BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

Record 1982/6

GEOLOGY OF THE ALSACE

1:100 000 SHEET AREA (6858)

QUEENSLAND

BY

G.M. Derrick and I.H. Wilson

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G.M. Derrick[1] and I.H. Wilson[2]

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ABSTRACT

The Alsace 1:100 000 Sheet area lies in northwestern Queensland, between latitudes 19°30' and 20°00'S, and 139°30' and 140°00'E, in the northern part of an extensive belt of Proterozoic rocks.

The oldest rocks in the area, the Leichhardt Metamorphics, are acid volcanics which were intruded by the probably co-magmatic Ewen and Kalkadoon Granites about 1865 m.y. ago. This granite-volcanic basement is overlain unconformably by basic and acid volcanics (Magna Lynn Metabasalt and Argylla Formation) about 1780-1800 m.y. old. They may be of similar age to the Candover beds in western Alsace. The volcanic rocks display contact metamorphic effects due to the granitic intrusions.

The Haslingden Group, a sequence of up to 6000m of metabasalt overlain by and interbedded with feldspathic sandstone, quartzite, siltstone and conglomerate, lies unconformably on the volcanic-granitic basement. The Group, which thickens dramatically westwards, was deposited in the Leichhardt River Fault Trough. Blanketing both the Haslingden Group and the older basement rocks are the Quilalar Formation and its correlative, and Mary Kathleen Group, about 1740 m.y. old; they thin markedly over basement highs.

During a hiatus of 50-60 m.y. the Quilalar Formation and older rocks were uplifted and gently folded. They were overlain by red beds and basalts of the Bigie Formation and Fiery Creek Volcanics; the latter were extruded about 1680 m.y. ago. Following further uplift and erosion sand, silt and mud of the Surprise Creek Formation were deposited, and, following a minor break, similar sediments and carbonates of the Mount Isa Group.

Regional metamorphism, most severe in the east, affected the Proterozoic rocks between about 1620 - 1670 m.y., and basin and dome folds developed; faulting of several orientations followed.

Outliers of conglomerate and sandstone of Mesozoic age crop out in northeastern ALSACE.

There are few economic mineral deposits in ALSACE, but some potential exists for further discoveries of copper in the basement rocks and Surprise Creek Formation.

INTRODUCTION

This report describes the geology of the Alsace 1:100000 Sheet area 6858*, Queensland, and should be read in conjunction with the ALSACE Preliminary and First Edition geological maps at 1:100000 scale.

Location and Access

ALSACE lies between latitudes 19°30' and 20°00'S, and longitudes 139°30' and 140°00'E, in the Dobbyn 1:250000 Sheet area (Figure 1). Gunpowder township is 20km west of ALSACE, the abandoned township of Dobbyn is just east of ALSACE, and Kajabbi township is 7km southeast of the southeastern corner of the Sheet.

The Kajabbi-Dobbyn-White Hills track provides access to the eastern part of the Sheet, and the Kajabbi-Gunpowder track traverses the southern part. Access to the central northern and northwest parts of the Sheet is limited.

Population and Industry

ALSACE is almost uninhabited. White Hills or Malcom (labelled "Alsace" on the Royal Australian Survey Corps 1:100000 topographic map) and Rocky Glen are the only permanently occupied homesteads. Tewinga homestead is abandoned, but is used occasionally as a stockcamp and outstation. Cattle-raising and some sporadic gouger mining are the only significant industries in the area.

Climate and Vegetation

The climate (Slatyer, 1964), is semi-arid tropical, with warm to hot summers and warm to cool dry winters. In summer monthly average maxima range from 32°C to 39°C, and minima from 20° to 25°C. Winter monthly average maxima range from 25°C to 32°C, and minima from 10° to 20°C. Rainfall is from 400 to 550mm annually, most of which falls in the period November to March.

Vegetation (Perry and Lazarides, 1964) is mainly shrublands and sparse woodlands, with short grassy understoreys. The sandy plains of the

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* Hereafter written as ALSACE.

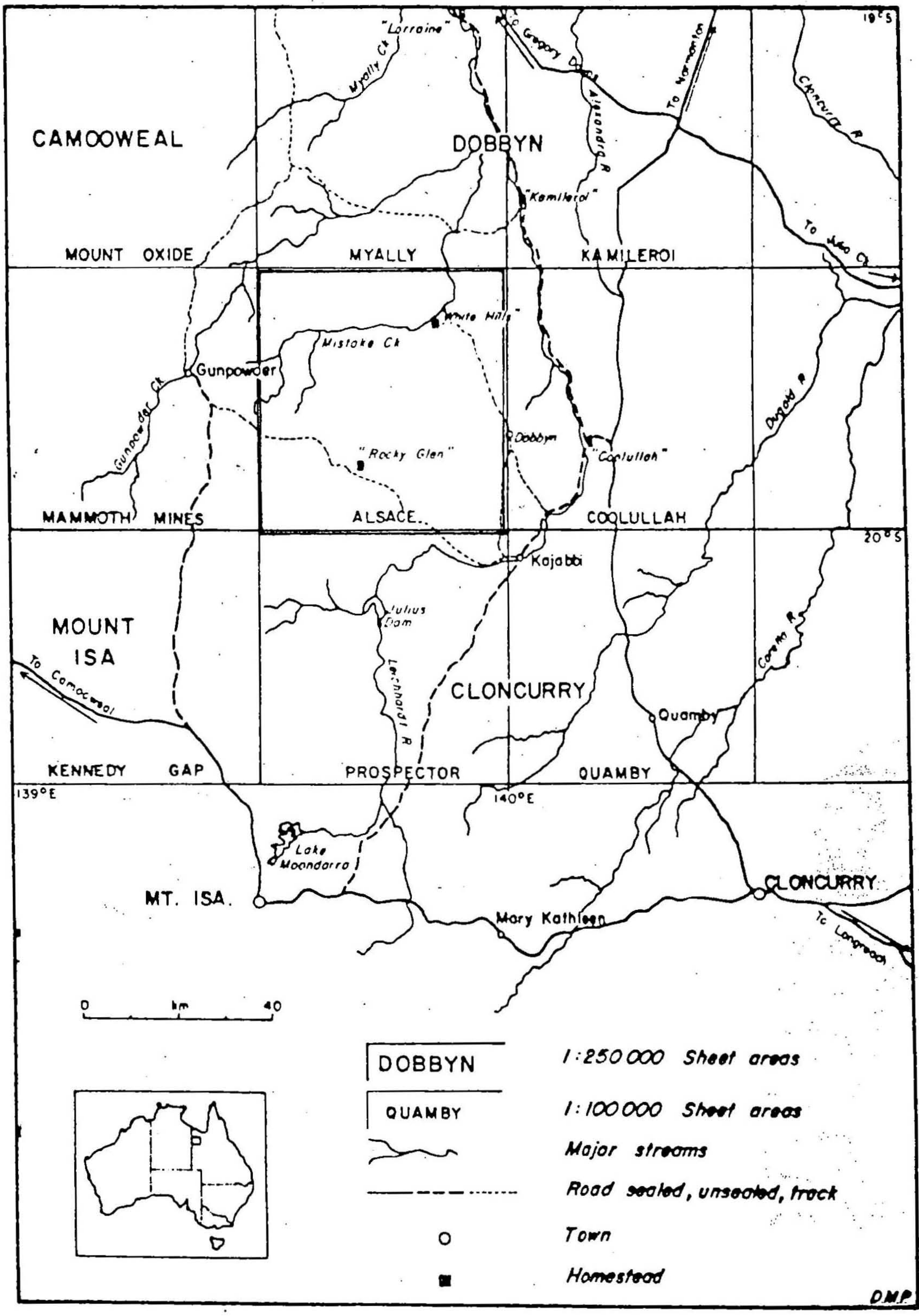
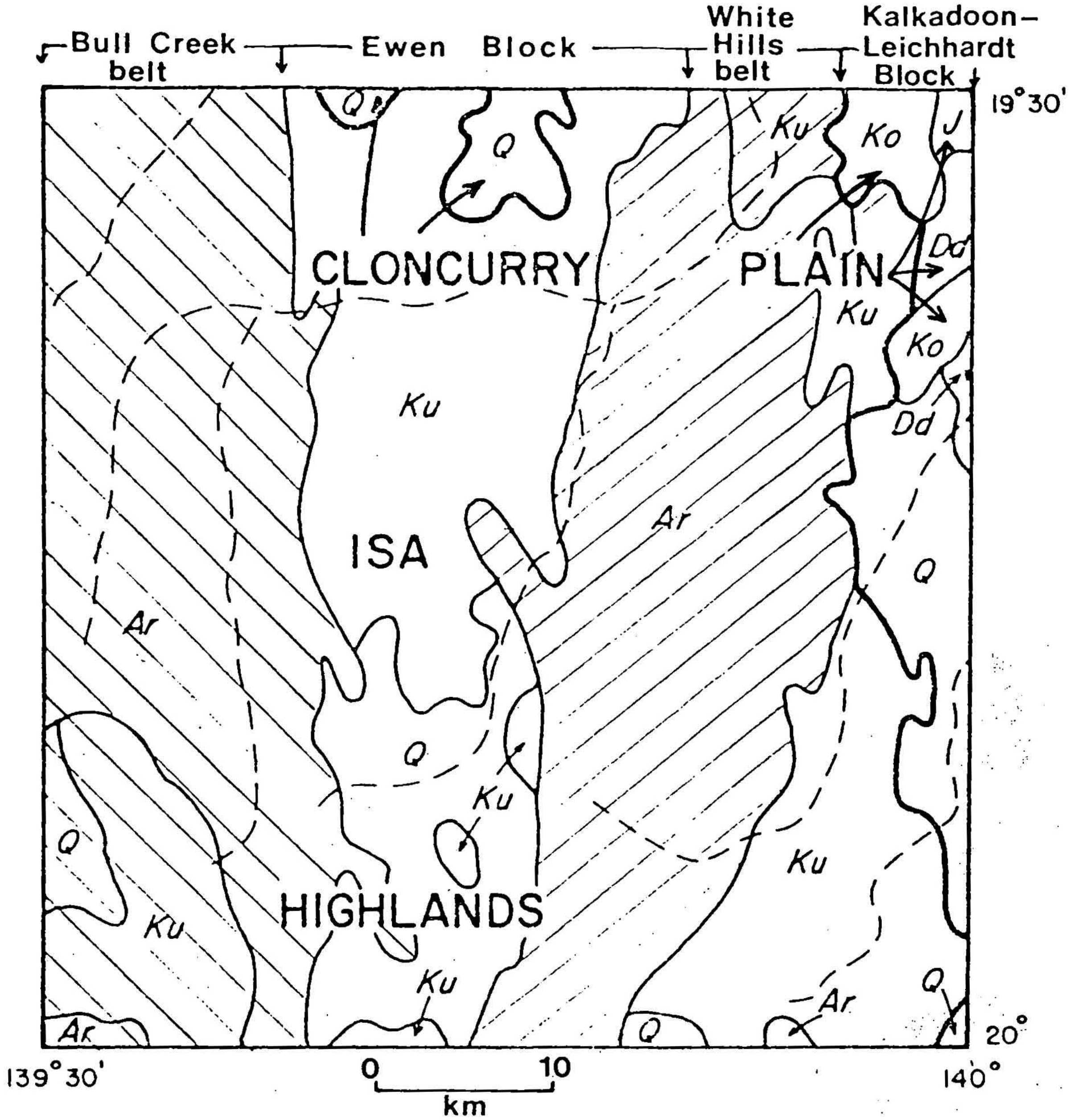


Figure 1: Location of Alsace Sheet Area



PHYSIOGRAPHIC DIVISIONS	GEOMORPHOLOGICAL UNITS	LAND	FORMS
ISA HIGHLANDS	Immaturely dissected plateaux and high plains	*Ar*	Argylla
	Maturely dissected ridges and vales	*Ku*	Kuridala
CARPENTARIA PLAINS (CLONCURRY PLAIN)	Plains of erosion	*Dd*	Donaldson
		J	Julia
		Q	Quamby
	Depositional plains	*Ko*	Korong

J.J.M.

Fig. 2 Physiographic divisions, geomorphological units, and land forms central and far eastern Sheet area support abundant grass, spinifex and sparse eucalypt growth, and clumps of gidyea. Quartzite ranges in the eastern and western Sheet area are more heavily timbered with various stunted eucalypts and acacia scrub, and ubiquitous spinifex. Large red and grey gums and paper bark trees are common along the major watercourses.

Topography and Drainage

Four distinct north-trending topographic belts, part of the Isa Highlands (Figure 2), extend across the Sheet area. From the west, the 18km wide Bull Creek belt, underlain by mainly quartzite, siltstone and basalt, forms rugged dissected ridge and plateaux topography, with highest points 350 to 400m above sealevel, and local relief of from 100 to 150m. Further east, a 15km-wide belt underlain by mainly granite and acid volcanics (the Ewen Block) forms subdued topography, with low bouldery rises and sandplains transected by an upstanding ridge of quartzite, the Mount Fox outlier. Average elevations are about 200m in the south, and 120m in the north.

The Ewen Block is flanked to the east by the White Hills belt, a rugged 15km wide zone of dissected quartzite ridges and plateaux similar to the Bull Creek belt. It is bounded to the east by the 5 to 15km wide Kalkadoon-Leichhardt Block, underlain by granite and volcanics, which form bouldery hills in the south and mainly sandplains with scattered boulder-strewn hills and rises to the north. Elevation ranges from 300m to 100m, south to north. In the north of ALSACE, erosional and depositional plains of the Carpentaria Plains - the Cloncurry Plain - flank the Isa Highlands (Figure 2).

Nearly all drainage is to the east or northeast to join the Leichhardt River, to the east of the Sheet area. Most creeks contain water only during the wet summer months, but many permanent waterholes are present along Dynamite, Mistake, Bull, Gum, Surprise and St. Paul Creeks.

Previous Investigations

Early work in the Sheet area was by A.G.G.S.N.A., who conducted geophysical surveys in mineralised terrain near Dobbyn (Nye and Rayner, 1936), and geological surveys in the Lochness area, from Surprise Creek in the south to Mount Fox in the north (Jensen, 1941). Jensen's report described the older Kalkadoon Series of "Archaeozoic" age (mainly granites, acid volcanics and amphibolite) and the Proterozoic Mount Isa Series (mainly quartzite, andesite, conglomerate, shale and limestone), and reported copper mineralisation from what is now mapped as Surprise Creek Formation.

Carter, Brooks & Walker (1961) include many general references to the geology of ALSACE. Geophysical surveys, mainly EM and IP methods, were conducted by BMR over the Dobbyn and adjacent mines (Gardener, 1964; 1965), and certain anomalous zones were tested by drilling in 1966 (Gardener, 1968). Dockery and Tipper (1964) reported results of an aeromagnetic survey over the Dobbyn-Mount Cuthbert area. Results of a BMR gravity survey in 1963 and 1964 (Smith, 1966) in the Kajabbi-Kamileroi area led to further gravity surveys in the Dobbyn area in 1967 (Smith, 1968). This geophysical work revealed no significant additional reserves in the copper deposits near Dobbyn.

Studies of Ewen Granite from areas just north of ALSACE revealed K/Ar biotite ages of 1776 and 1772 m.y. (Richards, Cooper & Webb, 1963), and a Rb/Sr whole rock age of about 1780 m.y. (McDougall and others, 1965), which can be recalculated to about 1740 m.y. using new constants.*

A history of mineral exploration in the Dobbyn 1:250000 Sheet area (Wilson, 1980) includes discussion of areas on ALSACE (e.g. Mt. Cuthbert, Dobbyn mines). The earliest copper production in the area was from Mount Cuthbert in 1900 (Wilson, 1980). Most recent exploration for copper has been directed to traces of mineralisation in siltstone of the Surprise Creek Formation south of Malcom (White Hills) homestead.

Present Investigations

A photo-interpreted map of ALSACE was prepared in July, 1976, prior to ground traversing by G.M. Derrick, R.M. Hill & I.H. Wilson (GSQ) from 7th to 15th September 1976. Field work by the above personnel was completed in 1977 using a Bell 3BG helicopter for 35 hours flying time from 24th July to 8th August, from a base camp at Dobbyn. The helicopter was used to drop and pick up personnel undertaking 5 to 10km walks, and for spot-checks across the Sheet.

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* Decay constant for ^{87}Rb of 1.42×10^{-11} yr^{-1}

Final ground traversing was undertaken from 15th-19th August, 1977. Vehicle traverses along all tracks supplemented the helicopter coverage.

Maps, Aerial Photographs, Landsat Imagery

The following maps, photographs and Landsat imagery of ALSACE are available:

Maps:

a. Topographic map at 1:250000 scale - DOBBYN SE 54-14, compiled in 1963 from 1950 K17 photography by Royal Australian Survey Corps; available from the Division of National Mapping.

b. Topographic map at 1:100000 scale - ALSACE, Sheet 6858 - compiled from RC9 aerial photography by Royal Australian Survey Corps, 1975; available from Division of National Mapping, Canberra.

c. Current 1:100000 scale Mining Lease Atlas maps (ALSACE); available from the Mines Department, Queensland.

d. Current 1:100000 scale Block Identification map, Series B; available from the Mines Department, Queensland.

e. Current 1:2500000 Authority to Prospect (Minerals) map of Queensland; available from the Mines Department, Queensland.

Aerial photographs (available from Divison of National Mapping, Canberra)

a. K17 black-and-white at 1:50 000 scale taken in 1950 by RAAF;
b. RC9 black-and-white at 1:85 000 scale, taken in 1966 by Adastra;
c. Colour at 1:25 000 scale taken in 1972 for the Commonwealth of Australia;
d. Photomosaic at 1:100 000 scale produced from RC9 photography.

Landsat imagery:

ALSACE is covered by coordinates PATH 106, ROW 074. Scene identifications up to 4.11.78 (with zero cloud cover) are as follows:

Scene no.	1027 - 00123
	2059 - 00012
	2239 - 00001
	2292 - 23594
	30154 - 00015
	30172 - 00020
	30244 - 00023

Enquiries regarding Landsat should be directed to the Australian Landsat Station, P.O. Box 28, Belconnen, A.C.T. 2616.

Nomenclature

Streckeisen's (1967) classification has been used in this Record for naming igneous rocks; Crook's (1960) for arenites; and Joplin's (1968b) for metamorphic rocks. The term 'granofels', defined by Goldsmith (1959), is used instead of 'granulite' or 'hornfels' for a metamorphic rock with a granoblastic texture. All textural terms describing both igneous and metamorphic rocks are used in the sense defined by Joplin (1968a, 1968b).

The grainsizes used to classify sandstones are as follows: fine, 0.125 to 0.25mm; medium 0.25 to 0.5mm; coarse 0.5 to 1mm; and very coarse 1 to 2mm. The bedding thickness terms used for sedimentary rocks are: laminated, less than 1cm; thin-bedded, 1 to 50cm; medium-bedded, 50cm to 2m; and thick-bedded, over 2m. If the grainsize of the granitic rocks is less than 1mm, it is described as fine; if 1 to 5mm, as medium, if 5mm to 3cm, as coarse, and if over 3cm as pegmatitic.

In describing the amount of a mineral present in a rock, 'accessory' is used to mean less than 10 per cent, and 'trace' less than one per cent; 'essential' is used to describe any mineral whose presence is essential to the classification of the rock. Estimated modal analyses are visual estimates of the percentage of mineral constituents observed in a thin-section, compared with standard charts for estimating percentage composition of rocks and sediments (Compton, 1962). All specimen numbers prefixed by 'R' are GSQ rock numbers and those prefixed by 'M' are GSQ microslide numbers; all other numbers are BMR registered numbers with the prefixes 7620, 7720 or 7820 deleted, except where otherwise stated. 'Agd' is used for average grain diameter, measured in millimetres.

Most petrography and geochemistry completed within BMR is summarised in Appendices 1 to 21; petrography and modal analyses of samples examined within GSQ are contained in Appendices 22 and 23 respectively.

LOWER PROTEROZOIC TO MIDDLE PROTEROZOIC (CARPENTARIAN) STRATIGRAPHY

Introduction

Precambrian stratigraphy is summarised in Table 1. The oldest rocks are volcanics, granites and some sedimentary rocks which are exposed in the Kalkadoon-Leichhardt Block and Ewen Block. The volcanics constitute the Tewinga Group (Leichhardt Metamorphics, Magna Lynn Metabasalt, Argylla Formation), about 1860 to 1780 m.y. old (Page, 1978). The Kalkadoon Granite (1865 m.y.; Page, 1978) intrudes the Leichhardt Metamorphics in the Kalkadoon-Leichhardt Block, and the Ewen Granite (1840 m.y.) intrudes them in the Ewen Block. Some metabasalt, metarhyolite and metasediment (Candover beds) in the Ewen Block may be equivalent to parts of the Tewinga Group, and are also intruded by granite mapped as Ewen Granite.

The basement volcanics and granites form the Tewinga Platform, a broad subaerial crustal edifice on which supracrustal sequences of the Eastern and Western successions were deposited.

In the Western Succession, the Haslingden Group (Eastern Creek Volcanics, Myally Subgroup) was deposited in the Leichhardt River Fault Trough*, a rift-like structure (Glikson & others, 1976; Derrick, 1982), formed to the west of Ewen Block.

A mainly transgressive shallow shelf sequence was then deposited across the mainly shallow-water Quilalar-Corella Shelf. In the east, the Mary Kathleen Group (Ballara Quartzite, Corella Formation) rests directly on Kalkadoon-Leichhardt basement, but to the west the equivalent Quilalar Formation (Derrick, Wilson & Sweet, 1980) rests conformably on the Haslingden Group, and unconformably or disconformably on both Kalkadoon and Ewen Blocks.

Younger units are preserved only to the west of the Kalkadoon-Leichhardt Block. Fiery Creek Volcanics and the related Bigie Formation

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* Shown as Haslingden Basin on Preliminary Edition map.

TABLE I: SUMMARY OF STRATIGRAPHY, ALSACE SHEET AREA

AGE	UNIT/SYMBOL	THICKNESS (m)	LITHOLOGY	RELATIONS, REMARKS
Mesozoic	M	30+	Conglomerate, pebbly red-brown sandstone, fine sandstone with plant remains, medium to coarse sandstone with mudstone intercalations.	Unconformable on older rocks; forms flat-lying mesas.
1670 m.y.	MOUNT ISA GROUP Native Bee Siltstone (Ꝑin, Ꝑin$_a$)	Ꝑin 750 min Ꝑin$_a$ 40 min	Ꝑin: Dolomitic siltstone and shale, dolomite, pyritic siltstone, basal chert layers. Ꝑin$_a$: Laminated algal chert.	Conformable above Breakaway shale; diagenetic albite and "cauliflower" chert nodules common.
	Breakaway Shale (Ꝑib)	150 - 200	Grey siltstone, shale, siliceous siltstone.	Conformable above Moondarra siltstone.
	Moondarra Siltstone (Ꝑim, Ꝑim$_c$)	Ꝑim 350 - 400 min Ꝑim$_c$: 350	Ꝑim: Laminated siltstone, fine sandstone, convoluted sandstone. Ꝑim$_c$: Dolomitic siltstone and dolomite.	Conformable above Warrina Park Quartzite.
Proterozoic	Warrina Park Quartzite (Ꝑiw)	35 - 200	Orthoquartzite, feldspathic quartzite, conglomerate; minor green-grey siltstone, fine sandstone.	Overlies Surprise Creek Formation concordantly, probably disconformably; overlies other units unconformably; some Cu staining.
	SURPRISE CREEK FORMATION Unit D (Ꝑrd)	100 - 300	Siltstone, fine sandstone, minor shale and dolomitic siltstone and sandstone.	Overlies Bigie Formation and Fiery Creek Volcanics with low-angle regional unconformity. Coarse channel sands at base.
	Unit C (Ꝑrc)	110 - 170	White to brown sandstone, siltstone.	
	Unit B (Ꝑrb)	100 - 270	Micaceous feldspathic sandstone, purple siltstone, dolomitic sandstone.	
	Unit A (Ꝑra)	50 - 900	Feldspathic sandstone, pebbly sandstone, conglomerate.	
	(Ꝑra$_c$)	0 - 780		

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TABLE 1: SUMMARY OF STRATIGRAPHY, ALSACE SHEET AREA (Cont'd)

AGE	UNIT/SYMBOL	THICKNESS (m)	LITHOLOGY	RELATIONS, REMARKS
1680 m.y.	Fiery Creek Volcanics (Ꝑfc)	Up to 80	Metabasalt, trachybasalt, breccia, feldspathic sandstone, arkose, agglomerate.	Overlies Ꝑfz and Ꝑfy concordantly or with local unconformity.
	Unnamed member (Ꝑfz) (Ꝑfzq)	Up to 250	Purple micaceous siltstone, feldspathic sandstone, dolomite, dolomitic sandstone and siltstone, shale-clast conglomerate; minor stromatolitic dolomite.	Volcanics overlie older rocks with regional unconformity.
	Bigie Formation (Ꝑfy)	100 - 490	Pebbly feldspathic quartzite, conglomerate, minor calcareous sandstone.	Overlies Quilalar Formation disconformably.
1720 m.y.	MARY KATHLEEN GROUP Corella Formation (Ꝑkc, Ꝑkc$_3$, Ꝑkc$_2$, Ꝑkc$_1$)	Ꝑkc$_3$, 400	Micaceous, calcareous, metasiltstone calc-silicate rocks.	Overlies Ballara Quartzite conformably; intruded by dolerite.
		Ꝑkc$_2$, 100	Feldspathic metasandstone.	
		Ꝑkc$_1$, 350	Calcareous metasiltstone, schist, arkose, limestone, marble, calc-silicate rocks.	
	Ballara Quartzite (Ꝑkb, Ꝑkb$_1$)	Ꝑkb, 100-300	Ꝑkb: Arkosic grit, sandstone, feldspathic quartzite.	Overlies Argylla Formation disconformably; equivalent to Quilalar Formation, unit W.
		Ꝑkb$_1$, 0-200	Ꝑkb$_1$: Arkose, grit, conglomerate.	
1720 min.	QUILALAR FORMATION Unit x (Ꝑqx)	Ꝑqx 430-700	Ꝑqx: Fine purple sandstone, dolomitic sandstone, siltstone, rhyolitic tuff and ashstone, shale-clast conglomerate, feldspathic sandstone, dolomite, dolomitic breccia.	Overlies Ꝑqw conformably; marked facies changes from sandstones to dolomites.
		Ꝑqxq, 50-650	Ꝑqxq: Orthoquartzite, feldspathic sandstone, minor conglomerate.	Sand lens in Ꝑqx.

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TABLE 1: SUMMARY OF STRATIGRAPHY, ALSACE SHEET AREA (Cont'd)

AGE	UNIT/SYMBOL	THICKNESS (m)	LITHOLOGY	RELATIONS, REMARKS
1720 min	QUILALAR FORMATION (Cont'd)			
	Other Members; $Ꞓqx_q$, $Ꞓqx_t$, $Ꞓqx_u$, $Ꞓqx_v$.	$Ꞓqx_t$, 450	$Ꞓqx_t$: Feldspathic quartzite, siltstone with sandstone pillows.	Local occurrence only.
		$Ꞓqx_u$, 170	$Ꞓqx_u$: Dolomite, dolomitic siltstone.	
		$Ꞓqx_v$, 50	$Ꞓqx_v$: Feldspathic quartzite, micaceous sandstone.	
	Ꞓqw	20-500	Feldspathic quartzite, orthoquartzite, sandstone, siltstone, shale, conglomerate, arkose.	Overlies Myally Subgroup conformably; overlies Tewinga Group unconformably.
	$Ꞓqw_1$	0-350	Arkose, conglomerate, quartzite, pyritic sandstone, minor acid tuff and basalt.	
	HASLINGDEN GROUP			
	Myally Subgroup (Ꞓhm)	0-3300	Feldspathic quartzite, orthoquartzite, clayey and ferruginous sandstone, conglomerate, arkose.	Undivided: Overlies Tewinga Group and Ewen Granite unconformably; thins rapidly west to east.
	Lochness Formation (Ꞓhn)	500	Feldspathic, kaolinitic and dolomitic sandstone, siltstone, dolomite.	Overlies Whitworth Quartzite conformably.
	Whitworth Quartzite (Ꞓhw, $Ꞓhw_s$)	Ꞓhw: 2000	Feldspathic quartzite, clayey sandstone.	Overlies Bortala Formation conformably; intruded by dolerite sills.
		$Ꞓhw_s$: 100	Feldspathic sandstone, siltstone.	
?1750 to ?1800	Bortala Formation (Ꞓhb)	150	Feldspathic sandstone, siltstone.	Overlies Alsace Quartzite conformably; intruded by dolerite sills.
	Alsace Quartzite (Ꞓha)	700-750	Feldspathic quartzite.	Overlies Eastern Creek Volcanics conformably.

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TABLE 1: SUMMARY OF STRATIGRAPHY, ALSACE SHEET AREA (Cont'd)

AGE	UNIT/SYMBOL	THICKNESS	LITHOLOGY	RELATIONS, REMARKS
?1750 to ?1800	Eastern Creek Volcanics (Ꝑhe, Ꝑhe$_q$)		Metabasalt, siltstone, quartzite, tuff, breccia, conglomerate, arkose, chlorite schist, pebbly sandstone.	All thicknesses minimum estimates; units thin rapidly west to east, except Dynamite Creek Member, which thins east to west; overlies Ewen Granite, Tewinga Group and Candover Beds unconformably.
	Pickwick Metabasalt Member (Ꝑhp, Ꝑhp$_q$)	1000	Metabasalt, ferruginous siltstone, tuff, chert, chlorite schist, pebbly sandstone, feldspathic quartzite.	
	Lena Quartzite Member (Ꝑhl)	200	Feldspathic quartzite, orthoquartzite, conglomerate, boulder beds.	
	Cromwell Metabasalt Member (Ꝑhc, Ꝑhc$_q$)	2500	Metabasalt, chlorite schist, siltstone, feldspathic sandstone.	
	Dynamite Creek Member	350	Labile sandstone, conglomerate.	
	TEWINGA GROUP			
	Argylla Formation (Ꝑea, Ꝑea$_t$, Ꝑea$_b$, Ꝑea$_h$, Ꝑea$_q$)	Ꝑea, 200-500	Ꝑea: Rhyodacitic crystal tuff, agglomerate, rhyolite, dacite, siltstone, phyllite, arkose, conglomerate, orthoquartzite.	Overlies Magna Lynn Metabasalt conformably; and overlies Leichhardt Metamorphics unconformably. May also overlie Ewen Granite. Age about 1780 my.
		Ꝑea$_t$, 20	Ꝑea$_t$: Rhyolitic tuff, tuffaceous shale and siltstone, minor crystal tuff and rhyolite.	
		Ꝑea$_b$, 50	Ꝑea$_b$: Metabasalt.	
		Ꝑea$_h$, 50	Ꝑea$_h$: Quartz-feldspar porphyry.	Sill intruding Magna Lynn Metabasalt.
		Ꝑea$_q$, 5	Ꝑea$_q$: Orthoquartzite	Thin lenses in crystal tuff.
?1800	Magna Lynn Metabasalt (Ꝑem, Ꝑem$_q$)	Ꝑem, 400-120	Metabasalt, basalt, chert, greywacke, tuff, quartzite.	Overlies Leichhardt Metamorphics disconformably.
	Undivided (Ꝑe, Ꝑe$_b$)	Ꝑe 300$^+$	Rhyolitic ignimbrite.	Ꝑe$_b$ may equate with Magna Lynn Metabasalt and other basalt members in Argylla Formation.
		Ꝑe$_b$, 50	Metabasalt.	

TABLE 1: SUMMARY OF STRATIGRAPHY, ALSACE SHEET AREA (Cont'd)

AGE	UNIT/SYMBOL	THICKNESS (m)	LITHOLOGY	RELATIONS, REMARKS
	CANDOVER BEDS (Ꝑb, Ꝑsa, Ꝑs, Ꝑv)	Ꝑb, 400	Metabasalt, with granite and pegmatite veins.	Relations not well known; overlain unconformably by Eastern Creek Volcanics; intruded by granite which may be Ewen Granite or younger phase; also intruded by dolerite.
		Ꝑsa, 500	Arkose, conglomerate, quartz-magnetite rock, schist; minor rhyolitic tuff, metabasalt, quartzite, greywacke breccia.	
		Ꝑs, 600	Mica schist, psammitic schist, cordierite schist, quartzite, tuffaceous greywacke and breccia.	Concordantly overlies volcanics of Ꝑv.
		Ꝑv, 400	Fluidal rhyolite, schistose tuff, mica schist, phyllonite.	May equate with parts of Argylla Formation.
?1850	EWEN GRANITE ($Ꝑge$, $Ꝑge_1$)		Ꝑge: Leucogranite, porphyritic granite, granodiorite, microgranite. $Ꝑge_1$: Granodiorite, tonalite.	Intrudes Leichhardt Metamorphics; granite mapped as Ewen Granite intrudes Candover Beds, but this may be a younger phase, intruded by dolerite.
1860	KALKADOON GRANITE ($Ꝑgk$, $Ꝑgk_h$)		Ꝑgk: Porphyritic granite, leucogranite, aplite, pegmatite. $Ꝑgk_h$: Porphyritic microgranite and microdiorite.	Intrudes Leichhardt Metamorphics; intruded by dolerite.

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TABLE 1: SUMMARY OF STRATIGRAPHY, ALSACE SHEET AREA (Cont'd)

AGE	UNIT/SYMBOL	THICKNESS (m)	LITHOLOGY	RELATIONS, REMARKS
	TEWINGA GROUP (Cont'd)			
1860	Leichhardt Metamorphics (Pel)	1000+	Rhyodacitic crystal tuff and porphyry, spherulitic rhyodacite, tuff, agglomerate, lapilli tuff, chert, metabasalt, quartzite, gneiss, minor andesite, migmatite, conglomerate.	Intruded by dolerite; oldest unit exposed in Sheet area.

(Hutton, Cavaney & Sweet, 1981) overlie the Quilalar Formation unconformably, and are themselves unconformably overlain by the Surprise Creek Formation (Derrick, Wilson & Sweet, 1980). The Mount Isa Group (Warrina Park Quartzite, Moondarra Siltstone, Breakaway Shale, Native Bee Siltstone), deposited in the Mount Isa Trough, overlies the Surprise Creek Formation and older rocks conformably and unconformably. Remnants of a thin, mainly non-marine Mesozoic cover occur throughout the Sheet area.

TEWINGA GROUP

Leichhardt Metamorphics

Map Symbol: Eel.

Nomenclature: The term "metamorphics" is a misnomer for this unit in ALSACE, as it consists almost entirely of little to moderately recrystallised acid volcanic material. Volcanics in the Ewen Block were assigned to the Argylla Formation by Carter et al. (1961), but they are now assigned to the Leichhardt Metamorphics on the basis of lithology, chemistry and relationships to dolerite dyke swarms.

Distribution: Throughout the Ewen and Kalkadoon-Leichhardt Blocks, and as inliers basal to the sequence in the White Hills belt, between the Ewen and Kalkadoon Blocks. Total area of outcrop is about 580km^2.

Field Occurrence: The volcanics form broad belts of low bouldery outcrop, with tors present locally. A fracture cleavage is present generally oriented north-south, which parallels lithological banding in the Kalkadoon Block; primary flow and eutaxitic layering in the Ewen Block trends northwesterly near White Hills Outstation (689320), with dips from 15° to 45° to the northeast. East-west-trending lithological layering is present in volcanics in the south of the White Hills block.

Lithology: Grey-green to pink-brown rhyodacitic crystal tuff and porphyry, spherulitic rhyodacite, tuff, lapilli tuff, agglomerate; minor chert, metabasalt, labile quartzite, grey gneiss and migmatite, andesite, conglomerate.

The crystal tuffs or ignimbrites are variably crystal-rich and crystal-poor; excellent eutaxitic texture is preserved in the White Hills block 6 to 10km SW of Mount Stanley (GR 850034) and north and east of White Hills outstation. Phenocrysts or crystal fragments are quartz, plagioclase and K-feldspar, set in a glassy or devitrified and recrystallised matrix. In areas of higher metamorphic grade the fine matrix of the volcanics is recrystallised to a quartz-feldspar mosaic with a.g.d. 0.1 to 0.15mm.

Agglomerate and 1 to 3m thick tuff bands showing graded bedding are present north of Mount Fox; some sparsely amygdaloidal andesite is recorded from both the Ewen and Kalkadoon-Leichhardt Blocks, and conglomerate is present near Eight Mile Creek - St. Paul Creek junction.

Thickness: The base of the formation is not exposed; a minimum thickness estimated from the White Hills block is 1000m.

Stratigraphic Relations, Age: Overlain (e.g. at 794960) disconformably or unconformably by Magna Lynn Metabasalt; dolerite dykes in the Leichhardt Metamorphics appear to be truncated by, or are feeders to the Magna Lynn Metabasalt, which also contains beds of cobble and boulder conglomerate in the White Hills block; overlain unconformably by bedded tuff and rhyolitic ignimbrite of Argylla Formation in Mistake Creek, GR 737320, where strike discordance of 10° to 20° has been measured; overlain unconformably by Myally Subgroup, and possibly Eastern Creek Volcanics, in the Mount Fox outlier e.g. at Dingo Gap; overlain unconformably by Myally Subgroup and Quilalar Formation along most of the eastern edge of the Ewen Block e.g. at Hendersons Soak, along the Kajabbi-Gunpowder track, and along Gum Creek 5km east of Mount Fox. At most of these contacts thick boulder conglomerate and arkose sequences are present at the base of the Myally Subgroup, whereas the basal Quilalar Formation contains only thin cobble conglomerate and pebbly arkose bands.

