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The Geology of the Charnley
1:250,000 Sheet Area,
SE 51 / 4
Western Australia

054064

by

*D.C. Gellatly, G.M. Derrick, R. Halligan,** and J. Sofoulis **

*Geological Survey of Western Australia

**Formerly Geological Survey of Western Australia

The information contained in this report has been obtained by the Department of National Development as part of the policy of the Commonwealth Government to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus or statement without the permission in writing of the Director, Bureau of Mineral Resources, Geology & Geophysics.



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1:250,000 SHEET AREA SE51/4 WESTERN AUSTRALIA

by

D.C. Gellatly, G.M. Derrick, R. Halligan¹, and J. Sofoulis²

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SUMMARY

The Charnley Sheet area lies in the West Kimberley Division in the northern part of Western Australia. This report describes in detail both the older Precambrian (?Archaean to Lower Proterozoic) igneous and metamorphic rocks, and the overlying Kimberley Basin sediments of Carpentarian and Adelaidean age, and includes also brief notes on Palaeozoic and Cainozoic sediments.

The oldest rocks in the Sheet area are the Halls Creek Group, a series of flysch sediments of ?Archaean age, that have been strongly folded and metamorphosed in the greenschist and locally in the almandine-amphibolite facies. They have been intruded in pre-Carpentarian times by the Woodward Dolerite which has been metamorphosed together with the Halls Creek Group.

The Whitewater Volcanics (of Lower Proterozoic age) consist of quartz and feldsparphyric rhyodacite tuffs and lavas. They overlie the Halls Creek Group with inferred unconformity and are intruded by high level quartz-feldspar-porphyry and granite (Mount Disaster Porphyry and Mondooma Granite) and by later granites. These later granites comprise the porphyritic Lennard and Kongorow Granites, and minor occurrences of leucocratic granite (Mount Amy Granite) that may have been derived from the Lennard Granite by fractionation.

The older Precambrian rocks are overlain unconformably by the Kimberley Basin succession (Speewah and Kimberley Groups) of lower Carpentarian age. This succession comprises about 7000 feet (2200m) of sandstone, 2000 feet (600m) of basic volcanics, and minor siltstone and conglomerate. The Kimberley Group is overlain unconformably by late Adelaidean sediments (Mount House Group) consisting of tillite, sandstone, and minor dolomite and shale.

Palaeozoic rocks, forming part of a Devonian limestone reef complex, lie unconformably on the older Precambrian in the south-eastern corner of the Sheet area. •

Cainozoic deposits include laterite of probable Tertiary age, superficial soils and alluvium, and inter-ridal recent marine sediments.

Strong folding along southeast and southwest plunging axes and gentle folding along northeast trending axes has affected the area; several periods of folding are represented. Major faults in the area trend mainly north, northwest and northeast, and include faults with a transcurrent component. Prominent joints and associated faults trend north, northeast, or northwest: the latter trend predominates in the older Precambrian in the southeast. The main metamorphism probably pre-dates the Whitewater Volcanics. Two main phases are recognised: an early low stress phase in which widespread development of andalusite took place, and a high stress phase in which andalusite was destroyed and garnet developed. Zonal distribution of andalusite, staurolite, and garnet has been mapped.

The only economic minerals that have been worked in the area are cassiterite and wolfram. A small deposit of kyanite with associated corundum, diaspore, and topaz has been found recently. Minor amounts of chalcopyrite, scorodite and fluorite have also been recorded. Laterites present in the area may be bauxitic but have not been examined in detail. Water from surface pools, shallow bores, and wells is used for watering cattle.

INTRODUCTION

Location

The Charnley 1:250,000 Sheet area SE51-4 lies between latitudes 16° and 17° South, and longitudes $124^{\circ}30'$ and 126° east. It falls within the Kimberley Land Division of the northern part of Western Australia. The southeastern corner of the Sheet area is about 60 miles (100km) from the port of Derby. Parts of Walcott Inlet and Doubtful Bay lie in the western part of the Sheet area.

Object

The work described in this report is part of a programme of regional reconnaissance mapping at a scale of 1:250,000 carried out jointly by the Geological Survey of Western Australia and the Commonwealth Bureau of Mineral Resources, and designed to map all the Precambrian rocks of the Kimberley region. Since the programme commenced in 1962, the following Sheet areas have been mapped: Montague Sound, Drysdale-Londonderry, Medusa Banks, Prince Regent-Camden Sound, Ashton, Cambridge Gulf, Mount Elizabeth, Lissadell, Lansdowne, Dixon Range, Mount Ramsay, Gordon Downs, and Lennard River. Mapping has also been completed in the Yampi Sheet area: the report on this is in preparation.

The aim of this report is to provide a preliminary description of all the rock units in the Sheet area.

The results of the Kimberley mapping programme will be published in four Bulletins describing the "Precambrian Geology of the Kimberley Region"; Bulletin 106, East Kimberley (Dow and Gemuts, in press); Bulletin 107, Lamboo Complex (Gemuts, in press); Kimberley Basin (Plumb, in prep.); and West Kimberley (Gellatly, Sofoulis, and Derrick, in prep.). The Kimberley Basin Bulletin will incorporate information on the Carpentarian and Adelaidean rocks, and the West Kimberley Bulletin will include that on the older Precambrian.

In addition, Explanatory Notes summarising the geology will be published with each coloured 1:250,000 Sheet.

Access

The main access route to the Sheet area is the Derby-Gibb River-Kalumburu road, a formed earth road which crosses the southeastern corner. Graded tracks from this lead to Mount Hart, Mount Barnett and Beverley Springs homesteads. Minor tracks radiate from these homesteads to cattle watering points and yards. Sporadically maintained station tracks from both Kimberley Downs and Napier Downs Stations give access to the southwestern corner of the Sheet area. Rough bush tracks lead from Oobagooma in the Yampi Sheet area to Hawkestone Creek in the southwest, and to King Creek Yard near the western boundary of the Sheet area; vehicle access eastwards and southeastwards from these points is possible for about 15 miles. About 80% of the area is inaccessible even to four-wheel-drive vehicles.

Two airstrips in the Sheet area, at Beverley Springs and Mount Hart, are suitable for DC3 and light aircraft respectively.

Population and Industry

The only known population of the area is centred at the cattle stations of Mount Hart, Mount Barnett, and Beverley Springs. The total population on these stations is probably around 100, most of whom are aborigines. Morgan (1955) found aborigines in their native state in the Drysdale Sheet area, and it is possible that a few aborigines not yet contacted by white men may exist in the rugged inaccessible northwestern part of the Sheet area.

Raising of beef cattle is the only industry in the Sheet area. Small scale mining was carried on for short periods around 1911-1912 at the King Sound Tin Mine, but apart from the efforts of a lone prospector (J. Stewart) no work has been done there since then.

Climate

The area has a moderately dry tropical monsoonal climate with a marked wet season during the summer period from December to March. There are no published rainfall and temperature figures available for the Sheet area. Extrapolated isohyets (Slatyer, 1960) indicate that the northwestern corner of the Sheet area has an average rainfall of more than 40 inches per annum and the south-east corner less than 30 inches. About 75% of the Sheet area lies in the 30-40 inch rainfall belt; the centre of the area probably has around 34 inches.

The temperature data for Derby and Halls Creek (Fitzpatrick and Arnold, 1964) provide a guide to temperatures of the coastal and inland parts of the Sheet area respectively. Derby has mean/monthly maxima in the range 84° (July) to 98° (November and December) and minima from 58° (July) to 80° (December). Halls Creek has maxima from 80° (July) to 100° (November) and minima from 47° (July) to 75° (January).

Vegetation and Pastures

The typical vegetation of low-lying parts of the area is grassy open eucalyptus woodland. Sandstone plateaux and ridges support mainly spinifex and stunted wattle, eucalypts, and cypress pine. Low sandstone hills in the coastal areas have a thick tangle of cane grass (annual sorghum) and creepers. Dolerite and basalt hills generally support blue grass or white grass. Black soil areas have mostly wire grass and Flinders grass. Pandanus and paper barks fringe water holes in river courses; elsewhere along the drainages eucalypts and baobabs predominate. Dense mangrove communities fringe the tidal bays, inlets, and estuaries.

Previous Work

The earliest exploration of the Sheet area was made by Alexander Forrest (1879) who examined the King Leopold Range in the vicinity of Mt Matthew, and by Hann (1901) and Brockman (1902) who both followed the Hann and Charnley Rivers. Although these explorers were concerned largely with the pastoral potential of the area, they also made brief geological observations. The journey of these early explorers are charted in Feeken and Feeken (in prep.).

The King Sound (Clara Hill) Tin Mine was mentioned briefly by Campbell (1909). It has been described in detail by Blatchford (1914), and summarised by Simpson (1948), and by Finucane (1939) who made a detailed map of the deposit.

More recently, Harms (1959, 1965) and Speck et al. (1960, 1964) have furnished good general accounts of the geology and geomorphology of the whole of the North and West Kimberley areas.

Present Investigation

Prior to the commencement of fieldwork in the area, a photo-geological map was prepared by W.J. Perry (B.M.R.) (Perry and Richard, 1965). This photo-geological map has formed the basis for much of the present map. Field work on the Carpentarian and Adelaidean rocks was carried out by R. Halligan (G.S.W.A.) in June and July 1965. Mapping of the lower Proterozoic rocks in the south-west corner and further observations of the adjacent Carpentarian sediments were carried out in 1966 and 1967 by D.C. Gellatly, G.M. Derrick and C.M. Morgan (1966 only) (B.M.R.), and J. Sofoulis (G.S.W.A.). All of these, except Morgan have contributed to the writing of this report.

Detailed ground traverses were made only in the southwestern part of the Sheet area. Most of the area was subject only to rapid reconnaissance traverses and scattered observations using a helicopter for transport.

In this report metric measurements are given in parenthesis following the imperial measurements. This practice foreshadows future conversion to the metric system.

A short report on the Hawkstone Creek Kyanite occurrence - containing the first detailed observations on this deposit - has already appeared (Derrick and Morgan, 1966). Also, data on palaeo-currents collected from the Charnley Sheet area have been incorporated in a report on palaeocurrent data for the whole Kimberley region (Gellatly, et al., in press).

This report, together with similar reports on the Yampi (Sofoulis et al., in prep.) and Lennard River (Gellatly et al., 1968) 1:250,000 Sheet areas, and the Oscar Range of the Lennard River Sheet area (Gellatly and Derrick in prep.), will form the basis for the Bulletin on the geology of the West Kimberley.

At the time of the present investigation the following airphotos and maps were available.

1. Vertical air photographs - 1:50,000 (approx.); 1949 photography by R.A.A.F.
2. Topographic base maps (unpublished) at 1:50,000 scale and
3. Topographic map at 1:250,000 scale compiled by the Royal Australian Survey Corps in 1962 and 1963, respectively.
4. Air photo mosaics at 1:63,000 compiled by the W.A. Department of Lands and Surveys from 1949 photography.
5. Air photo mosaic at 1:250,000 compiled in 1950 by the Commonwealth Division of National Mapping, Department of National Development.
6. Topographic map at 4 miles to 1 inch by W.A. Department of Lands and Surveys.

7. Geological map of the Kimberley Region (10 miles to 1 inch)
by J.E. Harms (1959).

Since the geological mapping described in this report was carried out, vertical air photographs (RC-9 Series) on a scale of 1:85,000 (approx.) have become available for the southern part of the Sheet area and should soon be available for the whole area.

PHYSIOGRAPHY

The physiography of the Sheet area is essentially that of an irregular dissected plateau which occupies the whole of the area except the southwestern corner. This corner consists of low rocky granite hills which are separated from the plateau by the King Leopold Ranges.

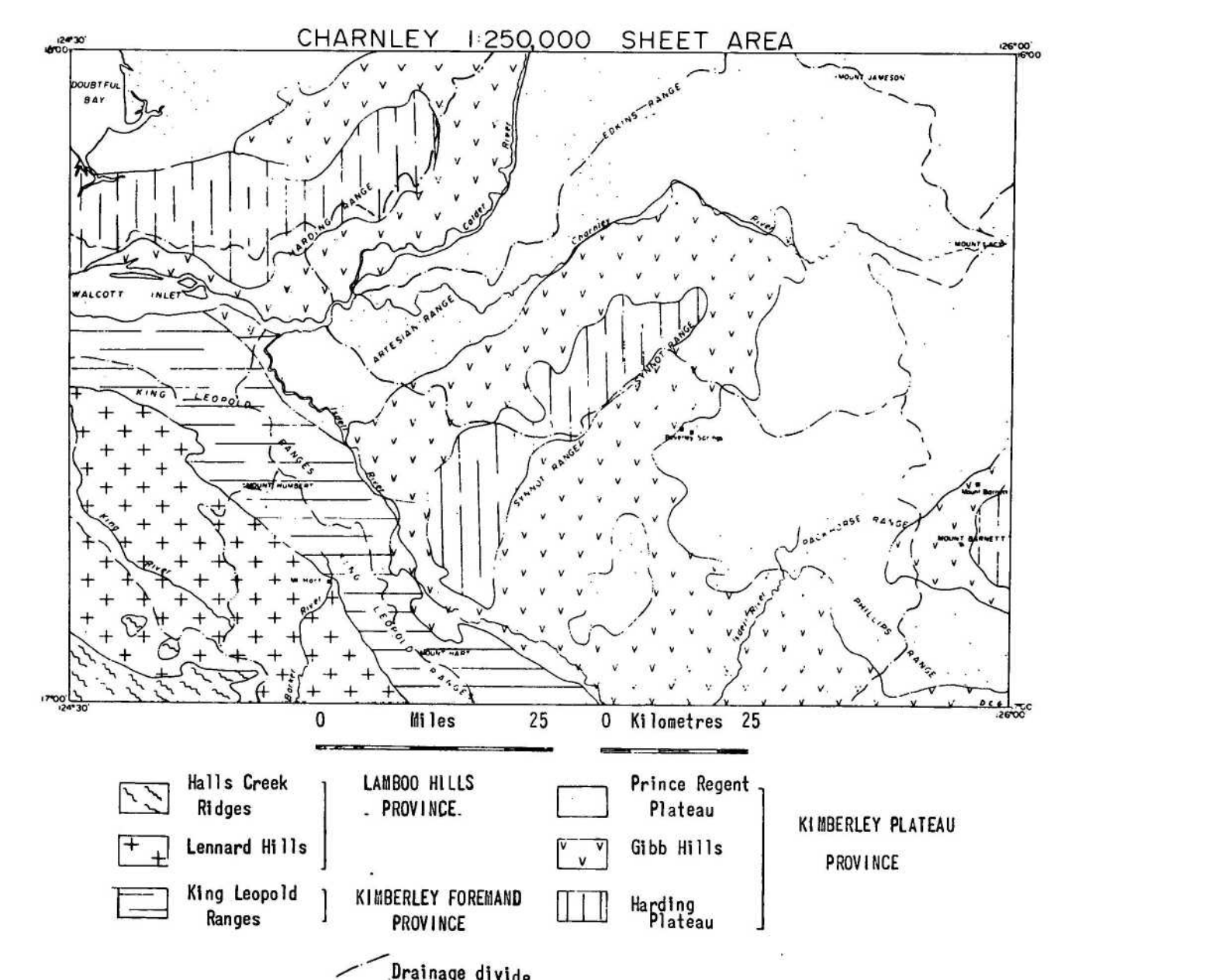
The principal landforms are grouped into three physiographic provinces comprising a total of six subprovinces (Fig. 1). Two of the provinces, the Kimberley Plateau and the Kimberley Foreland, fall within the North Kimberley Division of Jutson (1950): the third province, the Lamboo Hills, falls within Jutson's Fitzroyland Division.

The two subprovinces of the Lamboo Hills are underlain by older Precambrian crystalline rocks; the other subprovinces are underlain by Carpentarian sediments.

Drainage

Parts of the catchment areas of seven major rivers fall within the Sheet area. The central part of the area is drained by the Calder, Charnley, and Isdell Rivers, which converge and debouch into Walcott Inlet; the catchment areas of these three rivers cover more than 50% of the area. The eastern border of the map area includes parts of

Figure 1. The effect of the concentration of the solution on the adsorption of the dye. The concentration of the solution was 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 15.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, 100.0, 150.0, 200.0, 300.0, 400.0, 500.0, 600.0, 700.0, 800.0, 900.0, 1000.0, 1500.0, 2000.0, 3000.0, 4000.0, 5000.0, 6000.0, 7000.0, 8000.0, 9000.0, 10000.0, 15000.0, 20000.0, 30000.0, 40000.0, 50000.0, 60000.0, 70000.0, 80000.0, 90000.0, 100000.0, 150000.0, 200000.0, 300000.0, 400000.0, 500000.0, 600000.0, 700000.0, 800000.0, 900000.0, 1000000.0, 1500000.0, 2000000.0, 3000000.0, 4000000.0, 5000000.0, 6000000.0, 7000000.0, 8000000.0, 9000000.0, 10000000.0, 15000000.0, 20000000.0, 30000000.0, 40000000.0, 50000000.0, 60000000.0, 70000000.0, 80000000.0, 90000000.0, 100000000.0, 150000000.0, 200000000.0, 300000000.0, 400000000.0, 500000000.0, 600000000.0, 700000000.0, 800000000.0, 900000000.0, 1000000000.0, 1500000000.0, 2000000000.0, 3000000000.0, 4000000000.0, 5000000000.0, 6000000000.0, 7000000000.0, 8000000000.0, 9000000000.0, 10000000000.0, 15000000000.0, 20000000000.0, 30000000000.0, 40000000000.0, 50000000000.0, 60000000000.0, 70000000000.0, 80000000000.0, 90000000000.0, 100000000000.0, 150000000000.0, 200000000000.0, 300000000000.0, 400000000000.0, 500000000000.0, 600000000000.0, 700000000000.0, 800000000000.0, 900000000000.0, 1000000000000.0, 1500000000000.0, 2000000000000.0, 3000000000000.0, 4000000000000.0, 5000000000000.0, 6000000000000.0, 7000000000000.0, 8000000000000.0, 9000000000000.0, 10000000000000.0, 15000000000000.0, 20000000000000.0, 30000000000000.0, 40000000000000.0, 50000000000000.0, 60000000000000.0, 70000000000000.0, 80000000000000.0, 90000000000000.0, 100000000000000.0, 150000000000000.0, 200000000000000.0, 300000000000000.0, 400000000000000.0, 500000000000000.0, 600000000000000.0, 700000000000000.0, 800000000000000.0, 900000000000000.0, 1000000000000000.0, 1500000000000000.0, 2000000000000000.0, 3000000000000000.0, 4000000000000000.0, 5000000000000000.0, 6000000000000000.0, 7000000000000000.0, 8000000000000000.0, 9000000000000000.0, 10000000000000000.0, 15000000000000000.0, 20000000000000000.0, 30000000000000000.0, 40000000000000000.0, 50000000000000000.0, 60000000000000000.0, 70000000000000000.0, 80000000000000000.0, 90000000000000000.0, 100000000000000000.0, 150000000000000000.0, 200000000000000000.0, 300000000000000000.0, 400000000000000000.0, 500000000000000000.0, 600000000000000000.0, 700000000000000000.0, 800000000000000000.0, 900000000000000000.0, 1000000000000000000.0, 1500000000000000000.0, 2000000000000000000.0, 3000000000000000000.0, 4000000000000000000.0, 5000000000000000000.0, 6000000000000000000.0, 7000000000000000000.0, 8000000000000000000.0, 9000000000000000000.0, 10000000000000000000.0, 15000000000000000000.0, 20000000000000000000.0, 30000000000000000000.0, 40000000000000000000.0, 50000000000000000000.0, 60000000000000000000.0, 70000000000000000000.0, 80000000000000000000.0, 90000000000000000000.0, 100000000000000000000.0, 150000000000000000000.0, 200000000000000000000.0, 300000000000000000000.0, 400000000000000000000.0, 500000000000000000000.0, 600000000000000000000.0, 700000000000000000000.0, 800000000000000000000.0, 900000000000000000000.0, 1000000000000000000000.0, 1500000000000000000000.0, 2000000000000000000000.0, 3000000000000000000000.0, 4000000000000000000000.0, 5000000000000000000000.0, 6000000000000000000000.0, 7000000000000000000000.0, 8000000000000000000000.0, 9000000000000000000000.0, 10000000000000000000000.0, 15000000000000000000000.0, 20000000000000000000000.0, 30000000000000000000000.0, 40000000000000000000000.0, 50000000000000000000000.0, 60000000000000000000000.0, 70000000000000000000000.0, 80000000000000000000000.0, 90000000000000000000000.0, 100000000000000000000000.0, 150000000000000000000000.0, 200000000000000000000000.0, 300000000000000000000000.0, 400000000000000000000000.0, 500000000000000000000000.0, 600000000000000000000000.0, 700000000000000000000000.0, 800000000000000000000000.0, 900000000000000000000000.0, 10000000



the catchments of the Drysdale River, which drains northwards, and the Hann River which drains southwards into the Fitzroy. In the southwest the Barker River (a tributary of the Lennard River) and the Robinson River drain southwestwards and westwards to King Sound; and King Creek* and Humbert Creek drain northwestwards and westwards into Secure Bay. Other rivers along the western margin have short courses and drain directly into Doubtful Bay and Walcott Inlet.

Geological structure has played a part in controlling the courses of the major rivers. Broad anticlines of King Leopold Sandstone and remnant plateaux of Warton Sandstone in the centre of broad synclines generally form the divides between catchment areas. Over distances of up to 50 miles (80 km) major rivers follow closely the contact between the Carson Volcanics and the King Leopold Sandstone. Where rivers break through the anticlines spectacular gorges are developed, e.g. on the Isdell and Charnley Rivers. A notable feature is the deflection of the Isdell River by the King Leopold Ranges. It flows initially south-westwards, but is deflected northwestwards by the Ranges and for the rest of its length runs parallel to them. This is in direct contrast to the breaching of the King Leopold Ranges by the Fitzroy River at Diamond Gorge to the southeast of the Sheet area.

The courses of tributary streams are closely controlled by geology and are described under each physiographic subprovince.

Coastal Features

The small coastal areas found in the Charnley Sheet area are part of the drowned ria-type coastline that surrounds the Kimberley region on its northern and western sides. Spectacular

* Known locally as King River

narrow rocky rias are found at the mouths of rivers draining into Doubtful Bay, especially the Sale River. Walcott inlet is a broad drowned valley. It is 20 miles long, up to seven miles across and has a mean effective tide of 36 feet (Gordon, 1964). Echo soundings show that the floor of the inlet is irregular, being deeper (over 200 feet below sea level) near its northern shore, where steep slopes and cliffs forming the southern edge of the Harding Plateau rise to about 400 feet above sea level. At its mouth, in the adjacent Yampi Sheet area, the floor of the inlet is 280 feet below sea level.

Lamboo Hills Province

The Lamboo Hills Province occupies the southwestern corner of the Charnley Sheet area.

In the Lennard Hills subprovince the principal landforms are rugged bouldery granite hills and tors, whalebacks characterised by smooth exfoliation surfaces, broad sandy pediments with isolated monadnocks, and narrow alluvium filled valleys. Minor watercourses are closely spaced and commonly follow joints or faults. Elevations range from sea level to 1200 feet; local relief is generally around 400 to 500 feet.

The Halls Creek Ridges, which cover a small area in the southwest, consist of small hummocky rounded hills and ridges of easily eroded phyllite and schist, and of intervening clay-soil plains. Minor streams are closely spaced and commonly have a dendritic pattern, but where they traverse plains they are incised and meandering. Elevations range from 300 feet to 1000 feet; local relief is generally around 200 feet.



Fig. 2a. Typical physiography of Mondooma Granite. Vertical air photograph.
 Note black boulder scree and well defined joint pattern. Lennard Granite forms
 low ground at base of photo. GA 1292 (Photograph by RAAF)
 Centre point of photograph is 4 miles east-northeast of King Creek Yard.



Fig. 2b. Physiography of Kimberley Plateau. Mesas of Warton Sandstone
 (in distance) overlying Carson Volcanics which are cut by quartz-filled
 north-trending fault (foreground). Looking northeast from near Byrnes Hill. RH.

Kimberley Foreland Province

The King Leopold Ranges are a narrow belt of parallel, steep-sided commonly flat-topped ridges, which form the steeper western edge of the Kimberley Plateau. They are separated by more easily eroded dolerite valleys, especially along the southern margin. The topography is strongly controlled by the structure, and typically consists of long strike ridges with subsequent and consequent minor streams. The ranges have been deeply dissected, and form the divide between those streams draining into Walcott Inlet, and those which drain into Secure Bay to the west, or through the Barker and Lennard River systems into the Fitzroy River and King Sound. No major watercourses cross the ranges. The impressive peaks of Mount Hart, Mount Matthew, Mount Humbert and Mount Hepple form the highest points of the ranges in the Charnley Sheet area.

Kimberley Plateau Province

The Prince Regent Plateau is underlain entirely by the King Leopold Sandstone. It is gently undulating, and has rocky butte topography and deeply incised drainage. It differs from the Harding Plateau subprovince in its lack of escarpment and cuesta topography. Local relief is mostly around 200 to 500 feet but is as much as 1000 feet in places, e.g. at the lower end of the Isdell Gorge. Elevations range from sea level to 2500 feet at Mount Lacy, the highest point in the Sheet area.

Minor drainage is closely controlled by faults and joints, and tends to have a rectilinear pattern following northwest and southwest fractures.

The Gibb Hills are a series of low, generally smooth and rounded hills formed on basalt. In the centre of the Sheet area, near Beverley Springs homestead, the hills are capped by small laterite mesas. Elevations range from sea level to over 1700 feet. Local relief seldom exceeds 500 feet. Quartz-filled major faults form

prominent narrow ridges. Joint fractures, in contrast to those in the Prince Regent Plateau, are not deeply eroded, and minor drainage is dendritic rather than rectilinear.

The Harding Plateau subprovince consists of escarpment-bounded plateaux. It includes the Harding Range, the Synnot Range, and part of the Mount Barnett plateau. The surfaces of the plateaux are broken by scattered mesas and cuestas: in the Harding Range cuestas are a dominant feature of the topography. Local relief is mostly around 200 to 400 feet. Elevations range from sea level to over 1700 feet.

Minor drainage is irregular. It is partly controlled by fault and joint fractures, partly subsequent controlled by strike ridges, partly consequent flowing down dip slopes, and partly dendritic.

The Harding Plateau is similar physiographically and geologically to the Karunjie Plateau subprovince in the eastern part of the Kimberley Plateau.

INTRODUCTION TO STRATIGRAPHY

The stratigraphy of the Charnley Sheet area is summarised in Table I. Most of the rock units exposed in the Sheet area are of Precambrian age. The older Precambrian rocks - the Halls Creek Group and the Lamboo Complex - are assigned to the Archaean(?) and Lower Proterozoic respectively. The younger Precambrian rocks of the Kimberley Basin succession are assigned to the Carpentarian system. These are overlain by Upper Adelaidean sediments including tillite.

The subdivision of the Precambrian of the Kimberley Region into Archaean(?), Lower Proterozoic, Carpentarian and Adelaidean is based on isotopic age determinations (Bofinger 1967; Miss R. Bennett

[illegible]

Age	Rock unit and Symbol	Thickness in feet	Lithology	Distribution	Topography	Remarks		
P R O T E R O Z O I C	A D E L A I D E A N	M O U N T H O U S E G R O U P	Throssell Shale Bht	?	Grey-green shale; buff and grey-green fine sandstone interbeds.	Small area in extreme SE.	Shale-strewn pediments and gentle debris slope.	Light toned, mottled photopattern. Probably only a few feet of section preserved.
			Traine Formation Bha	About 200	Green to brown coarse lithic sandstone. Minor sandy dolomite and dolomitic sandstone. Scattered glacial erratics.	Small area in extreme SE.	Low rounded hills and rises.	Dark toned photopattern.
			Walsh Tillite Bhw	About 150	Tillite, pink fine pebbly sandstone, pink to brown dolomite. Minor purple-brown siltstone and algal dolomite.	Extreme SE	Scarp (tillite) and dip-slope (dolomite)	Topography distinctive. Interfingers with and overlies Beverley Springs Member.
			Beverley Springs Member Bhb	160	Poorly-sorted pebbly quartz sandstone.	Low conical hills	S and W of Beverley Springs.	Unconformable on Kimberley Group. Fills in ancient lowland.
	U N C O N F O R M I T Y							
	C A R P E N T A R I A N	K I M B E R L E Y G R O U P	Hart Dolerite Bdh	Up to about 10,000, mostly ca 4000	Dark grey and grey-green tholeiitic dolerite; granophyre.	Widespread mainly along SW flank of King Leopold Range.	Valleys and ridges; steep slopes beneath sandstone escarpments.	At least two main sills; in SW granophyre is more prominent at top of lower sill.
			Pentecost Sandstone Bkp	ca 750 feet	White to pale brown well-sorted quartz sandstone; minor pale red-brown feldspathic sandstone and arkose with thin red-brown siltstone interbeds.	Extreme W between Doubtful Bay and Walcott Inlet.	Resistant sandstone cuestas; feldspathic beds form smooth rounded hills.	Feldspathic beds form upper part of sequence and may be unconformable on lower part.
			Elgee Siltstone Bke	100-200?	Red-brown shale, siltstone and fine-grained sandstone. Minor pebble conglomerate at base.	Extreme W between Doubtful Bay and Walcott Inlet.	Valleys and scarp-slopes.	Very poorly exposed. Lithology from adjacent parts of Yampi Sheet area.
			Warton Sandstone Bkw	1500-2000	White to pale-brown well-sorted quartz sandstone; minor feldspathic sandstone.	Harding, Synnot and Barnett Ranges.	Broad plateaus bordered by cliffs; rugged scarp and dip slope topography in W.	Top eroded except in far W.
			Carson Volcanics Bkc	1600-3000?	Tholeiitic basalt and spilite; minor agglomerate feldspathic sandstone and siltstone.	Surrounding the Harding, Synnot and Barnett Ranges.	Broad rolling lowlands with isolated hills and ridges.	Agglomerate well developed in W and siltstone in Barnett Range.
			King Leopold Sandstone Bkl	About 3000-3500	White medium to coarse-grained quartz sandstone.	King Leopold, Artesian, Edkins, Packhorse and Phillips Ranges; Sale River and Upper Charnley River areas.	Rugged hills and ranges; butte topography locally. Deeply dissected by fault and joint valleys.	Overlies Speewah Group conformably.

