee Siltstone	Ein	500+	bedded dolomitic siltstone	conformably overlies Eib	
	Breakaway Shale	Eib	150-200	grey shale, minor siltstone	conformably overlies Eim;	
	Moondarra Siltstone	Eim	500	dolomitic siltstone, siltstone	conformably overlies Eiw	
	undivided	Eiw	35-575	quartzite, feldspathic quartzite, conglomerate	unconformably overlies Myally Subgroup and 'Mammoth Formation' equivalents	mostly Eiw_3, but may include some Eiw, & Eiw_2
	Warrina Park Quartzite	Eiw_3	35-300	orthoquartzite, conglomerate		shown by screen on map
	'Mammoth Formation' equivalents	Eiw_2	0-400	ferruginous siltstone and sandstone, minor limestone	conformably overlies Eiw_1, unconformably overlies Myally Subgroup; overlain unconformably by the Warrina Park Quartzite	formerly part of Warrina Park Quartzite
		Eiw_1	0-160	fine ferruginous sandstone, feldspathic sandstone	unconformably overlies Myally Subgroup; conformably overlain by Eiw_2	" "

TABLE 2 (contd). SUMMARY OF PROTEROZOIC STRATIGRAPHY, PROSPECTOR 1:100 000 SHEET AREA

C. WESTERN SUCCESSION (continued)

Group	Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
HASLINGDEN GROUP — Myally Subgroup	undivided	Ᵽhm		sandstone, siltstone, shale, minor acid volcanics	conformably overlies Eastern Creek Volcanics; unconformably overlain by Mount Isa Group	
	Police Creek Siltstone Member	Ᵽhm$_5$	0-400	siltstone, phyllite, rhyolitic tuff	a member at top of Ᵽhm$_4$	
	Lochness Formation	Ᵽhm$_4$	400-1200	ferruginous sublabile and calcareous sandstone, purple siltstone, oolitic dolomite, quartzose dolomite	conformably overlies Ᵽhm$_3$; conformably or disconformably overlain by Surprise Creek Beds	
	Whitworth Quartzite	Ᵽhm$_3$	400-2000	massive feldspathic and micaceous quartzite, pebbly sandstone	conformable with Ᵽhm$_2$ and Ᵽhm$_4$	
	Bortala Formation	Ᵽhm$_2$	80-700	highly labile feldspathic sandstone, quartzose sandstone, ferruginous siltstone, chert	conformable with Ᵽhm$_1$ and Ᵽhm$_3$	
	Alsace Quartzite	Ᵽhm$_1$	70-600	orthoquartzite, feldspathic (sub-labile) quartzite, minor siltstone	conformably overlain by Ᵽhm$_2$; conformably overlies Eastern Creek Volcanics	
HASLINGDEN GROUP — Eastern Creek Volcanics	undivided	Ᵽhe		metabasalt, amygdaloidal metabasalt, quartzite, tuff	conformably overlies Mount Guide Quartzite and Leander Quartzite; conformably overlain by Myally Subgroup	
	Pickwick Metabasalt Member	Ᵽhp	up to 1500	metabasalt, amygdaloidal metabasalt, flow-top breccia, minor tuff	conformably overlies Ᵽhl, conformably overlain by Myally Subgroup	
		Ᵽhp$_q$		epidote sandstone, quartzite	lenses in Ᵽhp	shown as stipple on map
	Lena Quartzite Member	Ᵽhl	up to 700	quartzite, feldspathic quartzite, minor shale at base	conformable with Ᵽhc and Ᵽhp	
	Cromwell Metabasalt Member	Ᵽhc	up to 6000	metabasalt, amygdaloidal metabasalt, flow-top breccia, minor tuff	conformably overlies Mount Guide Quartzite and Leander Quartzite; conformably overlain by Ᵽhl	
		Ᵽhc$_q$	0-100	epidote sandstone, quartzite, conglomerate	lenses in Ᵽhc	shown by stipple on map
		Ᵽhc$_t$	0-150	siltstone, calcareous or dolomitic siltstone	lenses in Ᵽhc	

TABLE 2 (contd). SUMMARY OF PROTEROZOIC STRATIGRAPHY, PROSPECTOR 1:100 000 SHEET AREA

C. WESTERN SUCCESSION (continued)

Group	Rock Unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
HASLINGDEN GROUP	Mount Guide Quartzite	Ehg$_2$	1000+	quartzite, feldspathic quartzite	unconformably overlies Leichhardt Metamorphics (south of Sheet area); conformably overlain by Eastern Creek Volcanics	only minor outcrop in southwest
	Leander Quartzite	Ehq$_1$	600+	orthoquartzite, quartzite	conformably overlain by Eastern Creek Volcanics; base of formation not exposed	

and the apparently continuous sedimentation from the Leichhardt Metamorphics to the Lawn Hill Formation. Subsequent Rb-Sr age determinations have yielded ages for the basement block ranging from 1930? to 1650 m.y., and have shown that the granites intruding the western and eastern successions are as young as 1540 m.y. and 1450 m.y. respectively. (Richards, 1966; Farquharson & Wilson, 1971; Page & Derrick, 1973). Thus the Complex contains rocks of the Carpentarian System (1800-1400 m.y.) as defined by Dunn, Plumb & Roberts (1966). Plumb & Derrick (1975) place the base of the Carpentarian System at 1770 ± 20 m.y. from work on the Cliffdale Volcanics in the Westmoreland area. Geochronological work is continuing.

In the following sections, the stratigraphy of the basement, eastern succession, and western succession will be described separately in ascending stratigraphic order, where possible; the acid plutonic rocks and the basic intrusives are described in a later section. The stratigraphy of the Sheet area is summarized in Table 2.

A. STRATIGRAPHY OF THE KALKADOON-LEICHHARDT BASEMENT

TEWINGA GROUP

Leichhardt Metamorphics

Introduction

The Leichhardt Metamorphics are named after the Leichhardt River, which flows through the central and northeastern parts of the Prospector Sheet area. Carter et al. (1961) discussed the previous classification of these metamorphic rocks, and formerly defined the formation with reference to a type area which extended for 8 km westward along the track from the Referee copper mine (798 532) to the gorge on Doughboy Creek (718 524). They considered that the formation was highly to moderately metamorphosed, recrystallized, and locally migmatized or granitized.

Although the formation has been regionally metamorphosed in the greenschist and lower amphibolite facies it contains rocks with well preserved primary textures. The rocks are predominantly porphyritic acid volcanics; sedimentary rocks are extremely rare. Areas of more deformed rocks are restricted to the vicinity of the Kalkadoon Granite intrusions and major fault zones.

In the Prospector Sheet area the formation is exposed in the centrally located Kalkadoon-Leichhardt basement block. It is generally poorly exposed on low undulating plains, but towards the east it forms rugged bouldery hills and low plateaux. The total area of exposure of the Leichhardt Metamorphics in the Sheet area is 315 km^2.

Stratigraphic relations

The Leichhardt Metamorphics contain the oldest rocks exposed in the Sheet area. They are overlain with apparent conformity by the Magna Lynn Metabasalt, and are intruded by the Kalkadoon Granite, porphyry dykes of the Argylla Formation, and swarms of dolerite dykes. Current work in the Duchess area, to the south, indicates that a significant time-break may exist between the metamorphics and the overlying Magna Lynn Metabasalt (R. Bultitude, pers. comm.).

Since the base of the formation is not exposed, and deformation has been intense, the true thickness of the Leichhardt Metamorphics is not known. A minimum thickness of 2000 m occurs near Mount Olive and thicker sequences are probable in the large exposures in the northeast of the Sheet area.

Lithology and field occurrence

Most of the Leichhardt Metamorphics consist of metamorphosed porphyritic dacite or rhyodacite which are typically medium grey, bluish grey, or greenish grey, and only rarely pink in colour (cf. the Argylla Formation). The phenocrysts are 1-5 mm long and composed of bluish rounded quartz, abundant greenish euhedral plagioclase, and less abundant pinkish euhedral microcline in a very fine-grained quartzofeldspathic matrix. Biotite flecks and mafic clots occur in some specimens. Lapilli, ash-flow, and ash-fall tuffs are present throughout the formation, and display a primary foliation defined by flattened volcanic clasts and eutaxitic textures, and variations in the quartz and feldspar phenocryst content. Spherulites are present in rhyolites from the northeast of the Sheet area.

Thin layers of pale grey to cream very fine-grained slightly porphyritic banded volcanics occur towards the top of the formation. These rocks are partly silicified rhyolites. East and southwest of the Lillimay copper mine extensive areas of grey, cleaved fine-grained andesite? are associated with grey laminated rocks which may be tuffs or water-laid sediments. In the same area, cycles of agglomerate-thick porphyritic dacite-thin laminated rhyolite have been observed.

Outcropping sediments include: grey water-laid tuff and siltstone immediately north of the eastern end of the Lillimay lode; epidotitized sandstone one kilometre west of the Lillimay copper mine; quartzite in the northeast corner of the Sheet area; and ferruginous biotitic quartzofeldspathic rocks near the Great Northern copper mine (860 710).

A north-trending belt of amygdaloidal basic rock immediately west of the Lillimay copper mine contains foliated epidote-quartz rocks which were thought to be metasediments. This unit is shown on the Prospector Preliminary Edition 1:100 000 map as Pel_b and described as amygdaloidal basalt, but it is now thought to be a contaminated amygdaloidal high-level dolerite.

Adjacent to the Kalkadoon Granite the volcanics are recrystallized. Xenoliths in the Kalkadoon Granite become medium to coarse-grained, feldspar phenocrysts are recrystallized, and gneissic layering is prominent (Fig. 6). Along faults and shear zones the volcanic rocks are commonly phyllonitic.

Petrography

About 100 specimens from this formation have been examined petrographically; they have all been metamorphosed to some extent. Many specimens show well preserved primary volcanic textures consisting of undeformed phenocrysts in a microcrystalline groundmass. The composition of these rocks is summarized by plots in quartz-alkali feldspar-plagioclase triangular diagrams. The more highly deformed rocks are schistose or gneissose, and appear to be highly altered as a result of metasomatism accompanying the metamorphism. Estimated modal compositions of selected specimens are listed in Table 3; the specimens are plotted on a QAP diagram (Fig. 7).

The porphyritic acid volcanic rocks contain phenocrysts and fragments of quartz, plagioclase (albite to andesine), and potash feldspar up to 5 mm long. The phenocrysts tend to be euhedral, and the quartz crystals are typically subrounded embayed bipyramids. Clots of biotite, chlorite, sphene, and opaques up to 2 mm across occur in some specimens. The groundmass is mostly a very fine-grained (0.01 to 0.03 mm) mosaic of quartz and microcline with varying amounts of plagioclase. Accessory minerals are zircon, tourmaline, apatite, opaques, sphene, and calcite; the last two are probably of metamorphic origin.

The least altered rocks show minute flakes of muscovite in the feldspar phenocrysts and in the groundmass, chlorite-biotite-opaque clots probably pseudomorphous after ferromagnesian phenocrysts, and mortar texture in the quartz and feldspar phenocrysts. In higher-grade rocks the phenocrysts are fractured, strained, and recrystallized; microcline has replaced some plagioclase phenocrysts, liberating calcium in the form of calcite; minute epidote, calcite, and muscovite crystals have

TABLE 3. ESTIMATED MODAL ANALYSES, LEICHHARDT METAMORPHICS

Rock No.	Phenocrysts C	K	P	Groundmass q	k	p	mu	ca	bi	ch	Accessories	a.g.d.	Name
0141				30	50	10	3			5	2op		Metarhyolite
0151				40	35		15				7ep, 2sp, 1op, ap		"
4212				40	32	10	10	tr	18		op, sp, ep	0.2	"
4134	7	2	6	1[illegible]	47	1	17	1			op	0.03	Altered porphyry
4135	9	10	1	13	62	tr	4	1	1		op, sp	0.02	Sheared porphyry
4137	2	4	1	26	56	tr	9	2	tr			0.03	Rhyolite
4135	7	10	2	22	39	tr	18	tr	2			0.03	Porphyritic rhyolite
4132	5	9	9	18	30	1	10	1	9		to, sp, op	0.03	" "
4214	8	9	6	16	50	1	8	1	1		op	0.02	" "
4216	5	10	17	15	34	2	6	1	10		op	0.02	" "
R5916*	10	6	4	20	45	6	4		1		1sp, 1ac, op	-	" "
R5936	12	8		26	40	1	3	1	5		4ep, op	0.15	" "
0040	15	8	7	-(30)	-		20		10		2sp, 1to, 2op, 5ep	-	" "
0065	20	15	5	- (53)	-				3	2	2op	-	" "
0066	10	20	15	-(40)	-		1		7		2op, 3ep, 1sp, 1zr	-	" "
0070	30	20	10	-(25)	-		2		7		2op, 2to, 1ca, 1zr	-	" "
R5937	10	25	5	15	25	12	3		3		2ep	0.03	Metarhyolite
R5941	16	12	2	35	25	6	1		2		1op	0.15	"
R5942	6	10	4	24	36	13	2		3		2ep, al, sp	0.07	"
R5952	5	15		25	45	5	3				2ep, op, sp	0.08	"
R5953				30	45	18				2	2al, 1ep, 1sp, 1op	0.1	"
R5954	5	4	20	20	40	5			5	tr	1op, ep, sp, to	0.1	"
4102	5	5	12	16	30	28			4		op		Rhyodacite

Rock No.	Phenocrysts Q	K	P	Groundmass q	k	p	mu	ca	bi	ch	Accessories	a.g.d.	Name
4103	2	5	10	20	30	30			3		op		Rhyodacite
4128	9	1	31	17	31	3	2	1	5	tr		0.02	Porphyritic rhyodacite
4129	1	tr	17	20	18	3	27	2	12		sp,zr	0.02	" "
4130	6	5	18	17	30	4	9	1	10		zr	0.02	" "
4131	4	tr	18	18	34	5	10	4	7		zr,sp	0.03	" "
4133	7	8	32	16	15	4	16	2			op,sp,zr	0.02	" "
4179	3	tr	17	16	38	2	8	2	14		op,ep	0.03	" "
R5584	5	12	13	20	36	5			6		3ep,ap	0.03	" "
R5932	10	12	18	18	15	10	2		15	tr			" "
R5574	5	6	12	15	4	45			10		2ep,1op,sp,zr	0.02	Porphyritic dacite
R5575	3	6	21	20	4	30	3		7		4ep,2op,1sp,to,zr	0.03	" "
0041	25		20	15	-(10)-		18		10		2 op		" "
0042	10		20	30			15		15		2to,2sp,3op,2ep,1hb		" "
R5933	10		25	14	10	20			10	3	4op,2op,1sp,to,zr	0.05	Metadacite
R5943	1		14	30	20	30			3		2ep,al,op	0.07	"
R5934	6	3	21	20	17	23	2		6		2ep,zr,al	0.03	Porphyritic metadacite
R5958	10		25	30	10	25	8	tr	3	2	3ep,1op	0.15	" "
R5959	10	5	20	20	5	25	4		7	tr	4ep,to	0.05	" "
R5960	5	5	15	27	5	30	3		8	tr	2ep,op		" "
R5965	5		15	20		40	2		17		ep,sp		" "
R5967	10	5	20	15		27		tr	15		5ep,2sp,1op,zr		" "
R5966				25	18	40	5			4	4ep,3op,1sp	0.02	Dacite
4185	1		2	10	5	55	5	10	7		3ep,2op,ap	0.03	Andesite
4186				8	3	45	26	3	7		6op,2ep	0.03	"
R5935				12		24	32		15	10	4ep,3op	0.1	"

TABLE 3. Page 3

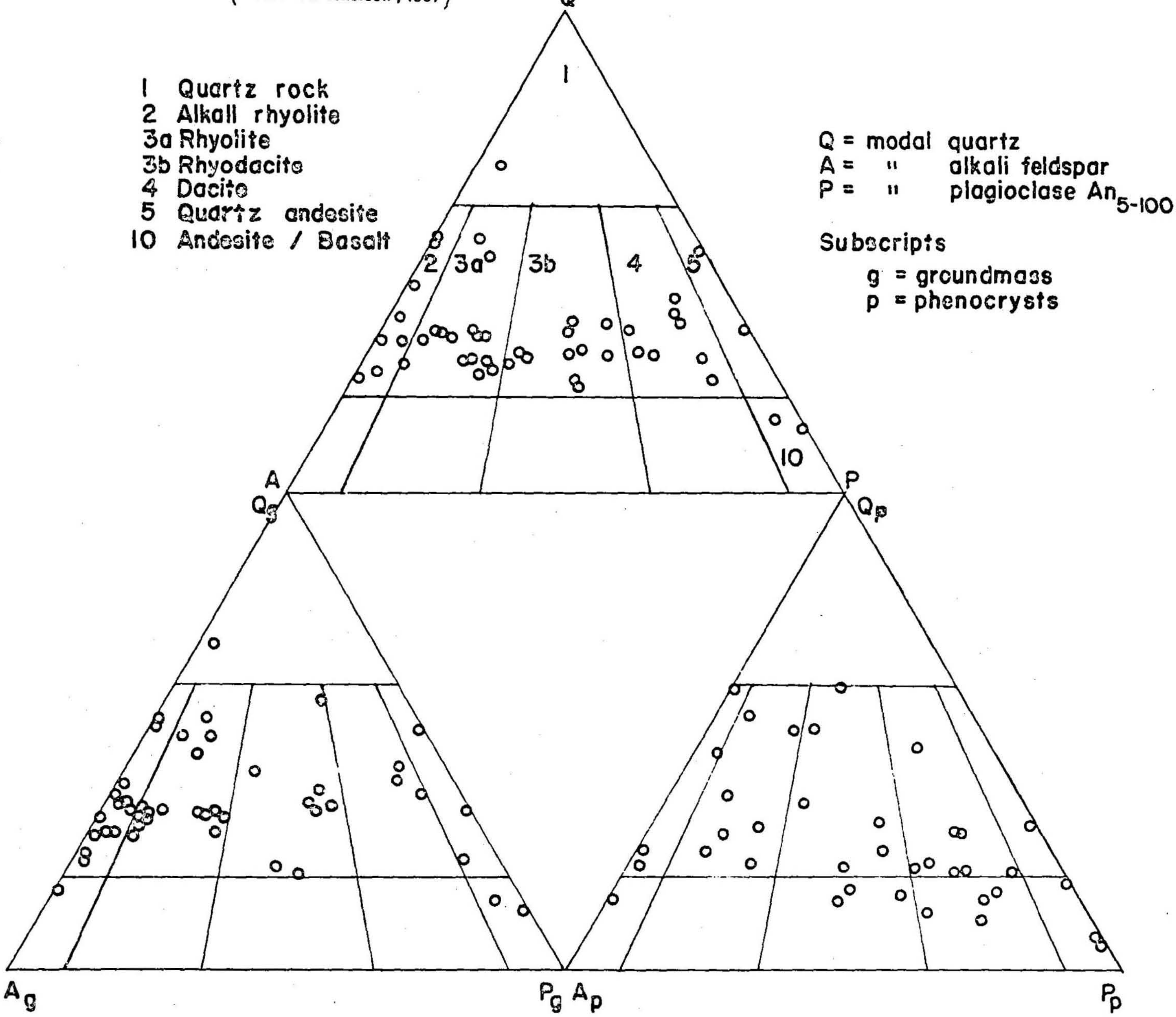
Rock No.	Phenocrysts Q	K	P	Groundmass q	k	p	mu	ca	bi	ch	Accessories	a.g.d.	Name
4174				2		14	14			(40ac)	7ep,18ap,5op,ap		Amygdaloidal dolerite
0061				98		1					1op	0.1	Quartzite
R5582				2		tr			tr	78	15ac,5op,zr	0.1	Amphibolite
4127	3	2	1	17	55	2	4	6	10		op,sp	0.01	Rhyolitic tuff
4178	5	8	7	18	13		20	5	7		1op (Clasts 16)	0.01	Ignimbrite ?

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

* R 0000 are GSQ rock numbers.

FIG. 7. CLASSIFICATION OF LEICHHARDT METAMORPHICS BY QAP DIAGRAM

(after Streckeisen, 1967)



Record 1977/4

F54/A2/170

grown within other plagioclase phenocrysts; opaque grains are altered to sphene; the groundmass has developed a mottled texture owing to the porphyroblastic growth of feldspar grains and the coarsening of other minerals; and the elongation and recrystallization of phenocrysts into lenticular fine-grained (0.05 to 0.1 mm) mosaics, and the development of a lepidoblastic texture by the micas - especially biotite - define a metamorphic foliation. In the highest grades, the rocks display a granoblastic to granuloblastic texture (average grain diameter 1.0 mm) that resembles the texture of microgranite; banding is typical of these rocks.

Pyroclastic (fragmental) rocks contain elongate lenticular and fiamme-shaped volcanic fragments, up to 10 cm long and 1 cm thick, which are mostly porphyritic and more mafic-rich than the enclosing poorly sorted porphyritic volcanic matrix; other fragments are very fine and even-grained volcanic? material.

The few specimens of fine-grained non-porphyritic volcanics examined are generally grey finely laminated dacite or andesite which have an even-grained texture and a poorly defined foliation. Plagioclase, the predominant mineral, forms a granoblastic mosaic with an average grain diameter of about 0.03 mm. Quartz, alkali feldspar, muscovite, calcite, epidote, biotite, and opaque minerals are minor constituents. In zones of severe metamorphism or intensive shearing these rocks are altered to grey schists containing strongly aligned muscovite, biotite and/or chlorite, and minor flakes of opaque minerals and sphene with intergranular quartz and feldspar grains up to 0.2 mm in diameter.

The metasediments are mostly fine-grained labile arenites. A specimen from near the Great Northern Copper mine contains quartz, plagioclase, and biotite (altering to chlorite); quartz grains form a granuloblastic mosaic and the strongly aligned biotite defines a foliation. Minor minerals are calcite, sphene, epidote, hornblende, and opaques. A specimen (73204176) from west of the Lillimay copper mine consists predominantly of poorly sorted subrounded strained or indented quartz grains from 0.3 to 1 mm in diameter in a granoblastic matrix of calcite, epidote, actinolite, quartz, muscovite, chlorite, and minor opaque minerals. The sediments from north of the Lillimay copper mine are fine-grained (agd 0.05 mm), poorly sorted, and composed of quartz, microcline, plagioclase grains, and biotite clots in a matrix of muscovite, calcite, and quartz.

Discussion

The Leichhardt Metamorphics were originally a sequence of acid volcanic rocks with minor intercalations of arenite. The very broad extent of the volcanics, their high phenocryst content, and the presence of graded layering, eutaxitic texture, and volcanic fragments of various types and sizes - all suggest the Metamorphics are a metamorphosed sequence of agglomerate, crystal tuff, ash-flow, and ash-fall deposits rather than a pile of acid lava. Other diagnostic features, such as shards, have possibly been obliterated during metamorphism.

Magna Lynn Metabasalt

Introduction

The Magna Lynn Metabasalt is named after the Magna Lynn copper mine in the Mary Kathleen 1:100 000 Sheet area (Derrick et al., 1976a, in press). It consists of a sequence of metabasalt, tuff, and metasediment exposed discontinuously as linear belts in the Kalkadoon-Leichhardt basement block. Faulting has repeated the generally east-facing sequence to form several north-trending belts up to 1 km wide. Some of the amphibolites in the east of the Sheet area near the Wonga Granite may be highly metamorphosed equivalents of this formation. The total area of exposure in the Sheet area is 40 km^2.

44

The Magna Lynn Metabasalt is exposed in broad gently undulating valleys; quartzite intercalations form low strike ridges.

Stratigraphic relations

The Magna Lynn Metabasalt overlies the Leichhardt Metamorphics with apparent conformity and is overlain conformably by the Argylla Formation. It is intruded by Argylla Formation porphyry and swarms of dolerite dykes and sills. Evidence from the Duchess area, to the south, suggests the Magna Lynn Metabasalt overlies the Leichhardt Metamorphics unconformably (R. Bultitude, pers. comm., 1976).

The thickness of the formation ranges from about 100 m in the north to 700 m in the south of the Sheet area.

Lithology and field occurrence

Two units of the Magna Lynn Metabasalt have been mapped, Ꞓem and $Ꞓem_q$. Ꞓem is the most widespread and consists of metamorphosed basalt, amygdaloidal basalt, basic tuff and minor sedimentary intercalations. $Ꞓem_q$ comprises the larger, generally quartzitic, metasedimentary intercalations. Geological sections of the formation are presented in Fig. 8.

Unit Ꞓem. Metabasalt occurs as flows, 5 to 20 m thick, which contain dark green to bluish black massive fine-grained metabasalt in their centres and towards the bottom, and amygdaloidal zones in the upper part and less commonly at the base. The upper amygdaloidal or vesicular zones are also marked by flow-top breccia and metabasalt/sediment mixes in which the basaltic blocks are mostly highly vesicular or amygdaloidal and epidotized. The sediment is mostly fine-grained epidote quartzite or metasiltstone.

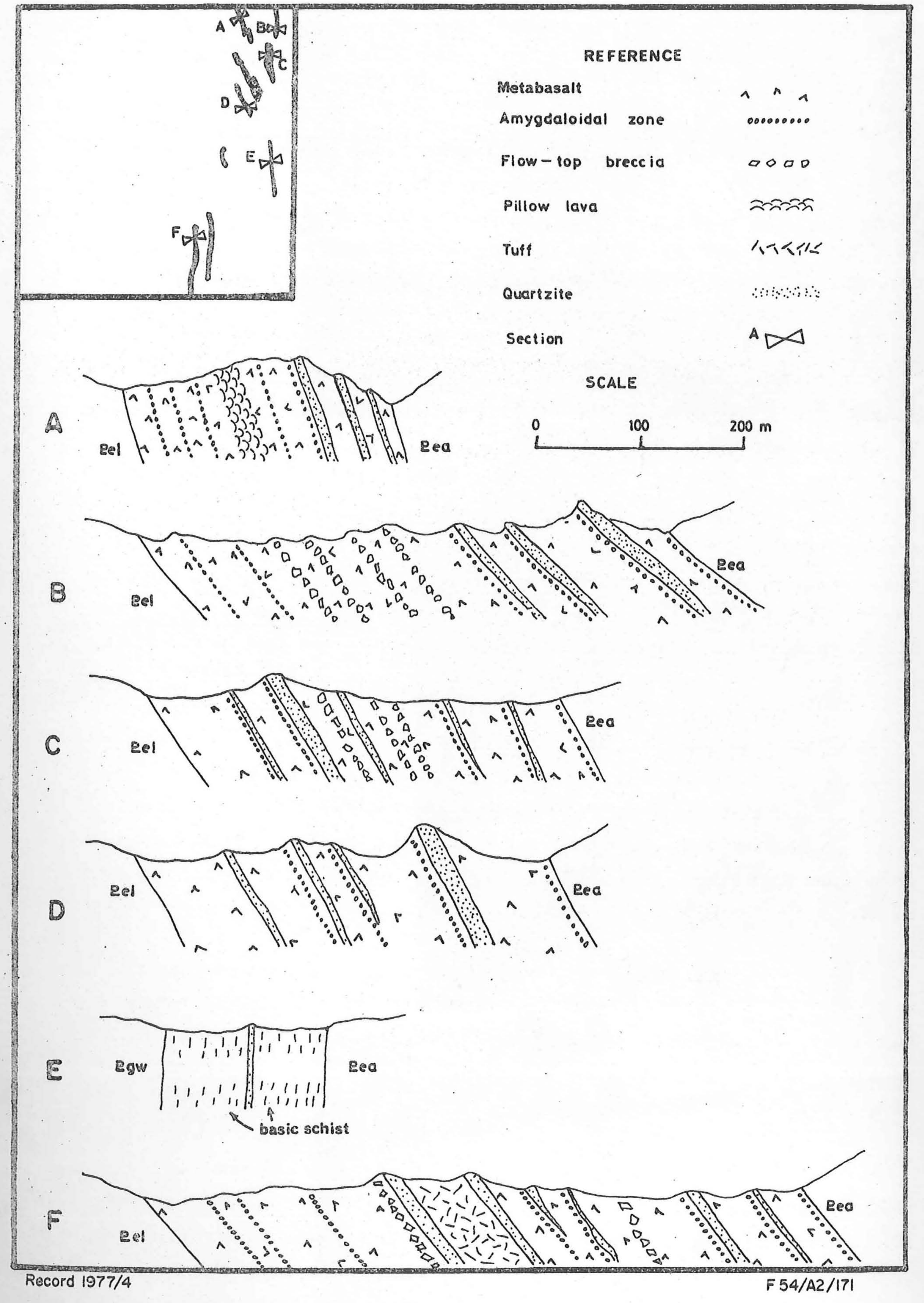
Amygdales in the more massive flow tops are up to 10 cm across (Fig. 9), but most amygdales are from 3 to 6 mm in diameter, and contain quartz, epidote, chlorite, and some calcite. The metabasalt is fine-grained, but microphenocrysts of plagioclase, minute porphyroblasts of amphibole, and blebs of pyrite and chalcopyrite have been observed.

Basic tuff, calcareous mafic-rich siltstone, and possibly pillow lavas occur towards the middle of the formation. At one locality, 4 km north of the Lillimay copper mine, hyaloclastic?' rocks crop out in a basic tuff sequence. They are dark fine to medium rocks containing spherical concentrically zoned structures 10 to 40 cm in diameter (Fig. 10). The cores of these structures range from basic compositions (some containing quartz 'amygdales'), to biotite-quartz-epidote assemblages, to highly siliceous compositions (Fig. 11).

Basic tuff in the formation contains up to 20 percent of angular fragments of fine-grained metabasalt from 1 to 10 mm long in a poorly sorted sand-sized matrix of dark volcanic ash. The tuff is poorly stratified and forms units 1 to 2 m thick. Some graded bedding is present, and tuff commonly grades upward into laminated labile siltstone and calcareous fine-grained sandstone. Some porphyritic dacitic tuff is also present.

The siltstone and sandstone units are mainly lenticular and less than one metre thick. They display parallel lamination and cross-stratification, and contain variable amounts of basic volcanic detritus - mainly ferromagnesian minerals, quartz, feldspar, calcite, and epidote.

Unit Ɛem$_q$ is mapped in the northeast of the Sheet area, where it marks the top of the formation. Similar but smaller lenticular quartzite beds occur in the upper and lower parts of the formation in most localities and their thickness rarely exceeds 10 m. The sedimentary units are typically lithic near their base and grade upward through sublabile beds into orthoquartzite. The labile quartzites are brown, green or buff,



Record 1977/4

F 54/A2/171

FIG. 8 SECTIONS THROUGH THE MAGNA LYNN METABASALT IN THE PROSPECTOR SHEET AREA

Fig. 8.
Strongly crenulated acid gneiss from a large xenolith in the Kalkadoon Granite 5.7 km southwest of Mount Olive copper mine. Gneiss is probably highly altered Leichhardt Metamorphics. M1509/32 IHW.

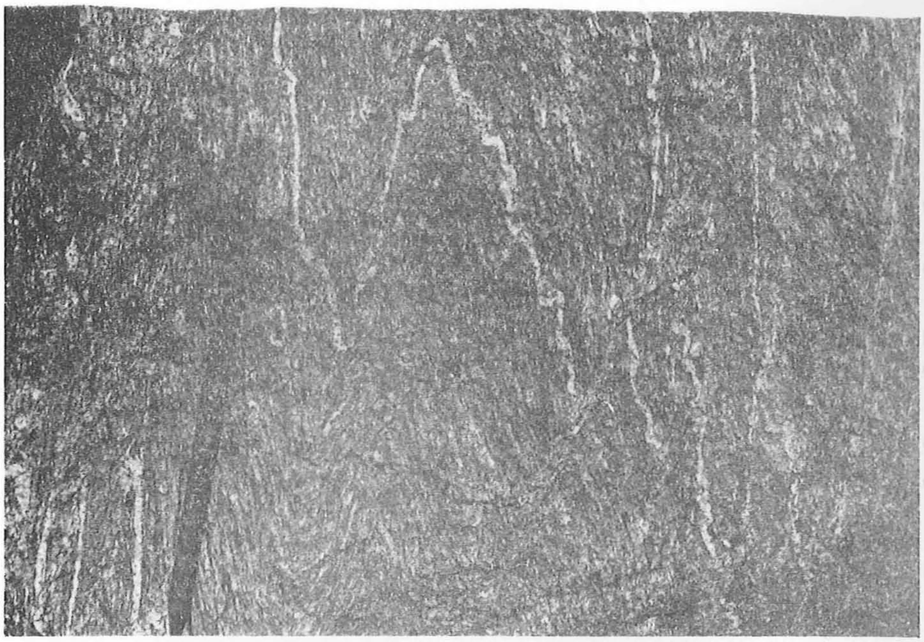


Fig. 9.
Large amygdales in Magna Lynn Metabasalt 3.5 km east of Mount Olive copper mine. M1537/10 IHW.

Fig. 10.
Hyaloclastite? flow in Magna Lynn Metabasalt. Note that pale concentrically zoned structures are surrounded by less well defined dark concentric zones to the left of main round structure. M1507/37 IHW.

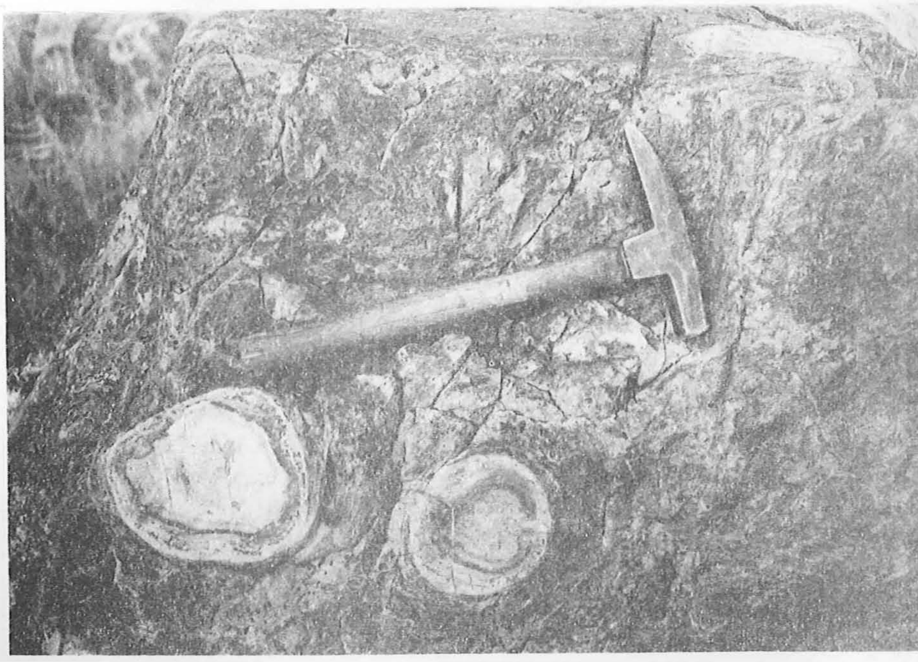


Fig. 11.
Round structure (vertical and horizontal sections) with an amygdaloidal basic core in hyaloclastite from Magna Lynn Metabasalt. Note the dark concentric zones to the left of main round structure. M1509/4 IHW.

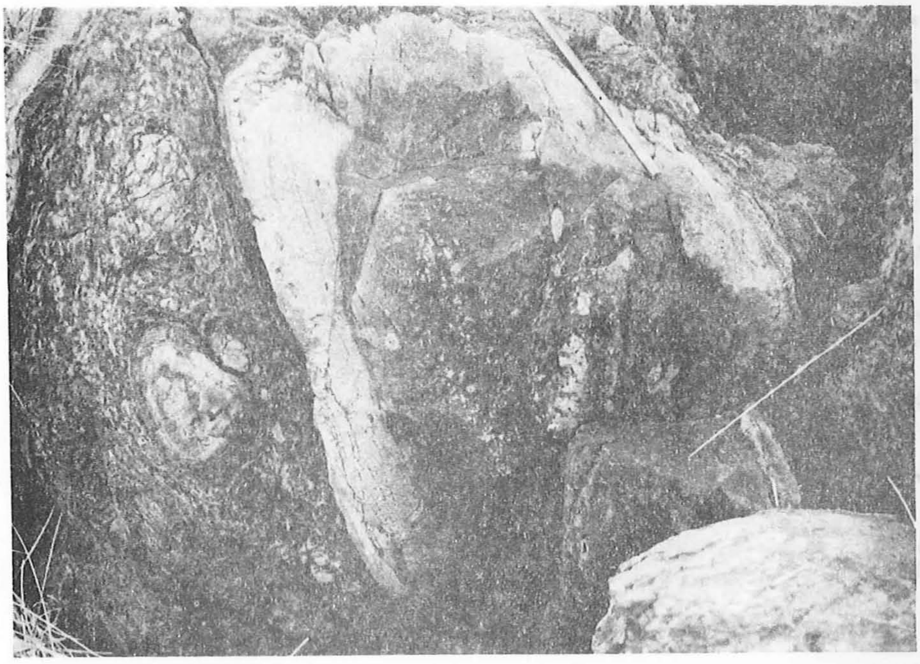
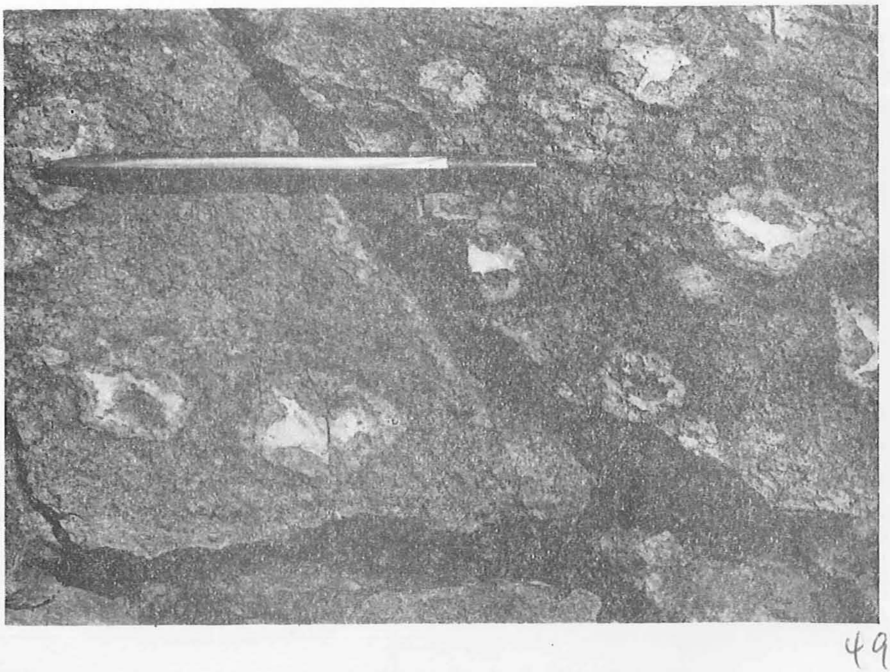


Fig. 12.
Sheared fragmental (fiamme?) porphyritic acid volcanic of the Argylla Formation in southeast corner of Sheet area. M1499/24 IHW.

Fig. 13.
Slightly deformed spherules in porphyritic rhyolite of the Argylla Formation 1.5 km east of Mount Razorback. Note spicule-shape of quartz-fillings in spherules. M1538/3A IHW.



parallel-stratified to cross-bedded, thinly to thickly bedded, and generally fine-grained. They contain abundant laminae of ferromagnesian minerals, which enhance the stratification. Epidote, feldspar, and calcite are also present, and pyrite and arsenopyrite blebs occur locally. Ripple marks, slumping, and flame structures are rare; mud-cracks have been observed at one locality in a siltstone intercalated with the labile quartzite. The orthoquartzite is pale grey to creamy white, thinly to thickly bedded, generally cross-bedded, and fine-grained to medium-grained.

Cross-bedding indicates currents came predominantly from the southeast or east, but currents from the northwest and north are also indicated.

Regional deformation of the Magna Lynn Metabasalt has resulted in the development of a weak north-trending foliation defined by the alignment of biotite flakes that formed after amphibole; amygdales are elongated parallel to this foliation. Biotite and chlorite schists, which locally contain relict amygdales, occur along zones of strike-slip faulting. The sediments are silicified, and locally fractured or mylonitized. Veins of quartz, quartz-epidote, and quartz-calcite are widespread. Euhedral tabular hematite crystals have been found in joints in the basic tuff and basalt.

Petrology

About 80 specimens from the Magna Lynn Metabasalt have been examined in thin section; estimated modal analyses of 57 of them are presented in Table 4.

Most metabasalts and amygdaloidal metabasalts have a relict igneous texture consisting of rounded amygdales and sparse 1-2 mm idiomorphic altered phenocrysts of plagioclase in a fine-grained (0.1-0.2 mm) felted to subtrachytic groundmass of plagioclase laths and intergranular ferromagnesian minerals. The amygdales consist of various proportions of quartz, epidote, calcite, and chlorite arranged in concentric zones. Typical sequences from the outer rim to the core are:

epidote to quartz (becoming coarser-grained towards the centre);
quartz to calcite (in some specimens calcite and actinolite); and
quartz to chlorite, sphene, epidote, and rarely opaques (sulphides).

Biotite forms rims around some amygdales. The phenocrysts of plagioclase are albitic, and contain small idioblastic to sub-idioblastic prisms of epidote, indicating metamorphism of more calcic plagioclase. The groundmass laths of plagioclase are also albite and their outlines have been indented by the metamorphic growth of the ferromagnesian minerals. Intergranular epidote occurs as subequant prisms, granular aggregates, and rarely radiating fibrous clusters. Amphibole, usually the most abundant ferromagnesian mineral, occurs as elongate decussate to slightly aligned prisms and more rarely as subidioblastic to ragged poikiloblastic subsequent prisms. The optical properties of the amphibole are a pleochroic scheme of yellow-green:green:bluish green, a 2V of about 75^{o}, and an extinction angle of nearly 15^{o}; these properties do not allow discrimination between hornblende and actinolite. Ragged anhedral opaque grains are present in most of the metabasalts. The accessories are sphene, apatite, quartz, and rarely zircon. Felted mats and polygonal grains of chlorite occur in several specimens from the north of the Sheet area, and may be of regional metamorphic origin, in contrast to basalts from the southern areas where chlorite is a product of retrogression.

In retrogressed metabasalts biotite replaces amphibole and forms subhedral corroded books which are partly to totally aligned. Chlorite occurs mostly as strongly foliated subhedral books replacing ragged biotite flakes. Calcite and quartz also

51

TABLE 4. ESTIMATED MODAL COMPOSITIONS, MAGNA LYNN METABASALT

Rock No.	Clasts etc.	q	p	mu	bi	ch	ep	ca	am	op	Accessories	a.g.d.	Name
4114			47				15		35	3	sp, ap	0.2	Metabasalt
4140			37				15		45	3	sp, zr	0.3	"
4192			40				14		45		1sp	0.3	"
4199			56				4		38	2		0.2	"
4205			50		25		5		15	5		0.1	"
4207		2	38				10		45	5		0.1	"
4211			43		tr	9	4		42	2		0.2	"
4240			35		7		18		38	tr	2sp	0.1	"
4242			35				12		49	4		0.2	"
4243			45				8		42	5		0.4	"
4245	2F(p)	2	48				1		42	5		0.5	"
4246			38		2		31		26	3		0.1	"
4253	V(q,ca,ep)		40		5		6		47	2		0.1	"
4113	20F(p,ep,mu)		40						35	5		0.4	Porphyritic metabasalt
0055	1F(p), 3A(q)	4	36					tr	35	15	1sp, zr		" "
0056	5F(p), 10A(q,ch)		60			14				11			Amygdaloidal metabasalt
0071	10(q,ep,ca)		35		5		3		40	7		0.5	" "
4112	2A (q)		43				15		35	5		0.5	" "
4193	1A (ep)		45				13		40	1		0.2	" "
4194	2A (q)		44				5		45	2	2sp	0.2	" "
4195	2A(q,ca,ep), V(q)		27				6		63	2	ap	0.2	" "
4198	10A(q, ca)	2	74				2	5		7	zr	0.2	" "
4200	5A	2	34		1		5		51	2		0.5	" "
4201	2A, V(q,p)		43						48	7		0.1	" "
4202	tr A		43		20		5		25	7		0.1	" "
4203	1A		35				5		54	5		1.5	" "
4204	10F(p), 20A(q,ca)		48		8		1	7		6		0.1	" "
4206	tr A		52		5		10		25	7		0.5	" "

Rock No	Clasts etc.	q	p	mu	bi	ch	ep	ca	am	op	Accessories	a.g.d.	Name
4217	1A(ep,q), 3F(p)	1	45		20		7		15	8		0.3	Amygdaloidal metabasalt
4237	1A(q,ep), V(ep,q)		40				15		42	3	zr	0.2	" "
4239	3A(q), V(q,ca)		26				10	3	20	1		0.3	" "
4244	8B(am), 2A(q)		47		3	30			5	5		0.1	" "
4247	4A(ep,q , ca)		30		6		18		37	5		0.4	" "
4254	3A(ep), V(q,ca)		35				15	3	42	2	sp	0.1	" "
4255	2A(q,ep)	2	38		10		15		30	3		0.1	" "
4068	8F(k,p)		50	2	5	10	10	1		10	4sp, ap	0.06	Contaminated metabasalt
4252	1F(p), 2(ep, ca)		32				4	8	49	4		0.1	" "
0062	7F(p), 5L	1	55		5	15				11	1zr		" "
4159	1F(p), V(q ,ep, ca)	1	44		25		3	tr	20	5	2sp	0.3	Sheared metabasalt
4160		12			1	85				2	sp	0.04	" "
4191			60		1	20	3	12		3	1to	0.2	" "
4196	2F(p), 1A(ep)	2	49		25		15			5	1sp	0.06	" "
4197	2A(q , ca)		65		5	14		4	3	7		0.2	" "
5578		1	79		5		1	8		2	4sp	0.1	? Hyaloclastite
DCG III 22b			65		15			10		10		0.1	"
DCG III 22d			80		5			5		10		0.2	"
DCG III 22a		50			8		2	38		2	sp	0.1	"
DCG III 22c		70			16		6	2		5	1sp		"
4238		2	48				5		35	10			Tuff
5589	L(p,ch,bi,am)	15			25	5	50			5		0.05	Agglomerate
4120		tr	64				5		18	13		0.5	? Andesite
4139		85				tr				tr	15to	0.5	Tourmaline quartzite
4208		70	6	3	2		2	12		3	1k, 1sp	0.1	Labile quartzite
4209		75	5	8	5					3	1k, 3sp	0.2	" "
0048		55				42					3sp	0.07	" "
4210		85	2	1	6					3	1k, 2sp	0.3	Sublabile quartzite
5588		99		tr	1					tr		0.1	Orthoquartzite

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

* Roooo are GSQ rock numbers

occur in these schistose rocks, some of which consist almost entirely of chlorite and quartz.

Contaminated metabasalts contain abundant epidote, muscovite, quartz, and rare microcline. One specimen, 4068, contains large idiomorphic microcline phenocrysts that have been partly resorbed, resulting in atoll structures with basaltic groundmass material replacing the centre of the phenocrysts.

The tuff and agglomerate have similar mineralogy to the metabasalts, except that quartz is generally more abundant and forms discrete grains in the predominantly basaltic matrix. Although the boundaries of the original pyroclastic fragments are diffuse, the fragments can be distinguished from the matrix by their finer grainsize and heavy dusting of opaque minerals. The fragments are generally angular to slightly rounded, elongate, and well foliated.

Andesite has been recognized at one locality 3.5 km east of the Mount Olive copper mine at the top of the formation. It is a fine-grained medium grey rock consisting essentially of decussate subhedral laths of albite, lesser amounts of intergranular actinolite, opaques, and epidote, and minor amounts of quartz. The rock has been classified as an andesite because of its lower colour index than the metabasalts.

The hyaloclastites? are leucocratic to mesocratic rocks with strongly developed concentric zones that have a wide range of compositions. The paler zones contain up to 80 percent plagioclase and quartz, which occur as a granoblastic mosaic of slightly strained and fractured grains 0.03-0.2 mm across. Calcite occurs as anhedral grains and radiating fibrous masses, and constitutes up to 60 percent of some zones. Biotite, epidote, opaque minerals, and sphene form from 10 to 80 percent of the various zones. The dark zones consist mainly of biotite flakes which are strongly aligned parallel to the zoning. The matrix between the spherical structures is also partly zoned;

quartz, calcite, plagioclase and biotite are the main minerals, and they form a granoblastic mosaic.

The metasediments are mostly poorly sorted fine-grained meta-arenites consisting predominantly of subangular to rounded slightly strained quartz grains with crenulate, sutured, or polygonal outlines. In the more labile metasediments, plagioclase, calcite, microcline, and mafic-rich grains occur in a granular matrix of muscovite, chlorite, biotite, sphene, and opaques. Specimen 4139 contains euhedral tourmaline prisms intergranular to and growing into the crenulate quartz grains.

Discussion

The rocks of the Magna Lynn Metabasalt contain sufficient primary structures to confirm their volcanic and sedimentary origin. Repeated outpourings of lava are indicated by the extensive thin flows with amygdaloidal margins, flow-top breccias, and sedimentary intercalations. An explosive phase of volcanicity towards the middle of the Magna Lynn Metabasalt eruptions resulted in the deposition of tuff and agglomerate. The mainly tabular flows indicate that the region had slight topographic relief, although some older acid igneous rocks must have been exposed to provide the microcline and quartz-rich tabular to lenticular sedimentary interbeds in the sequence. The arenaceous, locally calcareous, cross-bedded and ripple-marked sediments indicate a shallow-water environment, and either shoreline or fluvio-lacustrine conditions may have prevailed. Sinuous drainage patterns on relatively flat basaltic plains may account for the wide variation in current directions. Pillow lavas are virtually absent, indicating that the volcanism was probably not submarine.

The local occurrence of concentrically zoned round structures may indicate a hyaloclastite flow: lava flowing into a small lake - and decrepitating as a result of its sudden chilling in the water - may have formed discrete pillow structures in the debris (Macdonald, 1972, p. 105). Alternatively, the round structures may have originated from pillow or mud flows, or from agglomeratic eruptions. Normal pillow flows have been discounted because of the discrete and widely separated round structures. A mud-flow may have incorporated a variety of sedimentary and volcanic debris that was rolled along to form zoned spherical bodies; this process would also explain the concentric zoning around the bodies as flow lines. If the volcanics are agglomeratic the round structures might be interpreted as bombs, but the varied composition of the round structures or the zoning outside the bodies would be hard to explain.

Most of the Magna Lynn Metabasalt contains the assemblage albite-epidote-actinolite/hornblende-opaques, indicating metamorphism in the upper greenschist facies or the lower almandine-amphibolite facies of the Barrovian-type facies series, or the upper greenschist facies in the lower-pressure Abukuma-type facies series (Winkler, 1967). Despite the regional metamorphism the composition of these rocks still reflect their basaltic origin. Chemical compositions of these rocks are tholeiitic (Wilson, 1976).

Argylla Formation

Introduction

The Argylla Formation, composed mainly of acid volcanics, is named after Argylla Creek, which flows into the East Branch of the Leichhardt River 8 km south of the Sheet area Carter et al. (1961) formally defined the formation with reference to a type area along the old Mount Isa/Cloncurry road from about 6 to 9 km west of Deighton Pass, in the Mary Kathleen Sheet area. They also discussed the previous usage of the name. Derrick et al. (1976a, in press) have redefined the base of the formation as the lowest acid volcanic flow lying above the Magna Lynn Metabasalt.

In the Prospector Sheet area the Argylla Formation is exposed as several generally north-trending belts 1 to 4 km wide at the eastern margin of the Kalkadoon-Leichhardt basement and near the eastern margin of the Sheet area in structural highs surrounding the Wonga Granite. Faulting repeats both of these sequences, and has also exposed several small inliers within the Surprise Creek Beds near the middle of the Sheet area. The total area of exposure of the Formation in the Sheet area is 170 km^2.

The Argylla Formation generally forms bouldery ridges and plateaux, but in the eastern exposures the formation is more recessive than the Wonga Granite, and forms undulating valleys between the granite and the Ballara Quartzite.

Stratigraphic relations

The Argylla Formation conformably overlies the Magna Lynn Metabasalt and is unconformably and locally disconformably overlain by the Ballara Quartzite. The formation is intruded by the Wonga Granite and dolerite dykes of several ages. Its relation to the Kalkadoon Granite is not definitely known, but xenoliths of Kalkadoon Granite? in feeder dykes of the Argylla Formation suggest the granite is older than the Argylla Formation (Fig. 14).

Lithology and field occurrence

Porphyritic acid volcanic rocks predominate in the Argylla Formation. Most are rhyolitic in composition, some are rhyodacitic to dacitic, and andesitic volcanics occur locally. The base of the formation is commonly dacitic porphyry. Buff fine to medium-grained feldspathic sandstone and siltstone are intercalated with the volcanics, and increase in abundance towards the top of the formation. They are rarely thicker than 5 m. One small lens of metabasalt crops out in the southeastern part of the Sheet area. Dykes of porphyritic and locally xenolithic rhyolite (Fig. 14) cut the Argylla and older formations. The dykes, from 5 to 20 m thick, commonly contain lenticular transverse quartz veins, and are designated 'h' on the Prospector 1:100 000 Preliminary geological map.

The rhyolitic to dacitic volcanics are generally pink to dark grey, massive, poorly to distinctly stratified, and porphyritic. The phenocrysts are predominantly microcline and/or plagioclase although opalescent blue rounded quartz phenocrysts are abundant in some areas. Biotite and magnetite are visible in some specimens. Spherulitic rhyolite occurs near Flora Dora copper mine and 1.5 km east of Mount Razorback (Fig. 13). Inclusions that resemble fiamme are unevenly distributed in some of the volcanics (Fig. 12).

Sedimentary interbeds in the volcanic pile indicate that individual volcanic sheets range from 100 to 300 m thick in the area east of the Mount Olive copper mine, to as thin as 10 m in the northeast corner of the Sheet area. The sheets are extensive and locally show well preserved eutaxitic textures. No extrusive centres have been recognized.

The intensity of deformation increases towards the east. In the western exposures the flow or metamorphic foliation in the volcanics is locally contorted and zones of shearing and quartz-veining occur along faults. In the east the volcanics are recrystallized, and phenocrysts and inclusions are elongated parallel to a cleavage, schistosity, or locally gneissosity (Fig. 12). The interbedded and recrystallized sediments are micaceous quartzites and psammitic schists, and the quartzites show parallel lamination or medium-scale pi-type (Allen, 1963) cross-lamination and ripple marks. Some polymict conglomerate crops out in the southeast of the Sheet area near the top of the formation; it is cut by quartz, quartz-hematite, and quartz-tourmaline veins, and pegmatite and aplite dykes, and also contains bands of basic schist and amphibolite which may have been originally dolerite or basalt.

A generalized stratigraphic section of the formation is shown in Figure 15.

Petrography

About 100 specimens from the Argylla Formation have been examined in thin section; modal compositions of 51 of them - mostly alkali rhyolite and rhyolite - are listed in Table 5 and plotted in Figure 16. Most of the metasediments are labile fine-grained arenites.

The rhyolite is porphyritic and generally contains from 10 to 40 percent of quartz, plagioclase, and microcline phenocrysts. In the least metamorphosed rocks the quartz phenocrysts are rounded, subhedral (bipyramidal high-quartz), embayed crystals up to 2 mm long. The plagioclase and microcline phenocrysts are subhedral to euhedral and 1 to 4 mm long. The groundmass is a microcrystalline granular mosaic of quartz and microcline, and contains minor amounts of biotite, opaque minerals, muscovite, calcite, plagioclase, chlorite, and accessory sphene and zircon. The biotite and opaques tend to occur in clots up to 0.5 mm across. Some rocks are heavily dusted with an opaque mineral (probably hematite) and are distinctly pink in hand specimen and thin section. In slightly deformed rhyolite, the quartz phenocrysts are strained, and in some specimens are partly comminuted, resulting in a microcrystalline quartz rim. The feldspar phenocrysts are crowded with minute muscovite flakes and patches of calcite and epidote, and some display mortar structure. The groundmass contains abundant muscovite flakes, and is spotted under crossed polars owing to the recrystallization of the microcrystalline quartz and feldspar into optically continuous poikiloblasts up to 0.1 mm across. The groundmass quartz typically has a fibrous (chalcedonic?) appearance. In the most deformed rhyolite, phenocrysts are recrystallized and display irregular sutured boundaries, and the groundmass of quartz and strongly foliated muscovite flakes define a foliation (related to the F_2 deformation); potash feldspar phenocrysts

60

Fig. 14.
Large granitic and small basic xenoliths in Argylla Formation porphyry dyke 2 km north-northwest of the Lillimay copper mine. M1537/36 IHW.

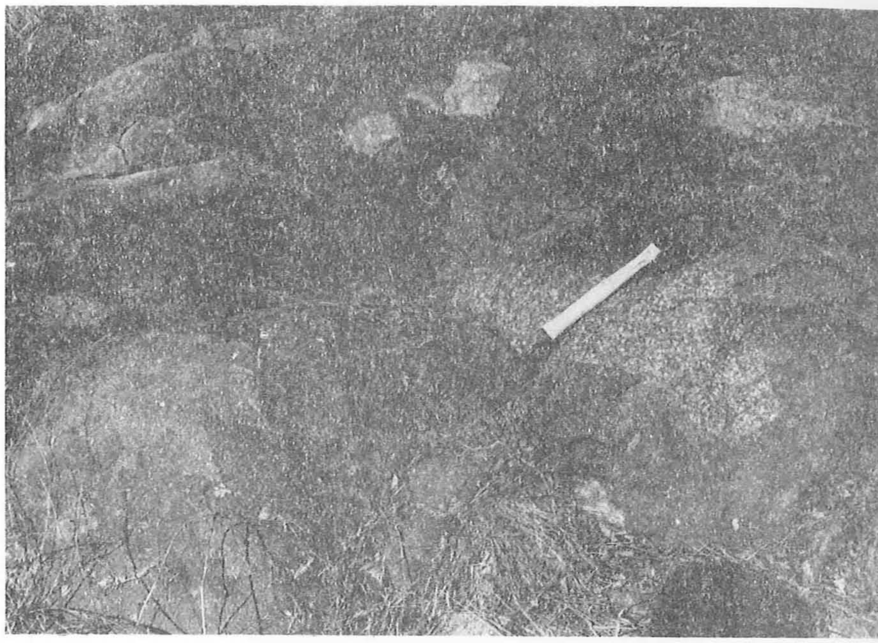


Fig. 17.
Rounded acid volcanic clasts in the basal conglomerate of the Ballara Quartzite (unit Ekb_1) 5 km east of Lillimay copper mine. M1518/11 IHW.

Fig. 18.
Cordierite-sillimanite schist in the Ballara Quartzite 9 km south of Yamamilla copper mine. M1507/22 IHW.

TABLE 5. ESTIMATED MODAL COMPOSITIONS, ARGYLLA FORMATION

Rock No.	Q	K	P	q	k	p	mu	ca	bi	ch	ep	op	Accessories	a.g.d.	Name
R5586	2	12	1	19	60		1			2		3			Porphyritic rhyolite
R5617	1	10	2	30	40	10		1	2	1		2			" "
R5623		15	5	27	45	5	tr		1			2			" "
R5918	13	35		(50)			tr		1			1	ac, zr		" "
R5917	5	13	7	(74)			tr		1	tr		tr	sp, ca		" "
4116	3	2	6	22	54	5	2	1	2	1		2		0.01	" "
4117	2	5	5	20	59		2	3	3			1	al	0.03	" "
4119	3	5	12	18	50	4	2		3			3	zr	0.02	" "
4121	2	5	10	28	40	8	2	tr	3			2	sp	0.02	" "
4141	1	7	11	18	45	1	9	tr	5			3	sp	0.02	" "
4142	1	2	11	22	51	5	2	1	1			3		0.02	" "
4145	tr	9	4	31	45	1	4	1	2			3		0.02	" "
4147	1	7	11	29	35	1	4	1	9			2	sp, zr	0.03	" "
4218	2	2	10	24	45	1	5	2	6			3	sp, zr	0.03	" "
4222	1	1	14	22	42	tr	5	1	11			3	sp, zr	0.02	" "
4226	1	1	8	24	45		7		13			1	zr	0.02	" "
4265	3	5	15	24	47	1	tr	1	1			1	2am, sp, zr	0.03	" "
0153				25	55			3	10			2	5sc		Metarhyolite
0162				40	48				10		10				"
R5983	5	20		(53)		5				tr	tr	1	16sp, fl		"
R5587	5	12		15	63				5						Sheared rhyolite
R5603				25	67			1	4	1		2	zr		" "
R5604	3	2	10	20	58			1	2			3	1sp		" "
R5605	2	9	4	25	49				7			3	1sp		" "
R5606	7	5		20	40				5			3	3sc, 1sp		" "
R5616	2	5	1	43	40				5			3	1sp		" "

TABLE 5. PAGE 2

Rock No.	Q	K	P	q	k	p	mu	ca	bi	ch	ep	op	Accessories	a.g.d.	Name
R5618	5	10		30	40				10			2	1sc, 1sp		Sheared rhyolite
R5620	5	10		36	40				3	1		3	1sp		" "
R5621		8	2	30	50	8			1			1			" "
R5625		10	4	25	45	5		tr	7		3	1	zr		" "
R5628	7	15	3	15	50	6			3			1	ap		" "
4118	4	5	8	18	57	5	1		1	1		tr	ru, sp	0.04	" "
4115	2		14	17	33	20	5	2	6			1		0.02	Rhyodacite
R5577	3	1	26	17	30	5	5	1	5			2			"
R5982				37	15	40	3		2			3			Metadacite
0175				4	(88)				5			3			Andesite
R5579			7	5	2	60		6	18			2	zr, ap		"
R5585				10		40			3	25	2	10	10ac		"
R5624						30						tr	5sp, zr, 65hb		Amphibolite
R5986				30		28							2sp, 5di, 35hb		"
R5985				30		34							1sp, 35hb		"
R5626						44					3	1	2sp, 45hb, 5sc		"
R5629				2		55			10			1	1sp, 30hb, 1ap, zr		Basic gneiss
R5631				1					90	9			ru, zr, sp		Chlorite-biotite schist
4271	1	1	6	20	23	5	3	1	32			4	1sp, ap, zr, 3X	0.1	Argylla Formation porphyry
R5968				75		12	4	1	3		1	4			Metasiltstone
0177				50	48							2			Arkose
0156				85	10							1	4sc		Feldspathic quartzite
R5619				64		20							15ac, 1ap		" "
0138				94	2		2					2			Orthoquartzite
0176				97			1					1	1sc		"

TABLE 5. PAGE 3

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

Roooo are GSQ rock numbers.