The Metamorphics are intruded by the Kalkadoon and Ewen Granites, porphyritic rhyolite or microgranite dykes, and possibly two generations of dolerite dykes - an older, sheared metadolerite and a younger, bouldery dolerite.

By extrapolation from PROSPECTOR to the south the Leichhardt Metamorphics on ALSACE are probably 1865 m.y. old (Page, 1978).

<u>Structure and Metamorphism</u>: Broadly anticlinal or east-facing in the Kalkadoon-Leichhardt Block and in the north of the White Hills block; apparently anticlinal and north-plunging in the south of the White Hills block; the only trends evident in the Ewen Block are north to north-westerly and east to northeast-dipping.

Volcanics in the Ewen and White Hills Blocks are generally lower grade than those in the Kalkadoon-Leichhardt Block. Very low-grade to almost unmetamorphosed volcanics occur along the eastern side of the Ewen Block; metamorphic grade increases to low and lower-middle greenschist facies in volcanics adjacent to the Ewen Granite, where fine glassy groundmass material has recrystallised to a polygonal quartz-feldspar mosaic, and chlorite-epidote-biotite-muscovite assemblages are present in small amounts. Middle greenschist to amphibolite grade volcanics in the Kalkadoon-Leichhardt Block resemble porphyritic quartzo-feldspathic gneiss in some areas, with accessory muscovite-biotite-sphene assemblages diagnostic.

A list of samples and localities and a summary of observed textural and metamorphic changes in the volcanics are listed in Appendices 1 and 2 respectively.

<u>Geochemistry</u>: Full silicate and selected trace element analyses of the Leichhardt Metamorphics are listed in Appendix 3. Preliminary examination of the data shows most volcanics to range from dacite to rhyolite. Ferrous/ferric iron ratios appear to be higher in samples from the Kalkadoon-Leichhardt Block, which is probably due to the more dacitic nature of the analysed samples, and possibly due to higher metamorphic grade.

Average Cu values are about 20 ppm, which is relatively high compared with values of less than 5 ppm recorded from similar rocks in MARY KATHLEEN to the south (Derrick & others, 1977), and mean values of less than 10 ppm from volcanics in the Newcastle Range area (Sheraton & Labonne, 1978).

Strontium values of over 200 ppm contrast with values of about 50 ppm recorded for the Argylla Formation (Wilson, 1978), a factor useful in separation of these two volcanic units when field evidence is lacking. Similarly the Leichhardt Metamorphics contain much lower average Zr, Nb and Y than Argylla Formation.

Magna Lynn Metabasalt

Map Symbol: Ꝑem; some units shown as Ꝑb and Ꝑe_b may be Magna Lynn Metabasalt.

Nomenclature: Defined by Derrick and others (1976a) with reference to a type section in MARY KATHLEEN.

Distribution: Along the eastern boundary of ALSACE, in the Kalkadoon-Leichhardt Block, and in north-plunging anticlines in the southern part of the White Hills Block. Metabasalt mapped as undifferentiated Tewinga Group (Ꝑe_b) may be Magna Lynn Metabasalt, and occurs in a narrow north-trending strip 5km east of Tewinga. The metabasalt is more-or-less continuous with exposures on PROSPECTOR to the south.

Field Occurrence: Generally forms a valley between acid volcanic units of the Tewinga Group; crops out as low bouldery rises; quartzite interbeds form low strike ridges.

Lithology: Basalt, metabasalt, chert, greywacke, tuff, quartzite; the basalts are massive to amygdaloidal, and little metamorphosed, and crop out in the south of the White Hills Block, with quartzite, basalt breccia and pebbly arkose and cobble to boulder conglomerate. Clasts are mainly of acid volcanic material and quartzite. Metabasalt in the southeast is typically cleaved and sheared to form chlorite-biotite schist; the quartzites are white, pale grey and buff, locally cross-bedded, and form lenses 1 to 3m thick throughout the unit, or a series of thick lenses at the base of the unit.

Thin sections of basalts (samples 76202035, 77202387, 78202390) show intersertal to pilotaxitic texture, in which abundant fine laths of altered plagioclase are intergrown with patches of chlorite and abundant iron oxide.

Thickness: From 200 to 400m in the southeast, apparently decreasing westwards to about 120m in the White Hills Block.

Stratigraphic Relations, Age: Overlies Leichhardt Metamorphics concordantly, probably disconformably. A time-break is indicated by truncation of dolerite dyke swarms in the Leichhardt Metamorphics by the Magna Lynn Metabasalt, and by basal polymictic conglomerates in the White Hills Block. Radiometric ages (Page, 1978) also indicate a substantial time break of about 80 m.y. between the Leichhardt Metamorphics and overlying volcanics of the Tewinga Group.

The metabasalt is overlain, probably conformably, by acid volcanics of the Argylla Formation, whose age (ca. 1780 m.y.; Page, 1978) probably approximates or is slightly younger than that of the Magna Lynn Metabasalt.

Structure and Metamorphism: Forms part of a regional north-plunging anticlinal structure; in the southeast and northeast, the unit forms the steep-dipping to slightly overturned east-facing limb of the anticline; closure of the anticline is seen in the south of the White Hills Block. Location of the western limb of the structure is not known; metabasalt 5 to 10km north of Surprise Creek (shown as Ɇb-undifferentiated early to middle Proterozoic on Preliminary map, and Candover beds on First Edition map) may be equivalent to the Magna Lynn Metabasalt, but structure there is complex and little understood.

Metamorphic grade is lowest in the White Hills Block (chlorite to biotite grade greenschist facies or lower), and increases to biotite-grade towards the east.

Discussion: From the Dobbyn area west to Dingo Gap the Magna Lynn Metabasalt appears to thin, possibly towards a basement ridge coincident with the central-eastern parts of the Ewen Block. The thinning is accompanied by an increase in the number of lenticular conglomerate beds associated with the metabasalt. The increase in metamorphic grade from west to east cannot be due to Kalkadoon Granite (which predates the metabasalt), but may be due to a younger metamorphism associated with the intrusion of the Wonga Granite 3km east of Dobbyn.

Argylla Formation

Map Symbols: Ᵽea; Ᵽea$_q$; Ᵽea$_b$, Ᵽea$_t$, Ᵽea$_h$.

Nomenclature: The Argylla Formation was formally defined by Carter and others (1961), and redefined by Derrick and others (1976a) as a mainly acid volcanic unit with some quartzite.

Distribution: Mainly in the south and east of the White Hills Block, and along the southeast edge of the Sheet; in a small area 6km west of Malcom, along Mistake Creek.

Field Occurrence: Occurs mainly as bouldery hills and ridges in the south and southeast; lesser outcrop in the northeast, and near Dobbyn. Volcanics in the unit display eutaxitic textures typical of crystal tuffs; bedding trends are northerly in the east, but trend westerly and southwesterly in the north-plunging anticlines in the south of the White Hills Block.

Lithology: Ᵽea: red-brown to grey rhyodacitic crystal tuff and agglomerate, porphyritic rhyolite to dacite, fluidal rhyolite; in the White Hills Block interbeds of arkose, conglomerate, greywacke, siltstone and phyllite are common, with some orthoquartzite. Some of the sediments may be part of the Magna Lynn Metabasalt.

Ᵽea$_q$: glassy orthoquartzite, forming lenses which appear to be folded, e.g. at GR 870090. One or two significant quartzite lenses (not shown on map) occur in the Mount Powell-Mount Henry belt in the southeast.

Ᵽea$_t$ is a sequence only a few metres thick of well-bedded rhyolitic tuff, tuffaceous shale and siltstone, thin-bedded crystal tuff and rhyolite; it occurs along Mistake Creek, 5km east of White Hills outstation, and appears to rest unconformably on Leichhardt Metamorphics.

Ᵽea$_h$ is quartz-feldspar porphyry, apparently forming a thin sill between flows of Magna Lynn Metabasalt, 3km west of Mount Cuthbert, near GR 837885.

Pea_b is metabasalt within crystal tuff, about 5km east of Tewinga homestead, along the eastern part of the White Hills Belt.

Most crystal tuff is quartz and feldspar crystal-rich. However, a unit of red brown crystal tuff and agglomerate near the top of the formation in the White Hills Block is quartz-poor and feldspar-crystal rich, and is notable for the presence of possible olivine pseudomorphs, and "snowflake" devitrification textures, in which volcanic glass recrystallises to a grouping of spherical, anhedral quartz crystals each of which encloses fine-grained feldspar crystals (spherulites) micropoikilitically (Lofgren, 1971). A summary of Argylla Formation petrography is listed in Appendix 4.

Thickness: 200 to 500m; it is thickest in the east and northeast, and appears to thin westwards to the White Hills Block, where the formation consists of one or two crystal tuff cooling units. Exposures in the White Hills Block also contain a greater proportion of arkose and conglomerate than exposures in the southeast.

Stratigraphic Relations, Age: Overlies Leichhardt Metamorphics unconformably in Mistake Creek, GR 737320; conformably overlies Magna Lynn Metabasalt; some interlayering of basalt and acid volcanic occurs in the contact zone; overlain disconformably or unconformably by the Ballara Quartzite and Quilalar Formation. Near Two Macks mine the Argylla Formation is overlain by massive boulder beds mapped as part of the Ballara Quartzite, and which contain clasts up to 0.5m diameter of acid volcanics, metabasalt and quartzite. To the north, 2km southwest of Dobbyn, the basal Ballara Quartzite contains a few metres of gritty, pebbly arkose and feldspathic quartzite. Similar rapid variations occur in the White Hills Block, and are described in the section on Quilalar Formation. Along Mistake Creek, at GR 743318, Argylla Formation is overlain unconformably by Quilalar Formation, the contact being marked by a 0.3m-thick bed of boulder to cobble conglomerate and arkosic breccia.

Just west of this locality at GR 736320 bedded tuffs mapped as Argylla Formation appear to overlie unconformably crystal tuff mapped as Leichhardt metamorphics. An angular discordance of 10^o to 15^o in both dip and strike is evident between the two volcanic units. The Magna Lynn

Metabasalt does not appear to be present.

Relationships of ?Ꝑea in the Surprise Creek area (as shown in the Preliminary map) are little known; acid metavolcanics now shown as a unit of the Candover beds appear to underlie undifferentiated schist, arkose and metabasalt, but are overlain unconformably by the Lena Quartzite Member of the Eastern Creek Volcanics. Granite, aplite and pegmatite pods assigned to the Ewen Granite intrude the volcanics in this area.

Unlike the Leichhardt Metamorphics, the Argylla Formation is intruded by few dolerite dykes. No dolerites have been recorded from Argylla Formation within the White Hills Block, but a few north-trending dolerites occupying fracture-cleavage planes intrude the Argylla Formation near Two Macks mine.

By extrapolation from PROSPECTOR to the south, the age of the Argylla Formation is about 1780 m.y. (Page, 1978).

Structure and Metamorphism: As for the Leichhardt Metamorphics; broadly anticlinal, the east limb being preserved in the belt south of Dobbyn, and the anticlinal fold closure being present in the White Hills Block.

Petrographic summaries in Appendix 4 show that metamorphic grade is lowest along the Quilalar Arch (chlorite grade of greenschist facies, or lower), and increases to biotite-amphibole grade of the high greenschist facies in the Kalkadoon-Leichhardt Block. The grade increase is probably due to proximity to the Wonga belt of high-grade metamorphics 3km east of Dobbyn, rather than to Kalkadoon Granite, which predates Argylla Formation (Page, 1978). Volcanics in the Surprise Creek area are of middle to high greenschist facies grade. Basalt of $Ꝑea_b$ retains an intersertal texture and is not recrystallised, but plagioclase laths are of albite-oligoclase composition.

Geochemistry: Four analyses of Argylla Formation are listed in Appendix 5. A fifth sample (2287), shown as undifferentiated Tewinga Group on the Preliminary map, is also included because of its geochemical similarity to Argylla Formation. The low Sr and CaO content (independent of SiO_2 content) remains a valid geochemical discriminant between Argylla

Formation and Leichhardt Metamorphics. The K_2O content in general is higher in the former compared with the latter.

Discussion: Volcanics in the Ewen Block were mapped as Argylla Formation by Carter and others (1961); we now consider these volcanics to be Leichhardt Metamorphics, mainly on the basis of their geochemistry, and by their relation to conjugate dyke swarms, which regionally appear to be older than Argylla Formation. The Argylla Formation constitutes part of a broad granitic-volcanic edifice (the Tewinga Platform) on which succeeding shallow shelf deposits were deposited. Like the Leichhardt Metamorphics, it appears to consist of a series of mainly ash-flow units which occur in an almost continuous belt 250km long (to Duchess in the south) and at least 40km wide and which thins westwards towards the Quilalar Arch.

Copper mineralisation occurs near the top of the Argylla Formation at the Two Macks, Mussolini, Little Wonder, Mighty Atom and Merry Monarch mines.

Unnamed Early to Middle Proterozoic units

Candover beds

Map Symbol: Ps, Pv, Psa, Pb.

Nomenclature: Unnamed on Preliminary Edition map; the name Candover beds is proposed for future reference, after Candover Holding, which lies just south of Surprise Creek, in PROSPECTOR; previously mapped as Ewen Granite, Eastern Creek Volcanics and Argylla Formation by Carter and others, 1961.

Distribution: In a small wedge-shaped area of $35km^2$ near Surprise Creek, GR 620890.

Field Occurrence: Psa: ridges and low hills of rubbly sandstone outcrop; Ps: poorly outcropping low strike ridges with much sand cover; Pv - low ridges and pavements; Pb - bouldery hills and ridges. Psa sediments show cross-bedding and graded bedding.

Lithology: Ps: mica schist, psammitic schist, labile quartzite,

?tuffaceous greywacke breccia. As mapped, easternmost areas of Ɛs are largely ?tuffaceous greywacke breccia, with some acid volcanics; western area of Ɛs is of mainly schistose rocks, apparently increasing in metamorphic grade from east to west, as mica increases in grainsize.

Pavement exposures in Surprise Creek show micaceous quartzite and mica schist intruded by microgranite parallel to layering in places; these in turn are cut by a pegmatite phase, and all units are cut finally by metadolerite. Subsequent deformation has affected all rock types.

Ɛv: green-grey fluidal rhyolite and crystal tuff, schistose in places; some mica schist and phyllonite; shown as Ɛea (Argylla Formation) on Preliminary map.

Ɛsa: arkose, conglomerate, quartz-magnetite rock (BIF), mica schist; minor rhyolitic and dacitic to andesitic tuff, metabasalt, quartzite, greywacke breccia. Some rock types overlap with other subdivisions, but Ɛsa is essentially an arenaceous unit. Greywacke and arkose conglomerate contains clasts of the BIF. Acid to intermediate volcanics are interlayered with sediments near GR 630883.

Ɛb: massive and amygdaloidal metabasalt, laced with granite and pegmatite veins. Forms extensive outcrops to the north, near GR615975; mappable bands of metabasalt within Ɛsa and Ɛs are also included in Ɛb.

A petrographic summary and sample listing of the "Candover beds" are listed in Appendix 6.

Thickness: Unknown; approximate minimum thicknesses are: Ɛs 600m; Ɛv 400m; Ɛsa 500m; Ɛb 400m.

Stratigraphic Relations, Age: All units overlain, probably unconformably, by quartzite and conglomerate mapped as Lena Quartzite Member of Eastern Creek Volcanics. Intruded by granite and pegmatite, larger masses of which are mapped as Ewen Granite, and by dolerite dykes.

Ɛs concordantly ?overlies the fluidal rhyolite mapped as Ɛv; relations between Ɛv and Ɛsa not known. Most other contacts with Myally Subgroup and Eastern Creek Volcanics are faulted.

Age is unknown; possibly younger than 1865 m.y. (Leichhardt Metamorphics; Page, 1978); possibly coeval with or younger than 1780 m.y., if volcanics mapped as Ɇv correlate with Argylla Formation to south and east. If Ewen Granite is comagmatic with Leichhardt Metamorphics, it follows that the small granitic pods and veins which intrude Candover beds may be part of a younger phase of granite; alternatively, it could also indicate the Candover beds are the same age as Leichhardt Metamorphics.

<u>Structure and Metamorphism</u>: The structure of the Candover beds is not fully understood. Unit Ɇs, the schist facies, contains no reliable facing criteria. Unit Ɇsa shows mainly west-facing structures, but is locally folded. The generally west-dipping structures in volcanics and sediments suggest Ɇv is the basal unit, ?overlain by Ɇs, Ɇsa, and Ɇb. The schistose rocks are strongly foliated, and a fracture cleavage is widely developed. Pegmatite, granite and dolerite which cut Candover beds are themselves deformed; some acid veins show folding and bou dinage.

All samples show evidence of greenschist facies metamorphism (up to actinolite/biotite grade). ?Cordierite in 2096 may indicate a slightly higher grade, possibly low amphibolite facies. Porphyroblastic muscovite in sample 2127 shows <u>no</u> evidence of an earlier sillimanite/andalusite phase. Metabasalts contain the typical greenschist assemblage of actinolite-chlorite-epidote-biotite-albite/oligoclase, the chlorite possibly being a retrogressive phase.

Field evidence suggests an unconformity is present between Ɇv, Ɇb, Ɇs and Ɇsa and the Eastern Creek Volcanics. A metamorphic unconformity can also be suspected because in the same general area, metabasalt of Ɇb is invaded by numerous granitic and pegmatitic veins, whereas basalts of Eastern Creek Volcanics are not, and in fact overlie Ewen Granite unconformably. The petrography of basalts in unit Ɇb, compared with that of Eastern Creek Volcanics (samples 2110, 2111, 2112; GR 640882) does not support unequivocally a metamorphic unconformity between the two basalt suites; the supposed younger suite (Eastern Creek Volcanics) has also been slightly metamorphosed, and contains chlorte-albite-iron ore assemblages with some actinolite.

However, sediments from the two suites show more convincing evidence of a metamorphic unconformity; sandstone sample 2109 from the Eastern Creek Volcanics displays primary grain sorting and rounding, whereas feldspathic quartzite from unit Ꝑsa shows development of triple-point grain boundary junctions, typical of a higher metamorphic grade.

Discussion: The Candover beds are older than Eastern Creek Volcanics, but other relationships are poorly understood. They are most likely correlatives of the Tewinga Group and/or the lower Haslingden Group. The sequence of arkose, conglomerate, mica schist, metabasalt, greywacke breccia and dacitic to andesite tuff resembles similar rocks of slightly lower metamorphic grade in basal Leander Quartzite in KENNEDY GAP (Wilson & others, 1979). If this correlation is accepted, it follows that the Candover beds may be correlated with the lower parts of the lower Mount Guide Quartzite (Derrick & others, 1977) and possibly the Yappo and Bottletree Formations in DUCHESS (Bultitude & others, 1978).

HASLINGDEN GROUP

Eastern Creek Volcanics

Map Symbols: Ꝑhe, Ꝑhd, Ꝑhc, Ꝑhl, Ꝑhp; Ꝑhc$_q$, Ꝑhe$_q$

Nomenclature: The three-fold division of the formation into an upper and lower basalt member separated by a quartzite member (Derrick & others, 1976b) is used in this report. From the base, the members are Dynamite Creek Member (Ꝑhd: new name); Cromwell Metabasalt (Ꝑhc); Lena Quartzite (Ꝑhl); and Pickwick Metabasalt (Ꝑhp). Undifferentiated volcanics are symbolised Ꝑhe; quartzite and conglomerate subunits are designated Ꝑhp$_q$, Ꝑhc$_q$ or Ꝑhe$_q$. The Dynamite Creek Member appears only on the First Edition map; it was designated Ꝑhe$_q$ on the Preliminary map.

Distribution: In the Bull Creek belt, west of the Ewen Block; some areas also mapped at the base of the Mount Fox outlier, in the centre of ALSACE.

Field Occurrence: Metabasalt and siltstone form areas of low relief, mainly broad rubble-strewn valleys and low, rounded bouldery strike ridges; north-trending, steep-dipping quartzites form thin, upstanding strike ridges, commonly planated, whereas east-trending quartzites in the core of an anticline form broad cuestas. Exposure very poor in extreme west of ALSACE.

Bedding and layering in sequence are outlined by sedimentary interbeds, and by regular transition from massive base to amygdaloidal and commonly flow-brecciated top of basic lava flows.

<u>Lithology</u>: Ꞓhe: massive and amygdaloidal basalt, purple siltstone, feldspathic quartzite, flow-top breccia, conglomerate, arkose, greywacke.

Ꞓhd: coarse labile sandstone and conglomerate.

Ꞓhc: mainly metabasalt and minor interbedded purple siltstone and feldspathic sandstone/quartzite.

Ꞓhp: as for Ꞓhc, but with tuff, chert and pebbly sandstone.

Ꞓhl: feldspathic quartzite, orthoquartzite, conglomerate, boulder beds, clayey sandstone.

The sandstones (Ꞓhd, Ꞓhl, Ꞓhe$_q$, Ꞓhc$_q$, Ꞓhp$_q$) are cross-bedded and ripple-marked, and become increasingly conglomeratic eastwards towards the Ewen Block. Lena Quartzite at Boozers Waterhole is highly conglomeratic, clasts being mainly acid volcanics, quartzite and minor ?basic rock. Trough cross-bedding forms very large sets up to 4m thick.

Purple-grey pebbly greywacke interbeds are commonly graded, and locally calcareous. Clasts are mainly of grey cherty acid volcanic debris, and some minor granite and basalt. Some labile conglomerates contain clasts of purple siltstone with liesegang rings developed, which may have formed by weathering prior to deposition.

Petrographic data for metabasalts and sediments are listed in Appendix 7. All basalts show greenschist facies metamorphism (albite-chlorite-actinolite-epidote assemblages), but many retain primary clinopyroxene. Sediments range from quartz greywacke to orthoquartzite, and display a fine cleavage in more micaceous samples.

Thickness: thicknesses in the west of ALSACE are:

Ɇhc 2500m; Ɇhl 200m; Ɇhp 1000m. The sequences show dramatic thinning from west to east towards the Ewen Block, and an increase in the amount of conglomeratic sediment relative to metabasalt. Unit Ɇhd (350m) is an arkosic wedge which thins from east to west.

Stratigraphic Relations, Age: Overlies Ewen Granite unconformably, e.g. Dynamite Creek member at GR 580280 just south of Mistake Creek; inferred to also overlie Leichhardt Metamorphics. Quartzite and conglomerate mapped as Lena Quartzite unconformably overlie unnamed Early to Middle Proterozoic rocks (Candover beds) 5km north of Surprise Creek, at GR 643940. Elsewhere, most contacts with older rocks are faulted.

Overlain conformably by undifferentiated Myally Subgroup sandstone, and Alsace Quartzite, the basal formation of the Myally Subgroup; overlain disconformably by pebbly sandstone of the Bigie Formation, at GR 562308, along Mistake Creek; overlain unconformably by flat-laying Mesozoic strata.

The volcanics are intruded by dolerite sills or dykes, which are far less common than in adjoining Sheet areas.

Age of the Eastern Creek Volcanics is between 1770 m.y. (K-Ar biotite age of Ewen Granite; Richards & others, 1963), and 1680 m.y., (age of Carters Bore Rhyolite, ?equivalent to Fiery Creek Volcanics; Page, 1978). The volcanics may be older than about 1740 m.y., based on relations to Quilalar Formation, and correlations with Mary Kathleen Group to the east.

Structure and Metamorphism: The volcanics outline a series of faulted synclines and anticlines; two anticlines are located along the western edge of the Sheet, and 1 to 2km west of the fault-bounded Ewen Block, respectively; intervening two synclines are formed north of the Lochness prospect, and in association with west-facing strata dipping off the Ewen Block. Plunges are mainly to the north. These meridional structures are disrupted by east-trending spoon faults with a north-block-up sense of movement.

Volcanics and sediments show some fracture cleavage in the fold crests. Sericite growth in pelitic sediments parallels the cleavage. Alteration of the volcanics to chlorite schist is widespread along the faulted contact with the Ewen Granite; some fault zones contain massive quartz, secondary carbonate masses and some copper mineralisation, e.g. the zone between volcanics and Mount Isa Group near Crystal Creek, in southwest ALSACE.

Abundance of albite, epidote, chlorite, actinolite and minor biotite and muscovite indicate greenschist facies metamorphism. Clinopyroxene is preserved in most metabasalts examined (see Appendix 7).

Geochemistry: No full silicate chemical analyses are available from ALSACE; however, analyses from volcanics in MAMMOTH MINES (to be discussed in a separate report) would be representative of ALSACE volcanics; they are mainly tholeiitic basalts, with high copper content, about 200 ppm average, and low uranium content, about 1 to 2 ppm.

Discussion: The marked decrease in thickness of the volcanics from west to east, and the associated increase in the proportion of conglomerate in the sequence, indicates the presence of a strongly subsiding zone in the west flanked by an uplifted basin margin, namely the Quilalar Arch (see structural sketch on Preliminary and First Edition maps) along the eastern edge of the Ewen Block. The hinge zone or faulted margin between the deeply subsiding rift zone and basin margin has possibly controlled later faulting along the western margins of the Ewen Block.

Basalts appear to have been deposited in subaerial or very shallow water environments. Marginal conglomeratic sediments probably formed in mainly alluvial environments, and the more extensive sandstone members (e.g. Lena Quartzite) may be shallow ?marine or near-shore deposits.

MYALLY SUBGROUP

Map Symbols: Ᵽhm; Ᵽha, Ᵽhb, Ᵽhw, Ᵽhw$_s$, Ᵽhn

Nomenclature: Undivided Myally Subgroup (Ᵽhm) may be subdivided into four formations. From the base, they are Alsace Quartzite (Ᵽha), Bortala

Formation (Ehb), Whitworth Quartzite (Ehw) and Lochness Formation (Ehn). Ehw_s is a recessive unit within Whitworth Quartzite.

<u>Distribution</u>: Myally Subgroup occurs in the Bull Creek belt and Crystal Creek area in the western part of ALSACE, and as outliers in the Ewen Block. The four-fold subdivision is recognisable only in the west limb of the regional syncline in the Bull Creek belt; in the east limb and in the Ewen Block outliers, only undifferentiated Myally Subgroup is mapped.

Thick sandstone units in the White Hills belt east of the Ewen Block were mapped as Myally Beds by Carter and others (1961), but are now mapped as part of the overlying Quilalar and Surprise Creek Formations.

<u>Field Occurrence</u>: Eha and Ehw form upstanding sandstone plateaus or ridges; Ehb and Ehn are valley-forming; thick quartzite units (Eha, Ehw, undifferentiated Ehm) form a characteristic smooth, relatively uniformly textured photo pattern with bedding trends evident, in contrast to a ridge-and-valley pattern formed in overlying quartzites of the Quilalar Formation.

Most sandstone and quartzite is white, pink or buff-coloured, medium to coarse-grained, cross-bedded and ripple-marked, and massive to blocky. Purple-brown ferruginous and silty sediments tend to be flaggy to blocky, with ripple marks and micro cross-bedding (possibly ripple lamination), silty to shaly partings, mud cracks, small-scale scour-and-fill structures, climbing ripples, sand dykes, load casting and convoluted bedding.

Some rain-drop impressions are present locally, 5.5km east of Mount Fox.

Most cross-bed current directions are from the northeast to southeast sector, and less commonly from the northwest.

<u>Lithology</u>: Ehm: feldspathic quartzite, orthoquartzite, clayey sandstone, ferruginous sandstone, conglomerate, arkose.

Eha: feldspathic quartzite.

Ɛhb: feldspathic sandstone and siltstone.

Ɛhw: feldspathic and clayey quartzite and sandstone.

Ɛhw$_s$: feldspathic sandstone and siltstone.

Ɛhn: feldspathic and dolomitic sandstone, siltstone, kaolinitic sandstone, mudflake conglomerate, dolomite.

Most quartzite and sandstone is variably feldspathic, containing 5% to 50% of pink to white feldspar and rock fragments, commonly altered to clayey patches. Orthoquartzite layers 1 to 2cm thick are commonly interspersed with highly feldspathic layers. The proportion of white clayey material in Ɛhm appears to increase from west to east.

In the Mount Fox outlier and along the Quilalar Arch the Myally Subgroup thins significantly, and contains basal or near-basal arkosic conglomerate. At GR 707923, acid volcanics of the Leichhardt Metamorphics are immediately overlain by well-bedded feldspathic ferruginous and dolomitic sandstone, and 20m of boulder beds containing acid volcanic and quartzite clasts in an arkosic groundmass. The conglomerate is especially well developed along Gum Creek, 5.3km east of Mount Fox, where up to 80m of coarse conglomerate is present.

Halite casts are present in fine feldspathic sandstone of the Lochness Formation between Mistake and Dynamite Creeks, at GR 517364.

A petrographic summary of Myally Subgroup samples is contained in Appendix 8.

Thickness: From northwest of Lochness prospect, Ɛha 700-750 m; Ɛhb 150 m; Ɛhw 2000 m; Ɛhn 500 m.

All units thin rapidly eastwards; most undifferentiated Myally Subgroup is arenaceous, and represents mainly units Ɛha and Ɛhw; units Ɛhb and Ɛhn are thin or absent east of Lochness.

Ɛhm on the east limb of the Bull Creek syncline is mainly fault-bounded; a thickness of about 1400 m is estimated from an anticlinal structure 8 km north of Boozers Waterhole and a minmum thickness of 900 m is estimated from a section just east of Lochness. At Dingo Gap, in the Mount Fox outlier, Ehm is reduced to about 200 m, and is very thin or absent along the Quilalar Arch.

These thickness estimates show that Myally Subgroup thins from about 3300 m to zero in about 15 km distance between the Bull Creek syncline and the Quilalar Arch.

Stratigraphic Relations, Age: overlies Eastern Creek Volcanics conformably, but overlaps this unit to rest unconformably on basement acid volcanics of the Leichhardt Metamorphics - good exposures of the unconformity, with associated arkosic conglomerate, can be seen at Dingo Gap, GR 708137, 5 km east of Mount Fox, GR 730200, and 2.3 km southwest of Henderson's Soak, GR 708923; inferred to overlie Ewen Granite unconformably.

Overlain, apparently conformably, by quartzite Eqw of the Quilalar Formation. Near the Quilalar Arch the contact may be locally disconformable, and is marked by thin beds of arkosic pebble conglomerate in the overlying Quilalar Formation; overlain disconformably by Surprise Creek Formation and Mount Isa Group in the southwest of ALSACE.

Dolerite sills intrude Myally Subgroup in the west and northwest of ALSACE, preferentially along boundaries of the recessive units Ehb and Ehw_s.

The Quilalar Formation which overlies Myally Subgroup is thought to be older than about 1740 m.y., based on correlations with Mary Kathleen Group near Mary Kathleen, and the U-Pb zircon age of the Burstall Granite intrusive into the Mary Kathleen Group (Page, 1979, 1980). A maximum age is possibly the K-Ar biotite age of 1770 m.y. for the Ewen Granite (Richards and others, 1963) which is inferred to underlie Myally Subgroup.

Structure and Metamorphism: Structure in the Myally Subgroup parallels that of the Eastern Creek Volcanics, viz, the Subgroup defines a series of broad meridional synclines and anticlines which have been disrupted by later faulting.

Metamorphism of the Subgroup in the west is negligible; clay minerals are recrystallised to sericite, and quartz grains show silica overgrowths. These effects may be due to diagenesis, burial, or very low-grade greenschist facies metamorphism. However, samples from near the Quilalar Arch show significantly higher metamorphic grade - mainly the chlorite-actinolite zone of the greenschist facies (see petrographic summary in Appendix 8); this is possibly attributable to proximity to the younger high-grade metamorphic belt near Dobbyn to the east.

Geochemistry: Four samples of quartzite (2230, 2232, 2243, 2250) contain 1 to 1.5 ppm uranium; a gossanous sample from the Lochness Formation (sample 2248; GR 570002) contains 380 ppm Zn.

Discussion: The Quilalar Arch probably marks the approximate eastern edge of the Myally Subgroup depositional basin, indicated by thinning of the Subgroup towards the Arch, accompanied by abundant conglomerate.

An abundance of acid volcanic rock fragments in the quartzite suggests that the Ewen Granite (and possibly Kalkadoon Granite) was not unroofed in Myally Subgroup time in ALSACE, and that the Myally provenance was mainly quartzitic and acid volcanic terrain. However, Myally Subgroup overlies Ewen Granite unconformably on MYALLY to the north.

Myally depositional environments on ALSACE are consistent with the shallow epeiric sea model proposed by Wilson and others for Myally Subgroup on the adjoinng PROSPECTOR sheet; dolomite and halite casts in the Lochness Formation suggest some depositon took place in a very shallow intertidal lagoonal environment.

QUILALAR FORMATION, MARY KATHLEEN GROUP

These mainly arenaceous, dolomitic, calcareous and pelitic units were deposited on the Quilalar-Corella shelf (see ALSACE geological map reference) and are considered to be correlatives, once continuous across the shelf but now separated by uplift of the Kalkadoon-Leichhardt Block (Derrick and others, 1980). The Quilalar Formation is subdivided into units W and X, and a number of subunits. Units W and X are broadly equivalent to Ballara Quartzite and Corella Formation respectively.

Quilalar Formation Unit W

Map Symbols: Ꝑqw, $Ꝑqw_1$: described as $Ꝑr_o$ and $Ꝑr_w$ in Derrick (1974).

Nomenclature: Quilalar Formation (new name) is named after the parish of Quilalar, near Kajabbi township, and has been formally defined by Derrick Wilson and Sweet (1980).

Distribution: occurs throughout most of ALSACE, in the White Hills and Bull Creek belts, and also in the Mount Fox outlier.

Field Occurrence: mainly as a series of upstanding parallel quartzite ridges, with narrow, intervening valleys; quartzites massive to blocky, thin to thick-bedded, medium to coarse-grained and mainly white, grey, and buff-coloured. Most quartzites display 5 cm to 50 cm-thick herringbone planar and trough cross-bedding, with moderate to high foreset bedding angles; low-angle cross-bedding and planar laminated beds (?beach deposits) are also common.

Sedimentary structures in the quartzites include symmetric, asymmetric and interference ripples, bevelled ripples, rain-drop impressions, and scour-and-fill structures. Finer-grained sediments between the quartzite ridges show local convoluted bedding and ball-and-pillow structures, and are also cleaved, especially along the Quilalar Arch.

Lithology: $Ꝑqw_1$ - arkose, conglomerate, feldspathic quartzite; minor pyritic sandstone, acid tuff and basalt.

Ꝑqw - feldspathic quartzite and orthoquartzite, clayey sandstone; minor siltstone, shale, conglomerate, arkose.

Unit $Ꝑqw_1$ assumes mappable proportions only in the White Hills belt, where it occurs in a series of fault blocks; reconstruction of the fault system suggests that $Ꝑqw_1$ may be a linear, NNE-trending channel deposit about 6 km wide and 50 km long, thinning to the west and northwest, and possibly to the east. It is incised only into Argylla Formation.

Boulder beds (at GR 873115) contain boulders to 40 cm diameter, mainly acid volcanic and quartzite, in an arkosic gritty groundmass; elsewhere Ᵽqw$_1$ contains pebble and cobble conglomerate, and coarse sandstone. ?Dacitic, chloritic tuff from GR 868112 is included in Ᵽqw$_1$, but may be part of the underlying Argylla Formation. Basalt is interbedded with pebbly arkose 7 km northeast of Malcom homestead at GR 873370.

Orthoquartzite and feldspathic quartzite of Ᵽqw are moderately well sorted, although immediately overlying Myally Subgroup the unit is distinctly bimodal. Basal sands of Ᵽqw tend to be purplish, due to iron-staining near the contact with Argylla Formation; some ferruginous banding is also present. Feldspar content and clayey rock fragments range from 5% to 25%, and feldspathic quartzite is commonly interbanded with orthoquartzite.

A petrographic summary of unit Ᵽqw is listed as Appendix 9.

Thickness: Ᵽqw$_1$ - 0 to 350m
Ᵽqw - 20 to 500m

Thickness variations in Ᵽqw$_1$ are probably due to its deposition in stream channels etc. Those in Ᵽqw are controlled mainly by proximity to basement highs i.e. the unit is thinnest along the Quilalar Arch and in the Bull Creek belt, and is thickest in the White Hills belt. Ᵽqw thickens northwards onto MYALLY, and southwards onto PROSPECTOR.

Stratigraphic Relations, Age: (Figure 3) Ᵽqw and Ᵽqw$_1$ overlie Argylla Formation disconformably in the White Hills belt. The region-wide change from acid volcanics to quartzite is accompanied by deposition of a persistent basal conglomeratic alluvial facies. The disconformity is well exposed in Mistake Creek (GR 743314), where pink, cleaved ignimbrite is in sharp contact with 0.2 to 0.3m of boulder to cobble conglomerate and breccia, which grade rapidly upwards to cross-bedded sandstone.

Along the Quilalar Arch in the Mount Fox Outlier, Ᵽqw overlies Myally Subgroup conformably, and locally unconformably; further south, at Hendersons Soak, it overlies Leichhardt Metamorphics unconformably; altered, well-cleaved acid volcanics are in sharp contact with 0.3 to 1m-thick beds of conglomeratic arkose interlayered with dull green siltstone beds.