Age		Rock unit and Symbol	Thickness in feet	Lithology	Distribution	Topography	Remarks	
PROTEROZOIC	CARPENTARIAN	SPEERAH GROUP	Luman Siltstone Bpl	About 120	Purplish red siltstone and fine micaceous sandstone,	King Leopold Ranges SE of Mount Humbert	Steep slopes below King Leopold Sandstone	Poorly exposed; grades into sandstone to NW
			Landsdowne Arkose Bpo	100- 510	White to cream medium quartz sandstone; minor feldspathic sandstone and quartz granule conglomerate.	King Leopold Ranges SE of Mount Humbert	Prominent ridges	Well developed festoon cross-bedding locally.
			Valentine Siltstone Bpv	About 50	Green and purple shale, siltstone and phyllite.	King Leopold Ranges SE of Mount Humbert	Low ground below Lansdowne Arkose	Rarely exposed
			Tungunary Formation Bpt	200- 300	White medium to coarse-grained quartz sandstone and feldspathic sandstone; minor siltstone and quartz granule conglomerate.	King Leopold Ranges	Prominent strike ridge	
			O'Donnell Formation Bpn	350- 550	Coarse quartz sandstone and pebble conglomerate; minor grey-green siltstone and shale.	King Leopold Ranges	Basal strike ridge of the Kimberley Basin rocks	Unconformably overlies Lamboo Complex.
	UNCONFORMITY							
	LAMBOO COMPLEX	UPPER	Mount Amy Granite Bbka		Fine and even-grained muscovite granite, aplite tourmaline-muscovite pegmatite	Small outcrops in extreme SW, and 12 miles S of Mount Hart homestead.	Low hills and pavements cut by more resistant dykes	Intrudes Mondooma Granite, Halls Creek Group, and Lennard Granite. Some beryl in pegmatite.
			Kongorow Granite Bbkk		Dark grey coarse-grained porphyritic granite.	Dykes, veins, and sheets in the Lennard Granite SW of the Pardaboora River.	Domes, pavements, and low whale-backs in hills of Lennard Granite.	Equivalent to younger phase of Kongorow Granite in Yampi Sheet. Forms large-scale intrusion breccia with Lennard Granite.
			Lennard Granite Bbkl		Massive to foliated coarse, even-grained to porphyritic-granite; local xenolith-rich zones, and contaminated zones.	Along and E of Barker River; Swift Creek, King Creek headwaters; immediately S of the Pardaboora River; S of Hawk Creek.	Elongate whale-backs and bouldery hills in far SW. Elsewhere massive rounded bouldery hills and tors with large sandy pediments.	Intrudes Mondooma Granite. Massive nature in NE of basement area contrasts with gneissose nature in SW. Xenolith swarm contains abundant blocks of ?Halls Creek Group.

TABLE 1. STRATIGRAPHY OF THE CHARNLEY SHEET AREA

Table 1. (133)

Age			Rock unit and Symbol	Thickness in feet	Lithology	Distribution	Topography	Remarks
PROTEROZOIC	LAMBEO COMPLEX	MIDDLE	Mondooma Granite Bbko		Medium-grained granite; porphyritic microgranite and microgranodiorite.	Most of the basement belt, except S margin of Sheet area.	Massive, rounded bouldery hills, moderately rugged.	Contains patches resembling Mount Disaster Porphyry. Bipyramidal quartz phenocrysts present in some areas. Marked joint control of drainage.
			Mount Disaster Porphyry Bbkd		Coarse-grained pale pink to grey quartz feldspar porphyry, minor porphyritic granite.	Extreme W, in headwaters of Hawkestone Creek, along Barker River, and flanking O'Donnell Formation SW of Mount Hepple.	Bouldery hills similar to Mondooma Granite. Near Mt Hepple forms whale-backs, domes, and low pavements with intervening sand.	Intruded by Lennard Granite. Dyke intrudes Whiteater Volcanics in SW.
		LOWER	Volcanics Bw	About 15,000	Undifferentiated grey and grey-green rhyodacitic and dacitic ash-flow tuff; minor andesitic lava.	Mainly NW of Mt Hart headstead; near Pardaboora River.	Low rounded ridges.	Andesitic types near base have prominent epidote replacing pyroxene.
			Whitewater Bwa		Massive crystal-poor rhyodacitic ash-flow tuff; minor crystal-rich tuff.	Extreme W on Pardaboora River about 4 miles NE of King Sound Tin Mine.	Low ridges.	Quartz and feldspar phenocrysts prominent; matrix 50% or more of the rock.
			Bwb		Dacitic and minor rhyodacitic biotite-rich ash-flow tuff.	In SW, a few miles E and NE of King Sound Tin Mine.	Prominent bouldery ridges. Less rugged than adjacent Mondooma Granite.	Phenocrysts and lenticles of biotite prominent; quartz phenocrysts less abundant than in other varieties.
			Woodward Dolerite Bbd		Dark grey-green very coarsely porphyritic to non-porphyritic amphibolite.	S.W. near Hawkestone and Alexander Creeks.	Upstanding bouldery ridges, heavily grassed.	Glomerocrysts of plagioclase up to 20 cm across. Intrudes and is folded with Halls Creek Group.
ARCHAEO	HALLS CREEK GROUP		Ah	Unknown about 5,000 preserved	Phyllite, minor quartzites, andalusite, chloritoid, staurolite, kyanite, and garnet mica schist. Actinolite-clinzoisite-garnet quartzite present locally.	Small inliers between Hawkestone Creek and headwaters of the Pardaboora River in SW.	Hummocky hills with short discontinuous ridges and closely spaced drainage.	Metamorphism appears polyphase low to moderate pressure-regional type. Arsenic and tin mineralization at King Sound Tin Mine. Kyanite-corundum-topaz deposit at contact with Woodward Dolerite.

unpublished data)*. In addition the Lamboo Complex has been informally subdivided into three parts on the basis of field relationships (Gellately et al. 1968) and the Whitewater Volcanics have been included in it. The Whitewater Volcanics are now placed in the Lower Proterozoic at the base of the middle unit of the Lamboo Complex, instead of the base of the Carpentarian as previously (Dunn et al., 1966); (Dow and Gemuts, in press).

Stratigraphic nomenclature of the Precambrian units will be defined fully in Dow and Gemuts (in press); Gemuts (in press); Gellately, Sofoulis and Derrick (in prep.); and Plumb (in prep.).

The Precambrian is overlain by sediments of Devonian age and by Tertiary laterite and other superficial Cainozoic deposits.

* As used in this Report the Lower Proterozoic ranges from 2300 m.y. to about 1800 m.y., the Carpentarian System from about 1800 m.y. to 1400 m.y., and the Adelaidean System from 1400 m.y. to 600 m.y. The subdivisions of the Precambrian used by the Geological Survey of Western Australia differ from these and are shown separately on the accompanying map.

ARCHAEN (?)

HALLS CREEK GROYP

Introduction

The Halls Creek Group, the oldest unit exposed in the Sheet area, is a sequence of phyllite, schist, and quartzite. The unit is named after Halls Creek, in the East Kimberley. The derivation of the name is documented in Dow and Gemuts (in press).

Stratigraphic Relationships

The base of the Halls Creek Group is not exposed. The Group is overlain by ash flow tuff of the Whitewater Volcanics (q.v.) and by Devonian conglomerate, and is intruded by the Woodward Dolerite, Mondooma, Granite, Mount Disaster Porphyry and the Lennard Granite.

Field Occurrence

The Halls Creek Group is exposed mainly in an east-west belt in the far southwest of the Sheet area, near the headwaters of Hawkstone and Alexander Creeks; in three inliers one to three miles across a few miles north of this belt, near the headwaters of the Pardaboora River; and in a small area at the western edge of the Sheet, about 3 miles (5km) west of the abandoned Federal Downs homestead.

Lithology

Phyllite, porphyroblastic mica schist and impure quartzite are the dominant lithologies in the Halls Creek Group, with minor amounts of hornfels. Their distribution, detailed assemblages and petrological significance are treated in a later chapter on Metamorphism.

Sericite phyllite is the most abundant rock type; it is generally buff to grey, laminated to flaggy and thin-bedded, with both cleavage and bedding in most places. Locally the phyllite contains small spots of andalusite.

Mica schist is also widespread, and generally contains porphyroblasts of one or more of the following: andalusite, chloritoid, staurolite, garnet and kyanite. Andalusite and chloritoid are abundant, but the remainder are confined to schist in the south-west part of the Sheet. Most andalusite is from 1 mm to 1 cm long, and is commonly pseudomorphed by sericite aggregates. In the Hawkstone Creek area andalusite locally forms up to 10% of the gravels; crystals from 2 to 6 cms by 1 to 2 cms predominate, but specimens up to 12 cm long have been found. In this area it is pseudomorphed by kyanite. Staurolite in schist occurs as both stubby and elongate crystals, the latter occurring in the more strongly deformed zones with garnet. Garnet porphyroblasts range from 2 mm to 1 cm in diameter, and appear to be restricted to the more highly cleaved schists. They show well developed pressure shadows in some places. Kyanite schist occurs near the headwaters of Hawkstone and Alexander Creeks, in association with lenses of coarse kyanite rock, corundum rock and kyanite-topaz rock. This kyanite deposit is about 1200 feet 400 metres long, and occurs at the lower contact between Woodward Dolerite and phyllite of the Halls Creek Group.

Impure quartzites are almost everywhere fine-grained and pale fawn to grey; they are poorly cleaved, flaggy to fissile and thin-bedded, though in some areas massive to blocky parting is common. Mica aggregates along bedding planes, and porphyroblasts of actinolitic amphibole and rare andalusite occur sporadically throughout the sandstones. Phyllite interbeds are common; ripple marks, graded-bedding, micro-crossbedding, convolute bedding and rare flame and pull-apart structures (Fig.3a) have been found.

Green-grey hornfels occurs at a contact with granite near the Pardaboora River, and shows spots of andalusite and chloritoid. A massive biotite-andalusite-quartz granofels 2 miles west of old Federal Downs homestead has been formed by relatively intense thermal metamorphism.

Less abundant rock types in the Halls Creek Group include graphitic phyllite, calcareous phyllite and breccia containing angular quartzite fragments in a metagreywacke matrix. An unusual large lenticular xenolith of net-veined quartz-amphibole-feldspar-garnet gneiss, measuring 150 feet (45 metres) by 20 feet (6 metres), occurs in Lennard Granite about 2½ miles (4 km) west-southwest of Federal Downs homestead. It is blue grey and quartzitic, with abundant grains of amphibole and small (1-2 mm) scattered grains of pink garnet. The net-veining by quartz produces a pseudoxenolithic effect (see Fig. 3b).

Structure

Pelites in the Halls Creek Group are generally highly cleaved, and at least two cleavages are present in most specimens. One cleavage is usually subparallel to the bedding; the other crenulation cleavage intersects the older cleavage, and has produced a lineation on bedding planes. Bedding is vertical or steeply dipping to the south or southwest, though northerly dips are common in the inliers near the Pardaboora River. Mineral lineations generally plunge to southeast, southwest and east.

Only smaller scale folding is recognisable; the microfolds are tight to isoclinal and plunge to both the northwest and southeast.

Petrography

(a) Phyllite contains bands composed principally of either quartz, quartz and muscovite, or muscovite; biotite and chlorite are less common. The micas are generally well oriented, but rare mica porphyroblasts are transverse to the schistosity in some cases. Rutile and

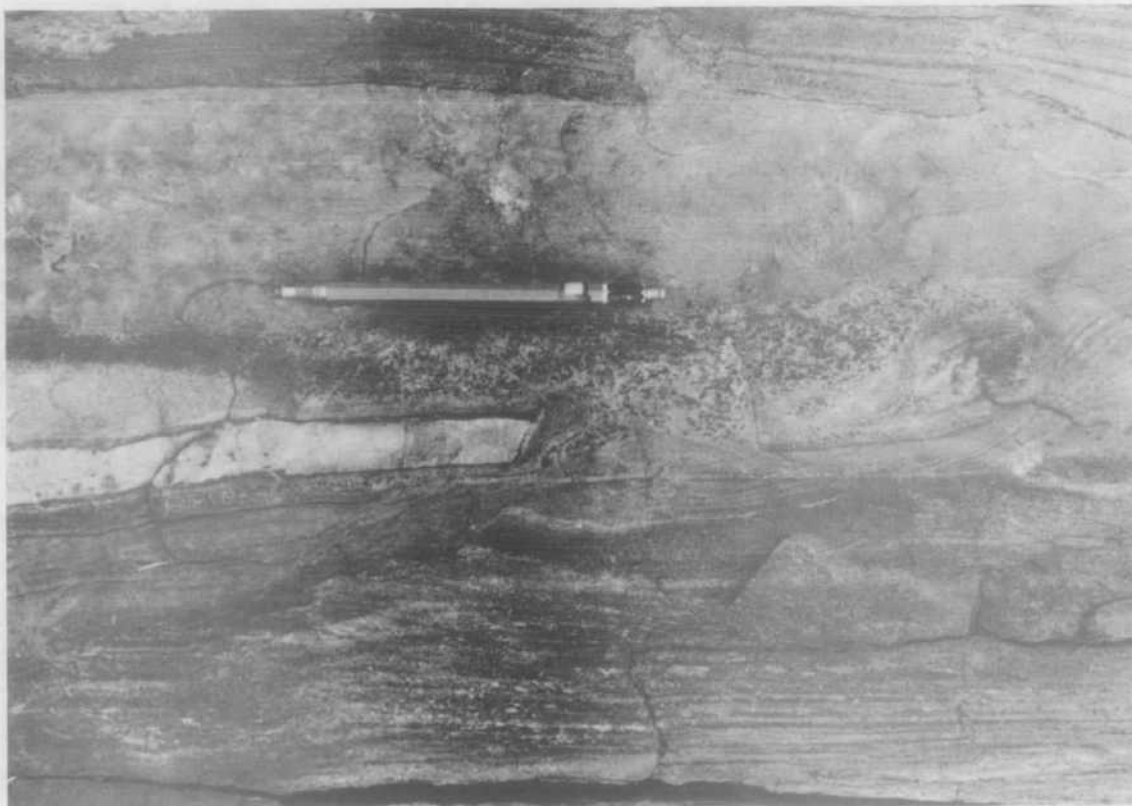


Fig. 3a. Bedded metasediments of Halls Creek Group, showing white bed of competent quartzite (centre) fractured during deformation and less competent pelite showing flow deformation. Note flame structures of psammite intruding upper pelite bed. M631 GMD.

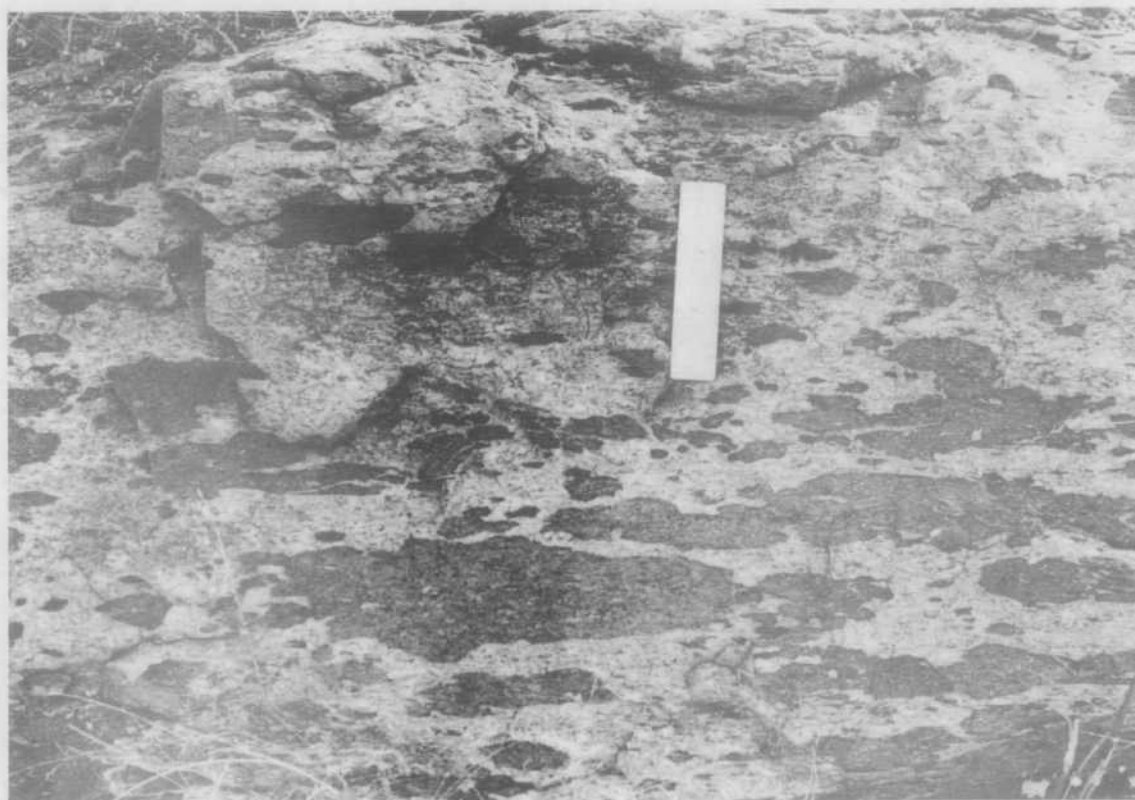


Fig. 3b. Dark patches of quartz-amphibole-feldspar-garnet rock intricately veined by quartz producing a pseudo-xenolithic effect. M431 GMD.
Halls Creek Group gneiss 4 miles west southwest of Federal Downs.

tourmaline are common accessories.

(b) Pelitic Schists. Staurolite-andalusite-muscovite-biotite-quartz assemblages are common in the Hawkstone Creek-Alexander Creek belt. Staurolite forms subhedral grains from 0.3 mm to 1 mm, some of which show cruciform interpenetration twinning. Quartz inclusions and vermiform intergrowths with quartz occur in the cores of some grains. Staurolite also forms concentrations in andalusite-muscovite porphyroblasts, in one case in association with kyanite. Garnet forms porphyroblasts 1 to 5 mm diameter. Trains of quartz and rare biotite inclusion are present, oblique to the schistosity in the rock, which wraps around the garnet. In one specimen from an inlier near the Pardaboora River chloritoid crystal aggregates with some chlorite are pseudomorphous after andalusite (Fig. 4a). Elsewhere it is independent of andalusite, and is commonly altered to inclusion-rich biotite. In the kyanite deposit chloritoid occurs with quartz in small veinlets. Andalusite forms large porphyroblasts which may contain abundant inclusions of quartz; chiastolite is also common. Muscovite is the most common alteration product though some crystals are altered to a biotite-muscovite aggregate. Many specimens show at least two generations of andalusite, and pre- and post-tectonic porphyroblasts.

(c) Aluminous rocks in the kyanite deposit. Kyanite schist (see Fig. 5a), tourmaline-dumortierite-kyanite rock and corundum-sericite rock from the kyanite deposit have been described by Derrick and Morgan (1966). In addition to these, corundum-mica-topaz and kyanite-topaz rock also occur. The corundum forms granular aggregates arranged radially about fields of a mica. Topaz in this corundum rock forms narrow veinlets of anhedral medium-grained aggregates.

In the kyanite-topaz rock, kyanite forms square sectioned metacrysts 1-2 mm diameter in a fine-grained topaz matrix. Fine-grained opaque inclusions in the cores of the square-sectioned kyanite crystals strongly suggest kyanite is pseudomorphous after chiastolite (Fig. 5b). Some of the metacrysts are altered to an aggregate of muscovite and coarse-grained topaz.

Yellow-green tourmaline and rutile are accessory minerals generally concentrated along microfractures. Sphene and actinolite are common in a calcareous bed within the kyanite-bearing sequence.

(d) Hornfels. A massive biotite-andalusite-quartz-granofels has been examined. Andalusite poikiloblasts up to 1.5 cms long are fresh, and contain abundant quartz intergrowths. Biotite is red-brown and free from inclusions, in contrast to muscovite with which it is associated. Quartz is abundant, and in places contains needles of sillimanite, which also forms fibrolitic aggregates closely associated with biotite. Locally it replaces andalusite, and this is similar to occurrences noted by Chinner (1961) and Gemuts (1965). Plagioclase (1%) is of composition An_9-12 ; accessories are coarse-grained olive-green tourmaline, and zircon and magnetite.

(e) A xenolith of net-veined gneiss in Lennard Granite shows prominent amphibole poikiloblasts with Z = grey-blue, extinction angle 11° and optic axial angle 85° . The amphibole is possibly actinolite, and forms slender euhedral prisms 1 to 4 mm long, with abundant iron ore and clinozoisite inclusions. The Z axial colour is more intense than in similar crystals in psammities in the Halls Creek Group, and probably reflects higher temperature conditions. Pale pink euhedral garnet crystals up to 2 mm diameter are also present, in a matrix of quartz, clinozoisite, epidote, plagioclase and iron ore.

(f) Psammities. These are well banded, siliceous and slightly calcareous. Actinolite is the most abundant poikiloblast (Fig. 4b), and forms euhedral crystals up to 3 mm long, with Z = pale blue-green. It is associated with granoblastic quartz, muscovite, sphene and plagioclase, in bands containing variable amounts of garnet and clinozoisite. Plagioclase ranges from An_{17} in one specimen to An_{31} in another.

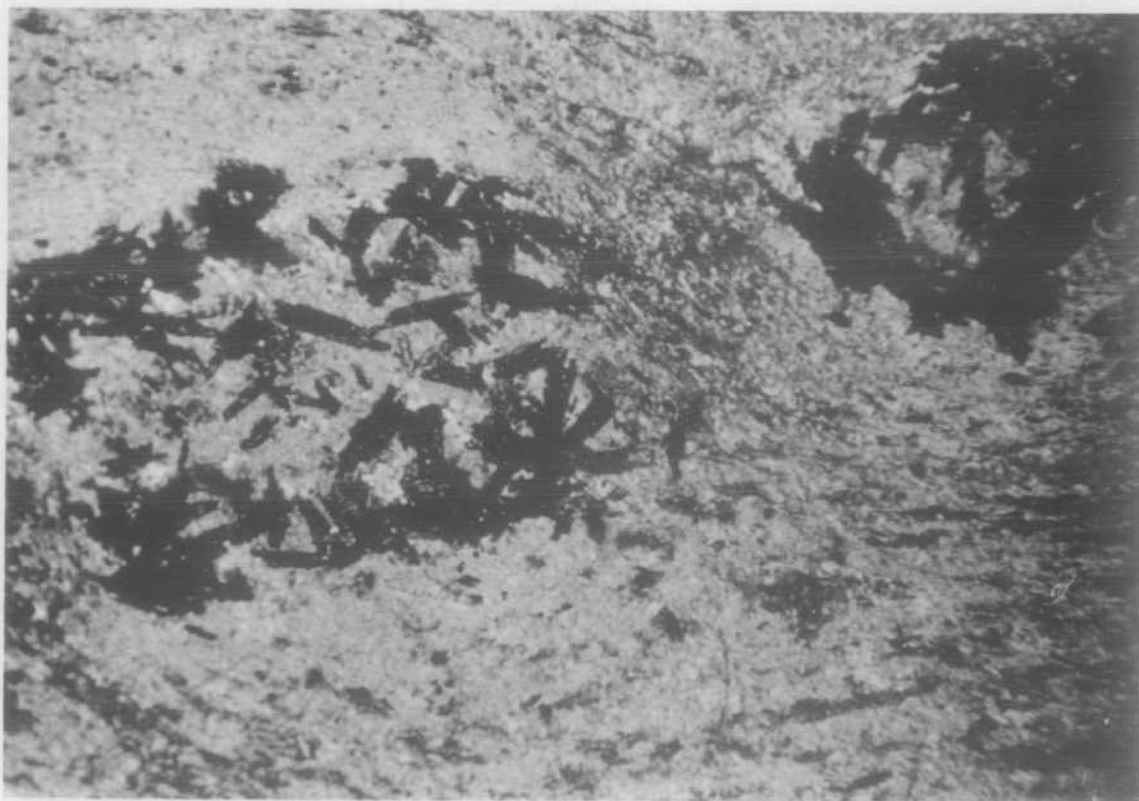


Fig. 4a. Chloritoid aggregates pseudomorphing andalusite porphyroblasts
in phyllite. Plane polarized light. x36 M 759 GMD
Halls Creek Group inlier 4 miles north-northwest of King Sound Tin Mine.