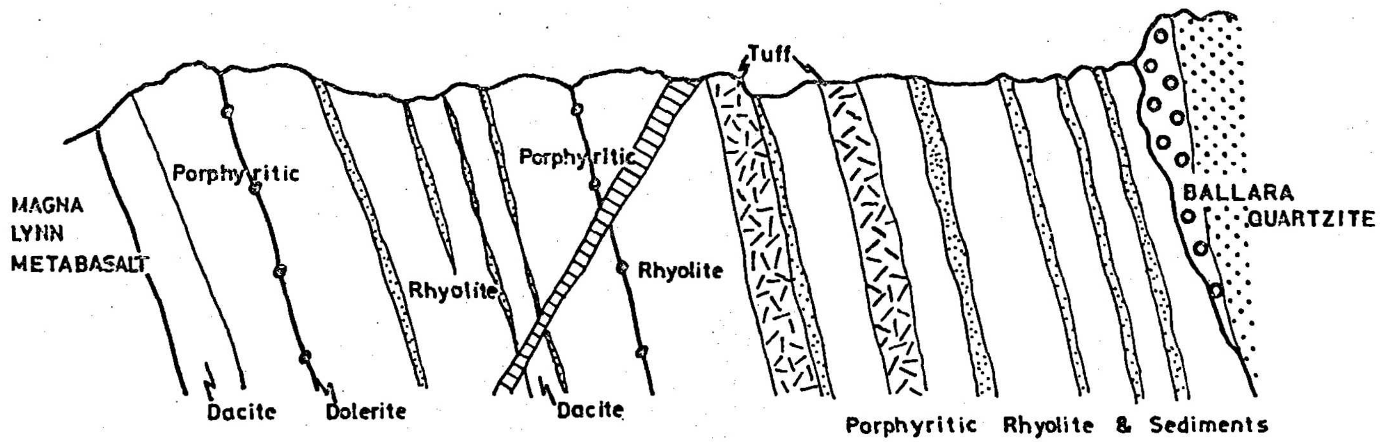


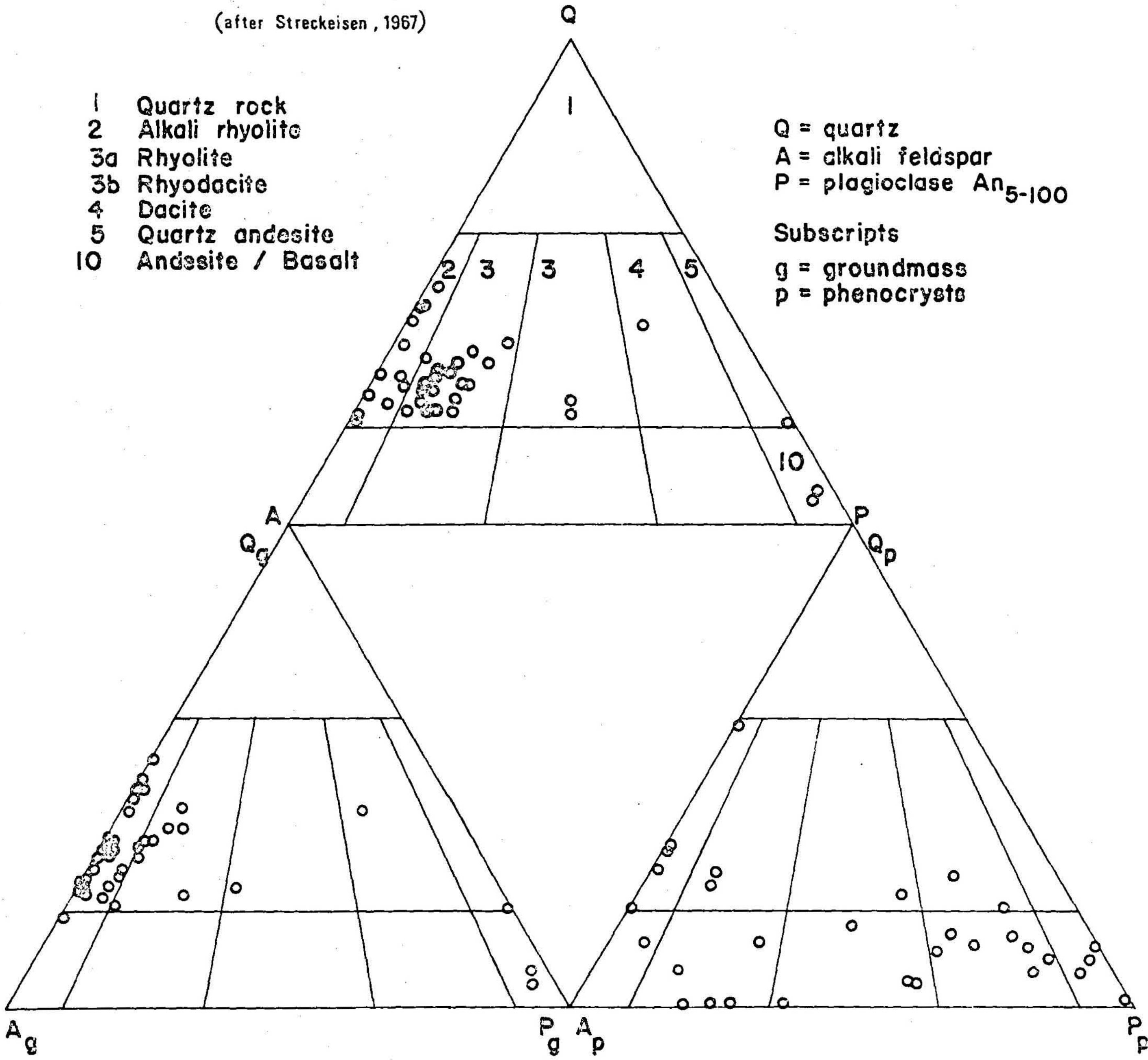
FIG. 15

GENERALIZED STRATIGRAPHIC SECTION OF THE ARGYLLA FORMATION IN THE SOUTHEAST CORNER OF THE PROSPECTOR SHEET AREA

Record 1977/4 F54/A2/172

FIG. 16. CLASSIFICATION OF ARGYLLA FORMATION BY QAP DIAGRAM

(after Streckeisen, 1967)



form augen with their long axis parallel to this foliation, and in one specimen (GSQ 5983) are partly replaced by sphene.

Rhyodacite in the formation is similar in most respects to the rhyolite, but contains more plagioclase and biotite. The biotite forms clots up to 1 mm across which may be pseudomorphous after hornblende or augite.

Dacite is non-porphyritic and consists of a fine-grained xenoblastic mosaic of quartz, potash feldspar, plagioclase, muscovite, opaques, and biotite. Metamorphosed specimens contain large poikiloblasts of muscovite.

The andesite is very similar to the dacite but contains much less quartz and more plagioclase, biotite, and opaques. The amphibolite consists of a granoblastic mosaic of plagioclase, hornblende, and minor amounts of sphene, opaques, and scapolite. Some specimens contain abundant quartz and diopside?. The sub-idioblastic hornblende crystals are typically strongly aligned.

The metasediments are submature or labile and contain poorly sorted angular grains of quartz, potash feldspar, and plagioclase with sutured boundaries and undulose extinction. Blocky to subequant grains of muscovite, biotite, and opaques occur in the groundmass which is predominantly of very fine-grained muscovite, epidote, quartz, and calcite. In some specimens scapolite occurs as embayed poikiloblastic grains. Towards the top of the formation the sediments are more siliceous and better sorted. Some are orthoquartzite consisting of strained and sutured quartz grains and minor sericite, opaques, alkali feldspar, epidote, and scapolite. In the more deformed orthoquartzite, quartz grains are flattened parallel to the foliation.

The porphyry dykes of the Argylla Formation are generally xenolithic, xenocrystic, and porphyritic, and are coarser-grained than most other acid volcanic rocks in the

Argylla Formation; the groundmass typically consists of an equigranular mosaic of microcrystalline quartz and feldspar grains about 0.1 mm across. Biotite is very abundant and probably reflects the assimilation of basic xenoliths derived from the Magna Lynn Metabasalt. The coarse-grained acid igneous xenoliths (e.g. at 788416, 769421, and 801464) resemble the older phase of the Kalkadoon Granite. Other, more even-grained, medium-grained granitic xenoliths are similar to the younger phase of the Kalkadoon Granite.

Discussion and geological history

Reconstruction of the faulted outcrops of the Argylla Formation suggests it had an original north-south extent of over 250 km, an east-west extent of about 100 km, and a thickness of up to 1200 m.

The origin of such a large volume of volcanics is not clear - much of the porphyritic volcanic sequence may be ignimbritic, and some of the more fragmental and better foliated rocks may be ash-fall tuffs. The more basic volcanics are probably lava flows.

At the end of the Magna Lynn Metabasalt extrusive episode, large vents or fissures opened; out of them poured acidic ash flows that became more potassic and then explosive, resulting in ash-fall tuff deposits. Between eruptions, thin sediments derived from the underlying acid volcanic terrain were deposited; the immaturity of the labile sediments indicates limited transportation. The sedimentary environment is not known, but the cross-bedding and ripple marks indicate a fairly high-energy environment, possibly on a shallow shelf or in a terrestrial drainage system. A decrease in volcanic activity or a marine transgression, or both, may account for the increase in volume and maturity of sediment towards the top of the formation.

Mineralization in the Argylla Formation in the Prospector Sheet area is sparse, unlike the formation in the Mary Kathleen Sheet area to the south, and the Dobbyn area to the north. The deposits in the volcanics that have been mined successfully included Yamamilla, TC, and Flora Dora. The copper mineralization is in shear zones, and only the enriched oxidized zones containing malachite, azurite, and minor chalcocite have been worked economically.

The xenoliths of possible Kalkadoon Granite in porphyry dykes of the Argylla Formation suggest that the Argylla Formation postdates the Kalkadoon Granite, whereas Carter et al. (1961) invoked the reverse relation. Isotopic age data are still not clear; the minimum age of the Leichhardt Metamorphics is nearly 1700 m.y. (Page & Derrick, 1973; Plumb & Derrick, 1975). The Wonga Granite, which intrudes the Argylla Formation, has yielded Rb-Sr dates of 1665 $\pm$ 16 and 1738 $\pm$ 20 m.y. (Page & Derrick, 1973), which place further limits on the minimum age of the Argylla Formation. Recently, Page (1976) has obtained a zircon age of about 1780 m.y. for the Argylla Formation, which may be the true age of extrusion.

B. STRATIGRAPHY OF THE EASTERN SUCCESSION

MARY KATHLEEN GROUP

Ballara Quartzite

Introduction

The Ballara Quartzite is named after the abandoned township of Ballara, in the southeast of the Mary Kathleen Sheet area. The formation was formally defined by Carter et al. (1961) with reference to a type section 4 km northwest of Ballara. Derrick et al. (in press) recognized a consistent two-fold subdivision of the formation in the Mary Kathleen Sheet area, and found that the formation extended farther north than was shown by previous mapping. Parts of the quartzite had previously been mapped as the Argylla Formation or the Deighton Quartzite.

In the Prospector Sheet area the Ballara Quartzite crops out in several north-trending belts in the eastern part of the Sheet area. The formation is disrupted and repeated by faulting and folding. The total area of outcrop in the Sheet area is 72 km^2.

It forms mainly rugged ridges, the tops of which are mostly flat and have uniform elevations (300 m in the north and 400 to 500 m in the south), indicating that they have not been degraded significantly since an earlier (Tertiary? and/or Mesozoic) erosion surface was formed (Fig. 5). The less resistant beds between the ridges are generally labile or calcareous sandstone, siltstone, or shale.

Stratigraphic relations

The Ballara Quartzite unconformably or disconformably overlies the Argylla Formation and is the basal unit of the eastern succession in the Sheet area. Well developed basal conglomerates occur in the southern exposures, but angular contacts with the underlying rocks are rarely observed. In the northern exposures, labile siltstone in the upper Argylla Formation is overlain by arkose and orthoquartzite of the Ballara Quartzite with apparent conformity. Extensive alteration of the underlying Argylla Formation in some areas may be due to weathering before the Ballara Quartzite was deposited. The Ballara Quartzite is overlain conformably by the Corella Formation. Dolerite dykes and phases of the Wonga Granite intrude the quartzite.

In the Sheet area the formation is thickest (1000 m) in the westernmost outcrops, and thins to a few metres in the east. An average thickness is about 400 m.

Lithology and field occurrence

Two informal members are mapped in the Prospector Sheet area. The lower member (Ꝑkb$_{1}$) consists of arkose, grit, and cobble and boulder conglomerate (Fig. 17); the upper member (Ꝑkb$_{2}$) consists largely of quartzite, micaceous quartzite, and feldspathic sandstone. The upper member is the more widespread member and the lower member is absent in some sections. Two minor units have also been mapped: Ꝑkb$_{2t}$ (laminated siltstone and minor shale) and Ꝑkb$_{21}$ (limestone and ferruginous siltstone). Metamorphosed amygdaloidal basalt has been identified in a small area in the south at 829 395 near the top of the lower member. Highly metamorphosed cordierite and sillimanite-bearing psammitic to pelitic sediments occur south-southwest of the Yamamilla copper mine (Fig. 18).

Near the eastern Sheet area margin the Formation is too thin to represent on the Prospector Preliminary geological map and it has been shown as Corella Formation. However, it will be shown on the First Edition map. Most of the undifferentiated Ballara Quartzite shown on the Prospector Sheet is the upper member.

Member Ꝑkb$_{1}$. This member - a sequence of conglomerate, arkose, grit, sandstone, siltstone, and rare basalt - is best developed in the south, although it is sporadically distributed in other areas. Lenticular conglomerate sequences (up to 300 m thick) contain rounded clasts of porphyritic acid volcanics up to 0.5 m in diameter southeast and east of the Mount Olive copper mine (Fig. 17). Polymict conglomerate containing acid volcanic, quartz, and basic clasts occurs in the southeast, 1 to 2 km southwest of the TC copper mine. To the north and east the conglomerates grade into pebbly grit and arkose. Grey siltstone, labile sandstone and minor amygdaloidal basalt are intercalated with pebbly sandstone towards the top of the member, which rarely exceeds 200 m in thickness and in many areas is less than 1 m thick.

Bedding is poorly developed; conglomerate and grit show some graded bedding, and most arenites are massive or parallel laminated; some are cross-bedded with sets from 10 cm to 2 m thick displaying pi, xi, and nu styles of cross-stratification (Allen, 1963). Cross-bedding is commonly enhanced by black heavy-mineral laminae. Ripple marks are rarely developed and are restricted to fine-grained sandstone and siltstone.

Current directions inferred from cross-bedding and ripple marks indicate currents from the south, southeast, and east in the southeast of the Sheet area, and from the southwest to west in the southwestern exposures.

In the east, extreme deformation has flattened the clasts in the conglomerate so that the ratio of maximum to minimum diameters is up to 10:1. Cleavage has developed parallel to the flattening, and some silicification has occurred. Primary structures in the sediments have been extensively obscured by this deformation. Recrystallization of arkose under amphibolite facies metamorphism has produced a rock of granitic aspect.

Member Pkb_2. The predominant rock types in this member are pink to buff, thin to thick-bedded, laminated to cross-bedded, fine to medium, feldspathic quartzite, and brown to grey fine-grained sandstone. White laminated medium to coarse orthoquartzite and micaceous quartzite are more common in the north, and dark mafic-rich quartzite crops out near the eastern boundary of the Sheet area.

This member is typically well stratified with sets of beds up to 2 m thick. Cross-bedding is common and the foresets are mostly low-angle, slightly concave upward, and in lenticular sets from 10 cm to 1 m thick. Pi, nu, xi, and beta styles of cross-stratification (Allen, 1963) have been identified. Most of the finer-grained sediments have parallel lamination. Ripple marks are less common, but are generally large with wave-lengths greater than 10 cm. Synaeresis cracks have been observed at a few localities, and limonite pseudomorphs after pyrite cubes have been reported.

Current directions inferred from cross-bedding indicate currents predominantly from the southeast and to a lesser extent from the north, north-west, and northeast. Symmetrical ripple-mark orientations indicate currents to or from the south to southeast and less frequently to or from the east to northeast.

Unit Ꝑkb$_{21}$ crops out southeast of Mount Olive and south-southwest of Yamamilla copper mines, and consists of massive grey laminated sandy limestone commonly deeply weathered to a porous fine-grained ferruginous sandstone. The only mappable outcrop of Ꝑkb$_{2t}$, to the north of 238 800 in a deep valley between quartzite ridges, is a sequence of grey laminated siltstone and shale grading upwards into grey laminated fine-grained calcareous sandstone.

Metamorphism has recrystallized the arenites to glassy quartzites, and micaceous feldspathic arenites to phyllitic quartzites. Cleavage is poorly developed, except in some highly altered finer-grained sequences - for example, 8 to 10 km south-southwest of Yamamilla copper mine, where grey porphyroblastic fine-grained schist containing cordierite poikiloblasts up to 10 cm in diameter and sillimanite needles up to 4 cm long have been observed (Fig. 18).

Petrography

Table 6 presents estimated modal analyses for 15 specimens of Ballara Quartzite.

The lower member, <u>Ꝑkb$_1$</u>, is typically very poorly sorted, and consists of angular sand-sized quartz grains and varying amounts of feldspar, sericite, and rock fragments. Almost all of the rock fragments in the coarser conglomerates are rounded subspherical deeply weathered acid volcanics which consist of granoblastic opaque-dusted quartz grains (0.1-0.2 mm), and a matted sericitic groundmass; other clasts include fine-grained granoblastic quartzite and very fine-grained elongate to subrounded shale.

The arkose and subarkose consist of quartz, alkali feldspar, and minor amounts of plagioclase, biotite, and scapolite. The grains are generally very poorly sorted but in some specimens the quartz grains are bimodal (a.g.d. 0.03 to 0.5 mm). They are typically angular to subrounded and subspherical, and commonly show alignment of the long dimension of the grain in the foliation.

The increase in metamorphic grade towards the eastern and southeastern margins of the Sheet area is manifested in quartzites by undulose extinction and sutured quartz grains, and recrystallized alkali feldspar elongated in the foliation, and in pelitic to schistose arenaceous rocks by large porphyroblasts of cordierite and sillimanite. The cordierite porphyroblasts are rounded, anhedral, poikiloblastic, sector-twinned, and slightly altered to pinite. The sillimanite porphyroblasts are subhedral to anhedral and slightly poikiloblastic. Strongly lepidoblastic biotite is the most abundant mineral in the matrix, which also contains anhedral granoblastic quartz grains (0.03-0.2 mm) and minor muscovite and chlorite.

The upper member, $\underline{Pkb}_2$, is characteristically less feldspathic and better sorted than the lower member. The most abundant constituent is quartz; in many specimens it exceeds 95 percent. The grains are well-sorted (0.6 to 0.8 mm), rounded, and show little or no flattening. Small equant microcline grains and biotite flakes are minor constituents in most specimens, and intergranular calcite grains occur in a few specimens. Calcareous arenite in $\underline{Pkb}_{2t}$ and $\underline{Pkb}_{21}$ contains up to 44 percent calcite as anhedral grains and intergranular patches, some of which may be recrystallized cement. The major constituent in these rocks is anhedral quartz; microcline, biotite, muscovite and opaques are the minor constituents.

TABLE 6. ESTIMATED MODAL COMPOSITIONS, BALLARA QUARTZITE

Rock No.	Clasts or Porphyroblasts	q	k	p	mu	bi	ch	ca	op	Accessories	A.g.d. mm
R5595	Cord 25	8			5	55	5			si1, zr1, ru, op	0.2
R5602	Cord 34	24			1	38	1			si2, zr, ap, op	0.2
R5596	Cord 40	35			2	22	1			si, zr, ap, ru, to	0.1
73205123	AV (q65, mu30, op5)	60			35				5		0.05
73205124	AV40, q10, bi2, op3	30	5	1	5		1	3			0.05
73205125	Amyg 20			25			8		12	kaol 35 sp	0.1
73205163		50	2		1	2		44	1	to	0.08
R5961		79		10	1				10		0.2
73200157		80	12			6				sc 2	0.4
73200167		98	1						1		0.6
73200168		99							1		0.8
73200183		97	2			1					0.6
73200047		83		5				10	2		0.3
73200053	Shale clasts 5	70		7		7			8	to3, zr	0.1
73200054		80		15			2		3		0.4

Rock No.	Name
R5595	Cordierite-porphyroblastic sillimanite-biotite schist
R5602	Cordierite-porphyroblastic sillimanite-quartz-biotite schist
R5596	Cordierite-porphyroblastic sillimanite-biotite-quartz schist
73205123	Labile conglomerate
73205124	Lithic labile sandstone
73205125	Altered amygdaloidal basalt
73205163	Calcareous quartzite
R5961	Feldspathic quartzite
73200157	Subarkose
73200167	Orthoquartzite
73200168	Orthoquartzite
73200183	Orthoquartzite
73200047	Sublabile quartzite
73200053	Lithic labile quartzite
73200054	Feldspathic quartzite

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, k - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.
Rooo are GSQ rock numbers.

Discussion

The abundance of acid volcanic clasts in the lower member suggests that the source rocks were the Argylla Formation and possibly the Leichhardt Metamorphics. The sand-sized fraction, consisting of angular quartz and alkali feldspar grains, and the quartzofeldspathic matrix, where present, were probably derived from these predominantly acid volcanic formations.

Derrick et al. (in press) inferred that the Ballara Quartzite was a near-shore deposit on a broad shallow shelf, and that the decrease in feldspar content and better sorting in the quartzite indicated maturing of the source areas by erosion or onlap, or both. Similar conclusions are supported in the Prospector Sheet area, where ripple marks, cross-bedding, and carbonate deposits reflect shallow water and possible embayments on a broad shelf. Extreme thinning of the Ballara Quartzite near the eastern margin of the Sheet area may indicate the presence of a basement 'high' as suggested by Derrick et al. (1974); other explanations are that the area was more distant from the detrital source, so that finer distal sediments predominated, or that subsequent tectonic flattening has been more intense in this region of higher metamorphic grade, so that the thinning is only apparent. Flattening of conglomerate clasts supports the final suggestion although other processes may have been involved.

Corella Formation

Introduction

The Corella Formation is named after the Corella River (Carter et al., 1961, p. 86), which is located southeast and east of the Prospector Sheet area. The Formation was formally defined by Carter et al. (1961) with reference to a type locality along the old road between the Federal copper mine and the Mary Kathleen uranium mine, in the northwest of the Marraba Sheet area.

The Corella Formation crops out between the eastern border of the Sheet area and the Mount Remarkable Fault, and also just west of this fault in the northeast part of the Sheet area. Good exposure west and southwest of Yamamilla mine makes a three-fold subdivision of the formation possible, but farther north poor exposure has precluded subdivision of the formation. The areas of outcrop of the lower, middle, and upper members, and undifferentiated Corella Formation as shown on the map, are respectively 88 km^2, 19 km^2, 36 km^2, and 73 km^2. The three-fold subdivision corresponds with similar subdivisions recognized by Derrick et al. (1971, in press) in the Marraba and Mary Kathleen Sheet areas. In general the formation is recessive, although psammitic units, especially the middle unit, form prominent ridges. Outcrops of calc-silicate breccia form low ridges and hills.

Stratigraphic relations

The Corella Formation overlies the Ballara Quartzite conformably; the contact is gradational. To the east of the Mount Olive copper mine, limey beds are present toward the top of the Ballara Quartzite, and the base of the Corella Formation is taken to be above the uppermost prominent quartzite in this part of the succession. In the southeastern part of the Sheet area, the Corella Formation is disconformably overlain by the Deighton Quartzite. In many places the formation is faulted against either the Ballara or Deighton Quartzites. In the northern half of the Sheet area it is separated from the basement by the Mount Remarkable Fault. The Wonga Granite probably intrudes the Corella Formation, and northwest of Yamamilla mine a thick sill-like dolerite intrudes the upper part of the formation.

Lithology and field occurrence

The Corella Formation in the Prospector Sheet area is a sequence of calcareous siltstone, scapolitic metasiltstone, limestone, pelitic schist, quartzite, psammite, metabasalt, and ortho-amphibolite. A continuous section of these rock types (Fig. 19) is well exposed below the Deighton Quartzite in the southeastern corner of the Sheet area in the western limb of a north-plunging syncline.

The upper and lower calcareous members (Pkc_1 and Pkc_3), mainly siltstone, are separated by about 100 m of quartzite and pelitic schist of the middle member (Pkc_2). The upper unit, however, is characterized by a greater proportion of metasiltstone, a characteristic scapolitic limestone near the base, and metabasalt towards the top. The members vary greatly in thickness and seem to be thickest in the region northwest of Yamamilla mine. Lateral facies changes are common, especially in the middle member, Pkc_2.

Description of members

Member Pkc_1. The lowest member of the Corella Formation is composed predominantly of greyish black metasiltstone with interbeds of quartzite and calcareous grey metasiltstone (Figs 20, 21). The basal fine to coarse kaolinitic psammite grades downward into the Ballara Quartzite and grades upward into medium-grained vuggy decalcified sandstone and non-calcareous shale. The member becomes more calcareous and scapolitic upward, and some silty layers contain more than 50 percent scapolite, which occurs as anhedral to euhedral ('matchstick'-shaped) porphyroblasts (Fig. 22). Calcarenites and metasiltstones are rich in actinolite close to faults. Amphibolite crops out north of Yamamilla mine.

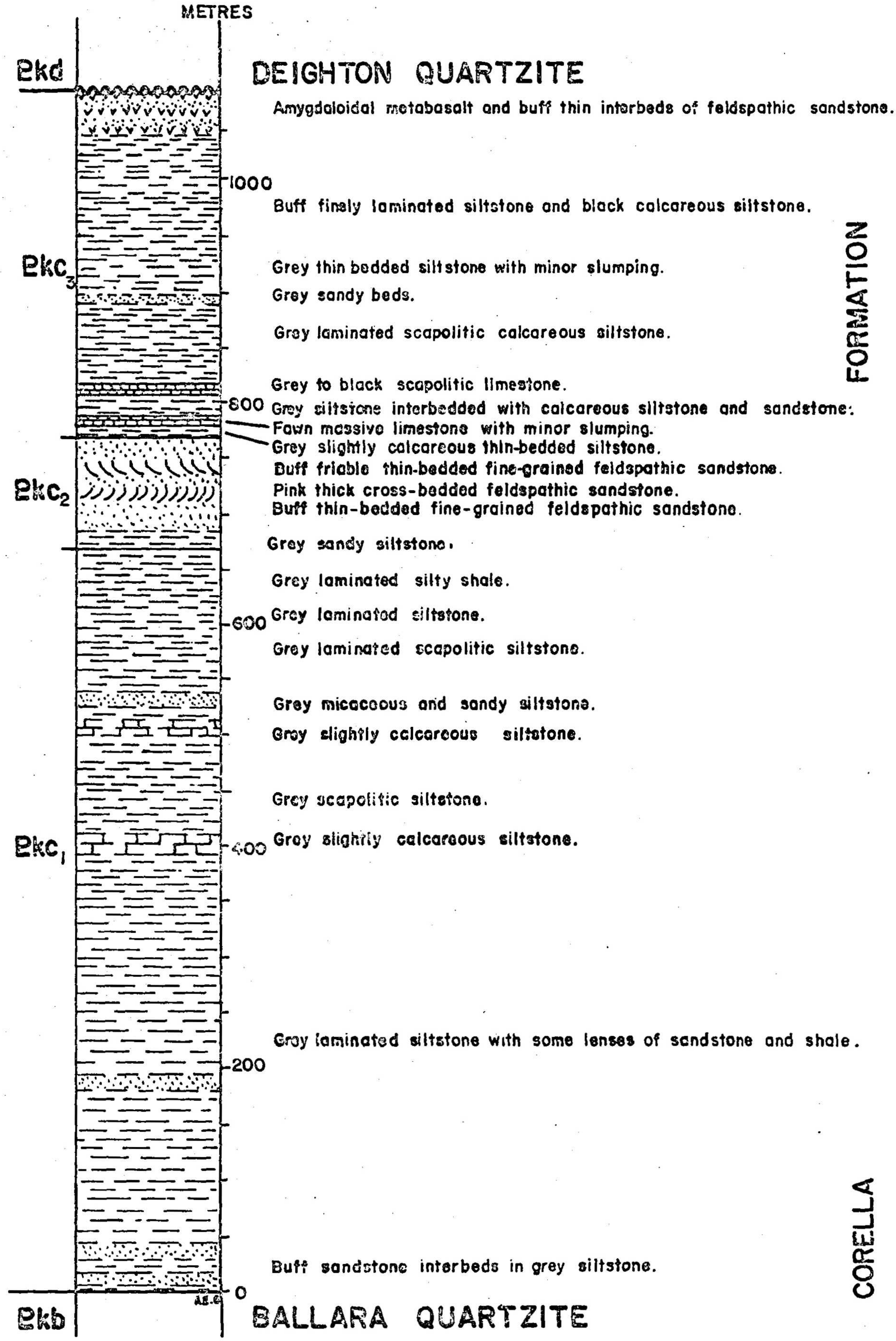
Sedimentary structures in the lowest member are rare, and generally only fine, parallel lamination is evident. Small-scale cross-lamination is present in some of the metasiltstones (Fig. 20). Towards the top of the member intraformational folding indicates soft-sediment deformation.

In thin section, the metasiltstones are composed predominantly of quartz, biotite, and microcline, with varying amounts of calcite, muscovite, and scapolite. Microcrystalline quartz is present as equant grains with undulose extinction and sutured boundaries. Biotite grains (0.005-0.4 mm) are blady or subequant, and have light to dark brown pleochroism. Alkali feldspar, commonly embayed, is predominantly microcline (0.01-0.08 mm) and is frequently embayed. Muscovite (0.005-0.05 mm) is present as blady laths. Anhedral poikiloblastic scapolite (0.04-10 mm) with numerous small inclusions of quartz, feldspar, and muscovite characterizes much of the metasiltstone (Fig. 22). Euhedral scapolite porphyroblasts (up to 8 mm) are common in the more calcareous rocks.

Metasiltstone north of Maylene mine has strongly sieve-textured and sector-twinned porphyroblasts of cordierite (0.01-0.4 mm). An actinolite-plagioclase-anthophyllite-biotite rock crops out two kilometres north-northwest of Maylene mine. Amphibolites interbedded with the metasediments north of Yamamilla mine contain in excess of 30 percent hornblende (Table 7).

Member Ekc$_2$. The middle member of the Corella Formation is well exposed southwest of Yamamilla mine along a sharp ridge. The base of the member consists of pink fine-grained feldspathic psammite which is locally pebbly. Higher in the member the psammite is medium-grained and more ferruginous. Near the top, beds of fawn laminated scapolitic siltstone occur. Medium-scale cross-stratification and ripple marks are well developed in this member.

Northwest of Yamamilla mine the member is poorly exposed and very thin, and consists mainly of brown to yellowish brown fine-grained micaceous metasiltstone and schist with porphyroblasts of amphibole. Buff to grey fine to medium-grained calcarenite and quartzite are intercalated with the siltstone and schist. The proportion of psammite in the member increases southwards.



Record 1977/174

F54/A2/174

Fig. 19 STRATIGRAPHIC SECTION THROUGH THE CORELLA FORMATION FROM 825430 TO 842430

Fig. 20.
Laminated micro-cross-bedded siltstone and calcareous siltstone of the lower member of the Corella Formation 6.3 km east of Mount Olive copper mine. M1518/9 IHW.

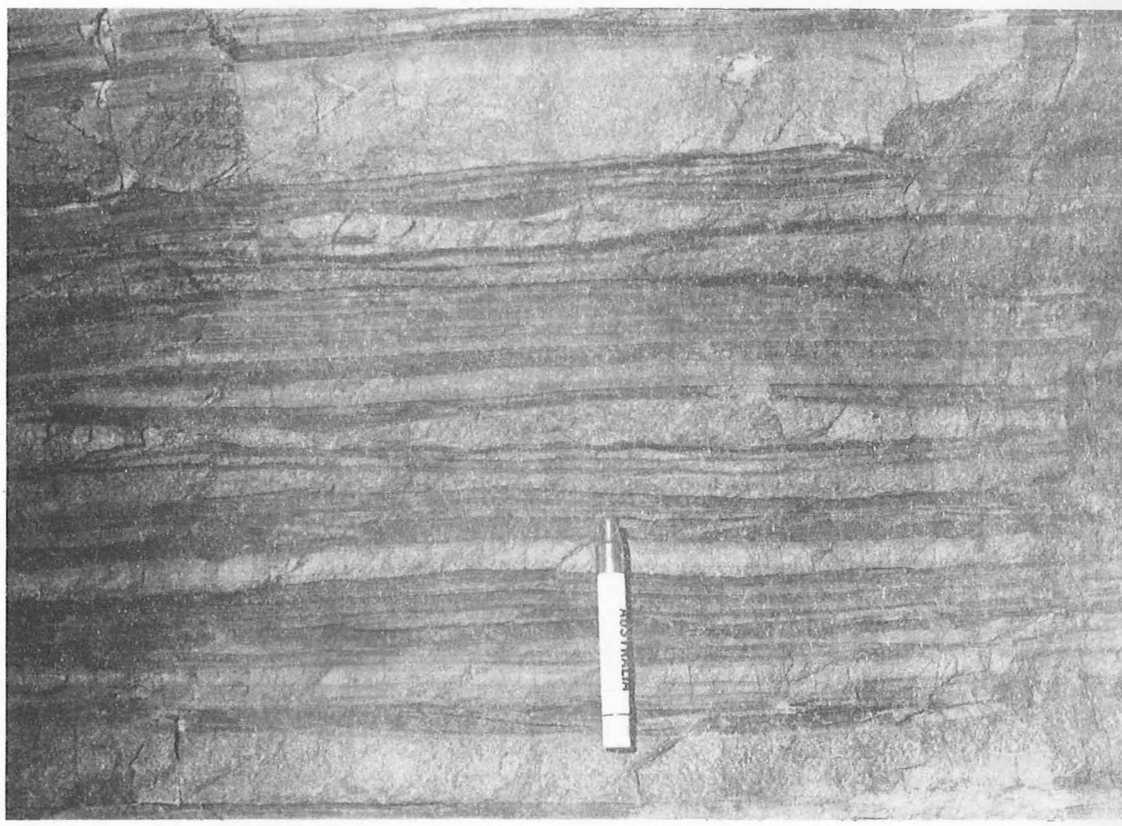


Fig. 21.
Thin lenticular bedding in fine calcareous quartzite and calcareous granofels in the Corella Formation 2 km east of Flora Dora copper mine. M1549/11A GMD.

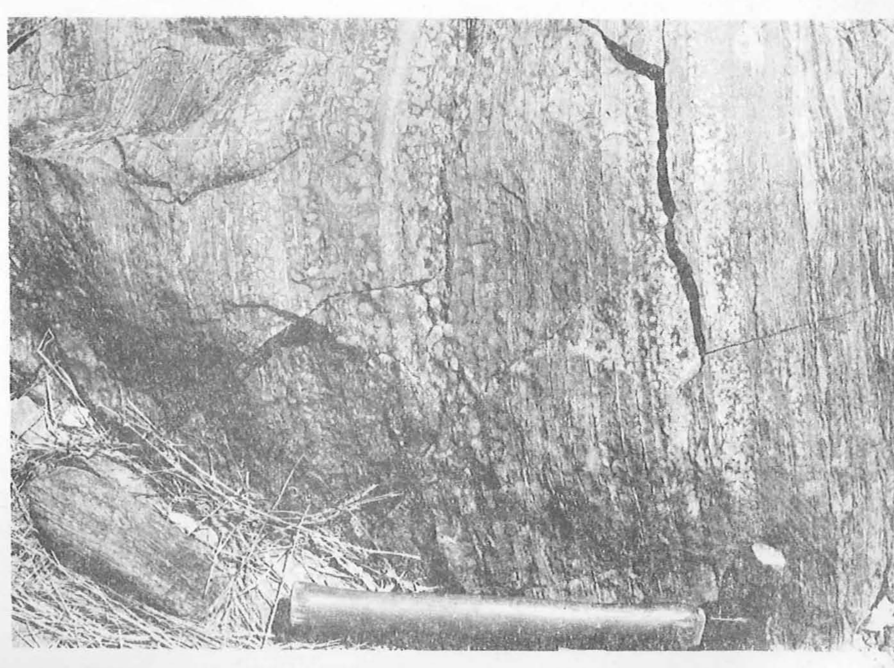


Fig. 22.
Scapolite porphyroblasts in laminated siltstone of the lower member of the Corella Formation 6.3 km east of Mount Olive copper mine.
M1518/8 IHW.

TABLE 7. ESTIMATED MODAL COMPOSITIONS, CORELLA FORMATION

Rock No.	q	k	p	sc	mu	bi	ch	ep	ca	hb	ac	op	Accessories
						Unit Pkc_1							
R5970	55					3	4						1 to, 1 zr
R5971	52					45			1			tr	2 to
R5972	45						tr	10	1	40		4	
R5973	28		10		10	2			tr		45	3	2 ao, ap
R5974	25	20	6	16	12	16			3			2	zr, ru
R5975	20	18				7		20	30			5	
R5977	25	13	2			25			5	30			
R5978	30	4		10	20	7	17	5				7	
0159	20	24		4	2	25			25				ap
0184	3	20		25	2	15			35				
						Unit Pkc_2							
R5976	53				3	3	1		40			tr	to
0158	20	30			10			5	32			3	
						Unit Pkc_3							
R5969	30				20	10			35			5	
R5980	30		5		10				20			35	
R5981	10			10		4	tr		75				1 and
0160	10	25		2	30				30			3	ap
0164	23	2		3	20	20		25	7				
0165	10	30			15	25		18				2	
						Undifferentiated							
R5989	15		30					15		40			

TABLE 7. Page 2

Rock No.	q	k	p	sc	mu	bi	ch	ep	ca	hb	ac	op	Accessories
R5990	1	35		6						10			45 diop, 3 sp
0170	35		35					1		28		1	ap
0172	53									42		2	ap, 3 sp
0173			20	25				4		3			45 diop, 3 sp
0187	10		20	20		23			20			7	
0188	2		45	5				2	15	30		1	
0190	16		48	15		20						1	
0195	7	10	20	20				7	5	10		1	20 diop

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q quartz, ru - rutile, sc - scapolite, sh - shale, sl - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

* Roooo are GSQ rock numbers

In thin section, quartz, microcline, and calcite are the major minerals of the psammite; epidote, biotite, and muscovite are present in lesser amounts.

Member Ekc$_3$. The uppermost member of the Corella Formation is similar to the lowest member in that the greater part of the succession is calcareous and non-calcareous metasiltstone. However, it is distinguished by the presence of impure limestones near the base, amygdaloidal metabasalt towards the upper contact with the Deighton Quartzite, and in general is more scapolitic. The basal limestone is a black or brown massive to laminated scapolitic rock about 20 m thick in the south. This is overlain by interbedded grey laminated shale and siltstone, scapolitic calc-granofels, and brown massive limestone with euhedral (matchstick) scapolite. Interlayering of discrete arenaceous and calcareous beds with thicknesses varying from a few centimetres to about 3 m is common, and brecciated rocks are mainly confined to these calc-silicates. Breccia is well exposed in a meridional valley just west of Yamamilla mine. Higher in the succession, in the core of the structural basin northwest of Yamamilla mine, scapolitic calcareous metasiltstone is interbedded with fine-grained calcarenite. The uppermost part of the succession is represented by at least three beds of dark grey amygdaloidal metabasalt interbedded with buff cross-bedded feldspathic quartzite which are unconformably overlain by the Deighton Quartzite.

The member is intruded by a massive to slightly foliated medium to coarse metadolerite which has been folded with the rest of the succession; it is probably a sill. At the southern extremity of the structural basin the metadolerite is intercalated with calcarenite.

Primary sedimentation features have been little deformed in the calcarenites and metasiltstones, and the dominant structure is parallel lamination. Convoluted bedding is present in various parts of the section on a small scale. Amplitudes are generally of the order of a few centimetres. Cross-stratification is present in arenites toward the top of the member.

In thin section, quartz, calcite, and alkali feldspar are the major minerals, with lesser biotite, muscovite, scapolite, and epidote. Quartz, present both as large grains (up to 3 mm) and small groundmass grains (0.08-0.12 mm), has undulose extinction. Coarse embayed alkali feldspar grains (2-3 mm) fill small veins transecting the fine matrix. Microcline typically has numerous inclusions. Biotite has straw to dark brown pleochroism and is present as ragged grains (0.1-0.5 mm) defining a weakly penetrative foliation. Poikiloblastic, irregular grains of scapolite enclose numerous small quartz and feldspar crystals.

Undivided Ꞓkc. Toward the eastern margin of the Sheet area and west of Surprise mine, subdivision of the Corella Formation is hampered by lack of exposure, an abundance of aplite and granite intrusions, and a higher-grade of metamorphism. Metamorphic effects increase in intensity eastward away from the Mount Remarkable Fault and towards the Wonga Granite, near which amphibolite-facies assemblages are present. Banded amphibolite constitutes the greater part of the Corella Formation in this region, and is interlayered with metadolerite and numerous aplite veins. Typically, hornblende-rich or diopside-rich layers alternate with calcitic and quartzofeldspathic layers varying in thickness from 2 mm to 2 cm. These layers are concordant with aplite stringers varying in thickness from about 5 cm to a few metres.

The most typical minerals, present in varying amounts, are quartz, alkali feldspar or plagioclase, hornblende, scapolite, diopside, calcite, and biotite, with accessory sphene, opaques, epidote, and ziosite. The mineralogy indicates that the rocks were probably pelitic or dolomitic, or both, before they were metamorphosed. Some metamorphic segregation has occurred. The metamorphic textures of these assemblages are described under 'Microstructures' in the section STRUCTURE.

Palaeogeography

An interpretation of the direction of provenance is difficult owing to the paucity of diagnostic sedimentary structures. Observations of the orientation of current ripple marks and cross-beds suggest that detritus was transported from a source west of the depositional basin; some current directions from the north and northwest are also inferred. That the provenance may have been the Kalkadoon-Leichhardt basement block is suggested by the presence of zircon, tourmaline, and apatite in much of the metasediment.

The pre-metamorphic lithology of the lowest member was probably a heterogeneous sequence of rhythmic parallel-layered siltstone, mudstone, and marl. Deposition was probably below wave base, either in deep open water or a restricted shallow-water basin. The carbonate content may be due to deposition in rather shallow water. The high sand content of the middle member and its medium-scale cross-bedding are typical of a higher-energy sedimentary environment such as a juvenile fluvial system, a marine tidal channel or bar, or a coastline. Most of these possibilities would imply some regression while the middle unit was being deposited. Later, a return to a quiescent, near-shore environment resulted in deposition of the uppermost member. The massive limestone near its base is consistent with a marine shelf environment; some evidence of high salinity and restricted circulation is provided by the abundance of sodic scapolite, which has been taken to reflect the initial presence of halite (Ramsay & Davidson, 1970).

MOUNT ALBERT GROUP

Deighton Quartzite

Introduction

The Deighton Quartzite is named after Deighton Pass, in the Mary Kathleen Sheet area. The formation was defined formally by Carter et al. (1961) with reference to a type section that extends 3.6 km northwards from a point 2.4 km west-northwest of Deighton Pass. In the Prospector Sheet area there are only two blocks of Deighton Quartzite, both in the southeast of the Sheet area. Several outcrops near the southern border of the Prospector Sheet area that were previously mapped as Deighton Quartzite on the 4-mile Cloncurry Sheet geological map, are now regarded as Corella Formation (Bkc_2), and an area 2 km west of the Yamamilla copper mine is now regarded as Ballara Quartzite. The major block of Deighton Quartzite lies in the axis of a north-plunging syncline 6 km southwest of the Yamamilla copper mine; a smaller block, previously mapped as Argylla Formation, is located 6 km west of the Yamamilla copper mine. The total area of outcrop of the Deighton Quartzite in the Prospector Sheet area is 25 km^2, which is about two thirds of the area that was previously mapped as Deighton Quartzite in this Sheet area.

The main block of Deighton Quartzite forms a large gently undulating steep sided plateau, and other blocks elsewhere form a series of upstanding ridges. The rocks are moderately well sorted arenites with minor intercalations of conglomerate, labile sandstone, and siltstone which show very little evidence of metamorphism.

Stratigraphic relations

The Deighton Quartzite overlies the Corella Formation with apparent conformity in the Prospector Sheet area; however, to the south, Derrick et al. (in press) report that the formation is unconformable on the Leichhardt Metamorphics, Magna Lynn Metabasalt, Ballara Quartzite, and the Corella Formation. In the Sheet area, no formations overlie the Deighton Quartzite and no granitic or dolerite intrusives have been found in the formation. Some dolerites that have not been affected by the deformation which folded the formation are inferred to be younger than the quartzite. The relation between the Deighton Quartzite and the Wonga Granite is not known.

Lithology and field occurrence

Five informal units - Epd_1, Epd_2, Epd_3, Epd_4, and Epd_5 - have been mapped within the Deighton Quartzite in the Sheet area. They are defined by their airphoto-pattern and lithology. Units Epd_1 and Epd_5 correspond to most of the undivided Deighton Quartzite, Epd, on the Mary Kathleen 1:100 000 geological map; units Epd_2 and Epd_4 correspond to the unit Epd_t; and unit Epd_3 is a minor sandstone interbed.

Unit Epd_1 is the most widespread unit in the Sheet area. The predominant rock type is a blocky white, pink, or buff thinly cross-bedded to thick-bedded feldspathic sandstone and quartzite. Minor amounts of kaolinitic sandstone, grit, and conglomerate occur in this unit. Pebbles in the conglomerate show low sphericity, and consist of quartz, quartzite, and siltstone; they are mostly well rounded, and in some beds they have well defined imbrication. Cross-bedding and less abundant ripple marks indicate palaeocurrent directions from the northwest. The unit is about 400 m thick.

Unit Epd_2 is a slightly recessive unit consisting of grey very thin bedded laminated siltstone that grades upward into poorly sorted sandy siltstone, and interbedded siltstone and grey feldspathic sandstone. The siltstones are locally calcareous and display primary structures such as intraformational breccia, slumps, ripple marks, grooves, and flute moulds. A few determinations of palaeocurrent directions from ripple marks and flute moulds indicate currents from the south, southeast, northwest, and west. The unit is about 150 m thick.

Unit Epd_3 crops out as a narrow ridge of cream to buff thin, cross-bedded, locally ripple-marked fine-grained labile sandstone. Palaeocurrents appear to have come from the southwest or west. The unit is about 60 m thick.

Unit Ꝑpd$_4$ is similar to unit Ꝑpd$_2$ consisting of grey siltstone and buff thin-bedded very fine-grained sandstone. It is about 100 m thick.

Unit Ꝑpd$_5$ forms a plateau in the core of the fold. It consists of creamy white, thin cross-bedded lithic and feldspathic sandstone, minor buff to white medium to coarse-grained feldspathic sandstone, and a few beds of conglomerate. The full thickness of this unit cannot be determined because its top is not defined, but at least 200 m of the unit are exposed.

Quartz and quartz-hematite veins cut the formation, especially along shear zones. Some alteration zones adjacent to quartz veins are several times the thickness of the veins, and contain 1 to 10 mm cubes of limonite pseudomorphous after pyrite.

Petrology

Two specimens from each of units Ꝑpd$_2$ and Ꝑpd$_3$ and one specimen from unit Ꝑpd$_5$ were examined in thin section, and estimated modal compositions are listed in Table 8. The specimens from unit Ꝑpd$_2$ are labile siltstones consisting of quartz, microcline, muscovite, and minor amounts of plagioclase, biotite, opaques, and tourmaline; one of these specimens contains 10 percent of angular shale fragments. The primary bedding structures can be recognized in the siltstones, which also have a well preserved clastic texture consisting of poorly sorted slightly rounded subangular grains with irregular interlocking boundaries and very minor matrix. Unit Ꝑpd$_3$ contains rocks very similar in composition to unit Ꝑpd$_2$, but they are coarser-grained, moderately well sorted, and contain significant amounts of matrix. The matrix is a recrystallized quartzofeldspathic mosaic incorporating small grains of sericite and opaques. The specimen from unit Ꝑpd$_5$ is more mature than the other specimens examined. It consists of well rounded subspherical quartz grains 0.2 to 0.8 mm in diameter in a matrix of sericite and opaques. The quartz grains are highly strained and some are recrystallized near their margins.

TABLE 8. ESTIMATED MODAL COMPOSITIONS, DEIGHTON QUARTZITE

Rock No.	Clasts/matrix	q	k	p	mu	bi	op	Accessories	a.g.d.	Name
				Unit Ꝑpd$_2$						
R5600		70	20	1	8		1	to	0.05	Grey labile siltstone
R5601	10 (shale)	35	35		5	5	10	to	0.05	Litho-feldspathic siltstone
				Unit Ꝑpd$_3$						
R5599		40	53		5		2		0.02	Labile sandstone
R5597	20 M	36	40		3		1		0.02	" "
				Unit Ꝑpd$_5$						
R5598	15 M	85							0.5	Quartzose sandstone

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

Roooo are GSQ rock numbers.

Discussion

The two blocks of Deighton Quartzite in the Sheet area are probably faulted portions of a thick sandstone unit that was originally much more extensive and may have been continuous with the outcrops 20 to 50 km to the south in the Mary Kathleen Sheet area. The nearby basement of acid volcanic and granitic rocks is a likely source for the detritus in the Deighton Quartzite. Transport distances were probably not great because grains are mostly subangular and the microcline is relatively fresh, and the majority of palaeocurrent directions are from the west, southwest, or northwest.

The Deighton Quartzite represents a different sedimentary environment from the broad shallow-water shelf environment of the underlying Corella Formation. The lower units contain poorly to moderately well sorted fine-grained sediments which suggest a relatively low-energy sedimentary environment; better sorting and higher maturity of unit Epd_5 indicates a higher-energy environment, possibly longer transport, and/or a maturation of the provenance. Conglomerate and pebbly beds, small to medium-scale cross-bedding, and ripple marks indicates current activity that may have operated in a shallow marine shelf or a fluviatile environment; a fluviatile environment was postulated by Derrick et al. (in press) for most of the Deighton Quartzite to the south, although an estuarine, deltaic, or near-shore shelf environment may be represented by some of the Deighton Quartzite in the Mary Kathleen Sheet area. The Deighton Quartzite may thus represent a regression to a very shallow marine, littoral, or terrestrial environment. In the Prospector Sheet area there is insufficient extent of outcrop to determine the shape of the basin of deposition, but the non-lenticular sedimentary units apparently preclude a confined north-trending river or submarine valley (cf. Derrick et al., in press). A broad coastal plain environment with easterly flowing streams is an alternative interpretation.

Slight metamorphism of the Deighton Quartzite has recrystallized the matrix and sutured grain boundaries. Many of the quartz grains are highly strained and some are slightly recrystallized. The grade of metamorphism is apparently less than that of the underlying formations and probably does not exceed the greenschist facies; this may be due to either the shallower depth of burial of this formation during the regional metamorphism, or the deposition of the formation after the metamorphism. The latter explanation is considered untenable because the Deighton Quartzite is metamorphosed and there is no retrogressive metamorphism in the older formations.

The Deighton Quartzite was correlated with the Mount Isa series by AGGSNA (1937). It was considered similar to the Surprise Creek Beds in lithology, structure and possibly age by Carter et al. (1961). Derrick et al. (in press) considered the Deighton Quartzite was probably younger than the Surprise Creek Beds and possibly younger than all of the Mount Isa Group. On the Prospector 1:100 000 preliminary geological map the Deighton Quartzite is shown as younger than the Mount Isa Group and the Surprise Creek Beds, but there is little evidence for this correlation. The most likely correlation is with sandstone and siltstone of units A to D in the Surprise Creek Beds, towards the base of the Mount Isa Group (Derrick, 1976).

C. STRATIGRAPHY OF THE WESTERN SUCCESSION

HASLINGDEN GROUP

Mount Guide Quartzite

Introduction

The Mount Guide Quartzite was formally defined by Carter et al. (1961) and was subdivided into two members by Derrick et al. (in press). Only the upper member (Phg_2) crops out in the Sheet area. It covers 3 km^2 and forms an upstanding

92

grey to buff flat-topped ridge. The airphoto-pattern of the member is enhanced by the presence of numerous meridional dolerite dykes.

Stratigraphic relations

Stratigraphic relations are not clear in the Sheet area. Farther south the Mount Guide Quartzite unconformably overlies the Kalkadoon Granite and the Leichhardt Metamorphics (Derrick et al., in press). The Mount Guide Quartzite is overlain conformably by the Eastern Creek Volcanics and is in fault contact with the Myally Beds. It is intruded by numerous north-trending dolerite dykes.

Lithology and field occurrence

The major outcrops of the quartzite are in the Mary Kathleen Sheet area, to the south, and only a small triangular section of the Mount Guide Quartzite extends into the Prospector Sheet area. It is composed predominantly of a white to grey medium-grained, well sorted, moderately thinly bedded quartzite and feldspathic quartzite. Faulting along the eastern edge of the outcrop has resulted in some overturning of the beds. Limonitic staining is pronounced adjacent to the dolerite dykes, which are deeply weathered and are preferentially eroded.

Discussion and correlation

Sediments of the Mount Guide Quartzite are mature and probably indicate deposition in a shoreline or near-shore environment.

The Mount Guide Quartzite is correlated with the Leander Quartzite, since both units occupy the same stratigraphic position, have similar lithologies, and have a similar airphoto-pattern. This correlation was first proposed by Carter et al. (1961).

Leander Quartzite

Introduction

The Leander Quartzite was defined by Carter et al. (1961) and is named after Leander Range, which is composed almost entirely of rocks of this formation and forms a rugged north-trending belt at the western edge of the Prospector Sheet area. About 38 km^2 of Leander Quartzite is exposed in the Sheet area.

Stratigraphic relations

The base of the formation is not exposed in the Sheet area, nor was it observed farther west by Carter et al. (1961). The formation is conformably overlain by the Eastern Creek Volcanics; the contact is mostly obscured by scree and in some places is faulted.

Field occurrence

Leander Range is a high planated range with steep scree-covered sides, and stands 80 to 150 m above the surrounding volcanics. The quartzite dips eastwards at moderate angles (20-60°) and forms the eastern limb of a dome with its axis in the adjoining Kennedy Gap 1:100 000 Sheet area, to the west. It displays some minor monoclinal flexures.

The Leander Quartzite in the Sheet area consists predominantly of fine to medium-grained quartzite; it is sporadically cross-bedded and ripple-marked through much of its thickness. The ripple marks are rectilinear or sinuous and generally asymmetrical. Medium-scale cross-stratification is of the alpha type (Allen, 1963) with planar bounding surfaces to the sets and asymptotic cross-laminae. Dip angles of up to 35° were observed; sets averaged about 60 cm in thickness. Small angular flattened green shale clasts are common throughout the sequence. Towards the top of the formation a very coarse-grained arkosic unit about

5 m thick contains coarse-grained quartzite clasts ranging from 1 to 8 cm in diameter, and green shale clasts. To the west of the Sheet area boundary the quartzite grades down into siltstone and phyllite.

Asymmetrical ripple marks indicate current directions with vector means of about 160° and 75°; the easterly direction tends to be the more dominant.

Numerous north-northwest-trending metadolerite dykes about 2 to 5 m thick pervade the eastern part of Leander Range, parallel to a penetrative set of joints which are parallel to the axial plane of folding.

Petrography

Table 9 summarizes the petrography of the Leander Quartzite. The sediments consist predominantly of rounded quartz grains (average diameter of 0.5 mm) with minor feldspar, opaque minerals, and, in some, lithic fragments including shale and quartzite. Quartz grains have sutured boundaries and undulose extinctions, indicating strain since deposition. Using Crook's (1960) classification these metasediments were originally sublabile and quartzose sandstones.

Discussion

The overall upward coarsening of sediments from shales to quartzite and the typical flat bedding of the Leander Quartzite with only rare isolated sets of cross-bedding indicate a prograding linear clastic shoreline (Selley, 1970). A deltaic shoreline has a similar vertical profile except that the succeeding sand will generally be more cross-bedded and there is likely to be an upward-fining of grainsize into a rippled, very fine sand. The well rounded, well sorted sand grains are those of a supermature sediment, and indicate deposition in areas of intense abrasion and sorting where energy is constantly being expended on the grains (Folk, 1968), such as in a clastic shoreline.

Shale fragments commonly dispersed throughout the sequence may be of very local derivation, and most likely represent fragments carried from local lagoonal and intertidal deposits which probably existed shorewards from the barrier sands which constitute the upper part of the Leander Quartzite.

The present outcrop suggests the shoreline was north-south; ripples and cross-beds suggest that the major sediment-bearing current was from the west, and was associated with a southwards long-shore drift which redistributed some of the sediment.

Carter et al. (1961) correlate the Leander Quartzite with the Mount Guide Quartzite as both formations conformably underlie the Eastern Creek Volcanics, are of similar lithology, and are similarly intruded by dolerite. The Mount Guide Quartzite overlies the Kalkadoon-Leichhardt basement block unconformably, but the base of the Leander Quartzite is not exposed. However, the abundant quartz, and the thin arkosic conglomerate near the top of the Leander Quartzite are consistent with a provenance of igneous and volcanic basement rocks.

Eastern Creek Volcanics

Introduction

The Eastern Creek Volcanics, a sequence of slightly metamorphosed continental tholeiitic basalt and intercalated sediments, cover about 4000 km^2 in a north-trending belt 300 km long. The name of the unit is derived from Eastern Creek, which joins Gunpowder Creek 20 km northwest of the Prospector Sheet area. The unit was formally defined by Carter et al. (1961) with reference to a type section in the Mary Kathleen Sheet area along the Mount Isa-Cloncurry road from 8 to 2.5 km east of Mount Isa.

TABLE 9. ESTIMATED MODAL COMPOSITIONS, LEANDER QUARTZITE

Rock No.	0002*	0007	0080
Quartz	83	95	96
Feldspar	15		
Muscovite		5	2
Opaques	2		
Tourmaline		tr.	
Biotite			2
a.g.d. (qtz in mm)	0.5	0.4	0.7

0002 Sublabile Arenite
0007 Quartzose Arenite
0080 Quartzose Arenite

* last four digits of BMR registered rock no. 74200002

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop- diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, k - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

The formation was divided into four members by Robinson (1968), but a three-fold division of the formation into two predominantly basaltic members separated by a quartzitic member is used here (Derrick et al., 1976b, in press).

In the Prospector Sheet area the Eastern Creek Volcanics cover about 415 km^2, mainly in the westernmost third and the north-central parts of the Sheet area. The formation generally shows low relief, the top and bottom basaltic members forming gently undulating valleys with some small ridges underlain by intercalations of metasiltstone and quartzite; the quartzitic middle member occurs as a strongly upstanding, jointed, and faulted ridge system. Trends vary from northerly in the north and northwest to predominantly easterly in the southwest of the Sheet area.

Stratigraphic relations

The Eastern Creek Volcanics conformably overlie the Leander Quartzite and the Mount Guide Quartzite, and are overlain conformably by the Myally Subgroup and in places unconformably by the Surprise Creek Beds and the Mount Isa Group. Contacts with these younger rocks are extensively faulted. Dolerite dykes of at least two ages intrude the volcanics.

The three members in the formation are the basal Cromwell Metabasalt Member, the Lena Quartzite Member, and the uppermost Pickwick Metabasalt Member. The maximum thicknesses of these members are about 6000 m, 700 m, and 1500 m respectively, although marked thickness variations do occur, especially in the top two formations, which generally thin to the east.

Lithology and field occurrence

The Cromwell and Pickwick Metabasalt Members have similar lithologies; both are predominantly metabasalt with minor metasediment. The metabasalt is a dense fine-grained rock with a grey-green colour which is due to the presence of greenschist facies minerals - epidote, chlorite, and actinolite. Individual lava flows can be distinguished by the concentration of vesicles at the top of each flow, and by the intercalations of sediment. The vesicles are typically infilled with quartz and epidote, chlorite, and more rarely calcite and minor sulphides. The flow tops locally contain a chaotic mixture of fragmental vesicular basalt and infillings of sandstone.

Numerous thin sedimentary beds, constituting 20 to 50 percent of the outcrop, are intercalated within the basalt sequences between flows. The beds are mostly lenticular with limited lateral extent, and include quartzite, epidote sandstone, siltstone, dolomitic siltstone, and, in some of the northeastern outcrops, conglomerate. The quartzite is mostly pink to cream, fine-grained, and thinly to thickly bedded. Cross-bedding and less commonly ripple marks occur in the quartzite, and heavy-mineral banding is abundant. Epidote sandstone is green, fine-grained, poorly stratified, and in many places intimately mixed with basalt fragments. Locally it has mud-cracks. Other sandstones include buff fine-grained impure sandstone with black heavy-mineral laminae, some cross-beds, and rare slumps; brown fine to medium laminated to thin-bedded ferruginous sandstone with interbedded siltstone and rare mud-cracks; dark grey medium-grained lithic sandstone; and dark grey fine-grained impure calcareous sandstone. Sand-grade and lapilli-rich greenish grey basic tuff occurs with some sandstone interbeds. The sandstones typically grade into siltstone near the top of the thicker interbeds. The siltstone is mostly grey, laminated and cleaved. Pencil siltstone occurs in several localities where two or more cleavages intersect. Sequences of pale purple-grey dolomitic siltstone, 10 to 30 m thick, are widely distributed in the Cromwell Metabasalt Member.

The conglomerate beds restricted to the northeastern outcrops are highly lenticular, with maximum thicknesses of about 15 m. One conglomerate 2 km west of the Julius Dam contains

99

well rounded clasts from 0.5 to 15 cm long of red granite, acid volcanics, and minor quartzite. The matrix constitutes about 60 percent of the rock and consists of coarse-grained subarkose or foliated grey micaceous metasiltstone. Near the Victoria gold mine some conglomerates contain more basalt fragments than acid volcanics. The matrix is locally calcareous, and minor beds of fairly pure limestone are intercalated with the conglomerate.

The Lena Quartzite Member is a fine to medium impure quartzite which has thin (10 m) shale intercalations towards its base. The quartzite is mostly brown to buff, massive to blocky, well jointed, cross-bedded, locally ripple marked, and rarely contains convoluted bedding. Some beds are pink and feldspathic. Pyrite and arsenopyrite occur in a few localities. Pebble bands containing well rounded basic volcanic and quartzite clasts are rare. An ophitic dolerite sill intrudes the contact between the Cromwell Metabasalt Member and the Lena Quartzite Member in most places.

Current directions inferred from the orientation of cross-beds and ripple marks indicate currents predominantly from the east to southeast during the deposition of the Lena Quartzite Member. Isolated observations from the sedimentary intercalations in the metabasalt members indicate currents from the northeast, southeast, and possibly southwest.

Structure

The Eastern Creek Volcanics and surrounding units are extensively folded, and also disrupted by faulting into blocks 15 to 30 km across. Minor faulting occurs within these blocks. The folds are mainly double plunging anticlines and synclines similar in style to those encountered elsewhere in the region, and are outlined by thin arenaceous interbeds within the Eastern Creek Volcanics. These tight macroscopic ellipsoidal structural domes and basins are oriented with their long axes roughly north-south. Folding observed in the Lena Quartzite Member, especially in the central and southern fault blocks, is more open and concentric, but the axes are north-trending, consistent with the regional trend.

The deformation attending this folding has flattened cross-stratification in the arenites, produced a slaty foliation in many of the sedimentary interbeds, and imparted a coarsely penetrative fracture foliation to the metabasalt. The meta-basalt in the hinges of the macroscopic folds is extremely fractured and pervaded by quartz-epidote veins. Within the Lena Quartzite Member a penetrative north-trending slaty foliation is developed only in the shales and the more feldspathic sandstones. Minor folding associated with the basin-and-dome style of folding is present in some arenites of the Cromwell Metabasalt Member.

The numerous east-southeast-trending strike-slip faults within the fault blocks postdate the episode of basin-and-dome folding.

<u>Petrography</u>

About 70 thin sections of rocks from the Eastern Creek Volcanics were examined. Estimated modal analyses for 25 specimens from the Cromwell Metabasalt Member, 2 from the Lena Quartzite Member and 9 from the Pickwick Metabasalt Member are presented in Tables 10, 11, and 12.

The <u>metabasalts</u> contain assemblages of the chlorite grade of the greenschist facies, and original igneous textures are locally preserved. The centres of lava flows consist of pale green acicular to tabular amphibole (tremolite-actinolite), plagioclase (albite-oligoclase) laths, chlorite (penninite), epidote-zoisite, quartz, rare calcite, sphene, and relict opaque oxides (magnetite and ilmenite). Epidote, chlorite, quartz, and calcite, commonly displaying concentric zoning, are concentrated within the vesicles.

TABLE 10: ESTIMATED MODAL COMPOSITIONS, CROMWELL METABASALT MEMBER

Rock No.	Clasts	q	k	p	t/ac	bi	ch	ep	mu	ca	op	Accessories	a.g.d.	Name
R5900	10 sst			45			32	2	1		12			Metabasalt
R5886		20						75	4		1			Epidotized basalt
R5544		tr		20	57		5	15			3	ap, zr	0.3	Metabasalt
R5545		22			10			50		tr	10	8 sp	0.2	Basalt, clast from epidosite
R5553		12			30			54		1	3		0.3	Metabasalt
R5551				8	56		7	25			4		0.2	Metabasalt
R5546	12 bas, sh, av	5		45			15	10	5	5	3	zr	0.3	Basic tuff
R5547	14(calc-ch)			56				20			10		0.2	Basic tuff
R5545		55			5			40					0.05	Epidosite
R5549		5					2	85			5	1sp, 2ap	0.2	Epidosite
R5901	5 bas	55	10	15			8	tr	5		2		0.6	Feldspathic sandstone
R5889		98					2					zr, tour	0.8	Orthoquartzite
R5887		65							33		2	tour	0.8	Metasandstone
R5885		85		10					5			zr, tour	0.8	Quartzite
R5572		63					10		20		7		0.03	Siltstone
R5571		33	(32)						5	8	2	zr, tour	0.4	Labile sandstone
R5548	10 bas	25		35		1	20			5	3	1sp	0.2	Metamorphosed labile sandstone
R5552		50	25	3					1		1	zr	0.2	Metamorphosed labile sandstone
0003	(65)	20		50				5		15	10		0.7	Labile quartzite
0004	(70 bas)	15		30			5	20		10	20		1.0	Labile quartzite
0005		10		30	25			15			10	10sp	0.1	Labile quartzite (?)
0006	(2)	30		40		3	5		2		15	5sp	0.4	Labile quartzite
0008		25		47		2	2		5	1	15	3sp	0.3	Labile quartzite
0009					10		5			83	2		0.4	Tremolite-calcite granofels
0010		30		15	3			50		1	1		0.07	Epidote quartzite

TABLE 11: ESTIMATED MODAL COMPOSITIONS, LENA QUARTZITE MEMBER

Rock No.	q	felsp	ch	op	Accessory	a.g.d.	Name
R5896	80	(15)	tr	5	zr	0.8	Feldspathic sandstone
0011	98			2		0.5	Quartzose quartzite or orthoquartzite.

TABLE 12: ESTIMATED MODAL COMPOSITIONS, PICKWICK METABASALT MEMBER

Rock No.	Clasts	q	k	p	to	cpx	ch	ep	mu	ca	op	Accessories	a.g.d.	Name
R5554	7amyg						50	40			3		0.3	Amygdaloidal basalt
R5566	3amyg			25	56		4	1		2	4	5 sp	0.1	Amygdaloidal basalt
R5557	3amyg			10	70		5	10			2		0.3	Amygdaloidal basalt
R5556	7amyg			50			16			1	5	3 sp	0.4	Amygdaloidal basalt
R5910		1		20	30	20	5	17			7			Metabasalt
R5537	40 bas, 5 sh	25		2			5			10	3		0.3+	Basic tuff
R5565		45	18	1					2	20	4	to, 10 clay	0.2	Calcareous sandstone
R5894		90	(9)								1	to		Quartzite
0020		80		10							7	1 to, 2 zr	0.15	Feldspathic quartzite

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k-k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

* Roooo are GSQ rock numbers.