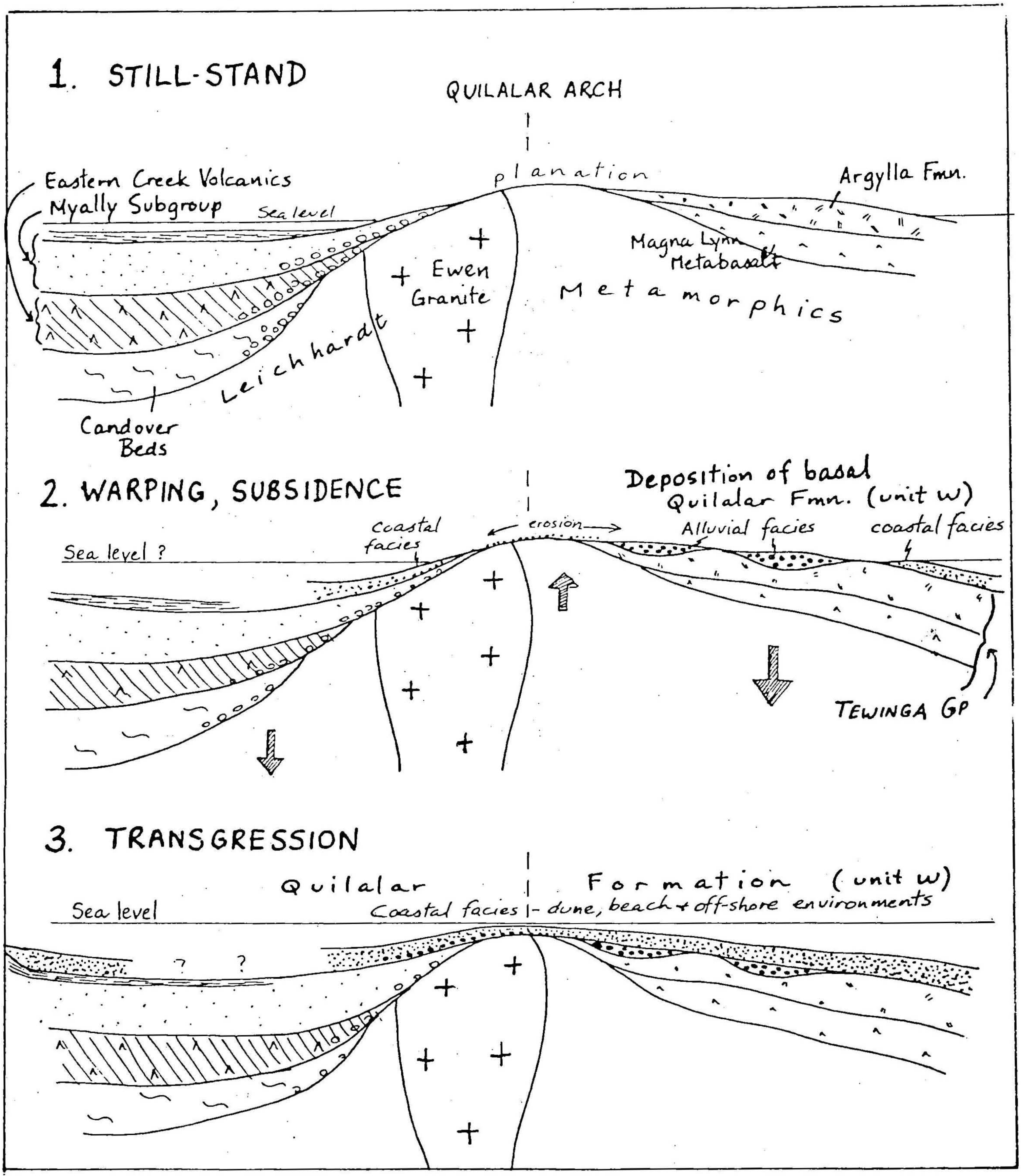


FIGURE 3: SCHEMATIC PALAEOGEOGRAPHY OF THE QUILALAR FORMATION, UNIT W.

In the Bull Creek belt, Ꞓqw overlies undifferentiated Myally Subgroup and the Lochness Formation conformably.

Age of Ꞓqw is not directly known; by extrapolation from MARRABA, MARY KATHLEEN and PROSPECTOR, Ꞓqw is younger than 1780 m.y. (Argylla Formation: Page, 1978), older than 1680 m.y. (Carters Bore Rhyolite; Page, 1978), and possibly older than 1720-1740 m.y. (Burstall Granite; Page, 1979/1980), i.e. it may have been deposited between 1780 and 1740 m.y.

Structure and Metamorphism: Ꞓqw defines a broad, north-plunging, highly faulted regional anticline with associated synclines in the White Hills belt, and a regional syncline in the Bull Creek belt. Northwest and northeast-trending faults cutting Ꞓqw show left lateral and right lateral displacements, respectively, typical of conjugate fault systems arising from east-west compression.

Along the Quilalar Arch the contact between Ꞓqw and acid volcanic basement rocks is commonly overturned.

Most samples of Ꞓqw are essentially metamorphosed or are recrystallised in the low greenschist facies. However, Ꞓqw in the east and northeast of the White Hills belt shows significantly higher grades of metamorphism, to chlorite-biotite grades of the greenschist facies. This is attributed to proximity of the belt to the high-grade Wonga belt just east of Dobbyn.

Geochemistry: Appendix 10 lists samples which have been analysed for U, Th, Cu, Pb and Zn, Rb, Pb, Y, Co, Ni, Ag, Mo and As. Arkoses and arkosic breccia from or near the base of Ꞓqw (samples 2028, 2029, 2030, 2272, 2273, 2292, 2317) contain from 2 to 16 ppm uranium (average 6 ppm) compared with 0.5 to 1 ppm uranium for orthoquartzites and feldspathic quartzites higher in the sequence. This enrichment of U in the basal sediments possibly reflects proximity to volcanic source areas containing an average of about 4 ppm uranium, and later, preferential migration and precipitation of uranium along the unconformity surface at the base of Ꞓqw. Alternatively, the basal sediments may contain uraniferous detritus, e.g. zircon, monazite. Zinc and copper values are about 5 ppm average for samples from the White Hills Belt.

Discussion: Facies changes in Ꝑqw from west to east are mainly in the nature and thickness of the basal sediments i.e. arkose and conglomerate increase to the east, and are best developed over areas of Leichhardt Metamorphics and Argylla Formation acid volcanic terrain. Minor arkose is developed between Ꝑqw and Myally Subgroup only locally, along the Quilalar Arch. In all areas Ꝑqw quartzites overlying the basal arkoses are similar, but thin rapidly along the Quilalar Arch, and, to a lesser extent, in the Bull creek belt. These features are interpreted as representatives of a transgressive/regressive shoreline sequence onlapping across a volcanic/granite basement in the east and central parts of ALSACE, and across an older sedimentary sequence (Haslingden Group) west of the Quilalar Arch. The basal arkosic facies represent reworking of exposed basement in alluvial systems, while the quartzitic facies represent the associated shore-line system of dune, beach and off-shore environments. The Quilalar Arch clearly defines the basin edge for Myally Subgroup deposition to the west, and was a submerged but still significant basement rise during Ꝑqw orthoquartzite deposition; it continued to influence sedimentation during Ꝑqx (upper Quilalar time), as will be described later. Relations between Ꝑqw, basement rocks and the Quilalar Arch are summarised in Figure 3.

Quilalar Formation Unit X

Map Symbols: Ꝑqx, Ꝑqx$_q$, Ꝑqx$_t$, Ꝑqx$_u$, Ꝑqx$_v$

Nomenclature: as for Ꝑqw; described as Ꝑr$_1$, Ꝑr$_2$, Ꝑr$_3$, Ꝑr$_x$, by Derrick (1974).

Distribution: as for Ꝑqw.

Field Occurrence: dolomitic and pelitic units mainly valley-forming, with interlayered sandstones forming low ridges; Ꝑqx$_q$ forms relatively rugged quartzite plateau topography in the Bull Creek belt.

Carbonates and pelites laminated to thin-bedded, purple-brown to grey, buff and white; sandstones white, buff and red-brown, fine to coarse-grained, massive to blocky and flaggy, thick to thin-bedded, good to moderate sorting; sandstones and quartzites ripple-marked and cross-bedded, especially Ꝑqx$_q$, which shows characteristic herringbone cross-beds in sets about 10cm thick. Upper units of Ꝑqx show mud-clast conglomerate zones and bevelled ripples. Unit Ꝑqx$_t$ is characterised by extensive convoluted bedding in fine sandstone and siltstone, associated with large fine to medium sandstone pillows.

Carbonate rocks contain stromatolites which occur throughout the Bull Creek Belt, and are well developed near Lochness prospect. At the base of the sequence, immediately overlying unit W quartzite, siliceous stromatolites form a thin, discontinuous biostromal layer 10cm thick, composed of branched and unbranched columnar (digital) forms 1 to 2cm diameter and with gently convex laminae. Individual columns tend to taper towards the base. Higher in the sequence the stromatolites are dolomitic and bulbous to pseudocolumnar and columnar layered. The bulbous forms are generally linked, and are up to 15cm high and 20cm diameter; similar forms are present in the Mount Fox Outlier (at GR 710157), and in the same unit (Ꝑr$_1$, Ꝑqx) on PROSPECTOR to the south (Wilson et al. 1977).

<u>Lithology</u>: Stratigraphic columns of Ꝑqx sections are listed in Figure 4. The detailed lithologies of these columns are listed below. A petrographic summary of Ꝑqx is listed in Appendix 11.

Section 1, Bull Creek Belt

upper Ꝑqx: 200m	Brown laminated ferruginous, calcareous or dolomitic feldspathic sandstone, purple micaceous siltstone with sandstone lenses, minor dolomite and green siliceous siltstone (?tuff).
Ꝑqx$_q$: 650m	medium to coarse white to buff orthoquartzite, feldspathic quartzite, some granule and pebbly beds; interlayered with purple micaceous and calcareous(?) siltstone and fine sandstone.
lower Ꝑqx: 500m	Stromatolitic dolomite, dolomite, purple dolomitic siltstone, ferruginous dolomitic sandstone; lenses of feldspathic quartzite and orthoquartzite; intraformational dolomitic and pelletal breccia.

Section 2, Mount Fox Outlier

upper Ɇqx: 255m	Dolomitic and feldspathic sandstone with mud flakes, grey siltstone, lenses of stromatolitic dolomite.
Ɇqx_q: 300m	White to buff/pink pebbly feldspathic quartzite.
lower Ɇqx: 440m	Purple grey fine sandstone and siltstone, micaceous and pyritic siltstone, purple shale, micaceous sandstone and medium to coarse feldspathic sandstone lenses; some fine ashstone or tuff.

Section 3, Quilalar Arch

upper Ɇqx: 110m	Flaggy purple-brown micaceous sandstone, grey-green siltstone, lenticular dolomite, dolomitic sandstone and siltstone.
Ɇqx: 120m	Orthoquartzite, feldspathic quartzite, clayey and pebbly and cross-bedded.
lower Ɇqx: 320m	Purple-brown siltstone and shale, micaceous sandstone, ashstone, dolomitic siltstone and sandstone gradational into stromatolitic dolomite, dolomitic and shale-clast ferruginous breccia.

Section 4, White Hills Belt

upper Ɇqx: 250m	flaggy fine sandstone, purple siltstone, coarse feldspathic sandstone with shale pellet conglomerate and pebbly bands; minor dolomitic sandstone and dolomite.
Ɇqx_q: 50m	coarse to medium orthoquartzite and feldspathic quartzite.
lower Ɇqx: 390m	Purple siltstone and shale with some pyrite casts, ferruginous micaceous fine sandstone, ashstone, dolomitic

siltstone and sandstone, dolomitic breccia. At base, flaggy fine to medium ferruginous feldspathic micaceous sandstone, minor siltstone.

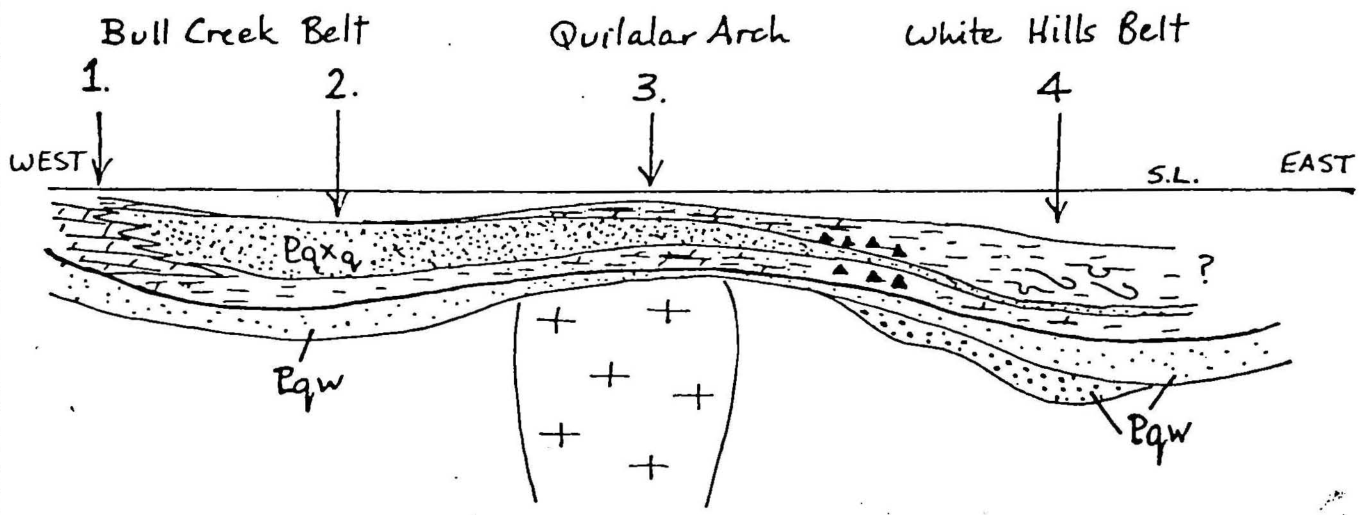
A local thickening of ?upper Ɛqx is also shown in Section 4, Figure 5. Lithologies are as follows:

$Ɛqx_v$: 50m	lenticular feldspathic and micaceous sandstone
$Ɛqx_u$: 170m	flaggy dolomitic siltstone, dolomitic sandstone and breccia.
$Ɛqx_t$: 450m	fine to medium feldspathic sandstone and quartzite, orthoquartzite grey-green siltstone with sandstone lenticles and sandstone pillows, convoluted bedding and graded bedding.

The most notable features are (1) the marked facies changes in the lower section of Ɛqx, from largely stromatolitic dolomite in the west to mainly ferruginous and dolomitic sandstone with minor siltstone towards the east; (2) an abundance of brown shallow-water sandstones along and just east of the Quilalar Arch; (3) presence of a local channel(?) deposit in the White Hills Belt containing abundant hydroplastic sedimentary structures; (4) lenticularity of dolomitic rocks in areas just east and west of the Quilalar Arch, and (5) persistent bands or lenses of dolomitic sandstone breccia, a result of possible slumping on a shallow-water shelf or slope.

Current directions throughout Ɛqx are variable, mainly from the northeast, southwest and northwest. Few currents are recorded from the east. Shallow-water ferruginous sandstone in upper Ɛqx of Section 4 (Figure 4) displays excellent, largely unimodal current directions from the southwest and west.

In $Ɛqx_q$ current directions are also variable, and appear to change from southwest and easterly near the base, to northwest and northeast near the top. The herringbone cross-bedding indicates persistent current reversals.



Note: From Eqw time, possibly transgression and slow subsidence of shelf.

Lithology & environments

1. Cryptalgal laminates, stromatolites (dolomitic); near-shore intertidal carbonate platform or bank.
2. Shallow water marine? sand body; tidal shelf or submerged coastal barrier complex; relatively high energy.
3. Ferruginous sands, silts, some laminated dolomitic + oolitic rocks, dolomitic sandy breccia; intertidal, lagoonal + shallow shelf areas, with local slumping of dolomitic rocks; relatively low to moderate energy.
4. Distal fine sands + silts with slumps + Bouma cycles; deeper? channels in delta environments marginal to Quilalar Arch

Tuff/ashstone common to all environments

FIGURE 4: SCHEMATIC PALAEOGEOGRAPHY, UNIT Eqx QUILALAR FORMATION

Thickness: Thickness variations are summarised in Figure 4. All subdivisions thin towards and across the Quilalar Arch, notably the quartzite member Ꝑqx$_{q}$. These patterns resemble those shown by Ꝑqw (See Figure 3).

Similarly the abrupt thickening of Ꝑqx in possible palaeochannels in the White Hills Belt (Figures 4, 5) parallels thickening in both the underlying Ꝑqw and overlying Surprise Creek Formation. These factors and the presence of unimodal palaeocurrents from the southwest in upper Ꝑqx indicate the presence of a long-lived northeast-trending palaeochannel 5 to 7km wide incised into coeval fine-grained shallow-water sediments, near the present-day course of Hare Creek and its tributaries.

Stratigraphic Relations, Age: Overlies quartzite of Ꝑqw or Myally Subgroup conformably; overlain disconformably and locally unconformably (e.g. at GR 761990) by the coarse-grained pebbly sandstone member of the Fiery Creek Volcanics, the Bigie Formation (Ꝑfy).

Ꝑqx, like Ꝑqw, is younger than 1780 m.y. (age of the underlying Argylla Formation), and older than 1680 m.y. (age of the Carters Bore Rhyolite, a probable correlative of the Fiery Creek Volcanics).

Structure and Metamorphism: structures in Ꝑqx, Ꝑqx$_{q}$, etc. parallel those of Ꝑqw; Ꝑqx and Ꝑqx$_{q}$ distribution defines the Bull Creek Syncline in the west; these units are also tightly folded adjacent to the eastern bounding fault of the Mount Fox Outlier. Complex outcrop patterns of members Ꝑqx, Ꝑqx$_{t}$ and Ꝑqx$_{u}$ 7km northwest of Mount Stanley (White Hills Belt) are due to gentle cross-folding in synclinal and anticlinal hinges.

Petrography of Ꝑqx samples suggests that a north-trending chlorite/biotite isograd is present midway across the White Hills Belt, the higher grade being to the east. As in other older units in the area, this grade increase may reflect proximity to the amphibolite-grade Wonga Belt just east of Dobbyn.

Geochemistry: results are listed in Appendix 12. Gossans and gossanous dolomitic rocks in the Bull Creek and western White Hills Belt are enriched in copper (average 540 ppm), and Zn to a lesser extent (average

90 ppm). Uranium values in the Lochness prospect, Bull Creek belt, are higher (30 ppm) than average.

Sediments sampled in the east of the White Hills Belt are mainly fine siltstone and sandstone, with average values of Cu 6 ppm, Zn 9 ppm and U 5 ppm. Dolomitic siltstone shows higher values of 20, 28 and 12 ppm respectively.

Discussion: Field and petrographic evidence show that most units in Ᵽqx formed in a marginal shallow-water marine(?) environment (Figure 5).

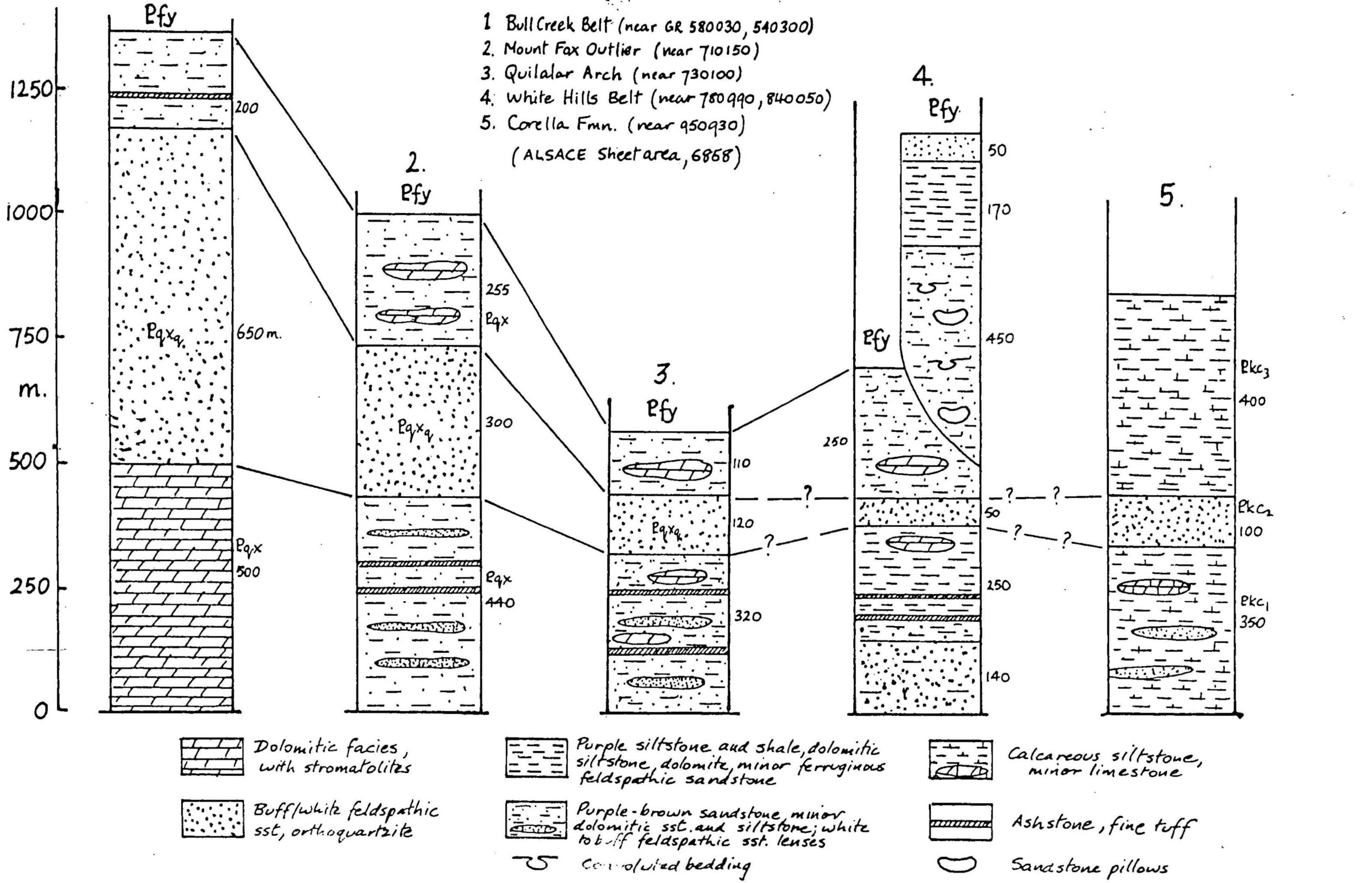
Unit Ᵽqx$_q$ extends from the Bull Creek Belt to the Quilalar Arch; its geometry is that of a broad sheet wedging and thinning eastwards, bound top and bottom by finer-grained arenaceous, silty and carbonate-bearing sediments; and laminated and stromatolitic dolomite, respectively. Herringbone cross-beds and petrographic characteristics are consistent with a shallow marine(?) tidal sand body paralleling the shoreline facies of Ᵽqw i.e. possibly a barrier island complex which is mainly submergent.

Unit Ᵽqx: the stromatolites of the Bull Creek belt are typical of shallow water intertidal environments e.g. tidal flats with carbonate banks. The ooid content of some dolomite represents active shoals on the tidal flat or platform; the quartz clasts in the dolomite and poorly sorted and rounded feldspathic sandstone suggest greater proximity to source areas than areas to the east, and also suggest an absence of sorting and rounding mechanisms such as might be found in beach or shelf environments. A partly restricted quiet lagoonal environment landward of the sand unit Ᵽqxq, is suggested.

Other dolomitic sandstones and fine ferruginous clastics from near the Quilalar Arch possibly formed in a shallow-water shelf environment, with some oolitic carbonate shoals, muddy bays and sandy distributary channels spread across the shelf. Some disruption of the shelf deposits by gravity slumping or tectonism along the Quilalar Arch caused the brecciation in dolomite, although some may also be due to post-depositional faulting.

In the eastern parts of the White Hills belt, the fine arkosic,

FIGURE 5: COMPOSITE STRATIGRAPHIC COLUMNS FOR UNIT X, QUILALAR FORMATION AND CORELLA FORMATION



ferruginous sandstones and siltstones with some dolomitic material are interpreted as tidal flat (mainly intertidal), lagoonal and distal deltaic deposits, where strong wave and current sorting are absent. Some of the sand layers may be distributary sands deposited in oxidising conditions, or derived from nearby, relatively feldspar-rich and oxidised source areas with some clayey weathered material. Siltstones with Bouma cycles are representative of deposition from relatively low-energy (distal?) turbidity currents; the presence of pillow, flame and hydroplastic structures in fine sand and mudstone also indicate relatively rapid depositional rates but involving fine rather than coarse sediment. A distal, low energy and possibly deeper water deltaic environment is indicated, partly overlapping the sandy east-northeast trending channel facies observed in the underlying unit Ᵽqw.

The distal deltaic facies in the White Hills belt is located 3 to 5km east of the Quilalar Arch, and may correspond to the "trough facies" described from the Quilalar and Surprise Creek Formations along strike to the south, in PROSPECTOR (Wilson et al., 1977). These features are shown schematically in figure 5.

MARY KATHLEEN GROUP

Ballara Quartzite

Map Symbols: Ᵽkb, Ᵽkb$_1$

Nomenclature: The Ballara Quartzite is named after the abandoned township of Ballara, in the southeast of the Mary Kathleen Sheet area (6856). The formation was formally defined by Carter and others (1961) with reference to a type section 4km northwest of Ballara. This definition has been revised by Derrick, Wilson and Hill (1977). Derrick, Wilson and Hill (1977) recognized two subdivisions of the formation in the Mary Kathleen Sheet area and these subdivisions were later recognized in the Prospector Sheet area (6857) by Wilson and others (1977) in areas previously mapped as Argylla Formation or Deighton Quartzite.

Distribution: occurs in the southeastern corner as north-trending discontinuous thin ridges, which define a faulted, south-plunging syncline. Most of the exposed rocks are quartzite belonging to the upper subdivision of the formation; only one area of highly feldspathic conglomeratic metamorphosed sandstone is mapped as the lower unit. The unit is repeated by faulting and deformed by folding. The total area of outcrop in the Sheet area is $3km^2$.

Lithology, Field Occurrence, Thickness: In the Alsace Sheet area the Ballara Quartzite (Ɇkb) consists mainly of quartzite but near the base of the formation brown feldspathic sandstone, arkose, grit and conglomerate occur locally ($Ɇkb_1$).

Member $Ɇkb_1$: this member is mapped 9km north of Mighty Atom mine; it consists of a highly sheared sequence of arkose and grit with thin bands of cobble conglomerate. The cobbles are siliceous well-rounded clasts which have been severely flattened. The largest clasts are about 10cm across and one or two centimetres thick. In hand specimen it has not been possible to determine if the clasts were acid volcanic rocks or quartzite.

The member is at most 200m thick and appears to be lenticular. In areas where the member is only a few metres thick it has not been divided from Ɇkb. Spectacular boulder conglomerate and arkose (mapped as Ɇkb) occur just east of Two Macks mine (GR 947973); clasts are of acid volcanics, metabasalt and quartzite, some of the latter displaying an alteration rim similar to those present in metaconglomerate at Mary Kathleen. Torrential cross-beds and channel structures are common. The magnetic nature of the clasts and matrix suggests erosion of some areas of Argylla Formation.

Unit Ɇkb: The basal beds are typically buff to pale brown thin to thick-bedded arkosic grit, medium to coarse-grained feldspathic sandstone and fine-grained labile sandstone. The coarser sandstones are mostly cross bedded, some of the finer grained sandstones show climbing ripples and some have flat-bedded laminations. Most of the unit consists of white to buff thin-bedded fine to medium-grained slightly feldspathic quartzite. Although some cross-bedding has been recorded, sedimentary structures are generally obscured by extensive fracturing and recystallisation, and veining by quartz and quartz-tourmaline veins. Minor beds of pale brown laminated siltstone with interbeds of buff thin-bedded fine-grained quartzite and some medium-grained calcareous sandstone occur in the southeast of the Sheet area.

Ekb is 300m thick in the most westerly outcrop, near Mount Cuthbert, and thins to about 100m in the east.

Current directions from the north to northeast are indicated by crossbeds and ripple marks.

Only two samples have been examined petrographically; 2379 is a feldspathic quartzite with up to 15% feldspar and rock fragments, and bimodally distributed quartz grains. Tourmaline, apatite, biotite and muscovite are accessories. Sample 2381 is a tourmalinised pebbly quartzite; green-brown crystals of tourmaline have formed metasomatically in the grain-boundaries of the quartzite. Source of the tourmaline is unknown.

Stratigraphic Relations, Age: The Ballara Quartzite overlies the Argylla Formation unconformably or disconformably, and is the basal unit of the eastern succession in the Sheet area. Because of the extreme deformation, no angular contacts between the Ballara Quartzite and the underlying Argylla Formation have been recorded in the Sheet area. Clasts in the basal conglomerate indicate erosion of Argylla Formation. The quartzite grades rapidly upwards into metamorphosed calcareous siltstone of the Corella Formation, and is considered to be a direct correlative of Quilalar Formation (unit Eqw) to the west of the Kalkadoon-Leichhardt Block.

The Ballara Quartzite is younger than 1780 m.y. (Argylla Formation age), and possibly older than 1730 m.y. (age of Burstall Granite to the south - Page, 1979, 1980).

Discussion: The generally high feldspar content of the Ballara Quartzite suggests that its source rocks were the acid volcanic and plutonic rocks of the Basement Succession. The transition from poorly sorted feldspathic sandstone and conglomerate to well sorted finer grained less feldspathic sandstone possibly represents a change from terrestrial to near-shore deposition. Ripple marks, cross-bedding and carbonate-rich sandstone support a shallow water environment with the dominant currents from the north and northeast. The gradational diminution in grainsize and increase in carbonate content from the Ballara Quartzite to the Corella Formation is an indication of a marine transgression.

Corella Formation

Map Symbol: Ꝑkc, Ꝑkc_1, Ꝑkc_2, Ꝑkc_3

Nomenclature: The Corella Formation was formally defined by Carter and others (1961) although the name Corella Limestone was first used by David (1932). The type locality is along the old road between the Federal copper mine and the Mary Kathleen uranium mine, in the northwest of the Marraba Sheet area (6956). A three-fold subdivision of the Formation in the Marraba Sheet area was introduced by Derrick and others (1971) and has subsequently been used in the mapping of MARY KATHLEEN (6856), PROSPECTOR (6857) and QUAMBY (6957) (Derrick and others, 1977; Wilson and others, 1977; Wilson and others, 1979b).

Distribution: The Corella Formation underlies about $24km^2$ in the southeastern corner of ALSACE. Most outcrop is of the basal member ($12km^2$). The middle member crops out over almost $1km^2$ and the uppermost member is exposed over almost $2km^2$. In general the formation is recessive and the low bouldery outcrops are surrounded by colluvium in broad valleys. The middle member is represented by sharp ridges within these valleys.

Lithology and Field Occurrence: dominantly laminated calcareous metasiltstone and fine to medium-grained feldspathic metasandstone; brecciated laminated calcareous rocks, calc-silicate rocks, amphibolite and schist constitute a minor part of the formation. The basal and uppermost members are dominantly calcareous metasiltstone and the middle member is dominantly metasandstone.

Member Ꝑkc_1: The basal member of the Corella Formation consists predominantly of black to dark brown-weathering grey laminated calcareous metasiltstone. The lamination is probably a primary sedimentary layering and locally ripple marks have been recognised. Palaeocurrents from the east and east-northeast are inferred from the ripple marks. The metasiltstone is mostly folded and in part highly fractured and silicified. Outcrops of extensively brecciated laminated calcareous metasiltstone occur about 7km north of Mighty Atom copper mine. In other areas the metasiltstone is strongly cleaved and locally contains scapolite porphyroblasts. Pelitic and calcareous psammitic schists occur in the more deformed zones. Some typical mineral assemblages in the schists are scapolite-biotite-muscovite, andalusite? - muscovite-quartz and calcitebiotite-muscovite-quartz.

Interbedded with the metasiltstone are lenses of arkosic meta sandstone, calcareous metasandstone and quartzite. Some extensive areas of laminated metalimestone, impure sandy metalimestone, and highly calcareous metasiltstone are also found in the basal member. Where these rocks have been more highly metamorphosed they are represented by black-weathering pale greenish grey and pink laminated calc-silicate rocks with calcite veins. Minor para-amphibolite is also present.

Member Ekc_2: The middle member of the Corella Formation consists predominantly of buff to pale brown thick-bedded medium-grained feldspathic metasandstone. Minor amounts of buff medium-grained quartzite, buff to brown calcareous metasandstone, and brown laminated very fine-grained feldspathic sandstone interbeds are present. The metasandstones are generally cross-bedded and some of the finer grained sequences are ripple-marked. Currents from the northwest, southwest, south and southeast are indicated from the cross-beds but extensive folding of this unit reduces the reliability of these readings.

Member Ekc_3: The uppermost member of the Corella Formation is not well exposed. The dominant rock type is a brown laminated micaceous and calcareous metasiltstone. Grey laminated metasiltstone and green and pink laminated calc-silicate rocks also occur in the southeastern corner of the Sheet area.

In thin section, sample 2382 is an impure marble with abundant granoblastic albite?, some muscovite and biotite; 2383 and 2384 are calcareous and albitic biotitic metasiltstones with muscovite and scapolite porphyroblasts, respectively. Epidote and chlorite are accessory minerals. Greenschist facies metamorphism is indicated.

Stratigraphic Relations, Thickness, Age: The Corella Formation overlies the Ballara Quartzite conformably. The boundary is usually gradational over a few metres. The upper boundary of the Corella Formation is not exposed in ALSACE but the formation is overlain unconformably by the Deighton Quartzite in MARY KATHLEEN (6856) (Derrick and others, 1977). Dolerite dykes and sills intrude the Formation.

The thickness of the Corella Formation is difficult to determine because of extensive folding and discontinuous outcrop. A moderately continuous sequence near the southern boundary of the Sheet contains about 350m of Ꝑkc$_1$, 100m of Ꝑkc$_2$, and 400m of Ꝑkc$_3$.

Age of the Corella Formation is between 1780 m.y. (Argylla Formation age) and 1740 m.y. (possible age of Burstall Granite, which intrudes Corella Formation on Marraba).

Discussion: The Corella Formation may have been deposited adjacent to or above Ballara Quartzite during a period of marine transgression. A minor regression or higher-energy depositional conditions are indicated by psammitic sediments in the middle member. The few palaeocurrent observations in ALSACE indicate a sediment source in the southwest or northwest, similar to the observations made in PROSPECTOR to the south (Wilson and others, 1977).

A relatively shallow basin is inferred from the carbonate content of the rocks and the sporadic cross-bedding and ripple marks. The dominance of parallel lamination in most of the siltstone indicates that the deposition occurred below wave base in a relatively protected sedimentary environment. Possible evidence of high salinity or even soda-rich evaporitic deposits is provided by the presence of sodic scapolite (Ramsay and Davidson, 1970), and abundant albite.

BIGIE FORMATION, FIERY CREEK VOLCANICS

These units comprise an as yet unnamed group which rests unconformably on older rocks; in ALSACE it is characterised by a basal clastic and dolomitic sedimentary facies (Bigie Formation), and an overlying volcanic facies consisting of altered basalt and trachybasalt. The change from Quilalar Formation to Bigie Formation and Fiery Creek Volcanics marks a period of deformation, uplift and erosion of Haslingden Group and older rocks.

Bigie Formation

Map Symbols: Ᵽfy, Ᵽfz

Nomenclature: formerly considered part of Quilalar Formation in PROSPECTOR to south (symbol Ᵽqy); it warrants a separate name, which is derived from the Parish of Bigie, County of Kamileroi because it unconformably overlies Quilalar Formation. The type section of the formation is on MOUNT OXIDE (Hutton, Cavaney & Sweet, 1981).

Distribution: Ᵽfy occurs throughout the Bull Creek belt, Mount Fox outlier and the White Hills belt; Ᵽfz mainly in the White Hills belt, and to a lesser extent in the other two belts.

Field Occurrence: forms moderately upstanding strike ridges and low hills of brown sandstone; sedimentary structures in Ᵽfy include cross-bedding of various styles - large planar cross-beds, gently curving trough cross-beds from 50cm to 1.5m thick, and more complex small-scale trough and herringbone cross-beds with local scoured bases and channelling. Pebbly beds are common in some foreset layers and graded pebbly beds are present near the base of the formation. A few current directions are from the south and southwest. Ripple marks are also associated with the cross-bedding.

Sediments of Ᵽfz are fine to coarse-grained and show ripple marks, convoluted bedding, planar and trough and flaser cross-bedding; most cross-bed sets range up to 10cm thick.

Lithology, Petrography: Ᵽfy: pink to brown feldspathic and lithic quartzite with pebbly layers, conglomerate, minor laminated coarse to fine orthoquartzite, and calcareous sandstone.

Ᵽfz: purple micaceous siltstone, ferruginous fine to medium feldspathic sandstone, micaceous dolomitic siltstone, dolomite, brown dolomitic sandstone, shale-clast conglomerate, conglomerate, minor stromatolitic dolomite. The stromatolites are small branched and unbranched columnar types, forming a thin tabular layer 5-10cm thick. Individual columns are 1 to 2cm diameter. The unit occurs at GR 766254 and is highly ferruginized and difficult to recognize. Shale-clast conglomerate forms a marker bed throughout the White Hills belt; it occurs near the base of the sequence.

Feldspar and fine rock fragments comprise from 5% to 30% of Ɓfy; pebbles of mainly well-rounded quartzite are dispersed through the unit, but thin, relatively continuous conglomerate bands are characteristic of the middle of the formation. Some shale clasts or clay pellets are present locally. Pebble content of the formation appears to decrease towards the eastern part of the White Hills belt.