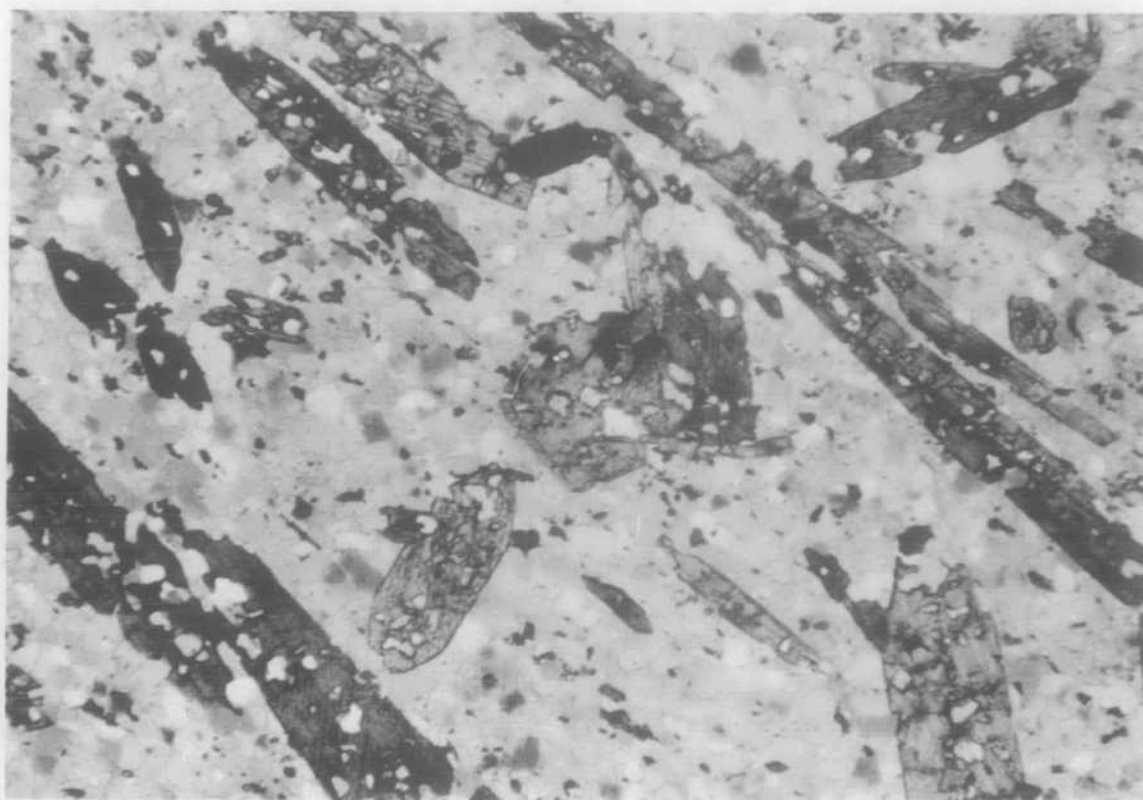


Fig. 4b. Actinolite poikiloblasts in quartzite. Crossed
polarizers. x36 M 692 GMD
Halls Creek Group; two miles west of Hawkestone Creek kyanite deposit

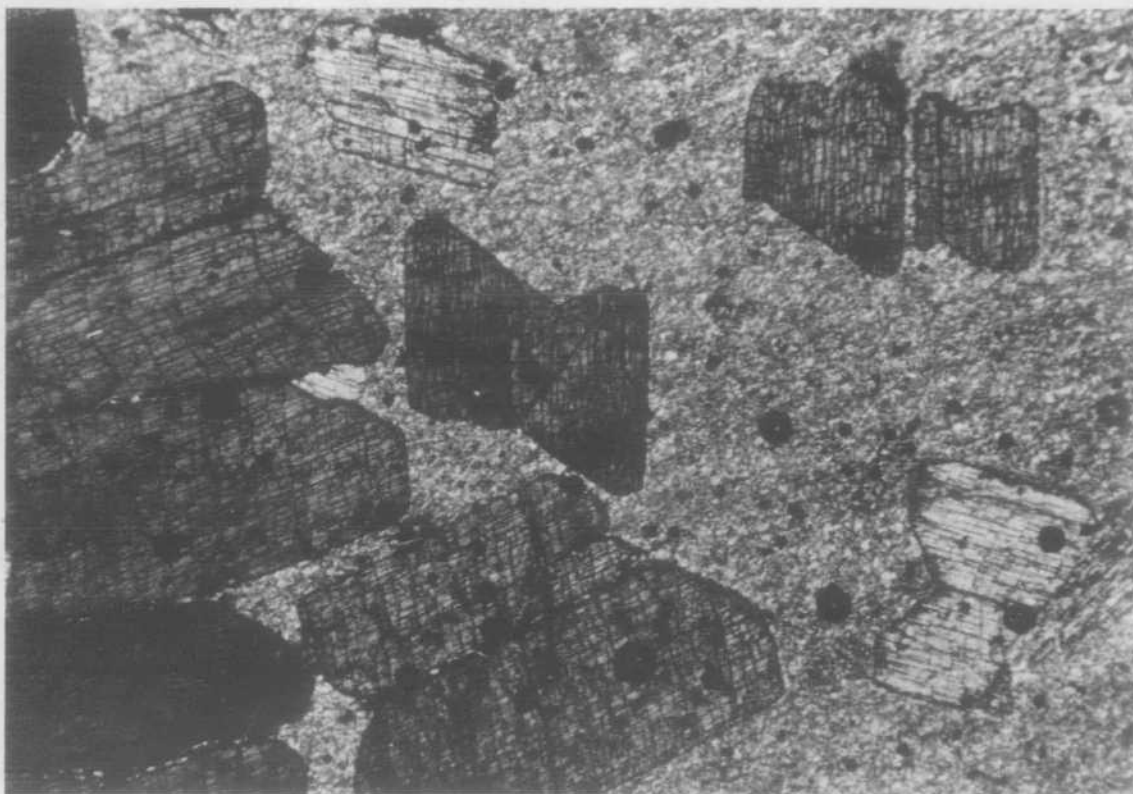


Fig. 5a. Twinned porphyroblasts of kyanite in mica schist. x 36. Crossed polarizers.
From Hawkstone Creek kyanite deposit

M692

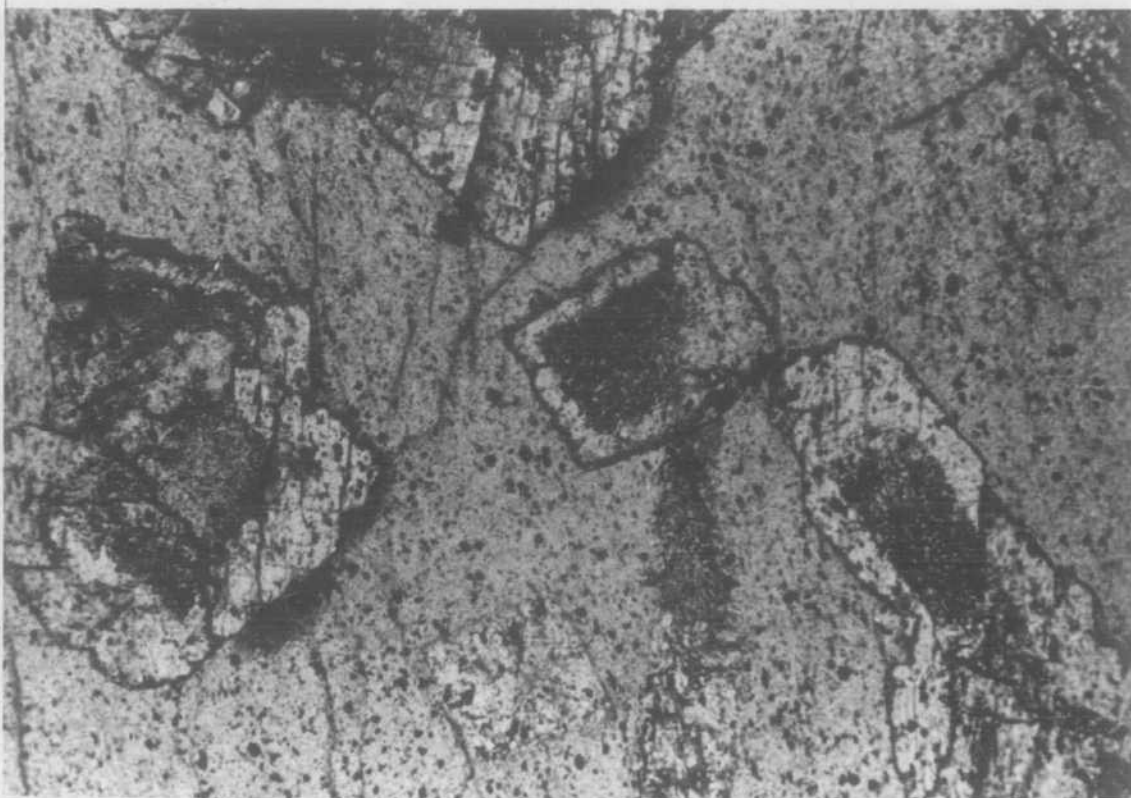


Fig. 5b: Pseudomorphs of kyanite after andalusite. Note relict chiastolitic cores in kyanite.
Fine-grained matrix is topaz aggregate. x 36. Plane polarized light. From Hawkstone
Creek kyanite deposit.

M759. GMD

LOWER PROTEROZOICEARLY LAMBOO COMPLEX

WOODWARD DOLERITE

Introduction

Sills of metamorphosed, commonly porphyritic, dolerite and gabbro that intrude the Halls Creek Group in the southwestern corner of the Charnley Sheet area are referred to the 'Woodward Dolerite', named by Dow and Gemuts (in press) from the Woodward Range in the Mount Ramsay Sheet area. The sills in the Charnley Sheet area are members of a discontinuous series that extends from Mt Nellie (Yampi Sheet area) in the northwest to Ruby Plains (Gordon Downs Sheet area) in the southeast.

Field Occurrence

In the Charnley Sheet area the Woodward Dolerite occurs only in the extreme southwest. The main outcrops extends from a point 3 miles (5 km) east-northeast of King Sound Tin Mine to Alexander Creek on the western boundary. The total extent of the outcrops is about 6 sq. miles (17 km²). A further 8 sq. miles (22 km²) are underlain by Woodward Dolerite but obscured by soil cover.

Topographically the Woodward Dolerite forms prominent smooth-sloped ridges, most of which have a dark, even-toned photo-pattern. Those near the southern boundary of the sheet area are light coloured on air photographs on account of their thick cover of cane grass. Parts of the intrusion are conspicuously banded on air photographs.

The Woodward Dolerite occurs mainly as a sill over 2000 ft (600 metres) thick that extends for about 20 miles (32 km); outcrops about $\frac{1}{2}$ a mile (1 km) west of the Hawkestone kyanite deposit and within the kyanite bearing area are probably part of a thinner sill underlying the main one. The strike is predominantly east-west and dips are mostly 60° or more to the south. Between Hawkestone and Alexander Creeks the sill is folded into tight synclines and anticlines that plunge southeast. The original way up of the main sill has been determined by examination of graded-bedding in hornfelsed Halls Creek Group sediments immediately underlying the sill.

Contact Relationships

The Woodward Dolerite intrudes the Halls Creek Group. Evidence from the Lennard River Sheet area to the southeast indicates that it is older than the Whitewater Volcanics and hence older than most of the granitic intrusives of the area.

Where exposed, contacts with the Halls Creek Group are conformable with bedding. The sediments at the lower contact of the Dolerite (e.g. $\frac{1}{2}$ mile (1 km) southwest of the Hawkstone kyanite deposit) are hornfelsed. The kyanite deposit itself is close to the lower contact of the main sill of Dolerite and may be at least partly the result of contact metamorphism and accompanying metasomatism.

Lithology

In hand specimen the Dolerite is dark grey-green, massive or poorly foliated, and is mostly non-porphyritic. Porphyritic horizons are found locally near the upper part of the main sill, and also in the thin sill that underlies it. Most porphyritic types contain equant plagioclase phenocrysts and glomeroporphyritic aggregates 1 to 2 cm across and comprising 20% to 50% of the rock. Porphyritic types with abundant 2-3 mm phenocrysts of hornblende but lacking plagioclase phenocrysts occur locally, e.g. $1\frac{1}{2}$ miles ($2\frac{1}{2}$ km) west of the kyanite deposit.

In one locality about 3 miles (5 km) south of the kyanite deposit large rosettes of plagioclase phenocrysts up to 20 cm across make up about 50% of the rock, but the size and abundance of phenocrysts decreases rapidly northwards (downwards in the sequence).

Phenocryst sizes and contents of sample areas of this outcrop have been studied in detail by grid point-counting of photographs taken at selected intervals across the outcrop. The variations in phenocryst size and content are shown in Fig. 6. Fig. 7 shows typical examples of the porphyritic Woodward Dolerite from this locality.

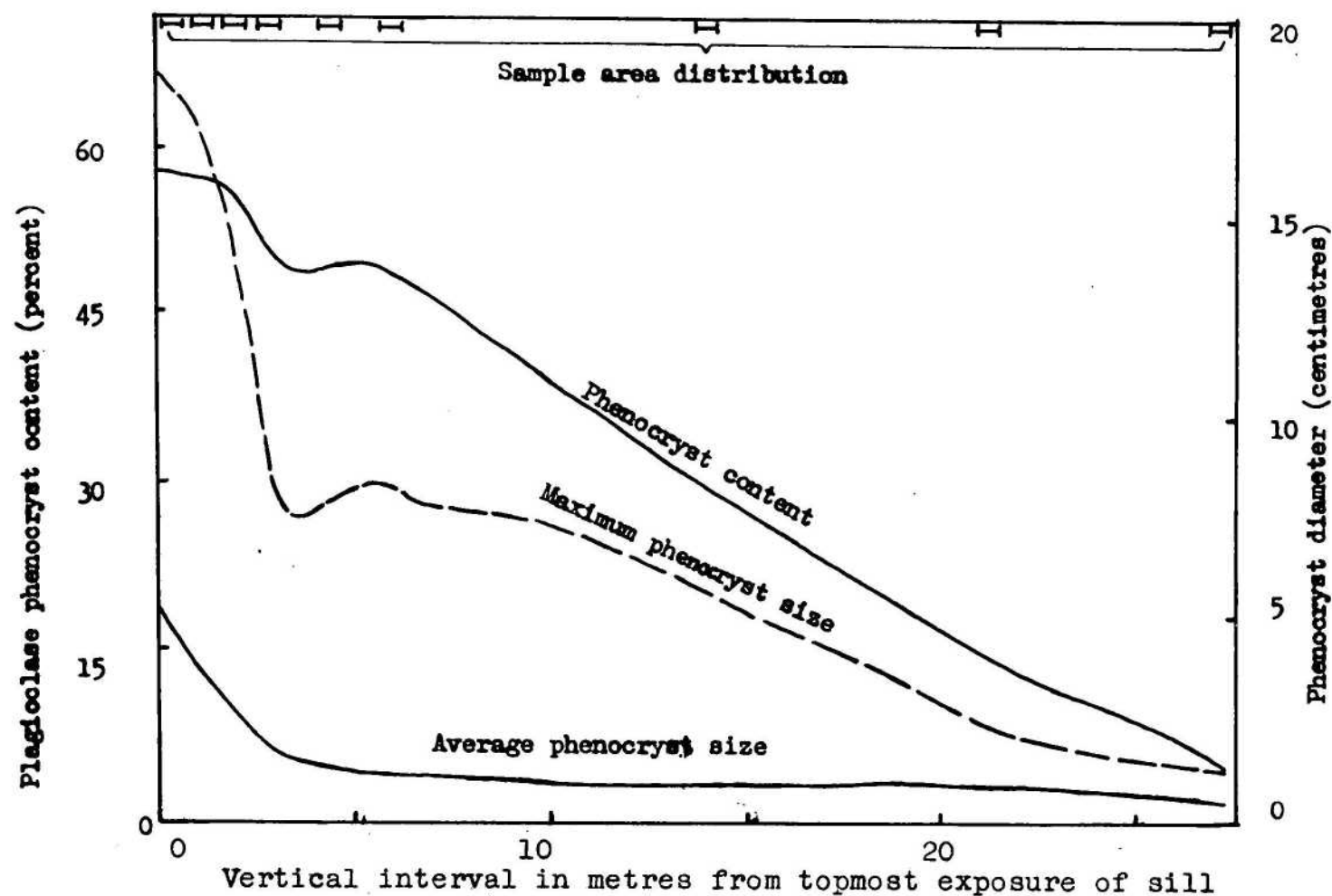


Figure 6. Variation in plagioclase phenocryst size and content in outcrop of Woodward Dolerite $3\frac{1}{2}$ miles south of Hawkstone kyanite deposit.

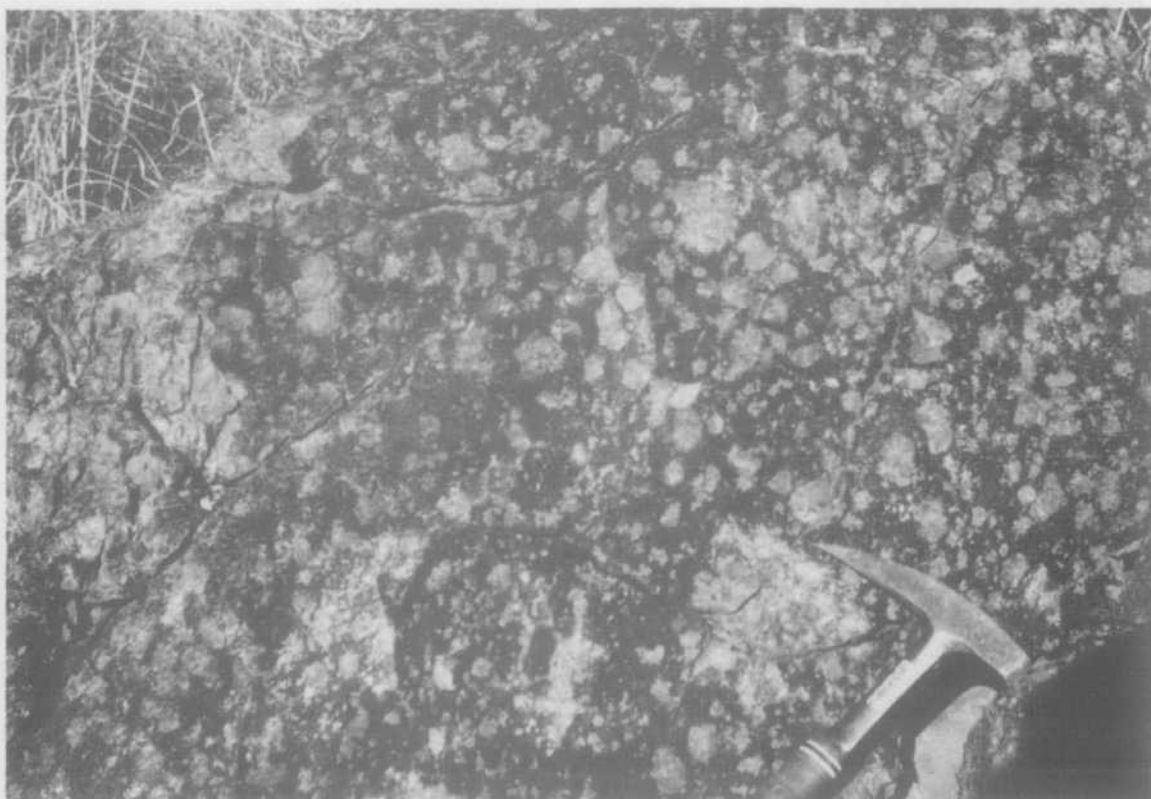


Fig. 7a: Porphyritic Woodward Dolerite containing 0.5 to 4cm. equant plagioclase phenocrysts, and rare larger glomeroporphyritic aggregates. Locality $3\frac{1}{2}$ miles south of Hawkstone kyanite deposit. GA414 DCG.

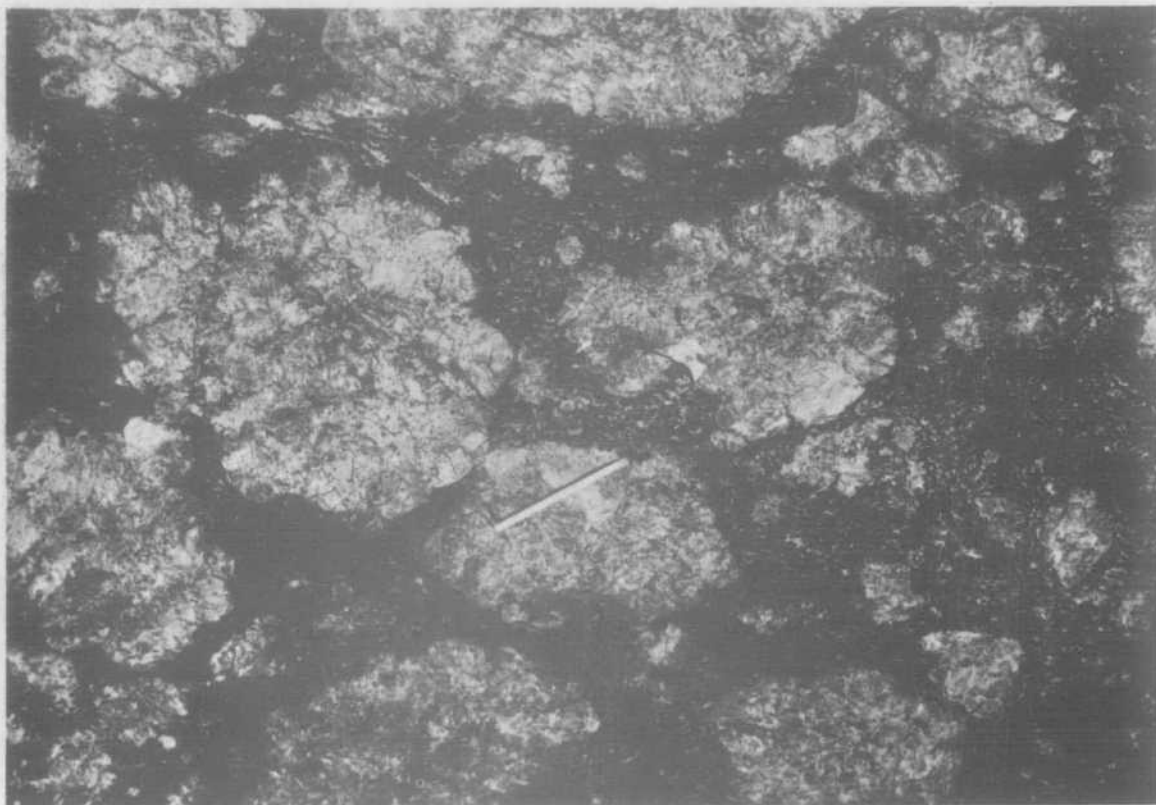


Fig. 7b: Porphyritic Woodward Dolerite containing abundant rosette aggregates of plagioclase phenocrysts. Specimen from near top of detailed section represented in Figure 6. Locality $3\frac{1}{2}$ miles south of Hawkstone kyanite deposit. GA2111 GMD.

The feldsparphyric types, for the most part, appear to be confined to a single horizon in the upper part of the main sill. locally, e.g. $1\frac{1}{2}$ miles ($2\frac{1}{2}$ km) west of the kyanite deposit, and also in the northwestern part of the Lennard River Sheet area about 2 miles (3 km) south of Hawkstone Yd the feldsparphyric types are regularly interlayered with the non-porphyritic.

Petrography

Specimens of the Woodward Dolerite are typically normal dolerites which have undergone metamorphism in the amphibolite facies producing rocks composed almost entirely of plagioclase and hornblende, and minor amounts of quartz, sphene, ilmenite, ?magnetite, goethite, and locally epidote, and zoisite and chlorite. In most rocks the hornblende content appears to exceed that of plagioclase. Only in the feldsparphyric rocks does plagioclase predominate, and in these hornblende generally makes up more than 50% of the groundmass.

Plagioclase phenocrysts consist of aggregates of subhedral equant and tabular grains and partly of anhedral sub-grains derived from larger grains by fracturing and recrystallisation. The plagioclase is fresh, but invariably contains aligned acicular hornblende inclusions, and small hornblendes developed along fractures. Albite, Carlsbad, and pericline twinning are common, pericline twinning conspicuously so. Composition of phenocrysts ranges from An₄₅ to An₆₅. Most are apparently unzoned.

Groundmass plagioclase occurs as subhedral tabular and anhedral equant grains up to 0.5 mm across. Twinning is similar to that in the phenocrysts, but pericline twinning is relatively less common. The grains are fresh and of composition An₆₀ to An₆₅. The groundmass plagioclase appears to be more calcic than plagioclase phenocrysts in the same rock, but more work is required to establish this.

Hornblende phenocrysts, present in only one rock (R 66.16.1000), occur as anhedral 3 mm grains elongated slightly in the cleavage direction. They contain ophitic and subophitic tabular plagioclases locally, and patchily arranged minute inclusions of plagioclase and ?magnetite. Hornblende phenocrysts commonly show twinning parallel to (100) and have $Z'c = 15^\circ$ and $Y = b$. Pleochroism is X very pale brown, Y pale olive green, Z pale blue green. Groundmass hornblendes commonly show good preferred orientation.

They are similar to the phenocrysts described except that ophitic texture is absent, $Z'c$ is generally in the range 18° to 24° , and blue green is absent from the pleochroic scheme. They are mostly free from inclusions but in one specimen (R 67.16.1023) hornblendes completely enclosed in plagioclase phenocrysts contain minute lenticular lamellae of ?magnetite aligned along cleavages.

Quartz occurs only as rare 0.2 mm grains associated with matrix plagioclase. Sphene forms coronas of varying width round ilmenite. Epidote, forming small inclusions in plagioclase, occurs only in one rock containing phenocrysts of hornblende (with blue-green absorption in the Z direction); the same rock contains scattered tabular grains of a colourless to very pale olive green chlorite. Scattered grains of zoisite are present in most of the other rocks both within and bordering plagioclase.

Discussion

Although few specimens have been examined microscopically and most of these come from one locality, the variations in pleochroism in hornblende, and the presence of epidote in one of the rocks indicates variations in metamorphic grade that can be correlated with variations in metamorphic grade in the enclosing Halls Creek Group. Metamorphism of the Woodward Dolerite is apparently greatest near the southern margin of the Sheet area where it occurs along strike from garnet-, and staurolite-andalusite schists; and is appreciably less (epidote present) immediately west of the kyanite deposit, where low grade phyllites form the country rocks. The hornblende phenocrysts noted in one rock are considered on the basis of their ophitic texture, to be pseudomorphous after pyroxene.

There are several unusual features about the plagioclase phenocrysts. These include the abnormal size (up to 20 cm) and rosette shape of the aggregates, the presence in the phenocrysts of aligned acicular hornblendes (originally exsolved needles of pyroxene?), and the fact that where compositional differences are apparent between phenocrysts and groundmass plagioclase, the phenocrysts are the more sodic instead of the groundmass plagioclase, which would normally be expected. These unusual features must be left unanswered at this stage, but it is of interest that crystallization

at depth favours more sodic compositions and that a deep crustal origin has been suggested for similar large plagioclase (oligoclase) phenocrysts in basalt from Gombe, Nigeria (Wright, 1968).

The mechanism of concentration of the phenocrysts is also of interest, although there is less relevant information available from the Charnley Sheet area than from the adjacent Lennard River Sheet area. The principal possibilities are (1) gravity separation in situ, (2) multiple intrusion of previously fractionated partly crystallized magma, (3) flow-separation during intrusion.

The complete absence of feldspar phenocrysts in the rock rich in hornblende (original pyroxene) phenocrysts, and the absence of hornblende phenocrysts from the feldsparphyric rocks, indicate complete separation of the two phenocryst phases which would be unlikely if separation took place during intrusion. The close correlation (Fig. 5) between maximum phenocryst size and phenocryst content suggests gravity separation in situ. Since the maximum concentration of phenocrysts is near the top of the sill the plagioclase phenocrysts are thought to have floated. However, regular interbanding of feldsparphyric and non-porphyrific layers indicates that there may also have been some separation of plagioclase phenocrysts prior to intrusion - probably due to flotation in a magma body at depth.

MIDDLE LAMBOO COMPLEX

WHITEWATER VOLCANICS

A sequence of acid volcanics, mainly ashflow tuffs, in the southwestern corner of the Charnley Sheet area is referred to the Whitewater Volcanics (Dow et al 1964, Dow and Gemuts, in press) which occur extensively throughout the older Precambrian of the East and West Kimberley areas.

Field Occurrence

Outcrops of Whitewater Volcanics in the Sheet area occur as large roof pendants in granite, in the southwest. These are located 10 miles (16 km) east-northeast of King Creek Yard, 10 miles (16 km) south of King Creek Yard, 4 miles (7 km) northeast of King Sound Tin Mine and 2 miles (3 km) south of Mt Hart Homestead. The total extent of outcrop is about 55 square miles (150 km²).

The Whitewater Volcanics crop out as low rounded bouldery ridges that are generally less rugged than the adjacent Mondooma Granite. The ridges mostly have a thick covering of grass which gives them a light tone on airphotos.

The outcrops northeast of King Sound Tin Mine and east of King Creek Yard are conspicuously layered. In the former area the layering is subvertical: in the latter it dips northwards at around 30° . The other outcrops are less well mapped and their structure is unknown. The maximum thickness exposed in the Sheet area is estimated to be about 11,000 feet, but the full sequence is not exposed.

Lithology

In hand specimen the predominant rock type is a pale grey-green coarsely porphyritic ashflow tuff containing prominent phenocrysts (up to 6 mm) of bipyramidal quartz and of feldspar, and small patches of mafic minerals. As in the other Sheet areas the ashflow tuffs have been subdivided into crystal-poor and crystal-rich varieties. Where possible these have been delineated on the map. In hand specimen it is difficult to distinguish crystal-rich tuff from the Mondooma Granite.

A more mafic variant, generally found near the base of the sequence has been mapped as biotite-rich ashflow tuff. This rock type is dark grey in hand specimen, contains only sparse quartz phenocrysts, has conspicuous spots and lenticles of biotite, and is dacitic in composition in contrast to the more common rhyolitic and rhyodacitic types.

An unusual variant which forms a continuous flow near the base of the most northerly outcrop is a black aphanitic porphyritic andesite. This rock is apparently a lava rather than an ashflow tuff. Boulders of fine-grained grey-green non porphyritic andesite (probably lavas) have also been collected from stream beds draining the sequence containing the black andesite.

Contact Relationships.

In the Charnley Sheet area the Whitewater Volcanics overlie the Halls Creek Group but the contact is obscured. Evidence from the Lennard River Sheet area (Gellatly et al, 1968b) suggests that the Whitewater Volcanics there are unconformable on the Halls Creek Group. The Volcanics are overlain unconformably by the basal beds of the Speewah Group.

The Whitewater Volcanics are apparently intruded by the Mondooma Granite, but the contact has not been observed. This probable intrusive relationship however is well displayed on a large scale by the truncation of the layering of the Volcanics by the Mondooma Granite about 7 miles east-northeast of King Creek Yard (see 1:250,000 map).

Petrography

The majority of specimens from the Whitewater Volcanics are ashflow tuffs of rhyolitic, rhyodacitic or dacitic composition. Most of the ashflow tuffs are densely welded. Rare lavas present are andesitic. Most of the volcanics are porphyritic and contain both whole phenocrysts and phenocryst fragments and splinters. Phenocryst content tends to be slightly lower in the intermediate varieties than in the acid ones but this variation is not consistent. The average grain size of the phenocrysts ranges from 1 mm to 2 mm.