The various mineral assemblages in the metabasalts are:-
Actinolite-albite-quartz-magnetite-chlorite-(sphene)-(epidote)-(calcite)
Actinolite-albite-quartz-magnetite-sphene-(epidote)
Actinolite-albite-magnetite-sphene
Albite-quartz-epidote-calcite
Albite-quartz-magnetite-epidote-calcite

The actinolite-free assemblage occupy zones of shearing adjacent to faults.

One specimen (GSQ 5910) contains clinopyroxene, probably as a primary mineral, and contrasts with the recrystallized state of other metabasalts in the formation. The specimen is from near the top of the formation and as temperatures during metamorphism probably decreased upward this could be an explanation of the relict mineralogy.

The sedimentary intercalations in the Cromwell and Pickwick Metabasalt Members are mostly fine-grained laminated calcareous and feldspathic quartzites, which consist of rounded to subangular quartz, minor iron oxides, kaolin, tourmaline, plagioclase (albite-oligioclase), calcite, and epidote.

The Lena Quartzite Member consists of quartz arenite containing rounded to subangular quartz grains in a matrix of sericite, minor opaque oxides, kaolin, and rare tourmaline.

Discussion

The uniformity of lava type and large areal extent of the Eastern Creek Volcanics were noted by Carter et al. (1961), who considered that the basaltic volcanism was accompanied by normal faulting, subsidence of the depositional basin, and continued rising of the 'median ridge'. The lavas were thought to have been extruded under water but some may have been extruded on land. The interbedded sediments are of shallow-water type and become more abundant towards the top of the formation (Carter et al., 1961, p. 50).

Robinson (1968) considered that the basalts were possibly of the orogenic spilite-keratophyre association of Turner & Verhoogen (1951) although the feeder dyke system he recognized in the underlying formations was more typical of flood basalts of non-orogenic continental regions.

Recent geochemical studies of the Eastern Creek Volcanics (Glikson, Derrick, Wilson & Hill, 1976) have shown that the basalts are calcalkaline quartz-hypersthene normative and olivine-hypersthene normative tholeiites. The tholeiites have some continental attributes but in Ti:Zr:Y plots they are between oceanic tholeiite and island arc calc-alkaline basalts. The extent of allochemical alteration during metamorphism is thought to have been slight.

Carter et al. (1961) correlated the Eastern Creek Volcanics with the Marraba Volcanics and with metabasalts in the Soldiers Cap Group, which occur to the east of the 'median ridge'. Glikson et al. (1976) showed that the Soldiers Cap Group basalts have more oceanic affinities than the Eastern Creek Volcanics farther west, indicating a transition from possibly open ocean in the east to an epicontinental environment in the west.

The sediments in the Eastern Creek Volcanics are shallow-water sandstones and calcareous siltstone. Their detrital components include quartz, feldspars, and ferromagnesian minerals derived from a mixed source containing exposures of older sediments, acid igneous rocks, and underlying basalt flows. The conglomerate clasts in the northern exposures were probably derived from the Kalkadoon-Leichhardt basement and there may have been significant topographic relief in this area during deposition. In other areas the depositional environment appears to have been flat to gently undulating.

HASLINGDEN GROUP, Myally Subgroup

The Myally Beds (Carter et al., 1961) have been redefined as the Myally Subgroup (Derrick et al., 1976b). It is a predominantly quartzitic sequence containing minor siltstone, shale, and rare acid tuff. The subgroup is divided into four formations and one member. On the Prospector 1:100 000 Sheet Preliminary geological map the subgroup is called the Myally Beds and the formations are numbered 1 to 4, (e.g. Ᵽhm_3). Unit Ᵽhm_5 is considered to be a member of unit Ᵽhm_4.

Some complete sequences of the Myally Subgroup are present in a number of fault blocks which occupy the western half of the Sheet area. In most localities the Myally Subgroup overlies the Eastern Creek Volcanics conformably, and is overlain conformably or disconformably by the Surprise Creek Beds, and unconformably by the Mount Isa Group.

Generalized lithology and thickness range of the constituent units of the Myally Subgroup are shown in Table 2.

Detailed descriptions of each unit are presented below; and their palaeogeography is summarized in Table 13.

Alsace Quartzite (unit Ᵽhm_1)

Field occurrence

The Alsace Quartzite is a psammitic unit present throughout the western half of the Sheet area. It is a resistant unit, and generally forms a small scarp overlying basalts and purple siltstone of the topmost Eastern Creek Volcanics. It is overlain conformably by the Bortala Formation.

Lithology

Feldspathic quartzite is the most common rock type. Up to 30 percent feldspar has been recorded from hand specimens, but petrographic examination indicates that the feldspar content of many samples is less than 10 percent; most of the 'feldspar' grains are white to pale grey kaolinitic patches and clayey rock fragments. The quartzite ranges in colour from grey to grey-pink, pinkish-brown, and pale purple, and is generally massive to blocky, thickly to thinly bedded, and extensively cross-bedded and ripple-marked. Some thin grey-green siltstone interbeds are present near the top.

Grainsize is medium to coarse, and in general the unit coarsens slightly towards the top.

The base of the quartzite is intruded by dolerite in the Paroo and Cromwell Creek areas, and large blocks of quartzite are rafted by the dolerite.

In most areas the beds are relatively continuous and parallel, but in a zone 7 km west of the Conglomerate Creek/ Leichhardt River junction a large lens of white very clayey friable feldspathic sandstone grades upwards into unit Ehm_2.

Thicknesses estimated at various localities are shown in Figure 23, and they range from about 70 to 600 m. Overall the unit is slightly thicker in the Paroo Creek area than elsewhere, and thins regionally from west to east; it is thinner in the southern fault block. The significance of the variations will be discussed later.

Sedimentary structures

Cross-beds and ripple marks are evident throughout Ehm_1. The cross-beds are medium scale pi and alpha types (Allen, 1963) in sets averaging 15 to 20 cm thick. Bases of the cross-bed sets are planar, and cross laminae are asymptotic towards the base. Ripple marks are mainly asymmetric, and in the lower half of the unit some are bevelled. Flute marks have been recorded from the northern exposures of the unit between Cromwell and Surprise Creeks. Grading is evident in specimen 6018.

Current-direction measurements from both cross-beds and ripple marks are shown in Figure 23; in the Paroo Creek area currents from the northwest are most common.

Petrography

Eight samples were examined, and their localities and composition are shown in Figure 23; the samples are listed in descending stratigraphic order.

Most samples are orthoquartzites, some of which contain abundant fine-grained matrix material. The sorting is generally good, (medium to coarse sand size; 0.3 to 1 mm diameter), and quartz grains are well rounded and of medium to high sphericity. Grains show sutured and slightly recrystallized margins, and are mainly silica-cemented. Clay matrix and rock fragments increase slightly upwards in the sequence; chert, clayey chert, and siltstone are common rock fragments.

Most quartz grains are monocrystalline, but up to 5 percent polycrystalline quartz is present in some northern samples - for example, 088.

In some specimens, bedding is outlined by fine opaque layers which probably contain ilmenite. Zircon, tourmaline, apatite, and ilmenite are the most common heavy minerals, but in the uppermost samples (6018, GSQ 5559) poorer sorting is accompanied by an increase in altered epidote grains.

Discussion

The abundance of chert, altered ilmenite, and epidote in 6018 suggests a dual source: a far distant sedimentary source or a mature silicic plutonic source for the quartz fraction, and a closer basic volcanic source such as the Eastern Creek Volcanics for the ilmenite, epidote, and chert, and some feldspar.

Deformation textures such as undulose extinction, highly sutured boundaries, and polygonization along some subgrain boundaries probably reflect a period of open folding followed by minor cataclasis during faulting. In spite of these formation textures, flattening of grains in most samples is negligible.

Palaeogeography of the unit is discussed later.

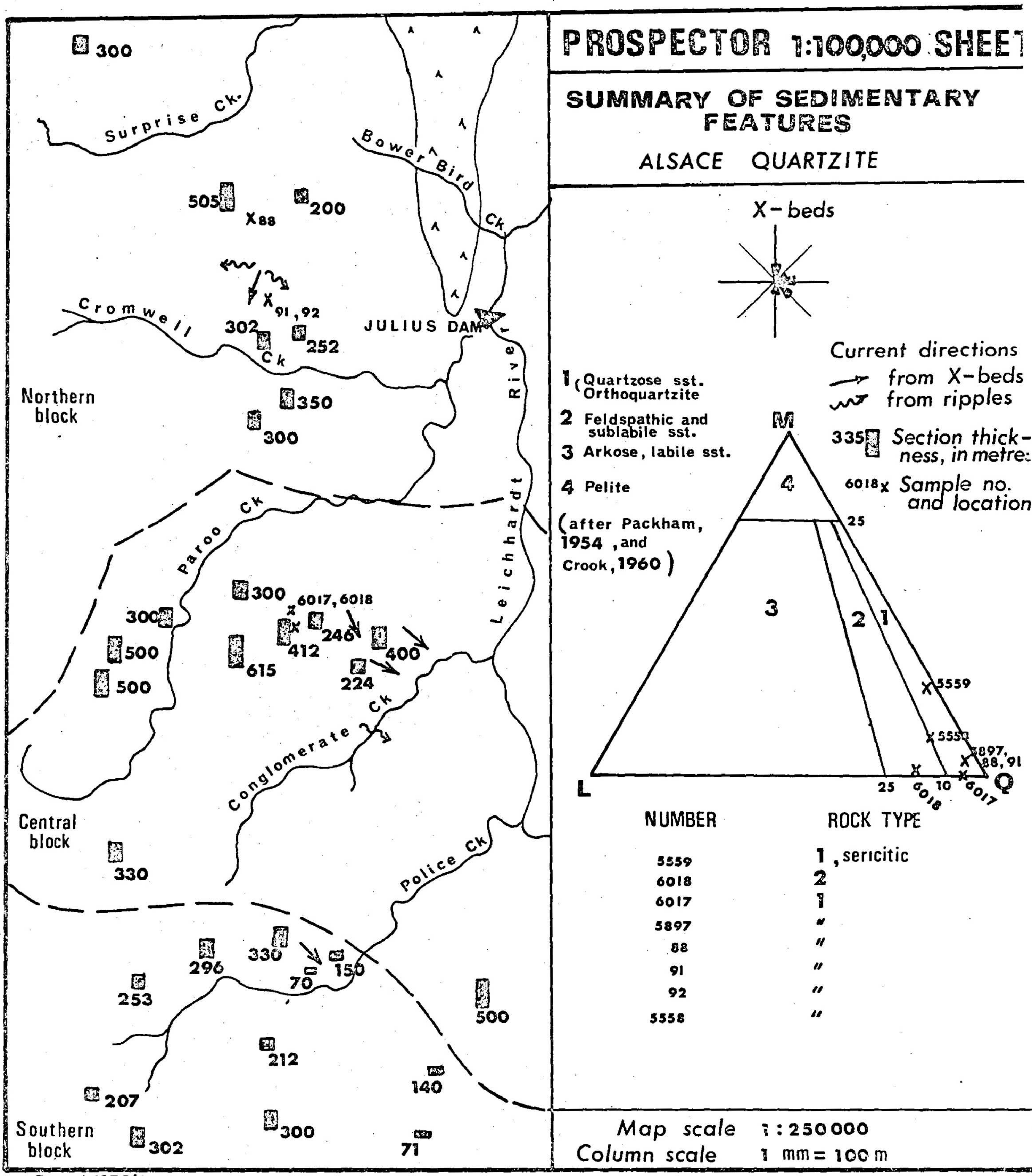
Bortala Formation (unit Ꝑhm$_2$)

Field occurrence

This is a recessive, fine-grained psammitic unit which forms a persistent valley between the upstanding quartzite ridges of units Ꝑhm$_1$ and Ꝑhm$_3$. It is conformable between these units over most of the Sheet area, but directly overlies the Eastern Creek Volcanics along the southern Sheet area boundary. It is also overlain unconformably by the Warrina Park Quartzite (part of the Mount Isa Group) in the far southwest corner of the Sheet. The major exposures are in the northern, central, and southern fault blocks of the western succession.

Lithology

Fine to medium pale brown to purple-grey siltstone and sandstone are most abundant, and characteristically contain abundant feldspar, clay minerals, and white mica on bedding-plane partings. Orthoquartzite and white friable sublabile psammite containing some chert and purple siltstone are recorded from the



Record 1977/4

Figure 23

F54/A2/175

northern and central exposures; grey shale, and coarse sand with shale clasts, are present in the south.

Near-basal sands in the central block contain 50 percent or more feldspar and other labile components.

Thickness estimates are shown in Figure 24, and range from 80 to 700 m. The unit displays a regional thinning from the south to the north, but most rapid variation occurs between the central and northern blocks.

Sedimentary structures

Parallel bedding predominates. Most beds show flaggy to blocky parting and are thin-bedded to laminated and fissile. Cross-bedding is present in some of the coarser sands, and rare current directions determined in the central block are from the south-southeast. Micro-cross-bedding, ripple marks, and some mud-cracks are also present, and graded bedding has been observed in thin sections.

Petrography

Twelve samples have been examined, and their localities and compositions are shown in Figure 24.

a. Northern block: Sample 0090 is a mature orthoquartzite which contains well sorted but subangular quartz grains, of which 7 percent are polycrystalline. White to pale green phengitic? mica at many grain interfaces may be derived from an original clay matrix.

b. Central block; Samples 6014 and 6015 are well sorted mature psammites containing a little clay and limonitic matrix and grain coatings; 6016 shows poor to moderate sorting, but roundness and sphericity are obscured by overgrowths of feldspar? and silica. All samples are characterized by a very high feldspar content (52, 60, and 90 percent respectively). Clouded plagioclase grains predominate over clear irregularly twinned microcline; the mica in all samples is fresh medium to coarse muscovite.

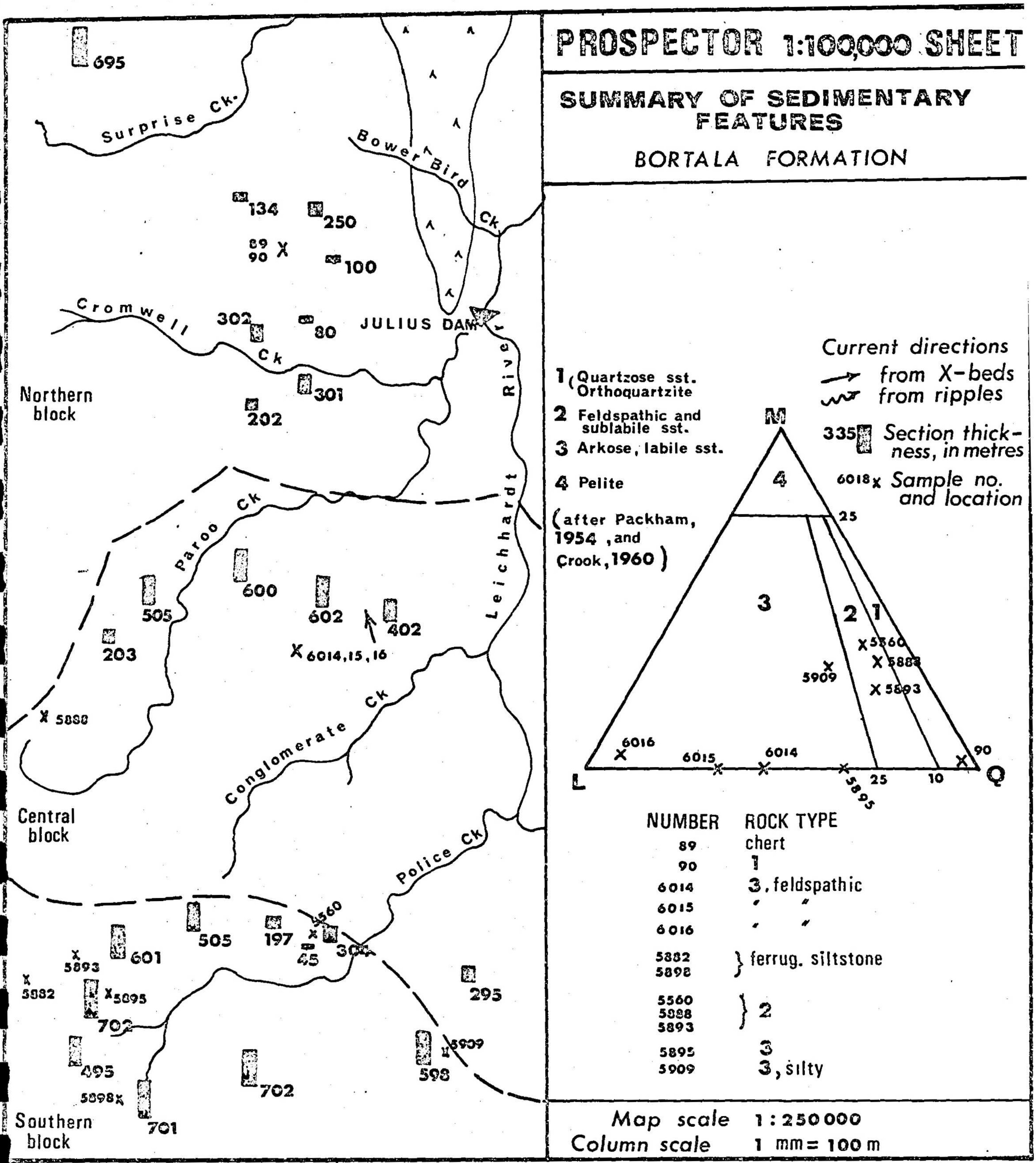
In 6014 and 6015 the major opaques and heavy minerals are ilmenite, iron oxides, tourmaline with overgrowths, subrounded zircon, and less commonly epidote. The addition of apatite and rutile to this assemblage in 6016 reflects a marked provenance change.

c. Southern block: siltstone and sandy siltstone (samples GSQ 5882 and 5898) contain subrounded quartz grains, and an abundance of iron oxide, muscovite/sericite, and chlorite, Psammites (GSQ 5888, 5893, 5895, 5560, 5909) like those in the central block, are also highly micaceous and feldspathic, and plagioclase generally exceeds microcline. Fragments of fine-grained siltstone and shale are present in 5895. Zircon and tourmaline are the major heavy minerals, and some quartz grains contain abundant inclusions of apatite.

Discussion

Notable features of this unit are the high clay, silt, and mica content of siltstone and some psammite, and the presence of well sorted highly feldspathic psammite. The increase in feldspar content, particularly plagioclase, possibly reflects an increased contribution of sediment from older basic volcanics, but more likely it represents uplift and erosion of mainly volcanic and plutonic source areas, possibly to the east and south-east, or even older plutonic areas to the west. Volcanic rocks rich in plagioclase phenocrysts are common in the Leichhardt Metamorphics and Argylla Formation, but source rocks exceptionally rich in plagioclase would be necessary for the formation of nearly pure feldspar sands such as 6016. Derivation of such feldspar-rich sands from pre-existing sandstones is unlikely. Clear microcline is probably derived from a recrystallized

112



Record 1977/4

Figure 24

F54/A2/176

plutonic source, and the sudden appearance of apatite and rutile in 6016 suggests local unroofing of possibly basalt and acid pegmatite in the source area(s).

The subangular to subrounded nature of the grains, their good to moderate sorting, and the high feldspar content, indicate an unusual balance between rates of erosion, transport and physical and chemical breakdown, probably in a near-shore or fluvial depositional environment. This aspect will be discussed further in a section on palaeogeography.

Whitworth Quartzite (unit Ꝑhm$_3$)

Field occurrence

The Whitworth Quartzite is a feldspathic psammite unit present throughout the western half of the Sheet area, and forms rugged dissected plateaux and planated ridges. It overlies the Bortala Formation conformably, and is overlain conformably by the Lochness Formation. The unit is best developed in the centre of the Sheet area, near Paroo Creek. Near Julius Dam, undifferentiated quartzite of the Myally Subgroup overlies Eastern Creek Volcanics, and may be mainly Whitworth Quartzite; it is shown incorrectly as Surprise Creek Beds on the Prospector Preliminary Map.

Lithology

Psammite in this unit is characteristically of fine to medium grainsize, grey, brown, dull red, buff, cream, and pale pink in colour, highly feldspathic (up to 30 percent feldspar), and extensively cross-bedded and ripple-marked. Massive to blocky partings are common, but most rocks are thin-bedded to laminated. Heavy-mineral bands outline bedding in many places. A striated photo-pattern in many parts of the Sheet area is due to alternation of harder and softer beds, the less resistant psammites being clayey and micaceous, and, in some cases, finer-grained. Thin siltstone partings and interbeds with pyrite clasts are scattered throughout the section, but their volume is insignificant. Sporadic pebbly sandstone layers in the middle and upper parts of the sequence contain scattered acid volcanic as well as quartzitic debris. Basal arkose and conglomerate are present in Whitworth Quartzite? immediately west and north of Julius Dam.

Thicknesses, shown in Figure 25, range from 100 m in the southwest of the Sheet area to over 2000 m in the Paroo Creek area. Apparent thinning in the southwest is mostly due to erosion before the unconformable deposition of the Mount Isa Group. True thickness variations are evident in the complete sections from the Police Creek/Conglomerate Creek areas (average thickness 1000 m) north to Paroo Creek (thickness 2000 m), farther north to the Cromwell and Surprise Creek areas (average thickness 650 m), and eastwards to near the Julius Dam, where the unit thins to about 400 m.

Sedimentary structures

Cross-bedding is ubiquitous throughout the unit, and is mainly medium-scale pi and nu type (Allen, 1963) arranged in sets from 5 cm to 2 m thick. The sets have planar to slightly curved basal contacts with other sets, and foreset dips range from 10 to 30^{o}, averaging 20^{o}. The lower foreset angles are more common in cross-bedding near the top of the unit. Ripple marks are abundant in psammite and in siltstone partings, and are chiefly asymmetric and interference types. They increase in abundance towards the top, where they are associated with coarse cross-bedding. A shallowing of the depositional environment from bottom to top of the unit is indicated.

Highly convoluted bedding is present in finer-grained psammites near the middle of the Paroo Creek sequence, in association with minor pyritic siltstone layers. Dessication or synaeresis cracks are also present, particularly towards the top, and may also represent a shallowing of the depositional environment upwards in the sequence.

Current directions measured from cross-beds are summarized in Figure 25. They are persistently from the southwest and northwest sectors, and compare with a mainly northwest current source deduced from ripple-mark orientations.

The significance of these directions will be discussed later.

Petrography

Twenty one samples of Whitworth Quartzite were examined in thin-section, 6 from the southern block, 10 from the central block along and near Paroo Creek, and 5 from the northern block.

Compositions and classifications of all samples are shown in Figure 25, which shows that feldspathic labile and sub-labile psammites are the most abundant rock type; no ortho-quartzites were recorded.

a. Central block: Three groupings have been made of the samples in the central block: group 1 contains (from the base upwards) samples 6019, 6020, 6021, 6012, 6013; group 2 samples - 6005, 6008, and 6009 - are from southwest of group 1; group 3 contains only sample 6040, the easternmost sample studied.

Group 1 samples are all relatively uniform, fine to medium feldspathic psammites. Samples 6019, 6012, and 6013 are massive, but 6020 and 6021 display subtle banding, show bimodal sand distribution - with grainsize ranging from about 0.08 to 0.3 mm; the finer bands are generally less well sorted, more angular, and more feldspathic than the coarser bands. Most psammites show close-packing, low porosity, moderate to high sphericity, good to moderate sorting, and cementing by silica overgrowths and clay and iron oxide films. Minor carbonate cement is present in 6013.

Feldspar constitutes 10 to 30 percent, and is chiefly microcline of two types - a clouded perthite and a clear microcline of plutonic and/or volcanic origin; plagioclase is uncommon. Rock fragments are present in most of this sequence, (up to 4 percent in 6012) and are chiefly chert, aggregates of microcrystalline quartz of possible volcanic origin, and, in 6019, tourmaline-bearing micaceous siltstone.

Heavy minerals are less abundant than in the underlying unit Ehm_2. Tourmaline and zircon and some iron oxides are the chief heavy minerals; 6013 contains rare detrital? tremolite.

Group 2 samples are all fine-grained feldspathic psammites, but display poorer sorting and less rounding than group 1 samples to the east, and are classified as submature. Although tourmaline and zircon are the main heavy minerals present, group 2 samples contain an abundance of relatively unstable accessories such as chlorite and biotite, and also contain a higher proportion of plagioclase to microcline than in group 1. These features suggest group 2 samples are closer to source area(s) than group 1, and that most of the sediment was derived from volcanic/plutonic terrains to the west which may have contained basaltic rocks.

Sample 6040 (group 3) lies east of group 1, and is also poorly sorted (grainsize 1 to 0.1 mm), but lacks chlorite and biotite. It contains a mature tourmaline-zircon heavy-mineral assemblage, and some quartz and feldspar and rock fragments of definite volcanic origin. Silica, and less commonly feldspar overgrowths and clay coatings, are the main cementing agents.

b. Southern block: Samples GSQ 5883 and 5881 are labile to sublabile feldspathic psammites containing subangular to subrounded quartz (Agd 0.22 mm) with sutured margins, and abundant

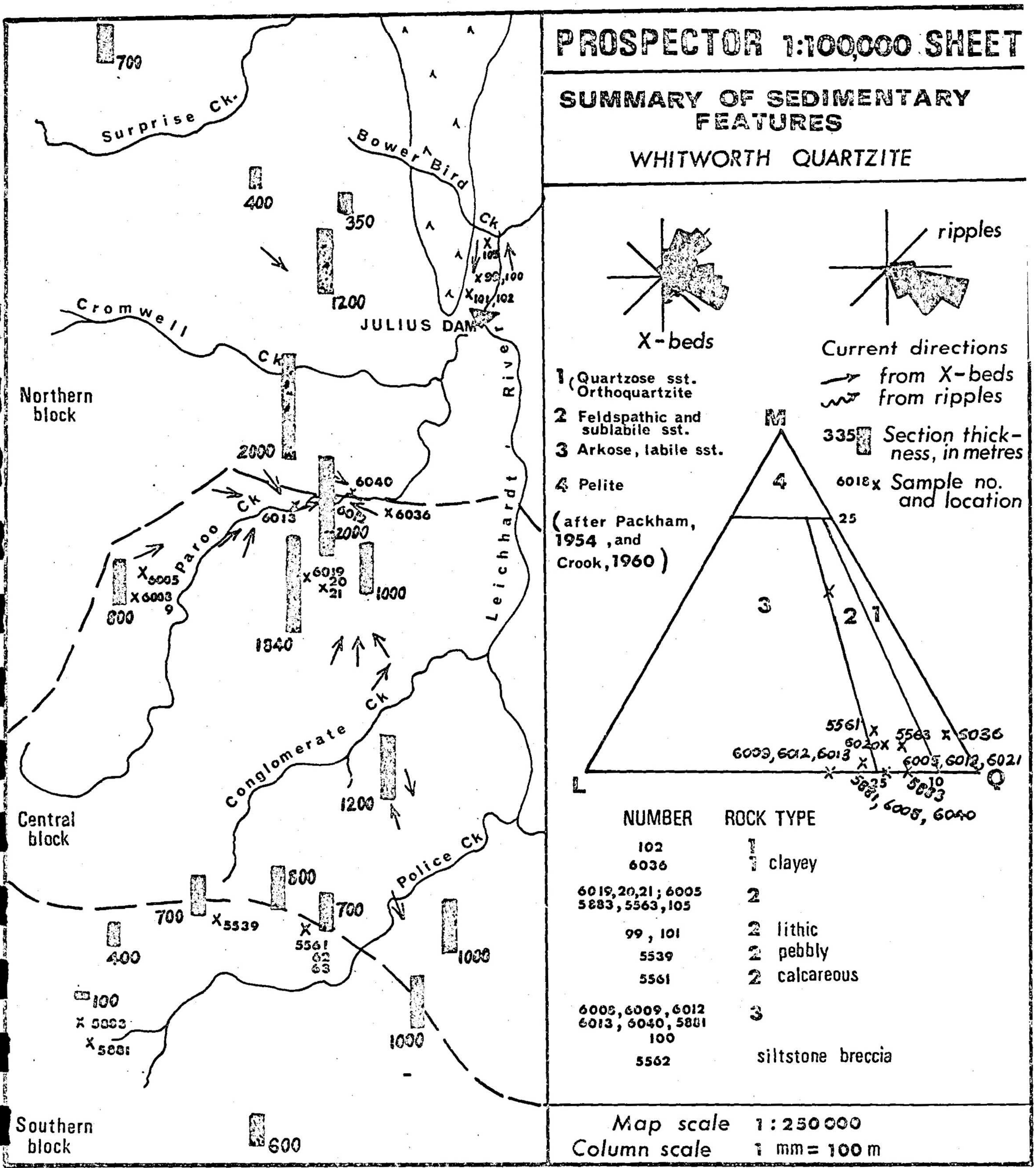

PROSPECTOR 1:100,000 SHEET
SUMMARY OF SEDIMENTARY FEATURES
WHITWORTH QUARTZITE
X-beds
ripples
Current directions
from X-beds
from ripples
335 Section thickness, in metres
6018x Sample no. and location
1 (Quartzose sst. Orthoquartzite
2 Feldspathic and sublabile sst.
3 Arkose, labile sst.
4 Pelite
(after Packham, 1954, and Crook, 1960)
M
L
Q
NUMBER ROCK TYPE
102 1
6036 1 clayey
6019,20,21; 6005 5883,5563,105 2
99, 101 2 lithic
5539 2 pebbly
5561 2 calcareous
6008,6009,6012 6013, 6040, 5881 100 3
5562 siltstone breccia
Map scale 1:250000
Column scale 1 mm = 100 m
Surprise Ck.
Bower Bird Ck
Cromwell Ck
JULIUS DAM
Leichhardt River
Northern block
Paroo Ck
Conglomerate Ck
Central block
Police Ck
Southern block

Figure 25

feldspar. Plagioclase exceeds potassium feldspar in both samples, but is extensively sericitized in 5883. Tourmaline, zircon, and opaques are the main accessories.

Conglomerate near the top of Ehm_3 (sample GSQ 5539) contains clasts of sublabile psammite and accessory subhedral tourmaline. To the east, sample GSQ 5563 is a sublabile psammite in which all the feldspar present is potassic, and which also contains up to 2 percent of microcrystalline quartz clasts of acid volcanic parentage. Siltstone in the sequence (GSQ 5562) contains abundant epidote; sample GSQ 5561, a sublabile psammite, is rich in carbonate cement, and potassium feldspar greatly exceeds plagioclase. Zircon is the main heavy mineral.

c. Northern block: Most samples are feldspathic quartzites, but contain a higher proportion of lithic fragments than in areas to the south and southwest.

Discussion

The Whitworth Quartzite is the most extensive unit in the Myally Subgroup. It is characterized by a great thickness (over 2000 m) and a very high feldspar content throughout, and its persistent cross-bedding and ripple marks suggest that it was deposited on a broad, steadily subsiding shallow shelf. Current directions from the western sector, together with a westerly increase in the proportion of plagioclase and other unstable minerals such as chlorite and biotite, suggest major source areas to the west of the Sheet area. Samples from the eastern part of the unit, particularly those containing pebbles of acid volcanic rocks, suggest some local derivation from areas to the east, such as the Ewen and Kalkadoon-Leichhardt blocks, and suggest that the present-day eastern margin of the unit is not far removed from a Proterozoic shoreline. Proposed source areas to the east and west were highly feldspathic plutonic, acid volcanic, and metamorphic terrains, with possibly some basaltic belts in the west. The overall high sphericity and good sorting of many of the feldspar-rich psammites indicates that the rate of chemical breakdown of feldspar during transport and deposition was low, and that, despite the operation of moderate traction currents and wave action, mechanical breakdown other than rounding was also low.

Palaeogeography of the unit is discussed later.

Lochness Formation (unit Ꝑhm$_4$)

Field occurrence

The Lochness Formation is a fine-grained feldspathic and ferruginous psammitic unit with abundant interbeds of siltstone, shale, and dolomite. It extends over the western part of the Prospector Sheet area and north into the adjoining Alsace Sheet area, but is absent in the Mary Kathleen Sheet area, to the south. It forms a prominent valley between the Whitworth Quartzite (unit Ꝑhm$_3$) and Surprise Creek Beds, and the base is particularly well defined by a sharp topographic drop of about 100 to 200 m from the high Whitworth Quartzite plateau. Stream drainage patterns also change from straight, joint-controlled courses to highly incised meandering courses in the softer unit. The unit contains the conformable Ꝑhm$_5$ member at its top. Unit Ꝑhm$_4$ is locally overlain disconformably by the Surprise Creek Beds.

Lithology

The unit is predominantly a fine-grained pinkish-brown feldspathic and ferruginous psammite. A typical section is described below, from an area 14 km southwest of Julius Dam. It is relatively uniform, and the measurements quoted mark the position of the various rock types from the top of the unit.

Stratigraphic distance from top (metres)	Unit Ꝑhm$_4$
120	Fine-grained micaceous, feldspathic sandstone, laminated, blocky to flaggy, microcrossbedded and ripple marked.
325	Ferruginous fine-grained sandstone characterized by micro-cross-bedding outlined by dark hematite?-rich laminae.
617	Alternating blocky fine to medium sandstone, dull red, and blocky phyllitic siltstone. Abundant ripple marks and possible mud-cracks. Minor dull red coarse sandstone with massive parting.
617 to 700	Medium feldspathic sandstone, blocky, interbedded with thinly to thickly bedded white to cream kaolinitic siltstone.

Total thickness 700 m.

Kaolinitic siltstone and earthy kaolinitic sandstone are also present near the base of Ꝑhm$_4$ to the southeast and south of the section listed above, and may be tuffaceous in part. Commonly the kaolinitic unit contains layers of mud-flake or mud-sliver conglomerate, and thin lenticular cross-bedded sandstone layers. Pink dolomite, and dolomitic and calcareous feldspathic sandstone, occur towards the top of Ꝑhm$_4$ in the southern areas near Police and Conglomerate Creeks, but are less common in the Paroo and Cromwell Creek areas to the north. The thickness of the unit varies from 400 to 1200 m, and it appears to thin slightly from south to north (Fig. 26).

Sedimentary structures

The unit is characterized by an abundance of ripple marks, particularly in the lower half of the sequence. They are asymmetric and interference types (see Fig. 27) with straight to linguoid crests; the zones of ripple marks are associated with desiccation cracks and/or fine sandstone dykes infilled with fine to medium ferruginous sandstone, and pull-apart structures in finer-grained bands, which may be either desiccation of synaeresis cracking - probably the latter (Fig. 28).

Micro-cross-bedding and associated small-scale scour structures are ubiquitous and are outlined by layers of heavy minerals, probably hematite. Coarser sandstone layers show cross-bedding of the pi type, with sets up to 10 cm thick with slightly curved bases.

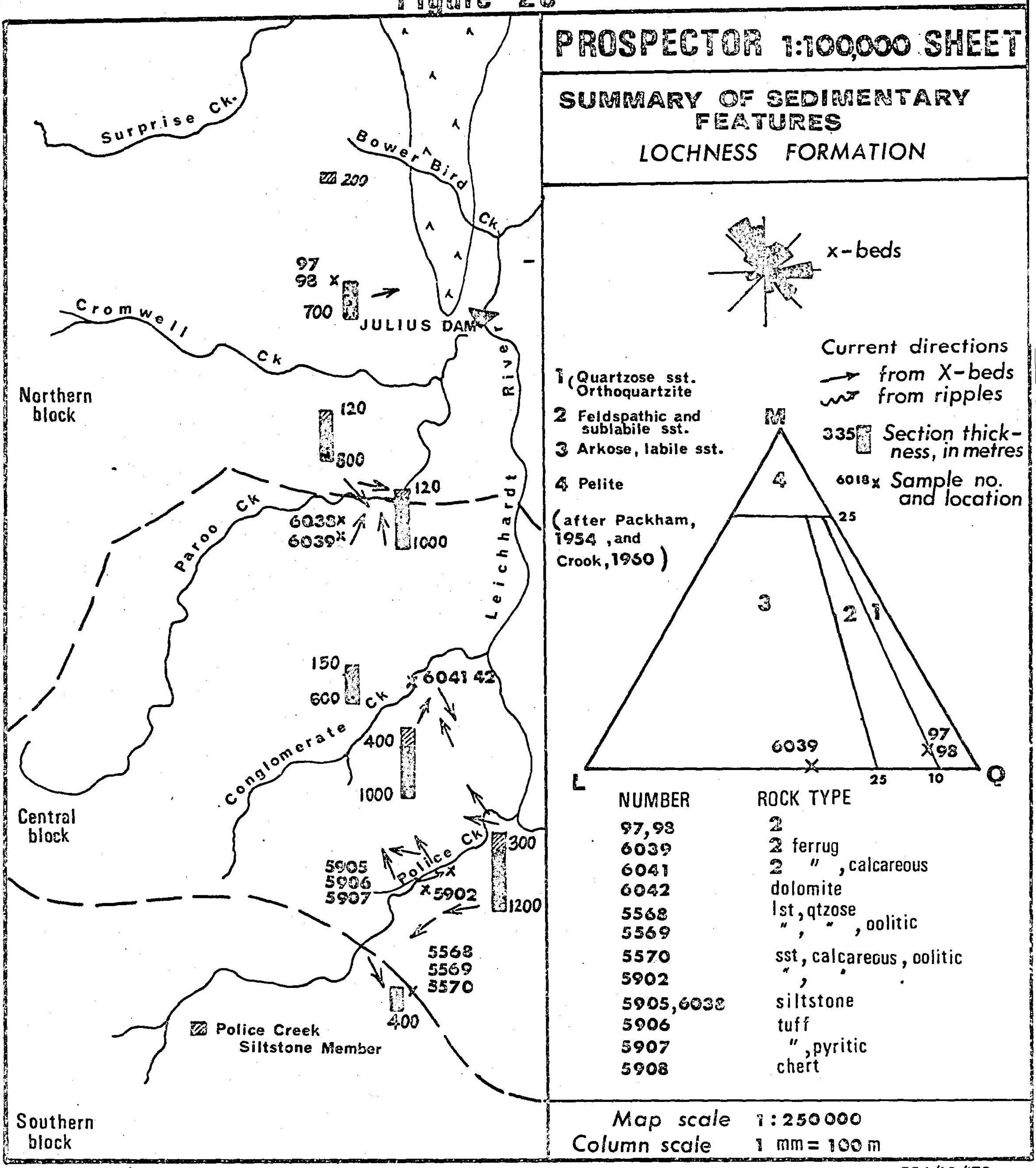
Convoluted beds and load casts are particularly abundant towards the base of the sequence. Parallel lamination with blocky to massive partings becomes more common in the upper parts of the unit.

Current directions from cross-bedding are shown in Figure 26, and the abundance of currents from the southeast, particularly in the Police Creek area, represents a major change from the westerly directions common in lower units of the Myally Subgroup. Currents from the northwest, west, and southwest are still prevalent, however, but appear to be most abundant in the Paroo Creek area, where similar current directions are indicated from ripple-mark orientations.

Petrography

Fourteen samples have been examined; their compositions and localities are plotted in Fig. 26.

Figure 26


PROSPECTOR 1:100,000 SHEET
SUMMARY OF SEDIMENTARY FEATURES
LOCHNESS FORMATION
Surprise Ck.
Bower Bird Ck.
200
97
98 x
700
JULIUS DAM
Cromwell Ck
Northern block
120
300
120
Paroo Ck
6038x
6039x
1000
Leichhardt River
150
600
6041 42
Conglomerate Ck
400
1000
Central block
300
5905
5906
5907
Police Ck
x 5902
1200
5568
5569
5570
400
Police Creek Siltstone Member
Southern block
x-beds
Current directions
from X-beds
from ripples
335 Section thickness, in metres
6018x Sample no. and location
1 (Quartzose sst. Orthoquartzite
2 Feldspathic and sublabile sst.
3 Arkose, labile sst.
4 Pelite
(after Packham, 1954, and Crook, 1960)
M
4
25
3
2
1
6039
97
98
L
25
10
Q
NUMBER ROCK TYPE
97,98 2
6039 2 ferrug
6041 2 " , calcareous
6042 dolomite
5568 lst, qtzose
5569 " , " , oolitic
5570 sst, calcareous, oolitic
5902 " , "
5905,6038 siltstone
5906 tuff
5907 " , pyritic
5908 chert
Map scale 1:250000
Column scale 1 mm = 100 m

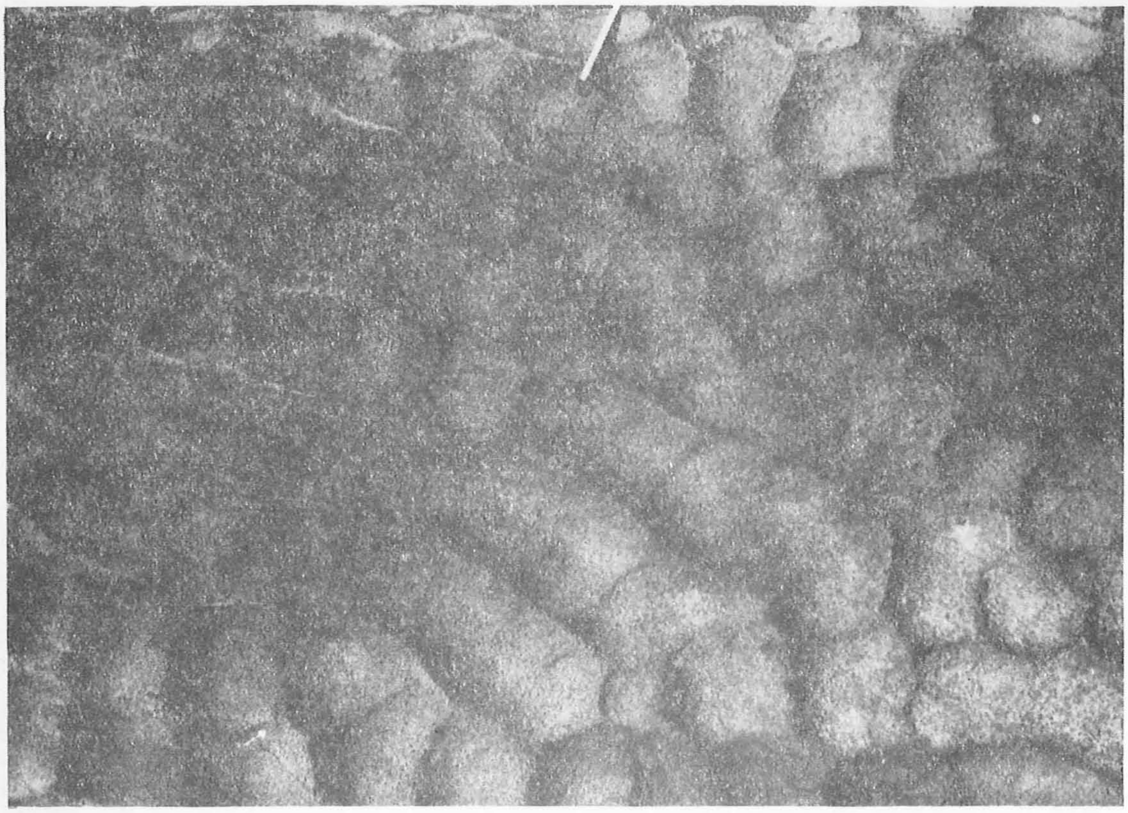


Fig. 27.
Asymmetric and interference ripple-mark moulds, Lochness Formation, 13 km southwest of Julius Dam, near Paroo Creek. M1503/16A GMD.

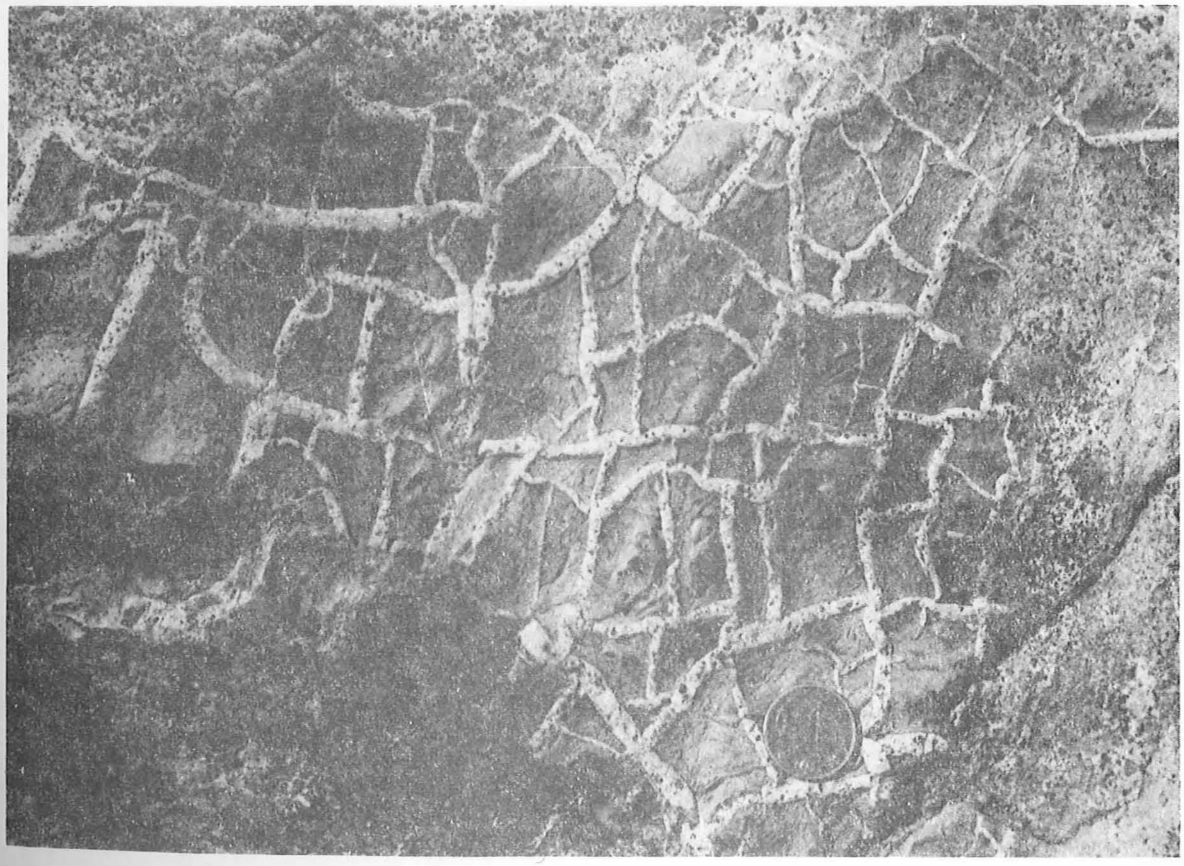


Fig. 28.
Sand infillings of desiccation or synaeresis cracks, on bedding planes of fine sandstone in the Lochness Formation, Myally Subgroup, at Paroo waterhole, 10 km southwest of Julius Dam. M2025 GMD.

a. Northern block: (0097, 0098) These are both sublabile psammites which are bimodal (grainsize from 0.6 to 0.06 mm) and submature to mature. Feldspar (mainly microcline and rare plagioclase) is clear to slightly clouded, and some of the quartz grains are polycrystalline. Specularite, hematite and limonite form up to 10 percent, as elongate large subhedral grains parallel to the bedding, and as intergranular cement.

b. Central block: (6038, 6039, 6041, 6042, 5902) Purple siltstone (6038) shows faint lamination outlined by ferruginous material. Samples 6039 and 6041 are sublabile psammites which are both ferruginous and feldspathic. 6039 is well sorted and mature, but most grains are subangular to subrounded; in 6041, porosity is high, but permeability low because of 50 percent or more of a ferruginous clay matrix. Quartz grains in 6041 range from .07 to .3 mm, and the larger grains are volcanic beta-quartz types. Both samples are characterized by a high proportion of relatively clear microcline.

Carbonate grains form up to 2 percent in 6039, and 15 percent in 6041. They are clastic grains which are well rounded and show some concentric (oolitic?) structures arranged around a core of quartz or finer-grained carbonate. Ferruginous material in both samples ranges from coarse detrital iron ore to ferruginous clay cement. Tourmaline is the main accessory mineral. GSQ 5902 is a calcareous sandstone.

Sample 6042 contains 85 percent dolomite? grains (some of which are oolitic) cemented by secondary carbonate overgrowths; feldspar (4 percent) and quartz (11 percent) form a terrigenous fraction, and zircon is a rare accessory.

c. Southern block; (5568, 5569, 5570) All these samples contain abundant (45-65 percent) carbonate (calcite?) as both intergranular cement and as rounded oolitic grains, in association with a terrigenous fraction of quartz and relatively fresh feldspar. Sorting throughout is good to moderate. Some oolite grains in 5570 are fractured and possibly reworked. Opaque minerals, tourmaline, and zircon are rare accessories.

Discussion

Unit Ƀhm$_4$ represents a marked change in the depositional environment compared with that of underlying units. Current directions from the east and southeast, and very fresh feldspars, suggest greater contributions from the nearby eastern basement areas. Features such as ripple marks, small-scale scours, mudcracks, and oolitic carbonates indicate very shallow, possibly intertidal or mud-flat areas of deposition. This will be discussed more fully in the section on palaeogeography.

Police Creek Siltstone Member (unit Ƀhm$_5$)

Field occurrence

Unit Ƀhm$_5$ is considered to be a member of the Lochness Formation; it parallels exposures of the Lochness Formation, and forms two or three low ridges at the very top of the Lochness Formation and underlies brown quartzite of the Surprise Creek Beds.

Lithology

Massive, earthy siltstone and phyllite (e.g., GSQ 5905, Fig. 26), and minor fine sandstone, chert (GSQ 5908), and rhyolitic tuff, characterize this member. Bedding is poorly defined or indistinguishable, partly because of a widespread blotchy pale purple to pale pink coloration. Rhyolitic tuffs (GSQ 5906) in the sequence are thin-bedded to laminated, beds having a pale green to pale brown siliceous appearance. Some tuffs are pyritic (GSQ 5907).

Thickness variations are shown in Figure 26. In general the unit is thickest in the southern block (300-400 m) and thins northwards, but the variations may not be significant in view of the difficulty in consistently locating the lower boundary of the member within the Lochness Formation.

Ripple marks and some cross-bedding are the only sedimentary structures noted.

Discussion

Although the Police Creek Siltstone Member is overlain concordantly by quartzite of the Surprise Creek Beds, the possibility remains that the generally massive and mottled habit of the unit represents an ancient soil or subsoil, or aeolian reworking of the near-shore ferruginous sands and silts of the Lochness Formation. Although a disconformity cannot be proved between the member and the overlying quartzite, this same stratigraphic level to the east and northeast is marked by an angular unconformity.

Palaeogeographic reconstruction of the Myally Subgroup

The four main units of the Myally Subgroup form a slightly metamorphosed conformable sequence over 3000 m thick, and extend laterally in the Prospector Sheet area for 60 km. They provide a good opportunity for large-scale vertical profile analysis of Precambrian strata (e.g., Visher, 1965), and for the application of Walther's Law of Facies, which states that - where there are no time breaks in a section - those sediments which were areally adjacent must succeed each other vertically. Many of the conclusions here are based on works by Pettijohn, Potter & Siever (1972), Selley (1970), Baars (1961), Heckel (1972), Swift (1969), Pryor (1961), Hollonshead & Pritchard (1961), and Conybeare & Crook (1968).

Essential features of the Myally Subgroup are summarized in Table 13, and sequential palaeogeographic reconstruction of the unit is shown diagrammatically in Figure 30. The large thicknesses of the Myally Subgroup, together with the marked lateral continuity and parallelism of the constituent formations, place certain constraints on a depositional model. A fluvial environment seems inappropriate for most of the sequence, because of a lack of very coarse sand associated with fining-upwards sequences, a lack of marked channelling and strongly unidirectional palaeocurrents, and a lack of marked scouring and lenticular sand bodies. Similarly a deltaic province is unlikely to have produced all of the extensive, thick, and uniform sand blankets of the Myally Subgroup although deltaic characteristics are possibly present in Phm_2.

The environment considered most likely in a shallow shelf or platform in an epeiric sea bounded by a relatively mature cratonic area to the east and a postulated tectonic foreland to the west. On a regional scale (see Fig. 29), this platform appears broadly funnel-shaped, being wider in the north and narrower or even closed to the south. Along the margins of the platform, the sand facies of the Myally Subgroup ($Phm_{1,3}$) have intertongued with near-shore or coastal-flat environments (Phm_4) and delta margins (Phm_2); in the central parts of the basin, uniform subsidence of the platform relative to source areas appears an essential factor in the deposition and preservation of the thick, monotonous sand sequences. A shallow, shoaling environment appears to have been maintained for a long period, accompanied by longshore? current activity from the north, northwest, west, and southwest, with local near-shore currents from the southeast. Major metasedimentary, volcanic, and plutonic source areas in the western sector are postulated (e.g., Yaringa Metamorphics and Big Toby Granite); the cratonic areas to the east (Kalkadoon-Leichhardt basement block) are thought to have contributed only minor amounts of sediment to the shelf, although the Whitworth Quartzite has onlapped in this direction. Thickness variations are probably caused by large-scale undulations in the platform, which was underlain by subaerial basalt flows, shale, and sandstone of the Eastern Creek Volcanics and possibly the Mount Guide and Leander Quartzites.

128

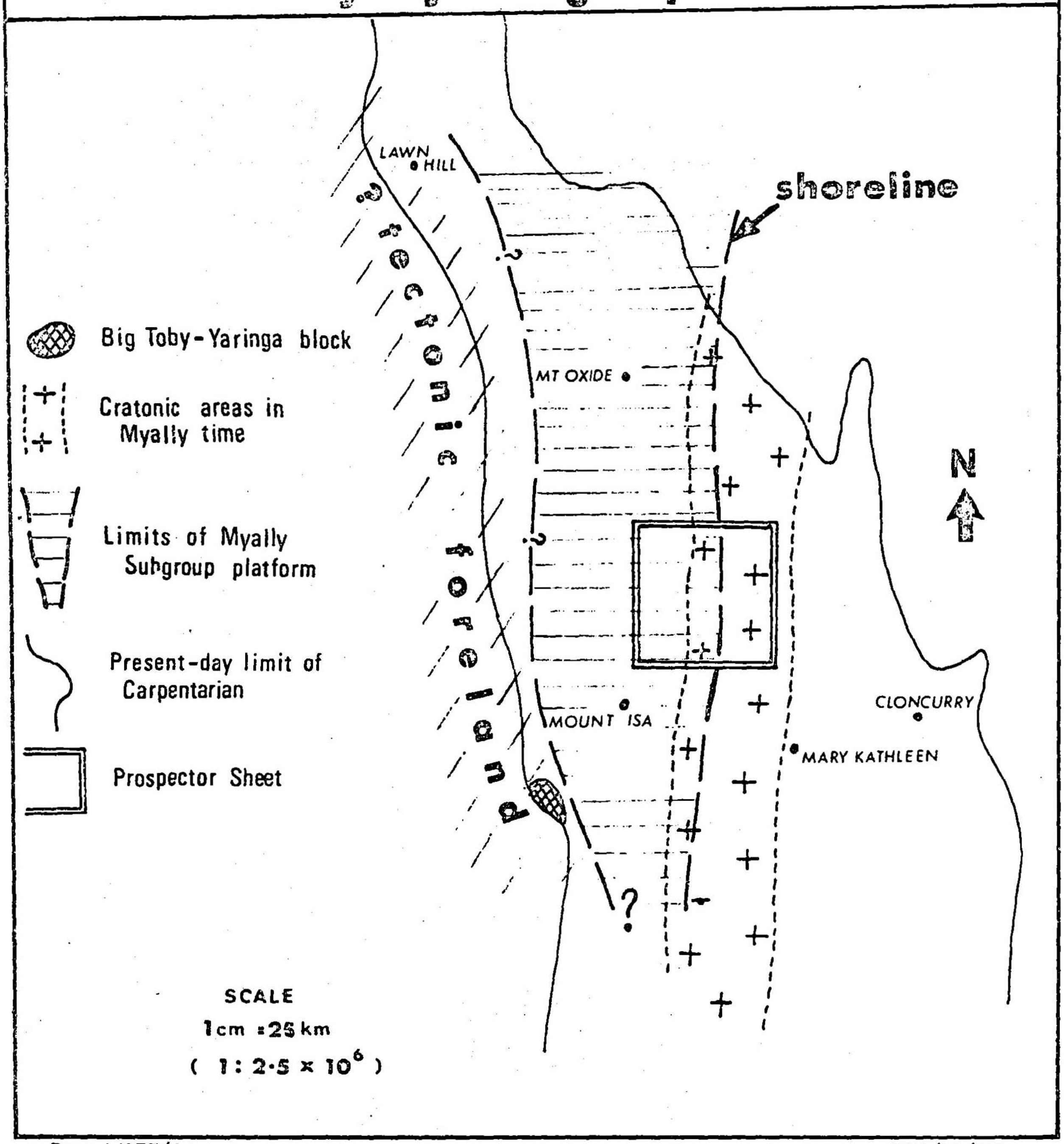
TABLE 13. PALAEOGEOGRAPHIC RECONSTRUCTION, MYALLY SUBGROUP

Unit	Geometry and palaeocurrent data	Structures	Petrographic data	Environment of deposition
Ɇhm$_5$	Thin lenticular unit with discontinuous distribution at top of Ɇhm$_4$. Up to 400 m thick	Minor ripples: relatively structureless		
Ɇhm$_4$	Sand wedge, thinning northwards from 1200 m to 400 m. Confined to Prospector Sheet, dimensions ca. 50 km x 10 km Influx of currents from southeast sector, particularly in southern block. Some currents from west and northwest in central and northern blocks. Ripples show currents from northwest	Ripple-marks dominant, asymmetric and interference types; associated with desiccation cracks and pull-apart structures. Micro-crossbedding of pi-type. Abundant load casts and convoluted beds near base	Sands bimodal, 0.6 to 0.06 mm, submature to mature well sorted, subangular to subrounded. Abundant ferruginous clay cement, clear microcline, and volcanic quartz fraction. Some specularite and limonite grains. Clastic carbonate grains well rounded and oolitic, moderately sorted. Dolomite contains 10-15% terrigenous fraction. Tourmaline and zircon accessory	Mature shoreline of fine sand, silt, and carbonate shoals, probably paralic, periodically exposed. Ripples derived from onshore drift, but small-scale sand bodies and erosion surfaces produced by influx of sediment from easterly source areas, possibly by network of fine distributary channels. Lateral equivalent of upper Ɇhm$_3$
Ɇhm$_3$	Blanket or wedge sand; dimensions as for Ɇhm$_1$. Thickness 400-2000 m, but variations masked by unconformity in west. Unit varies from 2000 m in central block to 650 m in northern block. Central block is probably focus for continuing subsidence Persistent directions, from cross-bedding, from southwest to northwest sector; from ripple marks, currents mainly from northwest	Cross-bedding dominant, pi and nu-type, sets 5 cm to 2 m thick, planar to curved bases, 20^o average foreset dip. Lower foreset angles (10-15^o) more common near top of unit. Asymmetric and interference ripples common, particularly near top, associated with very coarse cross-beds. Minor convoluted beds, some desiccation cracks near top	Fine to medium grainsize, close-packing, moderate to high sphericity, good to moderate sorting. Some bimodal sands, 0.08 to 0.3 mm; cement mainly silica overgrowths and clay and iron oxide films. Rocks fragments are chert, micro-crystalline quartz of volcanic origin; some siltstone. Sands to west less well sorted, less rounded, and contain more unstable accessories and more plagioclase than samples to east. Zircon and tourmaline most common accessory	Scale of deposition precludes small-scale fluvial processes. Probably forms part of large open cratonic shelf containing local steadily subsiding depressions allowing very thick accumulation of sand. Shallow water and moderate traction currents are indicated, and active highly feldspathic source areas probably existed to the west, with local contribution from east. Some features aeolian. Transitional into paralic facies of Ɇhm$_4$. Some sands possibly reworked from Ɇhm$_2$.
Ɇhm$_2$	Blanket or wedge sand; dimensions as for Ɇhm$_1$. Thickness 80-700 m, but rapid thinning northwards, and westwards, to lesser degree in Kennedy Gap Sheet area	Parallel bedding dominant: cross-bedding and ripple-marks in some coarse sands. More cross-bedding, ripple marks, and some mud-cracks in finer sands. Graded bedding noted in thin section	Very high feldspar content (up to 90%) with plagioclase dominant over microcline; mica abundant, heavy minerals very common, including tourmaline, zircon, ilmenite, epidote, and locally apatite and rutile. Clay/silt matrix present in most sand-	Labile content reflects rapid erosion from highly feldspathic source areas, possibly in distal parts of delta, with parallel bedding, some micro-cross-bedding, graded bedding, and clay and silt deposited with sands. Shallower parts of complex indicated

TABLE 13. PALAEOGEOGRAPHIC RECONSTRUCTION, MYALLY SUBGROUP (cont.)

Unit	Geometry and palaeocurrent data	Structures	Petrographic data	Environment of deposition
	No data available on palaeocurrents, except for central block, where rare current directions are from south-southeast		stones, which show good to moderate sorting, subangular to subrounded grains. Fragments of silt and shale present in southern block	by beds, ripples, and mud cracks. Coalescing of delta fronts may produce the observed distribution of Ꞓhm$_2$, and environment probably modified by interaction with cratonic shelf
Ꞓhm$_1$	Sheet, blanket or wedge, 160 km N-S, 60 km E-W. Thickness 70 to 600 m; no systematic variation, but overall thickness greatest in centre of Sheet area and thinnest to south. Lens of clayey feldspathic sand transitional up to Ꞓhm$_2$ in central block North to northwesterly directions of current origin, but data insufficient. Northern block directions variable; central (and possibly southern) blocks show more uniform directions from northwest	Cross-bedding, ripple marks dominant. Cross-beds pi and alpha-type, medium scale 15 to 20 cm thin sets, planar bases: ripples asymmetric, bevelled in lower half. Minor flute structures	Sand 0.3 to 1 mm medium to coarse quartzose sandstones, well sorted, medium to high sphericity, silica-cemented. Clay matrix and rock fragments increase towards top. Some grading outlined by bands of ilmenite. Other heavy minerals are zircon, tourmaline, and apatite. Poorer sorting higher in sequence accompanied by increase in altered epidote grains	Possibly near-shore littoral or shallow platform sand derived from inhomogeneous source area containing sand-silt sequences, acid plutonics and volcanics, and basic rocks; basic rocks more prominent as source for rocks higher in sequence. Bevelled ripples indicate very shallow water locally. Silty interbeds, poorer sorting, and increase in rock fragments and parallel lamination indicate possible interaction with deltaic environment higher in sequence (Ꞓhm$_2$)

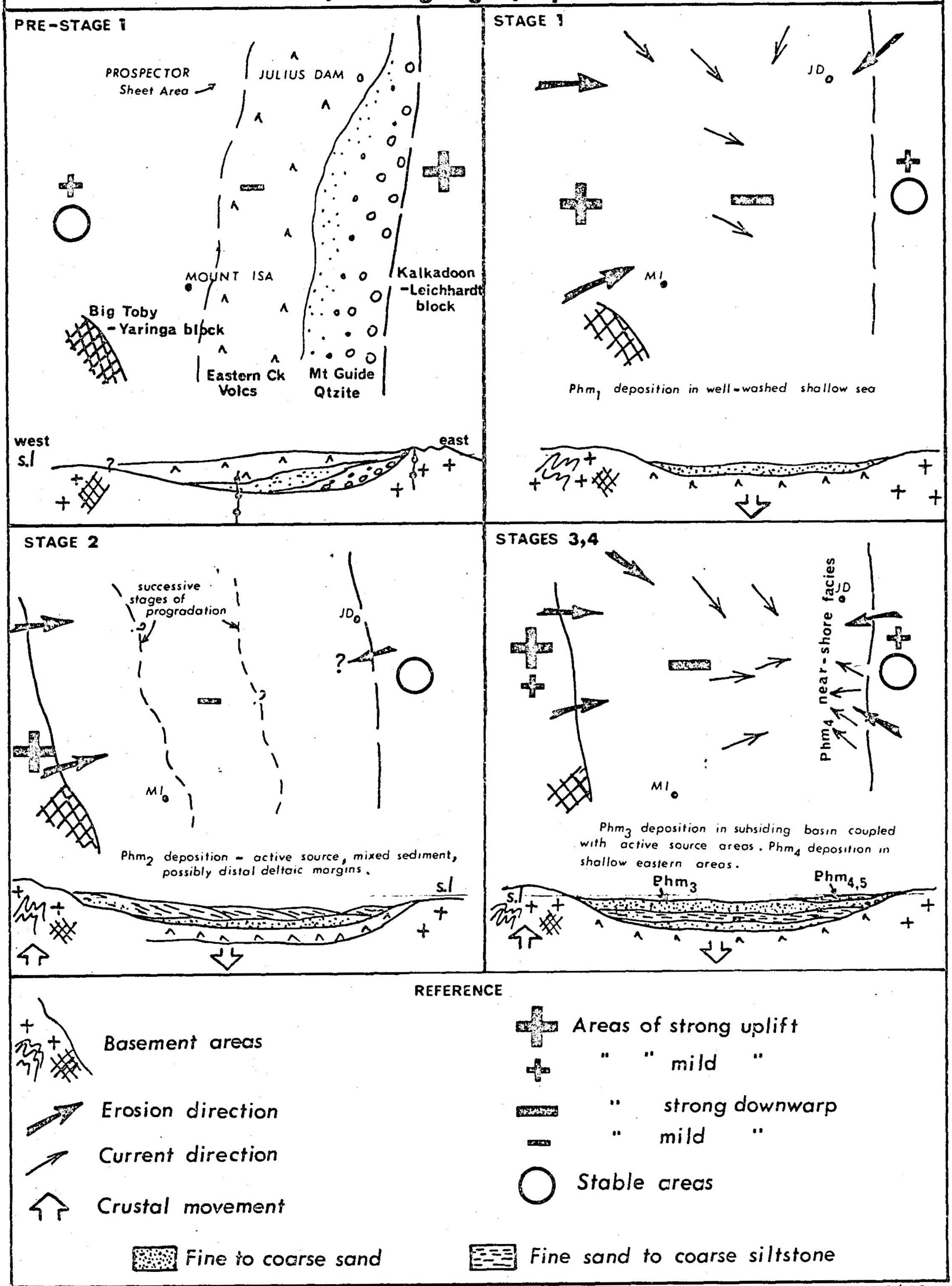
Figure 29 Regional setting of the Myally Subgroup



Record 1977/4

F54/A2/179

Figure 30 Stages in the development of Myally Subgroup palaeogeography



The proposed palaeogeographic model is presented below as a four-stage sequence. The reconstruction is based on detailed work in the small part of the Myally Subgroup exposed in the Prospector Sheet area and some consideration of exposures on adjoining Sheet areas. The reconstruction must be considered as a preliminary model only, because large areas in the north and west of the province have yet to be investigated.