Petrographic studies indicate that lithic fragments form up to 15% of some samples of Ɓfy; they are mainly of volcanic rocks - spherulitic volcanics, polycrystalline quartz, chert, fine-grained quartzofeldspathic volcanic groundmass material; and siltstone, fine sandstone and clay pellets. Beta quartz grains are also evident; quartz and feldspar grains are invariably subrounded to subangular, but are moderately well sorted and silica-cemented. Iron oxide is ubiquitous as flakes and grains, and as clouding in many grains. Small amounts of muscovite, zircon and tourmaline are the only accessory minerals.

A characteristic of Ɓfz is the coarsening-upwards of grainsize in the silty and sandy units.

Thin section studies show siltstones of Ɓfz to be very micaceous, feldspathic and clayey, with abundant iron oxide. Rock fragments are present in many samples. Sandstones from Ɓfz are better sorted than those of Ɓfy, but still contain abundant lithic fragments and mica flakes. Orthoquartzite and feldspathic quartzite ($Ɓfz_q$) are also present. In general the sandstones contain significantly more accessory zircon and tourmaline than the ?fluvial Ɓfy.

Metamorphic grade is low greenschist facies.

Sample localities with some petrography are listed in Appendix 13.

Thickness: Ɓfy in Bull Creek belt: 490m (west limb of syncline) to 290m (east limb of syncline); the unit thins to about 100m near the centre of the belt, at GR 521240.

Mount Fox Outlier/Quilalar Arch: 100-150m.

White Hills belt: 500m (Ɇfy, Ɇfz each 250m).

These compare with thicknesses of 530 to 380m to the south, on PROSPECTOR (Wilson & others, 1977), and 600m on MOUNT OXIDE to the northwest.

The variations above indicate that the Bigie Formation, like other formations, thins significantly across the Quilalar Arch; it also appears to thicken northwards in the Bull Creek belt, and to thicken slightly east of the Quilalar Arch.

Stratigraphic Relations, Age: overlies Quilalar Formation disconformably over all of ALSACE; a local angular unconformity is exposed 6km northeast of Henderson's Soak, where strike and dip discordances of 20° to 30° are present between the Bigie Formation and unit Ɇqx of the underlying Quilalar Formation.

Bigie Formation is overlain conformably by the Fiery Creek Volcanics, and unconformably by conglomerate and sandstone of the basal Surprise Creek Formation.

The Bigie Formation, an integral part of the Fiery Creek period of sedimentation and volcanism, is about 1680 m.y. old, or a little older; this age is from the Carters Bore Rhyolite (Page, 1978), thought by us to be equivalent to the Fiery Creek Volcanics.

Geochemistry: some geochemical data are listed in Appendix 14.

Structure and Metamorphism: Since the Bigie Formation rests disconformably only on Quilalar Formation, folding and deformation of the latter, before Bigie Formation deposition, has been slight. Most of the observed folding and faulting is therefore due to post-Mount Isa Group tectonism. Some may be due to pre-Surprise Creek Formation deformation. Bigie Formation forms part of the Bull Creek Syncline in the west, and is locally overturned. It also displays basin-and-dome deformation in the

White Hills Belt.

Metamorphic grade is low greenschist; only muscovite and some chlorite are present as grade indicators, and much of the muscovite is detrital.

Palaeogeography, Discussion (Rust, 1979; Walker & Cant, 1979).

Important characteristics of the Bigie Formation are

(1) lithic component of the sandstone, and relative angularity of quartz grains;

(2) presence of well rounded quartzite pebbles and cobbles, and local abundance of conglomerate;

(3) abundance of large-scale planar and trough cross-bedding, with some scour structures, and some ripple marks;

(4) presence of scattered shale clast/clay pellet material; and abundant iron oxide flakes;

(5) finer grained, better sorted nature of Ɛfx;

(6) indications of both volcanic and sedimentary provenance.

These features suggest a mainly non-marine palaeoenvironment. The lateral persistence of the unit throughout ALSACE (and PROSPECTOR, MOUNT OXIDE, etc.) and its thickness variations show the Bigie Formation to be a gently wedging sheet sand deposit.

We propose the data best fit a model of alluvial fan-braided stream and braid plain environments and adjacent peritidal environments. Uplifted areas of older Haslingden Group rocks to the west are a likely source area of much of the sediment, as well as locally uplifted areas of Ewen and Kalkadoon-Leichhardt Blocks. Abundant and well-rounded pebbles and layers of conglomerate indicate active currents carrying a mixed bed-load; the subangular, lithic, ferruginous and feldspar-rich nature of the sand fraction indicates a general lack of winnowing and reworking, and only moderate distances of transport from source regions. The shale clasts present locally may represent small-scale rip-up of thin clay layers deposited from suspension in waning flood currents, either in braided channels or on levee banks.

Relative to the Ɛfy, Ɛfz is finer-grained, better sorted and with a greater amount of heavy minerals, dolomite content and stromatolites. These suggest a nearshore peritidal environment, marginal to the braided plain-fluvial environment postulated for Ꞓfy. Planar, trough and flaser cross-bedding, and convoluted bedding, are consistent with a peritidal environment, possibly lagoonal, with moderate influx of labile and sublabile material. The presence of lithic fragments and abundant feldspar, mica and iron oxide indicate a shoreline with little or no active beach zone. However, the coarse, clean-washed sandstone lenses in Ꞓfz may be local sandy channels or barrier bars incised into the lagoonal? deposits.

The proposed braided stream-braid plain environments of Ꞓfy are possibly transitional into near-shore shallow water sandy, silty, dolomitic and stromatolitic environments indicated for the overlying unit, Ꞓfz.

Fiery Creek Volcanics

Map Symbol: Ꞓfc

Nomenclature: The type section of Ꞓfc is on MOUNT OXIDE, near GR 6759-170893 (Hutton and others, 1981).

Distribution: Ꞓfc restricted to the central part of the White Hills Belt, near GR 770240; Ꞓfc near GR 785210 is photo-interpreted.

Field Occurrence: forms low ridges, hills and valleys; volcanics crop out in scree slope beneath quartzites of Surprise Creek Formation.

Lithology, Petrography: massive to amygdaloidal ferruginous metabasalt, ?trachybasalt, scoriaceous metabasalt, basalt-sandstone breccia, feldspathic sandstone, arkose, agglomerate. The arkose commonly occurs between flows, and grades upwards from coarse angular to better-sorted sediments. The volcanics are ubiquitously pink and hematitic, and are highly altered. Elsewhere in the region (on MOUNT OXIDE for example) rhyolites are the dominant rock type.

Volcanics of Ꞓfc display intersertal to basaltic textures; laths of feldspar may be K-feldspar pseudomorphous after plagioclase.

Granules of iron oxide (possibly ilmenite) are widespread; some amygdales contain rutile growing on ilmenite grains, in a matrix of quartz and spherulitic K-feldspar. Tuffaceous feldspathic sandstone layers in the volcanics contain quartz, feldspar and volcanic rock fragments set in a ferruginous ash or devitrified glassy volcanic groundmass.

Thickness: Up to 80m. True thickness cannot be estimated because the volcanics are overlapped unconformably by the Surprise Creek Formation.

Stratigraphic Relations, Age: Ᵽfc volcanics overlie Ᵽfz concordantly, and locally overlap Ᵽfz$_q$, i.e. local unconformities of no regional significance may be present at the base of Ᵽfc.

Both Ᵽfc and Ᵽfz are overlain with a generally low-angle regional unconformity by conglomerate and pebbly sandstone of the Surprise Creek Formation e.g. 6km southwest of Malcom homestead.

Age is thought to be about 1680 m.y., age of the possibly equivalent Carter's Bore Rhyolite (Page, 1978).

Palaeogeography, Discussion: Coarsening upwards of the upper Bigie Formation marks a gradual uplift and increased erosion of the source areas, and regression of the sea, possibly eastwards, as the finer-grained and generally transgressive sediments of lower Ᵽfz give way to coarser sandstones and some conglomerate. Culmination of this uplift was extrusion of the basaltic to trachytic volcanics on an emergent land mass.

SURPRISE CREEK FORMATION

The Surprise Creek Formation is a conglomerate-sandstone-siltstone sequence which overlies older rocks unconformably. Sandstone and conglomerate in the lower half of the formation have been termed unit A (map symbol Ᵽra) throughout the Mount Isa Inlier. The silty upper half of the formation includes units B, C and D (map symbols Ᵽrb, Ᵽrc, Ᵽrd). The type section of the Surprise Creek Formation (Derrick and others, 1980) is in ALSACE, from GR 758885, to 743886.

Coarse Sandstone Facies - Unit A

Map Symbols: Ɇra$_c$, Ɇra.

Nomenclature: Quartzite unit A of the Surprise Creek Formation was mapped as part of the Myally Beds by Carter and others (1961). It has been discussed and defined by Derrick and others (1980). This unit may warrant a new formation name in the future.

Distribution: Central and northern part of the Bull Creek syncline; in the Mount Fox outlier, and throughout the White Hills belt. Subunit Ɇra$_c$ occurs only in the latter belt.

Field Occurrence: Forms moderately rugged hills, ridges and plateaux; sandstone and quartzite display a wide range of shallow-water sedimentary structures. Cross-bedding is ubiquitous commonly in tabular to gently wedging sets 0.3 to 2m thick, with local trough cross-bedding also present. Foreset dips range from 20^{o} to 40^{o}. Current directions are from the southwest, west and northwest directions; minor directions recorded are from the east and northeast. The base of many cross-bed sets is gently curved.

Ripple marks are moderately common; some rain-drop impressions are recorded from Ɇra$_c$. The latter also contains channel structures, and beds of shale-clast breccia. Giant cross-bed forms are characteristic.

Lithology, Petrography: Ɇra: white, pink and buff medium to coarse feldspathic and clayey quartzite and sandstone, pebbly sandstone and conglomerate; white clayey spots are common.

Ɇra$_c$: coarse feldspathic sandstone and quartzite, conglomerate, micaceous sandstone, minor shale and siltstone.

The pebbly layers are graded from coarse to fine upwards, although local coarsening-upwards cycles of conglomerate are present in Ɇra$_c$. Heavy minerals are common in parts of Ɇra and Ɇra$_c$.

Clasts in the conglomerates are quartzites of various types, vein quartz, acid volcanics, siltstone and fine sandstone, and characteristically, red jasper. Most clasts are well-rounded. Near outcrops of Fiery Creek Volcanics, clasts of jasper, ferruginous sandstone and dolomite are also present.

Conglomerate is dispersed regularly throughout unit Ᵽra$_c$, whereas it is present only at or near the base of unit Ᵽra. Quartzite of Ᵽra grades upwards into finer grained buff feldspathic quartzite of unit Ᵽrb. It is locally pyritic.

In thin section, the white-spotted quartzites are feldspatholithic; silica-cemented quartz grains (a.g.d. 0.5mm) are associated with from 10% to 20% of clayey sericitised acid volcanic fragments and sericitised fragments of plagioclase and alkali feldspar phenocrysts, and some muscovite. Many samples are highly strained. Heavy minerals include tourmaline, zircon and more rarely rutile.

A sample of labile quartzite from a fine interbed in Ᵽra$_c$ contained metamorphic biotite, which further defines the chlorite/biotite isograd determined from the Quilalar Formation. A summary of samples and their location is given in Appendix 15.

<u>Thickness</u>: Ᵽra and Ᵽra$_c$ display rapid thickness variations:

<u>Ᵽra</u>: <u>Bull Creek belt</u>: 100m in south and central areas, to 300m near Mistake Creek in the north.

<u>Mount Fox Outlier</u>: 120m.

<u>Quilalar Arch</u>: 50 to 100m.

<u>White Hills belt</u>: 200 to 420m in the west of the belt, increasing rapidly eastwards to nearly 900m in a prominent belt of thickening 10 to 15km west of Dobbyn. It is 230m thick in the type section.

<u>Ᵽra$_c$</u>: In the same zone of thickening, this unit thickens eastwards from zero to 780m.

Thickness variations indicate relatively emergent areas in south and central areas of the Bull Creek belt, and along the Quilalar Arch; the zone of thickening in the White Hills belt coincides with similar zones in units of the Quilalar Formation.

Stratigraphic Relations, Age: Ꝑra; Ꝑra$_c$: unconformably on sandstone of Bigie Formation, and volcanics and dolomitic sediments of Fiery Creek Volcanics. The low-angle regional unconformity is observable in a belt about 10km SSW of Malcom homestead, where Ꝑra overlaps Ꝑfc and Ꝑfz onto Ꝑfy going northwards along strike.

A well-exposed erosional break is present at GR 752286, along Gum Creek. White and massive quartzite becomes more ferruginous and pebbly downwards; A 20 to 30cm-thick lenticular conglomerate is in sharp contact with ferruginous sandstone and purple siltstone of Fiery Creek Volcanics Unit Ꝑfz.

Ꝑra overlies Myally Subgroup disconformably in the Crystal Creek area, in the southwest of ALSACE.

Most contacts are grossly concordant. Near Mistake Creek, the boundary between brown pebbly sandstone of Bigie Formation and white pebbly feldspathic quartzite of unit Ꝑra is taken at the prominent change of colour between the two pebbly units. Ꝑra is overlain conformably by, and gradational into, unit Ꝑrb.

Units Ꝑra and Ꝑra$_c$ are younger than 1680 m.y. (Fiery Creek Volcanics age?), but are older than 1670 m.y. (approximately age of Mount Isa Group) (Page, 1978; 1981). They are equivalent to Deighton and Knapdale Quartzites of the Mount Albert Group (Derrick and others, 1980), in the Eastern succession.

Structure and Metamorphism: Unit Ꝑra together with other units, outlines the Bull Creek syncline in the west of ALSACE. In the White Hills belt it forms prominent basin-and-dome structures elongated north-south, and cut by east-west normal(?) faults and northeast and northwest-trending conjugate faults.

Biotite in Ꝑra$_c$ indicates the biotite-zone of greenschist facies metamorphism; grade decreases westwards. Metamorphism may be due to proximity to the Wonga belt, east of ALSACE.

Palaeogeography: This will be discussed, together with the finer-grained units Ᵽrb, Ᵽrc and Ᵽrd, at the end of this section.

Fine Sandstone-Siltstone Facies - Units B, C, D

Map Symbols: Ᵽrb, Ᵽrc, Ᵽrd.

Nomenclature: These units coincide largely with the Surprise Creek Beds of Carter and others (1961). Locally, units Ᵽrb and Ᵽrc are difficult to recognize, or are too thin to adequately represent on the map; in these cases Ᵽrd is used as a general symbol.

Distribution: as for Ᵽra.

Field Occurrence: Ᵽrb and Ᵽrd are largely valley forming units; Ᵽrc is a quartzitic member which locally forms two closely-spaced low ridges which persist along strike for many kilometres.

Most fine-grained sandstone and siltstone is thin-bedded to laminated, cross-bedded in sets of 10cm thick, and very characteristically micro-cross-bedded; flaser and ripple cross-laminations in beds 5-10cm thick are common, as is convoluted bedding. Silty and shaly partings are present. Ripple marks in Ᵽrb indicate currents from the south and east; in Ᵽrc most current directions are from the southeast to northeast.

Lithology, Petrography: Ᵽrb: brown micaceous feldspathic sandstone, a.g.d. 0.1-0.2mm, purple siltstone, minor dolomitic sandstone and siltstone.

Ᵽrc: brown to white feldspathic sandstone and quartzite, grey-green siltstone, minor coarse sandstone. Typically the lower quartzite is white to brown-buff, blocky, medium to fine-grained and feldspathic (10-15%), moderately well-sorted, with some lithic fragments. Tourmaline and zircon are common accessories. Thin interbeds of graded coarse sandstone are present.

In contrast, the upper quartzite of unit C is brown-buff, ferruginous and feldspathic and micaceous, and characteristically contains apatite in the heavy mineral suite as well as tourmaline and zircon. The apatite may be diagenetic. Grey-green siltstone occurs between the two quartzitic units of Ᵽrc.

Ᵽrd is brown, grey, purple and buff siltstone, fine sandstone, minor shale and dolomitic siltstone and sandstone. Some siltstones are carbonaceous at depth, and show cream and red-brown laminations on weathered surfaces. Fine sandstone interbeds become more massive upwards in the sequence. Some siltstones near the base of Ᵽrd are possibly pyritic.

Throughout Ᵽrb and Ᵽrd, the abundance of coarse muscovite flakes, micro-crossbedding and convoluted bedding, and the scattered presence of malachite staining and small copper deposits, are regional characteristics.

Thickness: in the type section (White Hills belt):

Ᵽrd	300m
Ᵽrd	170m
Ᵽrb	270m

In the Bull Creek belt:

Ᵽrd	100m
Ᵽrc	110m
Ᵽrb	100m

However, these units thicken rapidly northwards onto MYALLY, where at least 1400m of fine sandstone and siltstone are preserved (Derrick and others, 1980).

Stratigraphic Relations, Age: Unit Ᵽrb overlies Ᵽra conformably; Ᵽrd is overlain conformably and unconformably by Warrina Park Quartzite, the basal unit of the Mount Isa Group.

Age is between about 1680 and 1670 m.y. (Page, 1978; 1981).

Geochemistry: Some geochemistry of the Surprise Creek Formation is listed in Appendices 16 and 17. Aim of the sampling was to determine background elemental levels in surface and subsurface samples, in view of the sporadic copper mineralisation present in units B to D, especially the latter.

Copper levels appear to be below average for shales, except for some anomalous values up to 190 ppm in a sample from unit C. Grey to black shale from Hidden Treasure mine contains Cu 355 ppm, Zn 66 ppm, and U 14 ppm, which contrasts with average values for the same unit (D) away from the mineralised zone, of 30, 16 and 10 ppm respectively. Base metal and U levels are all consistently higher in the fine-grained rocks of B, C and D compared with Unit A, probably reflecting the metal adsorption capacity of clayey material.

Anomalous values of molybdenum (27 ppm) are present in Unit D, sample 2147, and are accompanied by moderate levels of Cu and U. The sample comes from near the Hidden Treasure prospect.

Structure and Metamorphism: As for Era, except that the finer-grained suite (units B, C and D) tend to form tight to isoclinal folds, especially in those areas where the underlying sandstone of unit A is thin, e.g. along and just east of the Quilalar Arch. Intense small-scale folding and cleavage are present in the silty and shaley units near fault zones and in fold axial regions. Most folds plunge northwards at from 5^{o} to 25^{o}, but some are doubly plunging.

Metamorphic grade is low greenschist.

Palaeogeography, Discussion: (Figure 6) The sandstone facies, unit A, is of regional extent; it is characterised by very thick bed forms, abundant basal conglomerate and pebble beds, large scale tabular to smaller-scale trough cross-bedding, some ripple marks and, locally, rain-drop impressions. Sorting is good, but the sandstones contain a moderate amount of clayey lithic and feldspathic material. Palaeocurrents are polymodal, but nearly all are from the western sector. The sandstone unit thins significantly to the west, and displays rapid thickness changes east of the Quilalar Arch. It grades upwards into units which display lamination, convoluted bedding and microcross-bedding.

Basal beds of unit Ꝑra and unit Ꝑra$_c$, are interpreted as largely fluvial or alluvial floodplain deposits, deposited in braided streams and interfluve regions. The rapid thickness changes and lithology of Ꝑra$_c$ are typical of large-scale channel structures formed by strong traction currents.

Sandstones higher in the sequence are interpreted as dune, beach, delta and shallow shelf deposits; the thick bedforms may represent either aeolian or shallow shelf/beach deposits (sand waves, beach ridges), which regionally transgress the coeval or earlier formed fluvial or floodplain deposits lower in unit A. Source areas appear to have been uplifted areas to the west, i.e. basement volcanic and metamorphic rocks, some granite and folded sediments of the Haslingden Group and possibly Quilalar Formation. Derrick and others (1980) have proposed that areas to the east were also uplifted at this time, and were drained by large braided streams, depositing thick lenticular sand masses (e.g. Deighton, Knapdale Quartzites).

The siltstone, shale and fine sandstone of units B, C and D are characterised by lamination, abundant convoluted bedding (?water escape structures) microcross-bedding, flaser and graded bedding; the transition upwards from unit A appears to be a classic regional fining-upwards sequence, and possibly represents continued source planation and slow transgression of the fine clastics over the underlying coarse sand facies. Moderately rapid rates of deposition are implied by the water-escape structures, and the most favoured environment is the prodelta slope marginal to the sandy coastal regions. The abundance of coarse detrital muscovite in these units indicates erosion of a metamorphosed ?sedimentary provenance, possibly to the east.

The regional extent of these deposits and a lack of recognisably discrete deltaic lobes suggests modification of the delta-slope (and coastal deposits) by coalescence and reworking by long-shore currents and wave action. Carbonaceous siltstone and shale near the top of the Surprise Creek Formation may reflect a decreased rate of sediment supply and preservation of muddy restricted lagoonal or delta-marsh environments (Derrick and others, 1980). All these palaeogeographic features are summarised in Figure 6.

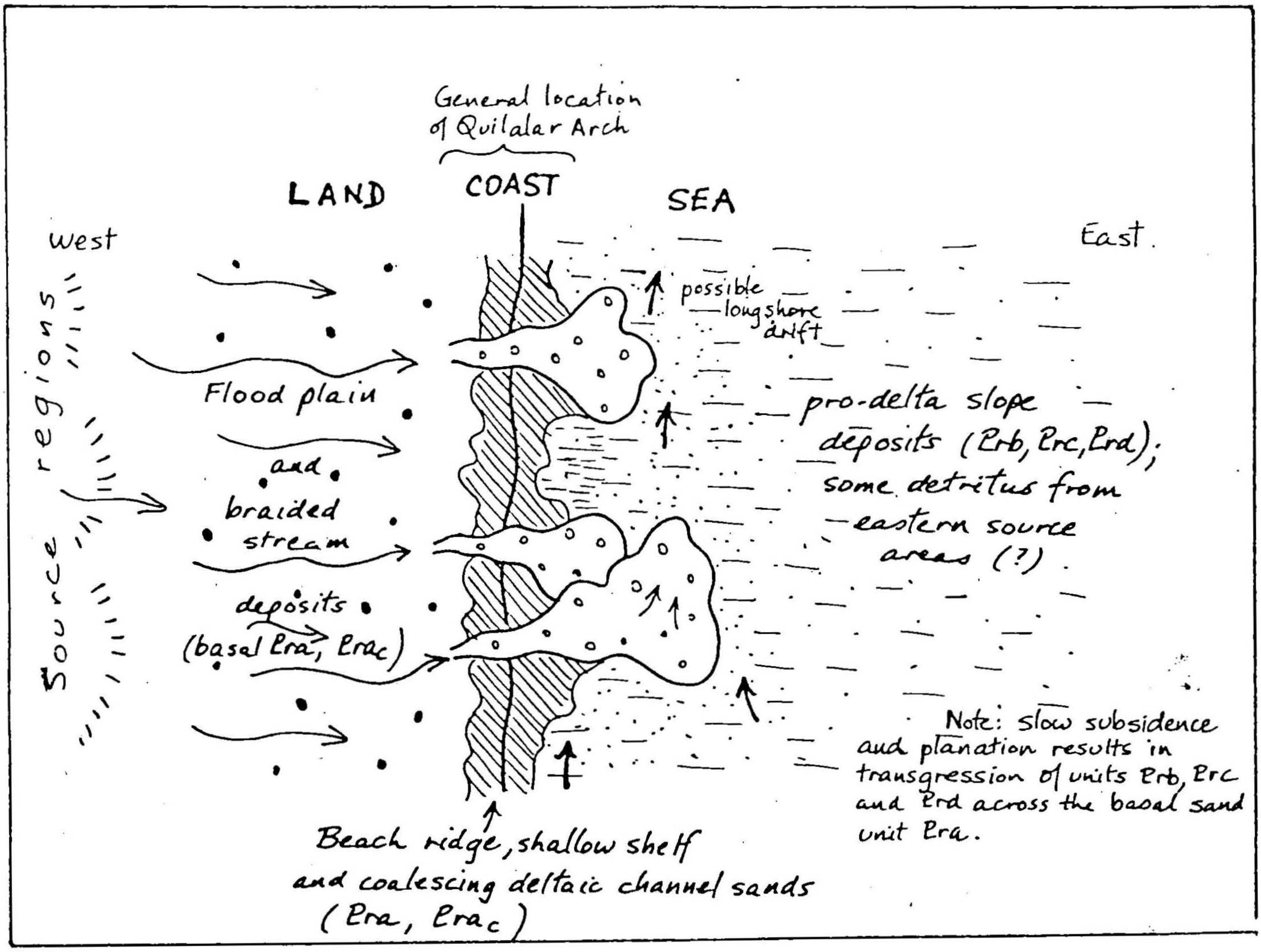


FIGURE 6: POSTULATED ENVIRONMENTS FOR UNITS OF THE SURPRISE CREEK FORMATION

Derrick and others (1980) correlated the Surprise Creek Formation sandstone with Deighton Quartzite to the south and east of ALSACE. After fault reconstruction the latter quartzite and thick units of Ꝑra and $Ꝑra_c$ may form a collinear belt of lenticular sand bodies extending about 100km north-south, from MARY KATHLEEN to ALSACE. It is possible they form part of a broad braided stream system flowing from the south or southwest to the north of northeast.

Copper mineralisation lies within the fine-grained facies, and may be related to diagenetic or epigenetic movement of Cu-enriched fluids along faults, in the vicinity of buried basement highs (Hidden Treasure), or near the margins of prominent channel-fill deposits (Mount Watson).

MOUNT ISA GROUP

The Mount Isa Group is the youngest Proterozoic unit preserved in ALSACE. It consists of the basal Warrina Park Quartzite, overlain by fine sandstone, siltstone, shale, chert and dolomite of the Moondarra Siltstone, Breakaway Shale, and Native Bee Siltstone. All units are represented in the Crystal Creek area, (southwest ALSACE), but only the Warrina Park Quartzite and Moondarra Siltstone are present in the White Hills belt. Age of the Group is about 1670 m.y. old (Page, 1981).

Warrina Park Quartzite

Map Symbol: Ꝑiw.

Nomenclature: Unit defined by Derrick and others (1976c).

Distribution, Field Occurrence: forms a prominent ridge-forming marker bed, commonly with prominent dipslope, in the Crystal Creek area in southwest ALSACE, and throughout the southern half of the White Hills belt. Isolated structural basins occur in the central or northern part of the Bull Creek belt.

Sedimentary structures include channel lag deposits with small scours, minor graded and convoluted bedding, abundant cross-beds which are generally tabular, parallel to low-angle, planar-based types, in sets 10 to 25cm thick, some of which are from the north to northwest. Ripple marks are mainly current types, and many are bevelled, indicative of very shallow water. Some convoluted bedding is present in softer, more labile beds in the quartzite. Malachite and turquoise staining is a feature of the quartzite in many places.

Lithology, Petrography: Orthoquartzite, feldspathic quartzite, conglomerate; minor green-grey to buff siltstone and fine sandstone. Samples examined in thin-section are listed in Appendix 18. Grains in the orthoquartzites are commonly well-rounded and sorted, and extensively silica-cemented; feldspathic quartzites contain up to 15% feldspar and some clayey volcanic and granitic rock fragments, and minor siltstone, and may be less well sorted in places. Most sands are coarse-grained, (0.5 to 1mm), but some are bimodal (concentrations of grains of 0.7-1mm, and 0.1 to 0.2mm).

Muscovite is a common accessory mineral. Rutilated quartz grains are common, and possibly indicate a plutonic source. Tourmaline and zircon are common heavy minerals, but epidote and biotite flakes are also present. Apatite, generally sub to euhedral, is very common in white orthoquartzite and feldspathic quartzite near the top of the formation. These grains are probably not of detrital origin, and may have formed about the time of silicification and/or diagenetic alteration, from circulating, phosphate-rich waters. Similar apatite-rich rocks occur in unit C of the Surprise Creek Formation.

Iron oxide and pyrite are present locally, in grain boundaries.

Thickness: 35 to 200m; the quartzite is possibly thinnest in the central area of the Bull Creek belt, and thickest in part of the White Hills belt.

Stratigraphic Relations: overlies Surprise Creek Formation concordantly; the contact may be disconformable. In southwest ALSACE, the quartzite appears to overlap unconformably onto the Lochness Formation (Ehn) of the Myally Subgroup.

It is overlain conformably by Moondarra Siltstone; the contact is commonly sharply gradational. Flat-lying Mesozoic strata overlie the quartzite 3 to 5km south-southwest of Malcom homestead; Warrina Park Quartzite correlates with the Torpedo Creek Quartzite in the McNamara Group, west of ALSACE.

Age is about 1670 m.y. (Page, 1981); the quartzite overlies Fiery Creek Volcanics, thought to be equivalent to the 1678 m.y. old Carters Bore Rhyolite (Page, 1978).

Structure and Metamorphism: The quartzite outlines tight to isoclinal folding in the White Hills and Bull Creek belt. In the former most folds are north-plunging, and are cut by east-trending faults which tend to cause repetition of the fold structures by mainly north-block-up movement. Some south-block-up movement is present also in northwest ALSACE. The folding is strongly isoclinal adjacent to the Quilalar Arch, apparently where sequences of underlying sandstone, etc. are thinnest. In southwest ALSACE the quartzite is displaced by left-lateral movement along east-trending faults.

Geochemistry: Analysed samples of Warrina Park Quartzite are listed in Appendix 19. Not unexpectedly, the highest metal values are concentrated in the more sericitic and labile interbeds (e.g. samples 2152, 2153, 2178) between the white orthoquartzite beds, which are relatively depleted in all elements analysed for (e.g. 2032, 2082, 2155). The high copper values in some samples are slightly anomalous.

Palaeogeography, Discussion: Throughout ALSACE, PROSPECTOR and MARY KATHLEEN the Warrina Park Quartzite appears remarkably uniform. The orthoquartzites are typically mature to supermature, with well-packed and rounded and silica-cemented quartz grains; abundant ripples, low-angle cross-bedding and some rain-drop impressions are entirely consistent with deposition in shallow-water, intertidal but relatively high-energy environments such as an active beach or coastal sand barrier complex. Local channel lag conglomerate and pebbly beds represent deposits in tidal channels or high energy swash zones. Most sand deposition is inferred to have occurred in the swash (foreshore) and surf, breaker and shoaling zones (shoreface).

Interbedded feldspathic and micaceous sandstones are less well sorted and contain more labile detritus than the orthoquartzites, and were possibly deposited seaward of the beach zone, in a shallow shelf; some may have formed in lagoons or inlets landward of the beach or barrier zone.

Apatite in many of the orthoquartzites is probably diagenetic, produced from circulating phosphatic waters; copper (and less commonly turquoise) staining also appears to be due to precipitation of copper along fractures during diagenesis or later folding.

Moondarra Siltstone

Map Symbol: Ꞓim, $Ꞓim_c$.

Nomenclature: Defined by Derrick and others (1976c); type section is in MOUNT ISA.

Distribution, Field Occurrence: As for Warrina Park Quartzite; $Ꞓim_c$, a dolomite-rich facies, has been mapped only in the Crystal Creek area, southwest ALSACE. Fine sandstones and siltstones are commonly laminated; the fine sandstones are lenticular, and show convoluted bedding, flaser bedding and some intraformational slumping. Flute marking and groove moulds are recorded from 2.5km west-southwest of Malcom homestead, where ripple marks present indicate current directions from the west.

Lithology: Ꞓim: red-brown to cream-buff laminated siltstone, fine-grained sandstone, convoluted sandstone.

$Ꞓim_c$: dolomitic siltstone, dolomite.

Some of the siltstone is probably carbonaceous at depth. The dolomitic rocks are pale grey to brown, and near Mount Osprey mine in the Crystal Creek area, massive secondary dolomite infills shears bounding the bedded dolomitic rocks.

Thickness: difficult to estimate because of folding:

Ꞓim in White Hills belt: 400m minimum.
Ꞓim in Crystal Creek area: 350m.
$Ꞓim_c$ in Crystal Creek area: 400m.

Stratigraphic Relations: Overlies Warrina Park Quartzite conformably, and is overlain conformably by the Breakaway Shale; probably equivalent to lower two-thirds of Gunpowder Creek Formation of McNamara Group to west.

Geochemistry: One sample, 76202064, has been analysed (Appendix 19); it is a brown ferruginous micritic dolomite, and contains no visible mineralisation. It assays .48% Cu, and mineralisation may be either syngenetic, or related to the apparently epigenetic vein Cu deposits at Mount Osprey. The high As content of 58 ppm is also anomalous.

Structure and Metamorphism: As for Warrina Park Quartzite; the north-plunging and doubly-plunging folds of the White Hills belt and central and northern areas of the Bull Creek belt contrast with east-trending fold axes in southwest ALSACE. Here it appears that the earlier north-trending folds have been markedly modified by folding about axes parallel to a major fault structure separating Mount Isa Group from Eastern Creek Volcanics. This fault (one of the "spoon" faults of Dunnet, 1976) trends east-west and displays north-block-up sense of vertical movement.

Chlorite and development of phyllite reflect regional green-schist facies metamorphism.

Breakaway Shale

Map Symbol: Ṗib.

Nomenclature: As for Moondarra Siltstone.

Distribution, Field Occurrence: Forms prominent ridge in Crystal Creek area; classified as Breakaway Shale on basis of topographic and lithological similarity to type area near Mount Isa, and on stratigraphic position above Moondarra Siltstone but below a chert marker bed.

Lithology: Grey siltstone, shale, siliceous siltstone; locally the siltstone appears slightly dolomitic.

Thickness: 150-200m.

Stratigraphic Relations: Overlies Moondarra Siltstone conformably, and overlain conformably by chert and dolomite of Native Bee Siltstone; probably equivalent to the upper part of the Gunpowder Creek Formation of the McNamara Group to west.

Structure and Metamorphism: As for Moondarra Siltstone.

Native Bee Siltstone

Map Symbol: Ꝑin, Ꝑin$_a$.

Nomenclature: As for Moondarra Siltstone; Ꝑin$_a$ is an informal unit.

Distribution, Field Occurrence: Present only in Crystal Creek area; forms subdued topography, except for Ꝑin$_a$, which forms a small ridge above the dolomitic sediments.

Lithology, Petrography: Dolomitic siltstone and shale, dolomite, pyritic siltstone, and thin laminated chert beds at base; Ꝑin$_a$ is a laminated algal chert which has not been examined by us.

Thin section studies show that dolomitic siltstones and micrite have quartz and sparry calcite/dolomite formed in poorly developed cleavage planes (sample 2058, 2059); notably, some samples contain spherules up to 0.8cm diameter of fibrous, radiating quartz or chalcedony typical of "cauliflower" chert nodules described by Walker and others (1977), and which represent possible pseudomorphs after evaporite minerals (anhydrite?, gypsum?). In addition, the micritic groundmass is cut by veins and aggregates of albite and albite-quartz intergrowths. The albite is clear, coarse-grained and subhedral to euhedral (sample 2060); in 2061, an albite-quartz-dolomite/siderite breccia, the quartz is fibrous and radiating, like "cauliflower" chert; patches of chlorite and tourmaline occur in the rock.

Sample 2062 is a well-bedded silicic rock which is composed solely of fine albite or a chert-albite mosaic; it is cut by monomineralic veins of coarse-grained albite with ?quartz, some of which is speckled with small euhedra of ?apatite and ?tourmaline.

The albite appears to be distinctly secondary, but whether it is diagenetic or of regional metamorphic origin is not known.

The chert marker at the base of Ᵽin is commonly formed of three chert layers - a basal layer of 0.5m thick, and a middle and upper layer each 15-20cm thick separated by dolomitic material. The upper chert band is commonly crenulated and brecciated.

Thickness: Top is not exposed: minimum thickness Ᵽin is about 750m; for Ᵽin$_{a}$, about 40m; the chert marker is about 1 to 3m thick.

Stratigraphic Relations: Overlies Breakaway Shale conformably, although local unconformities at the base of the unit are recorded by Mathias & Clark (1975) from Mount Isa. Top is not exposed on ALSACE, but elsewhere the unit is overlain by the Urquhart Shale, host to Ag-Pb-Zn mineralisation at Mount Isa.

The basal chert marker may correlate with the Breakaway Chert marker at Mount Isa, and the Mount Oxide Chert member of the McNamara Group to the west; the algal chert Ᵽin$_{a}$ may equate to the Native Bee Chert marker at Mount Isa, and to the "middle marker" of the McNamara Group. The Native Bee Siltstone is probably a direct correlative of the Paradise Creek Formation of the McNamara Group.

Geochemistry: The Native Bee Siltstone has been sampled and drilled by mining companies, but results of this work are not known to us. Grab samples of gossanous dolomite and gossan from the Native Bee Siltstone show anomalous values of Cu, Zn and to a lesser extent Pb and Co (Appendix 19).

Palaeogeography, Discussion: This discussion incorporates Moondarra Siltstone, Breakaway Shale and Native Bee Siltstone.

The rapid transition upwards from Warrina Park Quartzite into Moondarra Siltstone and other formations may reflect two types of palaeoenvironments - one a regressive sequence in which fine sands, silts and muds of a lagoonal environment overlap the beach-barrier deposits of the Warrina Park Quartzite; the other a transgressive sequence in which deeper shelf muds and silts transgress landwards across the Warrina Park Quartzite. Ripples, microcross-bedding, flaser bedding, lenticular fine sand layers, fine-scale graded rhythmic bedding and lamination, and convoluted bedding, some flute and groove casts are all consistent with intertidal conditions. The fine siliciclastics of lower Moondarra Siltstone grade upwards into dolomitic and cherty rocks, which possibly reflects progressive starvation of the basin, allowing carbonate precipitation and production of organic matter (e.g. Walter, 1978), the latter forming carbonaceous shale and siltstone. Indications of evaporative minerals in the Native Bee Siltstone also support a model of restricted lagoonal deposition.