Quartz occurs typically as equant pyramidal grains which commonly show prominent resorption embayments. In one of the more densely welded examples quartz has broad turbid overgrowths. Plagioclase is the dominant feldspar in most specimens. Composition is around An₃₀ to An₄₀ but can rarely be determined because of intense alteration to sericite and clinozoisite. Clinozoisite tends to be more abundant near crystal cores (suggesting zoning from intermediate cores to more sodic margins) but scattered plagioclase are altered to clinozoisite throughout. Potash feldspar is generally a microcline microperthite of the "patch" variety and is unaltered. Probable sanidine has been noted in one sample. Grains of original pyroxene (probably pyroxene) are pseudomorphed variously by biotite + clinozoisite or by chlorite + specks of magnetite, and are locally streaked out into lenticles. Minor amounts of apatite, granular magnetite and zircon are associated with these mafic pseudomorphs. Ilmenite bordered by sphene, and pink zircon are accessories.

The matrix is generally a partly recrystallised aggregate of polygonal cloudy grains of quartz and feldspar. Flow lines curving round phenocrysts are generally evident. Rare glass shards are preserved as recrystallised quartz.

The porphyritic andesite differs texturally from the ashflow tuffs in its lack of crystal fragments and shards. Phenocrysts are entirely of highly altered plagioclase and of euhedral aggregates of epidote and associated magnetite-ilmenite that apparently pseudomorph original pyroxene. The matrix is a streaky devitrified glass containing microlites of possible pyroxene.

A further example of a possible andesitic lava contains rare microphenocrysts of augite and scattered microlites of plagioclase in a chloritic matrix.

Discussion

The Whitewater Volcanics in this area are of interest since they contain the first lavas to be recognised with certainty in the formation. Lavas may also occur elsewhere, for example in the southwestern part of the Lansdowne Sheet area (Gellatly et al, 1965) but there they are too altered to be recognised with certainty. It is of interest that in both the Charnley and Lansdowne Sheet areas all the probable lavas are of andesitic composition, and that most of these occur near the base of the formation.

MOUNT DISASTER PORPHYRY

The Mount Disaster Porphyry is named from Mount Disaster, in the Yampi Sheet area (Sofoulis et al, in prep). The Porphyry is found throughout the West Kimberley and is closely associated with the Whitewater Volcanics.

Field Occurrence

The Mount Disaster Porphyry crops out mainly southwest of Mount Hepple and along the Barker River south of Mount Hart homestead. Very small and scattered outcrops occur in the headwaters of Hawkstone Creek, along King Creek, and 10 miles (17 km) west of Mount Humbert. An isolated dyke of the Porphyry occurs in the Robinson River near the western Boundary of the Sheet area.

The Porphyry occurs as thick sheets and small steep-sided intrusions which form moderately rugged bouldery hills generally indistinguishable from hills of Mondooma Granite and, to a lesser extent, Whitewater Volcanics. In the Mount Hepple/Barker River area it forms light coloured tors with intervening sandy pediments, like the Lennard Granite.

Lithology

The Mount Disaster Porphyry is a coarsely porphyritic quartz feldspar porphyry of granitic composition. Pink to white phenocrysts of potash feldspar up to 1.5 cm predominate, and locally form ovoids up to 6 cm in diameter (Fig. 8a). Cream-green plagioclase and glassy to pale blue-grey quartz phenocrysts up to 1 cm across are also abundant. Biotite is the only obvious mafic mineral present. The groundmass is fine-grained. Dioritic xenoliths are common in the Barker River area. Small xenoliths of pale green to grey Whitewater Volcanics occur in the dyke in the Robinson River. The chilled margin of the dyke is grey and less coarsely porphyritic. Quartz and potash feldspar form phenocrysts up to 2 mm, (Fig. 8b).

Contact Relationships

Contacts with Halls Creek Group: The Mount Disaster Porphyry is in contact with the Halls Creek Group in the Hawkstone Creek area, about 7 miles east of the King Sound tin mine. The contact is not exposed, but it is inferred that the Porphyry intrudes the Halls Creek Group. In this area the Porphyry contains moderately abundant metasedimentary xenoliths (probably Halls Creek Group), mostly about 15 cm across.

Contacts with Whitewater Volcanics: At most localities these are intruded by the Mount Disaster Porphyry. Along the Barker River large xenolithic blocks of fine-grained crystal-poor ashflow tuff show sharp contact with the enclosing Mount Disaster Porphyry. In the Robinson River the porphyry dyke (Fig. 8b), transgresses the flow-foliation in dark fine-grained crystal-poor tuff, and is chilled against the tuff sequence. The chilled margin shows contorted flow-banding.

Possible reverse relationships are suggested in the Hawkstone Creek locality, where the Mount Disaster Porphyry and biotite-rich crystal tuff are intimately mixed. The tuff contains a xenolith of possible porphyry, and also xenocrysts of quartz and feldspar, probably derived from the porphyry.

Contacts with Mondooma Granite: The Mount Disaster Porphyry is probably older than the Mondooma Granite though the two units appear coeval in many places. The Granite locally contains lenticular coarsely porphyritic patches 8 cm to 30 cm across resembling the Mount Disaster Porphyry. These are concentrated mainly near the margins of the Granite. Contacts between these patches and the host rock are both sharp and gradational, and they probably represent xenoliths which differed little in composition and temperature from the Mondooma Granite at the time of incorporation. These features are more fully described in the section on the Mondooma Granite.

Contacts with Lennard Granite: The Mount Disaster Porphyry, is intruded by the Lennard Granite. The contact is well exposed about 6 miles west of Mount Hepple. It is sharp and irregular, and the Lennard Granite shows a chilled margin 4 inches (10 cm) wide. Dykes and sheets of aplitic granite in the contact zone, cut the Porphyry.

Petrography

Three thin sections have been examined, two of which are from the dyke in the Robinson River. Modal analyses are given in Table 2. Specimen 67.16.1055 represents the porphyritic centre of the dyke, and 67.16.1058 is typical of the chilled margin. Specimen 67.16.1054 is typical of the larger masses of Porphyry throughout the Sheet area.

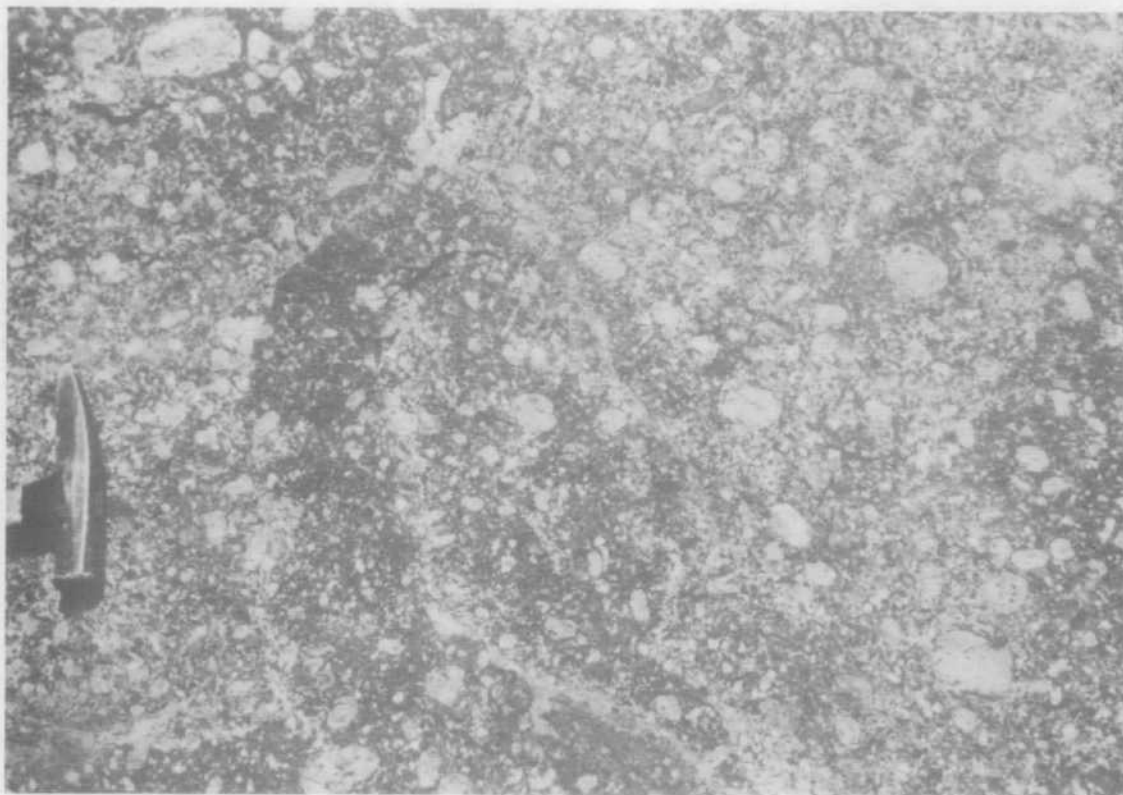


Fig. 8a. Highly porphyritic Mount Disaster Porphyry, with large ovoid phenocrysts of potash feldspar. Dark patches are due to weathering. 6½ miles east of King Sound Tin Mine. DCB.

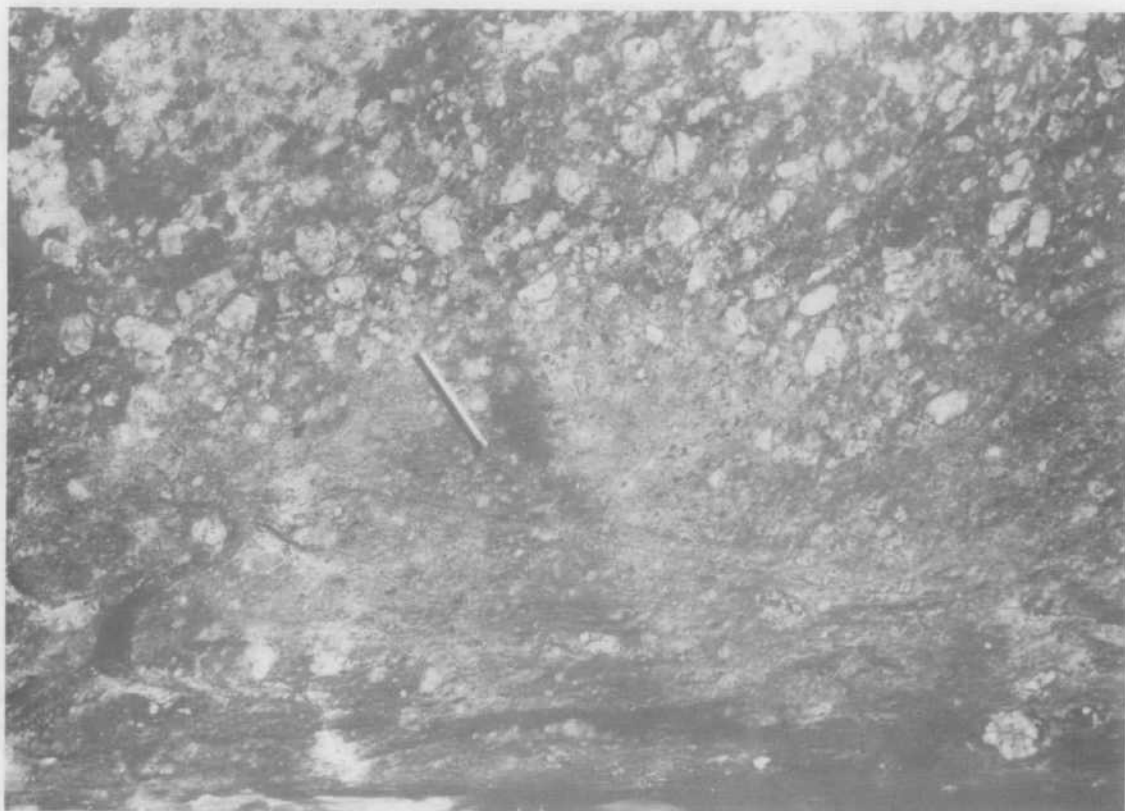


Fig. 8b. Dyke of Mount Disaster Porphyry showing phenocryst-rich centre and finer grained chilled margin, with rare large phenocrysts. Note orientation of phenocrysts at right angles to match stick. M 528, GMD. In Robinson River near western boundary of Sheet area.

TABLE 2.MODAL ANALYSES OF MOUNT DISASTER PORPHYRY

<u>Number</u>	R67.16.1055	R67.16.1058	R67.16.1054
<u>Locality</u>	1132 E 28835 N	2232 E 28835 N	2689 E 28741 N
<u>Phenocrysts</u>	25%	30%	45%
Quartz	16	12	13
Potash feldspar	4	7	4
Plagioclase	2	10	20
(Biotite	3 (bi)	1 (mu)	7
{ Muscovite°			
Hornblende	-	-	1
<u>Groundmass</u>	75%	70%	55%
Quartz	24	26	20
Potash feldspar	48	40	35
Mica (bi+mu)	1	1	-
Plagioclase	2	2	-
	<hr/> 100% <hr/>	<hr/> 100% <hr/>	<hr/> 100% <hr/>

The phenocryst content of the rocks and the relative proportions of the different phenocryst minerals vary widely.

The granular, highly potassic groundmass is typical. Optical methods and staining indicate an almost complete absence of plagioclase.

In most cases the porphyry is of granitic composition. Quartz phenocrysts are clear with slight undulatory extinction. Fine-grained polygonal aggregates are formed along microfractures in the larger quartz grains, which are embayed and marginally corroded. Potash feldspar forms subhedral to euhedral grains which are well aligned in the dyke rocks.

The grains are micropertthitic and show simple Carlsbad twinning; cross-hatching of the feldspar is rare and patchily developed. Plagioclase is highly altered to sericite and clinozoisite and the composition cannot be determined. In 67.16.1055 it forms very irregular, highly corroded grains. In 67.16.1054, the plagioclase contains granophyric intergrowths of quartz and potash feldspar.

Biotite is the dominant mafic. It generally occurs as elongate clots of fine-grained green-brown crystals. In 67.16.1054 it shows fawn to vivid red-brown pleochroism. Chlorite and clinozoisite are the main minerals associated with biotite. In one sample fluorite is developed along the biotite cleavage planes. Muscovite is common in the dyke rock, in which it poikilitically encloses part of the groundmass, and, less commonly, replaces potash feldspar phenocrysts. Green-brown hornblende occurs in 67.16.1054 and appears to post-date biotite and chlorite. Accessory minerals include zircon, apatite and iron ore usually associated with biotite, and fluorite and calcite. The latter two minerals occur in narrow veinlets with quartz and rare plagioclase. Allanite, showing strong zoning, forms grains up to 1.5 mm long in 67.16.1054.

Phenocryst Orientation in dyke rock.

The dyke in the Robinson River has a fine to medium-grained chilled margin which contains very rare large phenocrysts similar to those in the highly porphyritic centre of the dyke. The phenocrysts in the centre are aligned at a transverse to the dyke walls (Fig. 9). The orientation of the feldspar phenocrysts is possibly related to sinistral shear deformation along the dyke walls or alternatively may be due to irregular flow during intrusion.

MONDOOMA GRANITE

Introduction

The Mondooma Granite is named after Mondooma Yard in the Yampi Sheet area, and is fully defined in Sofoulis et al. (in prep). The Mondooma Granite consists essentially of porphyritic biotite microgranodiorite characterised by the presence of bipyramidal quartz phenocrysts. In places it closely resembles the crystal-rich phases

Figure 9:

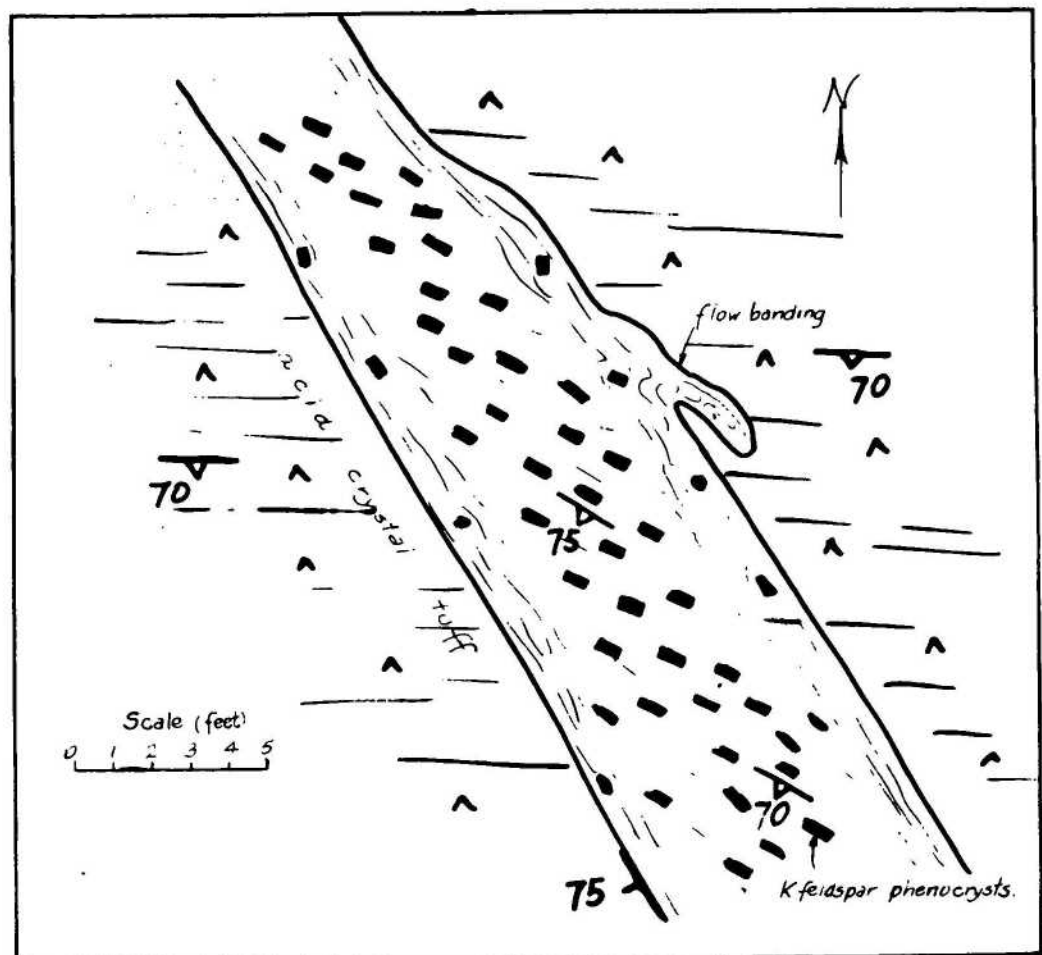


Fig.9: Sketch showing dike of Mount Disaster Porphyry cutting Whitewater Volcanics, in Robinson River 8 miles north-northwest of Federal Downs. Note oblique alignment of phenocrysts.

of the Whitewater Volcanics, and is also similar to and probably related to Bickleys Porphyry of the Lansdowne and Lennard River Sheet areas.

Field Occurrence

Distribution: The Mondooma Granite extends from the Barker River west and northwest to the margin of the Charnley Sheet area, and forms about two-thirds of the outcrop area of the pre-Carpentarian rocks. It is bounded in the northeast by the Speewah Group, and in the south by belts of Halls Creek Group and Whitewater Volcanics. This broad expanse of Mondooma Granite, totalling about 260 square miles (780 Km^2), is interrupted only by a series of roof pendants of Halls Creek Group, minor areas of Whitewater Volcanics and irregular intrusions of Lennard Granite. Scattered roof pendants of Mondooma Granite occur in the Lennard Granite east of the Barker River.

Topographic expression and Photopattern: The Mondooma Granite forms a monotonous series of dark rounded bouldery hills, especially from the Swift Creek area southeast towards Mount Matthew. Southwest of the Robinson River the hills are more widely spaced, and tracts of soil and alluvium are more abundant. Also the hills there are slightly elongate in a northwest direction.

Dissection along the multitude of intersecting joints in the Mondooma Granite has produced a trellised drainage pattern, and a marked large-scale segmentation of the outcrop (Fig. 2a). Photopattern of the Granite is dark grey and moderately smooth-toned, interspersed with black patches of vegetation-free boulders especially near the Lennard Granite. The photopattern of the Mondooma Granite is difficult to distinguish from that of the Whitewater Volcanics, though the latter tend to form lower hills and to show bedding-foliation trends.

The average elevation decreases from nearly 1200 feet along the foot of the King Leopold Ranges to about 800 feet in the far southwest. The tops of the hills are generally coincident, and are probably remnants of an erosion surface sloping gently to the west and southwest. Relief throughout the area is from 100 to 500 feet.

Lithology

The Mondooma Granite consists of coarse to medium-grained porphyritic microadamellite and minor porphyritic microgranite and microgranodiorite. A few specimens are non porphyritic. It varies from light to dark grey, grey-blue or pale fawn in colour. Discrete quartz phenocrysts from 2 mm to 5 mm are characteristic, and show a euhedral pyramidal form; some specimens contain anhedral quartz splinters similar to those found in the tuffaceous Whitewater Volcanics. The quartz dominates the appearance of the Granite in weathered outcrop, and generally forms up to 30% of the rock surface. Plagioclase and potash feldspar phenocrysts are less obvious, although both are widespread throughout the mass. They range from 2 mm to 1 cm, and occur singly or in thin discontinuous bands and patches. Mafic content varies widely, and appears to be lowest in the belt adjacent to the sandstone ranges south of Mount Humbert. Biotite is the principal mafic mineral. It occurs in clots of fine grained flakes or discrete plates. Laths of dark green amphibole up to 3 mm long are widespread, and show a highly altered yellow-brown core, possibly after pyroxene.

A common feature throughout the Granite are patches, lenticles, and discontinuous bands of coarsely porphyritic granite which resembles Mount Disaster Porphyry. These xenolithic remnants (Fig. 11a,b) are from 10 cm to 1 m long, and contain anhedral to euhedral alkali feldspar phenocrysts from 1 cm to 4 cm long, and locally ovoid phenocrysts up to 5 cm across. Contacts between these xenoliths and host rock are sharp to gradational, and some xenoliths are partly resorbed. Many of the large discrete potash feldspar phenocrysts in Mondooma Granite may in fact be xenocrysts derived by partial resorption of these xenoliths.

Form and Structure

Detailed information regarding the form of the Mondooma Granite is lacking because of its massive nature and the paucity of exposed contacts with other rocks. Foliations with gentle but variable dips measured in the Alexander Creek area suggest the granite there forms an undulating sheet. However, foliations elsewhere in the Mondooma Granite have steep dips. Observed contacts are steeply dipping, e.g. near the junction of Swift and King Creeks a roof pendant of Mondooma Granite has steeply dipping contacts with Lennard Granite and similarly the Mondooma Granite has steep contacts with roof pendants of Halls Creek Group east of Federal Downs.

Much of the Granite outcrop is massive and structureless except for joints trending northwest, north and northeast. Near contacts with Lennard Granite and Halls Creek Group a foliation is present, defined by alignment of phenocrysts or xenoliths, and by localised compositional banding.

Contact Relationships

Contacts with Halls Creek Group: The Mondooma Granite intrudes the Halls Creek Group, which forms three roof pendants up to 2 miles (3.5 km) across east and southeast of Federal Downs homestead. Flow banding in the granite is ubiquitous near contacts and is defined mainly by orientation of potash feldspar phenocrysts. Compositional banding of at least two types is also widespread, for example, near the Pardaboora River where bands up to 8 cm thick are defined by variations in mafic content. The bands show swirls and vague folds, and may be ghost relics of assimilated metasediment. Another type of banding, found along the eastern contact of the Pardaboora River inlier, consists of very thin laminae of non-porphyritic (metasomatised Halls Creek Group?) alternating with porphyritic Mondooma Granite rich in quartz phenocrysts (Fig. 14b). Elsewhere bands with abundant large potash feldspars also occur. Although such banding suggests assimilation of metasediment by Mondooma Granite, the Halls Creek Group is only slightly recrystallized at most other contacts. The Granite at one locality in the Alexander Creek area has a chilled margin 2 feet wide, while the Halls Creek Group is veined by quartz and some aplite. Xenoliths are common in the contact zones, and although slightly recrystallized, they retain their original lamination. Most are from 2.5 to 15 cm long, lenticular, fine-grained and biotite-rich.

Contacts with Whitewater Volcanics: In the Robinson River area the transition from crystal tuff of the Whitewater Volcanics to Mondooma Granite is inconspicuous, and marked only by a coarsening of the groundmass in the former, and abrupt changes of foliation direction between the two rock types. Platy xenoliths of ashflow tuff in the Mondooma Granite are evidence that the Whitewater Volcanics are intruded by the Mondooma Granite.

Contacts with Mount Disaster Porphyry: The numerous xenoliths resembling Mount Disaster Porphyry scattered throughout the Mondooma Granite indicate the latter is younger, although the varying degrees of assimilation of xenoliths and their diffuse margins suggest that the Porphyry may not have been completely crystallized at the time of intrusion of the Mondooma Granite and thus any age difference is very small.

Contacts with Lennard Granite: The Lennard Granite intrudes the Mondooma Granite, which is slightly hornfelsed and shows a coarsening of the groundmass. The more resistant nature of this contact zone is probably responsible for concentration of the massive black boulder outcrops around areas of Lennard Granite. About 2 miles (3.5 km) west of King Creek Yard the Mondooma Granite is cut by veins of a mafic-rich variety of the Lennard Granite. In the same area massive Lennard Granite becomes finer grained towards the Mondooma Granite and contains abundant flow-oriented tabular xenoliths parallel to the contact. These xenolith rich contact zones are described in the chapter on the Lennard Granite.

Contacts with Mount Amy Granite: About 4 miles (7 km) west of Federal Downs homestead small roof pendants of Mondooma Granite are heavily veined by large masses of aplite and tourmaline-bearing pegmatite of the Mount Amy Granite. Similar large aplite masses truncate the Mondooma Granite 2 miles (3.5 km) north of Alexander Creek. The mafic minerals in the Mondooma Granite are slightly recrystallized, and the granite has a thin 2 inch (5 cm) border which is more even-grained than usual.

Petrography

Both even-grained granite and porphyritic microgranite occur in the Mondooma Granite, and although differing texturally the two types are similar petrographically. Seventeen specimens have been examined in thin section, and their modal analyses and distribution are given in Table 3 and Fig 10 respectively. The modes were estimated from thin section and from rock slices stained for potash feldspar.

The phenocryst/groundmass ratio in the porphyritic rocks ranges from 3:1 to 2:1. Phenocrysts of quartz vary from 8 to 27% of the total rock, of plagioclase from 5 to 45% and of potash feldspar from 3 to 27%. Mafic minerals form from 3 to 10% of the suite.