Stage 1

The outpourings of Eastern Creek Volcanics abated rapidly, and the median ridge and adjacent western shelf became stable. Myally deposition commenced with widespread orthoquartzites. The westerly extent of this sedimentation might have been limited by restricted supply from the east and/or a rising foreland in the west, manifested by areas of Yaringa Metamorphics and Big Toby Granite. Carter et al. (1961) also inferred that these rocks might have been a source for younger sedimentary rocks to the east.

The quartzose nature of Ƀhm$_1$ suggests that source areas contained some quartzitic sedimentary rocks as well as feldspar-rich plutonic rocks. An increasingly heterogeneous source area is suggested by increased diversity of the heavy-mineral suites: zircon and tourmaline occur throughout the sequence, and ilmenite and epidote occur near the top of the sequence. The ilmenite and epidote were probably partly derived from the Eastern Creek Volcanics. The poorer sorting and increased amounts of silt and rock fragments that characterize the upper parts of Ƀhm$_1$ may have resulted from deep erosion of the Yaringa Metamorphics.

The slight coarsening upwards noted in some sands is a common feature of prograding delta ribbon sands, so it is possible that shallow shelf and delta environments have interacted. A similar environment has been described by Conolly (1969) from the Triassic Hawkesbury Sandstone near Sydney, Australia.

Stage 2

Although elements of the Ehm_1 shelf were preserved in Ehm_2-time, the latter period was marked by abundant silt and clay deposition, with sand that is less well sorted and more feldspar-rich than in any other unit. An abundance of feldspar, mica, and some rock fragments possibly reflects a fluvial environment, but coarse gravels are lacking. Parallel bedding predominates in silts and fine sands, though coarser sands show cross-bedding. These features resemble deposits of a delta-slope or delta-fringe, which must have prograded and coalesced with other systems along and across the platform areas to produce a blanket geometry. Source areas (probably to the west) were highly feldspathic (plagioclase-rich), and were rapidly eroded. The preserved sections of Ehm_2 are possibly the more distal parts of the proposed delta-fringe system, because of an absence of fluvial gravels, etc., which may have existed in areas to the west of the Prospector Sheet area. Top-set sand layers in the postulated prograding delta fringe might have been reworked when the overlying feldspathic sand unit, Ehm_3, was deposited.

Stage 3

Deposition of the thick, and uniform feldspathic sand of Ehm_3 suggest the onset of steady subsidence coupled with steady rates of erosion from westerly and possibly easterly source areas. Strand-lines do not appear to have migrated or oscillated to any degree because of the uniformity of sedimentation over large areas, and a lack of lateral facies changes. Sediment is thought to have been brought to the basin by fluvio-deltaic or piedmont-deltaic systems (which are not preserved) and redistributed by wave action and long-shore currents. Pebbly beds in the upper parts, coarser cross-bedding, and an increase in the proportion of ripples and mud-cracks represent a transition to the near-shore facies, Ehm_4. Some erosion and fluvial deposition from the eastern cratonic areas also occurred. Some sands possibly underwent aeolian reworking as basin areas become shallower. Arkose and conglomerate formed at the base of Ɓhm$_3$ as the quartzite onlapped eastwards onto areas of acid volcanic and granitic basement.

Slowing in the rate of subsidence of the basin, or a slight shift westwards of the main axis of subsidence, may have led to overlap of Ɓhm$_3$ by Ɓhm$_4$ along the eastern shoreline of the epeiric sea. This unit is a near-shore ferruginous sand and silt deposit with banks of oolitic dolomite and widespread but small-scale fluvial? channelling. It has been eroded from, or was never deposited in, the western shoreline areas of the basin.

Stage 4

Closure of Myally sedimentation is marked by bands of rhyolitic tuff in the Prospector Sheet area. Source areas matured and sedimentation ceased as the basin became stable. Some reworking of Ɓhm$_4$ and Ɓhm$_5$ by aeolian or soil-forming processes may have taken place during this time, to produce mottled poorly bedded siltstone preserved along the eastern margins. This was followed by transgressive quartzite deposition of the Surprise Creek Beds.

Summary

We stress that the palaeogeographic reconstructions are preliminary models only. Various parts of the Myally Subgroup contain some fluvial, deltaic, lacustrine, aeolian, and shallow open platform characteristics, and with further detailed analysis of individual units, the differences between these environments will become more apparent. Our discussion here emphasizes the sheet or blanket geometry of the Myally Subgroup, and the continuous nature of bedding structures and rock types for large lateral distances and for considerable thicknesses, and it is these features which have lead to the mainly epeiric sea model outlined above. There are few examples similar to the Myally Subgroup described in the literature of Phanerozoic rocks, and it does appear that direct comparisons between Precambrian and modern environments cannot always be made. Instead, account must be taken of features possibly more characteristic of the Precambrian, such as greater rates of erosion through climatic extremes and a general lack of soil and vegetation; a lack of chemical weathering because of arid climate, or atmospheric and hydrospheric conditions different from today; and source areas which may have contained a higher proportion of exposed highly feldspathic volcanic and plutonic rocks than is usual in younger rocks.

SURPRISE CREEK BEDS

The Surprise Creek Beds were described by Carter et al. (1961) as a diverse unit composed of quartzite, siltstone, shale, slate, impure dolomite, and conglomerate. Their type section falls within the Prospector Sheet area, near Glenroy homestead. The apparent thickness of about 12 000 m noted by Carter et al. is due to repeated faulting of the sequence, and a true thickness of between 2000 and 3000 m is now indicated.

The present mapping shows the existence of two distinct facies of the Surprise Creek Beds, a shelf facies and a trough facies, both of which extend north-south across the Sheet area in juxtaposed linear zones - the shelf facies to the west and the trough facies to the east - flanking the western margin of the Kalkadoon-Leichhardt basement block. Detailed accounts of these two facies follow and refer to units shown on the Prospector Preliminary Edition map.

Surprise Creek Beds (shelf facies)

A generalized stratigraphic column of the shelf facies is shown in Table 2.

The reference section for this sequence is along Paroo Creek between Carrs Flat (635 683) and The Palms (644 712), about

6 km south-southwest of Julius Dam. Partial sections are also well exposed in fault blocks which extend south from Carrs Flat to near Glenroy homestead. Most of the units are known to extend into the Alsace Sheet area to the north. Detailed descriptions of all the units follow, and are summarized in Table 14.

Unit Ꝑr$_0$

Field occurrence

Unit Ꝑr$_0$ forms a series of quartzite ridges and valleys, but overall is a resistant unit underlain by fine sands and silt of units 4 and 5 of the Myally Subgroup, and overlain by ferruginous sand and dolomite of unit Ꝑr$_1$ of the Surprise Creek Beds. Near the reference section along Paroo Creek the contact with the underlying Myally Subgroup is conformable or disconformable.

Lithology

Unit Ꝑr$_0$ contains four broad divisions traceable over the Paroo Creek/Glenroy area. From the top, they are as follows:

		Average thickness
1.	Resistant unit: fine to coarse, variable feldspathic quartzite (25% to 5% feldspar), massive to blocky, thick-bedded, white to buff, cross-bedded, ripple-marked, minor pebbly beds.	50 m
2.	Softer unit: Alternating medium to coarse friable ferruginous sandstone and kaolinitic siltstone, and rare granule sandstone interbeds	60 m
3.	Resistant unit: grey to white, fine to medium feldspathic, possibly kaolinitic, quartzite (15% -	100 m

	30% feldspar), massive, laminated to thin-bedded, highly rippled and cross-bedded; bimodal: minor 12 cm interbeds of green shale	
4.	Softer unit: brown-weathering, medium to coarse limonitic sandstone, feldspathic, massive to blocky, rippled, and cross-bedded. At base, ferruginous and gossanous, friable sandstone	120 m
	Total	330 m

To the north and northwest of Julius Dam a sequence of coarse basal conglomerate overlain by laminated, medium feldspathic quartzite overlies Eastern Creek Volcanics, and is shown as Ꝑr$_0$ on the Preliminary Edition map. The basal conglomerate contains 1 to 15 cm clasts of quartzite, acid volcanics, granite, and rare basic volcanics in an arkosic matrix and the sequence is now thought to be part of the Myally Subgroup. Some associated psammites show local soft sediment deformation or scouring. Conglomerate with pink and green acid volcanic clasts also crops out at The Palms, 2 km west of Julius Dam. Most of the sequence is highly rippled and cross-bedded.

Thickness variations in Ꝑr$_0$ are shown in Fig. 35.

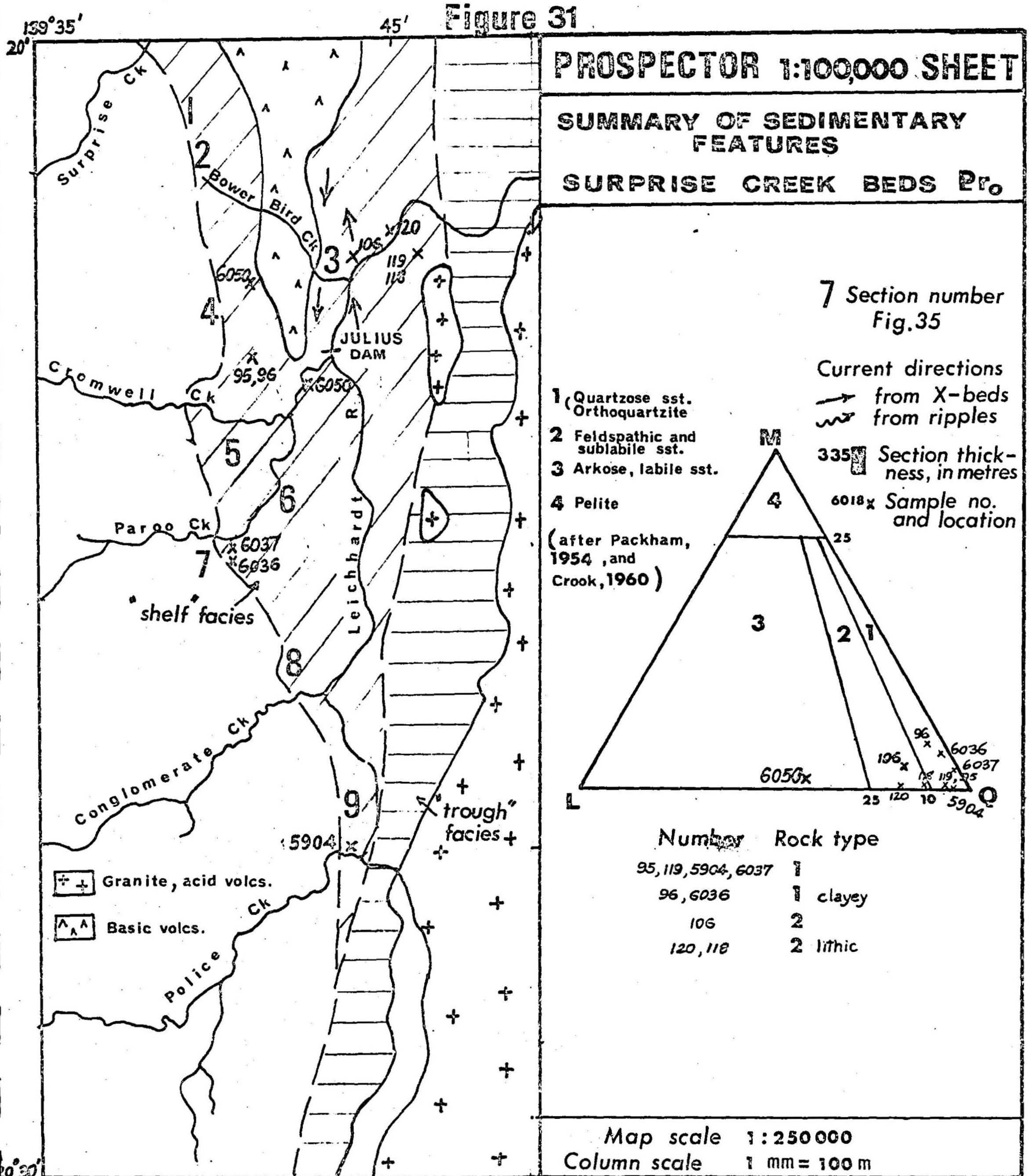
Sedimentary structures

Cross-bedding and ripple marks are ubiquitous. Cross-bedding is of pi and nu type in sets up to 1 m thick with planar to gently curved bases. Foreset angles of up to 30^o are common, especially in the basal sands, which also display some local channeling. Ripples are asymmetrical and interference types.

Bedding is laminated to thick, and in general the beds become more massive and thicker-bedded higher in the sequence.

Current direction data is lacking; sands high in the sequence near Julius Dam show currents from the south to southeast.

Figure 31



Record 1977/4

F54/A2/181

Petrography

Nine samples were studied, and their locations and compositions are shown in Figure 31. The samples range from very fine to coarse sandstone, with medium-grained sandstone most common. In the lithic sandstone, rock fragments are more abundant than feldspar, and form up to 30 percent of the rock. Most are varieties of acid volcanic and granitic rocks; polycrystalline quartz, chert, and basic volcanic fragments are less common. Quartz ranges from about 70 to 95 percent; the grains are generally close-packed, cemented by silica and clay, moderately sorted and subrounded, and derived from volcanic and granitic terrain. Higher in the sequence the sorting improves and feldspar decreases relative to rock fragments. Tourmaline is ubiquitous throughout the sequence, but zircon appears only in the better sorted and more mature sands.

Discussion: Both field characteristics and petrography suggest that unit Ᵽr$_0$ is composed of a possibly fluvial basal unit transitional upwards into shoreline sandstones.

The fluvial nature of the basal ferruginous sandstones from Cromwell to Police Creeks is based mainly on the presence of large-scale cross-bedding with local channeling and scour effects, but other evidence is lacking. Distribution of the ferruginous basal sandstone of Ᵽr$_0$ coincides with that of the underlying iron-rich Ᵽhm$_4$ unit of the Myally Subgroup, and we suggest that the Ᵽhm$_4$ sandstones were reworked in an alluvial and possibly paralic environment.

Stabilization of the Ewen block and gentle warping of the Myally Subgroup south of Cromwell Creek was accompanied by transgression of the sea westwards; reworking of earlier-formed sandstone in the paralic or beach zone is reflected in the better sorting and greater maturity of the upper sands both near the Ewen block and elsewhere, an increasingly massive habit, abundant parallel bedding and low-angle cross-bedding, and, locally current directions from the south and southeast. Some second-cycle sandstones may have formed by onlap of the strand-line westwards and erosion of sands of unit Ꝑhm$_3$ of the Myally Subgroup. Carbonate shoals with stromatolite zones were probably forming seawards (i.e., eastwards) of the Ꝑr$_0$ sands, and migrated westwards to subsequently overlie the sandstones of Ꝑr$_0$.

Unit Ꝑr$_1$

Field occurrence

Unit Ꝑr$_1$ is a recessive unit between the upstanding quartzite ridges of Ꝑr$_0$ and Ꝑr$_2$. It extends from the Police Creek area northwards onto the adjoining Alsace Sheet area, and is everywhere conformable on unit Ꝑr$_0$.

Lithology

Ꝑr$_1$ is predominantly dolomitic or calcareous; three broad divisions are distinguished, but they are not traceable for large distances because of poor outcrop. From the top, they are:

3. Dolomitic or calcareous siltstone, fine-grained dolomite, fine ferruginous sandstone, purple shale.

2. Well-bedded blocky dolomite, with siltstone interbeds; quartzose dolomite, stromatolitic dolomite, dolarenite, friable coarse sandstone, graded feldspathic sandstone; minor manganese concretions.

1. Buff ferruginous, calcareous, or dolomitic siltstone, with secondary limonite and manganese common in gossan-ous zones.

The stromatolitic dolomite is characteristic of the formation, and some typical forms are shown in Figures 32 and 33. Most stromatolites are simple dome-like structures with wavy bedding, and comprise single and small-scale colonial forms. Some small-scale columnar forms were located in August 1976.

Thickness variations are shown in Figure 35, and range from about 120 m in the north to a maximum of 525 m between Paroo and Cromwell Creeks.

Sedimentary structures

Fine laminae are common in the stromatolitic zones; cross-bedding in sets about 10 cm thick is common in quartzose dolomite and lenticular dolomitic sandstone (Fig. 32), and in friable ferruginous sandstone in the middle of the formation. In the black-weathering carbonate rocks the foreset beds are outlined by coarse rounded, clastic quartz grains. Brown sandstone near the stromatolitic zone displays graded bedding in sets 4 cm thick. Ripple marks are also present in brown sands locally.

Petrography

A sequence of 10 samples was collected from about 15 m of the stromatolitic section between Paroo and Conglomerate Creeks. From the top, the samples are:

6035	dolomitic siltstone
6034	dolomite[1]
6033	quartzose dolarenite[4]
6032	feldspathic (sublabile) sandstone
6031	stromatolitic dolomite[1]
6030	quartzose dolarenite[3]
6029	quartzose dolomite
6028	quartzose fine-grained dolomite[2]
6027	fine-grained dolomite[1]
6026	fine-grained dolomite[1]

Note;

1: synonymous with dolomicrite, less than 10% terrigenous fraction

2: from 10-50% terrigenous fraction, mainly quartz and feldspar

3: pelmicrite or oomicrite, where allochems are oolites and intraclasts totalling less than 25%, and set in fine matrix

4: Oosparite, in which 25% oolites are set in a coarse sparry cement.

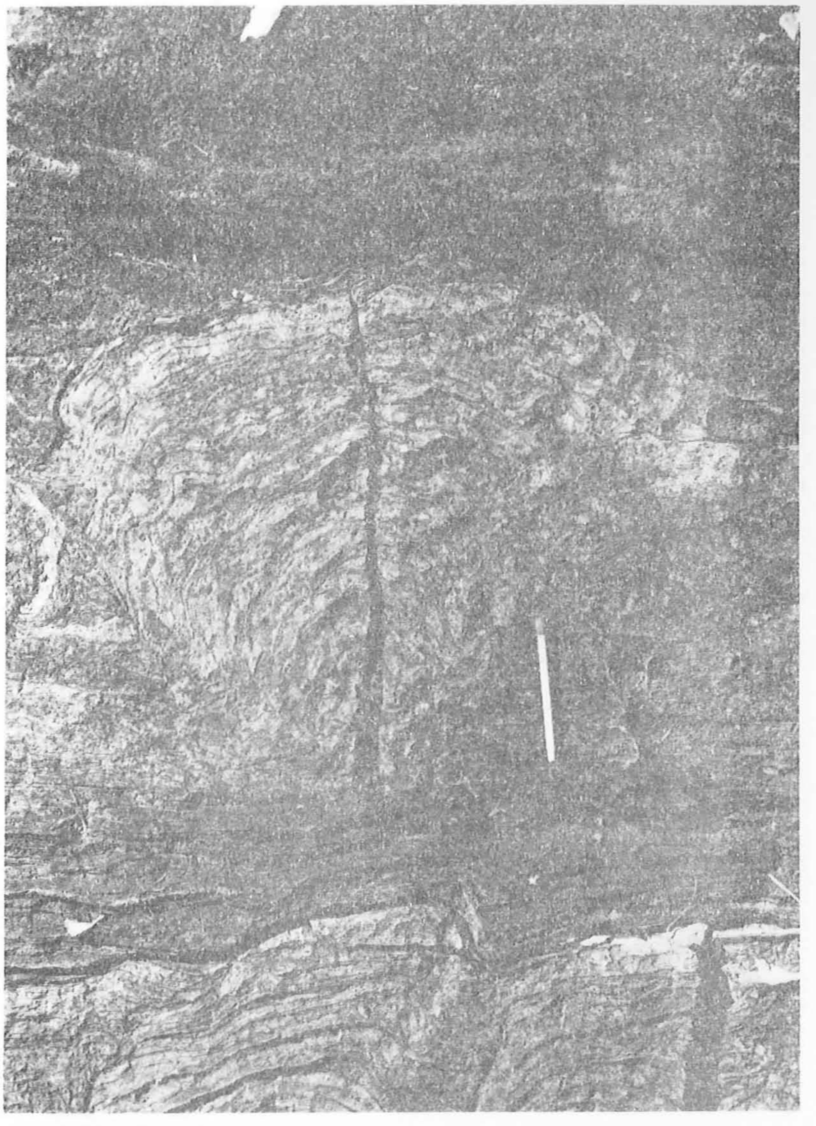
The terminology used here is based on that of Folk (1968), but rigid adherence to his scheme is difficult because of possible recrystallization.

Some of the fine dolomites show little or no crystallinity, and their fine-grained texture may be primary; in the psammitic rocks, however, some possibly secondary reaction is evident between terrigenous grains and dolomitic matrix (e.g., 6029). In some rocks, secondary calcite forms veins cutting fine dolomite, or pressure-shadow deposits between quartz grains, and is difficult to separate from possibly sparry calcite-dolomite which forms a coarse matrix enclosing oolitic grains in 6033.

The terrigenous fraction is made up of medium to coarse quartz and feldspar, mainly of granitic or volcanic origin, and abundant well rounded tourmaline and lesser amounts of subrounded zircon. Some quartz grains form cores to carbonate ooliths. The stromatolitic dolomite consists of laminae of fine dolomicrite interspersed with discontinuous layers of clastic quartz and feldspar, rare mica flakes, and heavy minerals.

143

Fig. 32.
Bedded dolomite, possibly of algal origin, overlain by domed stromatolitic dolomite, overlain in turn by cross-bedded quartzose dolarenite; in Br_1 13 km south-southwest of Julius Dam. M1503/9A GMD.



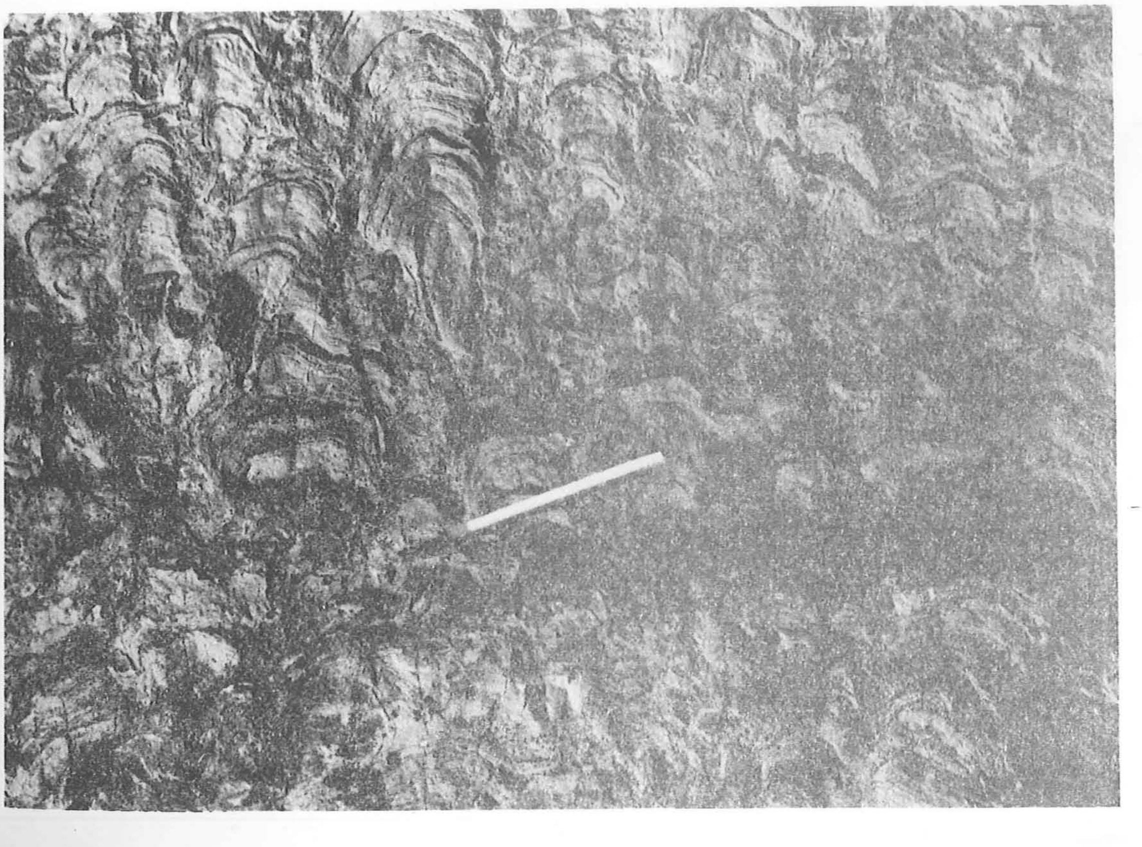


Fig. 33.
Domal colonial stromatolitic dolomite in Br_1 13 km south-southwest of Julius Dam. M1503/12A GMD.

Discussion

This unit was probably deposited on a shallow shelf bordering a long linear shoreline during a period of transgression westwards. In general the basal micritic part of the stromatolitic zone reflects a quiescent lagoonal or deeper-water environment in which dolomitic muds accumulated; cross-bedded oolitic dolarenites and sparry dolomites reflect deposition in relatively shallow agitated water in which current activity promoted good sorting, and into which terrigenous clastic material poured from time to time. Some of the terrigenous sediment was reworked, some was trapped on the surface of fine muddy algal mats, and some formed graded sand lenses. Purple shale and ferruginous sandstone near the top of the sequence may be contemporaneous tidal flat or deeper-water marine deposits, probably the latter.

Unit Ᵽr$_2$

Field occurrence

Unit Ᵽr$_2$ is an upstanding quartzite unit which parallels the Ᵽr$_1$ outcrop, and overlies it, apparently conformably. It extends north to south across the Sheet area in a belt just west of the Leichhardt River, and also crops out in a large fault block just east of the Leichhardt River near Julius Dam.

Lithology

Three broad divisions are distinguishable on aerial photographs: an upper and lower resistant quartzite unit, separated by a less resistant quartzite unit. A reference section is located about 5 km south-southwest of Julius Dam, along Paroo Creek. Buff feldspathic quartzite with up to 10 percent feldspar is the most common rock type, and is interbedded with grey to white orthoquartzite, some friable clayey feldspathic and limonitic sandstone, and minor green to grey locally convoluted siltstone. In general this unit differs from Ꝑr$_0$ sandstone in having a lower feldspar content and a higher proportion of orthoquartzite.

The unit is 750 m thick in the reference section, and appears to thin to the east and south to about 250 m. Thickness variations relative to underlying units are shown in Figure 35.

Sedimentary structures

Bedding in Ꝑr$_2$ is thick to thin, and parting massive to blocky; cross-bedding is ubiquitous, but differs significantly in type from other units. The pi-type of cross-bed is most common, in sets rarely thicker than 25 cm and most commonly 10 to 20 cm thick. Bases are planar to slightly curved, and herring-bone orientations (Fig. 34) and some festoon structures are commonplace. Ripple marks are present, but are less abundant than in unit Ꝑr$_0$.

Petrography

Samples studied are listed in Figure 36.

Most of the sandstones are only moderately sorted, but show high sphericity, moderate roundness, and relatively mature mineralogy - i.e., quartz of volcanic and plutonic origin, and abundant rock fragments (5 to 15 percent, mainly chert, and minor siltstone and acid volcanics); tourmaline, present in some samples, is the only heavy mineral. Silica overgrowths are the most common cement.

Discussion

The relatively mature quartz and chert fragment assemblage suggests that Ꝑr$_2$ may be second-cycle largely derived from pre-existing sandstones such as the Myally Subgroup and Ꝑr$_0$. Some scattered fresh feldspar grains and rare acid volcanic and

Fig. 34.
Cross-bedding style in Br_2. M1508/3 GMD.

Fig. 37.
Sparsely conglomeratic quartzite characteristic of unit Br_4, 14 km south of Julius Dam. The clasts are well rounded pebbles and cobbles of quartzite. M1508/5 GMD.

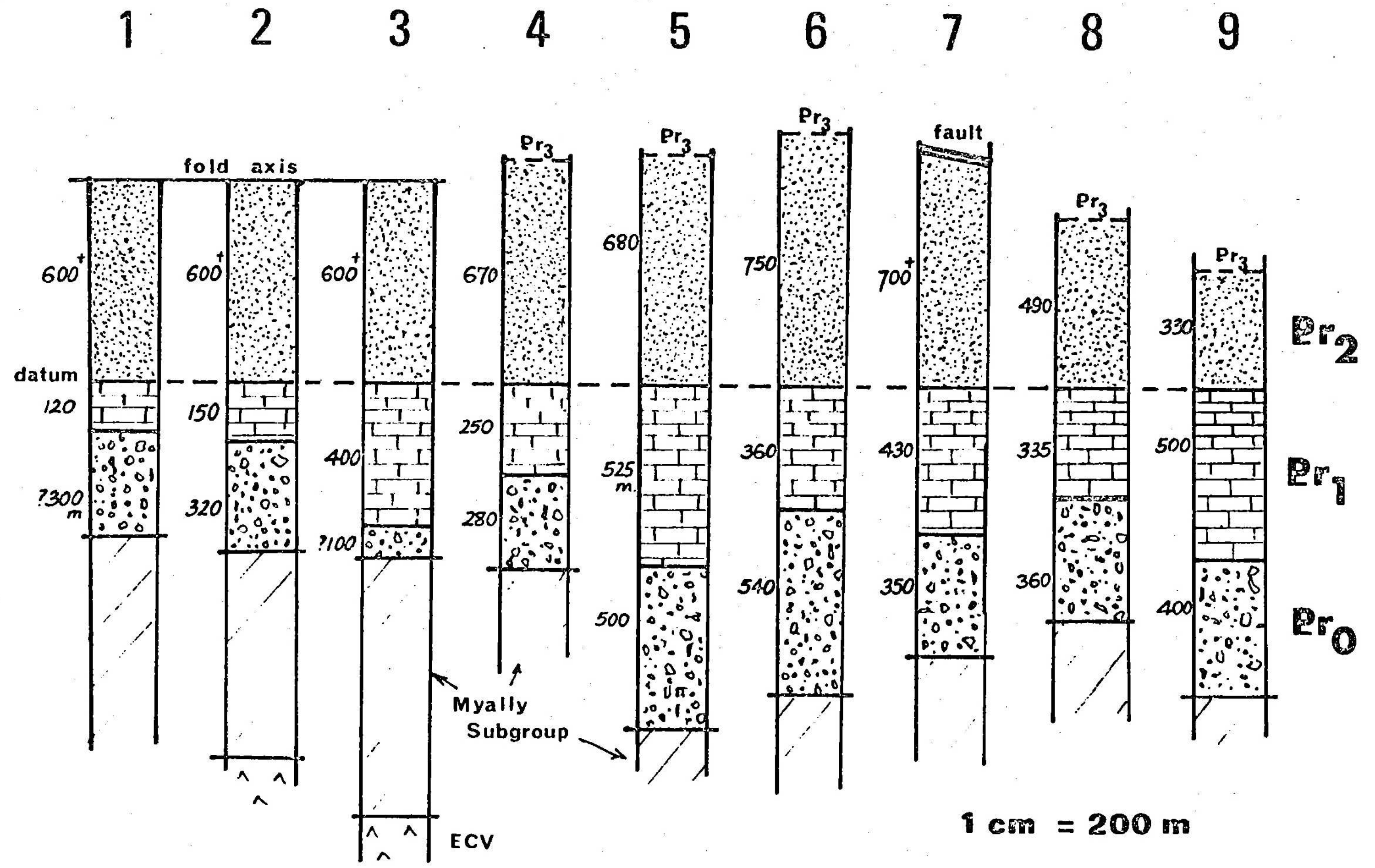
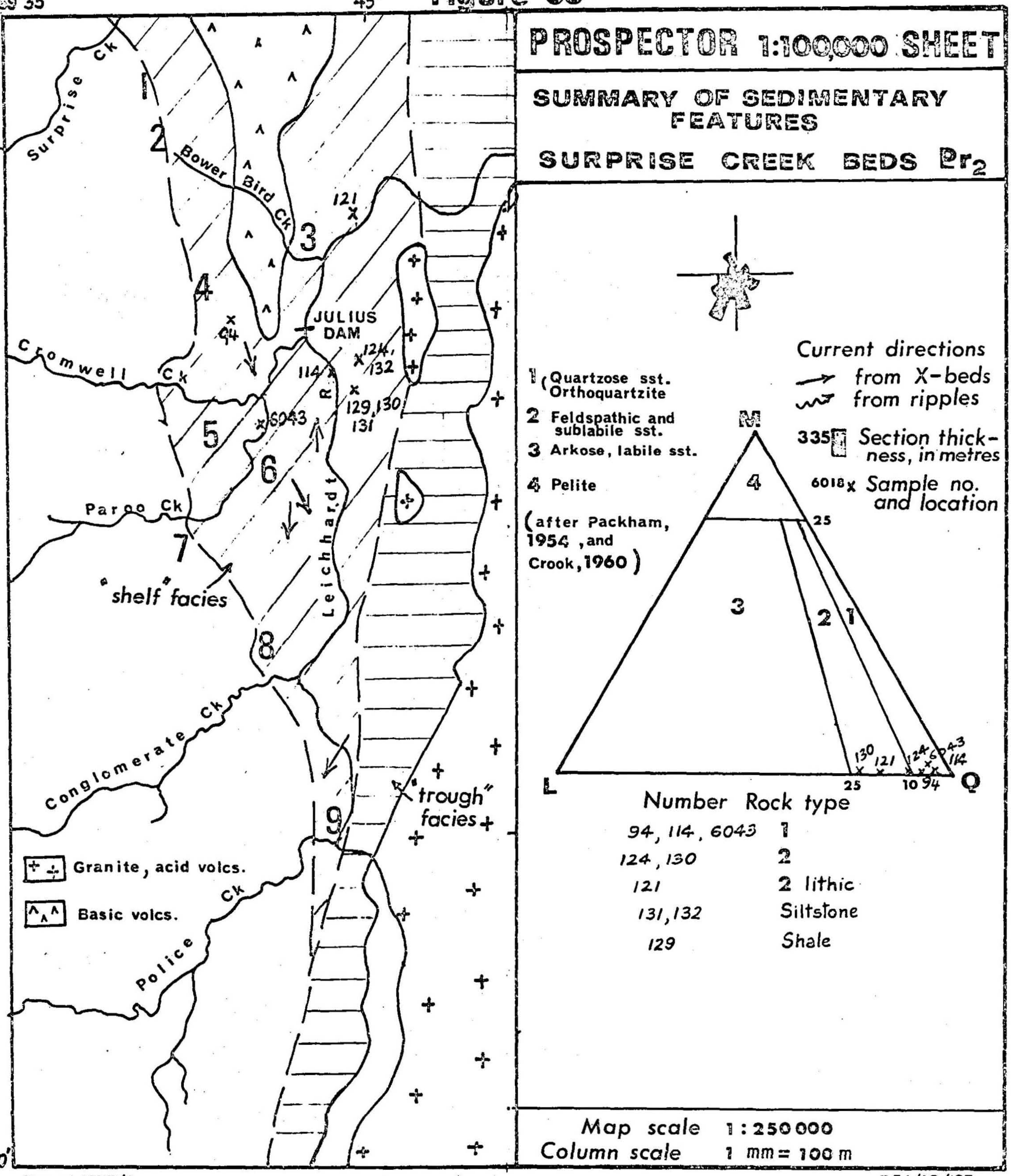


FIG. 35 STRATIGRAPHIC COLUMNS Pr_0, Pr_1, Pr_2, SURPRISE CREEK BEDS

Record 1977/4

F54/A2/182

Figure 36



Record 1977/4

F 54/A2/183

beta-quartz grains indicate some direct but minor contribution from basement source areas. The reworking of lithic feldspathic sandstone, such as Ꝑr$_0$ and Whitworth Quartzite, could well have eliminated much of the feldspar and unstable rock fragments, and left quartzose and chert-fragment residues typical of Ꝑr$_2$.

Some of the siltstone fragments in Ꝑr$_2$ resemble beds in Ꝑr$_1$, but in general there is no evidence of erosion of Ꝑr$_1$ during deposition of Ꝑr$_2$, although it could be expected. It is likely that much of the carbonate sequence of Ꝑr$_1$, if eroded, would not be preserved in a clastic shoreline environment because of comminution and dissolution.

The widespread conformity of units Ꝑr$_0$, Ꝑr$_1$, and Ꝑr$_2$ indicate uniform long-acting controls on sedimentation. If, as noted earlier, Ꝑr$_0$ and Ꝑr$_1$ are products of a westward-migrating strandline, Ꝑr$_2$ may reflect firstly stability of the strandline, and secondly an eastward regression of the strandline caused by gentle doming of the western and northern source areas. Earlier-formed sands have been winnowed in a beach or agitated shelf zone with active northerly and southerly trending currents, probably tidal and long-shore. The postulated eastwards regression in Ꝑr$_2$-time is reflected in a marked lateral contraction of younger units in the shelf facies, and the appearance of sandstone in carbonate sequences in the trough facies and the Corella Formation to the east. Alternatively, regression may not have occurred, and the sandstones in Ꝑr$_2$ may mark the transgression of an original offshore bar.

The pattern of Ꝑr$_0$ and Ꝑr$_2$ sand distribution is possibly analogous to the migrating strandline model applied by Hollonshead & Pritchard (1961) to the Mesaverde Sandstones in the San Juan Basin, New Mexico, USA.

Unit Ꝑr$_3$

Field occurrence

Unit Ꝑr$_3$ is a recessive shale and siltstone unit conformably overlying Ꝑr$_2$ sands. It displays a prominent blue-grey colour on airphotographs, and is well exposed in a faulted fold belt just west of the Leichhardt River, extending from near Julius Dam south to Glenroy homestead area. It is overlain, disconformably and conformably by conglomeratic sands of Ꝑr$_4$.

Lithology

A section of Ꝑr$_3$ from an area 14 km south of Julius Dam is as follows:

		Thickness
Upper:	purple-brown, flaggy micaceous siltstone (overlain by conglomerate of Ꝑr$_4$)	35 m
Middle:	fine-grained, locally gossanous siltstone; pale purple, poorly bedded micaceous siltstone and thin interbeds of blocky, brown feldspathic (25% - 30%) sandstone	15 m
Lower:	purple-grey poorly bedded shale	36 m
	dull brown to grey blocky, cleaved siltstone with minor shale interbeds	15 m
	purple-grey laminated shale, with grey, micaceous siltstone interbeds	18 m
	sandstone of Ꝑr$_2$ — TOTAL	119 m

In the reference section along Paroo Creek, and in areas to the east of the section above, calcareous siltstone and limestone/dolomite beds are present both at the base and top of the sequence. Beds transitional into Ꝑr$_2$ are rippled and cross-bedded friable brown limonitic sandstones.

Thickness ranges from 190 m to about 120 m from north to south, and the unit appears to thin eastwards to about 80 m.

Sedimentary structures

These are limited to fine lamination in shale and siltstone, some convoluted bedding, and minor ripple marks and cross-bedding in feldspathic sandstone.

Petrography

Samples 6051, 6052, and 6053 are ferruginous, laminated siltstones or fine sandstones. The sand fraction is angular to subangular and quartzose in 6051 and 6052, but very feldspathic in 6053. Some beds show fine grading.

Discussion

Unit Ꝑr$_3$ is possibly a more distal deposit associated with the underlying Ꝑr$_2$ sandstone. Fine sediment winnowed from the littoral shelf environment of Ꝑr$_2$ may have accumulated in deeper areas of the shelf; it may be transitional into siltstone deposited as unit Z in the trough facies. Conditions of sedimentation varied little, there being a balance between regression and slow relative uplift of the western source area on the one hand, and slow subsidence of adjoining trough areas to the east on the other hand.

Unit Ꝑr$_4$

Field occurrence

Unit Ꝑr$_4$ parallels unit Ꝑr$_3$, and overlies it apparently conformably. It is confined to an area just west of the Leichhardt River between Julius Dam and Glenroy homestead, and is moderately resistant, forming low ridges and rounded hills.

Lithology

Sparsely conglomeratic feldspathic sandstone is characteristic of the unit (Fig. 37). It is generally dull brown, friable and micaceous, coarse to medium, and blocky to massive. Green-grey shale and siltstone interbeds from 2 to 20 cm thick are present throughout the sequence, which ranges in thickness from 530 m in the shelf facies reference section to 380 m a few kilometres to the south.

Feldspar content is about 20 to 30 percent. The conglomerate fraction is cobble to pebble size, and clasts are mainly purple, brown, and white quartzite, chert, vein quartz, some purple shale, and minor acid volcanic material. A feature of the clasts is their extreme rounding and high sphericity. They are generally dispersed throughout the sequence at about 1 to 2 clasts per square metre, but in the reference section at least three highly conglomeratic beds are present, each a metre thick. The high rounding and relative maturity of the clasts are typical of orthoconglomerate (Pettijohn, 1957).

Sedimentary structures

Large-scale cross-bedding in sets up to 1 m thick is common, and many foresets contain pebbles and cobbles. Ripple marks are also present. Current directions in the Paroo Creek area are tightly grouped, and trend towards the 100^{o} to 160^{o} sector (southeast).

Discussion

The change from shale and siltstone of Ꝑr$_3$ to sparsely conglomeratic sandstone of Ꝑr$_4$ marks either regression of the sea or uplift of source areas, or both. The unit appears to thin eastwards; the depositional strike is northerly, parallel to the structural axes of shelf and trough areas, and the direction of transport is about normal to or slightly across the depositional strike. These and other features described earlier suggest deposition of unit Ꝑr$_4$ in an alluvial environment, possibly as a series of coalescing alluvial fan or braided stream deposits emanating from a zone of uplift to the west. The latter zone contains areas of Myally Subgroup, basal feldspathic sandstone of Ꝑr$_0$ and Ꝑr$_2$, and possibly acid volcanic terrain near its northern margins; there is evidence that areas of the underlying Ꝑr$_3$ unit were also eroded, thus implying an unconformity between Ꝑr$_3$ and Ꝑr$_4$.

Subtle differences exist between northern and southern areas of the unit, along the palaeostrike. In the north, cobbles and pebbles are less evenly distributed, shale interbeds are more common, cross-beds are less well developed, and ripple marks are more extensive than in areas to the south. This suggests that the northern areas contained more mature areas of the alluvial plain, or areas of near-shore mud and silt deposition in a deltaic or near-shore environment.

Equivalents of the Ꝑr$_4$ conglomeratic sandstone in the trough facies are possibly conglomerates in unit A. The two conglomeratic units show a tectonic and depositional setting similar to the Pottsville Conglomerates in the Central Appalachians (Meckel, 1967).

Unit Ꝑr$_5$

Unit Ꝑr$_5$ is a recessive unit found only in the reference section along Paroo Creek near Julius Dam. The lower part contains interbedded fine ferruginous, (specularitic) sandstone and pale green to dark grey shale and siltstone. The upper part contains medium to coarse feldspathic and ferruginous sandstone, and some laminated siltstone. Total thickness is 190 m. It is conformable over unit Ᵽr$_4$, and is overlain conformably by Ᵽr$_6$.

Convoluted bedding is characteristic of many of the thick (1 m) beds of coarse siltstone, but most are finely laminated and rarely rippled. Little or no cross-bedding was noted.

Samples 6044, 6045, 6046 and 6047 were examined in thin section. All are siltstones, with subangular quartz and feldspar grains enclosed in a brown sericitic or clay matrix. Some coarse mica flakes and chlorite outline the bedding, and tourmaline is the most common heavy mineral.

Discussion

Rapid transition from the pebbly beds of Ᵽr$_4$ into shale and silt of Ᵽr$_5$ indicates maturing of the western source areas and a deepening or transgression of the shelf zone. The lamination, grey-green colour, convoluted bedding, and lack of ripple marks and cross-bedding suggest a deeper water origin for Ᵽr$_5$, possibly as a distal equivalent of Ᵽr$_4$ conglomerates. Units B to D in the trough facies are possibly rock and time equivalents of Ᵽr$_5$, and both groups are similar in many respects.

Units Ᵽr$_6$, Ᵽr$_7$, Ᵽr$_8$

These conformable units form the restricted topmost part of the Surprise Creek Beds, and occur only in the reference section along Paroo Creek. A generalized stratigraphic column is shown in Table 14. Notable features are poorly sorted grit and conglomerate in Ᵽr$_6$, and zones of highly convoluted coarse siltstone and pebbly greywacke in Ᵽr$_7$.

TABLE 14. PALAEOGEOGRAPHIC RECONSTRUCTION, SURPRISE CREEK BEDS SHELF FACIES

Unit	Geometry and palaeocurrent data	Structures	Petrography	Environment of Deposition
Ꝑr$_8$	not known: min. thickness 70 m	Cross-bedding		
Ꝑr$_7$	not known: thickness about 90 m	Flame structures, convoluted bedding, laminated bedding, minor cross-bedding		Shelf slope or trough, marginal to moderately active western shelf edge
Ꝑr$_6$	not known: thickness about 80 m	Massive to blocky partings, thin-bedded; cross-bedding	Poor to moderate sorting, high feldspar and rock fragment content. Latter plutonic, acid volcanic, chert, rare siltstone	Unstable? fluvial zone bordering trough zone in which deeper water laminates of Ꝑr$_7$ deposited.
Ꝑr$_5$	Probably wedge-shaped, thickening from west to east. Thickness 190 m	Lamination, convoluted bedding; very rare ripple marks and cross-bedding	Subangular quartz and feldspar in brown clayey matrix. Tourmaline only heavy mineral	Reflects transgression of trough facies across shelf areas. Probably a deeper-water deposit, and may be distal equivalent of Ꝑr$_4$ conglomeratic sands
Ꝑr$_4$	Wedge or blanket, thinning west to east. Thickness ranges from 380 to 530 m Currents trend to south-east, across palaeostrike and down palaeoslope	Cross-bedding, large scale, foreset dips 25^{0} ; ripple marks in siltstone. Cobbles and pebbles in foreset beds		Structurally confined to centre of Sheet area; piedmont/alluvial fan deposits with some interaction with beach or coastal deposits in north. Locally uplifted older Myally block to west is probable source area
Ꝑr$_3$	Wedge or blanket: thickness ranges from 190 to 119 m north to south, and thins eastwards to 80 m	Fine laminae in shale and silt, some convoluted bedding, minor ripple marks and cross-bedding in feldspathic sandstone, and minor grading evident in thin section	Quartzose to very feldspathic subangular sand fraction	Deeper shelf or trough, possibly as distal deposit coeval with regressive? shoreline sand deposits of underlying Ꝑr$_2$

Table 14 (cont'd)

Unit	Geometry and palaeocurrent data	Structures	Petrography	Environment of Deposition
Ꝑr$_2$	Blanket, wedge: thickness varies from 250 to 750 m, but uniform over large areas Currents bimodal, from north and south, mainly the former. Possibly tidal plus long-shore current activity	Pi-type cross-bedding, sets most commonly 10 to 20 cm thick, with herringbone effects common. Some festoon cross-bedding, and fewer ripple marks than in Ꝑr$_0$	Mature sands mineralogically, but only moderate sorting. Increase in chert fragments, little or no heavy minerals	Littoral and shallow shelf - possibly derived by reworking and cleaning up of older sands of Ꝑr$_0$ and Myally Beds. Clays, etc., possibly winnowed and deposited as deeper-water silt of Ꝑr$_3$. Strandline possibly slowly eastward-migrating, and sequence slightly regressive
Ꝑr$_1$	Blanket: thickness variations from 120 to 525 m	Fine lamination in dolomites. Cross-bedding in sets 10 cm thick is common in quartzose dolomites. Limonitic sands also cross-bedded and ripple-marked	Fine dolomites show no crystallinity, and may be primary; some secondary calcite forms veins and resembles sparry calcite or dolomite matrix in some rocks. Rounded quartz and minor feldspar are clasts, and form cores to some oolites. Tourmaline very common	Shallow shelf bordering long linear shoreline; agitated carbonate shoals, lagoonal muds, and possibly deeper-water carbonate muds all present. Some periodic fluvial or aeolian influx of terrigenous material, some of which forms small lenticles of sand with graded bedding; some has become entrapped on the surface of muddy algal mats, forming thin laminae interspersed with dolomite
Ꝑr$_0$	Blanket in central and south: 100?-540 m thick; very thin or absent just west and northwest of Julius Dam Basal sequences in north show derivation from the north. Higher in sequence currents from south to southeast	Pi and Nu-type cross-bedding up to 1 m thick, with planar to curved bases and some channeling. Asymmetric and interference ripples. More massive and thick-bedded higher in sequence	Change from submature lithic sands near base to sublabile and quartzose sandstones near top. Rock fragments mainly plutonic and acid volcanic	Basal sands and arkose probably fluvial, with basal sands derived from basement areas in north, and ferruginous sands of upper Myally Beds to south. Fluvial environment transitional into neritic or littoral shoreline environment, as strandline possibly transgressed westward. Reworking of older Myally Beds sands probably resulted in more mature upper sands of Ꝑr$_0$.

Samples 6048 and 6049 from Ꞓr$_6$ are both coarse to very coarse feldspathic sandstones. Up to 30 percent feldspar is present in 6048, and 10 percent in 6049; rock fragments (5 percent) in both rocks are chert, acid volcanics, granite pegmatite, quartzite, and rare siltstone. The poor to moderate sorting and high feldspar content suggest a moderately unstable fluvial environment bordering the trough zone, in which deeper-water laminated sediments of Ꞓr$_7$ were deposited.

Units Ꞓr$_6$ and Ꞓr$_7$ may be equivalent to units C and D in the trough zone, and unit Ꞓr$_8$ may correlate with unit E quartzite, and the Warrina Park Quartzite at the base of the Mount Isa Group.

Surprise Creek Beds (trough facies)

Introduction

Interbedded siltstone, carbonate rocks, shale, and sandstone in a linear north-trending zone between the shelf facies to the west and the Kalkadoon-Leichhardt block to the east constitute the trough facies of the Surprise Creek Beds. The main features of this facies are continuity of thin units over large distances north-south, a lower sand-silt ratio than the shelf facies (1:2 and 2.4:1 respectively), and general indications of deeper-water flysch-like sedimentation than on the adjoining shelf. Trough dimensions in the Prospector Sheet area are about 3 to 10 km wide and over 50 km long.

A summary of the stratigraphy of the trough facies is listed in Tables 2 and 15.

Unit A was used as a marker bed near the middle of the sequence; beds between A and the underlying basement were designated units Z to W, and beds overlying A were designated beds B to H. Correlations between the shelf and trough facies are shown in Fig. 45, and are modified from those in Derrick (1974). Brief descriptions of each unit follows:

Unit W

This unit, which ranges from 315 m to 435 m thick, overlies the Kalkadoon-Leichhardt block unconformably, and is characterized by alternations of resistant quartzite with grey-green shale and siltstone. It forms a series of continuous, close-spaced ridges which flank the Kalkadoon-Leichhardt block, and extends along most of the eastern edge of the trough facies.

Lithology

At Sunday Gully, the unconformity with granitic and acid volcanic basement is well exposed; pebbly phyllitic arkose, grit, and buff to green-grey phyllite overlie sheared granite, although locally a glassy grey cross-bedded quartzite forms the very basal unit. Rock fragments in the grits include feldspar and quartz xenocrysts, quartzite, rhyolite, granite and vein quartz. Some zones of grit are massively bedded, and resemble granite sills. Beds of conglomerate and grit rarely exceed 3 m thickness.

Quartzites in the sequence are pink to brown, fine to coarse, massive to blocky and moderately feldspathic. The top-most bed is white and quartzitic.

Structures

Most of the quartzites are cross-bedded and ripple-marked; some fine siltstone with sandstone lenticles displays graded and flaser bedding.

Petrography

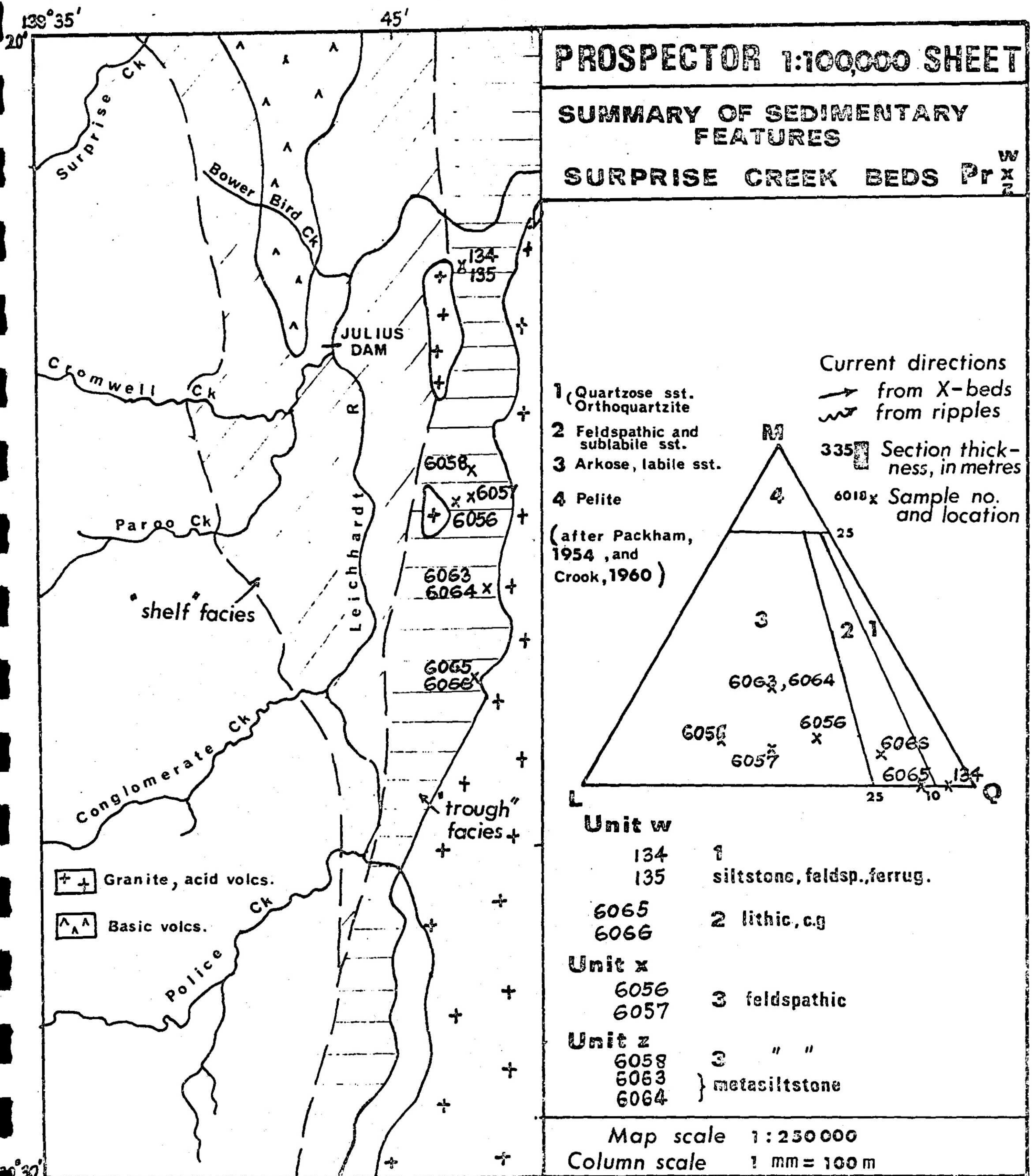
Five samples were examined; their localities and rock names are shown in Figure 38. Basal gritty quartzite (6065,

TABLE 15. PALAEOGEOGRAPHIC RECONSTRUCTION SURPRISE CREEK BEDS TROUGH FACIES

Unit	Geometry	Structures	Petrography	Environment of deposition	Correlations
Ꝑr$_H$	Sheet at least 275 m thick	Laminated bedding		Stable basin or trough	Native Bee Siltstone?
Ꝑr$_G$	Sheet: about 200 m thick	Laminated bedding		"	Breakaway Shale?
Ꝑr$_F$	Thick sheet: thickness 300 m Forms in synclinal keels	Laminated bedding, fine grading bedding, micro-cross-bedding	Silty beds contain higher proportion of iron oxide. Some rare coarse flakes of muscovite	Stable trough, relatively deep water; some flysch-like characteristics, but no evidence of turbidity currents	Moondarra Siltstone in Mount Isa Group
Ꝑr$_E$	Thin sheets & interdigitating sand and silt lenses; thickness 200 m	Minor cross-bedding	Orthoquartzites are super-mature; cherty rock fragments, zircon and tourmaline and apatite common	Transitional between agitated shelf environment and deeper shelf/trough zone with laminates	Warrina Park Quartzite (Ꝑiw$_3$) in Mt Isa Group
Ꝑr$_D$	Sheet or blanket, thinning to trough margins: thickness 280-350 m	Laminated bedding, highly convoluted bedding characteristic	Coarse muscovite flakes and tourmaline abundant in fine sand and coarse silt	Neritic shelf/trough zone, (possibly pro delta), subject to periodic influx of coarser detritus	Ꝑr$_7$ in shelf facies
Ꝑr$_C$	Thin blanket sands continuous over large areas but locally lenticular: thickness 25-80 m, with thin sands up to 10 m thick	As for D; sandstones contain cross-bedded top and convoluted base	As for D; sandstones show slight coarsening upwards	As for D, but arenites possibly transitional from deeper to shallower water. Sandstone in silt reflects mild tectonism	Conglomeratic sands of Ꝑr$_6$
Ꝑr$_B$	As for D: thickness 56 to 140 m	Ripple-marked arenites common; convoluted bedding in fine sand and silt	As for D; some samples pyritic	As for D	Ꝑr$_5$ in shelf facies

Table 15 (cont'd)

Unit	Geometry	Structures	Petrography	Environment of deposition	Correlations
Pr_A	Extensive blanket or wedge: maximum thickness near centre or central-east parts of trough zone i.e. from 75 to 300 m	Cross-bedding, ripple marks, lenticular bedding	Feldspar up to 30%; some basement fragments as well as sedimentary rock fragments	Possible unconformity at base. Fluvial or piedmont gravels interfingering with shallow shelf and strandline sands; reflects major crustal uplift in region	Unit Pr_4 in shelf facies; possibly Deighton Quartzite in eastern succession
Pr_Z	Blanket continuous over large areas; thickness 120 m. Overlapped by unit A north of Sheet area	Minor grading, some micro-cross-bedding	Sandstones submature to immature, feldspar-rich, with coarse muscovite and abundant tourmaline, and cherty rock fragments	Offshore zones adjacent to trough-edge, in moderately deep water i.e. delta front or delta-slope zones, with some pelagic and carbonate deposition. Probably deeper than stromatolitic shelf areas to west	Possibly Pr_3 in shelf facies; upper Corella Fm in eastern succession
Pr_Y	Blanket or wedge sand: thins towards western shelf areas; thickness 85 to 115 m	Cross-bedding, large amplitude and wave length ripple marks	Feldspar about 15%; some hematite outlines bedding	Coalescing fluvial or near-shore shelf sand resulting from mild rejuvenation of source areas	Middle Corella Fm in eastern succession; parts of Pr_2 in shelf facies
Pr_X	As for Z: thickness 170-200 m	Rare cross-bedding, flaser bedding, graded bedding	Feldspar-rich sand lenticles (30% Kf) in shale and siltstone; clay and calcite matrix	Sand-silt-shale lithology plus graded and flaser bedding and lack of ripples and cross-beds suggest a moderately deep shelf environment receiving submature detrital fines; some carbonate deposition	Possibly Pr_1 in shelf facies; lower Corella Fm in eastern succession
Pr_W	Sand blanket from 315 to 435 m thick	Cross-bedding, ripple marks. Some graded and flaser bedding in siltstone	Grits contain well rounded plutonic quartz grains, abundant feldspathic debris from basement volcanics and granites, some tourmaline and muscovite flakes	Probably forms part of a basal sand sheet continuous over shelf areas to west; trough possibly not developed; basal grits may be residual gravels or channel-fill deposits, extending seawards into shallow shelf sandstones	Unit Pr_0 in shelf facies (a transgressive sand?); Ballara Quartzite in eastern succession



Record 1977/4

Figure 38

F54/A2/184

6066) contains a coarse fraction of well rounded plutonic and volcanic quartz grains, mixed rock fragments, and minor feldspar grains set in a fine subangular matrix of quartzofeldspathic sand and abundant fine aggregates of iron oxide. Rock fragments include micropegmatite, fine acid volcanics, chert, quartzite and shale; the igneous fragments predominate. Rare blue-green tourmaline is the only accessory mineral.

Sample 134 is a well sorted mature orthoquartzite, generally with silica overgrowths and sericite grain-boundary coatings; rock fragments include chert, siltstone, and fine acid volcanics. Muscovite flakes, epidote, and tourmaline are the main accessories. Sample 135 is an associated ferruginous siltstone containing some large muscovite flakes.

Discussion and correlations

Much of unit W is derived from mainly basement granite and volcanic sources, probably as thin near-shore and fluvial sand sheets blanketing the Kalkadoon-Leichhardt block, and smaller acid volcanic inliers which occur near the western trough margins. The continuous well sorted mature quartzose sands at the top of unit W may represent strandline (linear clastic) deposits.

Within the Surprise Creek Beds repository, unit W is correlated with unit $Ꞓr_0$ of the shelf facies (Derrick, 1974); features common to both units include a succession of arkose, grit, conglomerate and poorly sorted fluvial sandstone at the base, grading upwards into better sorted, more mature linear clastic sand sheets; and a similar photopattern of 3 or 4 resistant ridges separated by less resistant strata.

Across the Kalkadoon-Leichhardt block to the east, unit W is correlated directly with the Ballara Quartzite, which also displays all the features listed above. Slight facies differences are reflected in the slightly more calcareous interbeds in the Ballara Quartzite than in unit W. The gradation upwards from grits, conglomerate, etc., to well sorted quartzite suggests a gradual maturing of the source areas during a period of overall submergence (or transgression).

Unit X

Unit X parallels and overlies unit W conformably over all of the Prospector Sheet area. It is a less resistant unit than W and the overlying sandstone of unit Y, and contains friable feldspathic ferruginous sandstone with silty micaceous partings, grey shale, flaggy siltstone, and calcareous siltstone and shale with 'flaser' sand lenticles.

Hematite laminae outline bedding. Cross-bedding is present, but is not common. Its thickness is relatively uniform, between 170 and 200 m, throughout its outcrop in the Sheet area.

Petrography

Samples 6056 and 6057 have been examined, and are plotted in Figure 38. Sample 6056 displays flaser bedding, in which highly feldspathic sandstone lenticles are contained in a fine siltstone or shale. The sandstone is graded, and contains some clay, and carbonate grains (8%), iron ore (5%), and about 50 percent quartz and 34 percent feldspar. Tourmaline is a rare accessory. Sample 6057 is similar to the sandstone lenticles; it is highly feldspathic (up to 50%), and contains calcite, chlorite, and possibly detrital iron ore in the matrix. Sorting of the sandstone is moderate, and the main cements are silica, ferruginous clay, and calcite.

Discussion and correlations

The highly feldspathic, fine-grained sandstone-silt-shale lithology showing graded and flaser bedding could represent a number of environments, including overbank alluvial deposits, tidal-flat or lagoonal areas, or distal pro-delta slope deposits. The graded bedding, flaser bedding, and some overturning of thin sandstone lenticles possibly favours the pro-delta slope environment; the high but fine-grained feldspar content reflects the immature suspension load of streams draining from source areas to the west, or from the Kalkadoon-Leichhardt block. A lack of ripples and only sporadic cross-bedding suggest deposition in deeper parts of the shelf-trough areas, accompanied by small amounts of carbonate deposition.