We therefore suggest that the fine-grained clastic and dolomitic facies of the Mount Isa Group were deposited in very extensive shallow-water intertidal lagoonal environments in a large, restricted marine(?) basin.

MESOZOIC

Flat-lying Mesozoic rocks occur mainly in northeast ALSACE, and as small mesa remnants scattered through the White Hills and Bull Creek belts. The latter are, in places, coarse oligomictic conglomerate, in which all clasts are quartzite or vein quartz. Conglomerate grades upwards into pale purple-grey pebbly feldspathic sandstone.

A section at GR 783273 contains the following, from top to base:

1m of sparsely conglomeratic red-brown sandstone.

6m of red, friable to white silicified fine sandstone with plant remains and tubular structures.

4m of friable and mottled red-brown medium to coarse sandstone with rare clasts.

min. 6m of conglomerate.

Minimum thickness 17m.

CAINOZOIC

Cainozoic deposits on ALSACE have not been studied in detail.

Czs contains areas of residual clay, sand and fine gravel, including pelletal ironstone scree; it occupies plains of erosion and deposition, and broad interfluves, mainly over granitic and volcanic rocks in the Kalkadoon-Leichhardt and Ewen Blocks.

Czb is black soil, commonly developed on Eastern Creek Volcanics.

Czg are coarse gravels which form thick outwash deposits adjacent to fault scarps just north of Surprise Creek, in southwest ALSACE.

Qa is sand, silt and clay alluvium occupying active stream channels, or relatively consolidated material forming flood plains, levee and overbank deposits which border the major streams.

LOWER PROTEROZOIC TO CARPENTARIAN INTRUSIVE ROCKS

ACID INTRUSIVE ROCKS

Kalkadoon Granite

Introduction

The Kalkadoon Granite was formally defined by Carter and others (1961). It is mapped in a north-trending belt 250km long, extending from south of Duchess to the northeastern part of ALSACE. The southern outcrops of the granite have been described in some detail by Joplin and Walker (1961), Derrick and others (1977) and Wilson and others (1977).

In ALSACE the Kalkadoon Granite occurs in the east where it crops out discontinuously in the north-northeast trending Kalkadoon-Leichhardt Block, in a block up to 5km wide, east of the Saint Paul fault. The granite forms low tor-strewn hills and broad bouldery pediments, partly covered by skeletal sandy soils. The total area of outcrop in the

Sheet area is about 45km^2.

<u>Lithology and Field Occurrences</u>: The Kalkadoon Granite contains a variety of rock types ranging from fine-grained leucocratic microgranite and microgranodiorite to xenolithic porphyritic medium to coarse-grained biotite granite or granodiorite. Most of the unit consists of medium to coarse-grained porphyritic granite, designated Pgk on the geological map. The microgranite, designated Pgk_h, occurs marginal to the coarser varieties and predominates in some small intrusions. Aplite, leucogranite and minor pegmatite veins are associated with the granite. Younger dolerite dykes are abundant.

<u>Pgk</u>: The large pluton west of the Warwick Castle and Mount Cuthbert mines is mostly pink, poorly foliated, slightly porphyritic, medium-grained granite. Decussate clots of biotite with many sphene inclusions are moderately abundant, and allanite has been recognised in some hand specimens. Plagioclase is albite to oligoclase, and zircon is an accessory. Towards the margins of the pluton, the granite is generally finer-grained, locally darker (granodiorite?), and more xenolithic. The coarser varieties appear to grade into microgranite (Pgk_h).

<u>Pgk_h</u>: The main outcrop of microgranite occurs at the western margin of the Kalkadoon Granite, between faults of the Saint Paul fault system. Two small intrusions in the Leichhardt Metamorphics to the east and south of the Warwick Castle mine are also predominantly microgranite and have been included in Pgk_h. Pink to grey coarsely porphyritic microgranite and microgranodiorite are the main rock types. The phenocrysts are mostly euhedral K-feldspar, plagioclase and blue quartz. Clots of fine-grained biotite also occur in the groundmass which is typically aphanitic to very fine-grained and foliated due to alternating thin pink and dark grey layers. Xenoliths from 2cm to 40cm occur locally; they appear to be dark grey porphyritic dacite. The microgranite is typically fractured or sheared and is locally silicified. Quartz, quartz-feldspar and minor dolerite dykes intrude the microgranite.

The country rocks intruded by the Kalkadoon Granite are Leichhardt Metamorphics, consisting mostly of grey foliated slightly porphyritic fine-grained rocks readily recognisable as dacitic meta-volcanics. The contacts are sharp and irregular. In places veins of granite from 10cm to 2m thick invade the country rocks, producing some banded acid gneiss or migmatite.

Stratigraphic Relations

The Kalkadoon Granite 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 and Ballara Quartzite in the south and the Argylla Formation, Quilalar Formation and Surprise Creek Formation in the west. The granite is overlain unconformably by the Quilalar Formation in PROSPECTOR to the south.

Swarms of dolerite dykes trending north-northeast, north-northwest and north intrude the granite.

The most recent isotopic age determination on the Kalkadoon Granite, using U-Pb zircon methods, indicates an age of intrusion of 1860 m.y. (Page, 1978). Previous Rb-Sr studies indicated ages of 1723* m.y. (Richards, 1966), 1889* to 1742* m.y. (Farquharson & Wilson, 1971) and 1669* to 1625* m.y. (Page and Derrick, 1973). Page (1978) explains this range of apparent ages by post-emplacement isotopic readjustment about 1640 m.y. ago. A later metamorphic event at about 1500 m.y. is recorded by K-Ar dating of biotite and total rock specimens of Kalkadoon Granite (Richards and others, 1963; Richards, 1966).

Discussion: Some of the minor dykes of grey coarsely porphyritic microgranite which intrude the Leichhardt Metamorphics may be comagmatic with the Kalkadoon Granite; some appear to be intruded by the granite. Other dykes appear to cut the granite and may be related to the Argylla Formation acid volcanics.

The sharp discordant contacts and reduction in grainsize towards the margins of the granite indicate that it is epizonal or mesozonal in the classification scheme of Buddington (1959). Field evidence and outcrop distribution suggest a higher level of the pluton is exposed in ALSACE compared with areas to the south.

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* Recalculated using decay constant for $^{87}Rb = 1.42 \times 10^{-11}\ yr^{-1}$

Joplin & Walker (1961) and Carter and others (1961) suggest that the Kalkadoon Granite is comagmatic with volcanics in the Leichhardt Metamorphics and this is supported by U-Pb zircon age determinations of Page (1978) which indicate ages of 1865 $^{+27}_{-21}$ m.y. and 1865 $\pm$ 3 m.y. respectively.

Further petrological and geochemical studies are in progress (Dr L. Wyborn, principal investigator) to determine the origin of the Kalkadoon Granite. The dark xenoliths and fine-grained biotite clots may represent palaeosome and melanosome (restite) phases related to partial melting.

Ewen Granite

Introduction: The Ewen Granite was formally defined by Carter and others (1961) who mapped it in a north-trending belt 4 to 7 km wide extending from Surprise Creek in the south through the central part of ALSACE and as far north as Mosquito Creek in MYALLY. Specimens of this granite were described by Joplin & Walker (1961).

The Ewen Granite occurs as several elongate plutons in the Ewen Block, which forms a north-trending structural high through the middle of ALSACE. Outcrop areas of Ewen Granite have been considerably revised compared with earlier work; it forms a near-continuous mass along the western half of the Ewen Block, and occurs also as two distinct plutons, one in the north centred on White Hills Outstation, the other due south of the Mount Fox outlier. The total area of outcrop of Ewen Granite in the Sheet area is about 250 km^2.

Outcrop is typically poor due to shearing and deep weathering. The granite is expressed as broad valleys with highly fractured pediments and rubble-covered low ridges. Some areas of fresh boulders and tors are found, especially towards the western margin of the granite, and along the track between Rocky Glen and Dingo Gap.

Lithology and Field Occurrences: Carter and others (1961) described pale grey fine-grained adamellite, red porphyritic fine-grained granite and potash microgranite from the Ewen Granite. Our observations indicate that a pink to red even-grained to slightly porphyritic fine to medium-grained granite is the most abundant rock type. Locally this rock type is coarsely porphyritic and in some areas the granite contains rounded to elongate xenoliths of fine-grained basic rocks or porphyritic very fine-grained acid rocks. Chloritised biotite is usually present but some of the darker grey varieties (possibly granodiorite) contain hornblende. A weak to well defined foliation is developed by alignment of feldspar phenocrysts or elongate xenoliths in some areas. Porphyritic granodiorite is common in the Rocky Glen-Dingo Gap pluton, and is characterised by clots of chloritised biotite, altered plagioclase and anhedral microcline, and some green amphibole. Zircon, allanite and apatite are the main accessory minerals. Xenoliths of biotite-quartz-plagioclase schist are also common in this area.

The finer grained granite tends to occur near the contacts of the plutons. In some sections slightly porphyritic medium-grained granite grades outward into porphyritic foliated microgranite which appears to grade into, or is difficult to distinguish from, porphyritic acid volcanics of the country rock. The granite is cut by aplite, feldspar porphyry, pegmatite, and dolerite dykes, and quartz-tourmaline veins.

Small stocks, dykes and veins of medium-grained granite intrude Candover beds in southwest ALSACE. It is moderately to strongly foliated and contains prominent muscovite, and, like other areas of Ewen Granite, abundant chloritised biotite. Tourmaline is a distinctive accessory mineral. Both fine granite and granodiorite veins are represented. In places it is difficult to separate sheared granite from sheared arkose, acid volcanics and schist in this area.

Along shear zones the granites are reddened, and locally mylonite is formed.

A granodioritic to tonalitic phase has been delineated in some areas, and is symbolised Ege_1. It displays a higher colour index than granite and granodiorite of the main mass of Ewen Granite; the mafics (up to 20%) include chloritised biotite, aggregates of hornblende, and clinopyroxene with some actinolitic alteration. Apatite and zircon are accessory minerals.

Stratigraphic relations: The Ewen Granite intrudes pink-weathering grey porphyritic acid volcanics which were mapped as Argylla Formation by Carter and others (1961), but which are now mapped as Leichhardt Metamorphics on the basis of lithology, structure and geochemistry. Granite mapped as Ewen Granite intrudes schist, greywacke and metabasalt of the Candover beds in southwest ALSACE, north of Surprise Creek.

The granite is overlain by arkose, conglomerate, quartzose sediments and basalt at the base of the Eastern Creek Volcanics near Mistake Creek, and is faulted against sediments of the Myally Subgroup; the latter overlie Ewen Granite unconformably on MYALLY to the north. Swarms of dolerite dykes trending north-northeast, north and northwest intrude the granite.

Isotopic age determinations on the Ewen Granite using Rb-Sr techniques have indicated ages of 1778* m.y. and 1765* m.y. (Arriens and others, 1966) to 1742* m.y. (McDougall and others, 1965). Biotite ages determined by K-Ar techniques have yielded 1772 to 1776 m.y. which are in good agreement with the Rb-Sr ages and indicate the absence of metamorphism at 1500 m.y. which has affected other granites to the south. Ages for the Ewen Granite are very similar to the U-Pb zircon age for the Argylla Formation (Page, 1978), supporting the suggestion of Joplin & Walker (1961) that the two may be co-magmatic. Preliminary results of U-Pb zircon dating of the Ewen Granite suggest it is about the same age or slightly younger than the Kalkadoon Granite i.e. about 1860 m.y.

Geochemistry: Some samples have been analysed for a range of trace elements (Appendix 20). The highest uranium values occur in the granites (most silicic) 7.5, 8.5 and 14 ppm, the latter sample showing some deuteric alteration and reddening. In other samples U values are about average.

The granodiorites contain the higher Cu and Zn values - about 15 ppm and 60 ppm respectively, compared with average values in granites of 5 ppm and 15 ppm respectively. High Ni and Co values in the tonalite of 20 and 24 ppm respectively reflect the high mafic content of about 20% compared with other granites sampled.

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* Recalculated using decay constant for $^{87}Rb = 1.42 \times 10^{-11}\ yr^{-1}$.

Discussion: The Ewen Granite differs lithologically from the Kalkadoon Granite in being generally finer to more even-grained, although parts of the Dingo Gap-Rocky Glen pluton closely resemble Kalkadoon Granite. Petrographically the Ewen Granite is characterised by an abundance of chloritised biotite, whereas the Kalkadoon Granite contains abundant decussate biotite with sphene inclusions. Both granites contain zircon, apatite and allanite as accessory minerals.

In places the Ewen Granite marginal phase is difficult to separate texturally from volcanics of the Leichhardt Metamorphics. This may suggest co-magmatism, but could also be a result of marginal chilling of the granite and metamorphic recrystallisation of the volcanic country rock.

Some problems exist concerning the age of the Ewen Granite. In some areas of MARY KATHLEEN and PROSPECTOR to the south, a dolerite dyke swarm intruding the Leichhardt Metamorphics is apparently truncated by the Magna Lynn Metabasalt i.e. the dyke swarm may be used as a relative age marker. In ALSACE a dyke swarm similarly occurs throughout the Leichhardt Metamorphics, and also intrudes Ewen Granite and Kalkadoon Granite. If this is a dyke swarm similar to that in MARY KATHLEEN and PROSPECTOR, it can be inferred that Ewen Granite and Kalkadoon Granite are also older than Magna Lynn Metabasalt, i.e. Ewen Granite may be as old as Leichhardt Metamorphics, and possibly comagmatic with them, like the Kalkadoon Granite.

However, the Candover beds, possibly equivalent to upper Tewinga Group or lower Haslingden Group, are intruded by rocks mapped as Ewen Granite i.e. in this area the Ewen Granite may be younger than Leichhardt Metamorphics, and possibly coeval with the 1780 m.y. Argylla Formation volcanics, as suggested by K-Ar biotite ages of 1772 to 1776 m.y.

Possibilities which must be considered are:

1) The Ewen Granite is mainly comagmatic with Leichhardt Metamorphics.

2) The Ewen Granite is comagmatic with Argylla Formation volcanism.

3) At least 2 ages of Ewen Granite are present.

4) The dolerite dyke swarm in the Ewen Block is a younger swarm than those noted earlier in Sheet areas to the south.

5) The Candover beds may be as old as Leichhardt Metamorphics.

Geochronology of Ewen Granite and Leichhardt Metamorphics in ALSACE is currently in progress to help solve these problems. Preliminary results confirm item 1 above, but the small areas of Ewen Granite intruding Candover beds may be a younger granite.

BASIC INTRUSIVE ROCKS

Dolerite

Introduction: Dykes and sills of basic rocks of mainly tholeiitic composition occur throughout the Kalkadoon Leichhardt and Ewen Blocks; they are virtually absent from the White Hills belt except in basement inliers, and occur sporadically in the Bull Creek belt. Their general symbol is dl; although possibly four periods of dolerite intrusion are recognised, no attempt has been made to delineate these separate phases on the map.

Dykes of monzonite and sills of syenite are also discussed in this section.

Field Occurrences, Lithology: Dolerite forms dyke swarms which intrude mainly Leichhardt Metamorphics, Kalkadoon Granite, and Ewen Granite. They trend mainly north-northeasterly, northerly and northwesterly; the latter trend is particularly prominent in the Ewen Block. Most dykes in the basement blocks appear to form a conjugate set, and it is possible that those in the Kalkadoon - Leichhardt Block have undergone further deformation and appression than the set within the Ewen Block.

The dolerites show varying degrees of metamorphism and shearing; metadolerite, amphibolite, biotite and chlorite schist are present in the basement blocks and along shear zones, but may include both older and younger dolerites.

Other dolerites are massive and form bouldery outcrops, and display well preserved igneous textures; some dykes show relict igneous textures but are extensively amphibolitised. Because deformation and metamorphism appear to be less in the Ewen Block than in the Kalkadoon Block, coeval dolerites will vary in texture and mineralogy accordingly i.e. schistose dolerites or amphibolites need not be the oldest dyke rocks.

In the southern parts of the Kalkadoon-Leichhardt Block some dolerites contain xenoliths of acid volcanics or microgranite, and commonly appear to be contaminated to produce hybrid dioritic zones. In the Ewen Block some dolerites display vesicular margins and prominent plagioclase phenocrysts. A large dioritic to monzonitic dyke or sill 2 km SSW of Dingo Gap contains prominent hornblende phenocrysts to 1 cm and large plagioclase phenocrysts to 2 cm, with chlorite reaction rims.

Stratigraphic Relations: Metadolerite dykes intrude Kalkadoon Granite and Leichhardt Metamorphics in the Kalkadoon-Leichhardt Block; they intrude Ewen Granite and Leichhardt Metamorphics in the Ewen Block.

In the Bull Creek belt, dykes and sills of dolerite intrude the Candover beds and Eastern Creek Volcanics; a prominent dolerite sill intrudes Myally Subgroup at two preferred stratigraphic levels, one near Bortala Formation contacts, and one within a softer unit in the Whitworth Quartzite.

Dolerite dykes appear to be absent from the Quilalar and Surprise Creek Formations and Mount Isa Group in the White Hills belt.

Petrography: A listing of samples with locality and rock name is given in Appendix 21. Routine trace element geochemistry of some of the dolerites is also listed.

a. Dolerite and Syenite from the Haslingden Group

Samples 2049 and 2366 intrude Eastern Creek Volcanics; both contain relict clinopyroxene, but otherwise show variable degrees of alteration. Sample 2049 retains an ophitic texture, but displays extensive alteration of pyroxene to actinolite, green-brown chlorite and biotite, which in turn is replaced by second-generation chlorite and epidote. Clots of chlorite and epidote independent of pyroxene suggest moderate amounts of element mobility in the dolerite. Titaniferous magnetite with ilimenite is altered to leucoxene with abundant sphene granules.

Sample 2366, by contrast, is little altered, and as well as cpx contains labradorite, An66, altered locally to epidote and sericite and some chlorite. Rare calcite and opaques are present.

A sample of dolerite from sills intruding Myally Subgroup resembles sample 2366 - fresh cpx and labradorite, but with significant alteration to actinolite -chlorite assemblages. Sample 2076, also from a sill intruding Whitworth Quartzite is a syenite, containing acicular Carlsbad-twinned k-feldspar(?) laths with interstitial muscovite, actinolite, sphene granules and skeletal opaques.

This group of basic to syenitic rocks appear to be the least metamorphosed suite, and retain their igneous texture. They may represent the youngest suite sampled and/or are most distant from the areas of higher-grade metamorphism in the east of ALSACE. They have been affected by a green schist-facies (chlorite-biotite) regional metamorphism.

b. Dolerites from the Candover beds

Sample 2094, like some in the previous grouping, contains relict labradorite but no cpx. Other samples 2098 and 2114 are, by contrast, strongly altered; igneous textures are lacking and the rocks are amphibolites with varying amounts of actinolite, chlorite, biotite, iron ore and sphene. Patches of chlorite, calcite and quartz are probably amygdales in the dykes.

The Candover beds, which underlie the Haslingden Group unconformably, may thus contain a suite of metabasic rocks older than those in group a above, and which may have undergone at least two greenschist facies metamorphisms, or at least greater deformation than group a rocks. The fresher sample (2094) may be representative of the younger suite of dyke rocks.

c. Dolerite and Monzonite from the Ewen Block

Dykes intruding the Ewen Granite and Leichhardt Metamorphics show little difference in their degree of alteration. The more basic dyke rocks are generally altered to assemblages of sodic plagioclase, actinolite, chlorite, biotite, epidote, sphene and iron ore. Relict cpx and labradorite are present in only one sample. Igneous textures are rarely preserved. Some amygdales in the dykes contain quartz, amphibole, chlorite and calcite.

Samples 2054, 2056 and 2057 are amphibolitic monzonites; they contain similar assemblages to the metadolerites, but in addition contain up to 15% of interstitial quartz-k feldspar graphic intergrowth.

This group has also undergone extensive, but locally variable, greenschist facies metamorphism.

d. Dolerites from the Kalkadoon - Leichhardt Block

Samples 2053 and 2323 are both amphibolites. Igneous texture is lacking, and the metamorphic grade is significantly higher than in any of the preceding three groups. Abundant coarse-grained hornblende, with deep blue-green axial colours, is the main mafic mineral, with some biotite and epidote present; chlorite is absent. Plagioclase is increasingly granoblastic and relatively fresh, and compositions of An 48 -An 55 (andesine to labradorite) may be metamorphic and not relict primary plagioclase. Textures and mineral assemblages indicate high greenschist to amphibolite facies metamorphism, which may be related to proximity to the Wonga belt of high-grade metamorphism to the east of ALSACE.

Discussion: Despite the variability of texture and mineralogy in dolerites of the same age, and possible similarity of dykes of different ages, it appears probable that dykes in the Ewen Block, Candover beds and Kalkadoon-Leichhardt Block have undergone at least two periods of metamorphism and/or deformation; dykes and sills in the Haslingden Group may have undergone only one metamorphism. This latter metamorphism may be of regional extent, but higher grade in the east than in the west. As in the Candover beds, dykes of the proposed younger suite may also occur in the Ewen and Kalkadoon-Leichhardt Blocks.

STRUCTURE

Four distinct structural provinces are recognised, paralleling the topographic divisions described earlier, i.e. from west to east, they are the Bull Creek belt, the Ewen Block, the White Hills belt and the Kalkadoon-Leichhardt Block (see Figure 2). The Ewen and Kalkadoon-Leichhardt Blocks are underlain mainly by basement granite and volcanics, the other belts by younger sediments and volcanics. Lithological differences, and to a lesser extent, age, are the major controls on the striking differences in structural style between the four blocks. Details of structure and metamorphism for most individual formations are given in earlier descriptions of these units, and structural evolution is summarised in Table 2. A simplified structural sketch map is shown on the ALSACE geological map.

Folding: All four structural belts constitute a north-trending series of anticlinoria and synclinoria. These folds are most obvious in the Bull Creek and White Hills belts, and are poorly expressed in the basement blocks.

Basement Blocks: No fold closures are evident in the Kalkadoon-Leichhardt and Ewen Blocks; steep easterly and steep westerly dips of equivalent younger sequences off these basement blocks indicate they are largely anticlinal features. Anticlines of Tewinga Group in the southern White Hills belt are north-plunging, and probably define the regional closure of basement sequences in the Mount Isa Inlier.

Dolerite dykes in the Ewen and Kalkadoon-Leichhardt Blocks form conjugate swarms, and appear to intrude the Ewen and Kalkadoon Granites, and the Leichhardt Metamorphics. The conjugate pattern could have resulted from an early east-west compression, prior to onset of deposition in the adjacent sedimentary basins. Unconformities between the Candover beds and the overlying Eastern Creek Volcanics clearly indicate pre-Haslingden Group warping and compression of the basement.

BULL CREEK BELT

This belt contains two anticlinal belts separated by a major tight to isoclinal syncline which extends south to north across ALSACE. A second syncline adjacent to the Ewen Block has been largely removed by faulting, and most contacts with the Ewen Block are faulted. To the west, the folding is very open, about north-trending and plunging axes; from west to east towards the Ewen Block the folding becomes tight to isoclinal, characterised by elongate basin-and-dome structures outlined by basal quartzite layers in the Mount Isa Group.

The change in fold style is directly related to lithology and thickness. In the west, most units are very thick and relatively uniform basalts and arenites of the Haslingden Group; to the east these units thin dramatically, and are overlain by an abundance of thin beds of quartzite, carbonates, siltstone and shale. Intense folding of the latter thin-bedded sequence is a result of inhomogenous flattening of the sediments, and marked lithological and competency contrast between them and the underlying crystalline rocks of the basement.

This prominent folding is post-Mount Isa Group, and probably formed during the last major folding and faulting event in the Mt. Isa Inlier. From other Sheet areas it is clear that gentle to moderate warping occurred in the Haslingden Group, prior to Fiery Creek and Mt. Isa Group deposition; in ALSACE, however, these earlier events appear to have been largely obscured by the youngest event.

Most of the folds are cut and displaced by later faulting; the east-trending folds in the Crystal Creek sequence probably result from vertical movements along the east-trending normal (or "spoon") fault system in the southwest of the Sheet.

WHITE HILLS BELT

This belt lies east of the Ewen Block, and its fold style is a mirror-image of that in the Bull Creek belt, i.e. intense and complex isoclinal folding occurs near the Quilalar Arch, where thickness of cover rocks over basement is least, and becomes more open and gentle eastwards, where thickness of sediments, especially arenites, is greatest.

The complex basin- and -dome structure is best illustrated by the Warrina Park Quartzite in the vicinity of the Air Disaster Memorial. Most folds are north-plunging, and cross-faulting has dislocated many of the fold surfaces, in the sense north-block-up.

Angular unconformities in the White Hills belt indicate some pre-Mount Isa Group folding viz. just before and just after Fiery Creek Volcanics and Bigie Formation deposition. However, these earlier fold episodes appear mild compared with the same episode in Sheet areas to the west, and to the main post-Mt. Isa Group deformation.

Tight folding is evident in Corella Formation along the eastern margin of ALSACE, in relatively high-grade metamorphic terrain; strong axial-plane jointing has been intruded by younger dolerite dykes near Two Macks mine.

Faulting

Syndepositional faulting is not discussed here, although parts of the Quilalar Arch were probably active during deposition of the Haslingden Group.

Post-depositional faulting probably commenced with development of complex north-trending fault systems localised along eastern and western edges of the Ewen Block. Extensive shearing has occurred in the basement rocks, particularly along the western margins of the Ewen Block, but in the east the basement appears to be more massive and undeformed. As in areas to the south, these first-formed faults were commonly reverse faults with east-block-up sense of movement, e.g. the bounding fault of the Mount Fox outlier, in the centre of the Sheet area.

Juxtaposition of Mount Isa Group against Quilalar Formation along the Quilalar Arch, e.g. at Henderson's soak, suggests that movement in the sense east-block-down has also occurred. That is, fault movements along the Quilalar Arch have been in opposite directions of vertical movement at various times.

The major north-trending faults were followed by major east-trending, commonly curved faults which segment the Haslingden Group in the Bull Creek Belt. These faults, commonly referred to as "spoon faults", result from a mainly north-south extension in the Leichhardt River Fault Trough, with subsequent formation of curved normal faults, or more rarely, reverse faults. Sense of movement is mainly north-block-up, but north-block-down movement is also recognisable. Some of these "spoon faults" may be reactivated growth fault fractures which crossed the original rift floor. Some of the earlier-formed north-trending faults may have become bounding faults to the "spoon faults", with associated strong shear movement.

It is noteworthy that the fault systems flanking the Ewen Block converge at a point on the southern Sheet boundary; the Ewen Block appears to be progressively downfaulted, and sedimentary sequences which in the north are up to 20km apart are juxtaposed in the south; this feature is especially evident on PROSPECTOR, where structural "telescoping" has occurred. There, the shelf and trough facies in Quilalar Formation and Surprise Creek Formation (Wilson et al., 1977) are close together, separated only by the Quilalar Fault, whereas on ALSACE to the north the same facies are up to 25 km apart, in about their original depositional positions.

The last phase of faulting has been the development of conjugate faulting on both major and minor scales. A major wrench fault separates the White Hills belt and the Kalkadoon-Leichhardt Block, and right-lateral movement of about 25 km has been estimated by Derrick and others (1980). This fault, and northeast and northwest-trending minor wrench faults, all show movement consistent with east-west compression.

METAMORPHISM

Details of metamorphic effects are given in descriptions of individual formations, and in some appendices (e.g. Appendix 2). Polyphase metamorphism is evident, but most early metamorphic effects tend to be overprinted and obscured by the major regional metamorphism associated with high-grade metamorphism to the east of the Sheet area, in the Wonga belt.

The earliest metamorphism can be ascribed to intrusion of the batholithic Kalkadoon and Ewen Granites. Recrystallisation of ignimbritic acid volcanics has occurred, and is best illustrated in the Ewen Block; contact effects are limited to an aureole tens of metres wide in the volcanics, and textures and assemblages are typical of low to middle greenschist facies.

A metamorphic unconformity exists in the southwest of the Sheet, between Candover beds and overlying Haslingden Group. Some ?cordierite has been recorded, and the area is locally invaded by granitic schlieren, possibly of local anatectic origin. This metamorphic event may be the same age as the Ewen Granite (i.e. possibly about 1850 m.y.) or younger, but predates Haslingden Group (i.e. pre-1800 m.y.)

Superimposed on both these earlier metamorphism is a pervasive regional metamorphism which displays a grade increase from west to east. Units which show a grade increase include dolerite dykes, Leichhardt Metamorphics and Argylla Formation, Eastern Creek Volcanics, Myally Subgroup, Quilalar Formation and Surprise Creek Formation. Detailed petrography of these units defines a chlorite/biotite isograd located within the White Hills belt. It runs almost north-south and passes through the Mount Watson prospect (GR 834 133). Actinolite and hornblende appear further east in the Kalkadoon-Leichhardt Block, as amphibolite facies rocks of the Wonga belt are approached. A summary of textural and mineralogical changes in volcanics of the Leichhardt Metamorphics is presented in Appendix 2.

This regional metamorphism has probably extended over a considerable period. Its earliest effects may have been some time after deposition of Quilalar and Corella Formations, possibly during deformation and uplift associated with the Fiery Creek Volcanics, but prior to deposition of the Surprise Creek Formation - the latter contains coarse detrital muscovite of possible metamorphic origin. Regional metamorphism continued post-Surprise Creek Formation, and possibly post-Mount Isa Group, accompanied by deformation which affected all units.

ECONOMIC GEOLOGY

ALSACE is not richly endowed with mineral deposits. Most mines which have operated in the past have been relatively small gouger operations, copper being the main metal sought.

1980? not in references.

Wilson (1979) described the economic geology and aspects of mineral exploration in the Dobbyn 1:250 000 Sheet, of which ALSACE is a part. Wilson's report presented a history of mining in the area, details of company activity and methods, and descriptions of some of the mines.

In this report we draw attention to the main types of deposits and their setting, and potential for further discoveries.

Copper in the Basement Blocks

Small copper deposits abound in the Kalkadoon-Leichhardt Block, but are less abundant in the Ewen Block. The larger deposits, worked from about 1900, include Mt. Cuthbert and Dobbyn. These deposit types are characteristically developed in ignimbritic rhyodacites of the Leichhardt Metamorphics; the lodes are commonly quartz-chlorite reef types formed adjacent to rhyodacite-dolerite dyke contacts. Copper has probably been derived from the basic rocks and, to a lesser extent, from the volcanics.

Variants of these deposits are those located along the eastern edge of the Sheet area, at or near the contact between Argylla Formation volcanics and the overlying quartzite of the Mary Kathleen Group (e.g. Two Macks, Mussolini). These are related to dolerite-filled shear zones in a region of high strain and elevated metamorphism, but also appear to be partly controlled by their stratigraphic position, which is a favoured zone of mineralisation along strike to the south, in PROSPECTOR and MARY KATHLEEN.

The general lack of these dolerite-related fissure deposits in the Ewen Block may be attributable to the lower grade of metamorphism there; mineralising fluids have probably not developed because of lower temperatures and their lesser capacity for leaching of copper from country rocks.

Copper in the White Hills Belt

Deposits such as the Hidden Treasure are representative of this deposit type. Copper mineralisation occurs almost solely stratabound within the shale-siltstone-fine sandstone facies of the upper Surprise Creek Formation (units Ᵽrb, Ᵽrc, Ᵽrd). Hidden Treasure occurs in carbonaceous siltstone of unit Ᵽrd; Mount Watson mineralisation occurs near the Ᵽrd/Ᵽrc contact, and drilling in the Catfish leases in the south of the belt has investigated units Erc and Erb. Carbonaceous and/or pyritic siltstone zones contain malachite/chalcocite mineralisation in fine fractures and joints.

The copper is thought to be of diagenetic/epigenetic origin, derived from a variety of source rocks by leaching and migration of basinal fluids; deposition has occurred in zones of reduction and low permeability. Palaeogeographic features may exercise some control on this type of deposit, e.g. the coarse sands and channel-fill conglomerates of lower Surprise Creek Formation may be an excellent aquifer for fluid migration, as would unconformities at this stratigraphic level, and pinching out of these sequences along basement highs, e.g. the Quilalar Arch.

Persistent copper and turquoise staining in the Warrina Park Quartzite, at the base of the Mount Isa Group, is probably related to the Surprise Creek mineralisation; fluids have migrated upwards through the sequence into the quartzite; turquoise has formed in those quartzitic units rich in apatite. Analyses of Warrina Park Quartzite listed in Appendix 19 show some copper enrichment in the more sericitic and labile interbeds in the quartzite (up to 326 ppm).

The potential for discovery of large stratabound deposits of the Hidden Treasure type would appear to be limited; small and locally high-grade chalcocite mineralisation can be expected to be found with further exploration.

Copper and Other Mineralisation in the Bull Creek Belt

The Mount Osprey prospect is located on a small fault splay of a major east-trending "spoon" fault separating Eastern Creek Volcanics and Mount Isa Group, in the southwest of the Sheet. Malachite and chalcocite aggregates and veins occur in quartz veins cutting dolomitic siltstone and dolomite of the upper Moondarra Siltstone. A massive pod of secondary limestone/dolomite also occurs adjacent to the fault system.

Source of the copper is probably basalts of the Eastern Creek Volcanics; mineralisation occurred either during or following the development of the "spoon"-fault system. Mt. Osprey is typical of the many small epigenetic copper deposits associated with fault zones in the Eastern Creek Volcanics throughout the Leichhardt River Fault Trough. Some potential may exist for larger copper deposits of the Mount Isa type where pyritic zones in the Mount Isa Group are juxtaposed by faulting against Eastern Creek Volcanics.

At Lochness, a massive manganiferous ironstone ridge is developed along a faulted contact between dolomite and quartzite units of the Quilalar Formation. Appendix 12 shows that the gossan (or ironstone) contains some anomalous Zn values, but drilling below it has revealed no significant mineralisation.

Similar small gossanous showings are widespread in Quilalar Formation dolomites on PROSPECTOR to the south, but their economic potential is limited.

Silver-Lead-Zinc Deposits

Most exploration for Mt. Isa-type Ag-Pb-Zn deposits has centred on the Mount Isa Group in the Crystal Creek area, in southwest ALSACE. Results of company exploration are still confidential. Gossanous ironstone from parts of the Native Bee Siltstone show some highly anomalous values of Zn and Cu (Appendix 19). Diagenetic albitic alteration is evident in the dolomites, which also contain evidence of evaporite structures and textures.

The Crystal Creek area is the only area of Mount Isa Group which contains stratigraphy approximately equivalent to that of the ore-bearing zones at Mt. Isa (Urquhart Shale/Native Bee Siltstone). Over recent years it has been intensely explored by a number of mining companies. All other areas of Mt. Isa Group (in both Bull Creek and White Hills belts) contain only the lower-most part of the Group (Warrina Park Quartzite, Moondarra Siltstone), and their potential for stratiform Ag-Pb-Zn deposits is relatively low.

Exploration guidelines for Mt. Isa-type deposits include recognition of growth faulting, particularly in a palaeorift environment, with associated pyritic stratigraphy (Derrick, 1982).

Gold

Gold showings have been reported from the area near Boozers Waterhole (GR 612 032) and the area 4 km to the south-southwest, near Lochness.

Uranium

Minor radiometric anomalies are present in parts of the Eastern Creek Volcanics 6 km west of Lochness.

Exploration for U was also conducted in the areas of Tertiary sediments flanking and overlying the Proterozoic rocks in the northeast of the Sheet. A model of Colorado Plateau roll front-type deposits was considered a possibility in the area. Results, however, were disappointing (Wilson, 1979). 1980?

GEOLOGICAL HISTORY

A generalised geological history of the Sheet area is listed in Table 2.

Volcanics of the Leichhardt Metamorphics were extruded, mainly subaerially, and were intruded by probably co-magmatic Ewen and Kalkadoon Granites, at about 1865 m.y.

A major hiatus of about 60 m.y. separates this granite-volcanic complex from younger volcanics of the Magna Lynn Metabasalt and Argylla Formation, which also were deposited subaerially over the period 1800 - 1780 m.y. In the west, arkose, conglomerate, pelite, greywacke and iron formation of the Candover beds were deposited, and metamorphosed and folded before onset of deposition of the Haslingden Group.

The latter group is confined to the Leichhardt River Fault Trough, a rift feature developed in the west of ALSACE. Basalt of the Eastern Creek Volcanics rest unconformably on the Ewen Block, and clastic wedges (e.g. Dynamite Creek member) interfinger with much-reduced sections of basalt along the east edge of the rift zone. The Mount Guide and

TABLE 2

SUMMARY OF PRECAMBRIAN GEOLOGICAL HISTORY, ALSACE SHEET AREA

AGE (M.Y.)	STRATIGRAPHY, SEDIMENTATION	VOLCANICITY	INTRUSIONS	TECTONIC EVENTS	METAMORPHISM	UNIT/ REMARKS
1450 - 1620			Granite to east of Sheet area; dolerite sills in Myally Subgroup and Eastern Creek Volcanics; younger dolerite in basement.	Onset of regional basin-and-dome deformation; north-trending faulting, 'spoon' faulting, then conjugate faulting.	Regional m'mism; high-grade to east (Wonga belt).	
1670	Quartzite, siltstone, shale, dolomite, algal dolomite chert.	Thin tuff beds.		Overlies older rocks conformably and unconformably.		Mt. Isa Group
1680 - 1670	Conglomerate, sandstone, siltstone, shale.			Overlies older rocks with low-angle unconformity		Surprise Cre Formation; fining up sequence, Cu-anomalous.
1680 - 1670				Uplift, erosion, some warping.	Mild regional m'mism.	
1680	Minor intercalated sediments.	Extrusion of básalt and rhyolite. Continental, subaerial, hematitic, potassic.				Fiery Creek Volcanics.