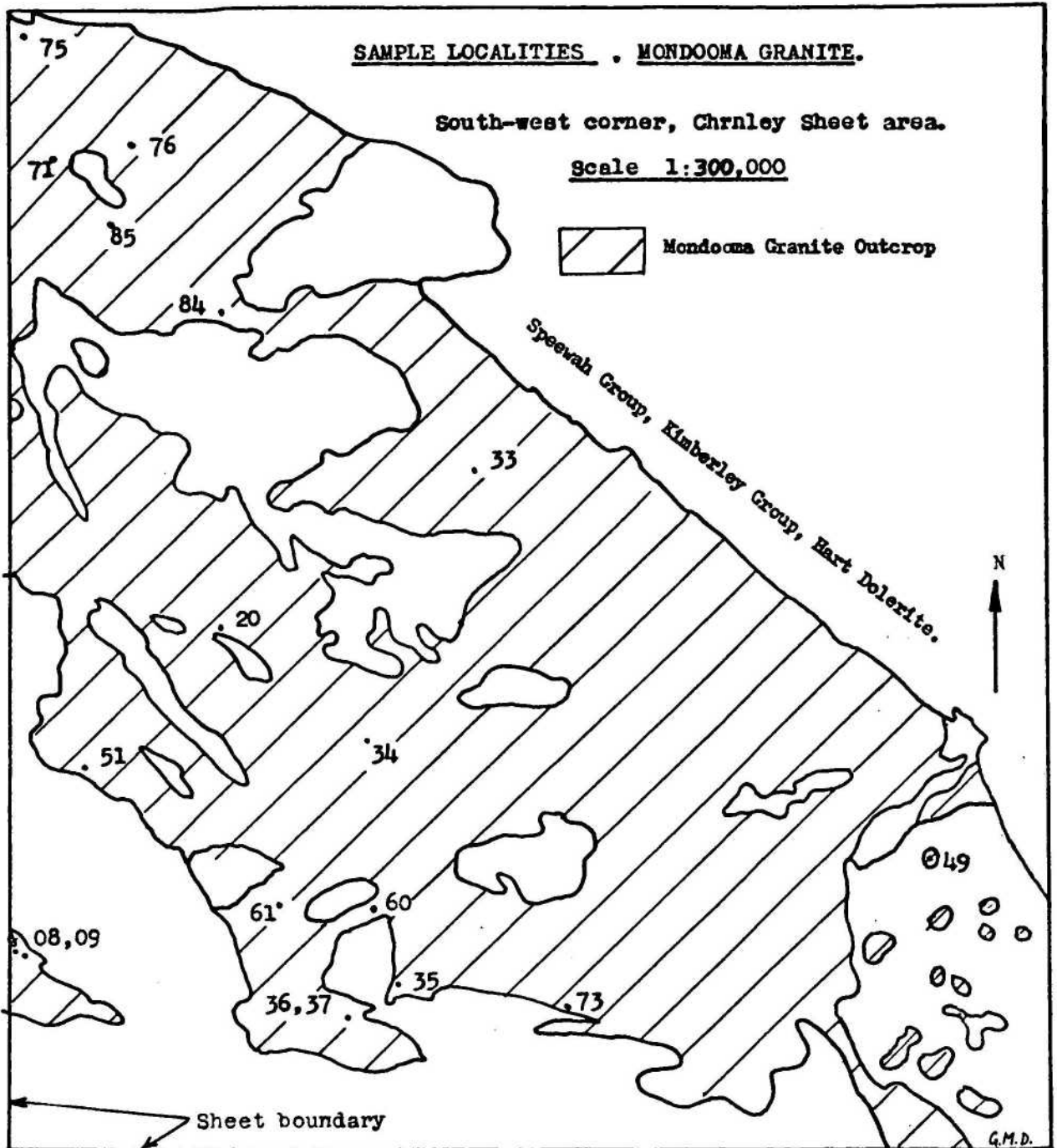
TABLE 3: ESTIMATES OF MODAL COMPOSITION - MONDOOMA GRANITE

Specimen No.*	66.16 1008	66.16 1009	67.16 1020	67.16 1033	67.16 1034	67.16 1076	67.16 1036	67.16 1037	67.16 1049	67.16 1051	67.16 1056	67.16 1061	67.16 1071	67.16 1073	67.16 1075	67.16 1076	67.16 1084	67.16 1085
Phenocrysts	65	90	100	50	100	50	60	60	55	75	65	60	65	60	70	65	55	75
Quartz	15	20	22	20	25	10	15	10	15	25	27	10	8	20	25	8	7	27
Plagioclase	25	45	40	15	30	17	30	35	30	12	5	25	28	10	25	35	35	15
K. feldspar	15	15	28	13	35	15	7	5	3	30	30	20	21	27	17	12	15	28
Biotite	10	2	4	1	5	8	8	10	4	8	3	5	4	3	3	10	-	5
Hornblende	-	3	6	1	5	-	-	-	3	-	-	-	4	-	-	-	-	-
Orthopyroxene	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Groundmass	35	10	-	50	-	50	40	40	45	25	35	40	35	40	30	35	45	25
Quartz	20	8	-	20	-	25	20	20	20	15	12	?15	?10	15	?12	15	15	10
K. feldspar	11	2	-	20	-	25	20	20	25	10	18	?15	?13	20	?12	20	25	15
Plagioclase	4	-	-	10	-	-	-	-	-	-	5	?10	?12	5	?6	-	?5	-
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Plagioclase phenocryst composition (average)	An ₄₁	An ₃₇	An ₄₀	+ An ₃₂	An ₃₇	An ₃₈	min. An ₃₀	An ₃₂	min An ₃₀	An ₄₂	-	min An ₃₀	An ₃₈	An ₄₃	min An ₃₀	-	-	min An ₃₂

+ Minimum value.

* B.M.R. Sample numbers. Location of samples shown in Figure 10.

Figure 10.



Quartz forms discrete clear phenocrysts from 1 to 7 mm (average 3 mm), which are subhedral to euhedral and commonly embayed and corroded. In rare cases grains are elongate, angular and completely anhedral, or are recrystallized to a fine-grained polygonal aggregate. Fine trails of dust-like inclusions are present. Most grains show a patchy and undulose extinction.

Potash feldspar (microcline - microperthite) generally forms clear subhedral to anhedral grains from 1 to 4 mm. Generally the microperthite is best developed in the centres of the grains, and the cross-hatching towards the margins. Zones of quartz blebs are prominent near grain margins, and in some cases limit the development of microperthite and cross-hatched twinning. The potash feldspar on both sides of the quartz bleb zone is usually optically continuous, but in two specimens feldspar in the zone between the quartz blebs and the grain margins forms distinct overgrowths with differing optical orientation from the phenocryst core.

Clouding of the potash feldspar with fine dusty ferruginous inclusions is widespread in rocks along the northeast margin of the older Precambrian cutcrop. Rocks with clouded potash feldspar form roof pendants in or occur at contacts with Lennard Granite.

Triclinicity values of 0.75 and 0.76, and compositions Or₉₄ and Or₈₄ have been calculated for two samples, 67.16.1033 and 66.16.1009, respectively.

Andesine ranging from An₃₀ to An₄₇ is the most abundant phenocryst mineral. It forms subhedral to euhedral grains from 0.6 to 5 mm (average 2mm) which show varying degrees of saussuritisation: the most intense alteration occurs in specimens which contain clouded potash feldspar. Values less than An₃₇ in the table of modal analyses are all minima, since intense alteration precluded accurate measurement. Normal, reverse, and oscillatory zoning are all present, and typically the zones are gradational over most of the grain. However, in many grains there is a sharp transition from zoned andesine to a narrow clear untwinned rim of sodic plagioclase, or, in rare cases, myrmekite. Table 4 shows the plagioclase variation within some zoned crystals.

TABLE 4.

ZONING IN PLAGIOCLASE, MONDOOMA GRANITE.

(Flat stage determinations using normal to a and combined Carlsbad/albite method).

<u>Sample</u>	<u>Type of Zoning</u>	<u>Composition</u> (\pm An ₅)
67.16.1020	Normal	An ₄₃ to An ₃₆ to sodic rim
67.16.1037	"	An ₃₇ to An ₃₅ to sodic rim
67.16.1035a.	Oscillatory/ reversed.	An ₃₇ to An ₄₄ to An ₃₅
b.	Normal	An ₄₇ to An ₃₃
67.16.1034	Normal	An ₃₈ to An ₃₂ to sodic rim
66.16.1008	Oscillatory/ reversed	An ₃₂ to An ₃₈ to sodic rim
66.16.1009	Normal	An ₄₇ to An ₃₆

Zones of quartz inclusions are present in plagioclase as well as in potash feldspar, though not to the same extent. They are particularly well displayed in sample 66.16.1009, which also contains many disrupted and corroded andesine phenocrysts.

Biotite forms either discrete plates from 1 to 2 mm or aggregates 2 mm across of fine-grained flakes. It occurs in nearly all of the samples, and is pleochroic from straw to red-brown or green-brown. Many of the plates are poikilitic, and enclose granular quartz, apatite, zircon, sphene, and iron ore. Clinozoisite is a common associate.

Amphibole occurs in seven of the samples. At least two types are present; a colourless to pale green actinolitic type which forms cores to most of the amphibole grains, and is intimately associated with an orange-brown alteration product; and hornblende, with X=fawn, Y=olive green and Z=dull green to deep blue-green, which forms irregular rims to the actinolite. The hornblende in particular poikilitically encloses quartz, plagioclase, and many of the accessory minerals. It occurs near the biotite but does not seem to be associated with it.

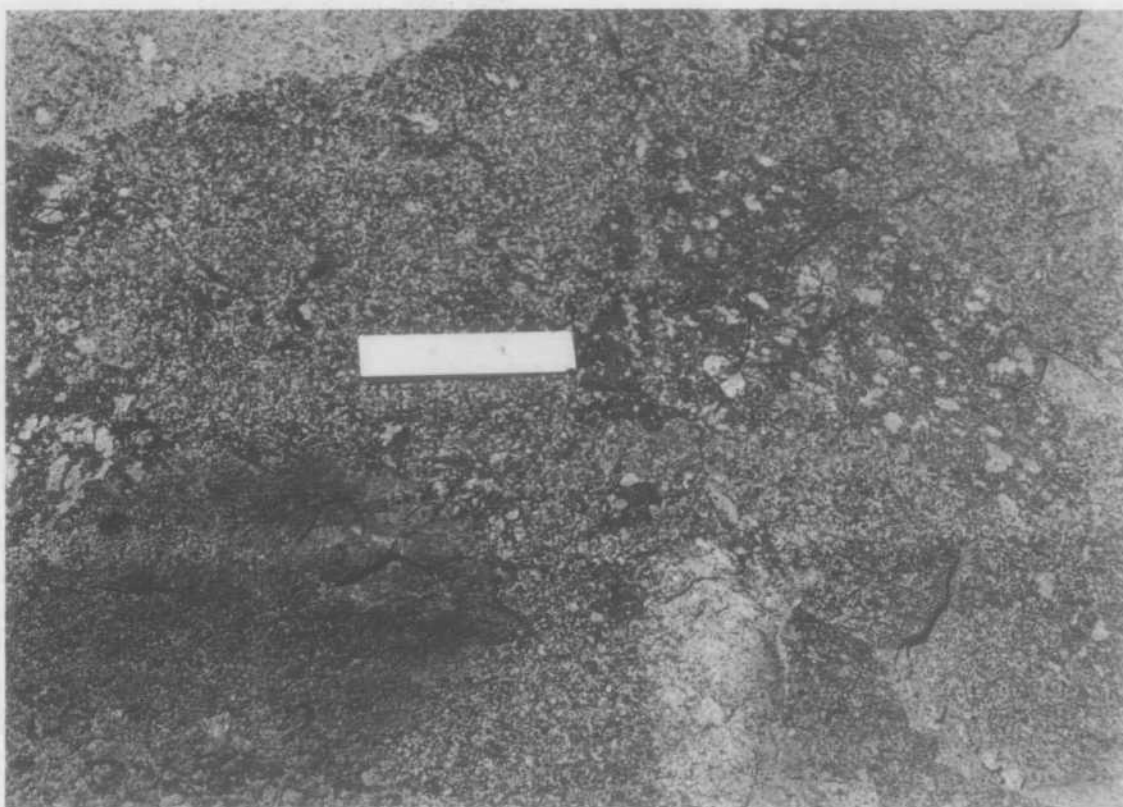


Fig. 11a. Discrete unassimilated angular xenoliths of Mount Disaster Porphyry in Mondooma Granite. Five miles east-northeast of King Sound Tin Mine. GMD.

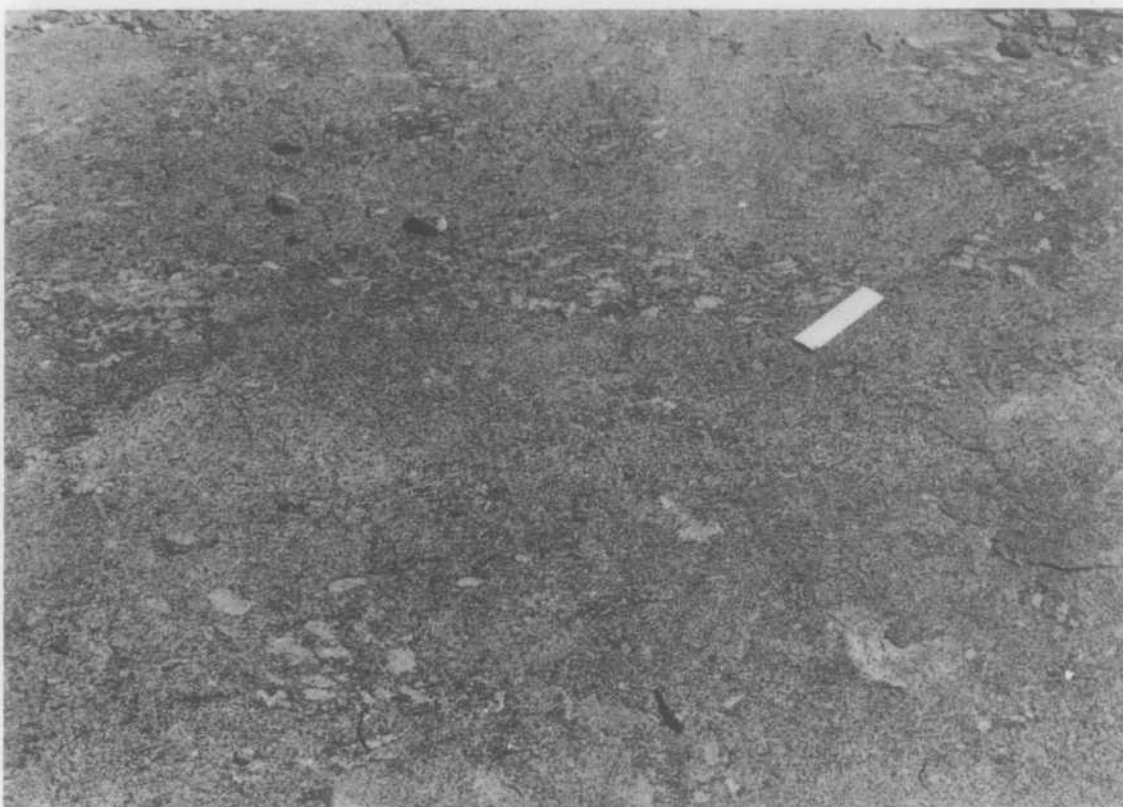


Fig. 11b. Lenticular partly-assimilated xenoliths of Mount Disaster Porphyry in Mondooma Granite. Note scattered phenocrysts probably derived from the xenoliths. Five miles east of Federal Downs, GMD.

Orthopyroxene (Fig. 12b) occurs only in specimen 66.16.1009 from near the Sheet boundary in the southwest (see also Sofoulis et al, in prep). It is faintly pleochroic, with X=very pale fawn, Y=pale fawn and Z-very pale green, and has an estimated 2V of 60° to 70° . Most grains are rimmed by a narrow zone of colourless to pale green actinolite and a broader zone of green-brown poikilitic hornblende. Extremely fine lamellar structure is present in some pyroxene grains.

In Table 5 a chemical analysis of a concentrate of this orthopyroxene is compared with analyses 16, 18 and 19 from Deer et al. (1963). The chemical analysis is directly comparable with eulite (Fs₇₀₋₉₀) and to a lesser extent ferrohypersthene, but contains significantly higher titanium and slightly higher calcium. This is possibly due to slight contamination of the sample by hornblende, which, as noted earlier, rims most of the orthopyroxene grains. The composition of the orthopyroxene from the estimated 2V is Fs₆₉ to Fs₇₇ (Deer et al., 1963).

TABLE 5.

CHEMICAL ANALYSES OF ORTHOPYROXENE, FROM MONDOOMA GRANITE
AND ELSEWHERE

<u>Sample</u>	<u>1.</u>	<u>2.</u>	<u>3.</u>	<u>4.</u>
SiO ₂	44.44	44.52	49.43	50.26
TiO ₂	5.60	1.39	0.17	0.16
Al ₂ O ₃	2.91	4.76	0.38	3.13
Fe ₂ O ₃ + FeO	38.07	39.92	34.95	27.19
MnO	0.80	0.28	1.19	0.76
MgO	5.17	6.59	12.96	16.36
CaO	2.23	1.40	0.71	1.76
Na ₂ O	0.17	0.39	(0.02	0.24
K ₂ O	0.25	0.19	(0.13
	<hr/>	<hr/>	<hr/>	<hr/>
	100.03	99.85	99.81	99.99
	<hr/>	<hr/>	<hr/>	<hr/>

1. Phenocrysts Mondooma Granite (R66.16.1009).
2. Eulite, granite.
3. Ferrohypersthene, ferrohypersthene-hornblende gabbro.
4. Hypersthene phenocrysts, augite-bearing hypersthene dacite.

Accessory minerals. Zircon is fresh, zoned and euhedral. Short prismatic crystals are predominant, but one grain in sample 67.16.1061 shows a length/breadth ratio of 9:1. Apatite is abundant, particularly as inclusions in amphibole. Sphene is widespread, and forms rims around ilmenite. The latter commonly shows a 60° exsolution pattern and alteration to cloudy leucoxene. Calcite occurs in one sample only.

In the groundmass quartz potash feldspar and minor plagioclase form an allotriomorphic granular aggregate. Myrmekite is developed between the groundmass and potash feldspar phenocrysts, as well as between the phenocrysts themselves.

Discussion:

Textures - The significance of textural variation in the Mondooma Granite is discussed in Sofoulis et al (in prep), where it is concluded that the Mondooma Granite is essentially a high level mass, parts of which have undergone rapid variations in magma-phenocryst equilibrium and rapid disruptive intrusion. Similar conclusions can be drawn from specimens of Mondooma Granite in the Charnley Sheet area. The triclinicity value of 0.75 for potash feldspar indicates a relatively rapid rate of cooling in contrast to the slow cooling of deeper seated batholithic granites. Variations in magma-phenocryst equilibrium are indicated by zones of quartz inclusions and overgrowths of alkali feldspar on alkali feldspar; this latter texture alternatively suggests that the cores of some of the feldspars may be xenocrystic. The presence of zoning in both plagioclase and potash feldspar is a further indication of rapid cooling of the rock at a high crustal level.

Coarsely Porphyritic Patches - All gradations are present between xenoliths of Mount Disaster Porphyry and porphyritic patches in the Mondooma Granite (Fig.11). These patches are of limited extent and large feldspar phenocrysts are generally absent except near the xenoliths. It seems improbable that the porphyritic patches are a direct result of crystallization from the Mondooma Granite magma since conditions of crystallization within a large body of acid magam are unlikely to vary over a distance as small as 10 cm. A more likely origin for the porphyritic patches is that Mondooma Granite magma was intruded into a body of Mount

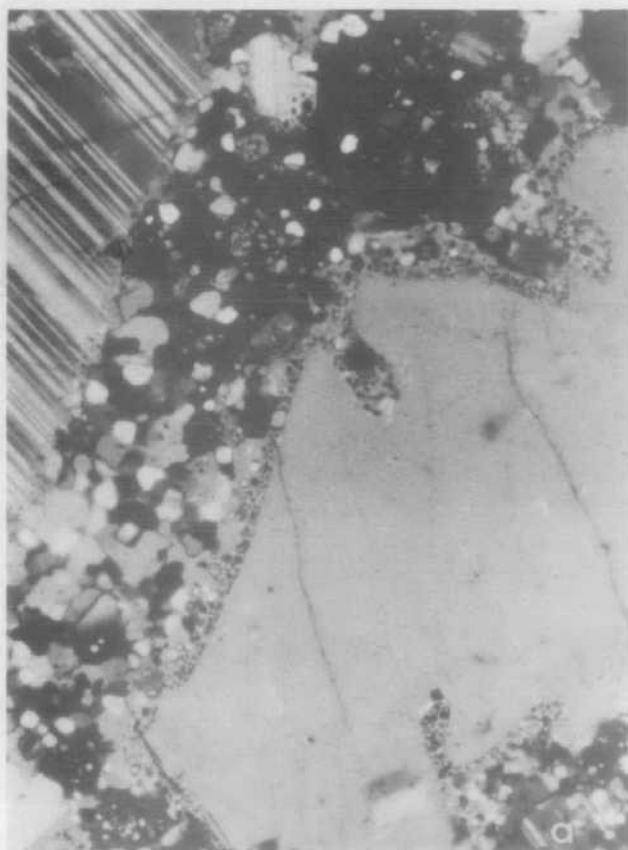


Fig. 12. Textural features of Mendooma Granite (a) Phenocrysts of plagioclase and partly resorbed potash feldspar both containing marginal quartz inclusions; x 28; crossed polarizers. (b) Orthopyroxene bordered by secondary iron oxide; x 28; crossed polarizers. (c) Typical porphyritic Mendooma Granite containing phenocrysts of plagioclase and potash feldspar (with marginal quartz inclusions in a medium-grained equigranular matrix studded with prominent quartz granules. x 36 crossed polarizers.

GMD.

Disaster Porphyry in varying stages of consolidation: completely consolidated Porphyry now forms discrete xenoliths, whereas incompletely crystallized material forms the diffuse xenoliths and dispersed xenoliths.

Absence of aplite and pegmatite - In contrast to the batholithic Lennard Granite, the Mondooma Granite is not accompanied by late stage aplite and pegmatite. This can be accounted for by loss of volatiles in the Mondooma Granite, which has crystallized and been intruded at a higher level than the Lennard Granite. Much of the volatile loss is probably due to extrusion of the Whitewater Volcanics as ashflow deposits prior to intrusion and crystallization of the related Mondooma Granite.

Correlations

The Mondooma Granite is equivalent to Bickleys Porphyry, in the southeast of the Lennard River Sheet area (Gellatly et al, 1968b). Orthopyroxene-bearing Mondooma Granite has no actual counterpart in the Bickleys Porphyry, but it does resemble the Little Gold River Porphyry from the Lansdowne Sheet area, which is a high level dacitic intrusion with 10% of ferrohypersthene similar to that in parts of the Mondooma Granite. The Little Gold River mass is also closely associated with and intrusive into the Whitewater Volcanics.

LATE LAMBOO COMPLEX.

LENNARD GRANITE.

The Lennard Granite is a coarse-grained leucocratic even-grained to porphyritic biotite granite, containing abundant, usually equant 2 cm. phenocrysts of potash feldspar. It locally resembles the Kongorow Granite but the latter is generally more mafic, and carries fewer and more elongate phenocrysts. The reference area is in the Lennard River Sheet area (Gellatly, et al 1968).

Field Occurrence.

Extent and location of outcrop: The Lennard Granite is exposed in the Charnley Sheet area between the Barker River and King Leopold Ranges, southwest of the Pardaboora River, along Swift Creek, near the headwaters of the Robinson River, and southeast of the King Sound Tin Mine.

Topography and Photo-pattern. In the Pardaboora River area and in the south of the Barker River area the Lennard Granite forms elongate northwest-trending whalebacks separated by narrow strips of sand. Elsewhere the granite is relatively poorly exposed; small domes and low whalebacks projecting through sand and soil cover are the usual forms, although monadnocks rising to over 300 feet (90m) above the plain are common in the Swift Creek area. The photo pattern is light-coloured because of soil cover, and contrasts sharply with the darker tonings and black boulder scree of the associated Mondooma Granite and Whitewater Volcanics.

Lithology.

The Lennard Granite is generally a mottled grey-white, leucocratic, coarse to medium-grained, even-grained to slightly porphyritic rock. It is usually massive, particularly in the Swift Creek area and southeast of Mount Hart homestead. Any foliation present is usually defined by alignment of phenocrysts and platy xenoliths. In general the intensity of foliation in the granite increases southwestwards from the King Leopold Ranges.

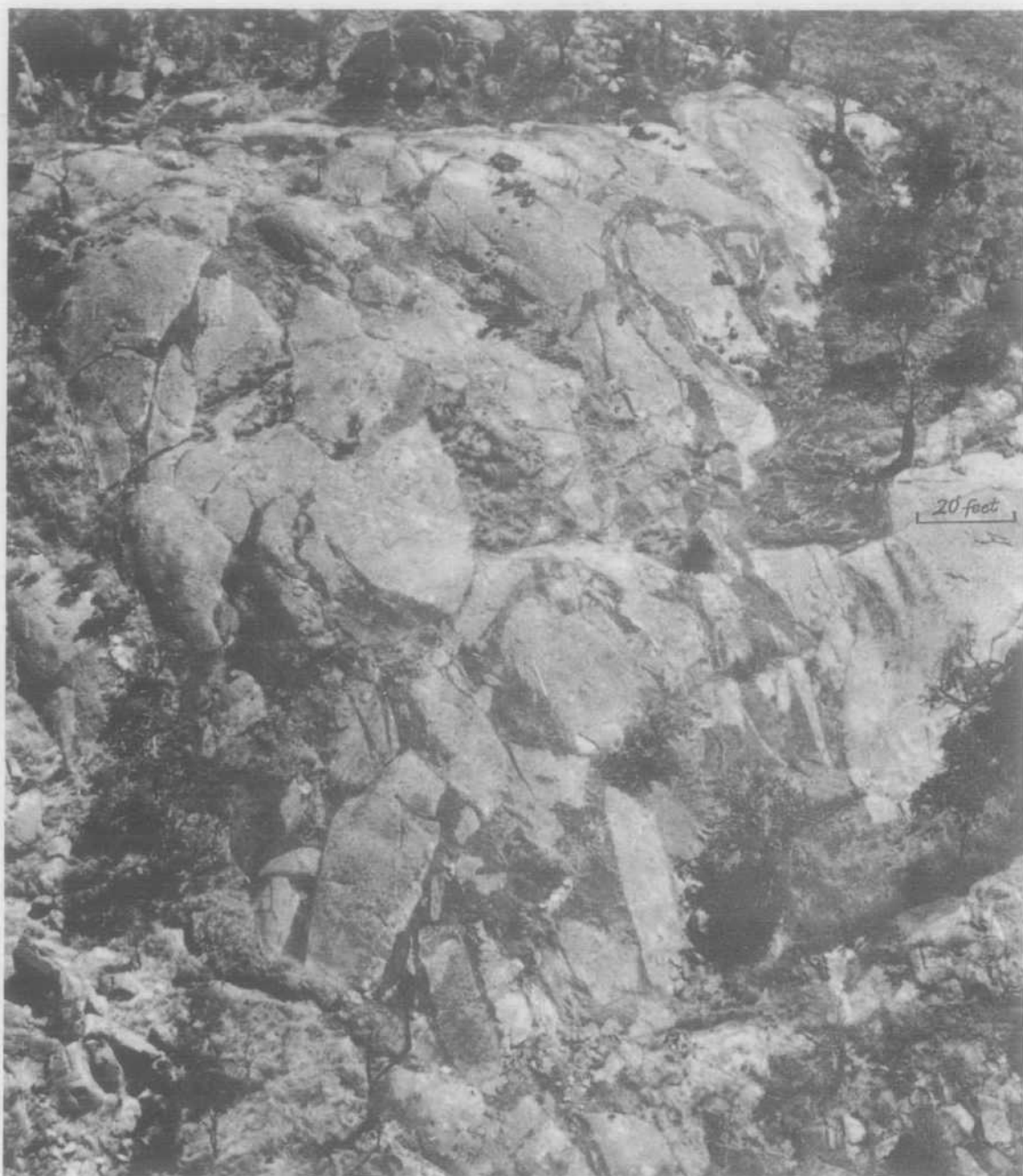


Fig.13. Aerial view of large-scale and intricate veining of Lennard Granite (light) by Kongorow (dark). Scale at right of photo. Locality about 2 miles southwest of Federal Downs. G.9653. GMD.

Contaminated, xenolithic and banded varieties of Lennard Granite are described separately.

Contact Relationships.

Contacts with Mondooma Granite: Lennard Granite intrudes Mondooma Granite with irregular but well defined contacts. At the contact zone the Lennard Granite is characterized locally by swarms of Halls Creek Group inclusions, and less commonly by scattered xenoliths of Mondooma Granite, which are generally flow-oriented parallel to the contact. The Mondooma Granite xenoliths range from small pieces to large blocks and slabs up to several feet across. Near the junction of King and Swift Creeks phenocrysts in the Lennard Granite become smaller and sparser close to the contact. Minor quartz veining, aplite and pegmatite veins are common in the marginal areas of the Lennard Granite. Rosettes of tourmaline intergrown with feldspar and muscovite occur locally. At some contacts the Mondooma Granite displays a thin (1.5 cm) recrystallised biotite-rich selvage.

Contacts with Mount Amy Granite: Lennard Granite is intruded by the Mount Amy Granite six miles (10 km) west of Mount Hepple. The Mount Amy Granite contains xenoliths of Lennard Granite near the contact; in the area south of Mount Hart it forms dykes and veins cutting Lennard Granite.

Contacts with Mount Disaster Porphyry: Dykes and veins of Lennard Granite cut Mount Disaster Porphyry adjacent to the Mount Hart road, near the southern margin of the Sheet area. Chilled margins up to 7 cm. wide occur in the Lennard Granite.

Contact with Halls Creek Group: At a contact between Lennard Granite and Halls Creek Group on the Pardaboora River about 2 miles (3 km) east-southeast of Federal Downs, veins of granite up to 6 inches (15 cm) wide and sub-parallel to the contact cut the metasediments. Apart from minor recrystallisation of muscovite there appears to be no significant contact metamorphism.

Contacts with Kongorow Granite are described in the section on that unit.

Petrography.

Detailed petrographic descriptions of specimens of Lennard Granite from the Charnley Sheet are given in GSWA Petrological Report No. 152 (R. Peers). Specimens of Lennard Granite are mainly medium-grained porphyritic adamellite containing phenocrysts of potash feldspar. The ground mass is composed essentially of quartz, microcline and plagioclase of a.g.d. 0.1 to 0.2mm. Grains are commonly anhedral with poorly defined boundaries. The texture of most specimens is xenomorphic granular. Estimated modal analyses of twelve specimens of Lennard Granite are given in Table 6.