Within the shelf and trough facies, unit X is correlated with unit Pr_1, a stromatolite-bearing transgressive sequence to the west. Both units overlie sandstones which are themselves correlatives; both contain calcareous rocks, but no stromatolites have been located so far in unit X in the Prospector Sheet area, possibly because of deeper shelf or trough conditions and an abundance of fine clastics.

Across the Kalkadoon-Leichhardt block to the east, a probable correlative of unit X is the lower Corella Formation, a sequence of limestone, calcareous siltstone, shale, and calcareous scapolitic granofels. All of these units (Pr_1, lower Corella Formation) are mainly fine-grained detrital or chemical-detrital deposits which formed or were deposited during a period of maximum transgression.

Unit Y

Unit Y is an upstanding unit conformably overlying unit X, and overlain conformably by unit Z. It is predominantly a sequence of feldspathic quartzite and shows a dull brown-grey colour on aerial photographs, in contrast to the white and brown-white colours of other quartzites in the sequence such as units W and A.

Near the base, fine-grained pink to brown feldspathic quartzite contains minor grey-green shale partings, some pyrite cubes and local pebbly bands. The upper parts of Y are fine to coarse feldspathic quartzite and orthoquartzite, also containing thin pebble beds. Cross-bedding and ripple marks are common, and some ripples show large wavelengths, up to 0.3 m.

Feldspar content generally exceeds 15 percent, and may reach 40 percent; hematite laminae outline bedding in some of the upper quartzites.

Discussion

The high feldspar content and presence of scattered pebbly beds indicate mild rejuvenation of source areas. A lack of mineralogical maturity accompanied by cross-bedding and ripple marks indicates rapid erosion but only minimal sorting, probably in a fluvial regime or shallow shelf environment.

The unit is correlated with unit Ᵽr$_2$ to the west. Conditions apparently were more stable in the shelf areas to the west and sedimentation rates slower, compared with the trough zone adjacent to the Kalkadoon-Leichhardt block; it thus appears likely that unit Y forms part of an offshore sand blanket continuous for long distances north-south, but wedging and thinning out westwards. East of the Kalkadoon-Leichhardt block a fine to medium feldspathic quartzite in the middle Corella Formation is a likely correlative of unit Y.

Unit Z

Unit Z parallels and rests conformably on unit Y, and forms a valley between Y and the upstanding ridges of unit A. The boundary with unit A appears mostly conformable, but some overlap of A over Z is evident 5.5 km north-northwest of Sunday Gully. North of the Prospector Sheet area, some overlap of unit A over Z has also been observed, and a regional unconformity between A and Z is postulated.

Main rock types in Z include flaggy to blocky brown and ferruginous feldspathic quartzite, friable sandstone, purple micaceous siltstone and laminated shale and siltstone, calcareous siltstone, limestone and/or dolomite. Thickness is about 120 m. Carbonate rocks appear to be more common in the western trough areas than in the eastern parts of the trough adjacent to the basement block. Some of the silty beds are phyllitic along the faulted western margin of the trough owing to mica recrystallization during metamorphism and shearing.

Petrography

Samples 6058, 6063 and 6064 have been examined (Fig. 38).

Sample 6058 is a fine, immature, feldspathic quartzite; abundant pore space is filled with sericite, clay minerals, and minor iron oxide; detrital grains show a subtle grading, and range from 0.1 to 0.35 mm diameter. Potash feldspar (40%), as both clear and clouded microcline, and quartz (30%) are the chief detrital minerals, together with 6 percent bent muscovite flakes and 9 percent iron ore defining laminations. Some cherty rock fragments are present, and blue-green and brown varieties of tourmaline are especially abundant.

Samples 6063 and 6064 are siltstones, showing average grain size of 0.05 mm; quartz and clear alkali feldspar are in equal amounts (35%) in a green-brown biotite matrix which also contains minor muscovite and hematite flakes, and abundant green-brown tourmaline. Small cross-cutting veins contain polycrystalline quartz and minor amounts of crystalline dolomite.

Discussion and correlations

The unit distribution, fine grainsize, and mineralogical immaturity, and an overall lack of shallow-water structures suggest deposition in offshore, probably deeper areas adjacent to the trough margins. Much of the sediment may be pelagic, or at least carried as suspension load away from near-shore zones into delta-slope and delta-front environments. Development of carbonate-rich zones in the western part of the trough zone may reflect a more quiescent environment with lesser detrital input, transitional between the eastern trough areas and the stromatolitic shelf facies farther west.

Correlations of unit Z are with unit Ꝑr$_3$ of the Surprise Creek shelf facies to the west, and with the upper unit of the Corella Formation across the Kalkadoon-Leichhardt block to the east. All of these units represent a period of relatively uniform transgression and still-stand, preceding major crustal movements which led to deposition of the overlying conglomerates and quartzite of unit A and its correlatives.

Unit A

This unit is essentially a massive quartzite with conglomerate at the base. It extends along the entire length of the trough zone, forms a marked ridge or plateau, and overlies unit Z apparently conformably or with slight angular unconformity.

Lithology

Conglomerate at the base of unit A is locally lenticular, but in general persists as a marker bed throughout the trough area. It contains well rounded and highly spherical clasts of mainly quartzite and ferruginous quartzite, minor acid volcanic pebbles, and rare but characteristic red jasper pebbles. At one locality 8 km southeast of Julius Dam, conglomerate forms three beds - 7 m, 1 m, and 12 cm thick - separated by beds of quartzite 1 m thick. Cobbles are the main clast size, and boulders are rare. These beds are in sharp contact with red-brown to grey micaceous siltstone of the underlying unit Z.

Quartzite overlies the conglomerate, and is locally pebbly or granular. Feldspar content is from 5 to 10 percent, but up to 30 percent is present locally. The sands are medium to coarse, dull white to pale brown, ferruginous in places, and contain some heavy-mineral bands and zones of pyrite cubes.

Structures

Cross-bedding and ripple marks are abundant; the former are generally large, up to 0.7 m thick, with planar bases and foreset dips of up to 30°. Bedding is thin to thick, and partings are massive to blocky.

Thickness variations

Folding of unit A reveals significant thickness variations throughout the Sheet area (see Fig. 39). In general the maximum thicknesses of 250, 285, and 300 m occur in the central or central-eastern parts of the trough; the unit thins westwards to thicknesses of between 100 and 180 m, and appears to thin southwards to 75 m.

Petrography

Two samples, 27 and 115, were examined. Sample 27 is a submature to mature sandstone containing quartz (85%) and feldspar (5%), and rock fragments (10%) of acid volcanics, siltstone, chert, and microcrystalline quartz. Tourmaline and zircon are accessories. Sample 115 is a fine labile arenite, with grainsize 0.1 to 0.2 mm, and contains abundant Na and K feldspar (30%), subangular quartz (44%), up to 15 percent of ferruginous clay/sericite matrix, and 8 percent of opaque oxide flakes. Muscovite (3%) is also present.

Discussion

Coarse cross-bedding, ripple marks, heavy-mineral bands, and lenses of conglomerate indicate a depositional zone of moderate to high traction currents. Well rounded clasts in the basal conglomerate suggest some reworking and transport from older quartzite terrains - for example, unit W; similarly chert, siltstone, and jasper fragments indicate a mainly sedimentary source region, but acid volcanic pebbles show that some basement areas were exposed.

The herringbone cross-bedding characteristic of parts of unit A reflect bimodal (possibly tidal or beach-swash) currents, and hence a possible fluvial (estuarine?) or tidal shelf environment. Thickness variations show the sand unit to be a wedge thinning to the west, but it is not yet clear whether it thickens eastwards towards the source, or is thickest in the central parts of the trough - for example, as a submarine channel-fill sand, or possibly a fluvial channel sand. Conglomerate at the base of the unit is possibly an eluvial terrace or fluvial gravel deposit adjacent to uplifted source areas.

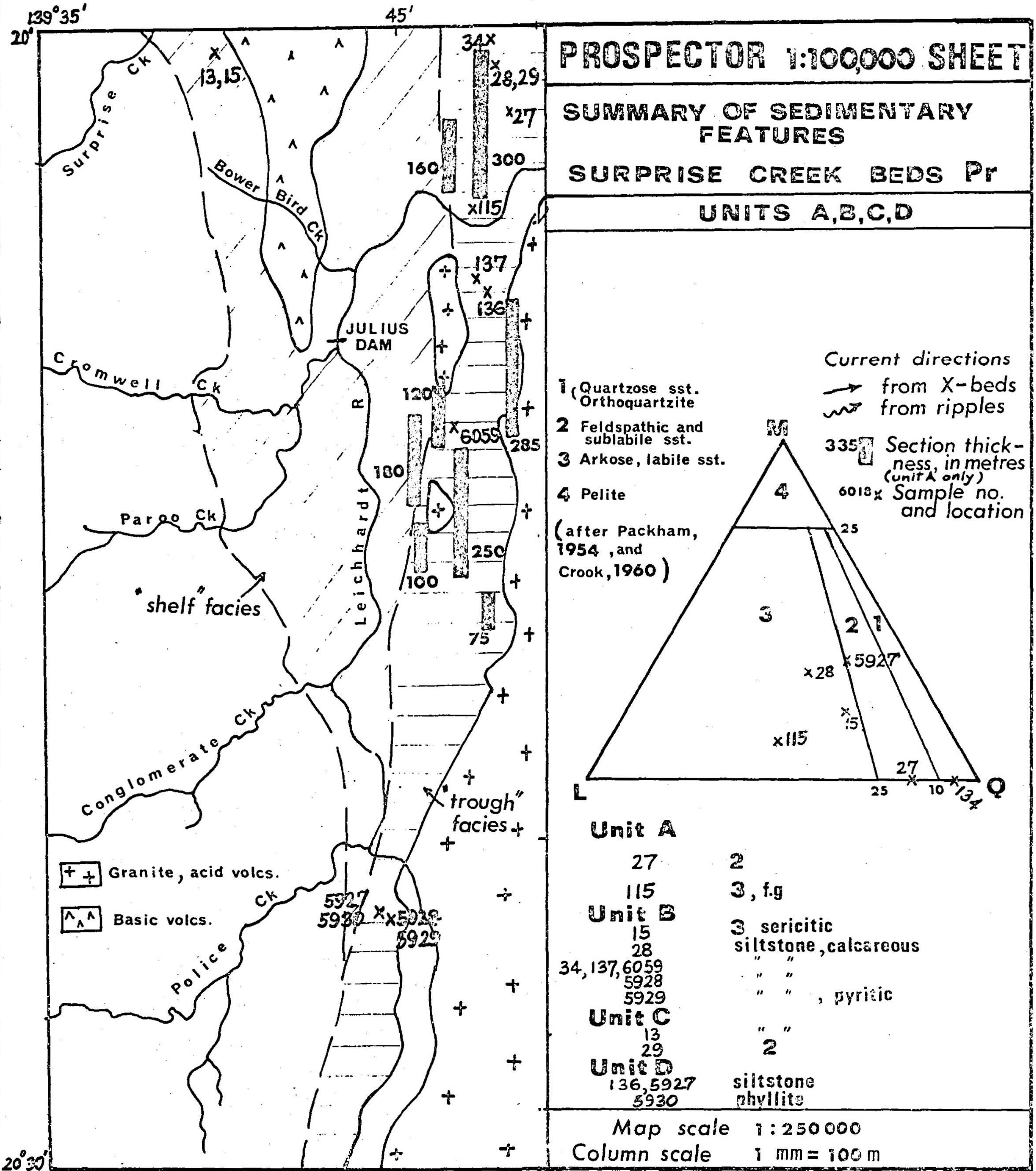
A probable correlative of unit A is the conglomeratic unit Ᵽr_4 in the Paroo shelf areas to the west. A possible correlative of unit A in the eastern succession is the mainly regressive, probably fluvial Deighton Quartzite, which also rests unconformably or disconformably on the transgressive/still-stand deposits of the Corella Formation (see Fig. 45).

Units B, C, and D

These units are continuous throughout the trough; they form valleys, but two thin quartzitic beds in the middle of the sequence form narrow strike ridges up to 20 m high, which, together with an intervening siltstone, define unit C; siltstone above the upper C quartzite is unit D, and siltstone below the lower C quartzite is defined as unit B.

<u>Lithology</u>

Units B and D and parts of C are mainly grey-green siltstone, laminated khaki-grey to brown fine sandstone, grey to

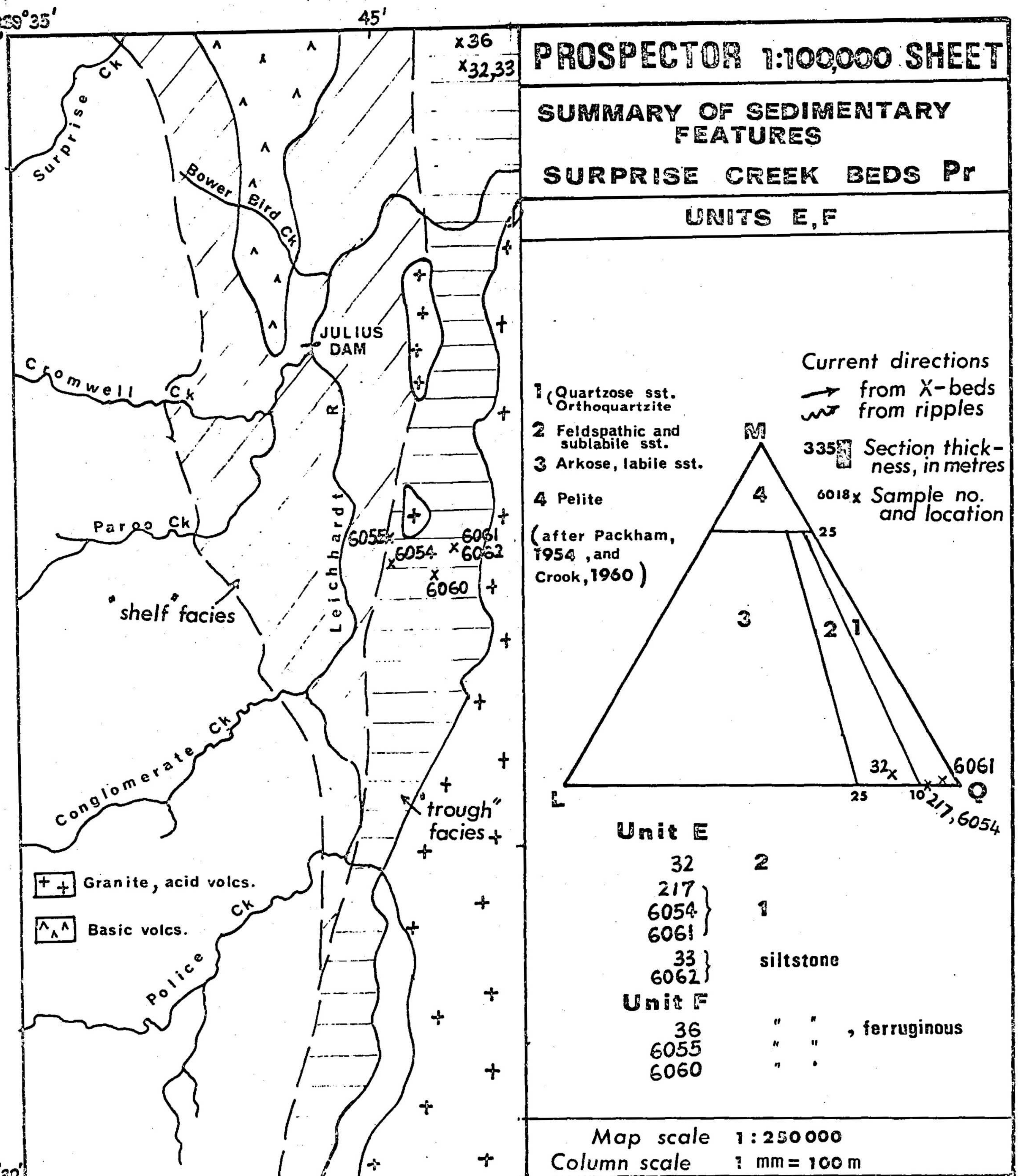


Record 1977/4

F54/A2/185

Figure 39

171



Record 1977/4

F54/A2/186

Figure 40

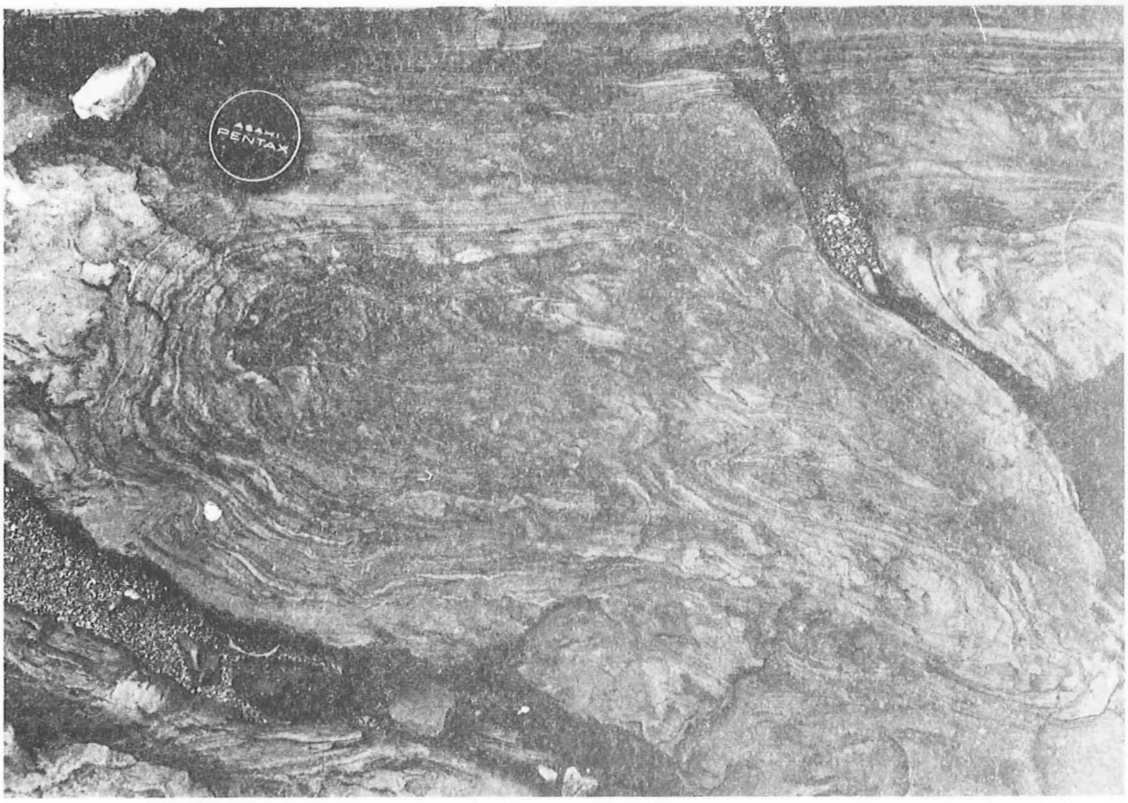
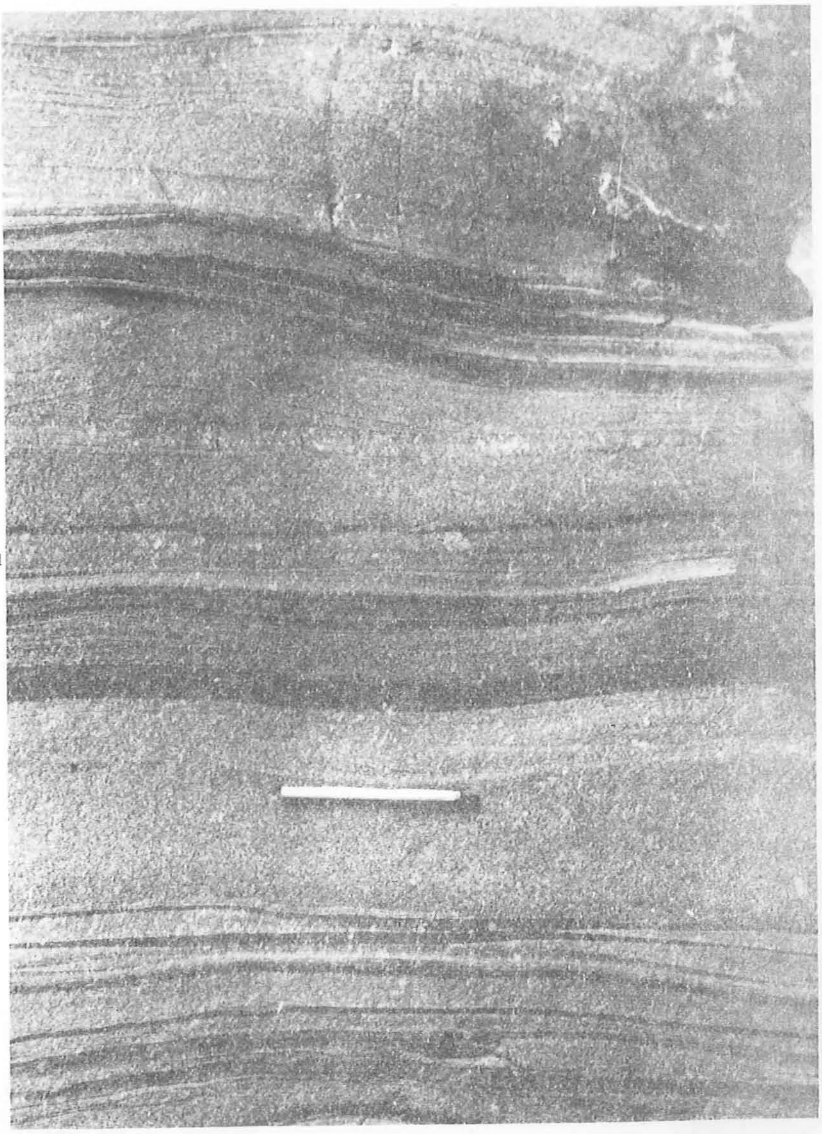


Fig. 41.
Convoluted bedding in silty sandstone of unit D or E of Surprise Creek Beds 6.6 km north of Sunday Gully. M1508/13 GMD.

Fig. 42.
Typical lamination and flaser bedding in siltstone and fine sandstone of units D, E, and F, Surprise Creek Beds, 6.6 km north of Sunday Gully.
M1508/14 GMD.



pale purple shale, and minor calcareous siltstone and limestone. In D, fine to coarse siltstone is regularly interbedded with flaggy to blocky fine sandstone. Siltstone of unit B appears transitional into quartzose arenites of unit A, via a sequence of massive feldspathic quartzite and friable arenite interbedded with flaggy buff siltstone. Some gossanous zones are evident towards the base of B about 12 km south-southeast of Julius Dam; some malachite is present in unit C 6 km south of Jamie mine, and unit D is host to sporadic malachite-chalcocite mineralization in the adjoining Alsace Sheet area to the north.

Quartzites in unit C vary in colour from dull brown to white. Towards the north of the Sheet area the lower quartzite is white to grey, and the upper quartzite dull buff to brown and generally slightly less prominent. Both quartzites are fine to medium and contain up to 15 percent or more feldspar; they are massive to blocky, and the upper quartzite decreases in grainsize from top to bottom.

Structures

All three units are characterized by zones of intensively convoluted bedding (Fig. 41), which is present in coarse siltstone and fine sandstone and also in the quartzites of unit C. In the latter the upper parts of each of the quartzite units are cross-bedded, and the lower parts convoluted.

Some of the sandstones in unit B are ripple-marked, but, in much of these three units, ripple marks are rare or absent. Micro-cross-bedding and flaser bedding are common (Fig. 42), especially in unit D.

Thickness variations

Unit B ranges in thickness from 56 to 140 m; unit C ranges from 25 to over 80 m near Sunday Gully, the quartzites of this unit averaging 10 m thickness; unit D ranges from 280 to

350 m thick. Variations in thickness are relatively insignificant in view of the continuous nature of all three units over large distances.

Petrography

Unit B samples are 15, 28, 34, 137, 6059, GSQ 5928, 5929

Unit C samples are 13, 29

Unit D samples are 136, GSQ 5927, 5930.

Most samples are siltstone or fine sandstone characterized by an abundance of muscovite and coarse tourmaline in a finer matrix of sericite and scattered detrital quartz and feldspar grains. Limonite coatings and spots are common. Cherty rock fragments are present in the fine quartzites, and some calcite fills interstices and gashes in 28 and 5927. Up to 4 percent pyrite is present in unit B sample 5929.

Discussion and correlations

Continuity of thin beds such as unit C over large distances indicate a moderately stable depositional environment. The abundance of interbedded grey-green siltstone, shale, and fine-grained sandstone, a scarcity of cross-bedding and ripple marks, the presence of lamination and parallel bedding, and an abundance of convoluted bedding, favour a moderately deep-water, slightly reducing environment, possibly in pro-delta or neritic zones of a broad shelf. Although the sequence is flysch-like, a lack of flute and sole marks and grading bedding show that turbid flow conditions were probably absent. Gradients on the shelf were low, and convoluted bedding throughout units B, C, and D reflects hydroplastic behaviour, possibly induced by differential compaction rather than by major slumping. Gradations observed in quartzites, from a fine-grained convoluted base to a coarser cross-bedded top, may indicate a transition from deeper to shallower water conditions; both the presence of quartzite interbeds in siltstone, and coarse grains of quartz, feldspar, and muscovite in fine-grained siltstone show that the postulated stable neritic shelf environment was subject to periodic influx of possibly storm or flood-induced stronger currents carrying coarser sediment outwards across the shelf zone. Petrographic data suggest the source areas were relatively mature, containing mixed plutonic and sedimentary rock types; erosion from the Paroo shelf areas to the west and possibly from the Kalkadoon-Leichhardt block to the east appears likely.

Copper mineralization in grey-green silty sandstone in units B to D resembles some of the African Copper Belt and Montana mineralization (Tourtelot & Vine, 1976), and further work is required to fully evaluate the relations between copper mineralization and the sedimentary environment.

Unit E

This unit is a sandstone separating the mainly siltstone units D and F. It forms upstanding ridges of thin white quartzite which are continuous over large areas of the trough facies. From one to four thin quartzite beds are normally present; the contact with unit D is drawn along the base of the lowermost quartzite, but the contact zone with unit F is transitional, as interbedded feldspathic sandstone and siltstone pass upwards into laminated grey, cream, and red-brown shales. Total thickness of the unit is about 200 m.

Lithology

Quartzites vary from quartzose to feldspathic varieties. They are massive to blocky, white to pale brown, and fine to medium. The basal white glassy orthoquartzite is commonly pyritic, and locally contains traces of turquoise on fracture planes. As in units B, C, and D, convoluted bedding is common in the finer sandstone and siltstone in the sequence.

Minor conglomerate was recorded from an area 2 km west of Sunday Gully.

Petrography

Samples studied were 6054, 6061, 6062, 32, 33, 217.

Sample 6054 is an orthoquartzite, with up to 8 percent cherty rock fragments, and a heavy-mineral assemblage of zircon and tourmaline.

Sample 6061, an orthoquartzite, is characterized by a quite different heavy-mineral assemblage, namely apatite, with little or no zircon and tourmaline.

Sample 217 is also orthoquartzitic, but contains significant amounts of muscovite. Feldspar and muscovite increase in sample 32, and tourmaline is the most common accessory. Samples 33 and 6062 are siltstones, the latter showing some coarse detrital muscovite flakes, iron oxide pseudomorphs after pyrite, and subtle grading from coarse to fine siltstone.

Discussion and correlations

Close packing, high sphericity and rounding, and over 90 percent of quartz grains in the orthoquartzites are typical of supermature to mature sands; they have formed in a shallow shelf environment subjected to current and wave agitation, constant winnowing, and sorting; the thin quartzites of unit E may represent the extremities of a thicker orthoquartzite mass to the west (the Warrina Park Quartzite) interfingering with the deeper?-water laminated rocks of the trough zone.

Copper in unit E is present as turquoise and malachite coatings on fractures; a source of the trace-copper mineralization is not known, but units D and B as well as E may be the host formations, and therefore likely exploration targets.

Unit E quartzite is labelled Warrina Park Quartzite on the Prospector First Edition map in preparation.

Units F, G, and H

Units F, G, and H are the topmost units preserved in the trough facies of the Surprise Creek Beds. Unit F, 300 m thick, is a red-grey laminated shale/siltstone sequence with minor dolomitic siltstone near the top; G is a grey, silicified siltstone about 200 m thick, and H is well bedded dolomitic and pyritic siltstone with minimum thickness of about 275 m. Units G and H crop out only in the extreme south of the trough facies, in the core of a tight syncline. Unit F overlies unit E conformably, and extends along all of the trough facies; it also occurs in a subsidiary trough near the headwaters of Bower Bird Creek.

Lithology

Cream-buff and red-brown lamination is diagnostic of unit F. In areas of lesser iron oxidation, the shales are grey-green, and locally contain some fine sandstone and coarse siltstone beds which show some graded bedding and micro-cross-bedding.

The red and cream lamination is a secondary effect related to the oxidation of iron in the shales; in some areas the colour banding is directly related to cross-cutting joints; water percolating along fractures has oxidized iron in the adjacent shales, and has also oxidized certain silty, more permeable beds extending away from the fracture (Fig. 43). Unit F is reported to be a black carbonaceous shale at depth.

Dolomite and dolomitic siltstone near the top of unit F are grey and thin-bedded.

Some zones in unit F display some of the Bouma cycles typical of flysch sedimentation. Bouma (1962) lists these divisions as follows, from the top:

e. pelitic division
d. upper division of parallel lamination
c. division of current-ripple lamination
b. lower division of parallel lamination
a. graded division

In unit F, division b is absent, and the sequence from the base is c - a - c - d (Fig. 44), totalling about 7 cm.

Petrography

Samples of unit F examined are 36, 6055, and 6060; all are laminated siltstone with varying amounts or iron oxide. Sample GSQ 5924 from unit G is a calcareous sandstone containing 40 percent calcite, 60 percent quartz, and pyrite and hematite as accessory minerals. Sample GSQ 5925 is a hematitic shale from unit H.

Discussion and correlations

Bouma zones as noted above are suggestive of flysch sedimentation (Walker, 1970); the overall fine grainsize and persistent lamination in unit F indicates that it is a product of distal rather than proximal turbidite-like sedimentation. Fine detritus is thought to have been transported laterally into the stabilizing trough areas from marginal, mature source regions, and distributed by weak longitudinal currents acting along the trough. At no stage are extensive, unidirectional turbidite flows envisaged as acting either into or along the Surprise Creek trough zone.

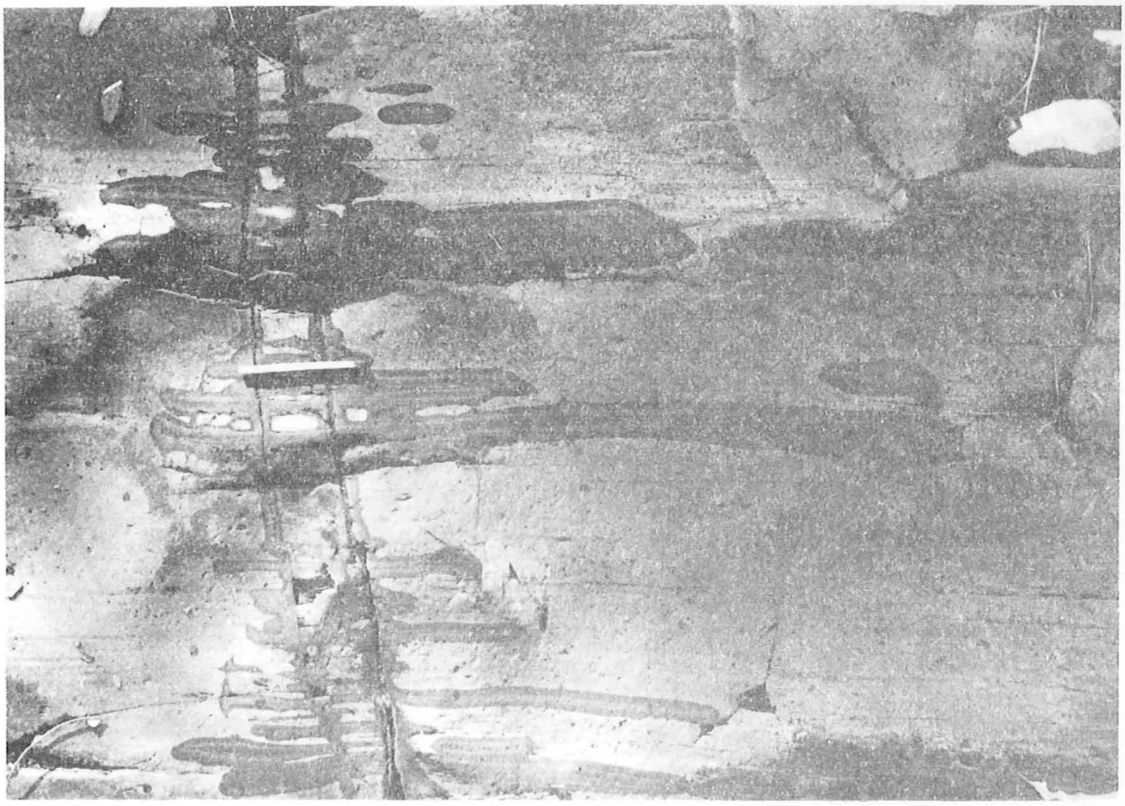


Fig. 43.
Preferential iron oxide along joints and bedding planes in shale and siltstone of unit F, Surprise Creek Beds. M1508/12 GMD.

Fig. 46.
Poorly sorted boulder conglomerate at the base of the Warrina Park Quartzite, Paroo Range area. M1507/2 IHW.

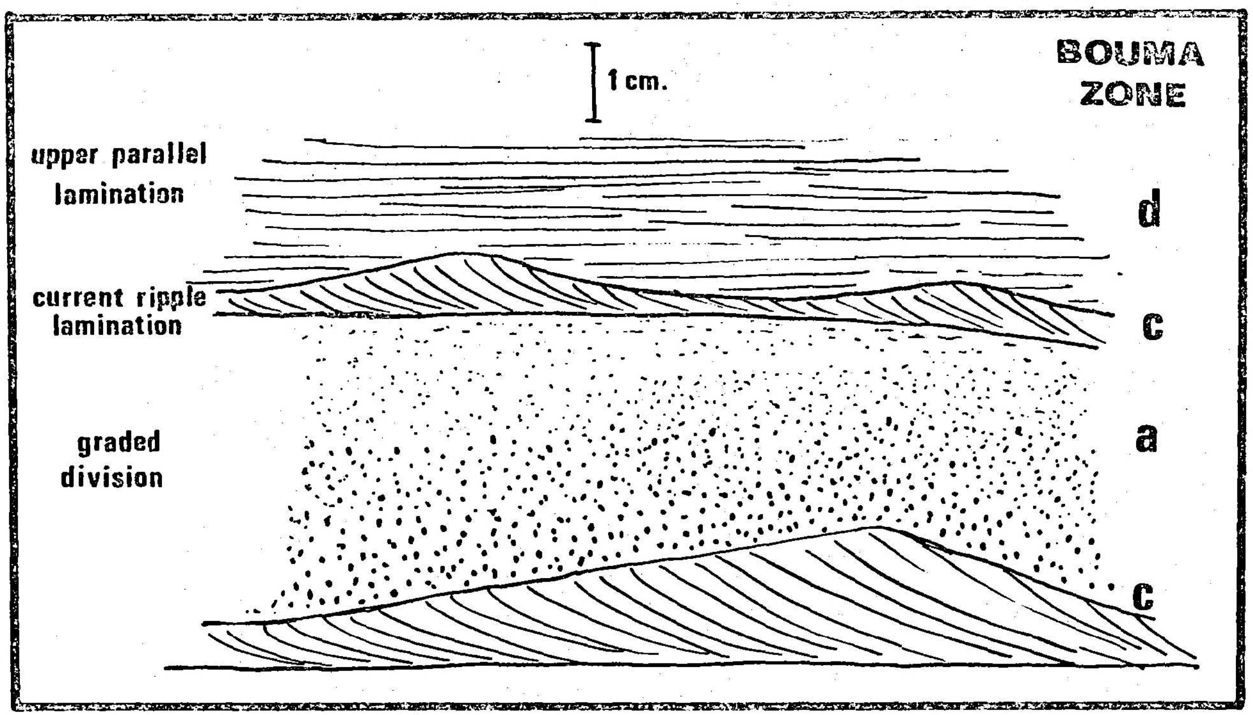
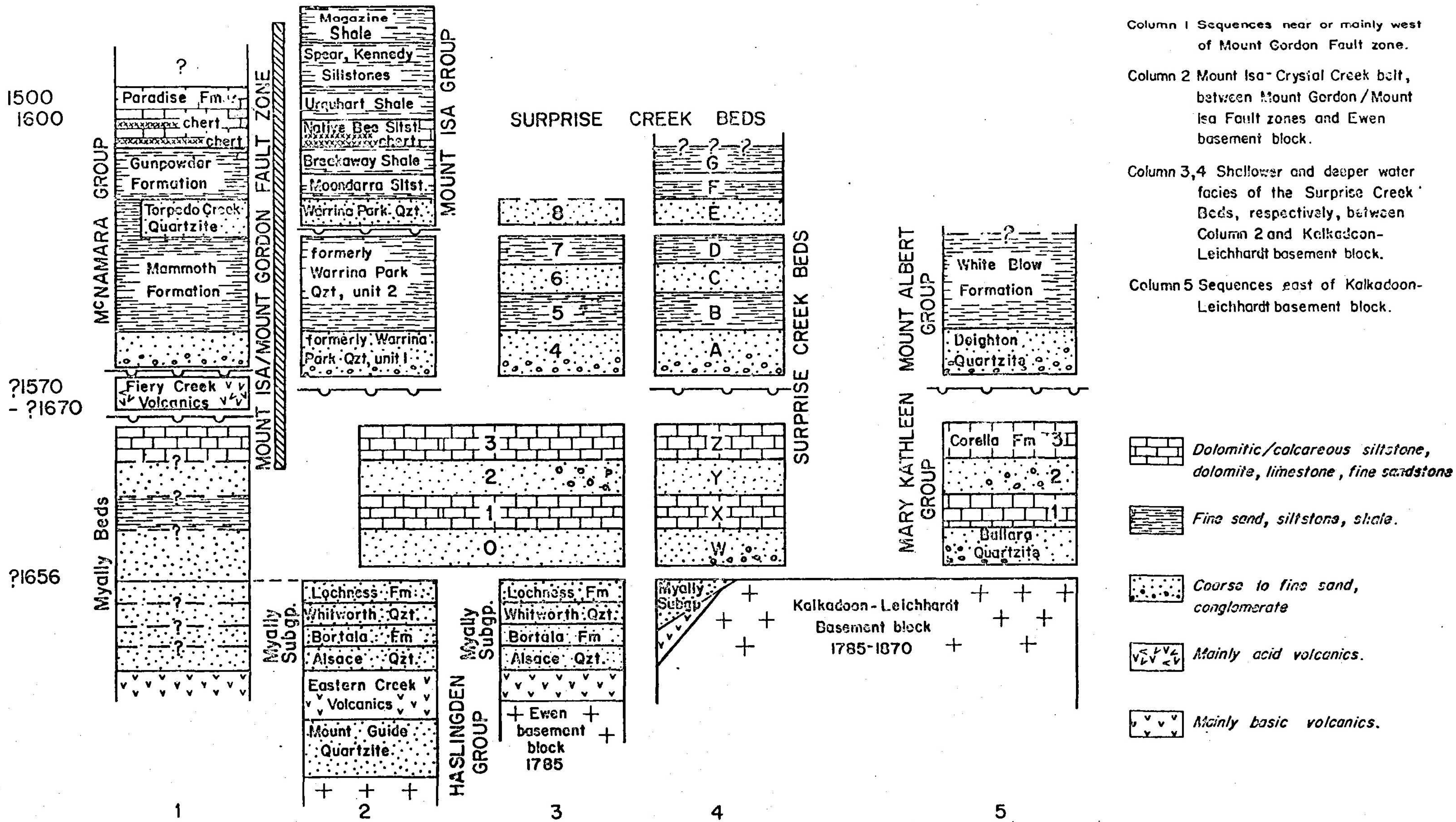


Figure 44. **Possible Bouma divisions in sample 6060, unit F, Surprise Creek Beds (=Moondarra Siltstone).**



Record 1977/4

Q/A/646/A

Figure 45. Detailed stratigraphy and correlations north and northeast of Mount Isa

'MAMMOTH FORMATION' EQUIVALENTS

Thin lenticular units of sandstone, siltstone and dolomite resting between the older Haslingden and younger Mount Isa Group are equivalent to the 'Mammoth Formation' of Cavaney (pers. comm., 1975). Two divisions are recognized: a lower unit, up to 160 m thick, of buff to brown ferruginous, friable, and locally gossanous flaggy feldspathic sandstone and quartzite; and an upper unit 45 to 400 m thick of red-green to grey laminated siltstone with interbeds of fine-grained feldspathic sandstone, and laminated dolomitic or calcareous fine-grained sandstone and siltstone. These units were previously mapped as part of the Warrina Park Quartzite (Derrick, 1974), and are shown as Ꝑiw$_1$ and Ꝑiw$_2$ on the Prospector Preliminary Edition map, and Ꝑra and Ꝑrd on the First Edition map.

Distribution and stratigraphic relations

The 'Mammoth Formation' equivalents are best exposed in the Paroo Range in the southwest part of the Sheet area, and in a narrow northeast-trending belt east of the Leander Range 18 km north of the Paroo Range. In the Paroo Range only the upper dolomitic siltstone unit is present, and it rests unconformably on the Whitworth Quartzite of the Myally Subgroup; in the Leander Range area both upper and lower units are present, and the lower unit rests with marked unconformity on the Whitworth Quartzite. In both areas the Warrina Park Quartzite overlies the 'Mammoth Formation' equivalents unconformably.

Sedimentary structures

The lower unit is extensively cross-bedded, and has symmetrical ripple marks, which are more prevalent at the base than at the top. The upper unit is laminated and micro-cross-bedded, and certain zones are extensively convoluted. Ripple marks indicate current directions from either the east or west;

cross-bedding indicates some currents came from the northeast sector.

Petrography

Four thin sections from the lower unit were examined, and estimated modal compositions of these rocks are presented in Table 16. Sample 6004 is a fine to medium (0.4 to 0.1 mm) ferruginous feldspathic psammite, characterized by an abundance of apatite, possibly diagenetic, and the presence of some rutilated quartz grains similar to those in the basal unit of the Surprise Creek Beds shelf facies. Rounded zircon and tourmaline are the other main heavy minerals. The grains are close-packed, and cemented by silica, iron oxides, and minor clay. Samples 6006 and 6011 are better-sorted and more mature than 6004; most grains are quartz, from 0.2 to 0.6 mm diameter, and appear to have been well rounded and highly spherical before cementation by silica overgrowths. Some grains are rutilated. Rock fragments are polycrystalline quartz and chert.

Siltstone from the upper unit is composed of a microcrystalline aggregate of quartz, feldspar, clay particles and muscovite. Some coarser grains of quartz and feldspar up to 0.1 mm, and subangular tourmaline grains, are also present.

Discussion and correlations

Source areas for the 'Mammoth Formation' equivalents were probably the ferruginous and feldspathic sand terrain of the Myally Subgroup to the east of the Leander and Paroo Ranges. Rutilated quartz grains and some volcanic and chert fragments also suggest minor contribution from an acid volcanic/plutonic source, possibly the Ewen block to the north, or the Sybella Granite to the south. The poor to moderate sorting and mineralogical immaturity of much of the lower unit may indicate fluvial or deltaic conditions; symmetrical ripple marks indicate periods of low current activity, possibly in a lacustrine or

184

TABLE 16. ESTIMATED MODAL COMPOSITIONS MOUNT ISA GROUP AND 'MAMMOTH FORMATION' EQUIVALENTS

Rock No.	Fragments and Matrix	q	K	mu	bi	ca	op	ap	to	zr	li	Name
												Mammoth Formation equivalent, lower unit
6004		48	30		7		13	2	tr	tr		Labile sandstone
6006	1L 2M	94	2				1					Quartz sandstone
6011	2L	97					1					" "
R5542	25L	8	3		1	59	4		tr			Limestone
												Mammoth Formation equivalent, upper unit
R5541	45M	50									5	Limonitic sandstone
6010	99M						1					Feldspathic siltstone
R5540		20	1	1		76	1					Sandy limestone
												Warrina Park Quartzite, Piw
6000	12L	86	1				2		tr	tr		Sublabile arenite
6007	1L	98					1					Orthoquartzite
R5890		98					2					"
R5891		99					1					"
												Native Bee Siltstone
R5884		45		35			20					Slate

Abbreviations: Ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

*Roooo are GSQ rock numbers.

restricted shelf environment. The siltstone and carbonate rocks of the upper unit probably represent an offshore prodelta or distal shelf facies; the convoluted siltstones may have formed in the deeper part of the shelf or delta, and the dolomitic silts in shallower parts. Derrick et al. (1976c) suggest that the 'Mammoth Formation' equivalents were deposited in depressions in the older Haslingden Group erosion surface during a phase of transgression after major crustal disturbance. As the depressions were filled, the Warrina Park Quartzite formed as a mature sand blanket which overlapped both the Haslingden Group and 'Mammoth Formation' equivalents.

The 'Mammoth Formation' equivalents are correlated with the 'Mammoth Formation' west of the Mount Gordon fault zone, and with units 4 to 7, and A to D, in the Surprise Creek Beds.

MOUNT ISA GROUP

Introduction

The term 'Mount Isa Series' was first applied by Saint-Smith (1924) to rocks east of the Cambrian strata in the Beetle Creek area. He did not define the rock type or the area to which the term applied. The quartzite and shale sequence mainly to the east of Mount Isa was referred to as Mount Isa Series by Shepherd (1932) and as Mount Isa Shales by David (1932). In AGGSNA (1936) the term Mount Isa Shale referred to sedimentary and volcanic rocks to the north of Mount Isa, but was considered equivalent to the Mount Isa Series of Shepherd. The Mount Isa Shale was later extended to include quartzitic and calcareous sediments farther east, near Cloncurry (AGGSNA, 1937). Blanchard & Hall (1937) referred to the 'Mount Isa Shale series' as a 'thin evenly bedded shale between quartzites'. The name Mount Isa Shale Group was reserved for the shale west of the Leichhardt Fault by Knight (1953). Carter et al. (1961) formally defined the Mount Isa Shale following the usage of Shepherd (1932) and Blanchard & Hall (1937).

Subdivision of the Mount Isa Shale was proposed by Murray (1961), Battey (1961) , and Cordwell, Wilson, & Lord (1963). Bennett (1965) redefined the unit as a group containing seven formations overlying the 'Quartzite Marker' at the top of the Myally Beds. Later work has shown that the 'Quartzite Marker' is unconformable on the Myally Subgroup (Smith, 1969; Derrick et al., in press), so it has been placed at the base of the Mount Isa Group. It was formally named the Warrina Park Quartzite by Derrick et al., (1976c).

The Mount Isa Group covers 46 km^2 in the Sheet area. It crops out as small fault-bounded blocks in the southwest corner of the Sheet area, as a broad curvilinear belt forming the northern part of the Paroo Range, and as a narrow (1-2 km) north-northeast-trending belt adjacent north of Paroo Creek to the Leander Range. The basal Warrina Park Quartzite is always preserved as an upstanding ridge, usually with a well developed dip slope. The overlying Moondarra Siltstone and Native Bee Siltstone form broad valleys separated by low ridges of the Breakaway Shale. The Group extends south into the Mary Kathleen Sheet area and west into the Kennedy Gap Sheet area.

Stratigraphic relations

The Mount Isa Group unconformably overlies the Haslingden Group (Derrick et al., in press), and 'Mammoth Formation' equivalents. The formations within the group have conformable, gradational boundaries.

Lithology

The group consists of a basal conglomerate and quartzite sequence overlain by shale, siltstone, and minor quartzite.

Only the lower half of the group - i.e., the Warrina Park Quartzite, Moondarra Siltstone, Breakaway Shale, and Native

187

Bee Siltstone - are exposed in the Sheet area; they are described below.

Warrina Park Quartzite

This formation is well exposed at Paroo Range where it forms a well developed dip slope underlying the Moondarra Siltstone. Thickness of the formation in the Sheet area ranges from 35 to 300 m, and it appears to thicken from north to south. It is labelled Ꝑiw_3 on the Prospector Preliminary Map; as noted earlier, units Ꝑiw_2 and Ꝑiw_1 are now classified as 'Mammoth Formation' equivalents.

Lithology

The Warrina Park Quartzite consists predominantly of a white to buff glassy orthoquartzite, and massive, poorly sorted conglomerate at the base of the unit (Figure 46). Some thin poorly sorted conglomeratic lenses occur throughout the upper part of the member. The quartzite is well sorted, and medium to fine-grained. Cross-bedding, extensive ripple marks (mainly symmetrical), and possible raindrop impressions have been noted.

Petrography

Modal compositions of four specimens of Warrina Park Quartzite are presented in Table 16. Three specimens are supermature orthoquartzites, in which quartz occurs as well rounded strained fine to medium grains with sutured boundaries. The fabric is close-packed with a low porosity. Heavy minerals are rare. One specimen (6000) is composed predominantly of fine to medium quartz (86%) and rock fragments (12%). The rock fragments are predominantly polycrystalline quartz or fine-grained volcanic rock.

Moondarra Siltstone

The Moondarra Siltstone is a sequence of deeply weathered shale and siltstone, about 500 m thick, which forms broad undulating valleys. The thickest sequence is north of the Paroo Range, and another thin belt stretches for 13 km north-northeast from a point 2 km north of the Paroo Creek flow-gauge station (455 498). Deeply weathered outcrops of the siltstone crop out southwest of the Paroo Range. The siltstone is conformable on the Warrina Park Quartzite.

Lithology

The main rock types are variably cleaved brown to orange thin-bedded to laminated siltstone, white dolomitic siltstone, and green to grey laminated shale. Several outcrops of cream and purple, and cream and orange-brown ribbon shale have been noted. Highly ferruginous beds form ridges. Laminations, banding, and minor slump structures are the main sedimentary features.

Breakaway Shale

The Breakaway Shale is a sequence of shale and minor siltstone which forms low hills and ridges, in contrast to the generally poor outcrop of the Moondarra and Native Bee Siltstones. It is exposed in two areas: an east-west-trending curvilinear belt northwest of the Paroo Range, and a folded belt east of the Leander Range. It is conformable on the Moondarra Siltstone and the contact is gradational. The maximum thickness exposed in the Sheet area is about 200 m.

Lithology

The predominant lithology is a pale grey-green laminated shale. In weathered zones the colour tends to a pinkish hue. In places, white and purple banded finely bedded shale and fissile slate become predominant. Locally, gossanous outcrops are formed on closely jointed shale with well developed pyrite casts.

Native Bee Siltstone

The Native Bee Siltstone is exposed in two small areas; 5 km northwest of Paroo Range, and 20 km farther north to the east of Leander Range. The outcrop is mainly very poor and deeply weathered, but slightly more resistant beds are preserved as low ridges. The siltstone is conformable on the Breakaway Shale. No younger formations of the Mount Isa Group are exposed in the Sheet area.

Lithology

The formation consists of dark brown fissile strongly ferruginized, dolomitic siltstone, dark grey to black finely laminated fissile slate, several occurrences of thin highly siliceous rock, possible chert, and fine-grained sandstone.

Petrography

One thin section of Native Bee Siltstone was examined, and a modal analysis of it is presented in Table 16. It is a very fine grained dark grey well sorted fissile slate with a well developed mineral elongation; it consists of quartz, sericite, and opaque minerals which are too fine to determine.

Discussion and conclusions

The Mount Isa Group sediments display features that suggest deposition within a broad, relatively shallow lacustrine or intracratonic sea environment. The absence of evaporitic deposits indicates that circulation was not restricted, and the depositional environment was possibly lacustrine, but with lateral connection to a larger sea.

The Warrina Park Quartzite is a blanket sand typical of deposition on a shallow shelf subjected to constant agitation, and possibly periodic exposure (Derrick, 1974). The conglomerate at the base of the Warrina Park Quartzite is probably a high-energy beach deposit.

The siltstone and shale formations may be distal equivalents of the near-shore facies that were deposited in slowly subsiding basin areas adjacent to the shelf areas.

The Mount Isa Group in the Sheet area correlates with the Gunpowder Creek Formation, and units E, F, and G of the Surprise Creek Beds (Derrick, 1974; Derrick et al., 1976c).

LOWER PROTEROZOIC? TO CARPENTARIAN? INTRUSIVE ROCKS

ACID INTRUSIVE ROCKS

Kalkadoon Granite

Introduction

The Kalkadoon Granite was formally defined by Carter et al. (1961) and was further discussed by Joplin & Walker (1961) and Derrick et al. (in press). The granite crops out discontinuously as a series of irregular stock-like masses in a north-northeast-trending belt about 8 km wide. Topographically the Kalkadoon Granite forms tor-strewn hills in broad sandy valleys, but in places forms high bouldery plateaux bounded by faults.

It is intimately associated with the Leichhardt Metamorphics, and in the Prospector Sheet area these two units form most of the median ridge which separates the eastern and western successions.

Stratigraphic relations

The eastern part of the granite is faulted against and intrudes the Leichhardt Metamorphics. It is not seen to intrude any other units in the Sheet area, but is faulted against the Magna Lynn Metabasalt, Argylla Formation, Ballara Quartzite, and Corella Formation.

Along the western margin, the granite is in fault contact with, and unconformably overlain by, the Surprise Creek Beds. In places, the lowermost Surprise Creek Beds are composed of labile arkosic grits and thin conglomerate bands which contain some granitic clasts. The granite is intruded by numerous north-northeasterly and northwesterly trending metadolerite dykes.

The Kalkadoon Granite has been dated by rubidium-strontium methods; ages range from 1760 to 1670 m.y. (Richards, 1966) and from 1930 to 1780 m.y. (Farquharson & Wilson, 1971). Recent U-Pb-Zr studies indicate an age of 1870 m.y. (Page, 1976).

Lithology and field occurrence

Owing to the wide variety of 'granitic' rock types, it has not been possible to subdivide the Kalkadoon Granite at the current scale of mapping, except for a small mass (1.5 km^2) of muscovite granite (Pgk_2) which intrudes the Leichhardt Metamorphics 1.5 km south of Striped Mountain (800 610), and granodiorite masses near the southern Sheet area margin (Pgk_1). All other mapped outcrops of Kalkadoon Granite comprise granodiorite, granite, and late stage aplite and pegmatite dykes and veins.

Granodiorite;

Two types are present, a medium to coarse porphyritic granodiorite and a medium-grained massive granodiorite.

The porphyritic granodiorite is light to dark grey in colour with very coarse phenocrysts (up to 4 cm) of plagioclase and minor K-feldspar in a medium-grained groundmass composed predominantly of quartz, plagioclase, K-feldspar, and biotite. The massive granodiorite is grey to dark grey, medium-grained, and equigranular, and is composed of quartz, plagioclase, K-feldspar, and biotite, with minor actinolite and hornblende. The massive granodiorite postdates the porphyritic variety. Some massive leucocratic granodiorite is present 2 km northeast of Queen Elizabeth mine.

Generally, the granodiorite is marginal to the granite bodies and in some places exhibits a faint foliation. Small xenoliths of the Leichhardt Metamorphics and fine-grained basic material are common. The formation of local hybrid phases ranging in composition from quartz to monzodiorite is probably due to the assimilation of this material.

Granite:

The granite can be subdivided into a porphyritic and massive phases. Porphyritic varieties of granite contain pink to light grey phenocrysts in a dark grey groundmass. They contain coarse phenocrysts of K-feldspar (up to 4 cm) and quartz and plagioclase (up to 1 cm). The groundmass is medium-grained and composed of quartz, K-feldspar, biotite and minor plagioclase. One variety is a grey medium to coarse porphyritic sodic granite which has a high proportion of albite. The massive granites range in colour from pink to buff to various shades of grey. They are predominantly medium-grained and less commonly fine-grained. Quartz-biotite-microcline-plagioclase is the predominant assemblage. In some areas, xenoliths of medium-grained granite in the coarse-grained porphyritic granite, suggest that the former was emplaced first.

193

Muscovite granite:

A small stock of granite intrudes the Leichhardt Metamorphics 3 km west-northwest of Fishers Standby mine. It is medium to coarse, massive, abundantly quartz-veined, and characterized by the presence of muscovite. The massive habit, leucocratic nature, and presence of muscovite are typical of some late-stage varieties within the main mass of Kalkadoon Granite, and resemble those noted in the Mary Kathleen Sheet area, to the south.

Late-stage aplite phases of the Kalkadoon Granite are predominantly pink to buff and fine-grained. Other late-stages rocks include thin, pink to brown pegmatites, white to pink quartz-K-feldspar veins, and in places veins and pods of light brown graphic granite, all of which intrude Leichhardt Metamorphics (Figure 47).

Petrography

Thirty-one specimens have been petrographically described; their estimated modal compositions are presented in Table 17.

Porphyritic granodiorite is fine-grained, holocrystalline, porphyritic, and has a hypidiomorphic-granular texture. Plagioclase phenocrysts are large (2-10 mm) and subhedral, and are altered to fine-grained sericite and epidote. They are commonly rimmed by fine granular quartz. Microcline phenocrysts form slightly smaller (1-4 mm) subhedral grains which display strong 'tartan' twinning and commonly enclose small inclusions of quartz and biotite poikilitically. The groundmass (40%) is predominantly a fine-grained assemblage of quartz, biotite, and minor sericite, epidote, chlorite, apatite, and sphene. Quartz is fine-grained, anhedral and exhibits undulose extinction; it has sutured intergrain boundaries and is slightly elongated. Biotite (0.1-0.6 mm) is present as blady to subequant laths with yellow to brown-green pleochroism, and chlorite (0.1-0.2 mm) forms green pleochroic ragged equant grains. Accessory minerals include prismatic and subhedral to euhedral sphene commonly rimmed by biotite.

Massive granodiorite is homogeneous, fine to medium, equigranular, holocrystalline, and has a hypidiomorphic-granular texture. The predominant assemblage is quartz-plagioclase-biotite with minor amounts of epidote, zoisite, chlorite, muscovite, and perthite. Quartz is present as anhedral grains with sutured boundaries, undulose extinction and fine granular quartz rims. Some quartz grains exhibit rounded to rhomboid outlines and may be xenocrysts derived by assimilation of the Leichhardt Metamorphics. Biotite (0.05-0.8 mm) occurs as blady to subequant grains which exhibit straw yellow to dark brown pleochroism. Plagioclase forms twinned and zoned subhedral grains which are altered to sericite and epidote in the cores. Epidote is present also as discrete subhedral grains. Chlorite forms small ragged grains of chlorite which are intimately associated with biotite. Minor amounts of muscovite are present in most sections. Perthitic K-feldspar is present in some specimens and subhedral poikilitic blue-green hornblende was recorded in one thin section. Xenoliths of recrystallized metarhyolite fragments form up to 20 percent of some rocks.

Two basic variants of the granodiorite are a quartz monzodiorite (GSQ 5950) and a quartz diorite (GSQ 5956). The quartz monzodiorite is composed predominantly of plagioclase with minor amounts of quartz, sphene, epidote, and sericite. Sphene forms subhedral to euhedral brown pleochroic prisms. The quartz diorite is composed predominantly of subhedral grains of plagioclase, and blue-green hornblende. The hornblende, which is poikilitic and zoned, contains numerous pleochroic haloes surrounding small allanite grains.

Porphyritic granite is medium to coarse, with coarse unaltered phenocrysts of microcline up to 3 cm in length. The

195

TABLE 17. ESTIMATED MODAL COMPOSITIONS, KALKADOON GRANITE

Rock No.	Q	K	P	q	k	p	bi	mu	ep	ch	hb	sp	Accessories	a.g.d. (mm)	Name
R5914				35	55	3	5	2						0.4	Biotite granite
R5920				30	45	10	1	9	1			1	3op	0.1	Muscovite granite
R5923				60	20	10	5	2	1	tr		1	an	1.2	Biotite granite
R5940				39	45	15		1		tr				1.0	Granite
R5949				35	64		1	tr	tr					3.0	Alkali feldspar granite
R5951				15	48	32		3		1		1		1.0	Granite
R5962				30	39	25	2	4						2.0	Granite
R5963				30	44	20		4		2				1.2	Leucogranite
73200143				30	50	10	2		8						Granite
73200144				40	45	5	5		5						Granite
73200147				35	55		6		2			2			Granite
R5913	35			25	7	10	15	1	2				ap		Porphyritic biotite granite
R5938	20			35	3	30	10		2			tr	al		Porphyritic granite
R5939	10	5	20	15	5	23	15		4	3					Sodic granite
R5957	8	12	10	25	30	11	5					1	op		Porphyritic microgranite
R5581		20	30	25	11	10	1	1	1	1		tr	ap		Monzogranite
R5576	3	5	13	20	40		18								Biotite granite
73205069	2	3	5	30	49	5	5			1					Xenolitic microgranite
R5921		25	40	20			10	5				tr	ap		Porphyritic granodiorite
R5931		25	35	16			10	5	3			1	5ca		Porphyritic granodiorite
R5944				25	2	30	8	11			5	1		1.3	Granodiorite
R5945				25		30	35		8				2ca	0.4	Biotite granodiorite
R5948				15		19	35		3		25	3		1.0	Granodiorite
R5950				6		79		8	3			4		1.0	Quartz monzodiorite

TABLE 17. Page 2

Rock No.	Q	K	P	q	k	p	bi	mu	ep	ch	hb	sp	Accessories	a.g.d. (mm)	Name
R5956				5		50		15	5		20	2	1op, 2ca	1.5	Quartz diorite
R5964				37	5	35	10	2						2.0	Granodiorite
R5947				35		55	5	1	1	3				0.5	Leucogranite
R5919				37	45	10	5	2	1					0.25	Aplite
R5922				30	25	35		5		1		tr	1op	0.3	Muscovite aplite
R5580				25	50	15	5			1	2	2	ap		Hybrid granite
73200148						50			4		40	6			Diorite

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord - cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, K - k feldspar, L - lithic fragments, M - matrix, mu - muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

* Roooo are GSQ rock numbers.

groundmass is composed of anhedral strained quartz, and anhedral microcline which shows 'tartan' and Carlsbad twinning and in specimens is associated with myrmekite. Plagioclase is subhedral and sericitized albite to sodic oligoclase. The major mafic mineral is biotite (up to 18%), which occurs as small blady to subequant laths. Minor amounts of apatite, chlorite, sphene, and epidote are present.

Massive granite is fine to medium, relatively equigranular, holocrystalline, and hypidiomorphic-granular. Quartz occurs as small anhedral grains which contain minor inclusions of apatite and tourmaline, and also forms a graphic intergrowth with K-feldspar in one specimen (GSQ 5962). Anhedral, partly resorbed microcline grains exhibit well developed 'tartan' twinning. Plagioclase is present as saussuritized subhedral grains which show relict zoning and twinning, and range in composition from albite to andesine. In most specimens biotite (up to 5 percent) is the major mafic mineral. Minor amounts of muscovite, epidote, zoisite, chlorite, sphene, and opaques are ubiquitous. One sample (GSQ 5923) has trace amounts of andalusite.

Aplites are fine to medium, equigranular, holocrystalline, and hypidiomorphic-granular, and contain a quartz-microcline-sodic plagioclase assemblage. Muscovite, chlorite, zoisite, epidote, and sphene are present in minor amounts.

One specimen (GSQ 5947) was found to be a medium-grained leucogranite composed of quartz, albite, biotite, chlorite, muscovite and zoisite.

Hybrid phases are predominantly medium to coarse and dioritic, and contain the assemblage hornblende-epidote-sphene-plagioclase-opaques. The hornblende is pleochroic (light brown to green) and occurs as ragged irregular grains; together with plagioclase it constitutes the bulk of the rock. Plagioclase (An_{27}) is saussuritized and displays relict zoning. Sphene is abundant (5%) and present as fractured dark brown sphenoids.

Discussion and conclusions

Field and petrographic evidence show that the Kalkadoon Granite is a discordant, composite batholith. In places it has a linear structure but no strong planar foliation. The massive habit and abundant late stage dykes suggest emplacement of the Kalkadoon Granite in the epizone or mesozone, according to the classification of Buddington (1959).

Joplin & Walker (1961) and Carter et al. (1961) suggest that the Kalkadoon Granite is comagmatic with the Leichhardt Metamorphics volcanic pile. Insufficient chemical data is available at the time of writing to test this theory, but it is supported by recent age determinations and further fieldwork in the Duchess Sheet area to the south.

Wonga Granite

Introduction

The Wonga Granite was named by Shepherd (1946a), and subsequently formally defined by Carter et al. (1961). Joplin (1955) noted that a 'large mass of porphyritic granite' 24 km west of Quamby was apparently 'synchronous' (syntectonic). This body invaded calc-silicate country rocks, and its apparent deep-seated aspect was held to be a function of position in the geosyncline and the nature of the country rock.'