../2..

AGE (M.Y.)	STRATIGRAPHY, SEDIMENTATION	VOLCANICITY	INTRUSIONS	TECTONIC EVENTS	METAMORPHISM	UNIT/ REMARKS
1680+	Coarse red-bed clastics in fluvial and alluvial environments.			Overlies Quilalar Form. unconformably; start of Fiery Creek period of deposition.		Bigie Form.
			Possibly some dolerite intrusion of basalt pile	Regional uplift and erosion; some gentle warping of older rocks.	Possibly mild regional m'mism.	
?1740 - 1750	Quartzite-carbonate blanket across entire region; marked facies changes from carbonates to ferruginous clastics.	Thin interbeds of fine siliceous tuff.		Periods of transgression and regression. Thinning of units across old hinge lines.		Quilalar Fmn; Corella Fmn. and Ballara Quartzite.
? 1750	Feldspathic sandstone and orthoquartzite; conglomerate near eastern margins.			Steady subsidence of trough, but shallow epeiric sea environments prevailed. Units thin to east.		Myally Subgroup.
?1750 - 1780	Intercalated quartzite and conglomerate purple siltstone and tuff.	Extrusion of basalt of Eastern Creek Volcs. in Leichhardt River Fault Trough.		Thinning of units to east of trough; rapid subsidence of trough; unconformable on Ewen Block and Candover beds.		Volcanics mainly subaerial. Base of Haslingde[illegible] Group.

../3..

AGE (M.Y.)	STRATIGRAPHY, SEDIMENTATION	VOLCANICITY	INTRUSIONS	TECTONIC EVENTS	METAMORPHISM	UNIT/ REMARKS
1780-1800	Pelitic rocks, greywacke, BIF, arkose, conglomerates.	Rhyolites and basalts intercalated with sediments.	Some dolerite; intruded by granite and pegmatite; possibly younger than Ewen Granite.	Base not exposed; some folding before deposition of Haslingden Group.	Some metamorphism prior to Haslingden group.	Candover beds; may b as old as Leichhardt M'mics.
1780-1800	Tuff and tuffaceous siltstone plus quartzite intercalated in volcanics.	Basalt sharply transitional to rhyodacite and rhyolitic ignimbrite.		Volcanics unconformable on Leichhardt M'mics.		Magna Lynn Meta basalt and Argylla Formation.
1800 -1860			Dolerite dyke swarms.	Uplift, erosion; conjugate dyke set suggests E-W. compression.		
1860		Porphyritic dacite and rhyodacite of Leichhardt M'mics. Commonly non-magnetic.	Kalkadoon Granite and Ewen Granites.	Greater deformation and m'mism in Kalkadoon - Leichhardt Block.	Contact m'mism. adjacent to batholith margins.	Basal unit of Tewinga Group.

Leander Quartzites, basal units of the Haslingden Group in Sheet areas to the south, are absent from ALSACE.

Sedimentation continued within the rift zone, with deposition of Myally Subgroup arenites. As the rift zone stabilised, a quartzite-carbonate blanket (Quilalar Formation/Mary Kathleen Group) was deposited as a mainly transgressive sheet across ALSACE. Fine tuff beds are present in this sequence in the west, and marked facies changes from dolomite to ferruginous sandstone have been observed. This quartzite-carbonate unit thins markedly across old basement highs, which it overlies unconformably. Age of the Quilalar Formation is thought to be about 1740 m.y., the minimum age for Corella Formation rocks near Mary Kathleen, with which Quilalar Formation is correlated (Derrick, Wilson & Sweet, 1980). Thus the Leichhardt River Fault Trough is estimated to have been an actively subsiding feature for the period 1780 m.y. to 1740 m.y.

Regional uplift and gentle folding terminated Haslingden Group and Quilalar Formation deposition. A hiatus of some 50 or 60 m.y. is indicated before deposition of coarse red-bed clastics of the Bigie Formation and overlying Fiery Creek Volcanics, at about 1680 m.y. The latter unit ranges from basalt to rhyolite, but only thin altered basaltic remnants are preserved on ALSACE. Thicker sequences are preserved in MOUNT OXIDE to the northwest. It is possible that some regional metamorphism of the Corella Formation occurred during the interval 1740 m.y. to 1680 m.y.

Further uplift, gentle warping and erosion ensued, and sand sheets and wedges of the basal Surprise Creek Formation were deposited with low-angle regional unconformity across older rocks in ALSACE. The sandstones are sharply transitional upwards to micaceous sandstone, siltstone and shale of the upper Surprise Creek Formation, deposited relatively rapidly in distal shelf and delta slope environments. These sediments, locally carbonaceous, are host to minor stratabound copper mineralisation.

Minor warping of this and older sequences was followed at about 1670 m.y. by deposition of the Mount Isa Group - a basal quartzite blanket overlain by fine sandstone, siltstone and dolomite, deposited in large basins and sub-basins bordered by mature and planated source regions.

Some tuff beds are present in the Mount Isa Group, which appears to have been deposited mainly to the west of the Kalkadoon-Leichhardt Block.

Regional metamorphism, possibly over the period 1620 to 1670 m.y., was prominent in east ALSACE, where amphibolite-grade rocks are common. This main regional metamorphism, highest grade in the east, probably masked the effects of earlier regional metamorphisms in the eastern parts of ALSACE. Basin-and-dome deformation was followed by faulting of various orientations, the youngest event being conjugate faulting resulting from east-west compression. The last recorded Precambrian tectonic event was closure of K-Ar systems at about 1450 m.y.

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APPENDIX 1: SAMPLE LISTING, LEICHHARDT METAMORPHICS

* Indicates chemical analysis.

M Indicates positive response to hand magnet.

1a: Samples from Ewen Block, eastern edge: lowest metamorphic grade.

Sample Number	Rock Name	Location	
76202041*	Sericitised rhyolitic crystal tuff.	GR 713084	M
76202044	Flow-banded rhyolitic crystal tuff.	717951	
77202184*	Crystal tuff.	717328	M
77202185	Banded crystal tuff.	717328	
77202186	Rhyolitic lapilli tuff.	717328	
77202187	Crystal tuff.	722331	M
77202188	Crystal tuff.	730321	
77202189	Flow-banded rhyolite or tuff.	735318	
77202231	Rhyolitic flow breccia or tuff.	731188	M
77202236	Porphyritic microgranite/porphyry.	744182	
77202269*	Feldspar porphyry or crystal tuff.	713120	
77202352	Flow-banded rhyolite.	737433	
A7.78.4A*	Feldspar porphyry or crystal tuff.	717171	
78202395*	Andesite	?	

1b: Samples from Ewen Block, central zone, near Ewen Granite; low greenschist grade.

76202042	Porphyritic rhyodacite.	GR 663007	
77202116	Microgranite/rhyodacite.	671906	M
77202117	Porphyritic microgranite.	675918	
77202132	Recrystallised crystal tuff or porphyry.	675927	
77205003	Rhyodacite/crystal tuff.	663007	
A2.56.5A*	Rhyodacite/crystal tuff.	611368	
A3.84.2A*	Rhyodacite/crystal tuff.	659313	
A7.74.2B*	Rhyodacite/crystal tuff.	658159	
A7.74.3*	Rhyodacite/crystal tuff.	655159	
A7.74.4A*	Rhyodacite/crystal tuff.	649158	

APPENDIX 1: (CONTINUED)

2a: Samples from White Hills Block, southern areas; low greenschist grade.

Sample Number	Rock Name	Location	
77202388*	Perlitic flow banded rhyolite.	GR 813988	
78202389*	Rhyodacitic crystal tuff.	808997	

2b: Samples from White Hills Block, north-east areas; low to lower middle greenschist grade.

77202288	Altered rhyodacite.	GR 873217	M
77202373	Rhyodacite.	864249	M
77202374	Rhyodacite/dacite.	864249	M
77202375	Rhyodacite	864249	M

3: Samples from Kalkadoon-Leichhardt Block - mainly middle greenschist grade.

76202038*	Porphyritic rhyolitic tuff.	GR 909262	M
76202039	Porphyritic rhyodacitic tuff.	933174	
76202045	Porphyritic rhyodacite.	895067	M
77202140*	Porphyritic rhyodacite xenolith	918134	M
77202297	Tuffaceous rhyolite.	911240	M
77202298	Tuffaceous rhyolite.	911240	M
77202299	Conglomerate/agglomerate.	915240	M
77202300	Porphyritic rhyodacite.	919239	M
77202324	Gneissic metavolcanic.	906120	
77202325	Gneissic volcanic.	908119	
77202380	Porphyritic rhyodacite.	940089	M
A10.74.2A*	Porphyritic rhyodacite.	901018	
A10.74.7A*	Porphyritic rhyodacite.	885010	
A11.08.3A*	Porphyritic rhyodacite.	944988	
A12.58.8A*	Porphyritic rhyodacite.	878937	
A13.78.5*	Porphyritic rhyodacite.	813893	

APPENDIX 2: METAMORPHIC VARIATION IN THE LEICHHARDT METAMORPHICS

Significant metamorphic variations are present in the Leichhardt Metamorphics of the Ewen and Kalkadoon-Leichhardt Blocks. The textural and mineralogical changes with increasing metamorphism are summarised below.

Relatively unmetamorphosed to lowest greenschist facies:	Flow and eutaxitic textures well preserved; groundmass clouded with fine ?hematitic dust; crystal fragments embayed, but not recrystallised. Groundmass not resolvable except at very high magnification - essentially a slightly devitrified glass with some coarser-grained spherulitic and axiolitic structures evident. Sericite and chlorite present.
Lowest greenschist facies:	Slight coarsening of groundmass; fine-grained polygonal mosaic of quartz and feldspar barely resolvable. Development of small opaque oxide clots in association with lesser amounts of fine clouding. Polygonal boundaries of spherulitic mosaics sharper. Chlorite and epidote, sericite present, with traces of muscovite.
Lower to middle greenschist:	Groundmass a moderately even-grained mosaic of quartz, K-feldspar and plagioclase, a.g.d. 0.05 - 0.1 mm. Some variation in grain size may reflect original spherulitic mottling and axiolitic/mariolitic zones. Little or no clouding, most Fe oxide being present as opaque ore, or in phyllosilicates. Crystals of feldspar commonly saussuritised; quartz crystals and fragments commencing polygonisation around margins. Abundant and coarser biotite and epidote, rare chlorite, coarser muscovite.
Middle to upper (?) greenschist:	Volcanic textures absent, but overall porphyritic texture preserved - may be termed microgranitic in certain cases. Groundmass remains a clear quartz-feldspar mosaic, commonly 0.1 to 0.2mm a.g.d. Crystals of feldspar commonly replaced by a mosaic of microcline polygons; most quartz phenocrysts almost completely polygonised. Opaque oxides subhedral to euhedral; biotite abundant chlorite, generally absent; sphene appears, and epidote and muscovite are ubiquitous.

APPENDIX 2: (CONTINUED)

At higher grades (not encountered in ALSACE) biotite would give way to actinolite in the upper greenschist facies, and the original porphyritic texture would be increasingly recrystallised and difficult to recognise as such. Some chlorite in the highest grade volcanics (e.g. Wonga belt) may be of retrogressive origin. The rock increasingly tends towards a porphyritic granite or micro-granite, or a medium to fine-grained quartzo-feldspathic gneiss with sporadic coarser-grained patches.

APPENDIX 3: CHEMICAL ANALYSES, LEICHHARDT METAMORPHICS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	7620	7720	7720	7820	7820	7820	A	A	A	A	A	A	A	A	A	A	A	7620	7720
	2041	2184	2269	2388	2389	2395	2.56.5A	3.84.2A	7.74.2B	7.74.3	7.74.4A	7.78.4A	10.74.2A	10.74.7A	11.08.3A	12.58.8A	13.78.5	2038	2140
SiO_2 %	68.87	72.78	71.84	76.1	72.9	54.2	73.02	69.98	70.74	70.35	71.02	51.83	65.12	65.84	66.40	66.47	67.80	73.53	71.06
TiO_2	.26	.18	.18	.09	.16	2.03	.24	.30	.30	.28	.28	2.18	.69	.56	.55	.57	.49	.13	.36
Al_2O_3	14.74	13.59	14.44	11.9	13.7	13.6	13.56	14.99	14.98	14.59	14.49	12.29	15.06	15.01	15.60	15.18	15.47	12.89	14.30
Fe_2O_3	2.05	1.58	.21	1.41	1.31	2.74	1.19	1.40	2.35	1.80	1.71	3.52	2.54	.99	1.03	1.75	.52	2.01	1.52
FeO	1.24	.70	1.86	.49	.7	8.83	.96	1.37	.55	.90	.83	9.84	4.37	4.46	3.54	3.31	3.42	.83	2.01
MnO	.05	.04	.05	.02	.06	.20	.04	.05	.04	.07	.05	.31	.06	.07	.04	.09	.04	.02	.05
MgO	.38	.21	.25	.28	.4	4.31	.39	.53	.63	.53	.40	3.60	1.20	.90	1.19	.80	.85	.11	.29
CaO	1.61	1.98	1.41	.33	.79	6.92	1.41	1.87	1.52	2.43	1.96	4.18	2.38	3.52	2.07	3.20	1.59	.61	2.64
Na_2O	3.04	2.70	3.08	2.71	2.19	2.65	2.60	2.93	2.90	3.04	3.00	.37	3.42	2.96	3.76	2.55	3.70	3.03	3.08
K_2O	5.33	4.38	4.98	4.64	5.33	.88	5.08	4.56	4.91	4.16	4.80	4.23	3.39	3.65	4.22	4.11	5.00	5.31	4.08
P_2O_5	.04	.01	.02	.03	.05	.29	.06	.07	.07	.06	.05	.91	.15	.14	.14	.13	.10	.02	.09
H_2O^+	.98	.98	.99	.47	1.07	2.08	.80	1.08	1.14	1.08	.76	3.85	1.00	1.03	.95	.94	.69	.59	.47
H_2O^-	.12	.10	.14	.11	.14	.11	.06	.09	.03	.07	.02	.15	.11	.05	.04	.04	.07	.07	.04
Total	98.71	99.24	99.44	99.0	99.4	99.7	99.41	99.21	100.15	99.35	99.37	97.26	99.48	99.18	99.54	99.16	99.74	99.14	99.98
Ba ppm	1250	1000	1150	150	840	110	780	880	840	820	780	960	740	820	1250	1100	1050	1650	880
Rb	210	200	190	160	200	36	240	190	230	180	210	120	150	160	180	140	160	140	160
Sr	200	180	210	42	80	170	220	250	220	280	240	65	150	220	240	250	190	120	190
U	4	6	4	6	8	-4	4	4	-4	4	6	4	4	-4	-4	8	-4	4	4
Th	23																	24	
Y	32	34	28	32	20	32	24	24	24	28	24	55	30	28	26	28	32	40	32
Zr	290	250	220	120	150	170	180	220	220	200	220	440	230	390	240	390	250	200	340
Cu	22	88	74	8	20	70	18	6	4	20	9	28	2	12	4	7	11	20	10
Pb	18	20	28	5	10	15	70	30	16	36	40	20	16	18	-2	20	14	12	18
Zn	78	74	50	-2	2	40	95	55	40	55	75	75	32	65	26	80	22	38	62
Cr	18	28	28	-10	-10	20	10	-10	10	20	10	-10	10	20	20	20	20	20	24

Analyst: AMDL

Analysis 1 - 12 Ewen Block, White Hills Block

Analysis 13 - 19 Kalkadoon - Leichhardt Block

APPENDIX 4: SAMPLE LISTING AND PETROGRAPHIC SUMMARY OF THE ARGYLLA FORMATION

* Asterisk indicates chemical analysis.

M Indicates positive reaction to hand magnet.

Sample No.(BMR)	Rock Name	Grid Reference	
76202036	Arkosic greywacke	792 964	
2040	Rhyodacite	700 118	
2043*	Flow-banded rhyolite	799 964	M
77202190-96	Crystal tuff, fine tuff	738 320	
2197A	Rhyolitic crystal tuff	741 319	
2197B*	Rhyolitic crystal tuff	741 319	
2271	Agglomerate	771 964	
2287*	Rhyolite	873 217	M
2289*	Quartz-poor crystal tuff	874 220	M
2296	Rhyodacite	907 240	M
2315	Crystal tuff/porphyry	869 093	
2358	Crystal tuff/ashstone	806 027	
2363	Feldspar-rich crystal tuff	861 353	M
2376	Rhyodacitic crystal tuff	870 247	M
2377	Rhyodacitic crystal tuff	870 247	M
2378	Rhyodacitic crystal tuff	870 247	M
2385	Rhyodacite porphyry	951 082	
2386	Rhyodacite porphyry	949 087	M
77202122	Quartz-mica schist	639 935	
2123	Flow-banded rhyolite	639 935	
2124	Quartz-feldspar gneiss	639 935	
2125	Gneissic volcanic	639 935	M
A13.74.9D*	Acid volcanic	924 887	

The samples listed above can be separated into at least five areas which show significant metamorphic and lithological variation. The areas are:

1. Ewen Block, eastern edge, along Mistake Creek; Argylla Formation is overlain disconformably by Quilalar Formation in the White Hills Block. Samples are 2040, 2190 - 2197.

APPENDIX 4: (CONTINUED)

2. White Hills Block - southern: samples are from the east-trending areas of Argylla Formation southwest of Mount Stanley. Samples are 2036, 2043, 2271, 2358.

3. White Hills Block - central and northeast: samples are from inliers of Argylla Formation between Mount Stanley and Eight-Mile Bore. Samples are 2315, 2287, 2289, 2363, 2376, 2377 and 2378; 2223 is metabasalt of ?Pea$_b$.

4. Kalkadoon-Leichhardt Block; samples are 2296, 2385 and 2386.

5. Surprise Creek area, along the southwest edge of the Ewen Block. Samples are 2122, 2123, 2124, 2125.

The lowest grade rocks are from area 1. They include bedded air-fall tuff and fine agglomerate, and possibly some flow-banded rhyolite. Most fragments are of quartz and alkali feldspar, set in a very fine-grained devitrified quartzo-feldspathic glassy matrix containing sericite and chlorite. A few flakes of ?primary muscovite are present. Ignimbrite/welded crystal tuffs overlie the bedded air-fall tuff, and show crystal fragments in a very fine devitrified groundmass which shows ?flow lamination, and some patches of spherulitic or axiolitic recrystallisation to coarser patches of quartz and feldspar. Chlorite and sericite and well preserved textures indicate very low-grade greenschist-facies metamorphism.

Area 2 rocks are also of very low metamorphic grade. They include red-brown ignimbrites (welded crystal tuffs) with well preserved flow textures; crystals and crystal fragments of quartz and feldspar are set in a groundmass of fine, devitrified quartzo-feldspathic material showing flow foliation and zones of polygonal quartz and feldspar mosaics, which may represent recrystallised axiolitic and spherulitic structures. Sample 2271, an agglomerate composed of ignimbrite fragments set in a quartzo-feldspathic tuffaceous matrix, contains excellent examples of "snowflake" texture, i.e. devitrification of silicate glass produces a series of blebs of quartz 0.2 to 0.5m across containing poikilitic intergrowths of feldspar, formerly a spherulitic growth. The blebs of quartz may be juxtaposed against other blebs of different orientation, to produce a mottled effect, or are separated by fine-grained masses of Fe-stained spherulitic material. At first glance, the texture resembles an intergrowth of bladed, clear quartz microlites and feldspathic spherulites, but the quartz, in fact, forms a single crystal containing many feldsparlaths. Anderson (1969) suggested such textures were almost unique to devitrified welded tuffs, and were rare or absent in devitrified lava flows. Lofgren (1971) reproduced snowflake texture experimentally from natural rhyolitic glass.

Recrystallisation micropoikolitic quartz and spherulitic feldspar texture may eventually lead to development of a granophyric texture. Some samples from areas of higher grade metamorphism show coarser, but still moderately well-preserved "snowflake" texture, e.g. 2363.

A feature of 2271 is the presence of possible pseudomorphs after olivine. The pseudomorphs are 1-2m long, and some show the characteristic outline of olivine. Additionally, the pseudomorphs consist of chloritic, serpentiferous material, cut by curved, iron-oxide-filled fractures, also typical of olivine. In view of the abundant iron oxide in the pseudomorphs, and the association with devitrified rhyolite, the olivine may have been fayalitic rather than forsteritic.

APPENDIX 4: (CONTINUED)

Sample 2363 from area 3 also shows all these features.

Sample 2358 contains abundant flattened ?pumice fragments which are preferentially sericitised compared with the fine quartzofeldspathic groundmass.

Area 3 resembles area 2, but many crystal tuffs examined are quartz - poor and feldspar-rich. The micropoikilitic quartz-feldspar "snowflake" texture is present, and some tuffs contain basalt fragments. The rocks are slightly more recrystallised than area 2 rocks, and in addition to chlorite they contain significant amounts of iron ore, biotite and epidote, i.e. low to middle greenschist facies. Calcite commonly replaces plagioclase. Metabasalt (2223) retains an intersertal texture with plagioclase (albite/oligoclase) laths intergrown with ?quartz, iron ore and calcite. Amygdales contain quartz and calcite.

Area 4 contains quartz-feldspar porphyry and crystal tuff metamorphosed to high greenschist grade (or slightly higher). Although the volcanic texture is well preserved, the quartz crystals are partially recrystallised to polygonal aggregates, and the groundmass is an even-grained quartz-feldspar granoblastic mosaic with average grain dimension of about 0.08 to 0.1mm. Hematite-clouding of feldspars, so common in volcanics of low-grade areas, is absent in the higher grade zones.

Coarse muscovite flakes, biotite flakes and clots, and minor amphibole are indicative of high greenschist facies.

Area 5, just north of Surprise Creek, is also metamorphosed to high greenschist; or possibly low amphibolite grade. Quartz-muscovite-biotite schist is most abundant; quartz-feldspar acid gneisses display flattened quartz aggregates of variable grain size, and may be sheared and metamorphosed acid volcanics. ?Flow-banded rhyolite in the sequence (2123) contains abundant quartz and feldspar crystals in a very fine-grained siliceous matrix. Both this rhyolite and the gneisses contain similar assemblages of mafic and other minerals such as sphene-amphibole-biotite-epidote-chlorite. Despite this similarity in grade, the textural differences suggest that some acid volcanic rocks are less susceptible to recrystallisation than others.

Textural and mineralogical variation in the Argylla Formation shows that the lowest grade rocks extend along the eastern edge of the Ewen Block (Quilalar Arch), and in the south of the White Hills Block; these rocks are of chlorite grade in the greenschist facies, or lower.

Metamorphic grade increases progressively to chlorite-biotite grade of the greenschist facies in Argylla Formation in the northeast of the White Hills Block, and to biotite-amphibole grade of the high greenschist-low amphibolite facies in Argylla Formation in the Kalkadoon Block west and southwest of Dobbyn. This grade change from west to east is probably related to proximity to the Wonga belt of high-grade metamorphics 3km east of Dobbyn, rather than to Kalkadoon Granite which predates Argylla Formation.

The grade increase from the Quilalar Arch west to the Surprise Creek area may be due to intrusion of Ewen Granite in the latter area; since classification of the volcanics in this area as Argylla Formation is uncertain, little can be said of metamorphic and lithological relations between volcanics in the Surprise Creek area and Argylla Formation in the White Hills Block.

APPENDIX 5 : CHEMICAL ANALYSES

ARGYLLA FORMATION

	7620 2043	7720 2197B	7720 2287 *	7720 2289	A13.74.9D
SiO_2	75.91	75.98	66.71	70.22	67.85
TiO_2	.12	.09	.68	.49	.83
Al_2O_3	12.06	12.14	13.27	15.51	12.32
Fe_2O_3	1.35	.61	3.96	.35	5.02
FeO	.85	.77	2.84	2.07	2.86
MnO	.02	.03	.04	.03	.03
MgO	.38	.59	.86	1.44	.95
CaO	.18	.09	1.50	1.95	.40
Na_2O	2.50	2.27	1.81	.65	2.26
K_2O	5.49	5.89	6.47	4.45	5.68
P_2O_5	.01	.01	.15	.26	.23
H_2O^+	.79	1.26	1.25	1.34	.92
H_2O^-	.09	.13	.09	.12	.07
Total	99.75	99.84	99.65	98.87	99.41
Ba	940	250	940	1250	900
Rb	150	220	260	230	120
Sr	65	26	38	15	18
U	4	8	8	8	8
Th	26				
Y	26	24	65	70	50
Zr	210	130	560	560	560
Cu	12	120	74	40	11
Pb	7	10	2	2	4
Zn	56	30	46	60	15
Cr	24	34	40	40	10

Analyst: A.M.D.L.

* Sample 2287 shown as Tewinga Group undifferentiated on Preliminary map; high Zr, and low Sr and CaO values indicate affinity with Argylla Formation.

APPENDIX 6: SAMPLE LISTING AND PETROGRAPHIC SUMMARY OF CANDOVER BEDS

Unit Psa

Sample Number	Grid Reference	Rock Name
77202090	634 890	Greywacke breccia.
2091	634 890	Greywacke breccia.
2099	621 886	Orthoquartzite.
2100	622 883	Arkose.
2101	625 884	Quartz-tourmaline rock.
2104	634 886	Altered ?andesite.
2105	634 886	Altered ?andesite.
2106	634 886	Siltstone.
2107	636 886	Arkose/greywacke.
2108	636 886	Quartz-magnetite rock. (BIF)
2118	636 946	Arkose.
2329	634 890	Greywacke breccia.

Unit Ps

Sample Number	Grid Reference	Rock Name
77202095	610 893	Psammitic schist.
2096	610 893	Cordierite schist.
2113	625 910	Micaceous feldspathic quartzite.
2119	650 947	Chloritic, dacitic breccia.
2121	648 947	Porphyritic dacite.
2126	634 937	Psammitic schist.
2127	630 937	Porphyroblastic mica schist.
2128	630 937	Schistose feldspathic quartzite.

APPENDIX 6: (CONTINUED)

Unit Ꝑb

Sample Number	Grid Reference	Rock Name
77202102	630 888	Metabasalt.
2103	630 888	Metabasalt.
2135	615 969	Metabasalt.
2244	620 977	Metabasalt.
2328	635 942	Metabasalt.
78202391	636 948	Metabasalt.
2392	636 948	Metabasalt.
2393	636 948	Metabasalt.
2394	636 948	Amphibolite.

Petrography:

Unit Ꝑs is mainly mica schist and psammatic schist; the latter includes micaceous meta-arenite. All samples contain variable amounts of quartz, feldspar, muscovite and biotite, and chlorite in zones of retrogression. Porphyroblasts in 2127 consist of coarse-grained decussate growths of muscovite. Tourmaline is a common accessory. As mapped the unit also contains some chloritic dacitic breccia (2119) and minor porphyritic dacite (2121), similar to rock types in unit Ꝑsa. Sample 2096 contains ?cordierite, forming 5-8mm porphyroblasts with some inclusions and local polysynthetic twinning.

Unit Ꝑsa is a mainly arenaceous unit, with interbedded acid to intermediate volcanics. The arenites are glassy quartzite and arkoses; the former (2099, 2101) display some recrystallisation and development of triple-point grain boundaries, and contain accessory tourmaline. The arkoses (2100, 2118) consist of quartz-feldspar (mainly volcanic and plutonic types), and accessory muscovite, zircon, chlorite, sphene, calcite and tourmaline.

?Greywacke breccias (2090, 2091, 2329) contain quartz and feldspar in a fine sericitic groundmass with abundant chlorite bands and trails, iron ore, sphene and calcite. These are problematical rocks, and may be metamorphosed sediments or basic to intermediate tuffs. Samples 2106 and 2107 are siltstone and pebbly greywacke respectively, and lithologically fall between the greywacke and quartz suites. Quartz-magnetite rock (2108) shows fine-scale layering of quartz bands and magnetite bands which may be of primary sedimentary origin. Volcanics interbedded with sediments (e.g. 2104, 2105) are highly altered and generally quartz-poor, except for quartzitic amygdales or spherules. Feldspar-iron ore-chlorite is the most common assemblage, and the volcanics are possibly dacitic to andesitic.

APPENDIX 6: (CONTINUED)

Unit Pb is mainly metabasalt; most samples display well-preserved even-grained basaltic/intersertal/subophitic texture, with some glomerocrysts of sodic plagioclase in 2102 and 2103. In all metabasalts the plagioclase is albite/oligoclase, either fresh or highly sa ssuritised; mafics are chlorite and actinolite, some biotite and muscovite, and variable amounts of epidote. Calcite, iron ore (?ilmenite) and sphene/ leucox ne alteration from the opaques are common. Most chlorite is retrogressive from actinolite.

Sample 2394 is an amphibolite with quartz and alkali feldspar - possibly a metamorphosed basic to intermediate tuff.

APPENDIX 7 : EASTERN CREEK VOLCANICS - SAMPLE LISTING AND PETROGRAPHIC SUMMARY

Basalts

Sample Number	Location	Unit
76202046	442 977	Ƥhc
2047	442 977	Ƥhc
2048	442 977	Ƥhc
77202110	640 882	Ƥhe
2111	640 882	Ƥhe
2112	639 892	Ƥhe
2136	474 024	Ƥhc
2142	598 095	Ƥhe
2267	720 104	?Ƥhe
2330	619 048	Ƥhe
2339	483 267	Ƥhp
2340	483 267	Ƥhp
2347	582 189	Ƥhe
2368	524 025	Ƥhp
2369	524 025	Ƥhp
2370	524 025	Ƥhp

Sediments (including Lena Quartzite Member)

76202073	612 031	Ƥhl
77202109	640 882	Ƥheq
2115	646 887	?Ƥhl
2141a	619 048	Ƥheq
2141b	619 048	Ƥheq
2143	598 095	Ƥheq
2331	619 048	Ƥheq
2346	583 188	Ƥheq
2347	582 189	Ƥheq
2367	519 022	Ƥhl

APPENDIX 7: (CONTINUED)

The Cromwell Metabasalt Member (Ehc) of the Eastern Creek Volcanics (2046, 2047, 2048, 2136) contains relict clinopyroxene in all samples except 2136. It forms ragged grains in various stages of replacement by actinolite, chlorite, calcite and epidote. Plagioclase is universally albite/oligoclase (An 8-10). Sphene, leucoxene and iron ore are abundant, and chlorite plus quartz are common in amygdales. An intersertal/subophitic texture is well preserved.

Samples from the Pickwick Metabasalt Member, Ehp, (2339, 2340, 2368, 2369, 2370) are similar to the lower member. Textures vary from even-grained to intersertal, but assemblages are universally cpx-actinolite-albite-chlorite-epidote-iron ore-sphene-calcite. Quartz may occur interstitially or with epidote and chlorite in amygdales. A flow-top breccia (2369) contains glassy (devitrified) basalt fragments in a fine silicified quartzofeldspathic groundmass with some muscovite and actinolite.

Undifferentiated Eastern Creek Volcanics, Ehe (2110, 2111, 2112, 2142, 2267, 2330, 2347) occur east of the basalts described above; they contain no clinopyroxene, which may reflect a slightly higher degree of greenschist facies metamorphism going from west to east. Sample 2112 contains albite glomerocrysts and patches of ?devitrified microlitic basalt within the more normal intersertal/subophitic basalt types.

Sediments within the Eastern Creek Volcanics have been mapped as Lena Quartzite Member (Ehl) or as interbeds in metabasalt (Eheq, Ehcq, Ehpq).

Lena Quartzite as mapped ranges from quartzite in the west to pebbly and conglomeratic arkose in the east, adjacent to the Ewen Block. Sample 2367 from the west is a moderately sorted quartzite with silica overgrowths, and few heavy minerals. Samples 2073 and 2115 are arkose and feldspathic quartzite respectively. Most quartz and feldspar is of volcanic and plutonic origin; grains are generally rounded, but grain boundaries are modified by suturing, some silica overgrowths and growth of sericite locally. Zircon and tourmaline are the main heavy minerals.

Eheq samples consist of greywacke and quartzite. Greywackes (2346, 2331, 2141a, b) are quartzose types, with abundant clastic quartz, some feldspar and abundant rock fragments of basaltic and rhyodacitic composition. Sample 2346 contains mainly volcanic quartz splinters in a chlorite groundmass, and could be a devitrified tuff. Calcite is a common cement in the pebbly greywackes, which also contain abundant clastic grains of iron ore. The groundmass in 2141 is sericite (pelitic).

Samples 2109 and 2143 are quartzitic, commonly bimodal, with rounded grains 0.5 - 0.8 mm set in a very fine-grained quartz mosaic. Grains are moderately rounded with silica overgrowths, and some suturing of their margins is evident. Acid and basic volcanic fragments are present. Chlorite and sericite are the main mafic accessory minerals.

All volcanic and sedimentary samples show greenschist facies metamorphism, and absence of cpx in the eastern outcrops of basalt suggest a grade increase from west to east. Source areas have been the volcanic-plutonic terrain of the Ewen Block, and areas of contemporaneous basaltic volcanism. Carbonate cement in pebble greywackes may indicate deposition in shallow, near-shore environments marginal to the Ewen Block landmass.

APPENDIX 8: SAMPLE LISTING AND PETROGRAPHIC SUMMARY OF MYALLY SUBGROUP

	SAMPLE NO.	GRID REFERENCE
Alsace Quartzite (Ƥha)		
	77202338	498 268
	2342	456 282
	2371	529 027
Bortala Formation (Ƥhb)		
	77202337	508 269
	2372	539 033
Whitworth Quartzite (Ƥhw)		
	76202077	538 089
	2078	538 089
	77202341	445 281
	2345	475 358
Lochness Formation (Ƥhn)		
	77202332	517 364
Undifferentiated (Ƥhm)		
	76202080	704 131
	77202229	731 204
	2230	731 204
	2232	738 207
	2243	605 982
	2250	772 112
	2251	772 112

Petrography summary

Samples of Alsace Quartzite include feldspathic quartzite (2338, 2342) and orthoquartzite (2371). The former display white spotting, consisting mainly of sericitic patches derived from altered acid volcanic material, some feldspar grains, and shaley rock fragments. The orthoquartzite contains quartz and chert grains, some polycrystalline quartz and minor feldspar. In all samples quartz grains show silica overgrowths, sericite and chlorite occur in some grain boundaries, and tourmaline and zircon are the most common accessory minerals.

Bortala Formation samples (2372, 2337) are feldspathic and lithic sublabile sandstone and quartzite. Feldspar content ranges up to 30%, and rock fragments 5 to 10%, mainly as white spots of sericite and sericitic metavolcanic matrix material.

APPENDIX 8: (CONTINUED)

Whitworth quartzite samples 2077 and 2078 are adjacent to an altered dolerite sill, and show some contact metamorphic effects. Most quartz grains are poorly sorted and silica-cemented and show relatively normal, rather than undulose extinction. Tourmaline is very abundant (4%) and recrystallised. Sample 2341 is a feldspathic quartzite, and 2345 a ferruginous orthoquartzite with moderate sorting and accessory zircon, tourmaline and muscovite.

Lochness Formation feldspathic quartzite/sandstone (2332) is fine-grained and contains 20 to 25% feldspar. Silica overgrowth and hematite are the major cements.

In all samples the white spots are altered acid volcanic fragments and metamorphosed shaley lumps, and feldspar grains to a lesser extent. Provenance has been mixed volcanic and plutonic terrain, with minor quartzite sources, giving rise only to simple zircon - tourmaline heavy mineral assemblage.

Undifferentiated Myally Subgroup samples are mainly sublabile quartzites, with abundant ?volcanic rock fragments and feldspar, the latter commonly hematite-stained. Most quartz grains are strained, and show silica overgrowths and considerable suturing of grain boundaries. Samples 2250 and 2251 are orthoquartzites. Zircon and tourmaline are the common accessory minerals. An abundance of coarse chlorite, (in 2080), and some coarse muscovite and rare actinolite in samples from the vicinity of the Quilalar Arch suggests these rocks are of slightly higher metamorphic grade than Myally Subgroup in the Bull Creek belt.

APPENDIX 9 : PETROGRAPHIC SUMMARY OF QUILALAR FORMATION QUARTZITE, UNIT Ꞓqw

In the areas below, the sample number, its name and grid reference locality are listed. An asterisk indicates the sample has been analysed for uranium and other elements (See Appendix 10).

White Hills Belt (Central, eastern and northeastern areas)

East, Northeast

Sample Number	Rock Name	Grid Reference
76202084	Pebbly quartzite.	870 322
77202217	Orthoquartzite (with rock fragments).	872 324
77202218*	Orthoquartzite (with rock fragments).	872 324
77202219	Feldspathic quartzite.	865 324
2220*	Orthoquartzite (with rock fragments).	865 324
2221*	Orthoquartzite (with rock fragments).	860 342
2292*	Sublabile (lithic) quartzite.	883 220
2293	Orthoquartzite.	888 222
2294*	Orthoquartzite.	888 222
2295	Orthoquartzite.	888 222
2316	Volcaniclastic tuffaceous greywacke.	871 110
2317*	Arkose.	873 113
2318	Feldspathic quartzite.	873 113
2319*	Orthoquartzite (with chert fragments).	875 114
2320	Orthoquartzite.	875 114
2321	Orthoquartzite.	876 116
2364	Ferruginous feldspathic quartzite.	864 358

Central

77202272*	Sublabile arkosic quartzite.	772 967
2273*	Arkosic quartzite.	772 967
2274	Pebbly arkose.	773 970
2275	Orthoquartzite.	773 970
2281*	Orthoquartzite.	773 974

APPENDIX 9: (CONTINUED)

White Hills Belt - Quilalar Arch

Sample Number	Rock Name	Grid Reference
77202134	Volcaniclastic arkose.	711 923
2198*	Siliceous tuff.	745 310
2199	Siliceous tuff.	745 310
2213	Feldspathic quartzite.	738 260
2227	Orthoquartzite.	736 215
2228	Orthoquartzite.	736 215
2234	Feldspathic quartzite.	740 206
2235	Feldspathic quartzite.	740 206
2252	Orthoquartzite.	725 114
2253	Orthoquartzite.	
2265	Feldspathic quartzite.	