TABLE 6

ESTIMATES OF MODAL COMPOSITION: LENNARD GRANITE

Charnley 1:250,000 Sheet Area

Spec. No.	K-Feldspar	Quartz	Plagioclase	Mafics
R67161044)	27	33	31	8
CH14-79-4)				
R67161045)	32	20	38	10
CH13-99-13a)				
R67161046)	50	40	5	5
Y14-29-2a)				
R67161047)	34	28	30	8
CH14-75-5a)				
R67161059)	40	38	15	7
Y14-31-28)				
Y10-02-1	30	25	35	10
Y11-02-2B	25	30	30	15
Y11-02-3	35	30	25	10
CH15-13-50	30	40	25	5
CH15-13-52	30	45	20	5

R prefix denotes BMR Registration Nos. Other numbers refer to GSWA specimens.

Microcline forms anhedral perthitic grains up to 10 mm., some of which contain quartz-filled microfractures. Quartz forms irregular grains up to 6 mm. which are commonly strained; the strain pattern in the quartz is parallel to a very weak foliation. Irregular patches of quartz are included micrographically in potash feldspar, and as vermicular blebs in plagioclase. Plagioclase forms subhedral to anhedral crystals (1-6 mm) which are zoned from andesine in the centres to oligoclase at the margins. Most grains are patchily saussuritised, and some smaller grains are almost completely replaced. Biotite in subhedral flakes (1-3 mm.) is strongly pleochroic with x=pale yellow, Y=straw yellow, and z=reddish-brown. In some specimens the original biotite has been partly or wholly altered to chlorite, muscovite and secondary green biotite. It usually occurs in fine-grained aggregates or as discrete crystals with a slight preferred orientation.

Zircon, apatite, epidote, and magnetite and ilmenite form inclusions in the biotite. Minor calcite is scattered through two specimens; several euhedral areas composed of brown amorphous material in specimen Ch. 14.79.1 are probably altered allanites.

Banding.

Prominent banding occurs in the Lennard Granite about $2\frac{1}{2}$ miles (4 km.) west of Federal Downs. The banded zone is from 3 to 6 feet (1-2 mm) thick, and 30 feet (10 mm) long, and forms part of a gently domed exfoliation pavement of granite.

The banding (Fig. 14a.) consists of alternate biotite-poor and biotite-rich layers in fine to medium-grained granite. The layers dip at 35° to the south, and generally show a sharply defined mesocratic base and an upward gradation into biotite-poor granite. The distance between the mafic-rich layers ranges from 2 to 15 cm, and they are more closely spaced towards the south of the outcrop (see Fig. 14a).

The zone overall grades into normal leucocratic Lennard Granite; on a smaller scale contacts between Lennard Granite and the biotite-rich bands are relatively sharp, but are gradational between Lennard Granite and the fine to medium-grained granite of the bands.

Petrography.

No thin sections of the bands are available. Staining for potash feldspar on cut surfaces and good exposures of quartz on weathered surfaces have allowed estimation of modal analyses across two typical bands. The sub-divisions of the bands are about equal.

TABLE 7 ESTIMATES OF MODAL COMPOSITION OF BANDED ROCKS IN LENNARD GRANITE.

	<u>biotite</u>	<u>quartz</u>	<u>potash feldspar</u>	<u>plag.</u>
(Upper	12	50	25	13
(
Band 1(Middle	8	35	28	29
(
(Lower	45	25	10	20
(Upper	10	50	30	10
(
Band 2(Middle	5	35	35	25
(
(Lower	25	30	20	25

Two types of quartz are present; one forms grains with an average diameter of 2.5 mm, while the other is generally interstitial to other minerals and occurs as grains from 0.5 to 1 mm diameter. The distribution of the coarser quartz defines a layering, while the finer type is more widely and evenly distributed through the rock.

Discussion.

The banding in the Lennard Granite has probably originated in one of two ways: by xenolith recrystallisation or primary magmatic layering.



Fig.14a: Banding in Lennard Granite. Band, covered by notebook shows good grading of biotite.
 Notebook 6 inches (10 cm.) long. Locality about $3\frac{1}{2}$ miles ($5\frac{1}{2}$ km.) west of Federal Downs.
 G9619, GMD.



Fig.14b: Probable relict sedimentary banding in Mondooma Granite close to contact with
 Halls Creek Group. Locality $3\frac{1}{2}$ miles ($5\frac{1}{2}$ km.) east of Federal Downs.
 GA 995 DCG.

If of xenolithic origin, spacing and grading of the bands, may reflect original bedding and grading in the recrystallised sediment, although such grading is possibly inverted through metamorphism. Partially resorbed xenoliths in the Yampi Sheet area show an irregular and streaky banding and a much lower granitic fraction than the banding under consideration here; recrystallised xenoliths forming swarms in the Charnley Sheet contain amphibole as well as biotite, and are associated with tonalite, neither of which have been found in this banding.

Rhythmically repeated mafic and granitic bands may be developed by crystal settling, magmatic currents and differentiation in situ. Examples of banded granitic rocks from Greenland, similar to those from the Charnley area, have been described by Emeleus (1963) and Harry and Emeleus (1960). There the layering typically occurs at high levels in the granite; trough banding, impersistent banding resembling sedimentary current bedding, and contorted structures attributed to slumping are present. In all occurrences a granitic magma with a high concentration of volatiles is postulated, in order to increase the time available for crystallisation and to lower the viscosity of the magma.

Abundant pegmatite, aplite, and quartz veining near the layering in the Charnley Sheet does indicate a higher concentration of volatiles than is usual in the Lennard Granite. This fact, together with the marked physical resemblance between this occurrence and known examples of layering suggests that primary magmatic layering is a more likely explanation of the banding than xenolith recrystallisation; however, there is little direct evidence to favour either origin.

Xenolith Swarms

Field Occurrence. Xenolith swarms are common in the Lennard Granite close to its contact with the Mondooma Granite. These xenolith swarms are particularly abundant at contacts in the vicinity of King Creek Yard where they probably form continuous zones along the margin of the Lennard Granite. However, through lack of outcrop and because of the reconnaissance nature of the mapping, it has been possible to delineate only isolated patches of xenolithic granite on the accompanying map.

The xenolith swarms are well developed in the middle of King Creek about 1 $\frac{1}{2}$ miles (2 $\frac{1}{2}$ km) and 3 miles (5 km) south of King Creek Yard. The xenoliths are angular to subrounded. Many are tabular in shape, suggesting derivation from bedded sediments. The size of xenoliths ranges from about 2 inches (5 cm) to 2 feet (0.6 m). The average size is about 8 inches (20 cm).

In many outcrops xenoliths make up about 30% to 40% of the rock. In others, particularly further from the contact xenoliths are sparse and diminish to around 1% or less. A poorly defined near-vertical flow foliation is present in some outcrops.

Most xenoliths are dark grey and fine-grained. Many show small scale lamination. Most are biotite-bearing homfelses of probable sedimentary origin. Rare examples are probably altered porphyritic ashflow tuff (Whitewater Volcanics?) and non-porphyritic amphibolite (Woodward Dolerite?). The two last mentioned types have been identified only in hand specimen, but one of the rocks examined in thin section may be an altered tuff.

The host rock for these xenoliths is a coarse-grained pale grey massive biotite tonalite which forms a marginal zone to plutons composed mainly of granite and adamellite. It is generally non-porphyritic, especially in the xenolith-rich outcrops, but becomes sparsely porphyritic in the more poorly xenolithic outcrops.

Petrography. Eight examples of the xenoliths have been sectioned. Four of the thin sections contain also patches of the enclosing granite. There is little difference between the xenoliths in macroscopic appearance, but two distinct petrographic suites are present. One is characterized by predominant quartz and plagioclase; and the other by abundant potash feldspar, generally with subordinate plagioclase, but with little or no quartz.



Fig. 15a: Xenolith-rich Lennard Granite near contact with Mondooma Granite. Xenoliths are metasedimentary. Swift Creek $1\frac{1}{2}$ miles southeast of King Creek Yard.
G 9715. DCG.



Fig.15b: Xenolithic Lennard Granite near contact Mondooma Granite. Note laminated nature of xenoliths. King Creek 2 miles south of confluence with Swift Creek.
G 9702. DCG.

Specimens in the first group (R67.16.1064-1067) contain abundant sericite-rich saussuritised tabular plagioclase crystals ophitically or sub-ophitically enclosed in quartz. Strongly pleochroic red-brown (locally with green-brown margins) to pale grey-brown biotite and a colourless fibrous ?amphibole are the predominant mafic minerals. This ?amphibole which is at present unidentified has low Z'c up to 24° and is neutral to very pale brown in colour. It is associated with, and is commonly peripheral to, lamellar twinned (locally untwinned) cummingtonite with Z'c = 15° and $2V_z = 70-80^{\circ}$. Small granules of opaque oxide (?magnetite) are common.

The second group (R67.16.1068-1070; 1018) is texturally variable. Most specimens are xenomorphic microgranites in which small equant grains of microcline-microperthite predominate over sericitized plagioclase. Quartz is rare or absent. Biotite is the dominant mafic mineral and is accompanied locally by a very pale brown ?sericitic mica. Small amounts of pale olive-green chlorite and opaque oxides are present. There are large areas of sericitic matrix which contain irregular, locally cusped patches composed of potash feldspar and pale brown microcrystalline micaceous material. The shapes of these patches are reminiscent of shards, suggesting that the rock may have been an ashflow tuff. If so, however, the absence of identifiable quartz is unusual.

The host rocks are mostly tonalites. However one specimen is a granodiorite in which highly altered plagioclase, quartz and biotite are the principal constituents. Potash feldspar where present is a slightly turbid microcline-microperthite. Minor constituents, mostly associated with biotite, include orthopyroxene, clinozoisite, chlorite, magnetite, apatite and pale pink-brown zircon.

The presence of abundant xenoliths in the Lennard Granite is unusual, but is paralleled by similar occurrences in the Lennard River Sheet area (Gellatly et al., 1968). The curious feature about the xenolith swarms in the Charnley Sheet area is that although the rock intruded is Mondooma Granite, the xenoliths consist entirely of metamorphosed equivalents principally of Halls Creek Group and rare examples of Woodward Dolerite and Whitewater Volcanics. The xenolith assemblage is even more surprising when it is considered that the nearest outcrop of Whitewater Volcanics is 4 miles (7 km) from the xenolith occurrences, and the nearest outcrop of Halls Creek Group is 11 miles (17 km) from them.

Any explanation is necessarily speculative. A suggestion that there has been flotation of country rock xenoliths towards the top of dome shaped intrusions of Lennard Granite is included in the discussion in ocellar hybrids below. This theory is doubtful since the xenoliths would be considerably denser than the enclosing granitic magma. The greater density of the xenoliths would depend partly on their composition they (contain more biotite and plagioclase than the granite) and partly on the density difference between magma and solid rock of the same composition.

Two alternatives are suggested. Firstly, that the xenoliths may have been carried upwards by flowage of a granitic crystal mush. Those near the contacts would have been trapped by rapid chilling whereas those in the main body of the intrusion would have tended to sink and would probably have undergone complete assimilation. Secondly (and perhaps less likely) that the Mondooma Granite, which must have been emplaced into a pre-existing complex of Halls Creek Group, Woodward Dolerite, and Whitewater Volcanics, was no more extensive before intrusion of the Lennard Granite than after it, and that the Lennard Granite advanced by stoping out of pre-existing more dense country rocks. This theory presupposes that the present contacts between Mondooma Granite and Lennard Granite are close to the original contacts between Mondooma Granite and older country rocks. If this theory is valid it means that the xenoliths have not been moved far from their original (pre-granite intrusion) location, and that they have been trapped almost in place, whereas material farther from the contact was stoped out and sank in the magma.

Other Xenolith Occurrences.

Xenoliths other than those described above are sparse in the Lennard Granite. They range from patches one inch (2 cm) or so across to roof pendants 300 feet (90 m) across. Most of these xenoliths consist of porphyritic microgranite or acid porphyry. Most are tabular, and the average diameter is from 6 to 12 inches (15 to 30 cm). They are only slightly concentrated at the margins of the granite.

In the area south of Mount Hart homestead large xenoliths of porphyritic microgranite form resistant tops to many of the low granite rises. The xenoliths appear slightly hornfelsed, and biotite is locally redistributed and recrystallized to form mafic-rich margins.

Thin sections of these xenoliths show that they contain quartz, plagioclase and potash feldspar phenocrysts in a microgranitic groundmass. Biotite and muscovite are the mafic minerals; clinozoisite, zircon and sphene are the chief accessories. Quartz in the groundmass is intergrown granophyrically with potash feldspar. The quartz phenocrysts are generally fractured and show undulatory extinction. These microgranites resemble and are probably related to the Mondooma Granite, Mount Disaster Porphyry and Whitewater Volcanics.

Contaminated Granite with Quartz Ocelli.

A contaminated variant of the Lennard Granite is closely associated with the Mondooma Granite in the Robinson River - Swift Creek area 3 to 8 miles (5 to 14 km) north of old Federal Downs homestead. The granite forms massive, rounded bouldery hills rising to 400 feet (130 m) above the plain, and resembles the Mondooma Granite in photo pattern and topography.

Field Occurrence The contaminated granite has been noted at four localities. It is a grey massive coarse-grained porphyritic adamellite to granodiorite, characterized by marked textural inhomogeneity. Euhedral to anhedral white plagioclase grains from 3 mm to 2 cm are the most common phenocrysts. Some contain biotite inclusions arranged zonally. Quartz ocelli (Fig. 16a) are abundant, and are rimmed by a dark green mafic corona up to 1 mm thick. These ocelli are from 2 mm to 1 cm diameter, and are usually subrounded or slightly elongate. In some cases the margins of the ocelli are gently curved and indented. Biotite grains up to 1.5 cm diameter and amphibole grains up to 3 mm are also present. The ground mass consists of quartz, grey feldspar and spots of hornblende.

Relationships with adjacent rock types are not known, although at one locality the contaminated granite encloses a patch of Mondooma Granite. No contacts have been seen.

Petrography Two thin sections from each of two specimens were examined. Estimated modal analyses of these two specimens are listed in Table 8.

TABLE 8: ESTIMATES OF MODAL COMPOSITION - CONTAMINATED LENNARD GRANITE

	66.16.1021	67.16.1038
Quartz (ground mass)	29	27
Quartz ocelli	3	3
Plagioclase	20	25
K feldspar	35	30
Amphibole	2	3
Pyroxene		1
Biotite	10	10
Accessories	<u>1</u>	<u>1</u>
	<u>100%</u>	<u>100%</u>

The most striking feature of these rocks is the presence of quartz ocelli (Fig. 16a). In specimen 67.16.1038 these are seen to be rounded to elongate and slightly embayed grains up to 1 cm across, surrounded by a rim of amphibole, pyroxene and minor biotite. In specimen 66.16.1021 the rims are entirely amphibole and biotite. The quartz occurs as large single grains or as groups of 2 to 3 smaller grains which contain abundant very fine-grained inclusions and have slight undulatory extinction. Rare large grains of potash feldspar, amphibole and biotite are developed in marginal areas of the large quartz ocelli; euhedral zircon and a single grain of tourmaline also occur as inclusions.

The mafic rims are about 1 mm wide, and contain clinopyroxene, red-brown biotite, and two varieties of amphibole: the following optical properties apply also to the same minerals in the host rock away from the rims. Clinopyroxene is very pale green but is non-pleochroic. The optic axial angle is about 60° , and $Z'c$ about 37° . This diopsidic augite occurs adjacent to the quartz ocelli, inside the hornblende rim. Two types of amphibole are present: the older variety is pale green, with pleochroism X=colourless to pale green, Y=pale green-brown, and Z=apple green. It has replaced some of the pyroxene rims, and also forms rims around pyroxene grains in the remainder of the rock.

FIGURE 16 a

SHAPES OF QUARTZ OCELLI natural scale density and distribution diagrammatic.

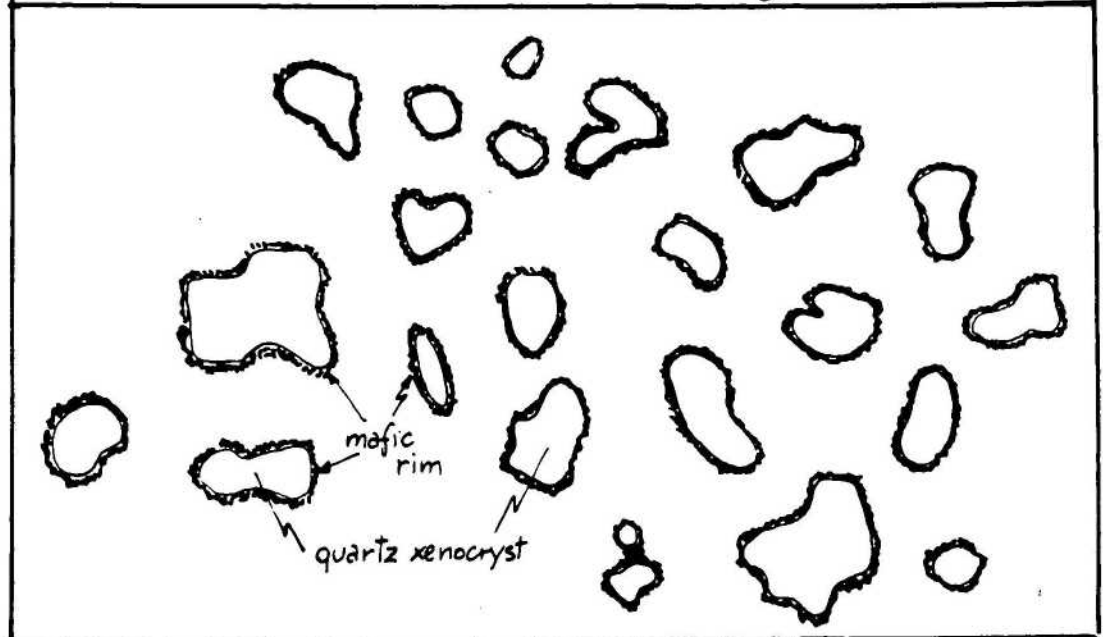
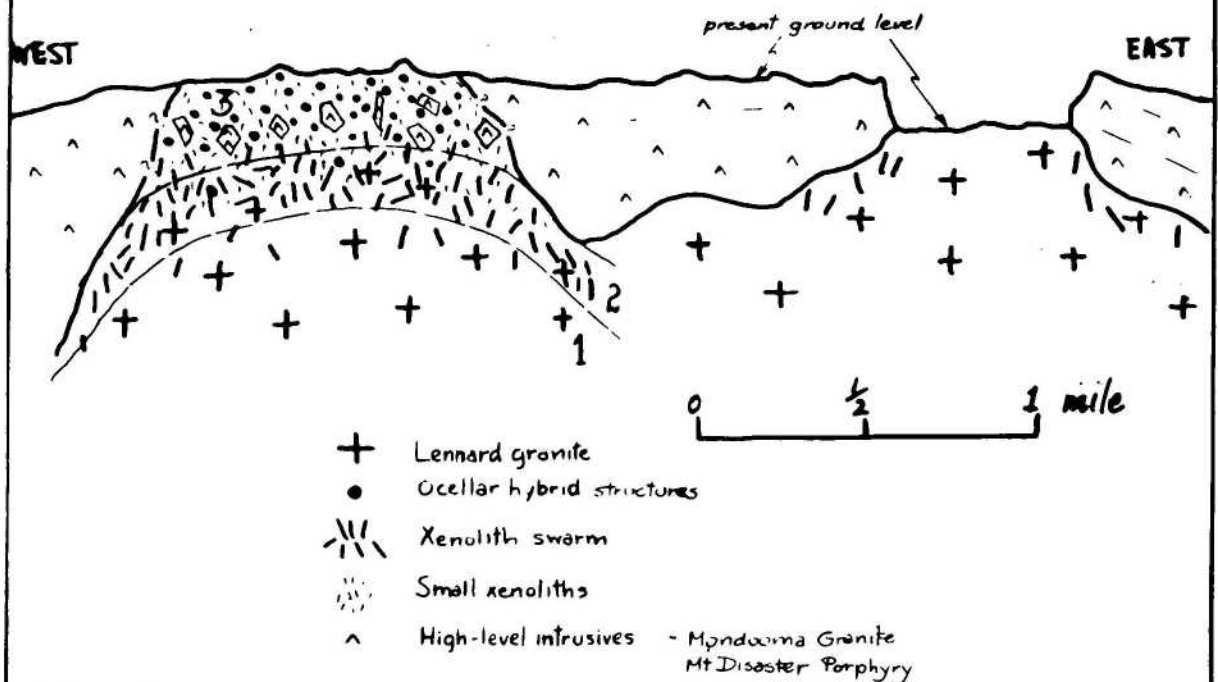


FIGURE 16 b.

DIAGRAMMATIC SECTION - POSTULATED RELATIONS BETWEEN OCELLAR HYBRID and ASSOCIATED ROCKS.



ZONE 1: Normal Lennard Granite with some xenoliths

ZONE 2: Lennard Granite contaminated by metasedimentary xenoliths concentrated along margins and roof of intrusion.

ZONE 3: Further contamination of contaminated Lennard Granite by assimilation of Mondooma Granite etc; subsequent crystallisation of hybrid rock containing quartz ocelli.

This variety is in turn being replaced by a common hornblende, with pleochroism X=fawn, Y=green-brown, and Z=olive green to dull blue-green. It also has partly replaced pyroxene. Extinction angles are from 14° to 20° for the pale green variety, and 23° to 26° for the green-brown hornblende.

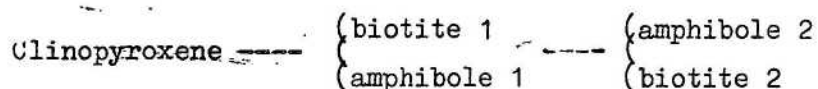
In the remainder of the rock anhedral plagioclase phenocrysts up to 1 cm long are highly saussuritised in sample specimen 6616.1021, but are fresh in 6716.1038.

Two varieties of biotite occur; an older dull brown fine-grained type associated with pale green amphibole and partly replaced by green-brown hornblende; and the fresh poikilitic red-brown plates which enclose quartz, plagioclase and potash feldspar. This type contains abundant acicular rods of ?rutile arranged at 60° intervals in the basal plane of the mica. Radioactive zircon and apatite inclusions, and ilmenite rimmed with sphene are also abundant.

The two types of amphibole present in the mafic rims are also widespread throughout the remainder of the rock. Rare clinopyroxene grains with amphibole rims are also present. Most of the groundmass is a quartz-potash feldspar-plagioclase aggregate with a.g.d. 0.8 mm.

Xenoliths and Mafic Patches. Small xenoliths present range from amphibolite to xenomorphic mesocratic granodiorite. The amphibolite contains a green amphibole, deeper in colour than the pale green amphibole described above. It shows pleochroism X=pale fawn, Y=pale green-brown, and Z=apple green, and occurs as anhedral to subhedral laths forming up to 70% of the xenolith. It is associated with abundant clinozoisite, plagioclase, biotite and quartz. Other xenoliths contain anhedral grains of twinned microcline, and altered plagioclase. Small amounts of quartz are present, and also pale fawn to pale orange-brown biotite. Patches of sphene are very common.

The suite of mafic minerals in these rocks shows the following reaction series:-



Amphibole 2 and biotite 2 both form large poikilitic plates, and although in contact in many places no reaction is evident between them.

Origin of Quartz Ocelli and the Contaminated Granite. Quartz ocelli have been recorded from many localities. Theories concerning the origin of these structures vary widely. Most authors are agreed that they are associated with hybrid rocks in which basic magma has assimilated acid material, or vice-versa. The quartz ocelli were called "birds-eye" quartz by Wells and Wooldridge (1931), and occurred in a considerably modified gabbroic xenolith in granite. Although the quartzes appeared xenocrystic, they were considered to have been "liberated from a hybrid magma at a late stage of crystallization". An inner rim of augite and an outer rim of hornblende characterised the ocelli described by Thomas and Smith (1932), who thought they were a direct result of hybridisation of norite by a granitic fraction. The hornblende occurred throughout the rock, and was a late stage alteration of the original pyroxene. They also considered the quartz to be a result of concentration of a residual silica-enriched liquid derived from alteration of hypersthene to augite and biotite i.e. development of quartz preceded the development of the mafic rims. Muir (1953) showed that augite crystallised around quartzite xenoliths to form large-scale ocellar structures, and was subsequently altered to hornblende. The ocelli described by Angus (1962) have hornblende rims with minor relict pyroxene, and have been produced from basalt inclusions by acid fluid metasomatism. The quartz is porphyroblastic in type, and grew from plagioclase-quartz-hornblende intergrowths by silica addition. Expulsion of iron and magnesium during the growth of the quartz created a minor basic front and contributed to the development of the mafic rims. Phillips (1968) recorded the presence of quartz ocelli, but remarked only that they were a product of hybridization.

The quartz ocelli in the Charnley region show no evidence of a porphyroblastic origin from basaltic inclusions (Angus, op cit), nor do they appear to be metasomatic silica infillings of voids following the development of mafic rims (Thomas and Smith, op cit). It is most likely they are xenocrysts, and that the clinopyroxene rims are a product of early crystallization from a contaminated granite-granodiorite magma, as was postulated also by Muir (op cit.). Clinopyroxene appears to have crystallized in the groundmass of the hybrid as well as around the quartz xenocrysts, and in both cases has been subsequently completely or partly altered to pale green amphibole and common hornblende. The xenocrysts have acted as bases or nuclei for crystallization of the early clinopyroxene phase.

The source of this postulated hybrid magma is unlikely to have been either the Mondooma Granite or Mount Disaster Porphyry, because of the lack of quartz phenocrysts in the groundmass of the contaminated granite, but assimilation of either of these rock types could have provided the quartz xenocrysts. The most likely parent magma is probably a non-porphyritic phase of the Lennard Granite which has previously been slightly contaminated by assimilation of basic and pelitic xenoliths. The postulated sequence of events is shown in Fig. 16b.

KONGOROW GRANITE

The Kongorow Granite, comprises a suite of various biotite-rich porphyritic granites which are widespread throughout the older Precambrian of the West Kimberley. It is named from Kongorow Pool, in the Lennard River Sheet area and is defined by Gellatly et al (1968).

Field Occurrence.

The Kongorow Granite occurs in a restricted belt within the Lennard Granite 2 miles (3 km) southwest of the abandoned Federal Downs homestead. It forms a large-scale net-veined complex, with Lennard Granite and nowhere forms large homogeneous exposures. The granite is dark grey and mesocratic, coarse-grained and porphyritic. Phenocrysts of potash feldspar up to 3 cm long are more abundant than quartz and plagioclase phenocrysts. The quartz phenocrysts in many cases consist of a sugary aggregate of finer grains. Muscovite is a common accessory.

Along with the associated Lennard Granite, the Kongorow Granite forms low whalebacks and smooth exfoliated rock pavements.

Contact relationships

Whereas Kongorow Granite of both pre and post-Lennard Granite age has been tentatively recognized in Lennard River Sheet area, only the younger variant is present in the Charnley Sheet area. Contacts with the Lennard Granite are most striking. The Kongorow Granite intrudes the Lennard Granite, forming localised net-veined complexes (Fig. 13), in which blocks of Lennard Granite up to 40 feet (12 m) across are common. The foliation in the separate blocks is essentially parallel to that in other blocks, which suggests that rotation of the blocks in the veining or brecciation process has been minimal. Contacts are generally sharp, and flow foliation in the Kongorow Granite parallels the contacts. Along contacts an aplitic selvage is usually present. Aplite and pegmatite veins and dykes, with abundant black tourmaline, are ubiquitous in the net-veined complexes.

Petrography

No thin-sections are available from the Charnley Sheet area. The Kongorow Granite here is similar to the type b Kongorow Granite described from the Yampi Sheet area. (Sofoulis et al., in prep) which is a quartz-rich biotite granite.

MOUNT AMY GRANITE

The Mount Amy Granite is named after Mount Amy in the Lennard River Sheet area. In the Charnley Sheet area the Mount Amy Granite forms small scattered outcrops near the Mount Hart track east of the Barker River, and in the southwest of the Sheet area about 6 miles (10 km) west of Federal Downs. The granite is highly weathered, and forms low rises, pavements and small bouldery hills associated with abundant sand and soil. The principal rock type is a medium to fine-grained muscovite adamellite. In the southwest it forms a small plug-like intrusion a few hundred feet across associated with veins of tourmaline pegmatite and aplite.

Contact relationships

Veins of Mount Amy Granite intrude the Lennard Granite and Mondooma Granite, and show narrow chilled margins. In the southwest the muscovite granite contains roof pendants up to 100 feet (30 m) across of Mondooma Granite, which is highly veined by tourmaline-bearing pegmatite and aplite. Nearby sediments of the Halls Creek Group are feldspathized, tourmaline-enriched and veined by quartz. A very local occurrence of andalusite sillimanite-biotite-muscovite-quartz granofels is possibly related to the thermal effects of this small intrusion of Mount Amy Granite.