Other authors (Carter & Brooks, 1960; Joplin & Walker, 1961; Carter et al., 1961) have emphasized the preservation in the granite of relict country rock structures suggesting an origin in potassium metasomatism. They noted that the granite 'invades' both the Corella and Argylla Formations. Working in the Sunset area, near Mary Kathleen, Hill (1968) concluded that the Wonga Granite was of magmatic derivation on the basis of structure. He considered that synplutonic regional metamorphism explained the absence of a contact aureole. Carter et al. (1961)

Fig. 47.
Metadacites of the Leichhardt Metamorphics intruded by aplite and pegmatite of the Kalkadoon Granite 5 km north-northeast of Mount Remarkable.
M1508/32 GMD.

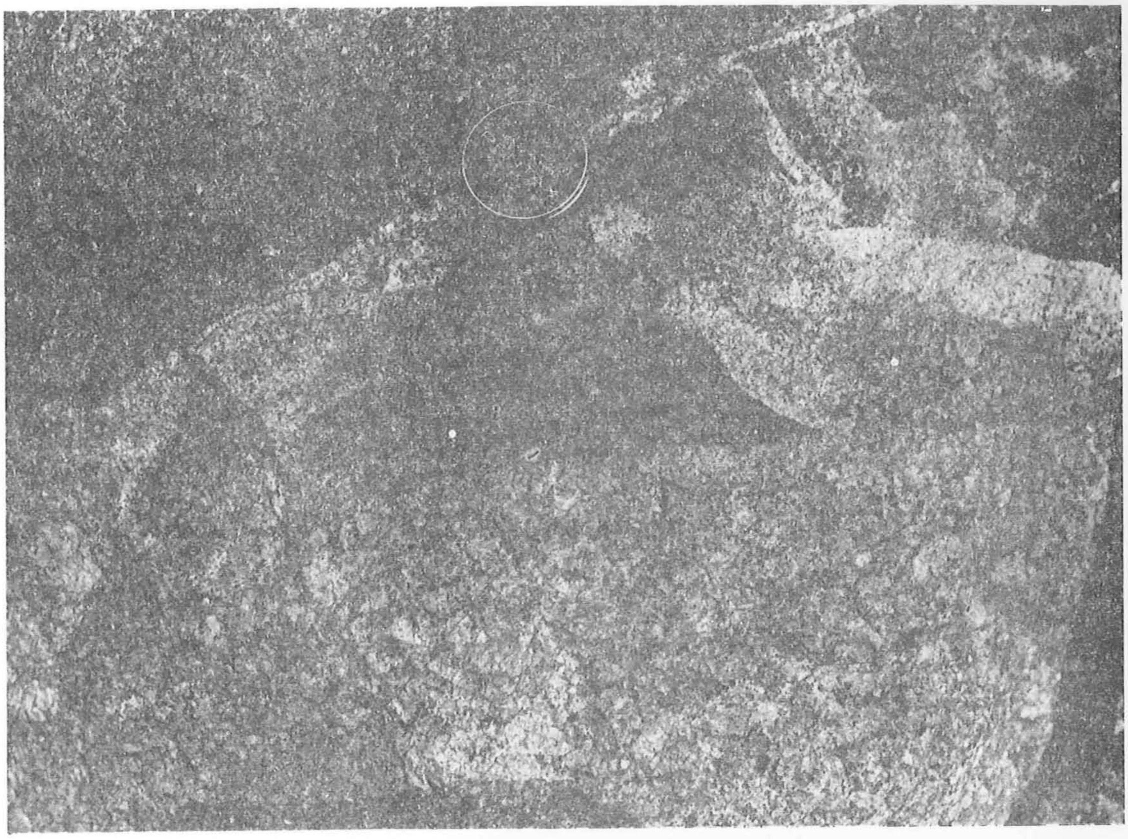


Fig. 48.
Texture of the porphyritic phase of the Wonga Granite from the southeast corner of the Sheet area.
M1507/12 IHW.

Fig. 49.
Aplitic phase of the Wonga Granite intruding highly metamorphosed laminated para-amphibolite of the Corella Formation 7 km east-southeast of Yamamilla mine. M1538/22A IHW.

200

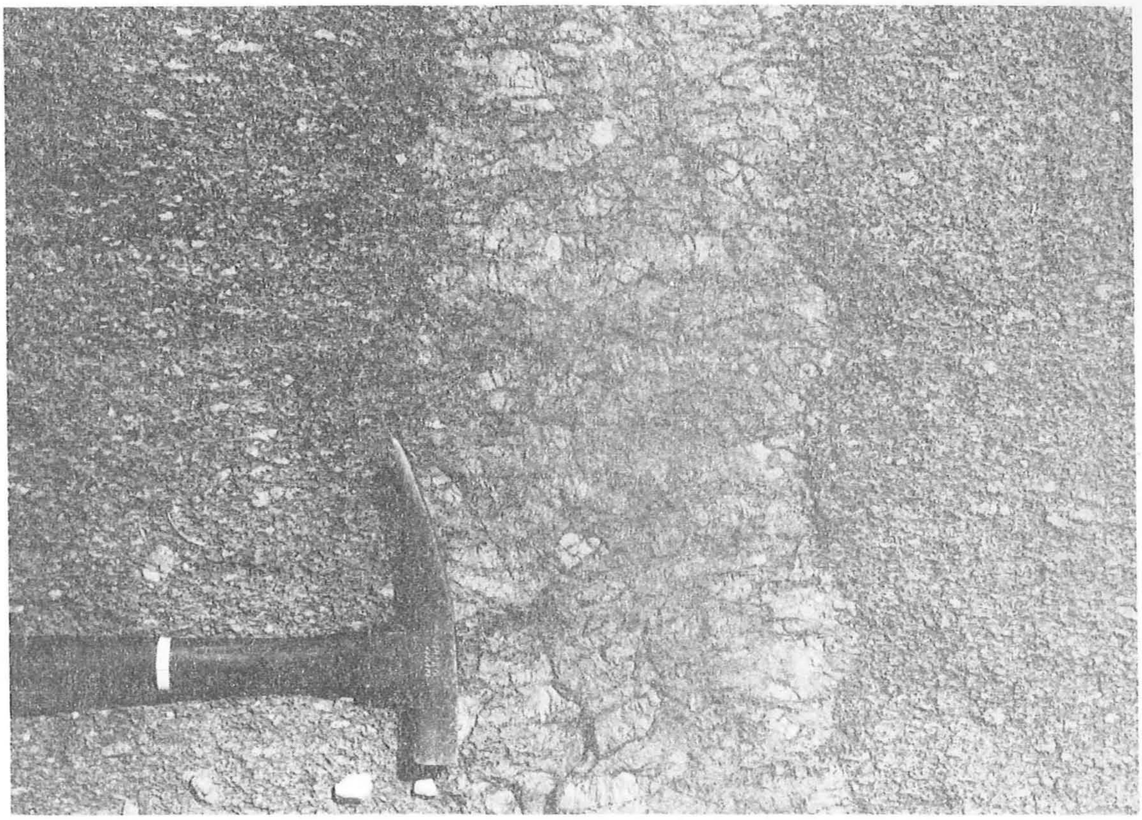


Fig. 50.
Pegmatite vein cross-cutting porphyritic Wonga Granite; alkali feldspar crystals in the pegmatite are aligned parallel to the regional foliation in the granite. M1549/14A GMD.

Fig. 51.
Foliated augen gneissic Wonga Granite with concordant segregations of granite leucosome 4.8 km east of Yamamilla mine. GA8887 TAN.

also noted that in some localities the Wonga Granite has a magmatic character.

Derrick et al. (1971) rejected a metasomatic origin for the granite in the Marraba Sheet area and invoked partial melting of older volcanics as a possible source of magma. Various features indicated that the granite was a medium to deep-level type (Derrick et al., in press).

The granite is exposed in several north-trending zones near the eastern border of the Sheet area. In the southern half of the area it is clearly discordant with, and most probably intrudes, acid volcanics of the Argylla Formation; further north, near Surprise mine, it is also intimately associated with para-amphibolites and calc-silicate rocks of the Corella Formation. In this area all rock types are regionally concordant, but it is thought that the Wonga Granite probably intrudes the Corella Formation. The area of exposure in the Sheet area is 65 km^2.

The granite typically forms low rounded bouldery hills and broad sandy valleys. Some large smooth exfoliated whaleback ridges up to 1 km long occur in the southeast and central east of the Sheet area.

Lithology

Three texturally distinct phases are recognized in the Sheet area. They are:

(i) coarsely porphyritic gneissose granite
(ii) medium to coarse-grained porphyritic granite
(iii) aplite and pegmatite
(iv) migmatite

The gneissose granite is characterized by large (3-5 cm) augen (Figure 51) of microcline aligned in the regional foliation, and separated and enclosed by schlieren of biotite.

It crops out poorly, mainly in the mid-eastern parts of the Sheet area.

The porphyritic granite is commonly foliated, and contains numerous phenocrysts of alkali feldspar 1 to 3 cm long (Figs. 48, 50). It forms bouldery hills and is the most widespread variety of the Wonga Granite in the Sheet area. It is not differentiated from the gneissose phase, but it is possibly younger. In the southeast, the porphyritic granite intrudes acid volcanics of the Argylla Formation, and becomes finer-grained and richer in mainly basic xenoliths towards its margins. To the northeast, near Surprise mine, foliated granite is apparently interlayered with metadolerite, and para-amphibolite of the Corella Formation, and intrudes similar rocks in a circular structure 6 km eastnortheast of Yamamilla mine. Local migmatization occurs in areas of highest metamorphic grade in the northeast and mid-eastern parts of the Sheet area at contacts between Corella Formation para-amphibolite and the foliated granite.

At the other contacts - for example, 4.5 km east-northeast of Flora Dora mine - skarn is developed in calc-silicate rocks of the Corella Formation.

Pegmatites consisting of quartz and alkali feldspar are common near the margins of the Wonga Granite. Meridional masses of tourmaline-bearing pegmatite near the eastern Sheet area margin intrudes the Corella and Argylla Formations and the porphyritic phase of the Wonga Granite. In some areas alkali feldspar crystals in cross-cutting veins of pegmatite are aligned parallel to the regional foliation (Figure 50).

Aplite dykes and veins cut country rock (Figure 49) and all other phases of the Wonga Granite. They vary in thickness from a few centimetres to several metres, and form an integral part of migmatite near Surprise mine.

203

Migmatites, or heterogeneous mixes of granite, aplite, and para-amphibolite, are restricted to the zone of most intense regional metamorphism in the Sheet area, near Surprise mine. The country rocks contain amphibolite facies assemblages, and some aplitic segregations - the leucosome - have developed locally (Fig. 51). Para-amphibolite of the Corella Formation is the palaeosome of the migmatites (Mehnert, 1968) which, in contrast to the aplitic leucosome, is well foliated (gneissic). The palaeosome is generally characterized by the assemblage quartz-biotite-plagioclase-sphene-epidote with minor scapolite, and the leucosome by quartz-microcline assemblages.

This leucosome has deformed plastically, in contrast to the more competent palaeosome, and is concordant with palaeosome in the layered and boudinaged zones. 'Pinch-and-swell' structures and ptygmatic folding in the aplitic leucosome reflect its non-brittle character.

The migmatite complex represents a local zone of relatively high-temperature deformation and metamorphism of an orthogneiss complex, in which metamorphism has segregated aplitic material. Similar small areas of migmatite have been recorded from Wonga Granite contact zones in the Mary Kathleen and Marraba Sheet areas, to the south, and at contacts between the Corella Formation and Naraku Granite in the Quamby Sheet area.

Petrography

Porphyritic, augen gneissose, and even-grained granites generally contain 80 to 90 percent quartz and microcline. The predominant assemblage is quartz-microcline-biotite-hornblende-plagioclase with accessory apatite, sphene, chlorite, and opaques. The texture is hypidiomorphic-granular and weakly foliated. Generally the coarser alkali feldspar is present as unaltered microcline augen or large relict grains of orthoclase. Estimated modal compositions are presented in Table 18. The modes are plotted on a QAP diagram (Fig. 52) and classified according to the scheme of Streckeisen (1967); the specimens examined fall in the alkali granite, granite and tonalite fields.

Pegmatitic and aplitic phases generally contain very coarse graphic-textured quartz and microcline grainsq subhedral to euhedral muscovite books, and euhedral tourmaline prisms. Foliation is poor or absent.

Fine-grained cream aplites consisting of quartz, microcline, biotite, plagioclase and epidote (Table 18) in places grade into pegmatite. The texture is predominantly allotriomorphic granular, and has a weak penetrative foliation.

Petrogenesis

The origin of the Wonga Granite is uncertain. Carter et al. (1961) described both in situ granitization effects and features more typical of magmatic origin. Derrick et al. (in press) considered it to be essentially an intrusive mass derived by partial melting of a mainly acid volcanic pile, and recognized that orthogneiss, migmatite, and endogenous acid veins occur locally within and at the margins of the granite.

Although much of the Wonga Granite is regionally concordant, most contacts are locally discordant, and there is little doubt that the bulk of the Wonga Granite has been intruded into place. It is also bordered by a high greenschist to amphibolite facies, low pressure regional metamorphic aureole, in which skarn deposits and andalusite, sillimanite, cordierite, and diopside-rich assemblages have formed in the pelitic and calcareous country rocks of the Ballara Quartzite and Corella Formation.

A strong regional foliation in the main outcrops of Wonga Granite has led some previous workers (e.g., Derrick et al., in press) to classify it as a catazonal to mesozonal pluton. While this may be true, the low-pressure metamorphic aureole, abundance of late-stage veins, and field association with the

TABLE 18. ESTIMATED MODAL COMPOSITIONS, WONGA GRANITE

Rock No.	q	k	p	mu	bi	ch	am	op	Accessories	a.g.d.	Name
R5984	38	50	5		7		tr				Porphyritic biotite granite Ꝑgw$_1$
R5987	55	22	20	2	1						Granite, Ꝑgw$_2$
R5991	10		40		20		5	5	ap, 25opx		Hybrid tonalite, Ꝑgw$_2$
R5993	15	20	25	1	10		20	1	3sp, ap		Hybrid granite, Ꝑgw$_2$
0166	41	57	1					tr	ap, ep		Alkali feldspar granite
0174	35		40		1		20	2	2sp		Tonalite
0178	43	48	3		3	tr	tr	tr	1sp, 1sp		Alkali feldspar, granite
0180	42	42	5		9		tr	tr	ap, sp		" " "
0181	39	51	1	2	3		2	1	ap, sp		" " "
0189	43	50	2		2		1	tr	ap		" " "
0193	40	40	5		10			2	ap, 2ep		Aplite
R5622	20	60	17	tr	3				zr, fl, al	0.3	Granite
R5630	20	66	7		5			tr	zr, al		Alkali feldspar, granite

Abbreviations: ac - actinolite, a.g.d. - average grain diameter, al - allanite, am - amphibole, amyg - amygdales, an - andalusite, ao - anthophyllite, ap - apatite, AV - acid volcanic clasts, B - porphyroblasts, bas - basalt, bi - biotite, ca - calcite, ch - chlorite, cord- cordierite, cpx - clinopyroxene, diop - diopside, ep - epidote, F - phenocrysts, fl - fluorite, gt - garnet, hb - hornblende, K - microcline phenocrysts, k - k feldspar, L - lithic fragments, M - matrix, mu muscovite, op - opaques, P - plagioclase phenocrysts, p - plagioclase, Q - quartz phenocrysts, q - quartz, ru - rutile, sc - scapolite, sh - shale, si - sillimanite, sp - sphene, t - tremolite, to - tourmaline, tr - trace, V - veins, X - basic xenoliths, zr - zircon.

*Roooo are GSQ rock numbers.

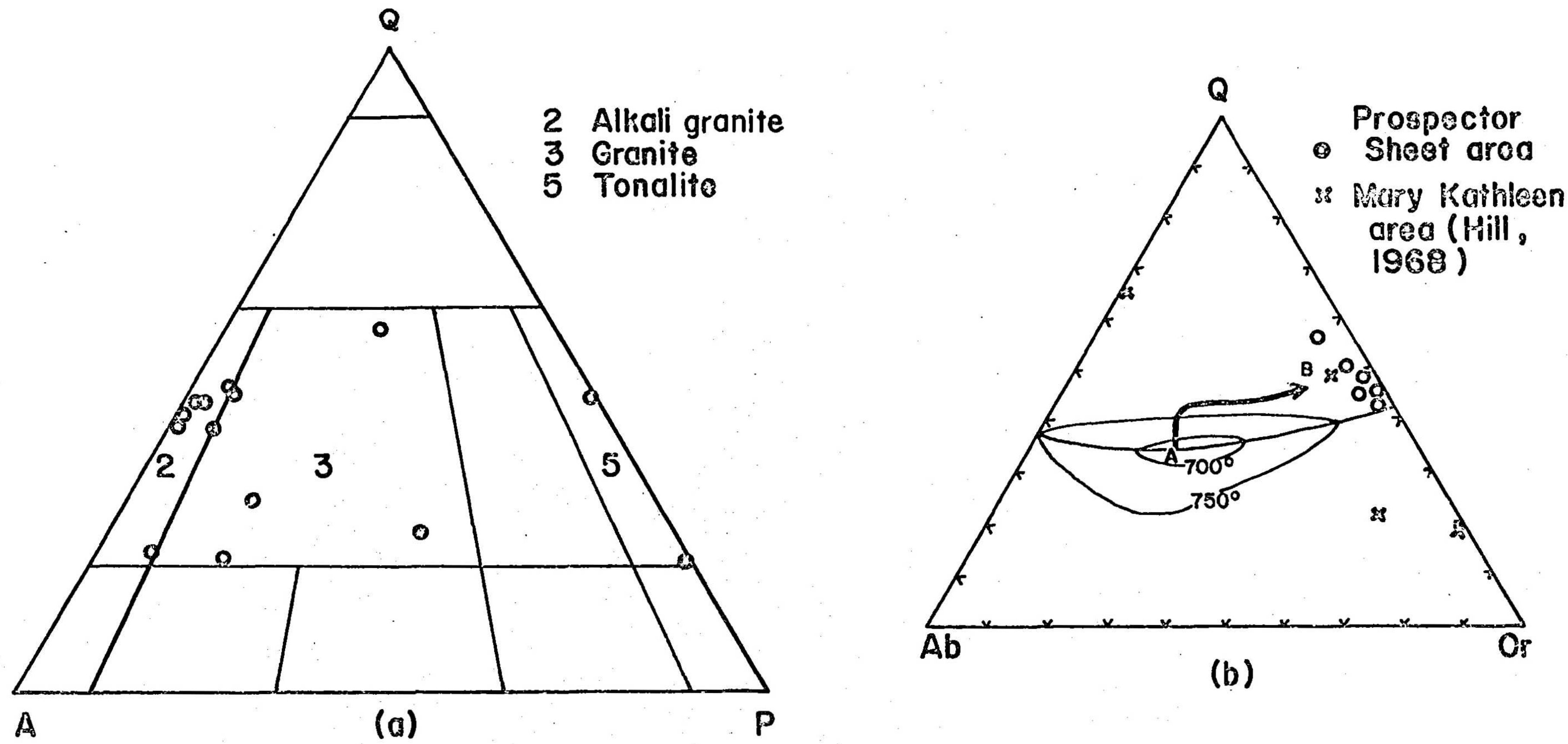


Fig. 52. a) Modal Q (quartz), A (alkali feldspar), P (plagioclase An_{5-100}) of Wonga Granite and the classification scheme of Streckeisen (1967).

b) Estimated weight percent of quartz, albite and orthoclase in Wonga Granite showing remoteness from the ternary thermal trough of Tuttle & Bowen (1958) and Shaw (1963) for An/Ab = 0 and P_{H_2O} = 2kb. Curve A–B represents the migration of the "point of minimum melt" with increasing An (at B An/Ab ≑ 0·6), (after Winkler, 1967, Figs 44 & 47).

F54/A2/188

208

youngest rocks in the section strongly suggest that a higher-level tectonic environment may be more appropriate. The fact that even late-stage veins are commonly sheared, that aplites fill fault planes (Carter et al., 1961), and that cross-cutting pegmatite veins show crystal growth parallel to the regional foliation (Fig. 50) - all suggest intrusion of the Wonga Granite during a major deformational episode. The linear nature of the Wonga Granite outcrop indicates that such intrusion may have been localized along long-acting lines of weakness, such as the Mary Kathleen-Pilgrim Fault lineament. The increasingly massive habit of smaller, satellitic bodies of Wonga Granite to the east and west of the main areas of outcrop may be due either to their intrusion during the waning stages of metamorphism and deformation, or to their intrusion at a greater distance from the main locus of deformation.

Granitization and migmatite formation occur locally within the Corella Formation near contacts with the Wonga Granite. Some migmatite may be of the injection-type, and/or a product of endogenous segregation of the granite-forming elements during metamorphism. In the Prospector and other Sheet areas to the south these processes are evident mainly in the high-level Corella Formation rather than in older rocks, and have probably been facilitated by a late-stage hydrothermal fluid phase, and a high water content of the sediments. It is also noteworthy that quartzofeldspathic or light-coloured sediments are more susceptible to granitization than interbedded para-amphibolitic and calc-silicate rocks.

We propose that the Wonga Granite formed by:

(1) generation at depth of a partial melt, derived from a pile containing old protocontinental rocks, and possibly anhydrous volcanics of the Leichhardt Metamorphics, and more hydrous and less metamorphosed sequences of the Magna Lynn Metabasalt and Argylla Formation. The rhyodacite and rhyolite in the pile are likely sources of the high potassium content of the Wonga Granite.

This melt moved upwards through the crust during a major deformational and metamorphic episode, and intruded as high as the Corella Formation.

(2) The Corella Formation was metamorphosed, and extensively veined by aplite and pegmatite near granite margins. In addition, local in situ granitization and metamorphic differentiation of a leucosome in metasediments resulted in the local formation of orthogneiss and migmatite complexes.

(3) Shearing and large-scale regional stress accompanied crystallization and cooling of the granite masses. Some satellitic intrusions of massive Wonga Granite may have intruded and crystallized later in the deformational episode.

Relations between structural events of the intrusion of the Wonga Granite are shown in Figure 59.

BASIC INTRUSIVE ROCKS

Dykes and sills of tholeiitic composition are widespread in the Proterozoic rocks of the Mount Isa region. They are present in both the eastern and western successions as well as the Kalkadoon-Leichhardt basement. The dykes have been grouped on the basis of their structural relations with the intruded rocks and their relations to the regional metamorphism. The relations between these groups and the stratigraphy is shown in Table 19. Estimated modal compositions for 29 dolerites are presented in Table 20.

Western succession dolerites

Two generations of dolerite dykes and sills are recognized within the western succession in the Prospector Sheet area. The relative timing of intrusion is shown in Table 19. The older generation intrudes both the Eastern Creek Volcanics and Myally Subgroup and is represented mostly by east-trending, folded

TABLE 19. TIMING OF DOLERITE INTRUSIONS IN THE PROSPECTOR SHEET AREA

Western succession	Kalkadoon-Leichhardt basement	Eastern succession
		Deighton Quartzite
DOLERITE	DOLERITE ?	DOLERITE Wonga Granite DOLERITE
Mount Isa Group		Corella Formation
Surprise Creek Beds		Ballara Quartzite
DOLERITE	DOLERITE (or older than Mount Guide Quartzite)	
Myally Subgroup		
Eastern Creek Volcanics		
Mount Guide Quartzite		
	DOLERITE	
		Wonga Granite ?
	Argylla Formation	(Argylla Formation)
	Magna Lynn Metabasalt DOLERITE ?	
	Kalkadoon Granite DOLERITE ?	
	Leichhardt Metamorphics	

TABLE 20. ESTIMATED MODAL COMPOSITIONS, DOLERITES

Rock No.	q	k	p	mu	act	hb	bi	ch	ca	op	cpx	ep	sc	Accessories	a.g.d.	Name
					Western sedimentary succession											
R5903			60	2		5		8	tr	10	15					Metadolerite in Phe
R5892			15		50			5				20			0.8	Metadolerite in Phe
R5564	tr		50	5	10			15		5		15			0.3	Metadolerite in Phm
R5545			30		32			10		3	5	20		zr	0.3	Dolerite in Phe
R5555			25		20			34	5	6		3		2sp	0.2	Metadolerite in Phe
R5550	2		8		16			40		4		30		ap	0.2	Metadolerite in Phe
R5538	1		83					2	10	4					1	Metadolerite in Phe
R5543			60					25		15					0.7	Altered dolerite in Phm
					Kalkadoon-Leichhardt basement											
R5583	2		2			15		77		4					0.2	Amphibolite in Pel
R5582	2		tr			15	tr	78		5				zr	0.2	Amphibolite in Pel
73205158			55	6			30	1	1	2		5		zr, al	0.1	Metadolerite? in Pel
73205136	tr		42		5		25	1	2	5		19		1sp, ap	0.3	Metadolerite in Pel
73205241	tr		40		30		15		2	6		7		ap	1	Metadolerite in Pem
73205248	5				55				2	3		35		sp, zr	0.2	Amphibolite in Pem
73205249			10		70					5		15			0.1	Amphibolite in Pem
73205250	6	2			20		54			4		14			0.05	Amphibolite in Pem
R5986	30		28			35					5			2sp	0.3	Foliated orthoamphibolite in Pea
R5985	30		34			35								1sp	0.1	Orthoamphibolite in Pea
R5624			30			65				tr				5sp, zr	0.4	Amphibolite in Pea
R5626			44			45				1		3	5	2sp	0.2	Scapolitic amphibolite in Pea
R5629	2		55			30	10			1				1sp, 1ap, zr	0.3	Basic gneiss in Pea
R5631	1						90	9						ru, zr, sp	2	Chlorite-biotite schist in Pea

and faulted sills, and north-trending dolerite dykes. Sills within the Myally Subgroup appear to be overlain unconformably by the basal unit of the Mount Isa Group - the Warrina Park Quartzite - near the western margin of the Prospector Sheet area.

These older dykes and sills have been metamorphosed to the greenschist facies, and display similar mineral assemblages to the adjacent Eastern Creek Volcanics. Thus the greenschist facies regional metamorphism which affected this western succession occurred after intrusion of these basic bodies; it occurred before the intrusion of the younger generation.

In thin section the older basic rocks consist of:

Plagioclase-tremolite/actinolite-chlorite-epidote-magnetite-sphene-(quartz)-(sericite)
and more rarely :-
Plagioclase-chlorite-epidote-quartz-sphene or
Clinopyroxene-plagioclase-tremolite/actinolite-chlorite-epidote-magnetite-sphene.

In all samples the original doleritic texture is preserved; the plagioclase is now albite-oligoclase and contains microblasts of epidote. Remnant pyroxene has been observed in only one thin section (73205349).

The second group of dolerite dykes within the western succession in the Prospector Sheet area intruded after the Surprise Creek Beds and Mount Isa Group were deposited, and therefore represents the youngest Proterozoic rocks in the western succession in this area. They crop out as long linear bodies which generally trend north-south. Many of them appear to have intruded along the axial planes of major fold structures, similar to dykes of the earlier phase, though others are oblique to folds and faults.

These younger dykes can be distinguished in the field from the earlier dykes by their rounded bouldery outcrop and their generally lighter colour due to less alteration. They vary in width from several metres to 1.5 km, with the larger dykes tending to have finer-grained chilled margins. Individual dykes can be traced for up to 20 km.

In thin section, original igneous textures and minerals are preserved. Primary minerals present are:

Plagioclase-clinopyroxene-orthopyroxene-magnetite/ilmenite-(quartz)-(hornblende)-(biotite)

with variable amounts of some of the following secondary minerals:

sphene, tremolite, epidote, chlorite, quartz, albite, and calcite.

The original igneous feldspar displays normal zoning, and ranges from labradorite (An_{64}) to andesine (An_{30}). Groundmass oligoclase is intergrown with quartz.

Basement dolerites

At least two generations of dolerite dykes can be recognized within the Kalkadoon-Leichhardt basement in the Prospector Sheet area, although four or five ages of dolerite intrusion can be inferred. The older and most abundant dykes have been intruded along regional conjugate joint patterns which trend northwest and northeast. These may include dolerites which antedate and postdate the Kalkadoon Granite, and feeder dykes for the Eastern Creek Volcanics.

Unlike the dykes within the western succession, which often have a positive relief, those within the basement are much less resistant to erosion owing to their greater schistosity. In outcrop they are dark green to black rocks, with chlorite and biotite schist present in shear zones.

253

The younger generation of basement dykes is rare, and typically occurs as narrow, east-trending bodies which cut the earlier dykes. Post-metamorphic dolerite dykes are probably present in the basement complex, as in the Mary Kathleen Sheet area to the south, but none have been observed.

In thin section, both the conjugate and east-trending dyke sets have been metamorphosed up to the amphibolite facies, with local retrogression along shear zones to the greenschist facies. Typical mineral assemblages are:

Hornblende-plagioclase-quartz-magnetite-sphene-(biotite)-(epidote)-(calcite)
Hornblende-plagioclase-quartz-sphene
Garnet-hornblende-plagioclase-quartz-magnetite-sphene-biotite-(tourmaline)
Hornblende-plagioclase-quartz-magnetite-biotite-zoisite.

The presence of garnet, hornblende, and calcic plagioclase (oligoclase-andesine) indicate low amphibolite facies metamorphism, though towards the east of the Kalkadoon-Leichhardt basement the metamorphic grade in general decreases to the greenschist facies. However, farther east near the eastern margin of the Sheet area metadolerites in the Argylla Formation are of the amphibolite facies.

Retrogression along localized shear zones has produced the following greenschist facies assemblages :

Plagioclase-chlorite-quartz-magnetite-hornblende-(biotite)
Hornblende-plagioclase-chlorite-quartz-magnetite-biotite-zoisite-sphene-(tourmaline).

Albite, quartz, and chlorite are the predominant minerals within these schists.

Except in shear zones, the dolerites have either partly or wholly retained their primary texture. The euhedral laths of calcic plagioclase zone outward from cores of An_{50} to rims of albite, are a pale brown colour, and are mostly devoid of inclusions. Hornblende ranges from large ragged shaped crystals to subhedral prismatic blades with pleochroism from blue to green to yellow. They are usually optically homogeneous. Magnetite is typically rimmed with sphene and in some examples is entirely replaced by it. Garnet has been found in only one thin section. In several specimens, the plagioclase has rims of albite which in places are optically continuous with albite in the groundmass micropegmatite. In other specimens, metamorphic quartz is also present, and is most common in shear zones where retrogression has produced the assemblage chlorite-quartz-albite-magnetite. Schistosity defined by oriented chlorite, and augen of quartz-albite, is typical of this assemblage.

Many of the large older dykes which have been strongly sheared and metamorphosed show copper sulphide-quartz-calcite mineralization along the shear zones. Mines such as Referee, Queen Elizabeth, and Azurite are of this origin.

Eastern succession dolerites

Two generations of dolerite are present within the eastern succession in the Prospector Sheet area.

The older dolerites intruded mostly as sills into all of the units older than the Deighton Quartzite. Subsequent folding and faulting has resulted in their outcrop as discontinuous bodies within fault blocks. In outcrop they are black rocks that mostly have a pronounced foliation. One large sill to the east of Last Chance mine shows evidence of having assimilated the calcareous Corella Formation during intrusion, and in hand specimen it has distinctive feldspar crystals up to 2 cm long in a dense black base.

25

The older sills and dykes have been metamorphosed during regional metamorphism to the epidote-amphibolite and staurolite grade amphibolite facies. In thin section the following mineral assemblages have been found :

Plagioclase-green-yellow hornblende-sphene-quartz-(magnetite)-(scapolite)-(epidote)
Plagioclase-green-yellow hornblende-quartz-magnetite
Plagioclase-green-yellow hornblende-clinopyroxene-sphene-quartz-magnetite
Plagioclase-green-yellow hornblende-quartz-sphene-biotite-magnetite-scapolite
Plagioclase-actinolite-quartz-magnetite-calcite-biotite
Plagioclase-blue-green hornblende-quartz-magnetite-calcite-(biotite).

The presence of scapolite within many of these sills may be due to metasomatic addition of soda and chlorine from the Corella Formation. Many sills, especially those of the epidote amphibolite facies display relict igneous textures, with zoned laths of plagioclase, ophitic hornblende, and interstitial quartz-albite micropegmatite. The feldspar from these examples is a distinctive brown colour, zoned from cores of An_{50} to rims of albite. At higher grades the dolerites are recrystallized to an equigranular assemblage of plagioclase, green hornblende, quartz, and sphene.

Younger, fresh dolerite dykes occur in many parts of the eastern succession, but are extremely rare within the Prospector Sheet area. Only one outcrop has been found, intruding the Wonga Granite. In thin section it consists of zoned plagioclase laths (An_{50-20}), orthopyroxene, clinopyroxene, biotite, magnetite, and quartz. Minor alteration has produced actinolite and sericite at the expense of the pyroxene and feldspar respectively.

STRUCTURE

Introduction

Meridional folding and faulting has resulted in the repetition of recessive and non-recessive units in both eastern and western successions, and the formation of a distinctive north-trending narrow ridge-and-valley topography. Oblique to this trend are numerous subparallellquartz ridges (e.g. Mount Remarkable) which represent the fracture fillings of large northeast or northwest trending strike-slip faults.

The Prospector Sheet area is characterized by a similar sequence of structures to that mapped in the Mary Kathleen Sheet area, to the south (Derrick et al., in press). The structures resulted predominantly from brittle deformation; at least three sets of fault types have been distinguished, pervading both eastern and western successions and the basement. Folding is subordinate to faulting, and reflects the abundance of arenaceous successions and the structural homogeneity of the basement. Ellipsoidal basin-and-dome folding, however, is characteristic of plastic and/or highly anisotropic units such as the Corella Formation and the Surprise Creek Beds. Carter et al. (1961) genetically related both folding and faulting to a regional east-west compression; changes in orientation of the minimum and intermediate principal stress directions gave rise successively to a period of latitudinal thrusting, east-trending normal faulting (north-block-up), and conjugate strike-slip faulting. Numerous splays associated with the conjugate faults complicate the structural picture. Predominantly north-trending folds were associated with the initial stages of thrust faulting.

The evolution of the Corella Formation 'breccia', and some transposition of bedding, are related to a phase of axial-plane flattening associated with the folds.

2?

Faulting

(1) Thrust or high-angle reverse faults

A north-trending set of faults parallel to the regional bedding strike pervades the basement and the sedimentary successions. The sense of displacement is east-block-up in the eastern succession, and west-block-up in the western succession, with the dip-slip component predominant. This set has been displaced by all subsequent sets, and is the earliest recognized; it is associated in time and origin with the major north-trending folds. It may have an origin in 'break' thrusting on the limbs of folds; this is supported by the overturning of some fold limbs of the eastern succession, and by the location of the faults relative to macroscopic folds. Faults may have initially dipped steeply or have been steepened during the flattening episode.

In the western succession these faults have juxtaposed the Eastern Creek Volcanics and Myally Subgroup against the younger Surprise Creek Beds. In the eastern succession the Argylla Formation is repeated adjacent to the Corella Formation.

(2) Normal faults

After the reverse faulting and folding episode, east-trending normal faults displaced folded units in the sense north-block up; that is, the faults dip steeply south. This set is recognized in the eastern and western successions and is best developed where it displaces plunging folds e.g. southwest of Gereta homestead, where these faults repeat a tightly folded sequence of Surprise Creek Beds, and in the west of the Sheet area, where openly folded sequences of Haslingden Group and Mount Isa Group are repeated northwards. In the eastern succession a large syncline of upper Corella Formation and Deighton Quartzite has been preserved in a downfaulted block south of a structural basin of Corella Formation and older units.

This fault style may represent a brittle response to dilatation during and after folding.

(3) Strike-slip faults

Sets of conjugate strike-slip faults offset all other structures and are therefore recognized as the latest deformational event. Together with their complex array of splays they are the most intensively developed fault style, and are probably the most significant in terms of their displacement. Conjugate pairs trend northeast or north-northeast and northwest or north-northwest; the former is best developed in the eastern succession and commonly displaces the northwest conjugate set, which is more common in the western succession. The largest displacements occur along northeast-trending faults such as the Mount Remarkable Fault which has a calculated right lateral offset in the Sheet area of 25 km. Conjugate transcurrent faults pervade both supracrustal sedimentary successions and the basement areas, with little or no regard for the basement-cover interface; the final response to east-west compression was an homogeneously brittle one.

The geometry of one set of strike-slip conjugate pairs is markedly anomalous with respect to the usual model of fault development (Anderson, 1951). This predicts that the angle between the planes of maximum shearing containing the maximum principal stress direction will be equal to or less than 90^{0}. Carter et al. (1961) noted that the angle between the conjugate strike-slip faults in many cases was obtuse with respect to the east-west horizontal maximum principal stress and explained this by invoking a later flattening of 30 percent to exaggerate the initially acute angle. Observations that transcurrent faulting was the last structural event (offsetting the flattened basins and domes), and that the well developed S-fabric expected to result from such flattening is absent in many regions, mitigate against this interpretation. A conceptual model of stress reorientation following faulting, along the lines of Moody & Hills (1956), has been suggested (Derrick et al., 1971) in order to explain the disposition of the two conjugate sets. Chinnery (1966), however, has advanced arguments countering such a proposal, and has suggested that, after major faulting, shear stresses are reduced on either side of the fault surface. A more feasible approach lies in the control of maximum-shear directions by an inherent anisotropic basement fabric. This is manifest by the numerous penetrative north-northeasterly and north-northwesterly trending, extremely deformed and altered basic dykes confined to the basement. It is known that the orientation of fractures is related directly to the existence and relative orientations of a structural fabric (Donath, 1961) and the maximum principal stress. Strongly supporting this is the observation that the conjugate set with obtuse dihedral angles is best developed in the basement high whilst the more normal northeast set with a smaller dihedral angle is present in the cover of the eastern and western basins.

Fig. 57: Stereograms from structural domains in the Prospector 1:100 000 Sheet area.

a Western succession; 1,5,10 and 20 percent contours of poles to S_0 in Myally Subgroup, Surprise Creek Beds, and sedimentary rocks in Eastern Creek Volcanics. Squares are B_2 axes of minor folds. Dotted circles are poles to axial plane foliation, S_2 (fracture foliation).

b Eastern succession; Corella Formation from structural domain 1 (see Fig. 56). Crosses are poles to foliation S_o (and S_1, metamorphic segregation), circles are lineations, and triangle is B_2 axis of intrafolial fold (? L_1 lineation).

c Eastern succession; Corella Formation from structural domain 2 (see Fig. 56). 1 and 5 percent contours of poles to S_0 (and S_1). Squares are B_2 axes of minor folds. Dotted circles are poles to axial plane foliation, S_2.

d Eastern succession; Corella Formation from structural domain 3 (see Fig. 56). 1, 5, 10 and 20 percent contours of poles to

220

S_0 and S_1. Squares are B_2 axes of minor folds.

e Eastern succession; Corella Formation from structural domain 4 (see Fig. 56). 1, 5 and 10 percent contours of poles to S_0 and S_1. Circles are crenulation and mineral elongation lineations. Squares are B_2 axes of minor folds.

f Basement succession rocks from structural domain 4 (mainly Argylla Formation). Spots are poles to S_0. Crosses are poles to S_2.

g Eastern succession (?); Wonga Granite from structural domain 4. Crosses are poles to axial plane foliation, S_2. Circles are mineral elongation lineation, L_2.

h Basement succession; west of Mount Remarkable Fault. Crosses are mineral elongation lineation, L_2.

Structural elements

(1) Foliation (S_1 and S_2) and lineation (B_2)

A foliation and associated lineation postdating sedimentation structures is irregularly developed throughout the region, but is most intense toward the eastern margin of the Sheet area. The style of axial-plane foliation associated with the basin-and-dome folding in both eastern and western successions was determined by the competency of the particular units. In the Eastern Creek Volcanics and most psammites of the western succession a coarsely penetrative (spaced 3-4 cm) fracture foliation is the predominant axial-plane structure associated with broad open folds. Examination of microtextures indicates that little or no flattening of grains has occurred in these units, although amygdales of the metabasalt are characteristically aligned subparallel to the foliation. Within more arkosic and shale-rich sections of the Myally Subgroup and Lena Quartzite Member, a

222

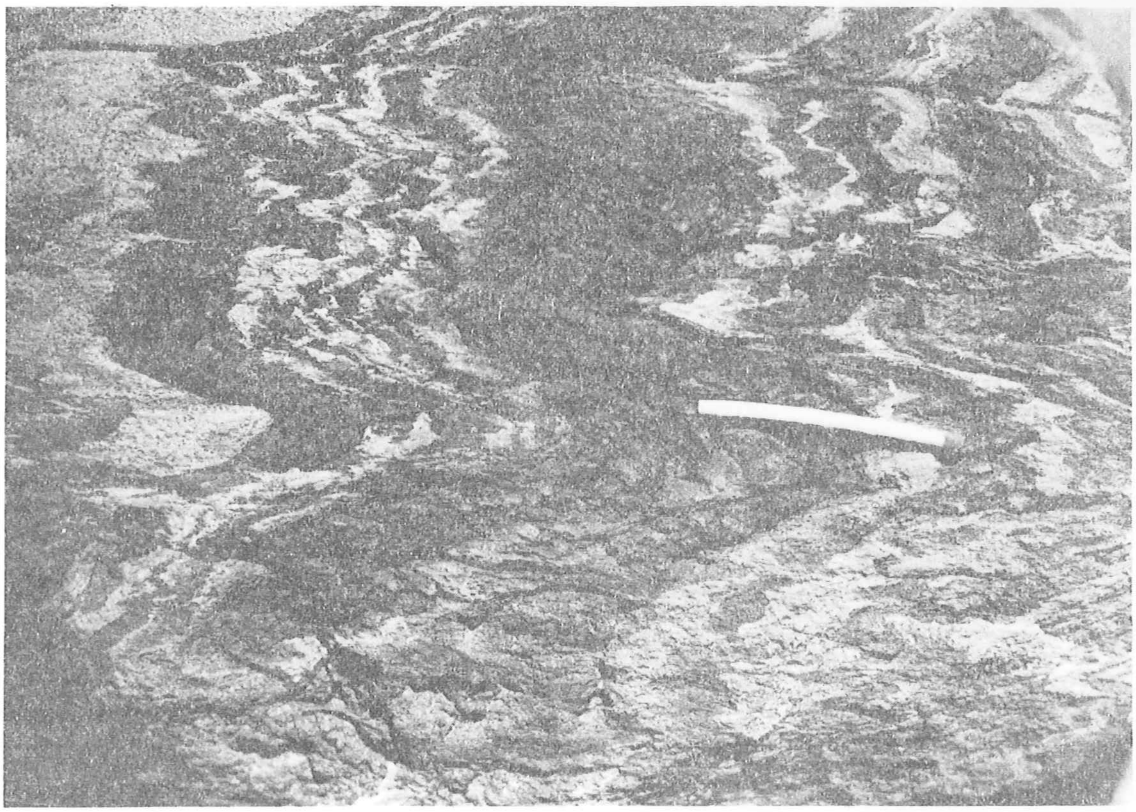


Fig. 53.
Folding in calc-silicate granofels of the Corella Formation in the axial zone of a syncline. Match parallels S_2 cleavage cutting S_0 bedding. Locality 2 km east of Flora Dora. M1549/13A.

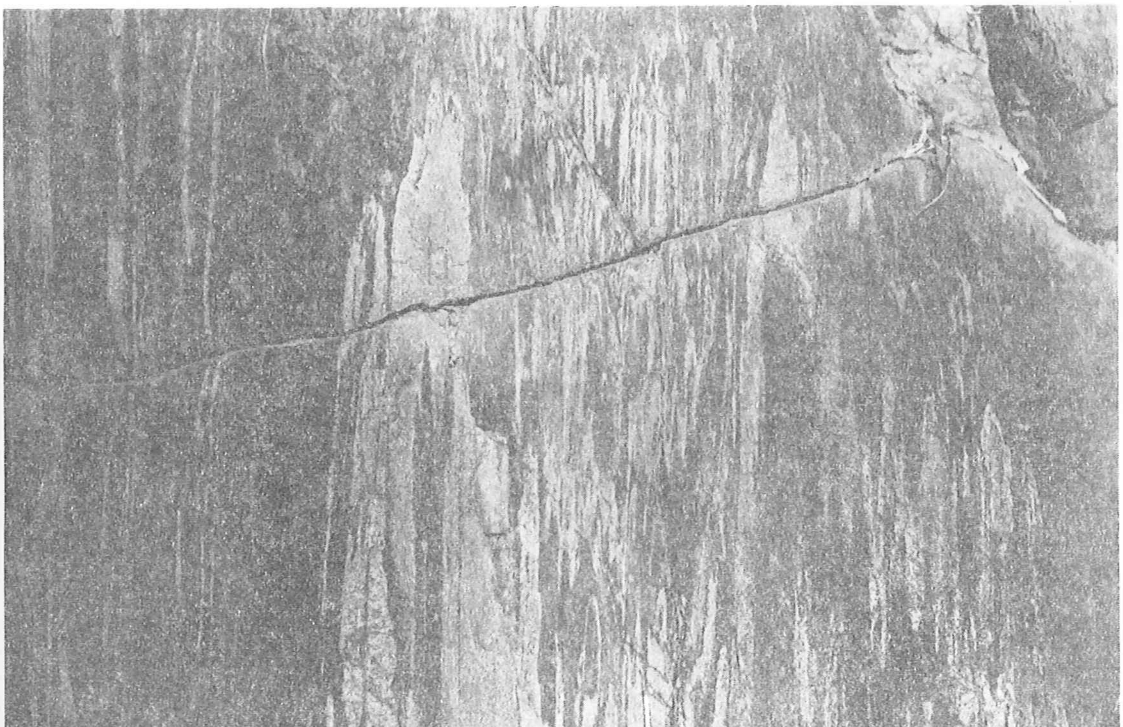


Fig. 54.
Isoclinal folding in feldspathic and calc-silicate granofels of the Corella Formation; bedding (S_0) or metamorphic foliation S_1 is partly transposed to form semicontinuous S_2 foliation in axial zones. Locality 2 km east of Flora Dora mine. M1549/12A GMD.

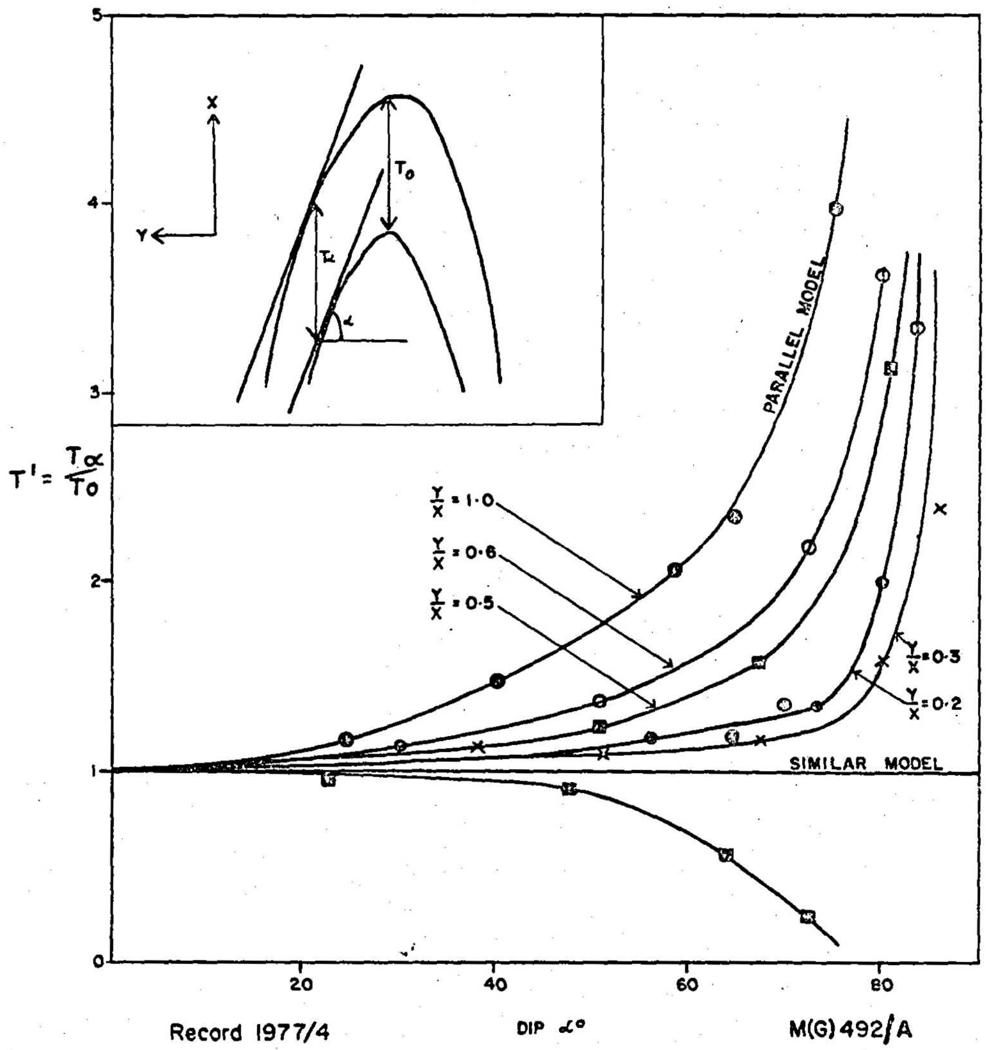


Fig. 55 Axial–plane thickness plots for minor folds in the Corella Formation: an indication of the amount of strain $(\frac{Y}{X})$ associated with basin-and-dome formation (after Ramsay, 1967).

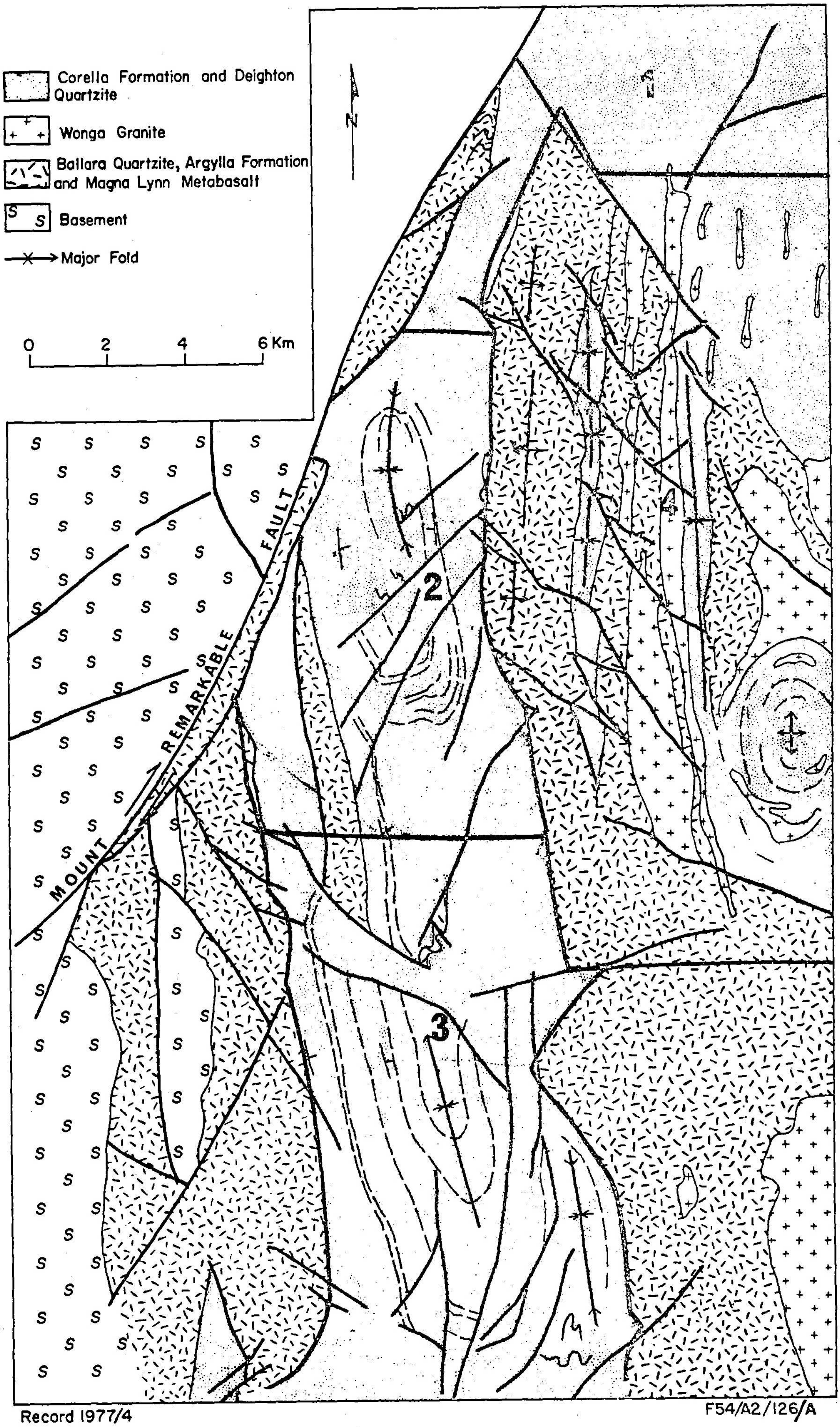


Fig. 56 Structural domains in the eastern succession

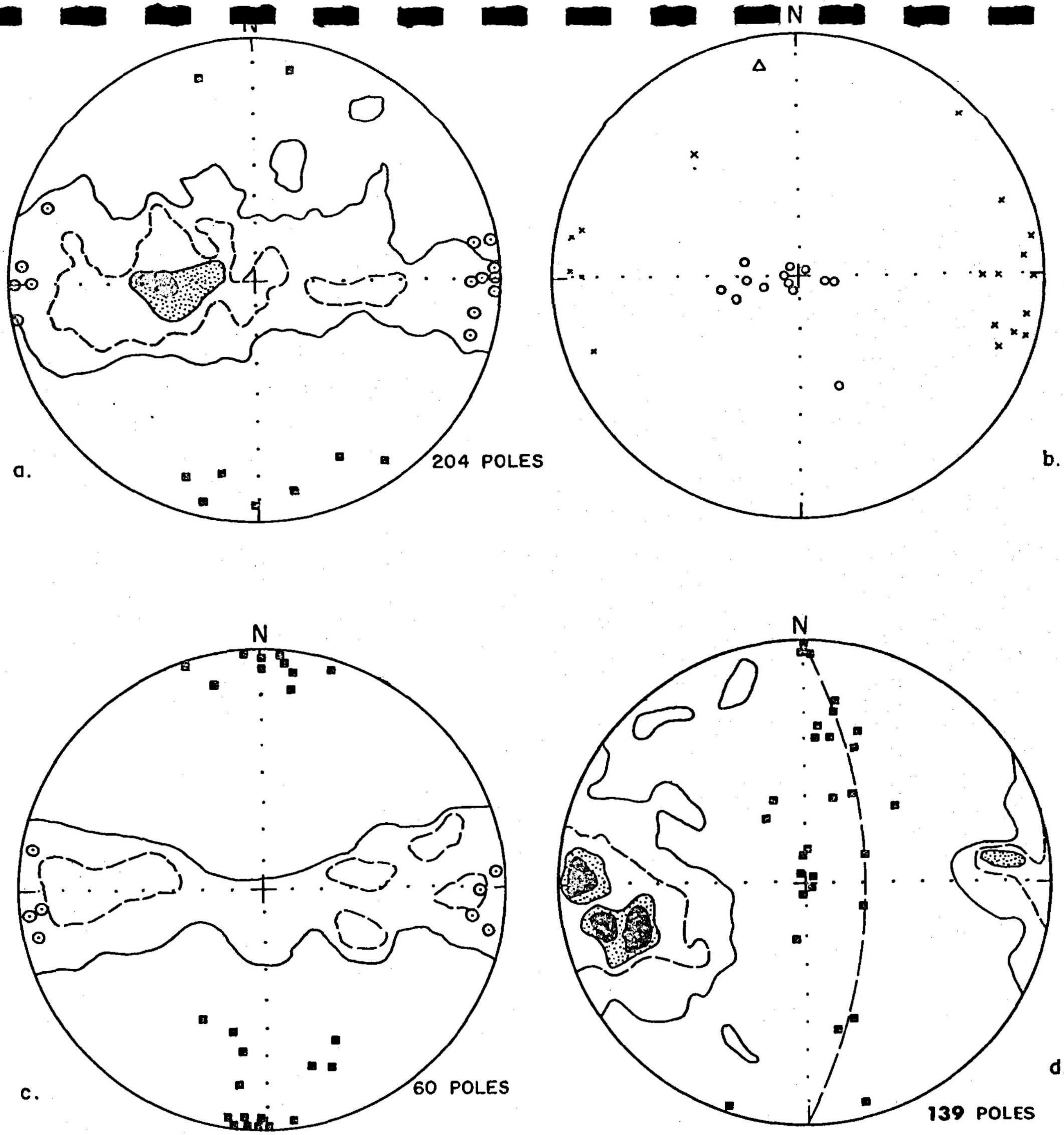


FIGURE 57(1)

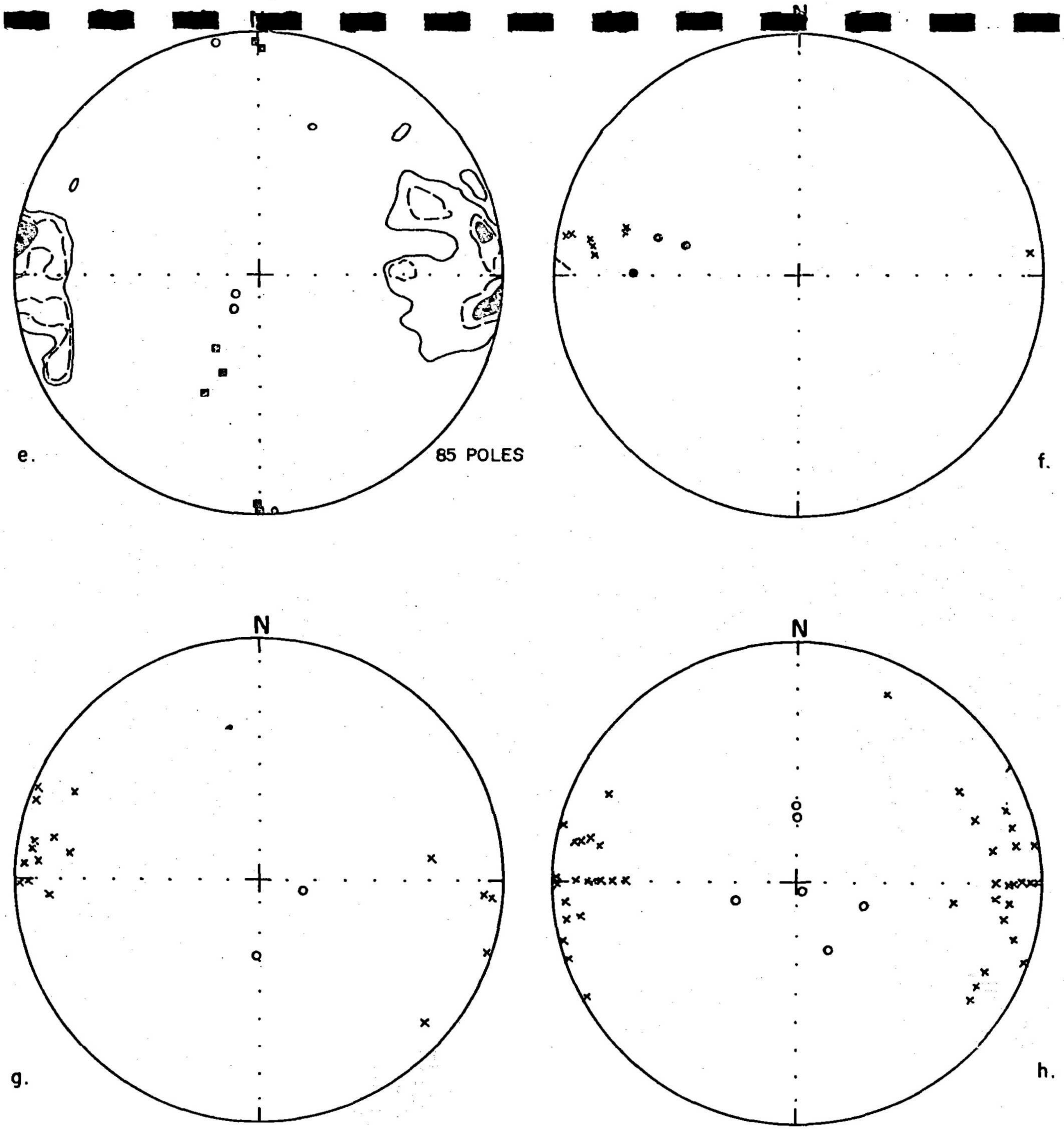


FIGURE 57 (2)

finely penetrative slaty foliation is more common with included quartz grains defining elongation lineation (B_2) parallel to the regional fold axis (Fig. 57a).

A metamorphic-differentiation foliation may be present in para-amphibolites and calc-silicate rocks of the eastern succession, particularly in areas of highest metamorphic grade near the eastern margins of the Sheet area, and is designated S_1 in distinction to bedding (S_0). Evidence for S_1 comes from intrafolial folds appressed within and parallel to the layering in relatively unfolded localities, and the tendency toward regular alternation of quartzofeldspathic and mafic layers. Such layers are typically about 0.5 to 1 cm thick, the darker layers being composed essentially of green to dark brown hornblende, with scapolite, biotite, and opaques. Within the para-amphibolites of the Corella Formation this layering imparts a banded gneissic aspect. It has been argued that such intricate layering must represent bedding since it is regionally continuous (Walker, Joplin, Lovering, & Green, 1959) but against this observation is the uniformity of thickness, the alternation of quartzo-feldspathic bands with hornblende-biotite rich bands characteristic of metamorphic differentiation, and the local recognition of pre-S_2 intrafolial folds. Since both amphibolite grade metamorphism and the particular calc-silicate lithology were extensive there is no apparent reason for rejecting regional metamorphic differentiation, albeit subparallel to the initial bedding.

The axial-plane foliation (S_2) developed in the macroscopic basins and domes immediately east of the basement is a north-trending fracture cleavage (Fig. 57, b-g; Fig. 56). This transects bedding in quartzites, and calcareous quartzite, and calcareous siltstone of the Corella Formation where folding is of an open type. Farther east toward the Sheet area margin, folding is much tighter, and a slaty 'flow' foliation in recrystallized lime-rich units is separated by shredded and transposed competent quartzitic and calc-silicate layers (Fig. 54). Both layering elements are recognized as separate aspects of a single progressive deformation parallel to the axial plane of the regional basins and domes.

Owing to the possibility of 'inheritance' of intrafolial folds from one generation to another, it is impossible to decide whether many intrafolial folds now contained within the new axial-plane foliation S_2 and parallel to B_2 actually represent a late stage of F_2 transposition after basin-and-doming, or reflect initial F_1 closures developed parallel to the metamorphic differentiation. This is a problem commonly encountered in areas of polyphase deformation; it is possible that initial intrafolial folds may rotate passively into subsequent planes of flattening. The S_2 layering is commonly an L-S fabric (Flinn, 1965a), a mineral elongation lineation lying within the foliation parallel to adjacent minor fold axes (Fig. 57 e). Within the Corella Formation para-amphibolites this is defined by the orientation of hornblendes, micas (esp. biotite), and scapolite. A strong foliation also is evident in all phases of the Wonga Granite. Within the porphyritic augen-phase it is defined by the alignment of microcline augen and is enhanced by ribbon quartz and the preferred orientation of biotite. The long axes of microcline augen define a prominent lineation (L_2) parallel to the regional B_2 axis. The different foliation styles are parallel irrespective of the host lithology and are axial-planar to the same set of north-trending basins and domes.

A penetrative, north-trending foliation (S_2) in the acid volcanics, metasediments, and granites of the basement has resulted from the dimensional orientation of grains. Hornblende in the acid volcanics defines a prominent lineation (Fig. 57 h).

(2) Folding

Phases and styles. A folding episode coeval with the earliest foliation (S_1) due to metamorphic differentiation possibly exists in areas of high-grade metamorphism and is illustrated by rare intrafolial folds. This folding phase is

228

denoted F_1; if it is real, complete transposition has occurred in S_1 and the rootless folds are the only vestiges of deformation. A less likely alternative explanation is that these folds are sedimentation features. The observation of partly transposed tension-cracks contradicts this view, as does the interpretation of the layering as metamorphic differentiation.

More significant in terms of outcrop pattern is the subsequent (F_2) phase of basin-and-doming with associated axial-plane structures (S_2 and L_2) present in both eastern and western successions (Fig 53, 54). These 'double folds' have an ellipsoidal form and are oriented with long axes in a northerly trend (Fig. 57 c-e). Fold wavelengths up to 15 km along the northerly axis and up to 5 km along the easterly axis are present. No minor folds or foliation are associated with the east-trending axis; lineations and minor fold axes of this F_2 phase (L_2 and B_2) are distributed at various inclinations within the axial plane (Fig. 57 d and e).

Geometric axial-plane thickness analysis (Ramsay, 1967) on six minor folds in the Corella Formation indicates that folding style is mostly of the flattened parallel type (Fig. 55). Interlimb angles of folds (Fleuty, 1964) are predominantly open in the western succession, and in the eastern succession immediately east of the basement, but are tight near the eastern margin of the Sheet area.