Bull Creek Belt

77202079*	Orthoquartzite.	
2242	Orthoquartzite.	
2245	Orthoquartzite.	
2246	Orthoquartzite.	

Petrography

White Hills Belt

Samples from the White Hills belt (northeastern and eastern areas) include arkose and quartzite. The arkoses are rock-fragment and feldspar-rich, and are derived from a mainly acid volcanic provenance. Most arenites are relatively clean-washed orthoquartzites, and less commonly, feldspathic quartzite, all with silica overgrowths or quartz grains as a cement. Grain sizes are from 0.1 to 1mm, and bimodal sorting is common. Tourmaline, zircon, and rarely apatite are the most common heavy minerals.

Ragged grains and clots of epidote, chlorite and biotite in the less quartzitic arenites, plus suturing and recrystallisation of quartz grain boundaries, indicates significant greenschist metamorphism to at least low biotite grade. This metamorphism reflects proximity to the high-grade Wonga belt to the east of ALSACE.

APPENDIX 9: (CONTINUED)

Samples from the central part of the White Hills belt are lithic sublabile quartzite and orthoquartzite. Sample 2272 is a labile quartzite (quartz and rock fragments) in which chert-cemented quartz grains display a coating of hematite (weathering prior to cementation?)

The sequence from 2272 to 2275 shows increased sorting and maturity, i.e. less hematite, and better rounding (especially of rock fragments). No chlorite and epidote are recorded, and the metamorphic grade is lower than in areas to the east and northeast.

Samples from Ꝑqw along the Quilalar Arch include volcaniclastic arkose, pebbly feldspathic quartzite, feldspathic quartzite and orthoquartzite. White to cream spots in most samples are cherty ?volcanic rock fragments, not feldspar. All quartzites show silica overgrowths on quartz grains, and moderate sorting. Some bimodality is present. Zircon and tourmaline are the most common heavy minerals. Sample 2198 is a fine siliceous tuff interbedded with the quartzites. The metamorphic grade appears similar to the central White Hills belt, and lower than the eastern areas.

Bull Creek Belt

These samples are all bimodal orthoquartzites, with up to 5% of cherty rock fragments. Grain sizes of 0.2mm and 0.8 - 1.0mm are most abundant.

Overall, unit Ꝑqw consists of a basal lithic and feldspathic arkose and quartzite blanket, overlain by orthoquartzite and feldspathic quartzite. Although feldspars may exceed 20% in some samples, whitish cherty volcanic? rock fragments generally exceed feldspar in most quartzites. Sorting is fair to good and commonly bimodal, and tourmaline and zircon are the main heavy mineral suite. Greenschist facies metamorphism is evident only in the eastern and northeastern outcrops. The petrographic evidence is consistent with the suggestion that unit Ꝑqw is largely a near-shore shallow-water sand sheet, deposited in alluvial, dune and beach environments, mainly the latter.

APPENDIX 10. GEOCHEMISTRY OF QUILALAR FORMATION

UNIT W

Sample Nos.	2028	2029	2030	2079	2198	2218	2220	2221	2253	2272	2273	2281	2292	2317	2319
Element															
Rb				14	111	31	46	-2	4	156	113	76	-2	111	
Pb	10	8	8	-2	2	-2	-7	-2	-2	5	6	-2	-2	4	-2
Th				4	15	10	8	4	6	26	19	10	6	16	
U	-4	8	16	0.5	2	2	2	1	1	5	6	2	2	2	-4
Y				7	20	26	26	10	11	66	33	18	7	21	
Co	5	5	5	-	6	6	2	2	3	3	2	-	7	5	13
Ni				4	17	5	5	5	5	4	5	4	6	4	
Cu	18	18	18	3	2	2	4	8	6	4	5	4	6	19	12
Zn	25	8	22	1	13	4	1	2	1	7	5	2	7	9	80
Ag	-1	-1	-1												-1
Mo	-3	-3	-3												-5
As				-1	1	1	1	1	-1	2	3	-1	1	1	

ANALYST: AMDL

Sample No.	Grid Reference	Lithology
76202028	792964	Gossanous quartzite breccia
2029	792964	Gossanous quartzite breccia
2030	792964	Gossanous quartzite breccia
2079	533097	Quartzite
2198	745310	Grey-green tuff?
77202218	872324	Feldspathic quartzite
2220	865324	Grey quartzite
2221	860342	White orthoquartzite
2253	725114	Clayey feldspathic quartzite
2272	772967	Arkose
2273	772967	Feldspathic quartzite
2281	773974	Feldspathic quartzite
2292	883220	Grey arkose
2317	873113	Arkose
2319	875114	Purple sandstone

APPENDIX 11 : PETROGRAPHY OF QUILALAR FORMATION Ɐqxq, Ɐqx

Sample numbers, rock type and grid reference locality are listed below, with summaries of petrography.

Unit Ɐqxq

Bull Creek Belt

	Sample Number	Rock Name	Grid Reference
	77202241	Orthoquartzite.	588 993
	2334	Clayey feldspathic quartzite.	529 334
	2335	Clayey feldspathic quartzite.	534 336

White Hills Belt

	77202226	Orthoquartzite.	741 214
	2254	Clayey orthoquartzite.	733 116
	2255	Feldspathic quartzite.	733 116
Western part	2256	Orthoquartzite.	734 115
	2261	Feldspathic quartzite.	725 100
	2262	Chlorite orthoquartzite.	725 100
	2263	Orthoquartzite.	724 101
	2264	Feldspathic quartzite.	724 101
	2312	Orthoquartzite (carbonate cement).	852 057
Eastern part	2313	Feldspathic quartzite.	852 057

All samples are medium to coarse-grained, with good to moderate sorting and some bimodal grain-size distribution. Cementation is by silica overgrowths and interstitial chlorite-sericite aggregates, the latter representing an initially clayey matrix. Rock fragments are present, but are not common; they include chert, ?acid volcanics, and grains of graphic granite or graphic quartz-feldspar intergrowth. There is an overall lack of heavy minerals; tourmaline and rare zircon are present. Clayey material is very abundant in the northern part of the Bull Creek belt.

Unit Ɐqx

Bull Creek Belt:

77202247	Siliceous stromatolite.	574 001
2348	Feldspathic sandstone.	557 207
2350	Quartzose dolomite	577 974
2351	Stromatolitic dolmicrite	577 974

APPENDIX 11: (CONTINUED)

The columnar stromatolites are cherty and contain quartz grains infilling the inter-column regions; 2350 contains clastic quartz grains and some recrystallised ooids; 2351 displays layers of fine micritic dolomite separated by other layers of sparry dolomite or calcite; 2348 contains subangular to subrounded grains, 20% feldspar and abundant rock fragments.

Quilalar Arch Area: Western White Hills Belt

Sample Number	Rock Name	Grid Reference
77202212	Dolomitic sandstone/breccia.	740 259
2237	Dolomitic sandstone/quartzite.	719 154
2355	Ferruginous feldspathic quartzite.	770 147
2266	Siltstone and fine sandstone.	722 102
2225	Fine tuff or ashstone.	745 215

The dolomitic sandstones are associated with feldspathic ferruginous sandstones displaying only moderate sorting and containing abundant rock fragments. Breccia fragments include oolitic quartzose dolomite.

White Hills Belt (Eastern)

76202005	Tuff/ashstone	788 979
2007	Tuff/ashstone.	788 979
2069	Tuff/ashstone.	789 974
2070	Ferruginous arkose.	787 974
2071	Ferruginous siltstone.	786 977
2072	Tuff/ashstone.	788 979
77202215	Feldspathic quartzite.	831 312
2301	Siltstone (with Bouma cycles ABC).	808 072
2302	Siltstone or ashstone.	807 072
2303	Tuffaceous siltstone.	805 074
2304	Sandy siltstone.	805 072
2305	Fine arkose.	805 072
2306	Chloritic feldspathic quartzite.	811 059
2307	Ferruginous siltstone.	833 054
2308	Dolomitic breccia.	837 055
2309	Ferruginous siltstone.	837 055
2310	Tuff.	839 055
2311	Tuff.	839 055
2359	Fine ferruginous arkose.	799 037
2360	Ferruginous siltstone.	798 039
2361	Chloritic feldspathic quartzite	793 043

APPENDIX 11: (CONTINUED)

The fine ferruginous sandstones/quartzites contain from 5% to 30% feldspar, are moderately sorted and contain abundant hematite and some tourmaline and zircon. Former clay matrix is now represented by chlorite and biotite.

Ferruginous (hematitic?) siltstones display graded bedding and ripple cross-laminated fine sand lenticles - partly developed Bouma cycles A (graded zone), B (laminated cycle) and C (rippled, cross-laminated cycle).

Tuffs are fine-grained and some appear cherty and siliceous, but others contain abundant felted masses of fine phyllosilicate (chlorite?) and some orb textures, suggestive of devitrification to clay of spherulitic structures and glassy tuff layers.

APPENDIX 12 : TRACE ELEMENT GEOCHEMISTRY, QUILALAR FORMATION, UNIT X

SAMPLE KEY

BULLCREEK BELT:

2000	Brecciated siltstone
2249a	Gossan - Lochness Prospect
2249b	Gossan - Lochness Prospect
2249c	Gossan - Lochness Prospect

WHITE HILLS BELT (Western):

2225	Fine grey-green siliceous tuff
2238	Limonitic dolomitic sandstone
2239	Limonitic dolomitic sandstone
2240	Limonitic dolomitic sandstone
2266	Siltstone with sandstone lenticles
2270a	Limonitic dolomitic siltstone
2270b	Limonitic dolomitic siltstone
2270c	Limonitic dolomitic siltstone
2277	Limonitic siltstone

WHITE HILLS BELT (Eastern):

2005	Grey-green siliceous ?tuff
2006	Cherty limonitic breccia
2007	Quartzite-pink chert breccia
2008	Gossan
2071	Purple siltstone
2072	Grey siltstone
2222	Ferruginous dolomitic siltstone
2261	Grey feldspathic quartzite
2263	Feldspathic quartzite
2301	Siltstone with sandstone lenses
2304	Fine sandstone
2306	Labile sandstone
2307	Purple siltstone
2311	Siliceous ?tuff

. . . .

APPENDIX 12: (CONTINUED)

	BULL CREEK BELT				WHITE HILLS BELT (WESTERN)								
	7620 2000	7720 2249a	7720 2249b	7720 2249c	7720 2225	7720 2238	7720 2239	7720 2240	7720 2266	7720 2270a	7720 2270b	7720 2270c	7720 2277
Ba													
Rb					238				278				
Sr													
Pb	12	6	2	12	3	9	9	15	5	16	20	38	2
Th					35				23				
U	6	30	32	26	6	8	8	4	4	22	8	38	10
Zr													
Nb													
Y					54				26				
Co	10	225	142	129	9	57	43	12	9	92	93	95	78
Ni					10				14				
Cu	12	46	74	580	1	730	600	98	21	1380	700	650	90
Zn	160	134	120	150	10	82	58	22	10	82	78	74	56
Ag	-1	2	2	2		2	1	-1		2	1	3	-3
Mo	10	20	35	-5		15	5	10		20	-5	60	5
As									12				

APPENDIX 12: (CONTINUED)

	7620 2005	7620 2006	7620 2007	7620 2008	7620 2071	7620 2072	7720 2222	7720 2261	7720 2263	7720 2301	7720 2304	7720 2306	7720 2307	7720 2311	7720 2360	7720 2361
Ba																
Rb	223				143	112		52	10	207	352	99	146	105		
Sr																
Pb	3	5	-5	-5	17	4	-2	-2	-2	5	4	4	6	2		
Th	35				13	30		10	4	27	36	25	15	27		
U	9	10	4	28	4	8	12	2	1	6	4	6	4.5	6		
Zr																
Nb																
Y	43				24	31		11	6	29	24	15	18	26		
Co	5	-5	-5	90	7	7	32	5	2	13	13	6	7	3		
Ni	7				8	6		7	7	26	12	8	5	2		
Cu	3	5	10	15	9	8	20	3	3	3	3	5	10	7		
Zn	7	10	12	30	7	8	28	7	2	12	11	13	5	4		
Li																
Ag		-1	-1	-1			-1									
Mo		-3	6	25			-5									
As					9	-1		1	1	1	-1	1	4	1		

APPENDIX 13: PETROGRAPHY OF BIGIE FORMATION AND FIERY CREEK VOLCANICS (Ɇfy, Ɇfz, Ɇfc)

Unit Ɇfy

Sample No.	Description	Location
77202214	Feldspatholithic (sublabile) quartzite.	758 285
2276	Feldspatholithic (sublabile) quartzite.	760 985
2280	Feldspatholithic (sublabile) quartzite.	766 000
2356	Feldspatholithic (sublabile) quartzite.	774 418
2362	Feldspatholithic (sublabile) quartzite.	791 045

All samples are pink to brown and medium to coarse-grained. They contain subangular to subrounded quartz grains and up to 25% combined feldspar and rock fragments. The latter are mainly chert, spherulitic material and polycrystalline quartz - all probably of volcanic origin - and siltstone and clay pellets. Iron oxide flakes and clouding impart the red-brown colour. Muscovite, zircon and tourmaline are present in small amounts.

Unit Ɇfz

77202156	Lithic quartzite.	770 236
2157	Feldspathic quartzite.	771 238
2158	Feldspatholithic sandstone.	766 252
2159	Feldspathic sandstone.	769 251
2160	Ferruginous stromatolite.	769 251
2166	Orthoquartzite.	774 236
2167	Ferruginous orthoquartzite.	774 236
2168	Clayey ferruginous sandstone.	774 236
2206	Ferruginous dolomite.	762 285
2207	Ferruginous feldspathic micaceous sandstone.	762 285
2208	Ferruginous feldspathic micaceous sandstone.	774 236
2209	Shale-clast conglomerate.	749 269
2216	Ferruginous feldspathic micaceous sandstone.	829 315
2322	Ferruginous feldspathic sandstone.	885 133
2357	Ferruginous feldspathic sandstone.	778 418

Sandstones are better sorted, cleaner washed but more micaceous than Ɇfy, and contain more accessory zircon and tourmaline. In the finer grained suite (2168 - 2357), abundant mica, high feldspar and high iron oxide contents are characteristic. The clay content is present as sericite and chlorite.

APPENDIX 13: (CONTINUED)

Unit Pfc

Sample No.	Description	Location
77202161	Feldspathic quartzite.	772 251
2165	Tuffaceous sandstone.	770 259
2162	Altered basalt?	772 251
2163	Altered trachybasalt	769 259
2164	As above, rutile in amygdales.	769 259
2169	Basalt-tuffaceous sandstone breccia.	774 232
2170	Basalt-tuffaceous sandstone breccia.	774 232

Volcanics are probably altered basalt or trachybasalt; texture is intersertal to basaltic, but K-feldspar may have replaced much primary plagioclase. Matrix is iron oxide, possibly ilmenite. Quartz (with ?K-feldspar) occurs in some amygdales.

APPENDIX 14 : GEOCHEMISTRY OF BIGIE FORMATION (Pfy) AND FIERY CREEK VOLCANICS (Pfz, Pfc)

	Pfy		Pfz							Pfc	
Sample No.	2276	2280	2166	2207	2208	2290a	2290b	2290c	2290d	2162	2163
Ba											
Rb	29	76	20	195	189					173	188
Pb	-2	4	2	5	8	7	4	-2	-2	7	7
Th	6	10	4	18	15					14	13
U	1	2	.5	3	4.5	8	8	6	6	5	6
Zr											
Y	11	18	5	32	23					45	35
Co	2	3	-	11	7	143	120	150	100	5	5
Ni	4	7	6	23	20					7	6
Cu	5	3	2	4	3	20	16	16	12	5	5
Zn	2	4	7	7	10	126	154	235	182	8	8
Ag											
Mo						-5	10	10	-5		
As	1	-1	-1	2	3					1	1

APPENDIX 15: PETROGRAPHY OF SURPRISE CREEK FORMATION

Unit A (Ꝑra, Ꝑra$_c$)

Sample No.	Description	Location
76202034	Conglomeratic feldspathic quartzite.	553 116
77202210	Clayey lithofeldspathic quartzite.	755 284
2211	Feldspatholithic quartzite.	752 286
2224	Chloritic orthoquartzite.	744 215
2282	Sublabile (lithic) quartzite.	833 194
2285	Feldspatholithic quartzite.	857 198
2286	Pyritic feldspatholithic quartzite.	860 201
2314 (Ꝑra$_c$):	Biotitic quartzite.	862 068
2354	Lithofeldspathic quartzite.	766 417

Unit B (Ꝑrb)

Sample No.	Description	Location
77202283	Fine feldspathic, micaceous quartzite.	835 196

Unit C (Ꝑrc)

Upper Unit:

Sample No.	Description	Location
76202066 }	Ferruginous, feldspathic micaceous.	743 898
77202149 }	Quartzite, with apatite.	751 237

Lower Unit:

Sample No.	Description	Location
76202067	Feldspathic, micaceous quartzite.	747 899
77202203	Feldspathic quartzite.	764 306
2204	Feldspathic quartzite.	764 306
2182	Feldspathic quartzite.	773 278
2183	Feldspathic quartzite.	773 278
2278	Feldspathic quartzite.	735 990
2284	Orthoquartzite with cherty fragments.	837 200

Unit D (Ꝑrd)

Sample No.	Description	Location
76202031	Granule feldspathic sandstone.	520 167
76202081	Khaki sericitic, feldspathic siltstone with sandstone layers.	519 168
76202083	Fine feldspathic micaceous quartzite.	517 166
77202147	Cream to brown ferruginous siltstone.	751 237

APPENDIX 16: CHEMICAL ANALYSES OF MINERALISED AND UNMINERALISED SILTSTONE OF UNIT D, SURPRISE CREEK FORMATION FROM HIDDEN TREASURE MINE

	7620 2144	7620 2145	7620 2146
SiO_2	55.32	61.97	65.10
TiO_2	.31	.46	.58
Al_2O_3	8.27	14.02	17.72
Fe_2O_3	1.84	.33	5.32
FeO			.38
MnO	.01	.02	.01
MgO	.51	1.86	1.24
CaO	.06	.05	.05
Na_2O	.09	.07	.04
K_2O	2.83	3.77	5.27
P_2O_5	.15	.33	.16
H_2O^+	4.09	3.73	3.61
H_2O^-	.26	.42	.53
C	0.05	2.24	0.05
Total:	73.79	89.25	100.05
Ba	220	250	360
Rb	85	160	260
Sr	32	55	60
Pb	5	4	4
U	24	14	4
Zr	170	160	140
Y	26	28	28
Cr	44	26	92
Cu	14.2%	4.6%	355
Zn	50	54	96

Sample No.	Description
76202144	Cupriferous siltstone.
2145	Carbonaceous siltstone.
2146	Laminated siltstone - surface equivalent of 2145.

APPENDIX 17 : TRACE ELEMENT GEOCHEMISTRY, SURPRISE CREEK FORMATION

	UNIT A					UNIT B				
	7620 2034	7720 2210	7720 2211	7720 2282	7720 2286	7620 2001	7620 2002	7620 2003	7620 2017	7720 2283
Rb		8	51	4	61					95
Pb	5	-2	2	-2	3	5	5	-5	5	6
Th		11	6	4	6					21
U	4	1.0	1.0	1	1.5	6	8	12	8	3.0
Y		16	11	9	8					31
Co	-5	1	1	2	3	18	15	45	12	5
Ni		2	8	3	1					5
Cu	12	3	5	5	3	12	18	8	60	13
Zn	2	1	3	2	2	55	35	50	22	5
Ag	-1									
Mo	-3					-3	3	4	-3	
As		-1	1	1	1					1

APPENDIX 17: (CONTINUED)

UNIT D

	7620 2018	7620 2019	7620 2020	7620 2021	7620 2022	7620 2023	7620 2024	7620 2025	7620 2074	7620 2075	7720 2147	7720 2031
Rb									260	203	225	
Pb	8	10	15	8	5	5	5	5	5	6	4	-5
Th									27	23	22	
U	10	14	8	8	4	8	10	10	9	10.5	11	-4
Y									28	28	25	
Co	-5	5	-5	18	15	25	8	-5	3	5	10	5
Ni									4	10	20	
Cu	22	1.46%	18	35	28	18	30	25	7	19	89	18
Zn	5	5	5	28	20	25	15	12	11	31	16	5
Ag	-1	2	-1	-1	-1	-1	-1	-1				-1
Mo	-3	-3	-3	-3	-3	-3	-3	-3	2	10	27	-3

ANALYST: AMDL

APPENDIX 17: (CONTINUED)

UNIT C

	7620 2015	7620 2016	7620 2026	7620 2027	7620 2066	7620 2067	7720 2182	7720 2203	7720 2284
Rb					116	73	90	86	-2
Pb	12	28	10	-5	5	5	5	5	-2
Th					14	6	13	12	8
U	4	10	8	6	3	1	2.5	3.5	18.5
Y					24	11	18	23	48
Co	-5	5	-5	12	9	2	1	3	2
Ni					15	5	4	6	6
Cu	8	28	190	32	24	5	3	7	14
Zn	12	45	12	18	8	2	3	31	6
Ag									
Mo	-3	5							
As					6	1	1	2	2

APPENDIX 17: (CONTINUED)

SAMPLE KEY: DESCRIPTION AND LOCATION

Unit Ꝑra:

76202034	Conglomeratic feldspathic quartzite	553116
77202210	Lithofeldspathic quartzite	755284
2210	Feldspathic quartzite	752286
2282	Sublabile lithic quartzite	833194
2286	Sublabile lithic quartzite	860201

Unit Ꝑrb:

76202001	Buff brecciated siltstone	843129
2002	Ferruginous silty breccia	843129
2003	Limonitic siltstone	843129
2017	Grey-green micaceous, fine grained sandstone	833131
77202283	Fine grained micaceous feldspathic quartzite	835196

Unit Ꝑrc:

76202015	Grey-green clayey sandstone	814133
2016	Purple micaceous fine grained sandstone/siltstone	814133
2026	fine grained micaceous feldspathic sandstone	743898
2027	Red-grey laminated siltstone	747899
2066	Ferruginous feldspathic quartzite	747899
2067	Feldspathic quartzite	747899
77202182	Feldspathic quartzite	773278
2203	Feldspathic quartzite	764306
2284	Orthoquartzite	837200

Unit Ꝑrd:

76202018	Purple laminated siltstone	834134
2019	Purple siltstone with Cu traces	834134
2020	Creamy grey micaceous siltstone	815135
2021	Red-grey laminated siltstone	739902
2022	Red-grey laminated siltstone	739902
2023	Buff-grey siltstone	739902
2024	Red-grey laminated siltstone	739906
2025	Red-grey laminated siltstone	736912
2074	Massive micaceous siltstone	815135
2075	Laminated siltstone	815135
77202147	Laminated siltstone	751237
76202031	Coarse grained quartzite	520167

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APPENDIX 18: PETROGRAPHY OF MT. ISA GROUP

Warrina Park Quartzite (Bull Creek Belt)

Sample No.	Description	Location
76202032	Orthoquartzite.	520 167
2033	Feldspathic quartzite, with pyrite, hematite.	520 167
2082	Orthoquartzite (with ?rhyolitic rock fragments)	519 168
77202349	Orthoquartzite.	548 205

Warrina Park Quartzite (White Hills Belt)

Sample No.	Description	Location
77202138	Lithofeldspathic quartzite.	715 982
2148	Orthoquartzite: zircon, muscovite access.	751 237
2150	Feldspathic quartzite: abundant apatite.	767 218
2151	Sericitic, feldspathic quartzite.	767 218
2152	As for 2151, plus bimodal orthoquartzite layers.	767 218
2153	?Tuffaceous siltstone.	767 218
2154	?Pyritic orthoquartzite.	767 218
2155	Orthoquartzite (highly strained).	767 218
2171	Micaceous feldspathic quartzite.	763 220
2172	Feldspathic quartzite, abundant apatite	763 220
2173	Bimodal quartzite.	763 220
2176	Cherty orthoquartzite; apatite, biotite access.	780 275
2177	Orthoquartzite.	780 275
2178	Feldspathic, micaceous quartzite.	778 275
2179	As above, but finer and more sericitic.	778 275
2180	Orthoquartzite; apatite, biotite access.	778 275
2181	Orthoquartzite, with apatite.	778 276
2200	Feldspathic quartzite; apatite access.	772 319
2201	Feldspathic quartzite.	772 319
2202	Orthoquartzite, highly strained; apatite access.	772 319
2257	Orthoquartzite; rutilated quartz.	740 107
2258	As above, with biotite flakes.	740 107
2259	Feldspathic quartzite.	740 107
2260	Bimodal feldspathic quartzite.	740 107
2279	Orthoquartzite.	733 991

APPENDIX 18: (CONTINUED)

Moondarra Siltstone

Sample No.	Description	Location
76202063	Quartzose dolomite; some ?chlorite.	446 938
2064	Ferruginous dolmicrite; some chlorite.	446 938
77202174	Coarse siltstone/fine feldspathic sandstone.	782 277
2175	Fine sandstone/siltstone, convoluted.	782 277
2205	Rhythmically banded fine siltstone, with grading.	778 322
2336	Phyllitic.	555 285

Native Bee Siltstone

Sample No.	Description	Location
76202058	Bedded dolmicrite with muscovite.	529 878
2059	Dolomitic siltstone.	532 916
2060	Albitic dolomitic breccia.	532 916
2061	Albite-quartz-dolomite breccia.	532 916
2062	Bedded chert-albite rock.	532 916

APPENDIX 19: TRACE ELEMENT, GEOCHEMISTRY, MOUNT ISA GROUP

	7620 2032	7620 2082	7720 2150	7720 2152	7720 2153	7720 2155	7720 2171	7720 2173	7720 2178	7720 2179	7720 2259	7720 2260	7620 2064	7620 2009	7620 2010	7620 2011	7620 2012	7620 2013	7620 2014	7620 2058	7620 2059
Rb	16	6	74	97	164	7	105	21	138	203	55	39	-2							80	17
Pb	2	2	8	6	5	-2	7	-2	7	7	6	3	21	200	12	8	10	65	8	21	7
Th	6	2	10	12	19	-2	9	2	16	19	6	6	2							9	9
U	45	1	5.5	4	6	2	4	3	5	4.5	1	5.5	2.5	20	8	6	10	8	4	2	2
Y	15	7	32	26	26	5	19	13	32	22	11	15	54							17	23
Co	2	-	18	19	5	-	2	>45	7	12	3	3	30	490	65	330	440	95	280	5	7
Ni	7	4	15	23	11	4	7	6	16	16	6	3	23							9	7
Cu	7	6	33	102	281	8	70	41	326	125	15	37	4890	2530	270	1020	1540	55	22	9	15
Zn	2	2	10	10	12	3	24	3	12	16	1	2	68	2400	240	460	630	1450	2600	175	15
Ag														-1	-1	-1	-1	-1	-1		
Mo														8	7	3	-3	3	-3		
As	3	01	10	12	2	1	2	2	2	1	1	1	58							8	6

SAMPLE KEY: DESCRIPTION AND LOCATION

Warrina Park Quartzite

Sample No.	Description	Location
76202032	Orthoquartzite.	520 167
2082	Orthoquartzite.	519 168
77202150	Brown feldspathic quartzite; apatite-bearing.	767 218
2152	Sericitic, feldspathic, fine grained quartzite.	767 218
2153	?tuffaceous siltstone.	767 218
2155	Orthoquartzite.	767 218
2171	Fine grained feldspathic micaceous quartzite.	763 220
2173	Bimodal orthoquartzite.	763 220
2178	Fine grained micaceous quartzite.	778 275
2179	Fine grained feldspathic micaceous quartzite.	778 275
2259	Feldspathic quartzite.	740 107
2260	Bimodal feldspathic quartzite.	740 107

Moondarra Siltstone

Sample No.	Description	Location
76202064	Ferruginous dolmicrite with limonitic and chloritic spots.	446 938

Native Bee Siltstone

Sample No.	Description	Location
76202009	Gossanous siltstone.	529 878
2010	Gossanous siltstone.	529 878
2011	Gossanous siltstone.	513 879
2012	Gossanous siltstone.	513 879
2013	Gossanous siltstone.	522 903
2014	Gossanous siltstone.	522 903
2058	Laminated dolmicrite.	529 878
2059	Dolomitic siltstone.	532 916

APPENDIX 20: TRACE ELEMENT GEOCHEMISTRY, EWEN GRANITE

	7620 2085	7620 2086	7620 2087	7620 2088	7720 2137	7620 2092	7720 2327
Rb	235	265	338	203	99	157	357
Pb	28	35	20	20	13	14	35
Th	26	31	57	33	12	38	48
U	5	5.5	14	8.5	2.5	3	7.5
Y	23	32	64	28	27	16	24
Co	10	8	13	7	24	13	4
Ni	7	8	12	10	20	13	4
Cu	8	23	3	7	20	11	5
Zn	58	48	23	11	97	34	12
As	1	1	-1	-1	1	-1	-1

Analyst: J. Pyke (BMR)

Sample Key:

Ewen Granite (main mass)

Sample No.	Description	Location
76202085	Granodiorite.	700 118
2086	Granodiorite.	693 068
2087	Red-pink altered granite.	693 068
2088	Red-pink altered granite.	693 068
77202137	Tonalite/granodiorite.	673 996

Ewen Granite in Candover beds

76202092	Medium granodiorite	634 890
77202327	Micaceous micrgranite	635 942

APPENDIX 21 : PETROGRAPHY AND GEOCHEMISTRY OF BASIC TO INTERMEDIATE DYKES AND SILLS, ALSACE SHEET AREA

PETROGRAPHY

Group (a): Dolerite and syenite from the Haslingden Group

Sample No.	Description	Location
76202049	Metadolerite (with cpx).	443 938
76202076	Syenite (sill).	538 089
77202343	Metadolerite sill (with cpx).	443 311
2344	Metadolerite sill (with cpx, labradorite).	457 363
2366	Metadolerite (with cpx, labradorite).	512 019

Group (b): Dolerite from the Candover beds

77202094	Metadolerite (with labradorite).	619 915
2098	Metadolerite.	610 893
2114	Biotite amphibolite.	628 897

Group (c): Dolerite and monzonite from the Ewen Block

76202050	Metadolerite.	698 094
2051	Metadolerite (with cpx).	698 094
2052	Metadolerite.	701 093
2054	Monzonite (with graphic texture).	700 118
2055	Biotite amphibolite.	700 118
2056	Amphibolitic monzonite.	700 118
2057	Amphibolitic monzonite.	700 118
77202131	Amphibolite.	675 927

Group (d): Dolerite in the Kalkadoon-Leichhardt Block

76202053	Amphibolite.	895 067
77202323	Amphibolite.	905 123

APPENDIX 21: (CONTINUED)

GEOCHEMISTRY

	7620 2050	7620 2051	7620 2055	7720 2098
Rb	45	70	414	19
Pb	5	4	9	2
Th	17	5	12	4
U	4	1	2.5	1
Y	61	22	54	46
Co	26	44	29	35
Ni	35	185	3	20
Cu	93	88	34	20
Zn	88	109	113	77
As	2	2	11	1

Analyst: J. Pyke (BMR)

APPENDIX 22: LOCATION AND PETROGRAPHY OF

G.S.Q. SAMPLES, ALSACE SHEET AREA

All sample numbers prefixed 'GSQ/R'

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6516	A-1-14-1A	443402	Eha	Quartzose sandstone
6517	A-1-14-3	435407	dl	Dolerite
6518	A-1-14-4A	437408	Eha	Quartzose sandstone
6519	A-1-14-5A	428430	Eqw	Quartzose sandstone
6520	A-1-16-1A	463388	Ehb	Labile sandstone
6521	A-1-16-4A	461425	Erd	Laminated micaceous siltstone
6522	A-1-16-6A	454426	Brc	Feldspathic sublabile sandstone
6523	A-1-16-9	450433	Bra	Ferruginous feldspathic sandstone
6524	A-1-16-12A	467428	Eiw	Quartzose sandstone
6525	A-1-18-5	505422	M	Fossil wood
6526	A-1-18-10A	513419	Eqx	Ferruginous sandstone
6527	A-1-18-12A	522417	Eqx$_q$	Quartzose sandstone
6528	A-1-18-12B	522417	Eqx	Laminated siltstone
6529	A-1-18-14	531417	Erd	Siltstone
6530	A-1-18-14B	531417	Brd	Slate
6531	A-1-20-10A	572421	Ehe	Metabasalt
6532	A-1-20-13	572398	Ehn	Calcareous sandstone
6533	A-1-22-2A	630422	Eel	Sheared porphyritic rhyolite
6534	A-1-22-3A	626408	Eel	Rhyolitic ignimbrite
6535	A-1-22-4A	594389	Ege	Medium-grained granite
6536	A-1-23-5A	615428	Eel	Sheared chloritised acid volcanic
6537	A-1-23-5B	615428	Bel	Sheared chloritised acid volcanic
6538	A-2-50-8A	802383	Efz	Feldspathic labile sandstone
6539	A-2-50-8B	803383	Bfz	Ferruginous laminated siltstone
6540	A-2-50-8C	803383	Efz	Ferruginous siltstone breccia
6541	A-2-50-8D	804383	Efz	Litho-feldspathic sandstone
6542	A-2-50-9A	806383	Efz	Dolomite
6543	A-2-50-11A	809379	Era	Lithic sublabile sandstone
6544	A-2-52-12A	749371	Eqw	Feldspatholithic sandstone
6545	A-2-52-12B	749371	Eel	Porphyritic dacite
6546	A-2-52-12C	749371	Eel	Sheared porphyritic rhyodacite
6547	A-2-52-13A	747370	Eel	Altered porphyritic rhyolite
6548	A-2-52-14A	744367	Eel	Recrystallised porphyritic rhyolite
6549	A-2-52-14B	744367	Eel	Recrystallised porphyritic rhyolite
6550	A-2-52-16A	732361	Eel	Vitroclastic andesite
6551	A-2-54-1A	724358	Eel	Reworked tuff
6552	A-2-54-3	713352	Eel	Sheared porphyritic rhyolite

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6553	A-2-54-5	706343	Ᵽge	Monzonite
6554	A-2-54-6A	678373	Ᵽge	Porphyritic microgranite
6555	A-2-56-1A	644379	Ᵽel	Porphyritic rhyolite
6556	A-2-56-3A	670358	Ᵽel	Rhyolitic ignimbrite
6557	A-2-56-5A	642347	Ᵽel	Rhyolitic ignimbrite
6558	A-2-58-1A	596353	dl	Altered dolerite
6559	A-2-58-1B	596353	M	Ferruginous pebbly sandstone
6560	A-2-58-2A	599354	Ᵽge	Fine-grained granite (?)
6561	A-2-58-6A	629366	Ᵽel	Porphyritic rhyolite
6562	A-2-58-6B	630365	dl	Dolerite
6563	A-2-58-6C	629367	Ᵽel	Porphyritic rhyolite
6564	A-2-58-7A	629364	Ᵽel	Porphyritic rhyolitic tuff
6565	A-2-58-8A	617350	Ᵽge	Altered granodiorite
6566	A-2-60-10A	577363	Ᵽha	Quartzose sandstone
6567	A-2-60-12A	568357	Ᵽqx$_{q}$	Quartzose sandstone
6568	A-2-60-13A	563351	Ᵽra	Feldspathic sublabile sandstone
6569	A-2-60-17A	566363	Ᵽqx	Feldspathic sandstone
6570	A-2-60-19A	566367	Ᵽqw	Feldspathic siltstone
6571	A-2-60-21A	576371	Ᵽhe	Albite-biotite schist
6572	A-3-80-1A	592330	Ᵽge	Porphyritic granite
6573	A-3-84-2A	653304	Ᵽel	Porphyritic rhyolite
6574	A-3-84-2B	653304	Ᵽel	Porphyritic rhyolite
6575	A-4-72-9A	711303	Ᵽel	Porphyritic dacite
6576	A-4-74-1A	698311	dl	Altered dolerite
6577	A-4-74-1B	698310	Ᵽge	Hornblende-bearing granite
6578	A-4-74-3A	678316	Ᵽel	Porphyritic rhyolitic ignimbrite
6579	A-4-76-2	627286	Ᵽge	Altered quartz diorite
6580	A-4-78-2A	600281	Ᵽge	Porphyritic microgranite
6581	A-5-18-8B	548233	Ᵽrb	Ferruginous siltstone
6582	A-5-16-1A	508236	Ᵽha	Lithic sublabile sandstone
6583	A-5-16-2A	511236	Ᵽha	Feldspathic sandstone
6584	A-5-16-3	513236	Ᵽhb	Feldspathic sandstone
6585	A-5-16-4A	517235	Ᵽhw	Feldspathic sublabile sandstone
6586	A-5-16-5A	522235	Ᵽhw	Feldspathic sublabile sandstone
6587	A-5-18-2	527234	Ᵽhw	Quartzose fine-grained sandstone
6588	A-5-18-3A	531233	Ᵽhw	Feldspathic sandstone
6589	A-5-18-3B	532233	Ᵽhn	Feldspatho-lithic sandstone
6590	A-5-18-4A	534233	Ᵽqx	Oolitic calcareous sublabile sandstone
6591	A-5-18-5A	537233	Ᵽqx$_{q}$	Quartzose sandstone
6592	A-5-18-6A	543233	Ᵽfy	Feldspathic sandstone
6593	A-5-18-7	544233	Ᵽfy	Lithic sandstone
6594	A-5-18-8A	546232	Ᵽra	Lithic sandstone