Petrography

One specimen has been examined. It is muscovite adamellite with a hypidiomorphic granular texture. Quartz (45%) is clear and unstrained, and forms polygonal aggregates. Plagioclase (30%) is fresh and well twinned, of composition An_{8-10} . Rims of myrmekite are abundant, and grow into microcline microperthite (20%) showing some Carlsbad twinning. Muscovite (4%) forms flakes 1 to 2 mm in diameter which enclose quartz and some plagioclase sub-poikilitically. Biotite (1%) is pale fawn to deep brown and forms stringers through the rock. Accessories are iron oxide and orange-green chlorite.

Discussion

As in the Lennard River and Yampi sheet area the Mount Amy Granite is one of the youngest stages of igneous activity in the Lamboo Complex, and is probably genetically related to the Lennard Granite. The contact metamorphic andalusite-sillimanite granulites represents the highest grade of contact metamorphism yet found in the west Kimberley. Although a small plug of Mount Amy Granite is tentatively thought to be responsible for this degree of metamorphism, the "aureoles" of both the Mount Amy and Lennard Granites elsewhere in the west Kimberley characteristically contain meta-sediments of only low metamorphic grade.

DYKES

Dolerite

Dolerite dykes are rare in the Charnley Sheet area compared to other parts of the West Kimberley especially to parts of the Lennard River Sheet area, Gellatly et al. (1968). The most notable dykes intrude the Kimberley Group and belong to the Hart Dolerite (q.v.). Others intrude the older Precambrian: they are from 0.5 to 8 miles (0.8 to 14 km) long and from 5 to 30 feet (1.5 to 9 m) wide. They intrude mainly the Lennard and Mondooma Granites, and trend northwest and northeast. Most are dark green to grey, fine to medium-grained, and show a relict sub-ophitic texture; some are variously amphibolitized or chloritized. These dykes may be earlier than and distinct from the Hart Dolerite.

Quartz Syenite

A quartz syenite dyke intrudes Lennard Granite about 8 miles (14 km) south of Mount Hart homestead, beside the Mount Hart track. It is about 4 feet (1 m) wide, and trends north-northwest for about one-third of a mile. Quartz is notably deficient in the rock, which is

grey-green and coarse-grained. Between the syenite and granite a narrow zone 2 to 5 cm thick contains abundant quartz grains, which appear to be a result of local diffusion and reaction between the two rock types. In thin section, perthitic potash feldspar (45%) is anhedral, clouded, intensely fractured and partially chloritized. Anhedral albite of An_5 (35%) contains fine inclusions of chlorite and mica, and has microfractures. Quartz (8%) is interstitial to feldspar, and forms anhedral and fractured grains. The mafic minerals (8%) are fine-grained biotite and chlorite forming aggregates and stringers. Associated with abundant zircon and apatite, and iron ore. Calcite (4%) is widespread throughout.

The dyke is slightly folded and microscopically deformed, and has probably been intruded at about the same time as dolerite in the area.

Aplite and pegmatite

Where exposures are sufficiently extensive aplite and pegmatite are mapped as part of the Mount Amy Granite. They also form comparatively isolated dykes up to $\frac{1}{2}$ mile (1 km) long and 2 to 35 feet (0.5 to 10 m) wide. Most are homogenous pink to grey aplite, fine-grained and porphyritic in places. Some are composite and have a central core of tourmaline pegmatite. Contacts with the enclosing rocks are sharp, and contact metamorphism slight.

Quartz veins and plugs

Quartz veins are widespread in the older Precambrian rocks and range from gashes a few inches thick to massive reefs at least 4 miles (7 km) long. Small quartz veins occur in the Halls Creek Group, usually subparallel to bedding and cleavage. They are lenticular, and usually contain large patches of green chlorite. Larger quartz veins from 50 feet to a $\frac{1}{2}$ mile long (15 to 800 m) and 2 to 10 feet (0.6 to 3 m) wide are also present in the Halls Creek Group. Some are

intimately associated with the Hawkstone Creek kyanite deposit and the King Sound Tin mine (see Economic Geology).

Within the granites quartz veins occupy curvilinear joints which trend north to northwest. A major shear zone trending east-west near the Robinson River contains abundant en echelon quartz gashes which diminish in abundance eastwards.

A group of at least six quartz plugs intrudes the Mondooma Granite near the Robinson River headwaters. They are roughly circular, and range from 50 to 120 feet (15 to 40 m) in diameter. All project between 20 and 40 feet (5 and 10 m) above the plain level and one or two form ring structures. The quartz is massive white and unmineralised, and has prominent horizontal jointing.

CARPENTARIAN

SPEEWAH GROUP

The older Precambrian rocks, described in the preceding chapters are overlain unconformably by early Carpentarian sediments of the (structural) Kimberley Basin. The Kimberley Basin Succession, which consists mainly of quartz sandstone, comprises the Speewah Kimberley and Bastion Groups.

The Speewah Group (Gellatly et al, 1965) overlies the Lamboo Complex with a major unconformity, and it is conformably overlain by the Kimberley Group. The Speewah Group comprises the following formations (1) O'Donnell Formation; (2) Tunganary Formation; (3) Valentine Siltstone; (4) Lansdowne Arkose; (5) Luman Siltstone. Definitions of these units are given in Gellatly et al (1965).

As a result of facies changes taking place northwestwards along strike from the Lansdowne Sheet area (from which the Speewah Group was redefined) the constituent formations of the Group can be recognised only with difficulty, and none can be traced as far west as the boundary

with the Yampi Sheet area. The nature of the westwards disappearance of the Speewah Group remains uncertain, but it seems likely that it is due more to a combination of lithological variations (particularly the disappearance of siltstone) and thinning of the sequence, rather than to removal by erosion as in the southeastern corner of the Lansdowne Sheet area and parts of the Mount Ramsay Sheet area (Roberts et al., 1965).

O'DONNELL FORMATION

Stratigraphic Relationships

In the Charnley Sheet area the O'Donnell Formation lies unconformably on the Whitewater Volcanics and non-conformably on the Mondooma and Lennard Granites. It is overlain conformably by the Tunganary Formation and is intruded by the Hart Dolerite. To the west it passes laterally into sandstones that have been mapped as King Leopold Sandstone in the Yampi Sheet area.

Distribution and Topographic Expression

The formation forms a narrow northwest trending outcrop in the southwest, from near Mount Hepple to Humbert Creek. The lower part mostly forms a single escarpment and narrow dip slope whereas the upper part forms the lower part of a poorly developed scarp slope capped by the lower beds of the Tunganary Formation.

Lithology

In the Lansdowne and Lennard River Sheet areas the O'Donnell Formation consists essentially of coarse quartz sandstone (lower part), and siltstone (upper part). In the Charnley Sheet area these divisions have been recognised near the southern border, but to the northwest, near Humbert Creek the upper part consists almost entirely of coarse quartz sandstone and granule conglomerate.

The lower part of the formation consists mainly of white, pale fawn, pale grey and very pale rust brown, medium to coarse, well-sorted quartz sandstone, and minor granule and pebble conglomerate. In the south near Mount Hart homestead the basal beds consist of pebble and cobble conglomerate. At higher levels the pebbles become smaller and conglomerate gives way to sandstone. Pebbles range from sub-angular to rounded and are mainly of vein quartz, phyllite, and quartzite, and rare altered dolerite. Bedding ranges from thin to thick; parting is blocky to massive. Individual conglomerate beds are about 20-30 cm thick. Sandstones interbedded with the conglomerates are coarse-grained, locally granule-bearing, and have a friable ferruginous matrix. Conglomerates diminish in abundance and become finer grained westward. Near Humbert Creek the basal beds consist of pale fawn coarse-grained thinbedded quartz sandstone, and granule conglomerate.

The upper part of the O'Donnell Formation is rarely present directly overlying the lower part in the Charnley Sheet area, but is present at least locally overlying Hart Dolerite and underlying the Tunganary Formation but obscured by detritus from it. In the south the upper part consists essentially of laminated grey-green siltstone, and minor white and fawn fine to coarse quartz sandstone, locally containing magnetite lenticles. A measured section of this is given in Table 9. To the west the upper part becomes more arenaceous and consists of white to pale rust brown coarse-grained thin to thick bedded, blocky, well-sorted quartz sandstone and granule conglomerate which locally contain thin tourmaline-rich beds. Thin partings of grey-green siltstone on bedding planes are all that remain of the characteristic silt component that predominates to the southeast.

Thickness

The thickness of the O'Donnell Formation in this area is uncertain because of extensive intrusion by the Hart Dolerite and consequent uncertainty as to the completeness of most sections. Over much of its length the preserved thickness underlying the Hart Dolerite is

TABLE 9 O'DONNELL FORMATION - SECTION D1

Section about (5 miles) 8 km west-southwest of
Mount Hepple. Measured by R. Halligan.

Overlain conformably by Tunganary Formation

O'Donnell Formation

Thickness
(metres)

- 56 Siltstone: dark green, red-brown weathering, crudely laminated, siltstone.
- 4 Sandstone and siltstone: white, coarse-grained, strongly cross-bedded quartz sandstone with magnetite stringers up to 1 cm thick; crossbedding comprises many short, steep units: interbedded with flaggy, pale brown weathering, very fine-grained, greenish, locally cross-bedded, laminated siltstone.
- 4 No exposure.
- 2 Quartz sandstone: Greenish-brown weathering fawn and green, fine-grained, very poorly sorted massive siliceous quartz sandstone: contains highly contorted beds near the base.

Hart Dolerite.

- ca 100 Quartz sandstone and pebble conglomerate: forms a prominent ridge: not examined in detail: thickness estimated from air photographs.

166 metres

NONCONFORMITY

100 ft (30 metres) feet or less. The full thickness of the formation probably ranges from about 300 to 550 feet (90 to 165 metres). No complete section has been measured. The only complete sequence, about 6 miles (10 km) northwest of Mount Humbert, is estimated from air photographs to be about 350 feet (105 metres). A section of probable Upper O'Donnell amounting to 216 feet (60 metres) has been measured a short distance southeast of Mount Hart, and the Lower O'Donnell a few miles southeast at Inglis Gap (Lennard River Sheet area) is estimated from air photographs to be about 350 feet (105 metres), giving a total thickness of around 550 feet (165 metres) about the southern boundary of the Charnley Sheet area. Considered in conjunction with a thickness of 1715 feet (520 metres) near Sandy Creek Gorge (Lennard River Sheet area) these figures indicate a general northwest thinning of the O'Donnell in this area.

TUNGANARY FORMATION

Stratigraphic Relations

The Tunganary Formation conformably overlies the O'Donnell Formation and is conformably overlain by the Valentine Siltstone in the south near Mount Hepple. In the west near Humbert Creek there is more or less a continuous sandstone sequence indicated on the map as "Speewah Group undifferentiated" comprising the Tunganary Formation, possible Valentine Siltstone (not exposed) and Lansdowne Arkose. It is intruded by, and largely overlies the Hart Dolerite.

Distribution and Topographic Expression

The Formation forms a narrow discontinuous outcrop near Mount Hepple in the south. It has been recognised in the field 35 miles (55 km) to the northwest near Humbert Creek but has not been traced for much of the intervening distance because of the similarity of its topographic expression and photo-pattern to those of the Lansdowne Arkose and King Leopold sandstone.

In the south the Formation variously forms the lower part of the prominent southwestern escarpment of Mount Hepple, and a narrow steeply dipping strike ridge. To the northwest, between Mount Matthew and Mount Humbert, it probably forms the lower parts of the steep southwestern slopes of the King Leopold Ranges.

Lithology

Near the southern border of the Sheet area coarse and medium-grained silica-cemented quartz sandstone predominates; quartz granule conglomerate, feldspathic sandstone, and green-grey and blue-grey siltstone and shale are subordinate. To the northwest near Humbert Creek medium-grained quartz sandstone predominates and siltstone and shale are absent.

Cross-bedding is well developed in some of the sandstones: A prominent lamination is a feature of others.

Thickness

No thickness has been measured near the southern margin of the Sheet area. The thickness near Humbert Creek is probably about 250 feet (80 metres) - a considerable reduction from the 500 feet (160 metres) measured in the Lennard River area and 740 feet (230 metres) in Lansdowne, but it indicates a continuation of the northwestward thinning already established for this formation.

VALENTINE SILTSTONE

The Valentine Siltstone is rarely exposed in the Charnley Sheet area and very little is known about it. The formation has been mapped mainly on the basis of its topographic expression and on isolated occurrences of siltstone detritus. Volcanic material which is characteristic of the formation farther to the southeast has not been recognised with certainty in the Charnley Sheet area.

The only exposure noted - on the southern slopes of Mount Hart - consists of a dark red powdery ochreous rock (altered volcanic?) overlain by poorly exposed pink-maroon siltstone. To the southeast near Mount Hepple and to the northwest near Humbert Creek float of similar dark red-brown weathered ferruginous siltstone has been noted.

No definite information is available on thickness.

LANSDOWNE ARKOSE

Stratigraphic Relations

The Lansdowne Arkose is conformable on the Valentine Siltstone and is conformably overlain by the Luman Siltstone.

Distribution and Topographic Expression

The Lansdowne Arkose forms a narrow northwest-trending outcrop from near Mount Hepple to Humbert Creek. It may extend westwards from Humbert Creek to the western boundary of the Sheet area but it cannot be distinguished there from the King Leopold Sandstone.

Near Mount Hepple it forms bold strike ridges bounded above and below by narrow soil covered valleys of Valentine and Luman Siltstone, both generally intruded by valley-forming Hart Dolerite. To the northwest of Mount Hart it forms the southwestern escarpment of the King Leopold Range; there is no distinct topographic upper boundary to the Lansdowne Arkose there, but a prominent short white dip-slope probably marks the top of the formation. In this area the base of the Lansdowne Arkose cannot be recognised and the Speewah Group has not been divided into its constituent formations.

Lithology

In the Charnley Sheet area the Lansdowne Arkose (which was named from the Lansdowne Sheet area where feldspathic sandstone and arkose predominate) consists of quartz sandstone and minor feldspathic sandstone.

Near Mount Hepple, where the formation is well exposed, it consists of medium to coarse white silica-cemented quartz sandstone. Sorting is good. Feldspar is rare, and some interstitial sericite is present. In outcrop the formation is mostly thick bedded and blocky to massive: laminated sandstones are present locally.

Six miles (10 km) northwest of Mount Humbert feldspathic sandstone is absent; quartz sandstone predominates and is associated with poorly-sorted quartz granule conglomerate containing quartz granules up to 5 mm.

Cross-bedding is common in the formation. The upper part locally contains well-developed festoon cross beds which are characteristic of the Lansdowne Arkose in parts of the Lennard River Sheet area. Palaeocurrent directions were from the northwest.

Thickness

A thickness of about 1,100 feet (350 m) has been estimated 3 miles (5 km) northwest of Mount Hepple, and about 500 (150 m) northwest of Mount Humbert. This represents a progressive thinning northwestwards from Mount Ord in the Lennard River Sheet area where a thickness of 2700 feet (850 m) has been measured.

LUMAN SILTSTONE

Stratigraphic Relationships

The Luman Siltstone is conformable on the Lansdowne Arkose and is conformably overlain by the King Leopold Sandstone. There is no direct evidence in the Charnley Sheet area or elsewhere for the suggested unconformity at the base of the King Leopold Sandstone (Dow and Gemuts, in press). The formation thins westwards.

Distribution and Topographic Expression

The Luman Siltstone forms a narrow discontinuous northwest-trending outcrop in the southwestern part of the Sheet area from near Mount Hepple to Humbert Creek. It may extend further westwards on the southern side of the King Leopold Range, but it cannot be recognised there on air photographs. The formation is poorly exposed and has been mapped largely on its photopattern and stratigraphic position. Between Mount Hart and Humbert Creek its presence is indicated only by a very thin, gently dipping soft bed overlying a short white dip slope of Lansdowne Arkose.

Lithology

Because of poor exposure few lithological observations are available. About 5 miles (8 km) southeast of Mount Hepple (about 2 miles (3.5 km) south of the southern boundary of the Charnley Sheet area) good exposures have been examined. The dominant lithology here is purple-grey siltstone with sporadic thin interbeds and nodules of cream siltstone. The rock is massive in outcrop, but because of its well-bedded nature it is flaggy in hand specimen. Elsewhere in the Mount Hepple/Mount Matthew area red-brown and khaki siltstone predominates: this grades into greenish fine-grained sandstone near the contact with the overlying King Leopold Sandstone. Towards the northwest of the Luman Siltstone becomes more arenaceous and near Mount Humbert is represented by only a thin (ca 10ft (3 m)) bed consisting of dark red-brown to purple-brown quartz sandstone and laminated white and dark purple-brown quartz sandstone with varying amounts of hematite.

Thickness

The formation thins from about 120 feet (35 m) near the southern boundary of the Sheet area to about 10 feet (3 m) near Mount Humbert.

TABLE 10 SPEEWAH GROUP - SECTION S1

Estimated section of part of Speewah Group 9 km northwest of Mount Humbert. Distances paced; lithological details by D. Gellatly.

Overlain by probable King Leopold Sandstone. (pale buff, coarse grained, very thick bedded, blocky to massive, poorly sorted silica-cemented quartz sandstone).

SPEEWAH GROUP

Luman Siltstone (?)

Thickness
(metres)

ca 3 Quartz sandstone: dark purple brown, and interlaminated pale buff and purple, fine-grained, flaggy, well-sorted, friable quartz sandstone; poorly exposed.

Lansdowne Arkose (?)

74 Quartz sandstone: white to pale pink-brown coarse-grained thin to thick bedded, blocky to massive, quartz sandstone; some are slightly sericitic - may have been originally feldspar-bearing; well developed festoon cross-beds locally.

10 No outcrop - alluvium in valley bottom.

16 Quartz granule conglomerate: white to pale buff, thick-bedded, blocky to massive, granule conglomerate and coarse-grained, poorly-sorted, quartz sandstone; gives way upwards to coarse-grained, well-sorted quartz sandstone: cross-beds indicate currents from west and northwest.

- 3 Quartz sandstone: white, medium-grained, thick-bedded, well-sorted quartz sandstone.
- 50 Quartz granule conglomerate: white to pale buff, thick-bedded, blocky to massive, poorly-sorted quartz granule conglomerate: contains granules up to 5 mm: cross beds indicate current directions from northwest.
- 17 Quartz sandstone: pale pink-brown, medium-grained, well-sorted quartz sandstone.

Valentine Siltstone?

- 5 No outcrop: detritus of dark red-brown siltstone and shale.

Tunganary Formation

- 42 Quartz sandstone: pale pink brown and pale grey, medium to coarse grained, thick-bedded blocky, well-sorted quartz sandstone; contains scattered grains of feldspar and prominent tourmaline grains.
- 30 Feldspathic sandstone: white to pale pink medium-grained, thick-bedded, blocky, feldspathic quartz sandstone; feldspar is highly altered, and makes up 5% to 10% of the rock.
- 5 Quartz sandstone: white to pale pink and pale red-brown thick-bedded, blocky, well-sorted quartz sandstone.
- 3 Quartz granule conglomerate: pale buff, very coarse grained, thick-bedded, blocky, clean-washed granule-bearing, quartz sandstone and granule conglomerate.

O'Donnell Formation

105 Quartz sandstone: coarse-grained quartz sandstone and
granule conglomerate with partings of grey-green
siltstone.

Total 363 metres

KIMBERLEY GROUP

The Kimberley Group overlies the Speewah Group conformably and is unconformably overlain by the Mount House Group.

The Kimberley Group comprises the following formations (1) King Leopold Sandstone (2) Carson Volcanics (3) Warton Sandstone (4) Elgee Siltstone (5) Pentecost Sandstone. The first three of these occur extensively; the Elgee Siltstone and Pentecost Sandstone are represented only by small outcrops. As far as is known relationships between the constituent formations of the group are conformable everywhere in the Sheet area.

KING LEOPOLD SANDSTONE

Distribution and Topographic Expression

The King Leopold Sandstone is widely distributed throughout the Sheet area except for the southwestern corner. The total area of outcrop is about 3,000 square miles - some 50% of the Sheet area.

The King Leopold Sandstone forms bold cliffs and escarpments along its southwestern margin. Cliffs are well developed also where fault or joint fractures are deeply eroded, and where the formation is intruded by sills of more easily weathered Hart Dolerite. This is particularly marked in the northeast, around Mount Jamieson and Mount Shadforth. Elsewhere the King Leopold Sandstone variously forms rugged, rocky butte topography and gently undulating sandy plains with scattered low rocky outcrops. Outcrops are mostly massive with good partings.

Lithology

The formation consists of a monotonous sequence of white to pale buff coarse-grained quartz sandstone. Near the base it contains scattered pebbles 1 cm to 5 cm in diameter, appears poorly sorted, and commonly has a small amount of clayey matrix. Most of the sequence

consists of well-sorted, coarse to medium-grained, thick-bedded, silica-cemented quartz sandstone with well rounded grains, and commonly shows well developed cross-bedding. Most of the sandstone weathers to a very pale rust brown. Leaching of the silica cement has taken place to varying degrees in surface outcrop, but silica-cemented sandstone is ubiquitous at the bottom of river gorges. Localised surface resiliification is also found. Generally this is confined to the outer 2 cm or so of outcrops which consist internally of friable poorly cemented sandstone.

Thickness

Insufficient dips have been measured in the area to allow computation of the thickness. A thickness of 2,700 feet (800 m) has been estimated 9 miles (15 km) east-southeast of Mount Ord in the Lennard River Sheet area, and a section 3,600 feet (1100 m) thick has been measured near Mount Nellie in the Yampi Sound area. The thickness in the Charnley Sheet area probably lies between these two values.

CARSON VOLCANICS

Distribution and Topographic Expression

The Carson Volcanics form broad elliptical outcrops surrounding the Harding, Synnot and Barnett Ranges, and a broad belt on the southwestern flank of the Phillips Range extending northwestwards to near Beverley Springs homestead.

The Carson Volcanics form broad lowlands with low rounded hills interspersed by pediments with a veneer of red-brown soils and by scattered areas of black soil plain. Hills become steep and conical near the Harding and Synnot Ranges, and west of Beverley Springs they are locally capped by laterite.

Lithology

The Carson Volcanics consist predominantly of tholeiitic basalt and spilite, and minor agglomerate. Siltstone forms the top-most part of the sequence in the east. A probable thin sandstone bed is present about 300 feet (90 m) above the base of the formation in the Calder River Valley near the northern margin of the Sheet area, but has been noted only from air photographs.

At the base of the formation at the head of the Charnley gorge excellent cliff exposures (Fig. 17a) contain seven flows, each about 25 feet (8 m) thick, which are constant in thickness over 200 yards, (60 m) of continuous outcrop. In other exposures flows thin out over $\frac{1}{4}$ mile (0.5 km).

The lower 10 - 15 feet (3.5 m) of each flow consists of tough dark grey-green basalt with sporadic large amygdales with chalcedony infillings. These are about 2 inches (5 cm) long, and have a domed tops. The next 5 feet (1.5 m) carries many small quartz veins and amygdales. The top 3 - 4 feet (100 cm) is highly amygdaloidal, with small amygdales of 0.5 to 1.5 cm diameter infilled with quartz and chalcedony. In other areas, infillings include quartz, chalcedony, chlorite, epidote, pyrite, chalcopryrite, and galena. No flow banding was seen in any of the faces exposed.

The upper part of the formation is lithologically variable. In the Synnot Range, about 80 -90 feet (25.30 m) of agglomerate is present immediately underlying the Warton Sandstone. The agglomerate is a dark greenish rock, crumbly on the surface, and forms steep, rough slopes. A crude stratification gives a stepped appearance to the outcrop. The agglomerate is cut by thin (up to 6 in., 15 cm) dykes and irregular sill-like bodies of an aphanitic pale grey rock. Also, basaltic agglomerate containing large angular xenoliths up to 10 inches (25 cm) across of fine-grained pink siliceous rock, possibly granophyre or meta-arkose, occurs close to the main Derby - Gibb River road near

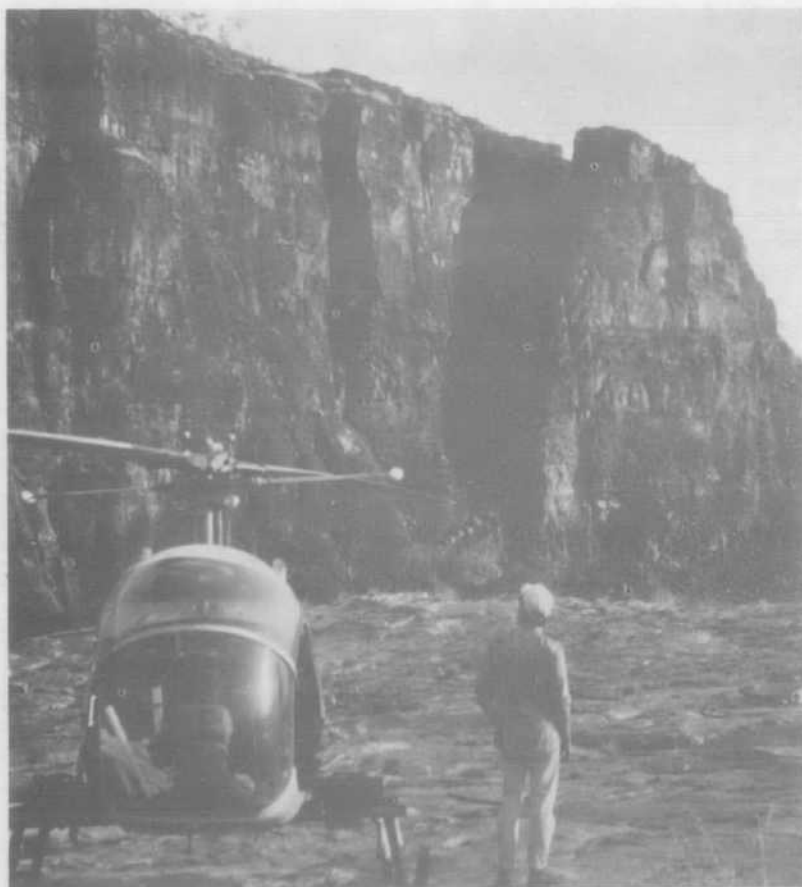


Fig. 17a: Basal flows of Carson Volcanics in Charnley River Gorge about 11 miles west-southwest of Mount Blythe. Seven flows are present within sequence in cliff face.

GA 1888 RH.



Fig. 17b: Sandstone breccia of Beverley Springs Member showing cavities produced through weathering out of angular siltstone fragments. Locality about 13 miles south of Beverley Springs Homestead.

G 1881. RH

the southern boundary of the Sheet area. A further outcrop of agglomerate, alongside the Mount House road, about 2 to 3 miles southeast of this contains ellipsoidal basic pyroclastic bombs in a matrix of quartz-rich tuffaceous agglomerate. These agglomerates are probably lower in the sequence than that in the Synnot Range.

Near Mount House homestead about 4 miles (7 km) south of the Sheet area grey-green and purple-grey siltstone with minor dolomite and algal chert form the topmost beds of the Carson Volcanics. These beds (which are found throughout the eastern part of the Kimberley Basin) are probably present below the escarpment of the Barnett Range but the topmost beds of the Carson Volcanics there are obscured by detritus from the Warton Sandstone. These siltstone beds have not been found in the central or western parts of the Charnley Sheet area and are apparently absent from the western part of the Kimberley Basin.

In the Mount House - Mount Barnett area the siltstones at the top of the Carson Volcanics are overlain by feldspathic sandstone assigned to the Warton Sandstone.

Thickness

A thickness of 1600 feet has been estimated from air photographs near Mount Barnett homestead. In the eastern part of the Yampi Sheet area a thickness of over 3,500 feet has been measured and it is probable that the formation thickens westwards in the Charnley Sheet area.

WARTON SANDSTONE

Distribution and Topographic Expression

The Warton Sandstone occurs in the centres of three broad synclines forming the Mount Barnett Plateau, and the Synnot and Harding Ranges; the Harding syncline in the west is the largest, and contains more than half of the total area of outcrop, which is estimated to be around 650 square miles (1700 Km²).

The Warton Sandstone is flat lying and forms large flat-topped plateaus except in the western part of the Harding Range where gently dipping cuestas are the predominant land-form. It can be distinguished from the King Leopold Sandstone on air photos by its more pronounced bedding and less well defined jointing.

Lithology

The Warton Sandstone consists principally of medium-grained (and rare coarse-grained) white to very pale rust-brown clean-washed well-sorted quartz sandstone, and subordinate feldspathic sandstone and possible siltstone. In outcrop the quartz sandstones are mostly thick-bedded and blocky, and are generally silica-cemented. Cross-bedding is common, with current directions mainly from west and north-west. Foresets are mainly around 1 foot (0.3 m) thick, but locally, especially in the lower beds, are up to 3 feet (1 m) thick. Large scale ripples with a wavelength of around 3 feet (1 m) have been noted in the extreme west in quartz sandstone near the top of the sequence. One example of an overturned cross-bed has been noted in the west.