Stereograms from domains in the Corella Formation (Fig. 57 b-e) emphasize the tightness of folding along the northerly axis; maxima are concentrated close to the primitive for the eastern succession. There is also an azimuthal component of spread in the contoured stereograms. Poles to bedding (S_0) and foliation (S_1) have been contoured together (contours 1, 5, 10, 20 percent poles per 1 percent area) because both bedding and metamorphic differentiation foliation have been folded alike during F_2 deformation. The disposition of poles to both layerings as indicated by the stereograms reflects the geometry of the macroscopic ellipsoidal basins and domes, showing the moderate to near-isoclinal and vertical north-component of folding and the short axis of the ellipsoids which bisects the azimuthal dispersion of the poles (pseudo-axial plane). These dispersions are significant in that they are a direct indication of the eccentricity of the basins or domes. Thus elongate near-isoclinal basins and domes tend more towards a north-trending cylindrical fold type; it is with this type that the foliation S_2 and lineation is most intensively developed. In the southern part of the eastern trough a section of the upper Corella Formation and Deighton Quartzite is preserved in a structural basin. Toward the eastern margin of the Sheet area the Wonga Granite and Corella Formation have been folded together (in part disharmonically) in a series of structural basins and domes, giving the impression of stratigraphic or layering control, and confirming that both the prograde regional metamorphic and granitic events antedated F_2 deformation. Further support for this interpretation comes from the existence of S_2 foliation in all granite phases.

In the western succession, doubly plunging folds of broad open style pervade the psammite and metabasalt of the Eastern Creek Volcanics. Few whole basins and domes have been preserved owing to subsequent normal and strike-slip faulting.

The Magna Lynn Metabasalt and Argylla Formation are involved in a series of tight F_2 folds toward the eastern margin of the Sheet area, demonstrating that basement and cover responded similarly to the same deformation. The Wonga Granite has been repeated in long northerly belts by these folds.

<u>Macroscopic geometry</u>. The competent psammitic units of the western succession lack structural homogeneity because of the large number of later faults that have rotated and translated the folds. However, in the eastern succession a large part of the section is dominated by plastic calcareous metasediments so that later faults have had only little rotational and translational significance, most ending 'blind' in the Corella Formation or

being 'absorbed' parallel to the layering. Accordingly, four domains of differing structural style have been delineated in part of the eastern succession (Fig. 56), and stereograms (lower hemisphere; equal area projection) have been compiled for each domain (Fig. 57). Poles to bedding (S_0) and planar metamorphic differentiation (S_1) have been contoured together, where sufficient readings were available. Minor fold axes and lineations have been included on the same stereogram for comparison. The Corella Formation is ideal for this sort of analysis since it has folded independently of lower, more competent units (disharmonic) during F_2 deformation, and the intensity of F_2 structures is relatively enhanced.

Domains 1 and 3 have maxima of poles to S_0 and S_1 close to the primitive (Fig. 57 b and d) reflecting more intense near-isoclinal F_2 folding. Minor fold axes (B_2), intrafolial folds, and lineations (L_2) are disposed within the axial plane towards the vertical. There are two possible explanations for this attitude: during F_2 flattening, passive rotation of L_2 lineations initially parallel to the axes of parallel folds may have occurred, the lineation moving toward the direction of maximum principal strain; alternatively, or possibly in addition, some vertical lineations may be associated with vertical drag-folds (F_3) adjacent to large strike-slip faults. Significantly, intermediate inclinations of L_2 lineations and F_2 minor folds lie in the axial plane bisecting the maxima of poles to layering, suggesting a flattening mechanism of rotation (Flinn, 1962).

The overturning of limbs in the southern region of the eastern succession is demonstrated in Figure 57 d. The point maxima are located near the western primitive, and the axial plane is steeply dipping eastward, consistent with a macroscopic westward vergence.

Domain 2 exhibits relatively open folding with an axial-plane fracture foliation and bedding preserved. The stereogram (Fig. 57 c) shows the broad even dispersion of S_0 and S_1 poles in a wide east-west girdle and the azimuthal dispersion of poles increasing toward the primitive. Minor folds are well clustered in a meridional direction; many exhibit a double plunge at hand-specimen scale. In this domain they are quite shallow in plunge.

Domain 4 contains folded Wonga Granite, Corella Formation, Ballara Quartzite, and Argylla Formation (Fig. 57, e-g). All lithologies display an isoclinal style with vertical or horizontal minor folds and lineations, and small azimuthal dispersions reflecting very elongate double-plunging folds.

This regional analysis emphasizes the uniformity in orientation of the basins and domes, and demonstrates a southward and eastward increase in intensity of F_2 deformation, evidenced by the rotation of lineations and fold axes toward vertical, and the isoclinal style of folding of all lithologies.

Inhomogeneous flattening and the Corella 'breccia'. Many of the structural features associated with F_2 deformation are interpreted in terms of the progressive deformation of initially parallel F_2 folds. These include the Corella 'breccia', the basin-and-dome structure, transposition structures, vertical lineations and fold axes, and the existence of an axial-plane fabric resulting from flattening in the Wonga Granite.

The following sequence of events is envisaged (Fig. 58):

(i) Concentric buckling of bedding and metamorphic differentiation foliation (S_1) produced open parallel-style cylindrical folds oriented north-south. Layer-thickening of more plastic units probably accompanied buckling which was a function of both competence and anisotropy (Rambert, 1964; Cobbold, Cosgrove, & Summers, 1971). Further buckling resulted in close folds (Fleuty, 1964) and incipient fracturing normal to the axial plane of thin competent units. These fractures were filled by

232

quartz, calcite, and epidote veins. A coarse fracture foliation developed as an axial-plane feature in competent units.

(ii) Buckling reached a limiting point (De Sitter, 1958) and further change in profile was accomplished by flattening of the existing folds normal to their axial plane. The compressive strain was inhomogeneous, varying along the axial plane, and this resulted in the production of basins and domes of ellipsoidal form (Ramsay, 1962) - that is, doubly plunging folds. Further flattening resulted in the steepening of the basins and domes.

Minor folds are typically doubly plunging to the north and south (Fig. 57, c, d).

Minor F_2 structures observed in the eastern succession are consistent with a progressive flattening deformation. Transposition has affected layers of varying ductility; intrafolial folds of all sizes are observed in the S_2 foliation. Some of these may be relict from possible F_1 deformation. In the Corella Formation transposition of S_1 metamorphic-differentiation foliation (Fig. 54) is represented by long isoclinal folds in S_2 with attenuated limbs and thick hinges. Single intrafolial folds (Turner & Weiss, 1963) are defined by hornblende-rich layers of relict S_1. Typically, the B axes of intrafolial folds are parallel to the regional B_2 axis and may have any inclination within the axial plane. Aplitic and pegmatoid veins and concordant layers are also transposed parallel to S_2 providing evidence for the Wonga Granite emplacement antedating F_2 deformation (Fig. 59).

It is clear also that quartz, calcite, and epidote veins normal to S_2 antedate F_2 flattening, because they are partly transposed in S_2. However they postdate initial F_2 buckling, as indicated by the less arcuate nature of the veins compared with the folded bedding and metamorphic layering (S_1) (cf. Ramsay, 1967, p. 344).

The orientation of folded veins, and the presence of transposition structures and boudinage, attest to flattening in the F_2 axial plane, and indicate that the maximum shortening direction (F_3) was normal to the axial plane. As expected these structures are associated with folds of isoclinal form (Fig. 57 d and e). Geometric analysis of the thickness of layers in the Corella Formation measured parallel to the axial plane (Ramsay, 1967) supports the interpretation of flattened parallel folds (Fig. 55); plots of single minor folds fall between those for the parallel and similar models. These enable a calculation of the principal strain ratios E_2/E_1; values decrease from 0.6 to 0.3 eastward from the Mount Remarkable Fault. This change corresponds to a greater flattening deformation eastward. These plots also support an origin for the basins and domes by inhomogeneous flattening; analyses of fold profiles at different positions along a single doubly plunging fold axis suggest varying amounts of flattening along the S_2 axial plane.

Corella 'breccia'

Both penecontemporaneous and tectonic origins have been invoked for the Corella 'breccia'. Carter et al. (1961) believed that most of the breccias were associated with slumping below wave base, cementation of organic reef detritus, and contraction due to dolomitization. They thought that faulting and folding had been of limited significance. Derrick et al. (1971), on the other hand, pointed to the intraformational nature of the 'breccia' as evidence of its tectonic origin in the buckling of competent and incompetent multilayers. Breccia in the nearby Cloncurry region was also interpreted as tectonic by Glikson & Derrick (1970).

It has been variously suggested (Glikson, 1972; Derrick et al., 1971; Derrick et al., in press) that both superposed folding, and evolution of the Corella 'breccia' were partly the result of granite intrusion. Intrusion of the Naraku and Williams Granites is supposed to have caused the double folding and this in turn to have produced the 'breccia'. Weaknesses in this interpretation are as follows:

234

(i) The only granites near the Corella 'breccia' in the Prospector Sheet area are the much older Kalkadoon basement granite and the Wonga Granite. The Wonga Granite, however is well foliated (S_2), and must therefore antedate the evolution of the 'breccia' during F_2 deformation. Further, granite concordant with S_1 layering in the Corella Formation has been folded into F_2 basins and domes (Fig. 57 g). Clearly then, at least within the Prospector Sheet area, basin-and-dome folding and brecciation cannot be ascribed to nearby granite intrusion.

(2) The hypothesis can be discarded also on theoretical grounds, since it is impossible to conceive of a strain field in which both maximum and intermediate principal strains are constrictional near an intruding granite; a tensional strain field is to be expected. Nor is it to be expected that double folding would occur at the sides of an intruding pluton.

The evolution of the Corella 'breccia' can be related to the flattening association with the F_2 basin-and-dome folding which followed the regional prograde metamorphic and granitic event. The development of the 'breccia' by progressive flattening deformation of the Corella Formation can be traced immediately east of the Mount Remarkable Fault (Fig. 58); two stages have been identified:

a) Incipient fracturing of competent calc-silicate layers after concentric buckling. This stage may have been pre-empted by micro-fracturing and veining normal to S_2 during buckling.

b) Near-isoclinal appression associated with planar boudinage of more competent calc-silicate layers. Boudinage depended on the thickness of the competent layers relative to the enveloping incompetent multilayers as well as the ductility ratios and compressive strain. This explains the irregular distribution of the 'breccia' on spite of its intraformational aspect;

boudinage occurred preferentially in the thinner calc-silicate layers.

The 'breccia' is therefore explained as an axial-plane boudinage feature, with the typical angular clast 'chocolate tablet' pattern usually ascribed to a flattening plane strain (Ramsay, 1967). Clasts may be angular or rectangular, ranging in size from 0.5 cm^2 to 15 cm x 18 cm. These size ranges may be correlated with the boudinage of competent layers of different thicknesses.

Incontrovertible support for the proposed origin of the 'breccia' comes from the observation of fold closures within some boudins or clasts, from the association of the boudins with intrafolial folds, and from the alignment of many clasts (boudins) within the S_2 axial-plane foliation. Moreover, boudinage of the pinch-and-swell type affects quartz and calcite layers concordant with S_1 layering. Large intrafolial folds of calc-silicate are dispersed in a recrystallized matrix of metamorphosed limestone. The size of these folds also depended on the thickness of the competent layers; the bullet-shape profile is characteristic of 'rootless' folds. An axial-plane foliation is preferentially developed in the more plastic metamorphosed limestone. Pinch-and-swell structure is absent in the boudins, reflecting the high ductility contrast of limestone with calc-silicate rock.

Microstructures

Features associated with cataclasis and annealing are common throughout the Wonga Granite and Corella Formation. Within the Wonga Granite, microcline augen are aligned parallel to the foliation S_2 and are in places enveloped by plastically deformed 'ribbon' quartz. The ellipsoidal shape of augen, the presence of mortar texture in the shadow regions at the tails of augen, and the tension-cracks oriented near-normal to the S_2 foliation attest to the flattening character of F_2 deformation (cf. Johnson, 1967). Quartz in both the Wonga Granite and Corella Formation possesses a

236

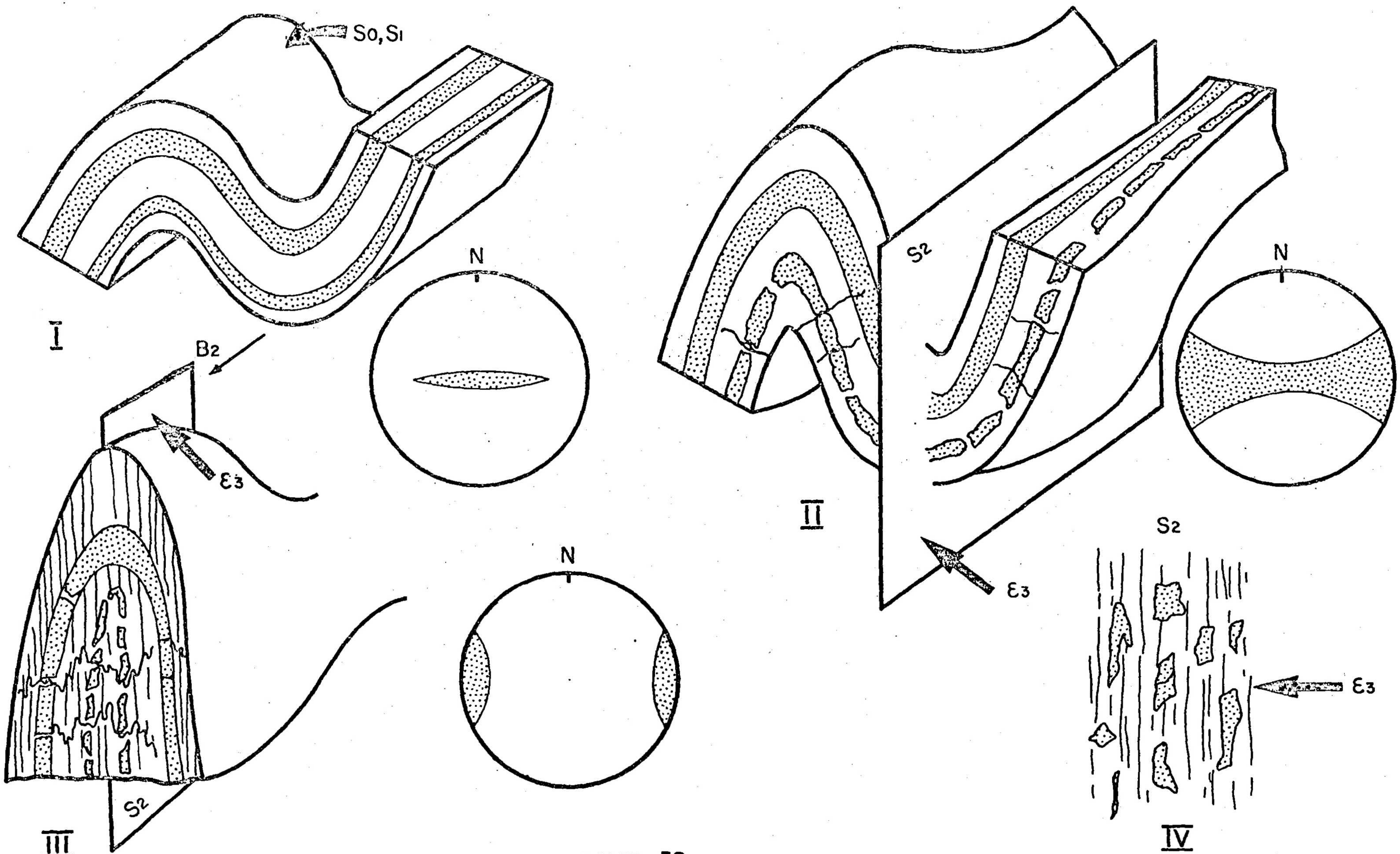


FIGURE **58**

Diagrammatic illustration, with corresponding stereograms of the evolution of the Corella 'breccia' and other minor structures associated with axial-plane flattening

Record 1977/4

M(Pt)184/A

237

variety of deformation textures: polygonization to subgrains, deformation lamellae, and sutured subgrain boundaries (Spry, 1969). Together with small anhedral alkali feldspar granules, quartz typically forms mortar texture at the apices of augen.

Whereas porphyroblasts of feldspar and relict hornblende grains in the granite have behaved brittly, being characterized by cataclastic microstructures, quartz has responded to the same F_2 deformation plastically; 'ribbon' and sutured boundaries are typical. Sutured intergrain boundaries are usually ascribed to strain-induced boundary migration (Flinn, 1965b), and in the calc-silicates and Wonga Granite this has occurred parallel to the foliation, S_2. Kinked albite-twin planes and mortar texture are common in feldspars of the Wonga Granite and are also attributed to F_2 cataclasis. It is possible to recognize all possible stages in the comminution of slightly undulose grains to grains with subgrain boundaries and finally to mortar texture. In calc-silicates, the regional penetration foliation S_1 is emphasized by the parallel layering of biotite flakes. Where bedding is preserved, this is generally at a low angle to the foliation or sub-parallel. Small intrafolial folds suggest a tectonic origin for this layering.

The microstructures amplify the sequence of thermal and deformational events obtained from mesoscopic field relations, and are in accord with the structural history interpreted. Triple-point aggregates of quartz and calcite, and polygonization textures, reflect an initial prograde regional metamorphic event during which the amphibolite assemblage was dispersed in a differentiated layering (S_1), apparently parallel to bedding S_0. This may have been accomplished by a possible F_1 deformation. F_2 basin-and-dome folding followed, and the metamorphic differentiation layering together with bedding (in more competent units) was transposed into the new S_2 axial-plane foliation. Amphibolitic phases of the previous regional metamorphism were then flattened during the same F_2 deformation that gave rise to the Corella 'breccia' and mesoscopic intrafolial folds.

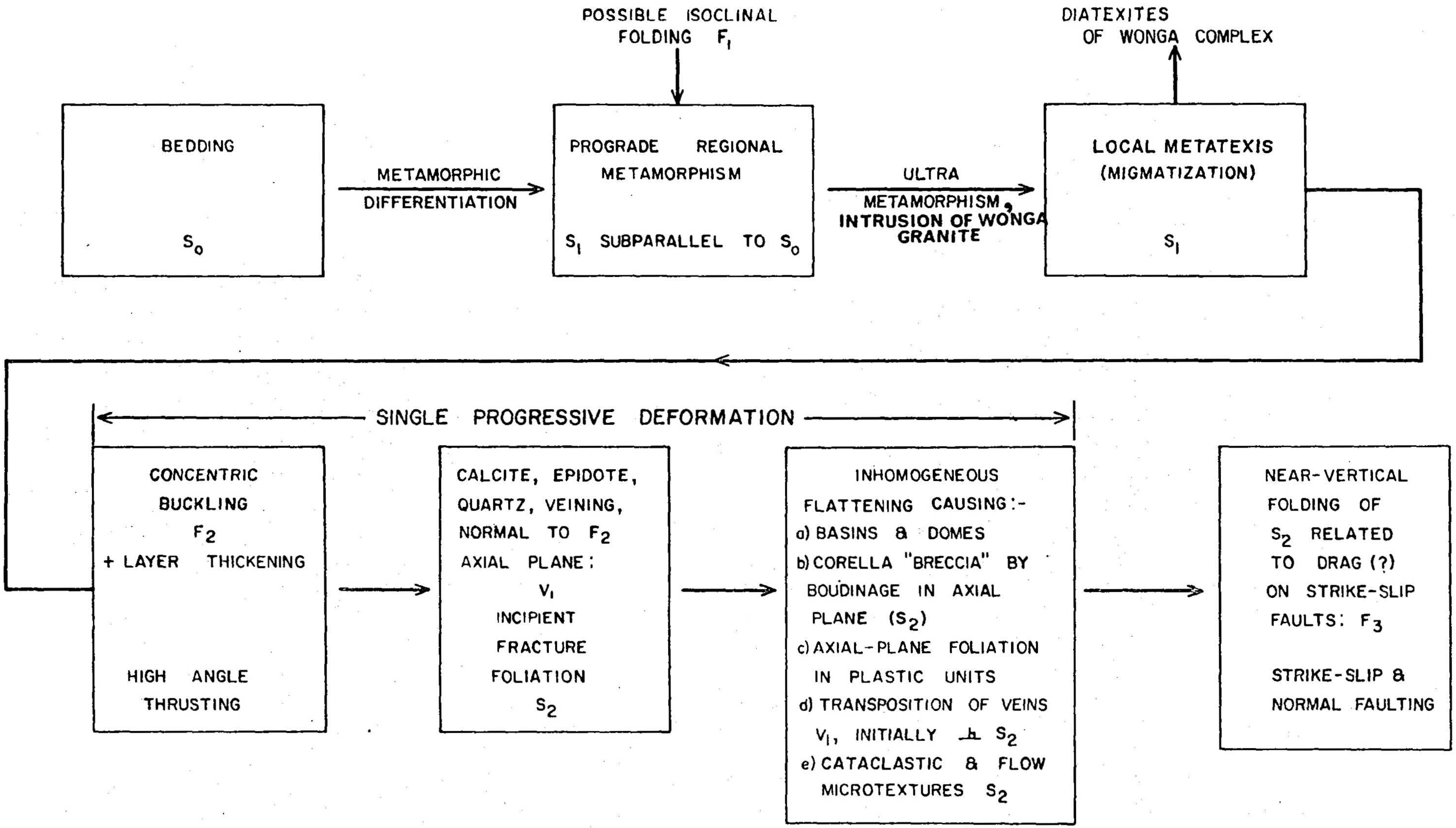
In contrast to the numerous deformation textures present in the units of the eastern succession, the psammites of the western succession possess few microstructures indicative of slight strain. Clasts are still well rounded and extinction is only slightly undulose. The biaxial nature of quartz recognized in the Wonga Granite and Corella Formation is absent from these psammites. These features correspond to the open, gentle warping and lack of distinct axial-plane foliation characteristic of the western succession. The different responses of eastern and western units to deformation was probably as much a result of the different competencies as it was of different intensities of deformation. Greater plasticity of the eastern succession units may explain their apparent greater deformation; by contrast a thick uniform sequence of psammities may be expected to deform brittly under equivalent stress conditions. This explains the greater intensity of faulting and absence of deformation textures in the western trough. Exceptions to this generalization are parts of the Surprise Creek Beds trough facies, which are extensively folded as a result of their high content of relatively incompetent shale and siltstone.

Structural synthesis

The following sequence of deformational (and thermal) events for the Sheet area is proposed (Fig. 59):

1. During a prograde regional metamorphism, differentiation produced layering, generally subparallel to bedding in calcareous siltstones and psammites of the Corella Formation, and mainly in the extreme east of the Sheet area where the metamorphic grade is highest. This metamorphism of middle to upper amphibolite grade may have been accompanied by deformation (F_1). If so, virtually complete transposition has occurred parallel to the original bedding in the high-grade areas, but, in lower-grade areas near the western limit of the eastern succession, sedimentary layering and depositional structures are evident - that is S_1 and F_1 are not significant structures.

239



Record 1977/4

F54/A2/127/A

Fig. 59 Schematic flow sheet of deformational and thermal events in the Prospector Sheet area.

240

2. The Wonga Granite intruded, and endogeneous segregation of pegmatoid and aplitic veins and layers concordant with the layering culminated in localized migmatization (cf. Holmquist, 1921; Mackenzie, 1957) or metatexis (Mehnert, 1968) of the Corella Formation. The relation of Wonga Granite evolution to this migmatization is equivocal, but at least some parts of the complex may have evolved from the Corella Formation through diatexis (Mehnert, 1968).

3. Concentric buckling (F_2) followed the thermal event; bedding and metamorphic differentiation layering were folded together. West-verging macroscopic folding gave way to 'break' thrusting along western limbs, thereby causing older units to be repeated in the eastern block, and producing north-trending fault traces parallel to the regional fold axes. Incipient fracturing of competent calc-silicate layers may have been associated with this stage (Derrick et al., 1971). Quartz, calcite, and epidote veining normal to the axial plane accompanied later buckling.

4. Inhomogeneous flattening led to basin-and-dome double folding with concomitant boudinage and transposition in the axial plane. This provides the most likely origin for the Corella 'breccia'. The earlier veins of calcite, epidote, and quartz were themselves partly transposed during this F_2 deformation. An axial-plane foliation (S_2) developed in the incompetent metamorphosed limestone layers, while a coarse fracture foliation was restricted to the competent calc-silicate and calareous psammite layers.

East-trending normal faults with displacement sense north-block-up developed owing to the dilatational effect of F_2 folding.

5. Major strike-slip faulting affected basement and eastern and western successions alike; folded units were offset along northeasterly or north-northeasterly and northwesterly or north-

northwesterly trending faults. Associated drag-folding (F_3) was of some significance, especially in the eastern succession.

GEOLOGICAL HISTORY

The geological history of the Sheet area is summarized in Table 21. The geological column is broken into four phases of deposition by three regional unconformities. The stratigraphic sequence deposited during each of these phases is defined as a group. The oldest of these is the Tewinga Group, which occurs in an uplifted median ridge that divides the depositional basin into an eastern and a western trough. Subsequent deposits have different characteristics in these two troughs and different group names are given to correlative sequences. Some groups are poorly developed or not exposed in the Prospector Sheet area. There are also some units that are informally defined (e.g., the Surprise Creek Beds). In the eastern trough the succession overlying the Tewinga Group (from youngest to oldest) is:

Mount Albert Group
Mary Kathleen Group
Malbon Group (not
exposed in the Sheet area).

In the western trough the succession is:

Mount Isa Group
Surprise Creek Beds
some informal units
Haslingden Group.

Kalkadoon-Leichhardt basement succession

Tewinga Group

The base of this group is not exposed. The oldest rocks are sheared and recrystallized dacitic and rhyodacitic porphyritic volcanics (Leichhardt Metamorphics), which probably formed from

242

TABLE 21. SUMMARY OF PRECAMBRIAN GEOLOGICAL HISTORY, PROSPECTOR SHEET AREA

Probable age (m.y.)	Sedimentation	Volcanicity	Intrusions	Tectonic events	Metamorphism	Remarks
			Minor dolerite dykes			Postdeformation
				Strike-slip faulting		
1400-1450			Burstall Granite equivalents in Wonga Granite(?)	Stabilization		Post-tectonic granite
				Major basin and dome deformation	Regional metamorphism	Possibly associated with Wonga Granite
?1500-?1600	Sequences of conglomerate, quartzite, siltstone, shale, chert, and dolomitic siltstone in Mount Isa Group and Surprise Creek Beds E,F,8	Possibly minor tuff towards top of exposed sequence		Transgression, then very stable basins and shelves established. Local unconformity or onlap at base of Warrina Park Quartzite		Warrina Park Quartzite contains orthoquartzite indicative of extensive reworking. Younger sediments deposited in broad shallow lacustrine or intracratonic sea environments. Minor syngenetic? and epigenetic copper deposits
?1600-?1670	Deposition of coarse sands and conglomerate (Surprise Creek Beds 4, A, & Deighton Quartzite) followed by maturing of source areas and deposition of fine flysch-like clastics (Surprise Creek Beds B,C,D, 5-7)					
	Erosion of areas of Haslingden Group			Regional unconformity		

TABLE 21. PAGE 2

Probable age (m.y.)	Sedimentation	Volcanicity	Intrusions	Tectonic events	Metamorphism	Remarks
?1670		Acid volcanics extruded to northwest of Sheet area	Possibly dolerite and Wonga Granite	Possible uplift in southwest	Contact metamorphism and migmatization?	Intrusion of final phases of Sybella Granite to south of Sheet area; Wonga Granite intrusion possibly associated with regional metamorphism
?1700–?1670	Sequence of conglomerate and quartzite then calcareous siltstone, limestone, minor quartzite, and shale in Mary Kathleen Group (in east). Conglomerate, grit, feldspathic sandstone, shale, limestone, and siltstone in Surprise Creek Beds (O-3, W-Z)	Minor basalt flows in upper part of Mary Kathleen Group		Transgression, then stable (carbonate) shelf established in east with minor ?regression		
	Erosion of areas of Haslingden Group			Regional unconformity		Overlying units show parallel or disconformable contacts with Haslingden Group, and unconformable contacts with basement
?1700				Uplift and possible block-faulting		
1780?–1700	Sequence of conglomerate, lithic sandstone, basalt, quartzite, siltstone, calcareous siltstone in Haslingden Group (in west)	Minor acid tuff at top of Haslingden Group. Extensive basalt flows in middle of Haslingden Group	Possible dolerite feeder dykes	Transgression with overlap to north and east. Deep fracturing and continental? basalt eruption		Clastic wedges and blanket deposits; deltaic or fluvial environment. Minor syngenetic? uranium epigenetic copper deposits. Equivalent deposition in east (Malbon Group) not exposed in Prospector Sheet area

TABLE 21. PAGE 3

Probable age (m.y.)	Sedimentation	Volcancity	Intrusions	Tectonic events	Metamorphism	Remarks
	Erosion of Tewinga Group			Regional unconformity		Poorly represented in Prospector Sheet area
?1870			Kalkadoon Granite(?)	Uplift and possible block-faulting	Contact metamorphism; recrystallization of Tewinga Group Volcanics	Two phases of Kalkadoon Granite identified in Sheet area
1870-1780?	Minor sandstone, quartzite, and silt-stone intercalated in Tewinga Group; becoming more abundant towards top	Porphyritic dacite and rhyodacite in Leichhardt Meta-morphics, amygdaloidal basalt in Magna Lynn Metabasalt, and porphyritic rhyolite in Argylla Formation	Porphyry dykes associated with Argylla Formation cut older formations. Kalkadoon Granite may be comagmatic with Leichhardt Metamorphics	Mature island-arc or continental volcanism. Possible uplift between Leichhardt Metamorphics and Magna Lynn Meta-basalt deposition		Lower Proterozoic to earliest Carpentarian deposits. Low relief and minor shallow-water in-cursions fluvio-lacustrine? Minor epigenetic copper deposits
1930						Possible event in pre-Carpentarian basement (not exposed)

245

ash flows and ash falls. They have some characteristics of continental volcanics. Minor shallow water sedimentation occurred during this volcanism, which terminated with the deposition of rhyolitic agglomerate and fluidal rhyolite and possibly with the intrusion of the Kalkadoon Granite.

Subaerial flows of amygdaloidal basalt with minor sedimentary intercalations (Magna Lynn Metabasalt) were extruded over the acid volcanics. Minor sedimentary intercalations were deposited in shallow-water fluvial or near-shore environments. The middle of the formation contains a sequence of basic tuff indicating a short period of explosive eruptive activity.

A younger sequence of acid volcanics (Argylla Formation) overlying the Magna Lynn Metabasalt contains extensive porphyritic, generally rhyolitic, ash flows or lava flows which are separated by thin sedimentary interbeds. Some feldspar porphyry dykes and sills were emplaced in the older rocks. Minor tuffs and andesitic flows were erupted later in the deposition of this formation. Volcanicity waned, and the proportion of sediment increased towards the top of the formation. The sediments indicate a shallow shelf or fluvial environment.

The Kalkadoon Granite intruded at about this time, or was comagmatic with the Leichhardt Metamorphics. The median ridge was uplifted, separating the eastern and western troughs. Extensive block-faulting controlled the shape of the western trough and influenced erosion of the Tewinga Group. Early phases of the Wonga Granite may have intruded the Tewinga Group at this time.

Western and eastern successions

Haslingden Group

The basal conglomeratic and labile sandstones of this group are not exposed in the Prospector Sheet area; the overlying quartzose psammites (Mount Guide Quartzite in the south and Leander Quartzite in the west) are evidence of near-shore marine?

sedimentation in a trough that probably resulted from block-faulting.

The overlying basaltic flows of the Eastern Creek Volcanics began to fill the trough; evidence of onlap to the north and east is provided by the basalt and interbedded conglomerate overlying the Tewinga Group in the north and the thinning of the basalts to the east. The amygdaloidal basalts may have been deposited subaerially but intercalations of sandstone and calcareous siltstone indicate that the environment was lacustrine or shallow marine. A temporary cessation of volcanism resulted in the deposition of a thick sequence of dark labile and quartzose sandstone and shale (Lena Quartzite Member). Subsequent basalt extrusion was less frequent, and sedimentary intercalations make up a large proportion of the top member of the Eastern Creek Volcanics.

The Myally Subgroup contains quartzose labile psammites, siltstone, oolitic dolomite, and minor conglomerate which form a thick blanket or wedge-shaped clastic sheet overlying the Eastern Creek Volcanics and thinning eastwards. The sediments were probably deposited in shallow water - in a shelf, littoral, or deltaic environment. Carbonate shoals developed towards the end of this sedimentation. A thin unit of rhyolitic tuff, phyllite, and siltstone at the top of the subgroup appears to have been deposited in shallow water, but the return of volcanicity was probably accompanied by instability.

Lower Surprise Creek Beds (0.3, W-Z), and Mary Kathleen Group

The sea transgressed from the east across the Kalkadoon-Leichhardt and Ewen blocks, and the Haslingden Group block farther west. Across a broad shelf cut by north-trending deeper-water troughs, basal grit and quartzite were deposited (Ballara Quartzite and units W and O of the Surprise Creek Beds) as blanket sands which may have covered the Kalkadoon-Leichhardt block. These were followed in the east by the deposition of calcareous

247

siltstone, carbonate rocks and psammite (Corella Formation), and in the west, dolomite, siltstone and psammite of the Surprise Creek Beds (units 1, 2 and 3, and X, Y and Z).

Middle Surprise Creek Beds (4-7, A-D) and Mount Albert Group

A regional uplift followed by erosion resulted in a regional unconformity and subsequent deposition of coarse psammites in shelf or fluvial environments (Deighton Quartzite in the east, units A and 4 of the Surprise Creek Beds in the west). A maturing of the source areas and increasing crustal stability resulted in the deposition of thick sequences of siltstone (units B, C, D, and 5, 6, 7 of the Surprise Creek Beds). Equivalents of these units are not preserved in the eastern succession in the Prospector Sheet area, but further south the White Blow Formation is probably equivalent.

Mount Isa Group and upper Surprise Creek Beds (8, E-H)

Stable shallow shelf conditions led to orthoquartzite deposition (Warrina Park Quartzite) at the base of the Mount Isa Group. Rapid transgression resulted in the deposition of siltstone, shale, chert, and calcareous siltstone in possibly deeper-water environments. In areas to the north and south chert and tuff beds appear in this sequence, but they have not been recorded in the Prospector Sheet area.

Units 8 and E of the Surprise Creek Beds are correlated with the lowest formation of the Mount Isa Group (Warrina Park Quartzite), and units F, 6, and H with the Moondarra Siltstone, Breakaway Shale and Native Bee Siltstone. No younger Precambrian rocks are preserved in the Prospector Sheet area.

Regional metamorphism and deformation

It has not been possible to determine the exact nature of metamorphism and deformation that occurred during the sedimentation and igneous activity described above because they have been largely obscured by a younger widespread deformation that was accompanied by regional metamorphism. Faulting, tilting, and folding of strata during sedimentation have been hypothesized, and contact metamorphism and local intense deformation probably occurred at the margins of the large granite plutons.

During this younger deformation, meridional doubly plunging folds were formed as a result of inhomogeneous strain. A north-trending cleavage developed. The region appears to have been compressed in an east-west direction and uplifted by this deformation. The accompanying regional metamorphism and possibly the Wonga Granite intrusion produced greenschist and lower amphibolite facies metamorphic mineral assemblages. Continued deformation caused north-trending reverse faulting and later east-trending normal faulting.

Granites intruded the eastern succession to the east and south of the Prospector Sheet area, possibly during and after this deformation. This intrusive event was followed by strike-slip faulting in conjugate sets trending northeast and northwest. Minor dolerite intrusions are the youngest Precambrian event that is recognized in the Prospector Sheet area, although younger terrestrial? sediments are known in other areas.

ECONOMIC GEOLOGY

History of mining

Gold was reported from Sunday Gully in 1867. The major gold production in the Sheet area was from the Bower Bird Gold Field, with some minor production from Sunday Gully and Doughboy Creek. A crushing plant and a small cyaniding plant were established in the Bower Bird area. Almost 1000 kg of gold had been produced by 1872 when most miners left for the Palmer Gold Field. Since then there has been negligible production of gold except as a byproduct of the smelting of copper.

Although Ernest Henry had reported 'extensive copper deposits' in the Cloncurry district in 1865 (Blainey, 1960), and other copper discoveries were made in the Prospector Sheet area between 1880 and 1900, development was retarded by the lack of communications. This situation changed in 1908 with the completion of the rail link to Townsville from Cloncurry. There was now a rapid and economical method for shipping ore to Townsville and thence overseas, or to southern states, for treatment. From that time, production increased and the region had its highest production in the years 1911-1920. Blast furnaces were employed at smelters erected at Mount Elliot, Hampden, Rosebud, and Mount Cuthbert.

The release of government control of the copper market in 1918 resulted in a decrease in the price of copper. Production declined, and, when the last smelter was closed in 1920, even small scale production was not economically viable despite the construction of the Mackay electrochemical plant in Cloncurry in 1928, the plant was never used.

The discovery of the Mount Isa deposit in 1923 was to be a controlling factor on mining in the district in subsequent years. Large scale production at Mount Isa Mines began in 1931, after the completion of the lead smelter. However, it was not until 1943 that small copper mines received any incentive to increase production. At this time, the lead smelter was converted to treat copper ore, as a wartime measure. In 1946, the smelter reverted to lead production and copper production declined, until the completion of the new copper smelter at Mount Isa Mines in 1953. Since then, small mines have flourished, albeit intermittently, and with increases in the price of copper and payment for the gold content of the ore, it has become economically viable to process ore from some of the old mine dumps. The payment for gold in the ores had not always been made before the copper smelter was established at Mount Isa Mines Ltd.

Mining activity in the Prospector Sheet has been less extensive than in Sheet areas to the south, and only 41 mines have recorded production (Table 22). The first Authority to Prospect in the Prospector Sheet area was taken out by Broken Hill South Ltd in 1947. A summary of all prospecting activity in the Prospector Sheet area, until December 1973, is presented in Tables 23 and 24.

Figures 60 a, b show the areal extent of each company's Authority to Prospect (A to P). Each rectangle represents the Prospector Sheet area and the central map is a simple geographical key for the Sheet area. Horizontal shading indicates the area of the original A to P, with vertical and diagonal shading representing the area of the A to P after the first and second reductions respectively (after Noon, 1974).

Copper has been the major mineral resource in the Sheet area. Gold, silver, and tungsten have also been mined. A variety of minerals has been found in the Sheet area, and the more important metals and their ores are discussed in alphabetical order below. This is followed by a section on non-metallic minerals.

Metallic minerals

Arsenic

The only reported occurrence of arsenic is at the Yamamilla mine (Nippon Mining, 1965), where minor amounts of olivenite are associated with malachite, chrysocolla, chalcanthite, brocanthite, chalcocite, and covellite.

Cobalt

Cobalt deposits are confined to the northeast corner of the Sheet area, at the northern end of a belt of cobalt mineralization which extends from Kajabbi to Selwyn (Carter et al., 1961). The Pinkie (Pink Cap) Lode is 20 km west of Kajabbi, and the ore

251

TABLE 22. PRODUCTION FROM MINES IN THE PROSPECTOR 1:100 000 SHEET TO DECEMBER 1972

Mine	M.L. No.	Years of Production	Ore (Tonnes)	Copper (Tonnes)	Au (g)	Ag (g)	W (Tonnes)
Azurite		1939-40	16.90	3.31			
Barbara	(6022)	1970-71	270.32	29.85			
Bessie	5853	1966	33.02	2.28			
Brumby Ridge	6935	1971	29.92	1.65			
Dry Dog	8836	, 1968	20.78	2.40			
Fishers Standby	(6168)	1939, 1966-67	118.05	9.63			
Fishers Standby Ext.		1967	39.79	1.78			
Fishers Standby Ext. No. 1		1967-68	45.20	2.71			
Florin	4104	1967, 70	84.75	4.94			
Gertrude					36 790		
Great Northern	5799	1966	6.83	0.87			
Jamie	5629	1966-67	31.0	2.44			
Lady Hall	6524	1970	200.39	6.41			
Last Chance	5772	1927, 34, 38-39, 66-68	115.19	12.03	244.2	95.6	
Lillymay	4522	1953-57, 67-69	2536.54	181.65			
Lillymay No. 1	Clm	1969-72	2268.33	157.43			
Lillymay Ext. No. 1	6766	1967-69	192.06	17.79			
Lone Hand	5785	1906, 67-68	27.50	1.83			
Manxman	5785	1944-46, 54-61, 68-69	2302.5	215.71			
Margaret	5428	1917-18, 44-45, 1966	178.91	3.74+			
Mt Metallic	RC 310	1906-07	56.19	?			
Mt Olive	5525	1944-45, 49, 53-60, 67, 69-70	2857.27	290.48			
Mt Olive No. 3		1968-69	701.49	45.50			
Mt Remarkable		1906-07	71.12	20.62E			
Prospector Ck		1906	59.95				
Queen Elizabeth	(5526)	1963-64, 66, 69	402.13	18.70			
Queenslander	436	1906	7.11	?			
Referee	(5666)	1905, 06, 26-30, 38-39, 44, 49-51, 53-57	5217.46	549.95			
Referee Ext.		1966-69	148.47	8.28			
Referee Ext. No. 1	5906	1968-69	60.72	1.95	16 088.6	382	
Referee No. 1		1969-70	464.13	44.91			
Referee No. 2	6054	1969-71	660.72	49.95			
Referee No. 3		1969	23.21	1.76			
Referee South		1971-2	343.63	19.42			
Referee West		1969-71	441.14	15.27			
Sally Ann	6431	1969	41.03	2.34			
Scheelite							2.88
T.C.	4093	1907, 08, 39-42,51, 68-69	577.16	53.51+	293.3		
Victoria					2 375.7		
Western	6221	1939-41, 56, 69, 71	125.09	25.17			
Yamamilla	(4096)	1941,56,69,71,1941-42,48,53-56,60-62,70	737.16	58.04	17.48	198.77	

TABLE 23
SUMMARY OF WORK BY COMPANIES ON PROSPECTOR 1:100 000 SHEET

A to P No.	5	84	90	136	141	149	232	269	292	296	361	365	367	380
Air Photography														
Photogeological Map									x	x		x	x	x
Geological Map	x		x		x		x		x	x		x	x	x
Detailed Geological Map								x		x			x	
Stream Sed. Sampling							x	x	x		x	x	x	x
Detailed Geochem.								x						
Costeaning								x						
Drilling - Rotary, Percuss. T.D. (m)													1400 m	
No. of holes													44	
Drilling - Diamond, T.D. (m)								786					600 m	
No. of holes								7					4	
Shafts, Adits														
Air Magnetometer									x					
" Scintillometer		x							x					
" Electromag									x					
Magnetometer														
Electromagnetic													x	
Electric (IP)								x					x	
Electric (SP)														
Radioactivity	x			x										
Anomaly Evaluation		x		x		x		x			x			
Petrography									x					
Mineralogy			x			x	x	x	x		x	x	x	x
General Geology	x						x	x	x	x	x	x	x	x
Prospect Evaluation							x	x						x

TABLE 23 (contd)

A to P No.	484	588	635	668	723	751	768	866
Air photography	4 chs:1"							
Photogeological Map	x			x				
Geological Map				1"=2000'				
Detailed Geological Map	x			x		x	x	x
Stream Sed. Sampling	x			x			x	
Detailed Geochem.								
Costeaning				x				
Drilling - Rotary, Percuss. T.D. (m)			x					
No. of holes								
Drilling - Diamond, T.D. (m)	143 m	2						
No. of holes	3							
Shafts, Adits								
Air Magnetometer					x			x
" Scintillometer			x					
" Electromag		x			x			
Magnetometer								
Electromagnetic								
Electric (IP)								
Electric (SP)								
Radioactivity	x		x					
Anomaly Evaluation	x	x		x	x			
Petrography			x					
Mineralogy	x			x	x		x	
General Geology	x		x	x	x		x	
Prospect Evaluation								

Reports not available Dec '73 for following A's to P:- 169, 204, 1035, 1133, 116 , 1234, 1284, 1311, 1312.

TABLE 24.

COMPANY REPORTS FOR AUTHORITIES TO PROSPECT

A to P No.	Company	Date Granted	Date Revoked	Qd Mines Dept Company Report No.
5	Uranium Search	5/54	4/55	3006
84	Rio Tinto	1/57	10/58	151, 243
90	MIM	4/57	8/57	227
136	Qld Mines	6/59	3/60	483, 537
141	Rio Tinto	6/59	11/60	353, 380, 2228
149	Qld Mines	9/59	5/60	537
169	Rio Tinto Southern & CRA	10/60	9/63	NR
204	MIM	10/62	10/66	NR
232	CRA Expl.	10/63	10/64	1288, 1289
269	Nippon Mining	1/65	3/67	1605, 1684, 1890, 1945, 2150, 2164
292	MIM	7/65	6/69	2559, 3832
296	Kern County Land	11/65	10/67	2082, 2083, 2577
361	Kennecott	8/66	2/68	2107, 2279, 2280, 2286, 2533, 2551, 2696
365	CEC	12/66	2/68	NA
367	CEC	12/66	2/68	2550
380	CRA Expl.	8/66	12/68	2110, 2185, 2261, 2451, 2789
484	Mineral Deposits	3/68	9/72	NA
588	CEC	3/69	2/71	3516, 3517
635	Qld Mines	7/69	10/70	3289
668	Anaconda Australia	10/69	10/71	3706
723	Placer Prospecting	3/70	6/71	3497
751	Aust. Ores and Minerals	3/70	3/71	3523
768	Aust. Ores and Minerals	4/70	3/71	3522
866	Naylor and Edson	11/70	12/72	NA
1035	Tasman Minerals	5/72	9/73	NR
1133	Oilmin	11/72		NR
1165	Aquitaine	2/73		NR
1234	AGIP Nucleare	6/73		NR
1284	AGIP Nucleare	8/73		NR
1311	Aquitaine	11/73		NR
1312	Aquitaine	11/73		NR
1330	CRA Expl.	12/73		NR
1347	Union Miniere	2/74		NR
1370	Union Miniere	6/74		NR
1417	Australian Hanna	9/74		NR

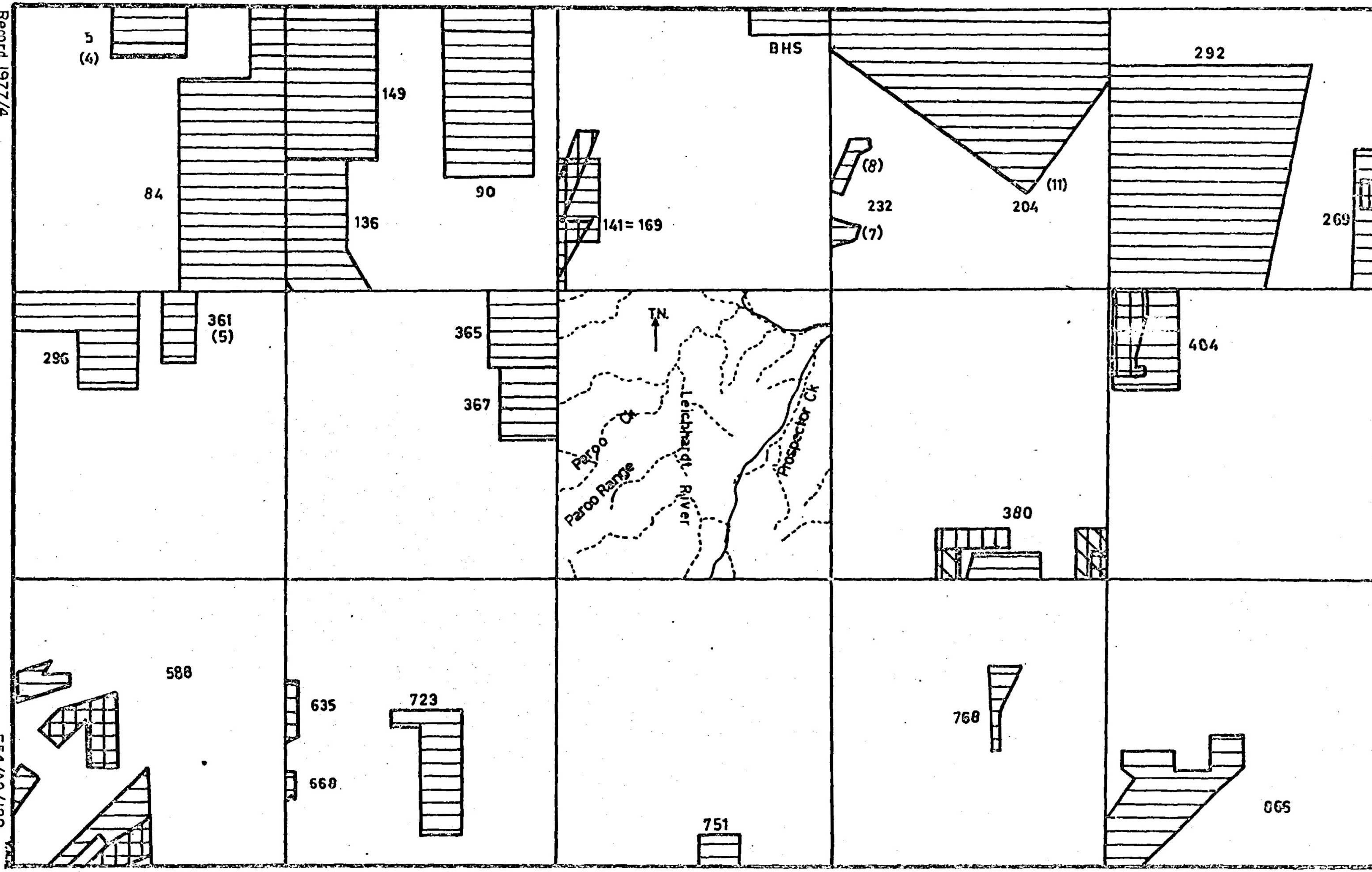
NA - Not available to public - confidential reports only
NR - No reports available

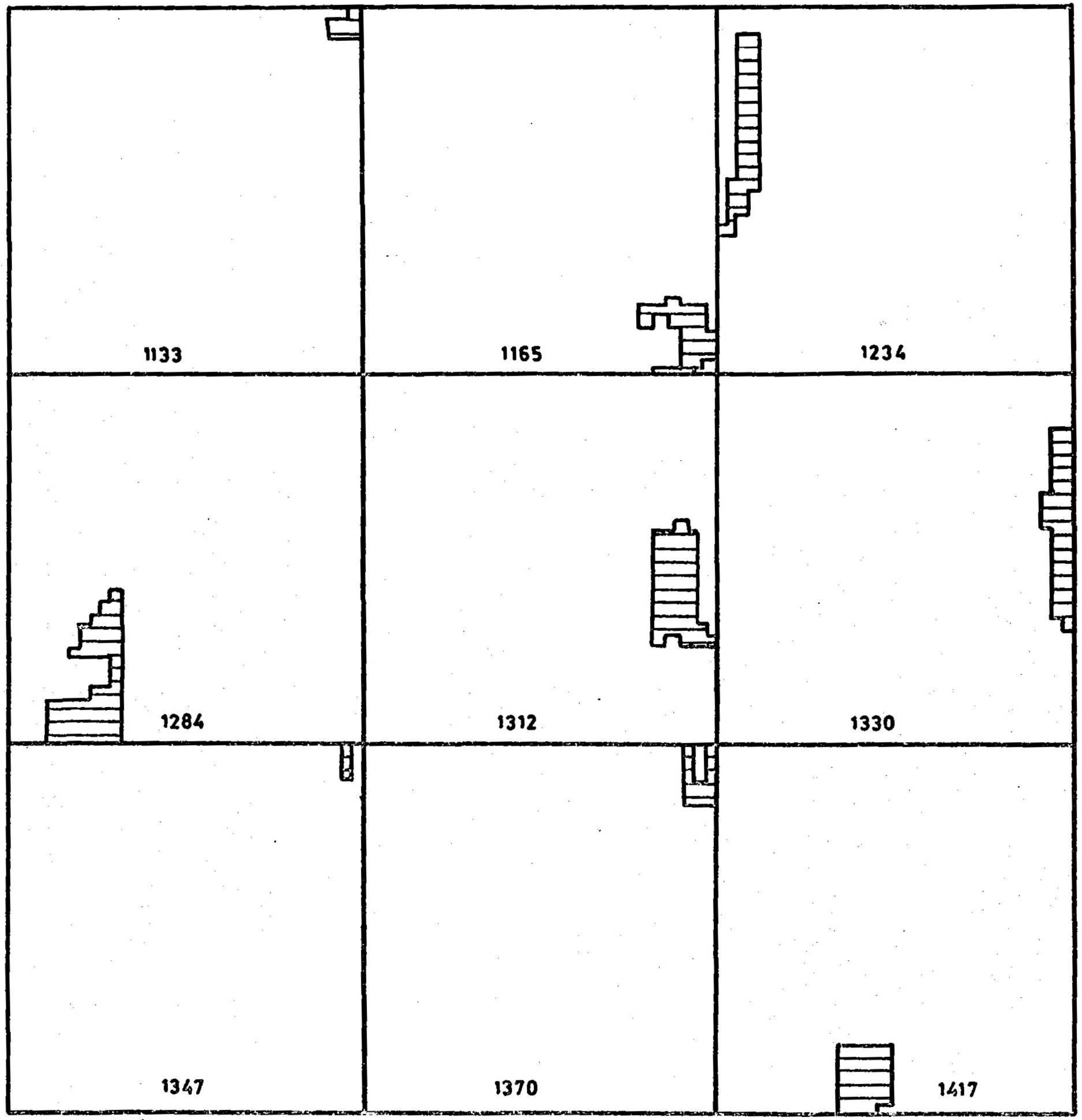
Record 1977/4

AUTHORITIES TO PROSPECT, PROSPECTOR SHEET AREA

FIGURE 60a

F54/A2/189





Record 1977/4 F54/A2/190

AUTHORITIES TO PROSPECT, PROSPECTOR SHEET AREA

FIGURE 60b

257

is associated with quartz and calcite in porphyry, amphibolite, and schist. The ore is malachite, azurite, chalcopyrite, and erythrite and analyses range from 0.7 to 5.3 percent cobalt (Rayner, 1938). There has been no recorded production from this lode in recent times.

Copper

Carter et al. (1961, p. 203) summarized the history and production of copper mining in northwest Queensland. Detailed accounts of the controls of mineralization of copper deposits in the Cloncurry area are in Carter et al. (1961), Derrick et al. (1971), and Wilson, Derrick & Hill (1972).

Small-scale copper deposits were known in the Sheet area in the 1880s, but prospecting and development was hindered by the lack of a treatment plant and lack of cheap transport. Mining activity increased with the completion of the rail link to Cloncurry from Townsville in 1908. Mines which stepped up production in the years immediately before the completion of the rail link included Referee, TC, Queenslander, Mount Remarkable, and Prospector Creek. Mining activity was reduced between 1918 and 1940 owing to low copper prices and industrial trouble. Since that time there has been intermittent production for many mines in the Sheet area. Up to December 1972 there had been a recorded production of 21 513 tonnes of ore at an average grade of 8.67 percent Cu. The major producing mines (and the tonnes of copper produced) are Referee (550 tonnes), Mount Olive (290), Manxman (216), Lillymay (182), Lillymay No. 1 (157), Yamamihla (58), and TC (54).

Copper deposits are widely distributed throughout the Sheet area. The Leichhardt Metamorphics, Magna Lynn Metabasalt, Argylla Formation, and Kalkadoon Granite contain prospects ranging in size from small gougings to larger mines such as Lillymay, Mount Olive, and Referee. Finely disseminated pyrite and chalcopyrite occur in the basalt of the Eastern Creek Volcanics. Concentration in shear zones and in vesicles of amygdaloidal basalts has resulted in minor deposits. Small copper occurrences are recorded in the psammitic and pelitic Myally Subgroup, Mount Isa Group, and Surprise Creek Beds, and to a greater extent in the calcareous and pelitic Corella Formation. The Leander, Mount Guide, and Deighton Quartzites are barren. There are no reported copper occurrences in the Wonga Granite in the Sheet area.

The major copper mines in the Sheet area are associated with siliceous lodes along faults and shears. Many mines are small gouger shows consisting of small open cuts or shafts rarely more than 10 to 15 m deep, but the larger mines are of the order of 30 to 40 m deep. Secondary mineralization is the predominant source of ore. The common ore minerals are malachite, azurite, chalcocite, and cuprite, with minor amounts of tenorite, chrysocolla, covellite, and bornite.

Primary mineralization is rarely of sufficiently high grade to warrant mining. The primary ore intersected is usually chalcopyrite, with different amounts of pyrite, in a siliceous gangue (e.g., Referee) or a calcitic gangue (e.g., Margaret). Chalcocite is reported as the primary mineralization in silty sandstone of the Surprise Creek Beds 6 km south-southwest of Jamie prospect.

Some gossanous zones in the dolomitic unit 1 of the Surprise Creek Beds contain up to 3640 ppm copper.

Gold

Gold was discovered at Sunday Gully in 1867, and this and other subsequent discoveries were responsible for the movement of population to the Cloncurry region in the latter part of the nineteenth century. Gold was mined intermittently until the mid 1940s. Since then production has been insignificant. Total recorded production for the region is 2800 kg, of which 75 percent was derived from auriferous copper deposits (Carter et al., 1961).

Significantly, the major producing gold mines in the Prospector Sheet area were not associated with copper. With the exception of Referee Extended No. 1, which produced 16.09 kg Au, the association of gold with copper is limited in the Sheet area, only being reported from Last Chance (244.2 g), TC (293.3 g), and Yamamilla (17.48 g).

Primary deposits are of two types; (a) reefs at the contact between quartzite and basic volcanics and (b) small fissure veins in slates and quartzites. Reef deposits were worked at two mines: Victoria produced 23.38 kg Au and Gertrude 36.79 kg Au. Smaller-scale mines were Lily of the Valley, Bertha Gully, and Two Mile Creek, all of which were in the Bower Bird/Doughboy Creek area (Honman, 1937).

Alluvial workings have been reported at Borah Creek, Sunday Gully, McPhails workings, and Coleman Creek.

Lead

There are no known economic lead deposits in the Prospector Sheet area. A minor occurrence of galena altering to cerussite was reported from the Doughboy Lode in the Doughboy Creek area (Denmead, 1937a).

Silver

The only reported production of silver is in association with gold/copper deposits: from Last Chance (95.6 g), Referee Extended No. 1 (382 g), and Yamamilla (198.8 g). There is no information on the associations or mineralogy of the silver in these deposits.

Tungsten

A small amount of scheelite (2.88 tonnes) was produced from the Scheelite mine, 20 km south-southwest of Kajabbi. There has been no recorded production since 1932.

Uranium

Several occurrences of radioactive minerals have been recorded in the Prospector Sheet area. Brooks (1960) noted that the Barrier mine had estimated reserves of 600 tonnes per vertical metre at an average grade of 0.1 percent U_3O_8. It is in carbonated, chloritized and albitized metabasalts of the Eastern Creek Volcanics in the northwest of the Sheet area. Other small mines located in metabasalts were reported in the Paroo Creek area, and include Mount River (av. 0.05 percent U_3O_8). Metasedimentary interbeds within the Eastern Creek Volcanics were also shown to be favourable sites for uranium deposits, such as Morning Star mine (av. 0.04% U_3O_8) and Mount Spring mine (av. 0.14% U_3O_8) (Brooks, 1960).

In general, the orebodies are lensoid and structurally, rather than stratigraphically, controlled, with the major mineralization consisting of uraninite, brannerite, and uraniferous magnetite. The mode of formation is considered to be hydrothermal replacement. The occurrence of uranium in association with copper is uncommon.

In the southeast corner of the Sheet area, numerous radioactive anomalies have been recorded (Shields, 1959). All these anomalies occurred in the gneissic micaceous phase of the Wonga Granite. No economic deposits were located.

Ridgway (1960) recorded the presence of carnotite in association with magnetite, pyrite and chalcopyrite in limestone and metasediments of the Corella Formation.

Zinc

No economic deposits of zinc have been reported in the Sheet area. Anomalies have been investigated in the Surprise Creek Beds (Fitch, 1966; Fishburn, Fitch, Graham, & Robinson, 1967), the Mount Isa "shales" (Muceniekas, 1964), and the

261

Leichhardt Metamorphics (Jones, 1967). Some gossanous areas of dolomite in unit 1 of the Surprise Creek Beds contain up to 2340 ppm zinc.

Non-metallic minerals

Construction materials

There is no shortage of aggregate in the Sheet area. Fill for roadworks is available, virtually in situ, in the form of siliceous scree material.

Sand and gravel deposits suitable for concrete are available in most stream beds. Coarse aggregate for the concrete in the Julius Dam was available in situ in the Leichhardt River and Paroo Creek (Hofmann & Barker, 1973).

Building stone and facing stone in the form of sandstone and granite is plentiful, but is rendered uneconomic by its distance from potential building sites.

Kyanite

Kyanite occurs as bladed aggregates in a biotite schist in a fault zone west of the TC mine. It is of mineralogical interest only.

Quartz

There are no reported deposits of pure silicate in the Sheet area. Fault fillings along the Mount Remarkable Fault zone, and orthoquartzites of the Warrina Park Quartzite, have the greatest potential for use as flux.

Water

Water resources in the area are described in the Introduction.

ACKNOWLEDGEMENTS

The fieldwork on which this report was based was greatly assisted by the staff of Mary Kathleen United Ltd, Mr C. Campbell of Rosebud station, Mr J. Banning of Calton Hills station, and Mr D. Fisher of Referee mine. Useful discussions were had with geologists of several mining companies, in particular, Anaconda Australia Inc., Aquitaine Australia Minerals Pty Ltd, Carpentaria Exploration Co. Ltd, Mount Isa Mines Ltd, and Pacminex Pty Ltd. Many BMR and GSQ staff members assisted in the preparation of this report, and we are particularly grateful to W.B. Dallwitz, D.B. Dow, D.H. Blake, and A.R. Jensen.

263

BIBLIOGRAPHY

AGGSNA, 1936 - Report for period ended 31st December, 1935. Aer. Sur. N. Aust.

__________, 1937 - Report for period ended 31st December, 1936. Aer. Surv. N. Aust.

ALLEN, J.R.L., 1963 - The classification of cross stratified units. With notes on their origin. Sedimentology, 2, 93-114.

ANDERSON, E.M., 1951 - THE DYNAMICS OF FAULTING. Oliver & Boyd, Edinburgh.

BAARS, D.L., 1961 - Permian Blanket sandstones of Colorado Plateau; in PETERSON, J.A., & OSMOND, J.C. (eds) - GEOMETRY OF SANDSTONE BODIES. Amer. Assoc. Petrol. Geol.

BALL, L.C., 1908 - Cloncurry copper mining district, parts 1 and 2. Geol. Surv. Qld. Publ. 215.

BATTEY, G.C., 1961 - Authority to Prospect No. 153M "Leichhardt", Progress Report No. 5 for the quarter ending 31/3/1961. Mount Isa Mines Ltd (unpubl.).

BENNETT, E.M., 1965 - Lead-zinc-silver and copper ore deposits of Mount Isa, in GEOLOGY OF AUSTRALIAN ORE DEPOSITS (2nd Ed). 8th Comm. Min. Metall. Congr., 1, 233-46.

__________, 1970 - A. to P. 588M (Eastern Creek) report for year ended 31st December 1969. Carpentaria Exploration Co. Pty Ltd (unpubl.).

BLAINEY, G., 1960 - MINES IN THE SPINIFEX. Angus & Robertson, Sydney.

264

BLANCHARD, R., & HALL, G., 1937 - Mt Isa ore deposition. Econ. Geol., 32, 1042-1057.

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

BROOKS, J.H., 1955 - Monthly reports, inspections of uranium leases, Cloncurry field, July-December 1955. Geol. Surv. Qld (unpubl.).

__________, 1957 - Copper mining in the Cloncurry Mineral Field. Geol. Surv. Qld Publ. 285.

__________, 1960 - The Uranium deposits of northwestern Queensland. Geol. Surv. Qld Publ. 297.

BROOKS, J.H., & SIMMONDS, N.A.H., 1964 - Copper mining in the Cloncurry and Mount Isa Fields, 1962. Geol. Surv. Qld Rep. 4.

BROWN, D.A., CAMPBELL, K.S.W., & CROOK, K.A.W., 1968 - THE GEOLOGICAL EVOLUTION OF AUSTRALIA AND NEW ZEALAND. Pergamon Press, Sydney.

BUDDINGTON, A.F., 1959 - Granite emplacement, with special reference to North America. Bull. geol. Soc. Am., 70, 671-747.

CAMERON, W.E., 1900 - Recent developments in the copper mining industry in the Cloncurry district. Geol. Surv. Qld. Publ. 153.

CAMPBELL, C.B., 1954 - Preliminary report on the uranium deposits of northwestern Queensland. Rep. geol. Surv. G.B. atom. En. Div. 172 (unpubl.).

CARR, M.J., 1971 - Final report on AP. 723M Mount Isa Cloncurry Mineral Fields. Placer Prospecting (Aust.) Pty Ltd (unpubl.).

CARRUTHERS, D.S., 1954a - Morning Star No. 1 and No. 2 uranium leases. Geol. Surv. Qld (unpubl.).