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6595	A-5-18-8C	546232	Erb	Micaceous siltstone
6596	A-5-20-1	566236	Eqw	Feldspathic sublabile sandstone
6597	A-5-20-1B	567236	Ehn	Feldspathic sublabile sandstone
6598	A-5-20-3A	576227	Ehp	Metabasalt
6599	A-5-20-3B	577227	Ehp	Altered metabasic tuff
6600	A-5-20-3C	579227	Ehp	Feldspathic siltstone
6601	A-5-24-2	688228	Eel	Recrystallised porphyritic rhyolite
6602	A-5-24-3A	704244	Eel	Recrystallised porphyritic dacite
6603	A-5-27	768262	Efc	Altered amygdaloidal basalt(?)
6604	A-5-30-2A	817227	Efy	Feldspathic sandstone
6605	A-5-30-3A	822228	Efz	Ferruginous feldspathic sandstone
6606	A-5-30-7A	829241	Eiw	Quartzose sandstone
6607	A-6-40-3A	807197	Erb	Micaceous siltstone
6608	A-6-48-1A	611211	Ege	Porphyritic microgranite
6609	A-6-48-2A	613207	Ege	Medium-grained granite
6610	A-6-48-3A	622202	Ege	Sheared medium-grained granite
6611	A-6-48-4A	626200	Ege	Medium-grained granite
6612	A-6-48-5A	636198	Ege	Granite
6613	A-6-48-6	659197	Eel	Recrystallised porphyritic rhyolite
6614	A-6-48-7A	662197	Eel	Porphyritic microgranite
6615	A-6-48-8A	664204	Ege?	Medium-grained granodiorite
6616	A-6-48-8B	664204	Eel	Recrystallised porphyritic rhyolite
6617	A-6-48-8C	663203	Eel	Tourmalinised andesite
6618	A-6-48-9B	665207	Ehe	Altered metabasalt
6619	A-6-48-9C	666208	Ehm	Feldspathic sandstone
6620	A-6-48-12A	664225	Eel	Porphyritic devitrified dacite
6621	A-6-48-12B	669224	Eel	Porphyritic dacite
6622	A-6-48-12C	669224	Eel	Silicified porphyritic dacite
6623	A-6-48-12D	671222	Eel	Porphyritic rhyolite
6624	A-6-48-1B	612208	Ege	Porphyritic medium-grained granite
6625	A-6-50-1A	599203	Ege	Hornblende-biotite granodiorite
6626	A-6-50-2	601193	Ege	Biotite granodiorite
6627	A-6-50-4A	613173	Ege	Fluorite-bearing porph. micro-granite
6628	A-7-74-2A	660158	Eel	Porphyritic andesite(?)
6629	A-7-74-2B	658158	Eel	Porphyritic rhyolite
6630	A-7-74-3	656158	Eel	Porphyritic rhyolite
6631	A-7-74-4A	649159	Eel	Porphyritic rhyolite

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6632	A-7-74-5A	640161	Ege	Biotite granodiorite
6633	A-7-74-5B	638160	Egc	Porphyritic sodic micro-granite
6634	A-7-74-5C	638160	Ege	Hornblende diorite
6635	A-7-74-6A	636160	Ege	Altered fine-grained granodiorite
6636	A-7-74-7A	619159	Ege	Contaminated aplite
6637	A-7-74-11A	633159	dl	Amphibolite
6638	A-7-76-5A	698178	Eqx	Sericitic siltstone
6639	A-7-76-8A	689175	Eqx	Sericitic siltstone
6640	A-7-76-11A	685169	Ehm	Feldspathic sublabile sandstone
6641	A-7-76-13A	678164	Eel	Porphyritic dacite
6642	A-7-76-14	676163	Eel	Silicified brecciated rhyolite
6643	A-7-76-15A	674161	Eel	Amygdaloidal andesite(?)
6644	A-7-76-15B	674161	Eel	Porphyritic rhyolite
6645	A-7-78-1A	715184	dl	Metadolerite
6646	A-7-78-3A	716176	Eel	Porphyritic rhyolite
6647	A-7-78-3B	716176	Eel	Dacitic agglomerate
6648	A-7-78-3C	716176	Eel	Rhyolitic crystal tuff
6649	A-7-78-4A	718172	Eel	Amydgaloidal metabasalt
6650	A-7-78-10A	750160	Era	Medium-grained quartzose arenite
6651	A-7-78-12A	756163	Eiw	Feldspathic sublabile sandstone
6652	A-7-82-3A	818143	Erd	Siltstone
6653	A-7-82-4	817145	Erd	Siltstone
6654	A-7-82-6A	814150	Eiw	Medium-grained quartzose sandstone
6655	A-7-82-6B	814151	Eim	Banded siltstone and shale
6656	A-9	918106	Eel	Metamorphosed porphyritic rhyolite
6657	A-9B	918106	Eel	Metamorphosed porphyritic rhyolite
6658	AE-7	882889	dl	Metadolerite
6659	AE-8	882889	dl	Metadolerite
6660	C-12-52-2	951946	dl	Metadolerite
6661	AF-M	925888	Bea	Andesite
6662	A-9-60-2A	952046	Ekc	Porphyroblastic scapolite-muscovite schist
6663	A-9-60-2B	952046	Ekc	Calcite-quartz-plagioclase granofels
6664	A-9-60-3A	918085	Egk	Granite
6665	A-9-60-4A	917065	Eel	Recrystallised porphyritic rhyolite
6666	A-9-60-4B	917065	Eel	Porphyritic rhyolite
6667	A-9-60-4C[1]	917065	Eel	Recrystallised porphyritic dacite
6668	A-9-60-4C[11]	917065	Eel	Recrystallised porphyritic dacite

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6669	A-9-60-4D	917065	Ᵽel	Recrystallised porphyritic dacite
6670	A-9-60-4E	917065	Ᵽel	Altered porphyritic dacite (?)
6671	A-9-60-5A	920064	Ᵽel	Very porphyritic rhyolite
6672	A-10-72-3A	945024	dl	Metadolerite
6673	A-10-72-6A	943011	Ᵽea	Rhyolitic ignimbrite
6674	A-10-72-8A	945995	Ᵽea	Recrystallised porphyritic rhyolite
6675	A-10-72-8B	945995	Ᵽea	Metamorphosed dacite
6676	A-10-72-8C	945995	Ᵽea	Scapolitic tuff
6677	A-10-72-8D	945995	Ᵽea	Tuff
6678	A-10-72-8E	945995	Ᵽea	Tuff
6679	A-10-72-9A	935035	Ᵽkb$_1$	Sublabile quartzite
6680	A-10-74-1A	899042	Ᵽgk	Medium-grained granite
6681	A-10-74-1B	899042	Ᵽel	Porphyritic microgranite
6682	A-10-74-2A	901018	Ᵽel	Recrystallised porphyritic dacite
6683	A-10-74-2B	903018	Ᵽel	Recrystallised porphyritic rhyolite
6684	A-10-74-4A	908008	Ᵽel	Recrystallised porphyritic rhyolite
6685	A-10-74-5A	910009	Ᵽel	Recrystallised porphyritic rhyolite
6686	A-10-74-6A	909014	Ᵽel	Recrystallised rhyolitic ignimbrite
6687	A-10-74-7A	885009	Ᵽel	Recrystallised porphyritic dacite
6688	A-10-84-4A	664007	Ᵽel	Altered porphyritic rhyolite
6689	A-11-08-3A	944988	Ᵽea	Recrystallised dacitic ignimbrite
6690	A-11-08-3B	944988	Ᵽea	Recrystallised porphyritic dacite
6691	A-11-08-5A	940983	Ᵽea	Recrystallised porphyritic rhyolite
6692	A-11-08-5B	939983	Ᵽea	Biotite schist
6693	A-11-08-6A	938979	Ᵽea	Silicified porphyritic rhyolite
6694	A-11-08-8A	922992	Ᵽel	Recrystallised porphyritic rhyolite
6695	A-11-10-1A	871002	Ᵽel	Sheared porphyritic rhyolite
6696	A-11-10-2	863978	Ᵽel	Porphyritic microgranite
6697	A-11-10-3A	908891	Ᵽel	Sheared porphyritic rhyolite
6698	A-11-10-4A	883983	Ᵽel	Recrystallised porphyritic rhyolite
6699	A-11-10-4B	884983	Ᵽel	Felsic tuff
6700	A-11-10-4C	884985	Ᵽel	Metamorphosed porphyritic dacite
6701	A-11-10-5A	881988	Ᵽgk$_h$	Porphyritic microgranite

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6702	A-11-10-5B	881989	Ꞓgk$_h$	Porphyritic microgranite
6703	A-11-10-5C	881989	Ꞓel	Recrystallised porphyritic dacite
6704	A-11-10-7A	877998	Ꞓgk$_h$	Porphyritic microgranite
6705	A-11-10-8A	866003	Ꞓel	Porphyritic rhyolitic ignimbrite
6706	A-11-12-2A	843984	Ꞓel	Recrystallised rhyolitic ignimbrite
6707	A-11-12-2B	843983	Ꞓel	Chlorite schist
6708	A-11-12-3A	826982	Ꞓgk$_h$	Porphyritic microgranite
6709	A-11-12-4A	816966	Ꞓgk$_h$	Porphyritic microgranite
6710	A-11-12-5A	839973	Ꞓgk	Medium-grained granite
6711	A-11-12-5B	839973	Ꞓgk$_h$	Recrystallised porphyritic microgranite
6712	A-11-12-5C	839973	Ꞓgk$_h$	Recrystallised porphyritic microgranite
6713	A-11-12-6A	849991	Ꞓel	Porphyritic rhyolite
6714	A-11-12-9A	847987	Ꞓel	Recrystallised porphyritic rhyolite
6715	A-12-56-1A	835951	Ꞓgk	Fine-grained granodiorite
6716	A-12-56-3A	814947	Ꞓgk	Medium-grained granodiorite
6717	A-12-56-4A	812936	dl	Metadolerite
6718	A-12-56-4B	812936	dl	Fine-grained metadolerite
6719	A-12-56-4C	812936	dl	Contaminated metadolerite
6720	A-12-56-4D	812936	dl	Contaminated metadolerite
6721	A-12-58-2	859950	Ꞓel	Recrystallised porphyritic rhyolite
6722	A-12-58-5A	868932	dlx	Recrystallised dacite(?) xenolith
6723	A-12-58-6A	872932	Ꞓel	Quartz andesite
6724	A-12-58-8A	878937	Ꞓel	Devitrified rhyolitic ignimbrite
6725	A-12-58-9A	887938	Ꞓel	Recrystallised felsic tuff
6919	A-12-58-9B	887938	Ꞓel	Tuff
6920	A-12-58-10A	888950	Ꞓel	Felsic tuff
6921	A-12-58-10B	888951	Ꞓel	Amygdaloidal altered andesite (?)
6922	A-12-58-12A	883968	Ꞓel	Porphyritic dacite
6923	A-12-60-1	906938	Ꞓel	Quartz-veined porphyritic rhyolite
6924	A-12-60-4A	934944	Ꞓem	Amygdaloidal metabasalt
6925	A-12-60-4B	934944	Ꞓem	Amygdaloidal metabasalt
6926	A-12-60-4C	933943	Ꞓel	Labile volcaniclastic sandstone
6927	A-12-62-4A	939941	Ꞓea	Altered prophyritic rhyolite
6928	A-12-62-4B	940941	Ꞓea	Blastoporphyritic chlorite-quartz schist
6929	A-12-62-4C	941941	Ꞓkb	Sublabile siltstone
6930	A-12-62-4E	943943	Ꞓkc$_1$	Tourmaline-chlorite-calcite schist

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6931	A-12-62-5A	942926	Pkc_2	Medium-grained quartzite
6932	A-13-76-12E	888895	Pel	Felsic tuff
6933	A-13-72-2A	953919	Pea	Spherulitic porphyritic rhyolite
6934	A-13-74-1A	899893	Pel	Sheared blastoporphyritic rhyolite
6935	A-13-74-2A	892893	dl	Coarsely porphyritic metadolerite
6936	A-13-74-2B	892893	dl	Porphyritic dolerite
6937	A-13-74-3A	896893	Pel	Rhyolitic tuff
6938	A-13-74-3B	896893	Pel	Rhyolitic ignimbrite
6939	A-13-74-6A	918892	Pel	Porphyritic rhyolite
6940	A-13-74-6B	920893	Pel	Spherulitic porphyritic rhyolite
6941	A-13-74-8	922888	Pem	Chlorite schist
6942	A-13-74-9A	924888	Pem	Amygdaloidal metabasalt
6943	A-13-74-9B	925888	Pea	Recrystallised porphyritic rhyolite
6944	A-13-74-9C	925888	Pea	Metamorphosed sublabile siltstone
6945	A-13-74-9D	926888	Pea	Porphyritic dacite
6946	A-13-74-9E	926888	Pea	Amygdaloidal(?) rhyolitic ignimbrite
6947	A-13-74-9F	926888	Pea	Flow-banded porphyritic rhyolite
6948	A-13-74-10A	927888	Pkb	Feldspathic sandstone
6949	A-13-74-11A	930888	Pkc_1	Sandy limestone
6950	A-13-76-2A	848889	Pgk	Medium-grained sodic granite
6951	A-13-76-3A	854893	Pel	Porphyritic rhyolite
6952	A-13-76-7A	868893	Pel	Devitrified rhyolitic ignimbrite
6953	A-13-76-7B	869893	Pel	Porphyritic rhyolitic ignimbrite
6954	A-13-76-8A	870889	Pel	Silicified rhyolitic tuff
6955	A-13-76-8B	871889	Pel	Sheared rhyolitic tuff
6956	A-13-76-9A	874888	Pel	Porphyritic microgranite
6957	A-13-76-9B	874888	Pel	Porphyritic microdiorite
6958	A-13-76-9C	874888	Pel	Porphyritic microdiorite
6959	A-13-76-10A	876893	dl	Metadolerite
6960	A-13-76-10B	877893	Pel	Porphyritic rhyolite
6961	A-13-76-11A	881889	Pel	Porphyritic microgranodiorite
6962	A-13-76-12A	888894	Pel	Felsic tuff
6963	A-13-76-12B	888894	Pel	Felsic crystal tuff
6964	A-13-76-12C	888894	Pel	Felsic crystal tuff
6965	A-13-76-12D	889892	Pel	Felsic litho-crystal tuff
6966	A-13-76-12F	888895	Pel	Sheared banded siltstone
6967	A-13-76-12G	888895	Pel	Felsic litho-crystal tuff
6968	A-13-78-3A	805896	Pel	Altered porphyritic rhyolite

GSQ Rock No.	Field No.	Grid Reference	Geological Unit	Rock Name
6969	A-13-78-5	815895	Eel	Porphyritic rhyolite
6970	A-13-78-5B	814895	Eel	Sheared andesite
6971	A-13-78-8A	826892	Eel	Sheared porphyritic rhyolite
6972	A-13-78-9	833892	Egk	Porphyritic granite
6973	A-13-78-10	836889	Egk	Porphyritic granite
6974	A-13-87-23	635888	Esa	Chlorite-muscovite schist
6975	PAX-1-44.54	770296	Erd	Black shale and pink tuff
6976	PAX-1-46.10	770296	Erd	Dolaranite
6977	A-S1-A	643933	Eea(?)	Sheared porphyritic rhyolite
6978	A-S1-B	640933	Eea(?)	Sheared litho-feldspathic arenite
6979	A-S1-C	640944	Eb	Amphibotite
6980	A-S1-D	637940	Es	Sericite schist
6981	A-S3-A	636943	Eb(?)	Metabasalt
6982	A-S4-A	636888	Esa	Chlorite-plagioclase granofels
6983	A-S4-B	636888	Esa	Sheared labile sandstone
6984	A-11-13-10A	803000	Eem	Metabasalt
6985	A-11-13-10B	803000	Eem	Amygdaloidal metabasalt
6986	C-8-5-1A	917106	Eel	Scapolitic recrystallised porphyritic rhyolite
6987	C-8-5-1B	917106	Eel	Recrystallised porphyritic rhyolite
6988	A-5-34-1A	915254	Eel	Slightly porphyritic rhyolite
6989	XII		Eel(?)	Porphyritic dacite
6990	A-7-87-1A	933175	Eel	Metamorphosed porphyritic rhyolite
6991	A-7-87-1B	933175	Eel	Metamorphosed porphyritic rhyolite
6992	A-9-52-2A	894067	Eel	Recrystallised porphyritic rhyolite
6993	A-9-52-2B	894067	Eel	Metamorphosed porphyritic rhyolite
6994	A-10-76-2A	854022	Eel	Talc schist
6995	A-10-76-3A	849023	Egk_h	Porphyritic microgranite
6996	A-10-76-6A	841026	Eem	Amygdaloidal metabasalt
6997	A-10-76-6B	840027	Eem	Porphyritic meta-andesite
6998	A-10-76-6C	839028	Eem	Metabasalt
6999	A-10-76-8A	842034	Eea	Devitrified porphyritic rhyolite
7000	A-10-76-10	840040	Eqw	Feldspathic sandstone

APPENDIX 23: MODAL ANALYSES OF G.S.Q. SAMPLES

ALSACE SHEET AREA

KEY TO ABBREVIATIONS USED IN TABLES OF MODAL ANALYSES

Upper case indicates large grains, phenocrysts, porphyroblasts or structures

A	amygdales
CA	calcite
FM	ferromagnesians (mostly relict)
K	potash feldspar
L	lithic fragments
MU	muscovite flakes
OT	oolites
P	plagioclase
Q	quartz
S	spherulites
SC	scapolite

Lower case indicates groundmass or small grains

al	allanite	lx	leucoxene
am	amphibole	mu	muscovite (including sericite)
ap	apatite	op	opaques
bi	biotite	p	plagioclase
ca	calcite	ph	phlogopite
ch	chlorite	q	quartz
do	dolomite	ru	rutile
ep	epidote	sc	scapolite
fl	fluorite	sp	sphene
gt	garnet	to	tourmaline
hb	hornblende	tr	trace amounts
k	potash feldspar	zr	zircon
ka	kaolinite		
lm	limonite		

Parenthesis enclose plagioclase compositions as percent Anorthite

All sample numbers are prefixed by 'GSQ/R'.

MODAL ANALYSES, ALSACE 1:100 000 SHEET AREA

Leichhardt Metamorphics

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6533		5	8	12		20	24			30				1	
6534	30	5	6	3(3)		15	20			18	1			2	ap, zr
6536		3		5 (4)		20				2		67		3	
6537		1		6 (5)		5		20		5	tr	60		3	lm
6545		12	4	8	2	28	7	39	tr	tr				tr	ru, sp, to
6546		3	2	2	2	25		35		31		tr		tr	
6547		18	4	2	1	28	20	7		20					zr
6548				5		29	30			40				1	zr
6549	10	1	1	10		25	22			30				1	zr
6550	25	1		15 (5)	1	10	40			5			1	1	lm, sp
6551		10	13	40		10				17	5			5	zr
6552	3	7	8	5		20		33		25	2	3		tr	
6555			8	4 (5)		5	80					1	2	tr	zr
6556		16	10	3 (4)		22	40		1	5	2	tr		1	zr
6557		10	7	4 (5)	1	32	40		tr	2	2	1		1	ap
6561		5	7	1		30	53		2			1	1	tr	zr
6563		5	6	3 (5)		30	50			5		tr		1	
6564	30	3	5	5		20	30			6				1	
6573		8	6	10 (30)	3	20	32	14	2	5	tr		tr		sp
6574	1	10	8	2	1	15	50		2	10	1	tr	tr		
6575	2	3	2	8		28	25		5	15	6	2	3		

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6578		5	4	10	2	15	48			8	6			2	
6601		5	4	3 (6)		30	45	10	1	2				tr	zr
6602		1		16		20		50		4	5		2	2	sp
6613		1	5	15		28	47		3		1			tr	al, ap, zr
6614		5	3	12		20	25	18	tr	1			2	tr	al, sp, zr
6616			2	18		25	40	8			3	3	tr	1	al, ap, zr
6617				5 (5)		5	25			2		34	20	2	5 to
6620	2	10		5		20	13	40		3		4	tr	1	2A
6621		2		10	4	35		45			tr	tr	4		al, sp, zr
6622				12	3	50		20	tr	3	12				am, sp
6623		5	1	3		20	45	14		10				2	
6628				12	8	16	10	30			5	16	2	1	sp
6629		5	2	6	1	30	34	10		10	2	tr	tr		hb, sp
6630		6	5	10	2	25	40			7	5			tr	fl, zr
6631		4	6	7	3	23	50	3	tr	2	2			tr	
6641		6	4	15	3	15	39		tr	15		2	tr	1	sp
6642	35	20	5			32				4				1	3 lm
6643				67								25		2	4A, 1 ap, 1 sp
6644		10	12	25	3	15	37			2	5		tr	1	
6646		8	6	3	3	15	55			10			tr		
6647	10	8	tr	13	1	16	10	25		15	tr		2		ph, sp, zr
6648		8	5	10	tr	15	8	30		20			4		zr
6649		1		20						7		45	18	6	2A, 1 ap, ru, sp
6656		10	14	5	1	10	40		3					tr	al, 10 hb, 2 sp, zr
6657		4	2	1		28	53		1	1	3			1	5 hb, 1 sp, zr
6665		4	1	16 (5)		30	40	5	2	tr	1	1		tr	sp
6666		5	tr	8		25	44		3	15				tr	sp

LEICHHARDT METAMORPHICS (Cont'd)

	L	Q	K	P		FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6667		3	1	5	(5)	3	20	50	7	5		1	1		3	ap, 1 sp, zr
6668		5	1	7		1	20	52	tr	5		5			4	ap, sp, zr
6669		3	5			1	20	56		7		2	1		3	ap, sp, zr
6670		3	5	1			60	20		6		2			3	sp, zr
6671		10	20	5		1	30	28		3	1	2		tr	tr	zr
6681		10	10	12		3	24	40		1		tr	tr	tr		lm, sp, zr
6682		2		6		3	40	36		8		3		1	1	ap, sp, zr
6683	10	5	3	6		1	30	30		2	5	2			1	zr
6684		12	5	10			20	22			10	2		tr	3	sp
6685		6	2	8			25	55			1	1		tr	2	ap, ru
6686		8	2	10		2	25	44		5		2			2	
6687				5		2	20	10	48	12		3			tr	ap, sp, zr
6688		5	1	28		1	30	26				5	2		1	1 sp, zr
6694		8	12	10		2	30	33		3		1			1	ap, sp, zr
6695		5	4	6	(5)	5	35	26		4	15				tr	sp, zr
6696		4	5	15	(5)	3	30	15	14	2		2	3		2	5 hb, ap, sp
6697		3	4	6	(5)		34	40		tr	10		tr	2	1	to
6698		5	1	8		3	30	46		5	2	tr				sp, zr
6699		20	40	20	(55)					13	1	4			1	1 sp, to, zr
6700		2	3	8			20		20	5		6			tr	35 am, ap, 1 sp, zr
6703		2		15		5	20	18	30	5		5				sp, zr
6705	15	2		10		8	25	20		5	15					sp, zr
6706		3	6	12		4	30	37		5		3		tr		sp, zr
6707		5								2			88		5	
6713		8	5	12			18	52		1	3			1	tr	
6714		10	5	7		1	20	53		2		2			tr	zr
6721		5	3	22		6	30	22		3	8	1			tr	sp
	L	Q	K	P		FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6723				6	(5)		15		55	18	1	3		tr	2	sp
6724				15		4	30	41		5	3	2			tr	sp
6725	15	5	1	9		2	20	18		5	20	1			4	
6919	20	2	2	10			30	16		5	12				3	sp, to
6920	2	5		3			30	43		5	6	3		3		ap, sp, to
6921		40	20							3	10			7		10A, ap, sp, to
6922		3		12		6	40	30		3	2	4				sp
6923		4	6	2			30	57		1	tr				tr	
6926	44	35	5				10	6		tr			tr		tr	
6932		30	61							2	3		3	tr	1	zr
6934	2	5		10		5	29	20		7	20	tr		tr		2 sp, zr
6937		10	7	1	(5)		35	22	5	2	7		2	1		8 ka
6938	8	5	3	15			30	36		2				tr	1	sp
6939		9	3	5	(3)		30	50			2				1	zr
6940		1	6	7			20	12			25			4		25S
6951		3	6	10		2	26	48			1	3	1		tr	sp
6952		5	3	25		4	25	35		1	2	tr				sp
6953		2	3	12		5	25	50		2	1	tr				sp
6954	15	2	3	10		3	20	45	14	2		tr		tr	1	gt, sp
6955	15	2	3	12			30	29	2	5		2			tr	sp
6956				10	(5)	3	26		54	2		2	tr	1	1	1hb, 2 sp, zr
6957				6	(5)	2	10		73	2		3			1	3 hb
6958		1		13	(5)	5	10		63			2			1	5 hb, sp
6960		3	2	8		5	25	52		3		2			tr	sp
6961		5	3	12		3	20		47	6		2			1	1 sp, zr
6962		2	1	3			36	14	10	2	30				2	

LEICHHARDT METAMORPHICS (Cont'd)

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6963	1	7	4	9		30	8		1	38				2	
6965*	16	8	7	5	2	32	20		1	20			5	tr	sp, zr
6966	2	2		3		43			3	40			7		sp
6967	15	4	3	6		33			4	32	1		1	1	sp, zr
6968		12	7	14	2	36	10		2	15	2			tr	sp, am
6969	2	1	2	10	5	25	50		3		tr			tr	2 am, sp, zr
6970	4			1			5	69			5			1	15 am
6971		5	2	16	4	42	24		1	5			1	tr	zr
6986		5	1	7		30	25	26	4	tr	2			tr	3 SC, 1 sp, al, ap, zr
6987		5	5	7		30	30	18	2	tr				2	1 sp, zr
6988		1	1	1		25	66		1	1	2			2	
6989	20	5	2	8	2	15	3	20		10	tr	tr	14	1	sp, zr
6990		10	10	7	3	25	40		5					tr	to, zr
6991		8	18	5	1	30	32		6	tr				tr	to, zr
6992		5	3	6	3	26	50		4		2			tr	1 sp, zr
6993		3	7	15	5	25	35		5	1	3			1	sp, zr
6994									1					tr	99 talc
*6964	1	10	8	11		24			2	35			6	3	

Magna Lynn Metabasalt

	A	P	q	p	bi	mu	ch	gt	am	ca	sp	ep	op	Accessories
6924	5		2	31	40		2			10			10	ap
6925	20			33	30		2			tr		3	12	ap
6941	3		2		tr		89						5	1 sp
6942	15	3		53 (5)	15	2	1			tr		1	10	ap
6984	tr			65 (30)	tr		20			10			5	
6985	25			15			35						20	5 lm
6996	19		2	37 (5)	25	tr	10					5	5	lm, sp
6997		5 (5)	3	65 (5)		2	15		1	3			6	ap, 2 sp
6998		1 (5)		33 (5)		2	40			2			10	2 sp

Argylla Formation

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6673	10	6	3	7	1	15	29		1	15	1	tr		2	al, sp, zr
6674	10	3		15 (5)	2	18	35		5	8	4			tr	sp, zr
6675		2		12		18	33		20	5	5	1	1	1	2 gt, ap, sp
6676		5		15		22	20		20	12					5 sc, 1 sp
6677		5		20	2	35	15		10	10		2		1	zr
6678	15	4	1	15	3	22	30		5		2		2	1	
6689		1		12	6	30	16	30	3		1			1	sp, zr
6690		1		12	8	25	16	30	4	1	2	tr		1	sp, to, zr
6691		2	2	12	8	25	45		5		1				zr
6692		4		1		8	7		70			6		4	
6693	10	4	2	5		40	30			5		tr	2	2	
6927		6		3		55				35			1		
6928		10				50						40		tr	lm, ru
6933		4	2	1		30	41	5		3		1	2	1	10 S
6943	5	7	20	12		20	25		4	15				2	
6944	10	70	10	2					1	4	1	tr		2	sp, zr
6945		10	1	15		20	4	43		4		1	1	3	lx
6946	20	2	2	12		18	44			1			tr	1	ap
6947	20	3	5	5		25	30		tr	4		1	tr	7	
6977			15	2 (5)		30	38		8			4			1 sp, zr

ARGYLLA FORMATION (Cont'd)

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6978	15					55				10	20				sp
6999			3	10 (5)		30	48			tr		tr	tr	8	1 sp, ka

Candover Beds

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6979								28		10	10	5	1	64	tr	A, ap, 2 sp, zr
6981								35			15	40	5		4	1 lx
6982						8		50				33	3		5	1 sp, zr
6983		30				20			5	40			5			
6980						35				64					1	sp
6974						25				40		30			tr	lm, ru

Eastern Creek Volcanics

	A	q	p	bi	mu	ch	gt	am	ca	sp	ep	op	Accessories
6531	2		65 (5)			2		20	5			6	
6571			30 (5)	45							10	10	5 lm
6618	2		48		10							40	
6598			50 (7)			15		24		1	5	5	ap
6599			40					7				18	35 lm
6600		40	7		15							3	25 k, 10 ka, zr

Myally Subgroup, undivided

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6619		72		22											3	1 lm, 2 to, zr
6640		84		10						5					1	ka, zr

Lochness Formation

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6532		50	6	2									15		2	25 ca cement
6589	15	65	10	5						5						to, zr
6597		85	8							7					tr	to, zr

Whitworth Quartzite

	L	Q	K	P	bi	mu	op	Accessories
6585	2	88		8		1	1	zr
6586	2	84		6		8		to, zr
6587		90		3	1	6		zr
6588		68	10	15		5	1	1 to, zr

Bortala Formation

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6520	22	40	tr	6		20				12						
6584	2	62	9	10		10				6					1	lm, to, zr

Alsace Quartzite

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6516	9	70				5				15					1	
6518	1	95		4												ka
6566	1	82		2		10				5					1	to
6582	8	77		4						8					1	2 lm, to
6583	1	80		15						4						

Ballara Quartzite

	L	Q	K	P	q	k	p	bi	mu	ep	ch	op	Accessories
6679		82	5						13			tr	
6929		84									16	tr	to, zr
6948		70	6					2	20			2	lx, zr

Corella Formation

	L	Q	K	P	SC	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6931		85				10				5				tr	to
6930		15								5		24	40	1	15 ro
6949	1	6								2			90	1	
6662		2			10	2				58					ru
6663		5				15		52				2	25		1 gt, ru

Quilalar Formation

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6527	tr	80		3		5				10					2	to, zr
6567	2	94		4					tr						tr	to, zr
6591	2	87		1						10						to, zr
6526	tr	70					tr								30	
6528		55								42					3	lm, zr
6569	1	45		40						11					3	to, zr
6590	1	56		5									10		2	25 ot, 1 to, zr
6638		5				20				74					1	lm
6639		75		10						7					8	lm, to, zr
6519	2	60		3		35				tr					tr	to, zr
6544	14	45	12			15				1		5			tr	to, zr
6570		40	30						1	6		tr			3	20 ka, to, zr
6596	3	82	5							10		tr				to, zr
7000	6	70	16									4			2	2 ka, zr

Fiery Creek Volcanics

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6603			30				18					2			30	20A, lm
6538		55	30	3						8					4	to
6539	tr	25	35	tr						10					5	20 ka(?), 5 lm
6540		20	6	tr					1	8					5	55 ka(?), 5 lm
6541	50	15	15	5 (45)						3					2	20 ka(?), sp, to
6542		5								1					2	92 do
6605		40	37	4						3					6	10 ka, lm, to, zr
6592	2	70	15	3						8					2	to
6593	18	58	5							15					4	
6604	4	65	15	7		3				2					1	2 ka, to

Surprise Creek Formation

	L	Q	K	P	MU	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6523		70	15		2						8					5	to
6543	7	67	5				15				tr					tr	5 ka(?), sp, 1 to
6568	7	60	8								15					5	lm, zr
6594	18	74	5								3						
6650	1	91	5	2							1					tr	zr
6581		20	30	15			10				3					5	5 ka, 2 lm, to
6595	2	50	15								12					1	2 lm, 18 ka, zr
6607		44	20								5					8	3 lm, 20 ka, to, zr
6522	1	89	tr	7							tr					3	to
6521	15	60									20					5	
6529		45	15	10	12						10					8	
6530		20									78					2	
6652		45									41		tr			10	4 lm, to
6653		32									65					3	to, zr
6975		1					24				20		20	10		5	20 CA
6976	1						2				1			92*		1	3 cement (*dolomite)

Mount Isa Group

Warrina Park Quartzite

	L	Q	K	P	MU	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6524		97		2							tr					1	to
6606	1	89	5	2			2				tr		tr			tr	1 ka, sp, to, zr
6651		87	7	1							tr					tr	5 gt, zr
6654	1	94	3	1							1					tr	zr

Moondarra Siltstone

	L	Q	K	P	MU	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6655		30		13	7						20					10	20 ka
6655		10									30					5	52 ka, 3 lm

Mesozoic

	L	Q	K	P	MU	FM	q	k	p	bi	mu	ep	ch	ca	am	op	Accessories
6525		100															
6559	20	60	10							tr	5						5 lm

Ewen Granite

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6535		30	45	25 (2)						tr		tr	tr	tr	al, zr
6553		2	44	50 (30)	1						tr	1		tr	2 lm, zr
6554		20	25	8		16	20	4	4		2				al, 1 am, zr

APPENDIX 23: (CONT'D)

EWEN GRANITE (Cont'd)

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	op	Accessories
6560		6	34	40					3			7		5	ap, 5 lm
6565		18	5	66					3		1	7		1	ap, zr
6572			15	(55)		20	35	25	4		1	tr			ap
6577		25	45	20 (3)					6		1			tr	3 hb, ap, zr
6579		8		80					9		tr	tr			3 hb, zr
6580		12	5	8 (5)		10	10	45				10			
6608		10	7	3 (36)		12	44	20	2	1		1	tr	tr	zr
6609		25	53	18					2	1		1		tr	al
6610		15	13	10		7	43	5	3	1			3	tr	zr
6611		28	28	40 (5)					1	2		tr	1	tr	
6612		25	67	6 (30)	2					tr	tr				ru, zr
6615		20	21	50						2		6	tr	1	ap, sp, zr
6624		5	10	2 (8)		20	43	16		2			tr		zr
6625		25	2	55					12	tr	2	1	2	tr	1 hb, ap, zr
6626		25	10	49					8		3	2	tr	1	1 hb, sp, zr
6627			5	8	1	22	25	35	3	tr		1	tr	tr	al, ap, fl, sp, zr
6632		30	10	41 (5)					10		2	3		1	3 hb, sp, zr
6633		10	4	26 (5)		10	5	38	5					2	sp, zr
6634				55 (5)							3			2	36 hb, 1 ap, 3 sp
6635		25	9	55							3	7	tr	1	sp, zr
6636		5	45	38 (5)							5	3	3		1 sp

Kalkadoon Granite

	L	Q	K	P	FM	q	k	p	bi	mu	ep	ch	ca	ap	Accessories
6701		3	3	15 (5)	7	25	29	10	2		3		2		1 sp
6702	5	3	1	12 (5)	4	20	9	35	5		3			2	al, 1 sp, zr
6704		10	10	12 (5)		30	30	3	5	tr		tr		tr	al, ap, sp, zr
6708		5	15	10	3	30	35		2		tr	tr			sp, zr
6709		3	16	10	4	25	41		1		tr				al, ap, sp, zr
6711			20	5	5	35	20		3		tr				ap, sp, to, zr
6712		5	40	8	6	15	15	4	7				tr	tr	ap, sp, zr
6995		10	6	15	3	15	44		4		2			1	
6664		25	40	30					4		1		tr	tr	al, sp, to, zr
6680		24	44	30 (7)	2				tr		tr	tr		tr	zr
6710		26	40	15	4	15			tr	tr		tr	tr		al, sp, zr
6715		30	20	46					4		tr	tr		tr	sp, zr
6716		32	20	44							1	3		tr	
6950		32	10	55 (3)					1			2		tr	
6972	15	3	15	20 (5)		20	10	14	3			tr		tr	sp, zr
6973		5	20	16		18	21	5	3		2			2	al, sp, to, zr

Dolerite

	L	P	q	p	bi	mu	ch	gt	am	px	sp	ep	op	Accessories
6517				55 (60)	2					32			10	1 ap
6558			5	36			56						3	ap
6562			tr	30 (50)	tr		tr		4	47		5	4	ap
6576				45 (50)			15		5	25	1	5	4	lx

DOLERITE (Cont'd)

	L	P		q	p		bi	mu	ch	gt	am	px	sp	ep	op	Accessories
6637				3	40				1		43		tr	5	8	ap
6645					40				56					2	2	ap
6659					44	(5)	3			tr	40	3		5	5	ap
6660				2	31	(5)	32		5		6		1	18	5	
6672				1	40						40			15	4	ap
6717				2	60	(5)	16				7		12	2	1	ap, ca, zr
6718				2	25	(5)	35				25		8	2	2	1 ap
6719				7	70	(5)	9						5	2		5 k, 2 ap, zr
6720	12			8	62	(5)	12						3	3	tr	ap
6722				30	44	(5)	2		1				tr	8		15 k, ap
6935		35	(50)	3	16		25				2			12	7	ca, ka
6936		15	(60)	2	30	(5)	10				26			10	7	ap, ka
6959				5	39		38						1	12	1	3 k, 1 ca
6658		3	(5)		35		2		10		28	2		15	5	sp, zr