________, 1954b - Mount Spring-Mount Rover group of uranium leases. Geol. Surv. Qld (unpubl.).

CARTER, E.K., 1955 - Radioactive occurrences Cloncurry Field, Queensland. Qld Govt Min. J. 56, 428-33.

______, 1955 - The Precambrian of northwestern Queensland. Bur. Miner. Resour. Aust. Rec. 1955/74 (unpubl.).

______, 1956 - Review of stratigraphic nomenclature for the Precambrian of northwestern Queensland. Bur. Miner. Resour. Aust. Rec. 1956/58 (unpubl.).

______, 1957 - The Precambrian orogenic belt of northwestern Queensland. Bur. Miner. Resour. Aust. Rec. 1957/1 (unpubl.).

CARTER, E.K., & BROOKS, J.H., 1960 - The Precambrian of northwestern Queensland. J. geol. Soc. Aust., 7, 21-62.

CARTER, E.K., BROOKS, J.H., & WALKER, K.R., 1961 - The Precambrian mineral belt of northwestern Queensland. Bur. Miner. Resour. Aust. Bull. 51.

CHINNERY, M.A., 1966 - Secondary faulting. Can. J. Earth Sci., 3, 163-90.

COBBOLD, P.R., COSGROVE, J.W., & SUMMERS, J.M., 1971 - Development of internal structures in deformed anisotropic rocks. Tectonophysics, 12, 23-53.

CONOLLY, J.R., 1969 - Models for Triassic deposition in the Sydney Basin. Geol. Soc. Aust. spec. Publ. 2, 209-23.

CONYBEARE, C.E.B., & CROOK, K.A.W., 1968 - Manual of sedimentary structures. Bur. Miner. Resour. Aust. Bull. 102.

CORDWELL, K.S., WILSON, G.L., & LORD, J.K., 1963 - Geology of the area south of Mount Isa and its application to the structural control of the Mount Isa orebodies. Proc. Australas. Inst. Min. Metall., 206, 29-62.

CROOK, K.A.W., 1960 - Classification of arenites. Am. J. Sci., 258, 419-28.

DAVID, T.W.E., 1932 - EXPLANATORY NOTES TO ACCOMPANY A NEW GEOLOGICAL MAP OF THE COMMONWEALTH OF AUSTRALIA. Commonw. Counc. Sci. Ind. Res., Melbourne.

DENMEAD, A.K., 1937a - A silver-lead prospect near Doughboy Creek, Kajabbi District. Qld Govt Min. J. 38, 354-5.

____________, 1937b - Referee Mine, Kajabbi. Geol. Surv. Qld (unpubl.).

DERRICK, G.M., 1974 - Stratigraphic and paleogeographic evolution and revolution in the Mount Isa area. Australas. Inst. Min. Metall., N.W. Qld Branch, Reg. Meet., 177-87

____________, 1976 - Mount Isa-Cloncurry Project; in Geological Branch summary of activities, 1976 Bur. Miner. Res. Aust. Rec 1976/90, 103-11 (unpubl.; also Bur. Miner. Resour. Aust. Rep. 196, in press).

DERRICK, G.M., WILSON, I.H., & HILL, R.M., 1976a - Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland. I: Tewinga Group. Qld Govt. Min. J. 77, 97-102.

267

__________, 1976b - Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland. II: Haslingden Group. Qld Govt. Min. J. 77, 300-306.

__________, 1976c - Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland. III: Mount Isa Group. Qld Govt. Min. J. 77, 402-405.

__________, 1977a - Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland. VI: Mary Kathleen Group. Qld Govt. Min. J. 78.

__________, 1977b - Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland. VIII: Mount Albert Group. Qld Govt Min. J. 78.

DERRICK, G.M., WILSON, I.H., HILL, R.M., & MITCHELL, J.E., 1971 - Geology of the Marraba 1:100 000 Sheet area Qld. Bur. Miner. Resour. Aust. Rec. 1971/56 (unpubl.).

DERRICK, G.M., WILSON, I.H., HILL, R.M., GLIKSON, A.Y., & MITCHELL, J.E., in press - Geology of the Mary Kathleen 1:100 000 Sheet area, northwestern Queensland. Bur. Miner. Resour. Aust. Bull. 193.

DE SITTER, L.V., 1958 - STRUCTURAL GEOLOGY. McGraw-Hill, New York.

DONATH, F.A., 1961 - Experimental study of shear failure in anisotropic rocks. Bull. geol. Soc. Am., 72, 985-9.

DUNN, P.R., PLUMB, K.A., & ROBERTS, H.G., 1966 - A proposal for time-stratigraphic sub-division of the Australian Precambrian. J. geol. Soc. Aust., 13, 593-608.

268

DUNSTAN, B., 1913 - Queensland mineral index. Geol. Surv. Qld. Publ. 241.

EDWARDS, A.B., & BAKER, G., 1954 - Scapolitization in the Cloncurry district of northwestern Queensland. J. geol. Soc. Aust., 1, 1-33.

FARQUHARSON, R.B., & WILSON, C.J.L., 1971 - Rationalization of geochronology and structure at Mt Isa. Econ. Geol., 66, 574-82.

FISHBURN, D., 1966 - AP. 361M - Area 5 (Surprise Creek). Kennecott Exploration (AAust.) Pty Ltd (unpubl.).

FISHBURN, D., FITCH, F.A., GRAHAM, M.J. & ROBINSON, A.D., - 1967 - AP 361M - quarterly report 1 April-30 June. Kennecott Exploration (Aust.) Pty Ltd (unpubl).

FITCH, F.A., 1966 - AP 361M and 362M. Reports for period 1 July-30 September, 1966. Kennecott Exploration (Aust.) Pty Ltd (unpubl.).

FLEUTY, M.J., 1964 - The description of folds. Proc. Geol. Ass., 75, 461-92.

FLINN, D., 1962 - On folding during three-dimensional progressive deformation. Quart. J. geol. Soc. Lond., 118, 385-433.

_________, 1965a - On the symmetry principle and the deformation ellipsoid. Geol. Mag., 102, 36-45.

_________, 1965b - Deformation in metamorphism; in PITCHER, W.S., & FLINN, G.S. (eds.) - CONTROLS OF METAMORPHISM. Oliver & Boyd, Edinburgh.

269

FOLK, R.L., 1968 - PETROGRAPHY OF SEDIMENTARY ROCKS. Hemphill's Bookstore, Austin, Texas.,

GEOPHOTO RESOURCES LTD, 1967 - AP 380M, extension of areal geology and structural interpretation maps (unpubl.).

GLIKSON, A.Y., 1972 - Structural setting and origin of Proterozoic calcsilicate megabreccias, Cloncurry region, northwest Queensland. J. geol. Soc. Aust., 19, 53-63.

GLIKSON, A.Y., & DERRICK, G.M., 1970 - The Proterozoic metamorphic rocks of the Cloncurry 1:100 000 Sheet area, (Soldiers Cap belt) northwestern Queensland. Bur. Miner. Resour. Aust. Rec. 1970/24 (unpubl.).

GLIKSON, A.Y., & DERRICK, G.M., in prep - Geology and geochemistry of Proterozoic basic volcanic belts Mount Isa/Cloncurry, northwestern Queensland. Bur. Miner. Resour. Aust. Rep.

GLIKSON, A.Y., DERRICK, G.M., WILSON, I.H., & HILL, R.M., 1976 - Tectonic evolution and crustal setting of the Middle Proterozoic Leichhardt River fault trough, Mount Isa region northwestern Queensland. BMR. J. Aust. Geol. Geophys., 1(2), 115-29.

HAMILTON, W., & MYERS, W.B., 1967 - The nature of batholiths. U.S. geol. Surv. prof. Pap. 554-C, 1-30.

HANEY, T.H., 1957 - Beryl Authority to Prospect. Mount Isa Mines Ltd (unpubl.).

HANSEN, W.A., 1966 - Progress report No. 1 - Surprise Creek project 39. Kern County Land Co. (unpubl.).

HANSEN, W.A., & TESTER, D.K., 1966 - Progress report No. 5 - Surprise Creek project 39. Kern County Land Co. (unpubl.).

HECKEL, P.H., 1972 - Recognition of ancient shallow marine environments; in RIGBY, J.K., & HAMBLIN, W.K. (eds). - Recognition of ancient sedimentary environments. Soc. Econ. Palaeont. Miner. spec. Publ. 16, 226-86.

HILL, R.M., 1968 - Geology of Sunset area, Mary Kathleen, Queensland. Univ. Qld B.Sc. Hons Thesis (unpubl.).

HILL, R.M., WILSON, I.H., & DERRICK, G.M., 1975 - Geology of the Mount Isa 1:100 000 Sheet area, northwest Queensland. Bur. Miner. Resour. Aust. Rec. 1975/175 (unpubl.).

HOFMANN, G.W., & BARKER, R.M., 1973 - Mt Isa Region water supply - geological report on the Leichhardt River 242.9M Damsite. Geol. Surv. Qld Rec. 1973/2 (unpubl.).

HOLLONSHEAD, C.T., & PRITCHARD, R.L., 1961 - Geometry of producing Mesaverde Sandstones, San Juan Basin; in PETERSON, J.A., & OSMOND, J.C. (eds.) - GEOMETRY OF SANDSTONE BODIES Am. Assoc. petrol. Geol.

HOLMES, A., & SMALES, A.A., 1948 - Monazite from Bodmin Moor, Cornwall: a study in geochronology. Proc. Roy. Soc. Edinb., B., 63(2).

HOLMQUIST, P.J., 1921 - Typen und Nomenklatur der Adergesteine. Geol. For. Forh., 43.

HONMAN, C.S., 1937 - The Bower Bird auriferous area, Cloncurry district. Aer. Surv. N. Aust. Qld Rep. 19.

JENSEN, H.I., 1940 - The eastern portion of the Bower Bird area, Cloncurry District. Aer. Surv. N. Aust. Qld Rep. 48.

JOHNSON, M.R.W., 1967 - Mylonite zones and mylonite banding. Nature, 213, 246-247.

JONES, D.G., 1967 - Queen Elizabeth copper prospect, final report. Carpentaria Exploration Co. Pty Ltd Tech. Rep. 132 (unpubl.).

JONES, O.A., 1953 - The structural geology of the Precambrian in Queensland in relation to mineralization; in GEOLOGY OF AUSTRALIAN ORE DEPOSITS. Fifth Emp. Min. Metall. Congr., 1, 344-51.

JOPLIN, G.A., 1955 - A preliminary account of the petrology of the Cloncurry mineral field. Proc. Roy. Soc. Qld, 66, 33-67.

__________, 1968a - A PETROGRAPHY OF AUSTRALIAN IGNEOUS ROCKS (2nd ed.). Angus & Robertson, Sydney.

__________, 1968b - A PETROGRAPHY OF AUSTRALIAN METAMORPHIC ROCKS. Angus & Robertson, Sydney.

JOPLIN, G.A., & WALKER, K.R., 1961 - The Precambrian granites of Northwestern Queensland. Proc. Roy. Soc. Qld, 72, 21-57.

KENNECOTT EXPLORATION PTY LTD, 1966 - The Precambrian granites of northwestern Queensland. Proc. Roy. Soc. Qld, 72, 21-57.

__________________, 1967 - - AP 361M - final report of all results of prospecting for the area excluded on 1 August 1967 (unpubl.).

__________________, 1967 - AP 361M - quarterly report for period 1 July to 30 September 1967 (unpubl.).

KNIGHT, C.L., 1953 - Regional geology of Mount Isa; in GEOLOGY OF AUSTRALIAN ORE DEPOSITS. Fifth Emp. Min. Metall. Congr., 1, 352-60.

LAMSENS, O.R., 1969 - Airborne gamma radiation survey, Mount Isa area, Queensland. Geophoto Resources Ltd (unpubl.).

LAWRENCE, L.J., 1955 - Uranium mineralization in the Cloncurry-Mount Isa area. Proc. Roy. Soc. Qld, 66, 69-76.

LAYTON AND ASSOCIATES LTD, 1971 - Terminal report on AP 751M (unpubl.).

________________________, 1971 - Terminal report on AP 768M (unpubl.).

LEES, W., 1907 - The copper mines and mineral fields of Queensland. Qld Country Life Press, 45-60.

LEVINGSTON, K.R., 1954 - Uranium occurrences, Mount Isa-Cloncurry district. Geol. Surv. Qld (unpubl.).

MACDONALD, G.A., 1972 - VOLCANOES. Prentice Hall, Englewood Cliffs.

MCKENNA, D., 1963 - Summary report - geological investigations and diamond drilling, Hero Leases, north Mount Isa to March, 1963 (AP 169M). Conzinc Riotinto of Australia Ltd (unpubl.).

MACKENZIE, D.H., 1957 - On the relationship between migmatization and structure in mid-Strathspey. Geol. Mag., 94, 177-86.

MECKEL, L.D., 1967 - Origin of Pottsville Conglomerates (Pennsylvanian) in the central Appalachians. Bull. geol. Soc. Am., 78(2), 223-57.

273

MEHNERT, K.R., 1968 - MIGMATITES AND THE ORIGIN OF GRANITIC ROCKS. Elsevier, Amsterdam.

MIYASHIRO, A., 1961 - Evolution of metamorphic belts. J. Pet., 2, 277-311.

__________, 1974 - METAMORPHISM AND METAMORPHIC BELTS. Harcourt, New York.

MOODY, J.D., & HILLS, M.J., 1956 - Wrench fault tectonics. Bull. geol. Soc. Am., 67, 1207-46.

MUCENIEKAS, E., 1964 - Hero Lease area - north Mount Isa - eastern limb-geochemical report. CRA Exploration Pty Ltd (unpubl.).

__________, 1967 - Geochemical drainage reconnaissance. Report for AP 380 M. CRA Exploration Pty Ltd (unpubl.).

__________, 1968 - Second stage geochemical drainage reconnaissance AP 380M, Mary Kathleen, Queensland. CRA Exploration Pty Ltd (unpubl.).

MURRAY, W.J., 1961 - Notes on Mount Isa geology. Proc. Australas. Inst. Min. Metall., 197, 105-36.

NIER, A.A., THOMPSON, R.W., & MURPHEY, B.F., 1941 - The isotopic composition of lead and the measurement of geological time. III. Phys. Rev., 60, 112-6.

NIPPON MINING (AUSTRALIA) PTY LTD, 1965 - Report for quarter to 30 September 1965, AP 269M (unpubl.).

__________________, 1967 - Report for quarter to 31 December 1966, AP 269M (unpubl.).

NOAKES, L.C., & TRAVES, D.M., 1954 - Outline of the geology of the Barkly region, in Survey of Barkly Region, 1947-48. CSIRO Land Res. Ser. 3.

NOON, T.A., 1974 - Summary of mineral exploration surveys in the Cloncurry 1:250 000 Sheet area. Geol. Surv. Qld Rec. 1974/21 (unpubl.).

NYE, P.B., & RAYNER, E.O., 1940 - The Cloncurry copper deposits, with special reference to the gold-copper ratios of the ores. Aer. Surv. N. Aust. Qld Rep. 35.

PACKHAM, G.H., 1954 - Sedimentary structures as an important factor in the classification of sandstones. Am. J. Sci., 252, 466-76.

PAGE, R.W., 1976 - Response of U-Pb zircon and Rb-Sr total rock systems to low grade regional metamorphism in Proterozoic igneous rocks, Mount Isa, Australia. Ann. Rep. Geophys. Lab. Carnegie. Inst. Washington Year Book 1975.

PAGE, R.W., & DERRICK, G.M., 1973 - Precambrian geochronology in the Mt Isa-Cloncurry area, northwest Queensland. Rep. Aust. Ass. Adv. Sci., 3, 13.6-13.9.

PERRY, R.A., 1964 - General report on lands of the Leichhardt-Gilbert area, Queensland, 1953-54. CSIRO Land Res. Ser. 11.

PERRY, R.A., & LAZARIDES, M., 1964 - Vegetation of the Leichhardt-Gilbert area. CSIRO Land Res. Ser. 11.

PETTIJOHN, F.J., 1957 - SEDIMENTARY ROCKS. Harper & Brothers, New York.

275

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

PLUMB, K.A., & DERRICK, G.M., 1975 - Geology of the Proterozoic rocks of northern Australia; in KNIGHT, C.L., (ed.) - ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA. Volume 1: Metals. Australas. Inst. Min. Metall. Monogr. Ser. 5, 217-52.

PRYOR, W.A., 1961 - Sand trends and palaeoslope in Illinois basin and Mississippi embayment; in PETERSON, J.A., & OSMOND, J.C., (eds) - GEOMETRY OF SANDSTONE BODIES. Amer. Assoc. Petrol. Geol.

RAMBERG, H., 1964 - Selective buckling of composite layers with contrasted rheologic properties; a theory for simultaneous formation of several orders of folds. Tectonophysics, 1, 101-20.

RAMSAY, C.R., & DAVIDSON, L.R., 1970 - The origin of scapolite in the regionally metamorphosed rocks of Mary Kathleen, Queensland. Contr. Miner. Pet., 25, 41-51.

RAMSAY, J.G., 1962 - The geometry and mechanics of formation of similar type folds. J. Geol., 70, 309-27.

__________, 1967 - FOLDING AND FRACTURING OF ROCKS. McGraw-Hill, New York.

RANDS, W.H., 1895 - Leichhardt Gold Field and other mining centres in the Cloncurry district. Geol. Surv. Qld Publ. 104.

RAYNER, E.O., 1938 - The cobalt deposits of the Cloncurry district. Aer. Surv. N.Aust. Qld Rep. 34.

RICHARDS, J.R., 1966 - Some Rb-Sr measurements on granites near Mount Isa. Proc. Australas. Inst. Min. Metall., 218, 19-23.

RIDGWAY, J.E., 1960 - Final report - AP 136M and 149M. Queensland Mines Ltd (unpubl.).

RIO TINTO AUSTRALIAN EXPLORATION PTY LTD, 1961 - Final report on AP 128M, 141M, 1 October 1958 to 30 September 1960 (unpubl.).

ROBINSON, W.B., 1968 - Geology of the Eastern Creek Volcanics in the Mount Isa District (with discussion). Proc. Australas. Inst. Min. Metall., 226, 89-96.

RUDMAN, B.A., 1970 - Geologic report of Calton Hills uranium prospect AP 635M, Mount Isa district, Queensland. Minops Pty Ltd (unpubl.).

RUSSI, A., 1968 - AP 367M, Mount Cuthbert No. 3 final report. Carpentaria Exploration Co. Pty Ltd tech. Rep. 151 (unpubl.).

SAINT-SMITH, E.C., 1924 - Mount Isa (Cloncurry) silver lead, recent developments. Qld Govt Min. J. 25, 9.

SAKOMOTO, T., 1967 - Final report on AP 269M. Nippon Mining (Australia) Pty Ltd (unpubl.).

SCOTT, A.K., 1969 - Final report on AP 380M, Mary Kathleen area, Queensland. CRA Exploration Pty Ltd (unpubl.).

SELLEY, R.C., 1970 - ANCIENT SEDIMENTARY ENVIRONMENTS. Chapman & Hall, Norwich.

SHAW, H.R., 1963 - The four-phase curve sanidine-quartz-liquid-gas between 500 and 4000 bars. Am. Miner., 48, 883-896.

SHEPHERD, S.R.L., 1932 - Mount Isa silver-lead-zinc deposits, the Black Rock lode. Qld Govt. Min. J 33, 377-83.

______________, 1946a - Geological sketch map, Cloncurry area. Qld Govt Min. J. 47, 144-6.

______________, 1946b - Some mines on the Cloncurry field. Qld Govt Min. J. 46, 45-52.

SHIELDS, J., 1959 - Cloncurry-Mount Isa district Canso radiometric anomaly inspection sheets. Rio Tinto Exploration Pty Ltd (unpubl.).

SLATYER, R.D., 1964 - Climate of the Leichhardt-Gilbert area. CSIRO Land. Res. Ser. 11.

SMITH, W.D., 1969 - Penecontemporaneous faulting and its likely significance in relation to Mt Isa ore deposition. Geol. Soc. Aust. spec. Publ. 2, 225-35.

SPRY, A., 1969 - METAMORPHIC TEXTURES. Pergamon, Oxford.

STRECKEISEN, A.L., 1967 - Classification and nomenclature of igneous rocks. Neues Jb. Miner. Ahb., 107, 144-239.

SWIFT, D.J.P., 1969 - Evolution of the shelf surface and the relevance of modern shelf studies to the rock record; in STANLEY, D.J. (Convenor) - THE NEW CONCEPTS OF CONTINENTAL MARGIN SEDIMENTATION. Am. geol. Inst. Lecture 7.

TOURTELOT, E.B., & VINE, J.D., 1976 - Copper deposits in sedimentary and volcanogenic rocks. U.S. geol Survey prof Pap. 907-c

TUCKER, D.H., 1975 - Cloncurry regional and Prospector detailed airborne radiometric and magnetic surveys, Queensland, 1973. Bur. Miner. Resour. Aust. Rec. 1975/74 (unpubl.).

TURNER, F.J., 1968 - METAMORPHIC PETROLOGY. McGraw-Hill, New York.

TURNER, F.J., & VERHOOGEN, J., 1951 - IGNEOUS AND METAMORPHIC PETROLOGY. McGraw-Hill, New York.

TURNER, F.J., & WEISS, L.E., 1963 - STRUCTURAL ANALYSIS OF METAMORPHIC TECTONITES. McGraw-Hill, New York.

TUTTLE, O.F., & BOWEN, N.L., 1958 - Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O. Geol. Soc. Am. Mem. 74.

TWIDALE, C.R., 1964 - Geomorphology of the Leichhardt-Gilbert area. CSIRO Land Res. Ser. 11, 115-24.

TWIDALE, C.R., 1966 - Geomorphology of the Leichhardt-Gilbert area of northwest Queensland. CSIRO Land Res Ser. 16.

VISHER, G.S., 1965 - Use of vertical profile in environmental reconstruction. Am. Assoc. Petrol. Geol. Bull. 49, 41-61.

WALKER, K.R., JOPLIN, G.A., LOVERING, J.F., & GREEN, R., 1959 - Metamorphic and metasomatic convergence of basic igneous rocks and lime-magnesia sediments of the Precambrian of northwestern Queensland. J. geol. Soc. Aust., 6, 149-75.

WALKER, R.G., 1970 - Review of the geometry and facies organization of turbidites and turbidite-bearing basins; in LAJOIE, J. (ed.) - Flysch Sedimentology in North America Geol. Assoc. Can. spec. Pap. 7, 219-52.

WHITE, A.J.R., 1966 - Genesis of migmatites from the Palmer region of South Australia. Chem. Geol., 1, 165-200.

279

WILSON, I.H., 1976 - Possible Andean-type volcanics in the Proterozoic of northwestern Queensland. 25th int. geol. Cong. Sect. 2, 68-69 (abstr.).

WILSON, I.H., DERRICK, G.M., & HILL, R.M., 1972 - Copper mineralization (excluding Mount Isa) in the Precambrian Cloncurry Complex of northwest Queensland, Australia. 24th Int. geol. Cong. Sect. 4, 234-40.

WINKLER, H.G.F., 1967 - PETROGENESIS OF METAMORPHIC ROCKS (2nd Edn) Springer-Verlag, New York.

APPENDIX 1

GEOCHEMICAL PROSPECTING

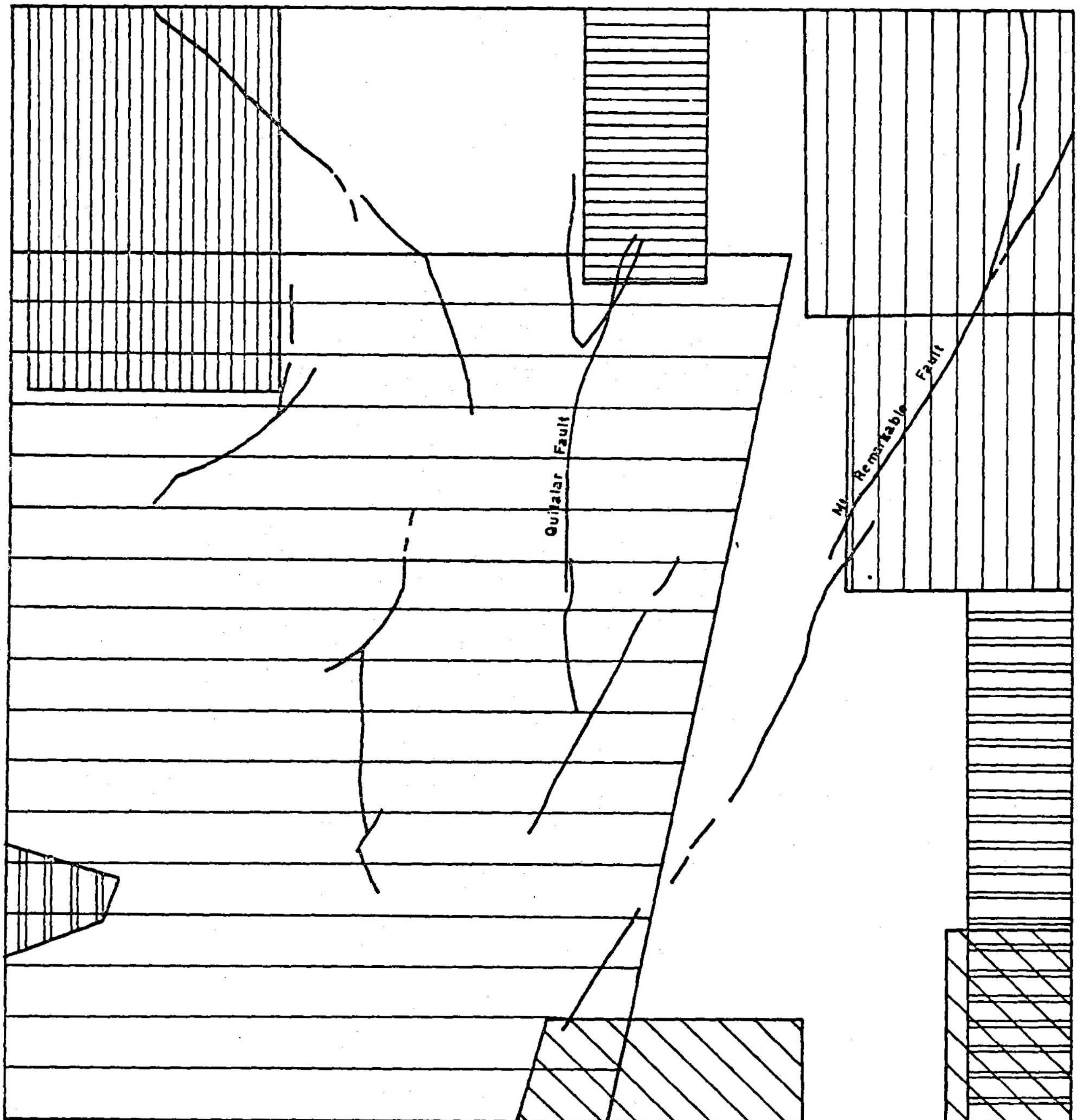
Geochemical prospecting was introduced as a worthwhile exploration technique in the Mount Isa region, by the Bureau of Mineral Resources in 1952. They applied a soil-sampling program to the Northern Leases of Mount Isa Mines Ltd, and in so doing proved the worth of the method. Since then seven companies have applied geochemical surveys within the Sheet area to areas shown in Figure A.

Conzinc Riotinto Australia (CRA) first applied stream-sediment sampling to a portion of the Hero Lease area using a sample density of about four samples per square kilometre (Muceniekas, 1964). Samples were analysed for cold extractable copper, as well as total copper, zinc, and lead. No anomalous areas were delineated and it was concluded that there was no economic mineralization at shallow depth. CRA also used geochemical techniques to evaluate Authority to Prospect 380(M) (Muceniekas, 1967). Work on the Sheet area comprised about 15 samples at a sampling density of one sample per square kilometre. Two copper anomalies were defined, but analyses for lead, zinc, nickel, cobalt, silver, and mercury failed to detect anomalous areas.

Nippon Mining (Australia) Pty Ltd carried out a program to evaluate Authority to Prospect 269 (M), (Sakomoto, 1967). Stream-sediment sampling of about 700 samples located an area of interest 305 m by 1525 m which was soil-sampled, and finally seven areas were selected for drilling.

Stream-sediment sampling was employed by Carpentaria Exploration Company (CEC) to evaluate Authorities to Prospect 292(M), 365(M), and 367(M). Samples were collected at about 1 km intervals along stream channels. The programs within

281



Record 1977/4

T.A.N.

FIGURE A: PROSPECTOR 1:100 000 F 54/A2/167

AREAS OF STREAM SEDIMENT SAMPLING

AP 232	CRA	Cu Pb Zn
AP 269	NIPPON MINING	Cu
AP 292	MIM	Cu Pb Zn Co Ni
AP 361	KENNECOTT	Cu Zn Co Ni
AP 355 367	CEC	Cu Pb Zn Co Ni
AP 300	CRA	Cu Pb Zn Co Ni Ag Hg U
AP 604	MINERAL DEPOSITS	U

SCALE

5 0 10

Km

TN

these areas defined 9 copper anomalies, 2 zinc anomalies, 3 nickel anomalies, 2 cobalt anomalies, and 1 lead anomaly. All anomalies were investigated, and subsequently 48 sites were selected for drilling at the Queen Elizabeth copper prospect (Jones, 1967).

Kennecott Exploration defined 9 copper anomalies and 5 zinc anomalies within Authority to Prospect 361(M). Mineral Deposits, and Australian Ores and Minerals have also employed stream-sediment sampling with moderate success.

The failure of geochemical methods to locate economic deposits within the Sheet area does not indicate deficiencies in the methods. In fact, the methods are mostly over-sensitive. because they detect small-scale mineralization, which does not warrant development by the large companies. These results indicate that the method is capable of detecting small bodies of mineralization. Careful consideration must be given to underlying geology as well as the elements being analysed, since background values, and hence anomalous values, depend on lithology and mobility of the particular element.

APPENDIX 2

MINE DESCRIPTIONS

AZURITE

Location: 6857/800682, about 11 km northeast of the Mount Isa/ Kajabbi road on the Queen Elizabeth mine road thence 8 km northwest by rough track.

Country rock: granodiorite of the Kalkadoon Granite intruded by numerous dolerite bodies.

Lode: the lode is gossanous, strikes east-west and is intersected by a quartz replacement zone. It occurs in the contact zone between granodiorite and amphibolite (altered basic).

Mineralization is azurite, malachite, chalcopyrite, and pyrite.

Workings: Narrow, east-west shaft which dips steeply to the north, and several small pits.

BARBARA (Green Monster) (Index No. 74)

Location: 6857/798418, 3 km by bush track northeast of Lillymay.

Country rock: quartz-biotite-chlorite schist of the Leichhardt Metamorphics.

Lode: the lode is discontinuous, being en-echelon in character. Mineralization is disseminated, and predominantly chalcopyrite, pyrite, and pyrrhotite.

Workings: several exploratory trenches, seven drill holes, no production.

284

BARRIER (Index No. 5)

Location: 6857/486830, about 19 km by track northeast of Calton Hills homestead.

Country rock: carbonated, chloritized, and albitized basalt with interbeds of quartzite, sandstone, and slate.

Lode: patchy outcrops of finely disseminated uraniferous magnetite in an area 57 m by 9 m.

Reference: Brooks, 1960.

BLACK VALLEY (Index No. 69)

Location: 6857/676457, 2.5 km west of Jamie.

Description: two upstanding iron-enriched gossanous zones which crop out in quartzite of the Surprise Creek Beds.

CONQUEST (Index No. 4)

Location: 6857 486838, about 20 km by track northeast of Calton Hills homestead.

Country rock: carbonated, chloritized, and albitized basalt of the Cromwell Metabasalt.

Lode: localized patches of finely disseminated uraniferous magnetite which crop out over 36 m by 6 m.

Reference: Brooks, 1960

DREADNOUGHT (Index No. 37)

Location: 6857 884688, 400 m west of Queenslander and 800 m north-northeast of White Gorge.

Country rock: metasediments of the Corella Formation adjacent to massive quartz infilling of the Mount Remarkable Fault.

Lode: limestone replaced by silica and limonite, some of which is cellular.

Workings: one shaft to a depth of 10 m.

Reference: Ball, 1908

DRY DOG (Index No. 8)

Location: 6857 807809 (p.d.) 1 km south of the junction of the Gereta homestead road with the Julius Dam road, 25 km west-southwest of Kajabbi.

Country rock: acid volcanics of the Leichhardt Metamorphics.

Lode: the lode is confined to a shear zone with quartz and sheared schist as the common gangue.

FLORA DORA (Index No. 67)

Location: 6857 878527, about 7 km by graded track north-northwest of Yamamilla.

Country rock: spherulitic rhyolite of the Argylla Formation overlain by Ballara Quartzite.

Lode: apparently in shear zone in acid volcanics. Mineralization is malachite and azurite with chalcopyrite at depth.

Workings: at the time of inspection, an exploratory shaft 10 m deep had been sunk. Development work had not commenced.

286

FLORIN (Index No. 85)

Location: 6857 782382, 0.5 km southwest of Mount Olive.

Country rock: hornblende-biotite schist in the Magna Lynn Metabasalt adjacent to faulted contact with porphyritic volcanics of the Leichhardt Metamorphics.

Lode: quartz-hematite-pyrite-hornblende gangue which strikes at 150° and dips 70° to west. Ore is chalcopyrite and chalcocite with azurite and minor malachite.

Workings: a 6 m shaft at southeast end of lode with a drive to the southeast. Twelve metres to the northwest is a 30-m-deep shaft, with several small pits and costeans farther northwest.

Reference: Brooks, 1957

GERTRUDE (Index No. 51)

Location: 6857 699542, 1.6 km northeast along Doughboy Creek from its junction with the Leichhardt River.

Country rock: metasediments of the Surprise Creek Beds.

Lode: small leaders in quartz veins which run north and south in clay slates, and dip to the west.

Workings: one shaft 30 m deep.

Reference: Rands, 1895.

IMPASSABLE (Index No. 6)

Location: 6857 485825, about 18.5 km by track northeast of Calton Hills homestead.

Country rock: altered basalt.

Lode: The lode crops out in two discrete areas; the northern lode is 60 m by 7.5 m and the southern lode is 33 m by 12 m. Mineralization is finely disseminated uraniferous magnetite.

Reference: Carter, 1955

JAMIE (Index No. 70)

Location: 6857 701457, 61.5 km from Mount Isa on the Mount Isa/Kajabbi road, thence 6 km west-southwest by rough bush track.

Country rock: sheared quartzitic sediments of the Surprise Creek Beds.

Lode: mineralization consists of malachite and minor chrysocolla in a sheared sandstone.

Workings: one shaft 20 m deep with a drive extending to the southeast.

KANGAROO (Index No. 33)

Location: 6857 813663, about 2 km southeast of Azurite.

Country rock: metabolcanics of the Leichhardt Metamorphics.

Workings: one open cut 10 m long by 5 m deep.

Reference: Ball, 1908.

LAST CHANCE (Index No. 54)

Location: 6857 818538, 2 km east-northeast of Referee.

Country rock: acid metavolcanics of the Argylla Formation.

Lode: in shear zone capped by a limonitic gossan. Mineralization is limited and predominantly malachite with minor chrysocolla.

288

Workings: one shaft 6 m deep with a drive extending to the north.

LILLIMAY (Index No. 79)

Location: 6857 772402, 58 km from Mount Isa on the Mount Isa/ Kajabbi road, thence 4 km east by graded track.

Country rock: dacite and rhyolite of the Leichhardt Metamorphics.

Lode: in a fault zone which is transgressive to the regional trend. The lode strikes at 78 to 87° and dips at 65° to the south. The outcrop is stringers of quartz and gossan separated by bands of talc-chlorite schist and biotite schist. The ore is chalcopyrite in quartz with malachite, azurite, tenorite, and covellite.

Workings: a small open cut and several small pits. Two shafts have been sunk, with drives along strike at the 12 m and 19 m levels.

Reference: Brooks, 1957

LILLIMAY NO. 1

Location: 6857 775402, 0.5 km east of Lillimay.

Description: the environment is similar to that of Lillimay. Mineralization is chalcopyrite with covellite coatings in quartz. Two shafts have been sunk.

MANXMAN (Index No. 81)

Location: 6857 768382, 2.5 km by track, south-southwest of Lillimay.

Country rock: feldspar porphyry of the Leichhardt Metamorphics.

Lode: fissure lode which strikes 105° and dips at 80° to the south. It occurs at the contact between feldspar porphyry and basic schist. The ore is malachite, azurite, tile ore, and glance, with chalcopyrite and tenorite at depth.

Workings: two shafts; No. 1 is 23 m deep with a drive at the 19-m level and No. 2 is 21 m deep with a drive at the 16.5-m level.
Reference: Brooks, 1957

MAYLENE (Index No. 76)

Location: 6857 874435, 6 km by bush track southwest of Yamamilla.

Country rock: thinly bedded siltstones of the Corella Formation.

Lode: confined to small shear zone, and indicated by a limonitic gossan in association with coarsely crystalline calcite. Mineralization is predominantly malachite.

Workings: a small pit following the lode.

MORNING STAR (Index No. 60)

Location: 6857 477512

Country rock: metabasalt of the Cromwell Metabasalt Member of the Eastern Creek Volcanics.

Lode: uranium mineralization is confined to two lenses of calcareous quartzite within the basalt.
Reference: Brooks, 1960.

MOUNT MARGARET (Index No. 65)

Location: 6857 818509, 3.5 km by rough track southeast of Referee.

Country rock: quartzite and siltstone of the Corella Formation.

Lode: in a fault zone in quartzite and chloritic schist. It is a gossanous lode with malachite and azurite with disseminated chalcopyrite in coarse crystalline calcite at depth.

Workings: one shaft 23 m deep with a south-trending drive at the 13-m level.

MOUNT METALLIC (Index No. 36)

Location: 6857 878670, about 1 km south of the White Gorge Range.

Country rock: brecciated metasediments of the Corella Formation.

Lode: the lode is very narrow, in a gossanous and cellular siliceous slate. Mineralization is mainly chalcopyrite, native copper, chalcocite, cuprite, and malachite.

Workings: four shafts and five open cuts
Reference: Ball, 1908

MOUNT OLIVE (Index No. 83)

Location: 6857 779387, 1.5 km by track south of Lillimay.

Country rock: rhyolite porphyry of the Leichhardt Metamorphics

Lode: in a shear zone and tends to bulge and pinch. The outcrop is leached limonitic quartz gossan with malachite. The ore is chalcopyrite with subordinate pyrite in a gangue of quartz, chlorite, and talc. Primary sulphide is enriched by covellite, chalcocite, and tenorite.

Workings: the working shaft is 40 m deep with drives at the 27-m, 32-m, and -40-m levels.
Reference: Brooks, 1957.

MOUNT ROVER (Index No. 49)

Location: 6857 471549, about 5.5 km northeast of the Paroo Creek flood-gauge station.

Country rock: chloritized magnetite-bearing metabasalt of the Pickwick Metabasalt member of the Eastern Creek Volcanics.

Lode: distribution of uranium mineralization is controlled by fracturing of the basalt.
Reference: Brooks, 1960.

MOUNT SPRING (Index No. 59)

Location: 6857 462489

Country rock: metabasalt of the Cromwell Metabasalt Member of the Eastern Creek Volcanics.

Lode: uranium mineralization is confined to calcareous quartzite interbeds within the basalt.
Reference: Brooks, 1960

PINKIE (PINK CAP) (Index No. 9)

Location: 6857 819842, about 21 km by rough track west of Kajabbi.

Country rock: porphyry, amphibolite, and chlorite schist of the Leichhardt Metamorphics.

Lode: in a fissure which transgresses the country rock. Cobalt is associated with calcite and quartz. Mineralization is erythrite and cobalt oxide, with minor azurite and chalcopyrite.

Workings: several small pits

Reference: Rayner, 1938

QUEEN ELIZABETH (Index No. 43)

Location: 6857 783633, 77 km from Mount Isa on the Mount Isa/ Kajabbi road, thence 4 km northeast along a graded track.

Country rock: porphyritic acid volcanics of the Leichhardt Metamorphics adjacent to a large dolerite mass.

Lode: in association with a mass of coarsely crystalline dolomite. Malachite, chrysocolla, and some chalcocite are associated with gossanous limonitic jasper marginal to the dolomite. Chalcocite and bornite are associated with crushed buck quartz in thin shears in the dolomite. Sulphides are disseminated throughout the dolomite and the sheared dacitic schist zone.

Workings: confined to numerous small trenches and pits and some shallow shafts. The main shaft extends to 48 m, but the bottom 30 m is under water.

Reference: Brooks & Simmonds, 1964

QUEENSLANDER (Index No. 38)

Location: 6857 888686, about 22 km southwest of Kajabbi on the old Mount Isa/Kajabbi road.

Country rock: metasediment of the Corella Formation.

Lode: gossanous and copper-stained material which passes at depth into a sintery formation carrying bunches of copper ore, yellow jasper, and brown calcite. Mineralization is chalcopyrite and chalcocite.

Workings: one shaft to a depth of 15 m and a small pothole.
Reference: Ball, 1908

REFEREE (RUTH) (Index No. 53)

Location: 6857 798531, on Bullockhead Creek, a small branch of Prospector Creek, 64 km from Mount Isa on the Mount Isa/ Kajabbi road, thence 7 km northeast on a graded track.

Country rock: pink medium-grained phase of the Kalkadoon Granite.

Lode: strikes at 84^{o} and dips 65^{o} to the south. The lode occurs in the footwall of a splay fault off the Mount Remarkable Fault. Mineralization is predomonantly chalcopyrite, covellite, and pyrite, with malachite, azurite, bornite, cuprite, tenorite (black oxide), chrysocolla, chalcocite, and tile ore.

Workings: four shafts have been sunk since mining commenced. Only the eastern shaft has been maintained and is being mined under tribute to the lessee (Fisher). Copper mineralization near the surface is malachite, chrysocolla, tile ore, and chalcocite. At the 18-m level chalcocite and tenorite are being mined.

The western ore shoot is now being mined by opencut methods. Copper mineralization is confined to carbonates in a limonitic gossan and quartz gangue. There is a zone of secondary enrichment between the 12-m and 20-m levels. Below the 20-m level the ore is mainly primary sulphides.
References: Ball, 1908; Brooks, 1957.

SCHEELITE (Index No. 39)

Location: 6857 942662, 4 km south-southwest of Surprise.

Country rock: hornblende schist intruded by porphyry.

Lode: in quartz veins associated with lenses of calcite. The lode strikes northwest, with a steep northeast dip. Mineralization is scheelite.

Workings: two open cuts.
Reference: Shepherd, 1946b

TC (Index No. 78)

Location: 6857 910422, 5.5 km by track south-southeast of Yamamilla.

Country rock: porphyritic acid volcanics of the Argylla Formation.

Lode: near the contact between basic schist and porphyritic acid volcanics. The lode strikes 160°. Mineralization is pyrite, chalcopyrite, and covellite in a quartz gangue, with minor malachite and azurite in fractures. There is much limonitic jasper.

Workings: several shafts and small pits. The main shaft is 40 m deep. Two smaller shafts to the south have caved-in.

VICTORIA (Index No. 14)

Location: 6857 637772, 5 km northwest of Julius Dam.

Country rock: quartzite of the Surprise Creek Beds.

Lode: The reef occurs between a footwall of quartzite and a hanging wall of greenstone. The reef strikes at 18^{o} and dips at 25^{o} to the east. Mineralization is gold without quartz.

Workings: shallow open cut and an inclined shaft
Reference: Honman, 1937

WESTERN (Index No. 35)

Location: 6857 856683, about 10 km northeast of Azurite.

Country rock: feldspar porphyry of the Leichhardt Metamorphics intruded by numerous granite dykes.

Lode: fissure lode which strikes 40^{o}. Mineralization consists of chalcopyrite, bornite, chalcocite, covellite, malachite, and azurite.
Reference: Jensen, 1940.

YAMAMILLA (Index No. 77)

Location: 6857 891469, 2.5 km east of Prospector Creek along Yamamilla Creek.

Country rock: quartzite of the Ballara Quartzite adjacent to the contact with calc-silicate rocks of the Corella Formation.

Lode: in a quartz breccia between a barren hangingwall and footwall. The lode bifurcates to the north, and the main development is in the western branch. The mineralized section averages 60 cm in width, and contains malachite, chrysocolla, and chalcocite, with limonitic jasper. South of the mainworkings, cuprite occurs in association with limonitic jasper.

Workings: an adit following the lode along strike to the south of Yamamilla Creek, and several exploratory pits to the north of the Creek.
References: Ball, 1908; Brooks, 1957

Unnamed mine (Index No. 55)

Location: 6857 830540

Country rock: metasiltstone of the Corella Formation.

Lode: in a quartz gangue associated with masses of coarsely crystalline calcite in a fault zone. Mineralization is malachite with minor chalcopyrite.

Workings: one shaft 10 m deep and inclined steeply to the west.

Unnamed mine (Index No. 68)

Location: 6857 885507, 4 km north-northwest of Yamamilla.

Country rock: calcareous siltstone of the Corella Formation/

Lode: in northwest-trending fault zone. Copper mineralization is malachite.

Workings: one shaft 10 m deep with a drive to the east at the base.

Unnamed mine (Index No. 87)

Location: 6857 711332, 50 km from Mount Isa on the Mount Isa/Kajabbi road.

Country rock: Porphyritic granite of the Kalkadoon Granite.

Lode: in shear zone, and is characterized by much limonitic staining. Mineralization is mainly malachite and azurite with chrysocolla and minor chalcopyrite.

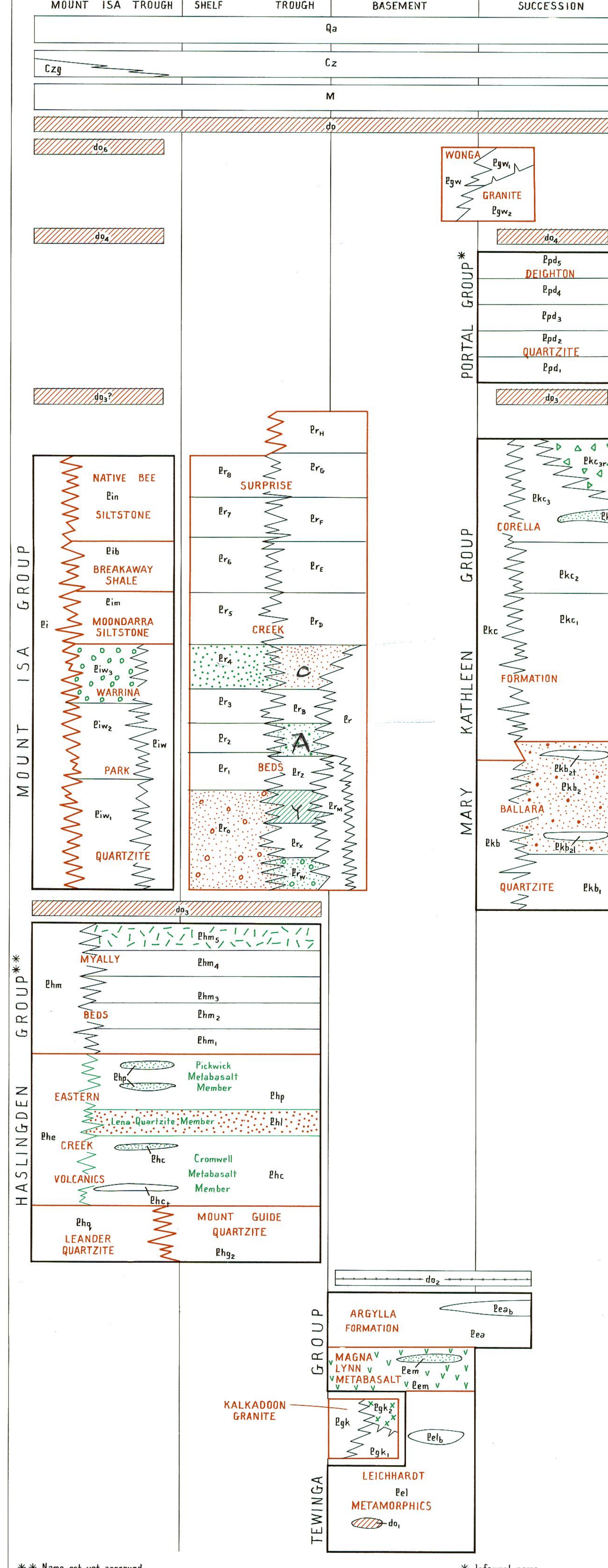
Workings: 8-m shaft with a drive extending to the northwest at the base, and several shallow trenches.

AUSTRALIA 1:100 000 GEOLOGICAL MAP

PROSPECTOR

QUEENSLAND

SHEET 6857



Qa Alluvium — QUATERNARY

Cz Soil, sand, alluvium, gravel
Czg Gravel — CAINOZOIC

M Conglomerate, sandstone, siltstone, laterite — MESOZOIC

do Dolerite, metadolerite, of various ages

do6 Coarse to medium pyroxene dolerite. Rock relationship diagram only

Ꝑgw1 Foliated porphyritic biotite granite, mega porphyritic foliated granite, xenolithic and gneissic granite
Ꝑgw Foliated coarse porphyritic granite, diorite, granodiorite, leucogranite, gneiss, aplite, pegmatite
Ꝑgw2 Foliated biotite granite, leucogranite, pegmatite, aplite
(could in part be older than Ballara Quartzite (Ꝑkb))

do4 Coarse to medium dolerite, metadolerite. Rock relationship diagram only

Ꝑpd5 Lithic medium to coarse sandstone
Ꝑpd4 Grey siltstone
Ꝑpd3 Cream fine sandstone
Ꝑpd2 Laminated grey slightly calcareous siltstone
Ꝑpd1 Buff fine feldspathic sandstone, rare pebbles

do3 Metadolerite, amphibolite. Rock relationship diagram only

ꝐrH Grey pyritic siltstone
Ꝑkc3r Calcareous breccia, limestone
ꝐrG Grey siltstone
Ꝑr8 Feldspathic quartzite
Ꝑkc3 Laminated calcareous siltstone, limestone, calcareous scapolitic granofels
Ꝑin Bedded dolomitic siltstone
Ꝑr7 Ferruginous siltstone and shale, minor grit, pebbly greywacke, feldspathic quartzite
ꝐrF Laminated siltstone, shale, dolomitic siltstone
Ꝑkc3 (stippled) Quartzite
Ꝑib Grey shale, minor siltstone
Ꝑr6 Ferruginous sandstone, siltstone, white feldspathic quartzite, minor conglomerate
ꝐrE Orthoquartzite, feldspathic sandstone and siltstone
Ꝑkc2 Quartzite, metasiltstone, scapolitic siltstone
Ꝑim Dolomitic siltstone
Ꝑr5 Flaggy ferruginous sandstone, siltstone, shale
ꝐrD Alternating siltstone and flaggy sandstone, minor shale
Ꝑi Undivided siltstone, shale and sandstone. Rock relationship diagram only
Ꝑkc1 Laminated calcareous siltstone, limestone, shale, calcareous scapolitic granofels
Ꝑkc Laminated ferruginous calcareous granofels, para-amphibolite
(stippled) Feldspathic quartzite and siltstone (ꝐrC)
Ꝑr4 Pebble and cobble conglomerate, ferruginous sandstone, minor shale and siltstone
Ꝑiw3 Orthoquartzite, conglomerate
Ꝑr3 Siltstone, shale, feldspathic sandstone, minor calcareous siltstone
ꝐrB Grey green siltstone, laminated feldspathic sandstone
Ꝑr Undivided feldspathic sandstone, siltstone and shale
Ꝑiw2 Ferruginous siltstone and sandstone, minor limestone
Ꝑr2 Feldspathic quartzite, orthoquartzite, minor siltstone
(stippled) Feldspathic quartzite, conglomerate (ꝐrA)
Ꝑiw Quartzite, feldspathic quartzite, conglomerate
Ꝑkb2t Laminated siltstone, minor shale
Ꝑr1 Ferruginous feldspathic sandstone, algal and oolitic dolarenite, dolomitic quartz arenite, siltstone
ꝐrZ Laminated limestone, flaggy marl, feldspathic sandstone, siltstone
Ꝑkb2 Quartzite, micaceous quartzite
(hatched) Fine feldspathic quartzite, locally pebbly: minor shale and siltstone (ꝐrY)
ꝐrM Undivided conglomerate, arkosic grit, feldspathic quartzite, shale and siltstone
Ꝑiw1 Fine ferruginous sandstone, feldspathic sandstone
ꝐrO Feldspathic and kaolinitic quartzite, minor shale and pebble beds, arkosic grit
ꝐrX Feldspathic sandstone, shale, siltstone
Ꝑkb Quartzite, micaceous quartzite, minor pebble beds
Ꝑkb2l Limestone, ferruginous siltstone
ꝐrW Conglomerate, arkosic grit, feldspathic quartzite, grey siltstone
Ꝑkb1 Arkose, grit, cobble and boulder conglomerate

do3 Metadolerite, amphibolite. Rock relationship diagram only

Ꝑhm5 Ferruginous mottled grey-pink phyllite, calcareous and ferruginous siltstone, acid tuff and lava
Ꝑhm4 Ferruginous sandstone, mudstone, siltstone, minor dolomite
Ꝑhm Undivided sandstone, siltstone and quartzite
Ꝑhm3 Feldspathic sandstone, pebble quartzite, minor siltstone
Ꝑhm2 Flaggy fine to medium ferruginous and feldspathic sandstone, minor siltstone
Ꝑhm1 Feldspathic quartzite

Ꝑhp (stippled) Quartzite
Ꝑhp Metabasalt, amygdaloidal metabasalt
Ꝑhl Quartzite, feldspathic quartzite
Ꝑhe Metabasalt, amygdaloidal metabasalt, quartzite, tuff
Ꝑhc (stippled) Feldspathic sandstone, epidote sandstone, quartzite
Ꝑhc Metabasalt, amygdaloidal metabasalt, flow-top breccia, tuff
Ꝑhct Siltstone, calcareous or dolomitic siltstone
Ꝑhq Orthoquartzite, quartzite
Ꝑhg2 Quartzite, feldspathic quartzite

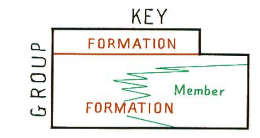
do2 Metadolerite, amphibolite. Rock relationship diagram only

Ꝑeab Metabasalt
Ꝑea Porphyritic rhyolitic to dacitic tuff, quartzite, schist, minor siltstone
Ꝑem (stippled) Quartzite
Ꝑem Metabasalt, amphibolite, agglomerate
Ꝑgk2 Coarse to medium muscovite granite, aplite
Ꝑgk Coarse to medium granite, granodiorite, leucogranite, aplite, gneiss
Ꝑelb Meta amygdaloidal basalt, quartzite
Ꝑgk1 Coarse porphyritic granite, biotite granite. Rock relationship diagram only
Ꝑel Porphyritic tuffaceous rhyolite, rhyodacite and dacite, phyllonite, acid gneiss
do1 Metadolerite, biotite schist, amphibolite. Rock relationship diagram only

LOWER PROTEROZOIC OR CARPENTARIAN — PROTEROZOIC

** Name not yet approved
* Informal name

KEY



Geological boundary
Unconformity (U opens towards younger formation)
Anticline, showing plunge
Syncline, showing plunge
Fault
Inclined fault
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
Plunge of minor anticline
Plunge of minor anticline, unmeasured
Plunge of drag fold
Plunge of folds, showing "S" vergences
Plunge of folds, showing "Z" vergences
Plunge of folds, unmeasured, showing "Z" vergences
Locality of superposed folds
Plunge of fold axes
Shear zone
Strike and dip of strata
Strike and dip of strata, dip not measured
Strike and dip of strata, facing not known
Vertical strata
Strike and dip of overturned strata
Strike and dip of overturned strata, dip not measured
Dip < 15° }
Dip 15°-45° }
Dip > 45° } airphoto interpretation
Trend line }
Lineament }
Joint pattern }
Generalised strike and dip of undulating strata
Top of bed indicated by cross bedding
Strike and dip of joints
Strike and dip of joints, unmeasured
Vertical joints
Strike and dip of foliation
Strike and dip of foliation, unmeasured
Vertical foliation
Strike and dip of cleavage
Vertical cleavage
Direction and plunge of lineation (undifferentiated)
Lineation (mineral elongation)
Lineation (pebble elongation)
Lineation (crenulation)
Kink lineation
Slickensides
Lineation on bedding
Lineation on bedding, facing of bedding not known
Foliation with plunge of lineation
Foliation with plunge of lineation (mineral elongation)
Foliation with plunge of lineation (rodding)
Platy flow, inclined
Platy flow, vertical

Direction of sedimentation (x - cross stratafication, r - asymmetrical ripple marks)
Direction of sedimentation, sense unknown
Dyke or vein; unless stated otherwise, all dykes are dolerite. Cu - copper, Fe - iron, h - porphyritic microgranite, Ls - limestone, q - quartz

•As Minor mineral occurrence
Prospect
Mine
Mine not worked
Open cut
Treatment plant not operating
Costean
DD Diamond drill hole
As Arsenic
Co Cobalt
Cu Copper
Au Gold
Ls Limestone
Mn Manganese
W Tungsten
U Uranium

Bore with windpump
T Water tank
WH Waterhole
RH Rock hole

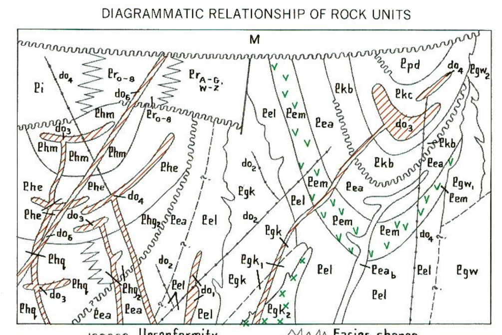
Road
Vehicle track
Railway, abandoned
Gereta Homestead
Building
Yd Yard
315 Elevation in metres, accurate
abd Abandoned
pd Position doubtful

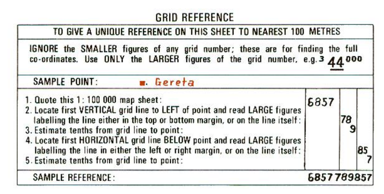
Mining and Lease Index

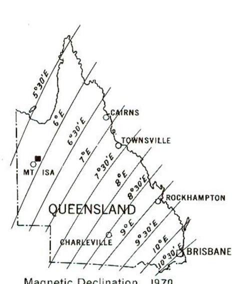
Numbers refer to location on map

1		Cu	46		Cu
2		Cu	47		Cu
3		Cu	48	Fishers Standby	Cu
4	Conquest	U	49	Mount Rover (pd)	U
5	Barrier	U	50		Au
6	Impassable	U	51	Gertrude	Au
7		Cu	52		Au
8	Dry Dog (pd)	Cu	53	Referee (Ruth)	Cu
9	Pinkie (Pink Cap)	Co, Ls, Cu	54	Last Chance	Cu
10	Lady Acre	Cu	55		Cu
11	Ned Kelly (pd)	Cu	56		Cu
12	Map	Cu	57		Cu
13		Cu	58		Cu
14	Victoria	Au	59	Mount Spring (pd)	U
15		Au	60	Morning Star (pd)	U
16	Tablelands	Cu	61		U
17	Brumby Ridge	Cu	62		U
18		Cu	63		U
19		Cu	64	Bessie (Bully)	Cu
20		Cu	65	Mount Margaret	Cu
21		Cu	66		Cu
22		Cu	67	Flora Dora	Cu
23	Great Northern	Cu	68		Cu
24	Rhonda Fay	Cu	69	Black Valley	U
25	Deanne	Cu	70	Jamie (Fishers Gift)	Cu
26	Southern Light	Cu	71		Cu
27	Surprise	Cu	72		Cu
28	Azurite	Cu	73		Cu
29		Cu	74	Barbara (Green Monster)	Cu
30	Beautiful View	Cu	75		Cu
31		Cu	76	Maylene	Cu
32		Cu	77	Yamamilla	Cu
33	Kangaroo	Cu	78	TC	Cu
34		Cu	79	Lillimay (Royal)	Cu
35	Western	Cu	80	Lillimay No. 1	Cu
36	Mount Metallic	Cu	81	Manxman	Cu
37	Dreadnought	Cu	82		Cu
38	Queenslander	Cu	83	Mount Olive	Cu
39	Scheelite	W	84		Cu
40		Au	85	Florin	Cu
41	Sing's Reward	Au	86		U
42		Au	87		Cu
43	Queen Elizabeth	Cu	88		Cu
44		Cu	89		Cu
45	Lady Hall	Cu			

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS





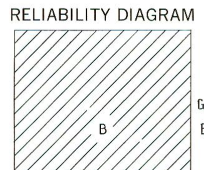


Scale 1:100 000

KILOMETRES

MILES

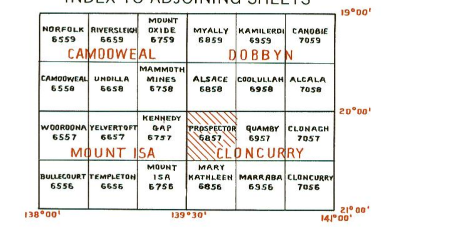
RELIABILITY DIAGRAM



Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of Minerals and Energy. Issued under the authority of the Hon. R.F.X. Connor M.P., Minister for Minerals and Energy.
Base map compiled by the Division of National Mapping from aerial photography at 1:80 000 scale.
Horizontal Datum: Australian Geodetic Datum 1966

Geology 1952-1959 by E.K. Carter, J.M. Bennett, R.A. Searl, J.F. Ivanac, K.A. Townley, K.R. Walker, R.B. Fraser, W.M.B. Roberts and C.E. Prichard (BMR); J.H. Brooks and B.W. Hawkins (GSQ)
1973 by I.H. Wilson (GSQ); R.M. Hill, G.M. Derrick, B.A. Duff, and D.J. Ellis (BMR); T.A. Noon (GSQ)
Compiled 1973 by M. Little
Cartography by Geological Branch, BMR
Drawn by M. Little
Printed by: Mercury—Walch Pty Ltd., Hobart, Australia

INDEX TO ADJOINING SHEETS

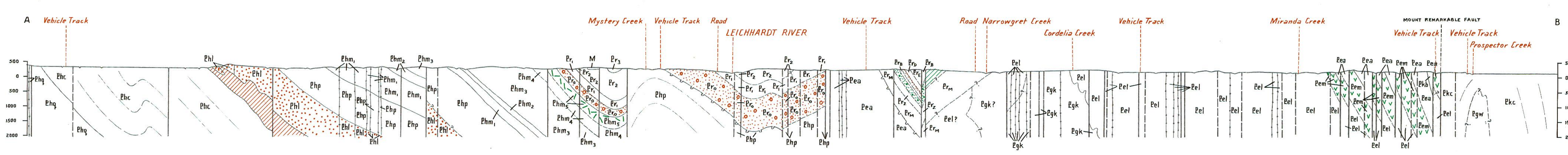


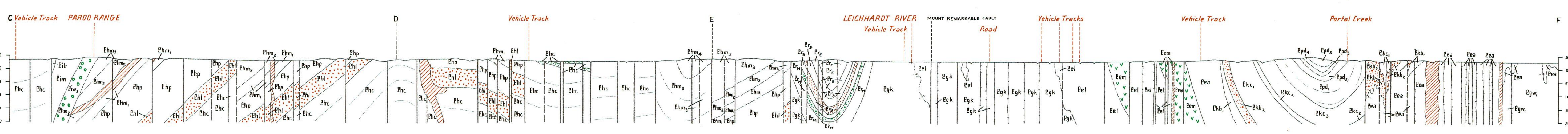
Sections

Scale $\frac{H}{V} = 1$

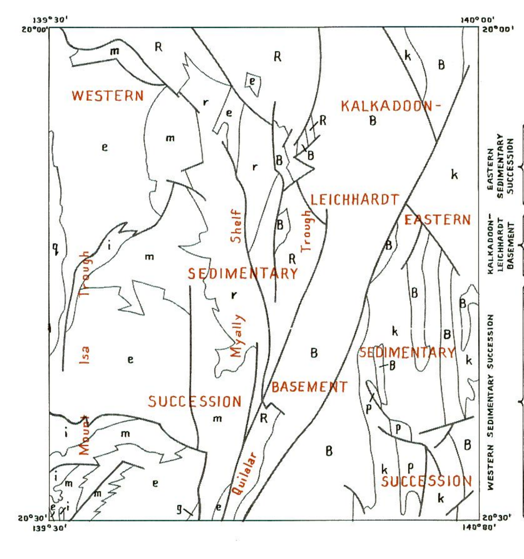
Cainozoic sediments omitted

Depth in metres





STRUCTURAL SKETCH MAP



p Portal Group (Deighton Quartzite)
k Mary Kathleen Group (Ballara Quartzite, Corella Formation) + Wonga Granite
B Tewinga Group (Leichhardt Metamorphics, Magna Lynn Metabasalt, Argylla Formation) + Kalkadoon Granite
m Myally Beds
e Eastern Creek Volcanics } Haslingden Group
g Mount Guide Quartzite
q Leander Quartzite
i Mount Isa Group
r Surprise Creek Beds (Myally Shelf)
R Surprise Creek Beds (Quilalar Trough)

PRELIMINARY EDITION 1974
SUBJECT TO AMENDMENT

PROSPECTOR
SHEET 6857