Feldspathic sandstone makes up the basal part of the sequence, especially in the east where about 600 (180 m) of feldspathic sandstone are present forming a steep rubble covered slope at the base of the main Warton Sandstone escarpment south of Mount Barnett homestead. The feldspathic sandstone is flaggy to blocky, locally micaceous, mostly medium-grained, and contains angular grains of pink feldspar. Minor amounts of arkose are also present. Feldspathic sandstone is commonly present in other Sheet areas in the middle and upper parts of the Warton Sandstone, and may also be present at equivalent stratigraphic levels in the Charnley Sheet area. Similarly from photogeological evidence it appears that a siltstone member which is present in much of the Yampi Sheet area, may be present about 8 miles (13 km) west-southwest of Mount Lochee in the Harding Range.

Thickness

The full sequence of Warton Sandstone is preserved only in the extreme west of the Sheet area between Doubtful Bay and Walcott Inlet. Because of faulting and lack of measured dips the thickness there is uncertain. Some 25 miles (40 km) to the southwest in the Yampi Sheet area 1700 feet (550 m) of Warton Sandstone have been measured and to the north in the Prince Regent Camden Sound Sheet area the thickness has been estimated to be about 3000 feet (900 m). A thickness of around 2000 feet (600 m) is thus likely in the west of the Charnley Sheet area. In the east the full sequence is not preserved: extrapolation of data from the adjacent Lansdowne Sheet area suggests that the formation is thinner in the east of the Charnley Sheet area than in the west.

ELGEE SILTSTONE

Distribution and Topographic Expression

The Elgee Siltstone crops out only in the extreme west of the Sheet area between Doubtful Bay and Walcott Inlet.

The siltstone crops out in escarpments capped by more resistant Pentecost Sandstone, and is generally obscured by detritus from it. Most outcrops are in rugged inaccessible country where even helicopter landing spots are rare.

Lithology

Little is known of the lithology of the Elgee Siltstone in this area. A few fragments of red-brown siltstone and laminated sandstone have been found near the southern end of the most southerly outcrop of Elgee Siltstone, and to the north of this, red-brown to maroon flaggy beds (probably flaggy micaceous sandstone and possible siltstone) have been observed from the air.

At a locality 4 miles (6 km) southeast of Eagle Point (3 miles (5 km) west of the Charnley Sheet area) a basal bed of pebble conglomerate and granule sandstone is present overlain by fine-grained red-brown quartz sandstone; and fragments of dark red-brown shale and siltstone have been found at the same locality.

Thickness

Because of lack of exposure, and lack of access where exposures occur, no section of Elgee Siltstone has been measured either in the Charnley Sheet area or in the immediately adjacent part of the Yampi Sheet area. From flight observations of exposed Elgee Siltstone around 2242E; 29470N it appears that only about 100-200 feet (30-60 m) of section are present.

PENTECOST SANDSTONE

Distribution and Topographic Expression

The Pentecost Sandstone is present only in the extreme west of the Sheet area, immediately south of Doubtful Bay.

The lower beds form resistant cuestas overlying the more easily eroded Elgee Siltstone. They are light-coloured on air photographs and show well-developed bedding and jointing. The uppermost beds form rounded hills with a dark grey even toned photo-pattern: bedding and jointing in these beds cannot be detected on air-photographs.

Lithology

The lower beds have not been examined in the Charnley Sheet area but their lithology is known from exposures about 3 miles (5 km) southeast of Eagle Point in the Yampi area. There they consist of white to pink and pale buff, mostly medium-grained, well-sorted quartz sandstone commonly containing 1 to 2% of weathered feldspar. It is thin to thick-bedded, blocky, and has well developed cross-beds.

The upper beds consist mainly of white and red-brown fine-grained highly feldspathic sandstone. The sequence contains thin interbeds of grey-green siltstone up to 2 feet (0.6 m) thick which themselves contain thin interbeds of ripple-marked fine-grained sandstone.

Thickness

Since only part of the Pentecost Sandstone succession is present in this area no section has been measured. It is estimated roughly that there are probably about 400-500 feet (120-150 m) of the lower beds present and about 300 feet (100 m) of the upper beds.

Correlation

The relationship of the upper beds here to the lower beds is uncertain, as is also their place in the Pentecost Sandstone succession. If the upper beds are conformable on the lower then they must be the products of a localised facies change, since lateral equivalents 4 miles (7 km) to the northwest are less feldspathic and contain no known siltstone interbeds.

An alternative explanation is that these beds are correlatives of the feldspathic facies of the Yampi Member (of the Pentecost Sandstone), which is present a few miles to the west overlying beds some 600 feet (200 m) higher in the Pentecost Sandstone sequence than they overlie in the Charnley area.

Both explanations would infer that movement had taken place during the deposition of the Pentecost Sandstone in this area. One would infer tectonic control of facies changes; the other would infer temporary uplift and erosion of rocks now depressed in a graben (see 'Structural Geology').

PALAEOCURRENT DIRECTIONS

Palaeocurrent directions from cross-bed orientations have been recorded from most other Sheet areas in the Kimberley region. Insufficient observations have been made from the Charnley Sheet area to come to any independent conclusions. However the data agree well with those from other sheet areas and help to complete the regional picture of palaeocurrents in the Kimberley Basin sediments (Gellatly, Derrick and Plumb, in press).

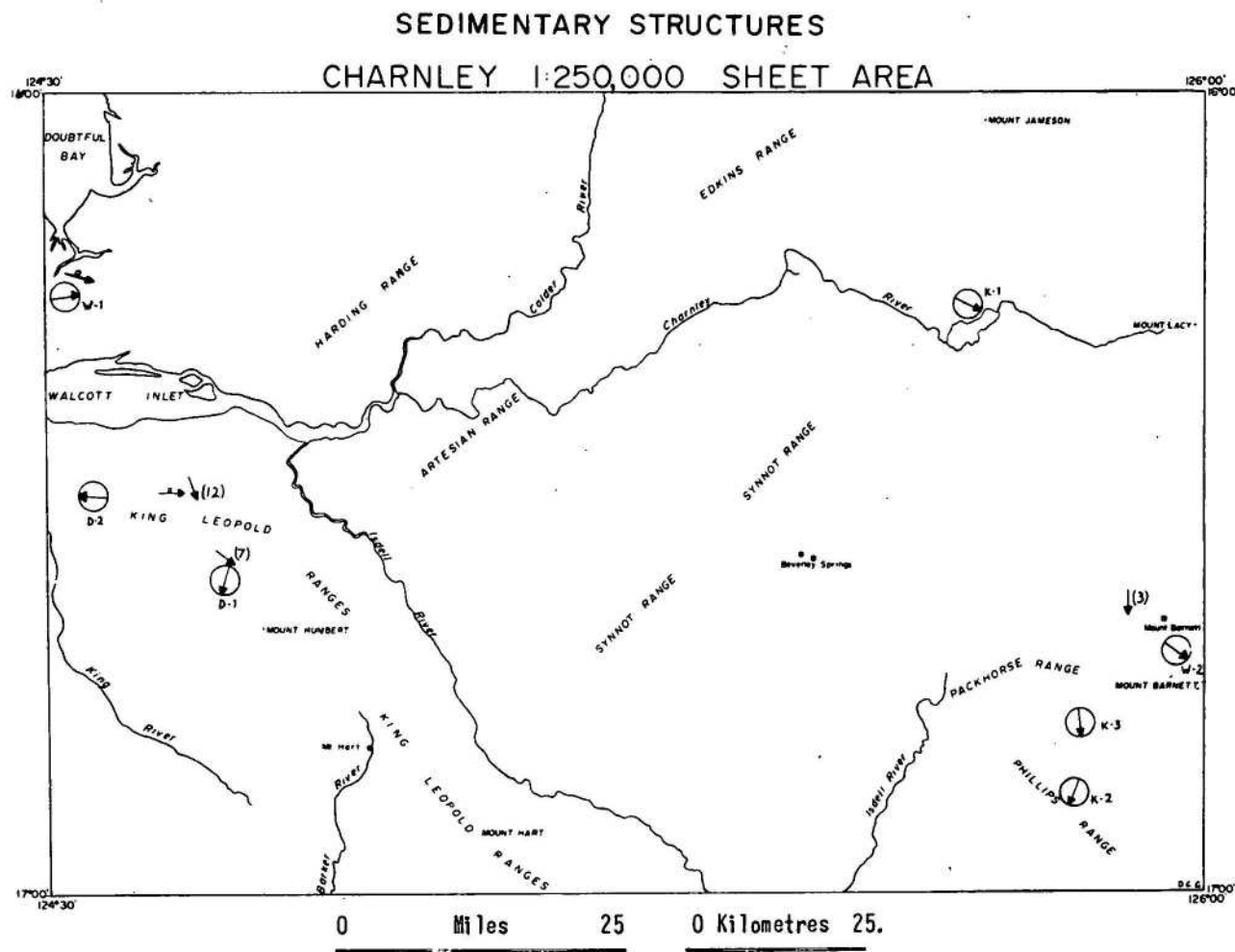
Cross-bed orientations have been measured mostly in sets of 25 readings from each locality. Lesser numbers of measurements have been made from other localities. The data are presented in Figs. 18 and 19.

Current directions near the base of the sequence (two sets of readings south of Walcott Inlet) are from east and northeast - as in the Speewah Group and lower part of the King Leopold Sandstone elsewhere in the Kimberley area.

Other measurements, from the upper part of the King Leopold Sandstone and from the Warton Sandstone, indicate currents mostly from north and northwest and conform with other measurements from these formations. A southwesterly direction noted from the Warton Sandstone in the extreme west is unusual, but has a parallel in one set of recordings from the eastern part of the Yampi Sheet area.

HART DOLERITE

The name Hart Dolerite is given to extensive sills of tholeiitic dolerite and associated granophyre which intrude the sediments of the Kimberley Basin. The use of the name follows that of Harms (1959) who renamed the 'Hart Basalt' of Guppy et al. (1958).



Current direction from cross-beds:
average of 25 or more measurements.

Current direction from cross-beds:
less than 25 measurements.

Overturned cross-bed.

Figure 18

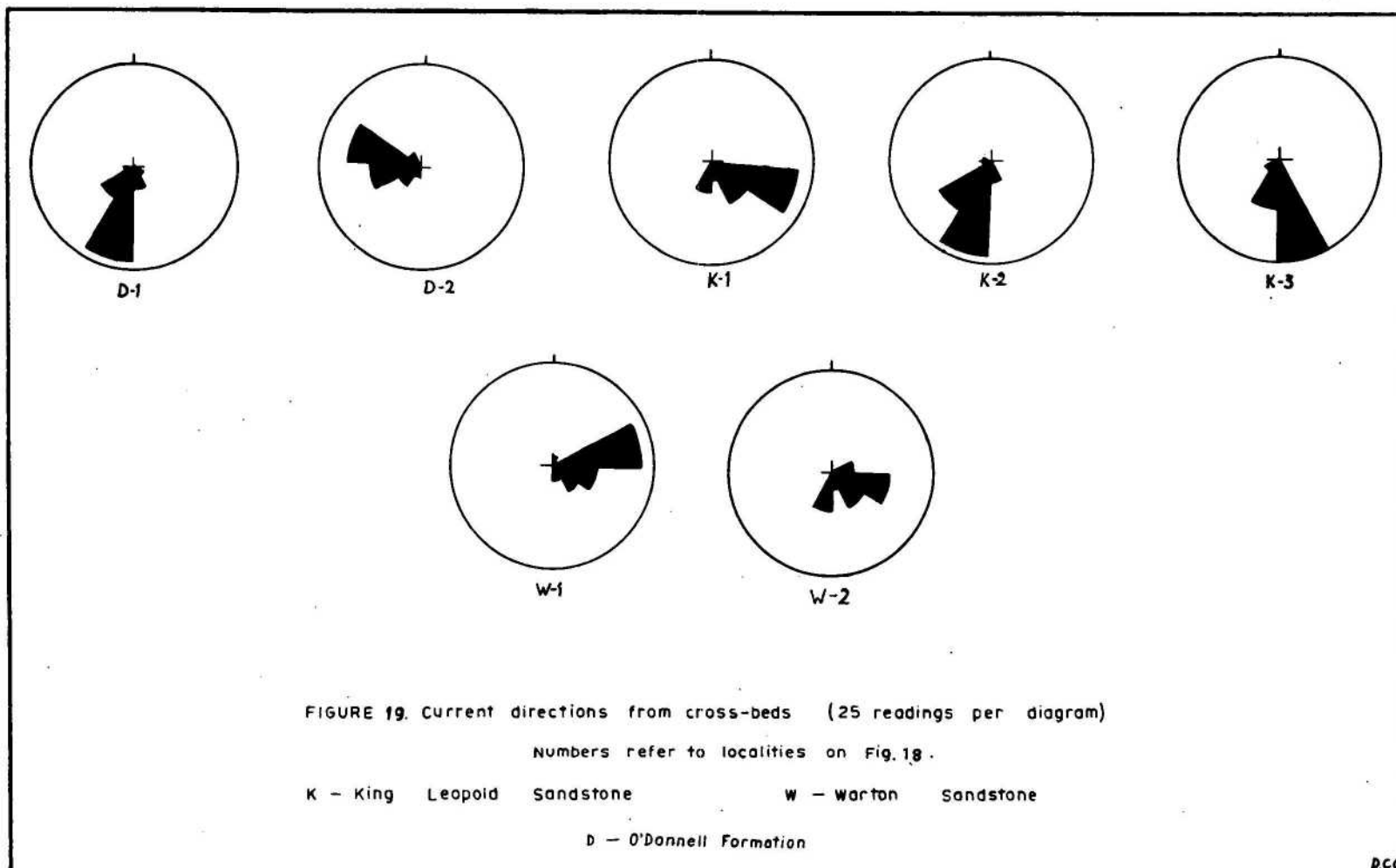


Figure 19.

Field Occurrence

Distribution, Thickness and Topographic Expression. Sills of Hart Dolerite occur extensively throughout the Kimberley Basin. In the Charnley Sheet area they are best developed along the southern flank of the King Leopold Ranges where concordant sills extend for over 50 miles (80 km). The dolerite also occurs extensively within the surrounding the Synnot Range syncline, and in the north-eastern part of the sheet area where long sinuous outcrops are exposed at the bottom of narrow valleys and gorges developed in the King Leopold Sandstone. The total area of outcrop is around 480 square miles (1200 Km²).

The main sill intruding the lower formations of the Speewah Group is up to 10,000 feet (3000 m) thick, but is mostly around 4000 feet (1300 m). Sills intruding higher formations have thicknesses mostly in the range 100 to 1000 feet (30 to 300 m) but a few exceed this.

The Hart Dolerite forms rounded, boulder-strewn hills and ridges which on air photographs have an even grey tone broken by scattered black patches indicative of dark weathering, vegetation-free, rocky residual boulders. Broad valleys underlain by dolerite are characterised by treeless, generally stony, black soil plains. The upper part of the granophyre is mostly erosion resistant and forms a prominent strike ridge (e.g. Mount Humbert) but the basal part of the granophyre is commonly easily weathered and forms a narrow valley floored by red-brown soil.

Stratigraphic Relationships. The Hart Dolerite intrudes all the formations of the Speewah and Kimberley Groups up to and including the Pentecost Sandstone, but is most extensive where it intrudes the Speewah Group. Locally it intrudes the Whitewater Volcanics and the Mondooma Granite. The thickest and most extensive sills intrude the O'Donnell and Tunganary formations and the Valentine Siltstone.

Except for a thick sill intruding the Carson Volcanics east of the Isdell Gorge, intrusions in formations higher than the Valentine Siltstone are thin and laterally impersistent. Horizons higher than the Valentine Siltstone that have commonly been intruded by the Hart Dolerite include the Luman Siltstone, an horizon near the top of the King Leopold Sandstone, the contact of the King Leopold Sandstone and the Carson Volcanics, and an horizon near the base of the Warton Sandstone.

The only contact that has been observed in the Charnley Sheet area is in the Synnot Range. Here Warton Sandstone overlying the Hart Dolerite has been contact metamorphosed and has developed a strong columnar jointing with 3 ins. (8 cm) diameter columns.

Form of the Intrusions. Most of the sills are concordant and appear to have been intruded by splitting of the sediments (especially siltstone) along favourable horizons. Contacts are concordant for considerable distances, especially the basal contact of the main sill. The granophyre forms a concordant layer near the top of the main sill and grades downwards into the dolerite.

Transgressive parts of sills which are rare in comparison to the concordant parts, mostly follow north or northeast-trending joint or fault fractures. Good examples of transgressive sills are present in the Charnley Gorge, on the southern side of the Harding Range, and near Hann Pass. A notable feature of the Hart Dolerite is the way in which large areas of sediment have been rafted out of place by dolerite over considerable distances, e.g. north of Mount Humbert and near Mount Hepple.

Two northwest-trending major dyke systems, one of them 70 miles (110 km) long, and each consisting of several discontinuous sections (some of them on echelon) of what at depth is probably a single dyke, are also regarded as representatives of the Hart Dolerite. In the Lennard River Sheet area the southeastern continuation of one

of these dyke systems cuts the basal sill of Hart Dolerite but does not apparently cut the immediately overlying sill, and may have been a feeder for it. The northwestern end of this same dyke system terminates a few miles east of Doubtful Bay against a major east-northeast fault.

A few northeast and northwest-trending dolerite dykes are present cutting the older Precambrian rocks in the southwestern corner of the Sheet area but their relation to known Hart Dolerite is uncertain.

Lithology

The Hart Dolerite is a dark grey medium to coarse-grained ophitic dolerite which in the lower parts has small scattered pits on the weathered surface due to preferential weathering out of altered olivine. Locally, in the southwestern part of the sheet area of the dolerite is saussuritised and is green-grey in hand specimen.

The granophyre is a coarse-grained pale pink to pale grey rock with pale pink and pale green feldspar phenocrysts and thin elongate pyroxenes (up to 1 cm) set in a granophyric quartz-feldspar matrix.

No thin sections are available from the Charnley Sheet area.

Age

The age of the Hart Dolerite is early Carpentarian. Bofinger (1967) using specimens from the Lansdowne Sheet area, has determined the age to be about 1800 m.y.

ADELAIDEAN
MOUNT HOUSE GROUP

Introduction

In the Charnley Sheet area the Mount House Group comprises the Walsh Tillite (1) the Traine Formation (2) the Throssell Shale (3), and the Beverley Springs Member which is a lateral equivalent of the Walsh Tillite. Apart from the Beverley Springs Member, the occurrence of the Group in the Charnley Sheet area is confined to a small area in the southeastern corner of the Sheet.

Except for the Beverley Springs Member, little is known about these Adelaidean rock units in the Sheet area. Some information has been supplied by K.A. Plumb who has examined exposures in the Lennard River Sheet area a few miles south of the southeastern corner of the Charnley area.

Stratigraphic Relationships

The basal formation of the group, the Walsh Tillite, lies unconformably, but with very little discordance, on the Carson Volcanics. It is conformably overlain by the Traine Formation, which in turn is overlain conformably by the Throssell Shale. The group is overlain only by superficial Cainozoic deposits.

The relationship between the Walsh Tillite and the Beverley Springs Member has not been observed in the Charnley Sheet area. However, the Beverley Springs Member may be traced intermittently to near Mount House in the Lennard River Sheet area, and is probably represented there by a coarse, pebbly sandstone at the base of the Mount House Group. Thus the Beverley Springs Member is regarded as a facies equivalent of basal beds of the Walsh Tillite.

Correlations and Age

The Mount House Group is correlated with the Moonlight Valley Tillite of the Duerdin Group of the east Kimberley (ref.) The Duerdin

Group has been dated at 740 m.y. by Bofinger (1967). This places the Duerdin Group and thus also the Mount House Group near the top of the Adelaidean.

WALSH TILLITE

Distribution and Topographic Expression

The Walsh Tillite proper (excluding the Beverley Springs Member) is restricted to the extreme southeast of the Sheet area where it forms a narrow outcrop some 3 miles (5 km) long.

The tillite, which is easily weathered, forms a small escarpment capped by resistant dipslope-forming dolomite.

Lithology

The basal beds consist of coarse-grained pebbly sandstone but these are rarely exposed, being obscured by detritus from the overlying beds. The tillite consists of striated cobbles and boulders - mainly of sandstone - in a grey-green clayey matrix. The tillite grades up into siltstone through a decrease megaclast content. Dolomite, which forms the topmost beds of the formation, is pink to brown and contains well preserved dome-shaped algal structures.

The thickness has not been measured; a rough estimate from air photographs, based mainly on the height of the escarpment, suggests that it is around 150 feet (50m) thick.

BEVERLEY SPRINGS MEMBER

Distribution and Topographic Expression

The Beverley Springs Member occurs as scattered exposures around Beverley Springs Homestead where it unconformably overlies Carson Volcanics and King Leopold Sandstone.

The formation occurs as a series of low conical hills which are generally lower than the surrounding hills, and it appears to have been deposited in a pre-existing valley or depression in the Carson Volcanics. The hills have a dark, even tone on air photographs.

Lithology

The Beverley Springs Member consists mainly of sedimentary breccia consisting of a matrix of tough, pale coloured quartz sandstone containing large numbers of angular pebbles of siltstone and flaggy siltstone (or their impressions) which are randomly distributed throughout the rock. (Fig. 17b) Stratification is not normally present, but on Clemens Hill and Sams Knob a crude and impersistent stratification is present.

The matrix of the rock is much more abundant than the pebbles. It consists of medium to fine-grained angular quartz, and rare feldspar grains set in a fine ferruginous or siliceous cement. Sorting is poor, and the grains are angular to sub-angular.

TRAINE FORMATION

Distribution and Topographic Expression

The Traine Formation is confined to a small outcrop in the southeastern corner of the Sheet area. It crops out as low hills and knolls at the foot of the dolomite dip slope of the Walsh Tillite and has a dark photopattern.

Lithology

The Traine Formation has not been examined in the Charnley Sheet area. In the adjacent Lansdowne and Lennard River Sheet areas the Formation consists of massive dark green to brown, medium to coarse-grained chloritic feldspathic sandstone, lithic sandstone with scattered glacial erratics, and minor sandy dolomite and dolomitic sandstone. The chloritic sandstone locally contains about 2-3% of apatite.

The thickness is uncertain but is estimated from air photographs to be around 200 feet (60 m).

THROSSELL SHALE

Minor outcrops of this formation occur on the southern edge of the Sheet area in the extreme southeast. Only a few feet of section are preserved out of a total 760 feet (235 m) known in the region. It forms shale-strewn pediments and gentle debris slopes.

The lithology is predominantly of grey-green shale (commonly red-brown where weathered), with thin interbeds of fine-grained buff and grey-green sandstone.

DEVONIAN

A small part of the Devonian limestone reef complex that forms the northern margin of the upper Palaeozoic sequence of the Fitzroy-Canning Basin crops out in the extreme southwestern corner of the Sheet area. The reef complex has been described by Guppy et al. (1968) and Playford and Lowry (1966) who have subdivided it into three main facies - reef, back-reef and fore-reef. The reef complex overlies and inter-fingers with conglomerate. Only the back-reef facies and conglomerates are present in the Charnley Sheet area.

VAN EMMERICK CONGLOMERATE

This conglomerate forms a very low rounded hill covered by cobble and boulder scree. Granite clasts predominate, and the matrix is arkosic. The conglomerate is probably part of a large alluvial fan which intertongues with the reef complex at its southwestern margin.

PILLARA LIMESTONE

The Pillara Limestone is the back-reef facies and consists predominantly of bedded flat-lying or gently-dipping stromatoporoid and algal limestone with interbedded oolite, clacarenite and calcilutite. The reef complex dies out a short distance to the northwest and the Pillara Limestone

here forms a narrow northwest-trending, well exposed ridge flanked by soil cover on both sides.

NAPIER FORMATION

The Napier Formation is the fore-reef facies. It consists largely of well-bedded, rather steeply dipping (20° - 30°), sparry calcarenite containing scattered small masses of reef limestone interpreted by Guppy et al., (1958) as bioherms and by Playford and Lowry (1966) as fallen blocks of reef limestone. The dips are essentially depositional rather than tectonic. The most obvious difference between the back-reef deposits is that of dip and this has been used for distinguishing these units by photointerpretation.

CAINOZOIC

Laterite of Tertiary age, and eluvium, residual soils and lateritic soils (partly transported) of Tertiary to Quaternary age are found in the Sheet area. Alluvium in and around river courses, and coastal muds and sands in Walcott Inlet and Doubtful Bay are of Quaternary age.

TERTIARY

Laterite (Tp)

Scattered areas of laterite are preserved overlying the Carson Volcanics on the eastern side of the Synnot Range, and the western side of the Packhorse Range south of Beverley Springs homestead. A few areas of laterite overlie the King Leopold Sandstone and the Beverley Springs Member.

The laterite occurs mainly as a capping on small mesas. Its thickness ranges from 30 feet (10 m) in the Synnot Range and 18 feet (6 m) near Eyles Field (4 miles northeast of Beverley Springs homestead) to zero. The mesas are generally 120 feet (35 m) or more above the surrounding lowlands, and are believed to represent remnants of a much more extensive sheet.

UNDIVIDED CAINOZOICFerruginous Pisolitic Soil (Czl)

Ferruginous pisolitic soils are developed over laterite, and near the junction of laterite with sandy soils in the Synnot and Packhorse Ranges. Areas of pisolitic soils derived from erosion of laterite form alluvial fans, but these are too small and too localised to show on the accompanying map.

The soils are dark red-brown, friable, and contain small nodules and pellets of limonite up to 1 cm across.

Black Soil (Czb)

Residual black and dark grey-brown soils and cracking clays are developed in low-lying areas overlying the Carson Volcanics and the Hart Dolerite. Inextensive areas of these soils are also developed over the Halls Creek Group and Woodward Dolerite. They are usually hummocky, and during the dry season have deep polygonal cracks and sinkholes ("gilgai")

Other Soils (Czs)

In this category are grouped various residual soils and eluvium. The principle types are (1) light textured pale grey-brown shallow sandy soil developed over sandstone (2) Dark red-brown fine-textured clayey loams and podzols, and gravelly soils, developed over basic volcanics, over the granophyric phases of the Hart Dolerite, and over pediments underlain by the Woodward Dolerite. (3) Coarse-grained grey and red-brown sandy clays overlying granites in the southeast (4) Red-brown and grey-brown clayey soils (locally skeletal) overlying the Halls Creek Group in the southwest. (5) Localized areas of alluvial soils developed on flood plains adjacent to some of the major rivers. Some of the soils bordering the Isdell River near Plover Hill are probably of this type.

QUATERNARY

Coastal muds and sands (Qc)

The shores of Walcott Inlet and Doubtful Bay are lined by mud-flats composed of dark grey clay, silt, and mud. They are colonised by mangroves along their seaward margins and generally have a salt crust above normal high water mark.

Shoals of sand with well developed megaripples are found locally in Walcott Inlet. Their presence is probably influenced by the strong tidal currents that are characteristic of the region.

The coastal regions of this Sheet area and of most of the western part of the Kimberley region are of interest in that extensive deposition of mud, silt, and fine-grained sand is taking place in the intertidal zone. Coarse-grained sands occur only away from the shoreline, especially in the bottoms of tidal channels.

Alluvium (Qa)

Alluvial sand, gravel, and silt occur extensively within and close to most of the water courses. Sand predominates in the river beds because of the ponderance of sandstone and (in the southwest) granite as source rocks. River bank and flood plain alluvial deposits are confined mostly to within about $\frac{1}{2}$ mile (1 km) of the water courses, many of which are braided.

METAMORPHISM

Introduction

Metamorphism in the Charnley Sheet area is confined mainly to the Halls Creek Group and Woodward Dolerite. The Halls Creek Group has undergone at least two episodes of metamorphism producing assemblages containing variously sericite, andalusite, staurolite, kyanite or garnet as the highest grade mineral. The Woodward Dolerite has been metamorphosed to amphibolites that are of uniform macroscopic appearance, but differ locally in the colour of the contained amphibole, in the presence or absence of epidote, and in the composition of their plagioclase. (See chapter on Woodward Dolerite).

In addition, evidence of minor metamorphism has been noted in the Whitewater volcanics, in dolerite dykes cutting the granites, in the Hart Dolerite, and in the Carson Volcanics.

The Whitewater Volcanics are less metamorphosed in the north, where pyroxene in andesites is replaced by epidote but original textures are still preserved, than in the south where mafic minerals are mostly altered to biotite and a superimposed foliation has largely destroyed original eutaxitic textures. Dolerite dykes cutting the granites have locally been chloritized (as in an east-northeast trending dyke 3 miles (5 km) north of King Creek Yard) or amphibolitized (north-northwest trending dyke in King Creek $1\frac{1}{2}$ miles ($2\frac{1}{2}$ km) north of King Creek Yard). The Hart Dolerite in places is greenish in hand specimen due to chloritization but has not been examined in this section. Simpson (1951) reports the occurrence of glaucophane from the Carson Volcanics near Synnot Creek, but in most places the Carson Volcanics are fresh and unaltered.

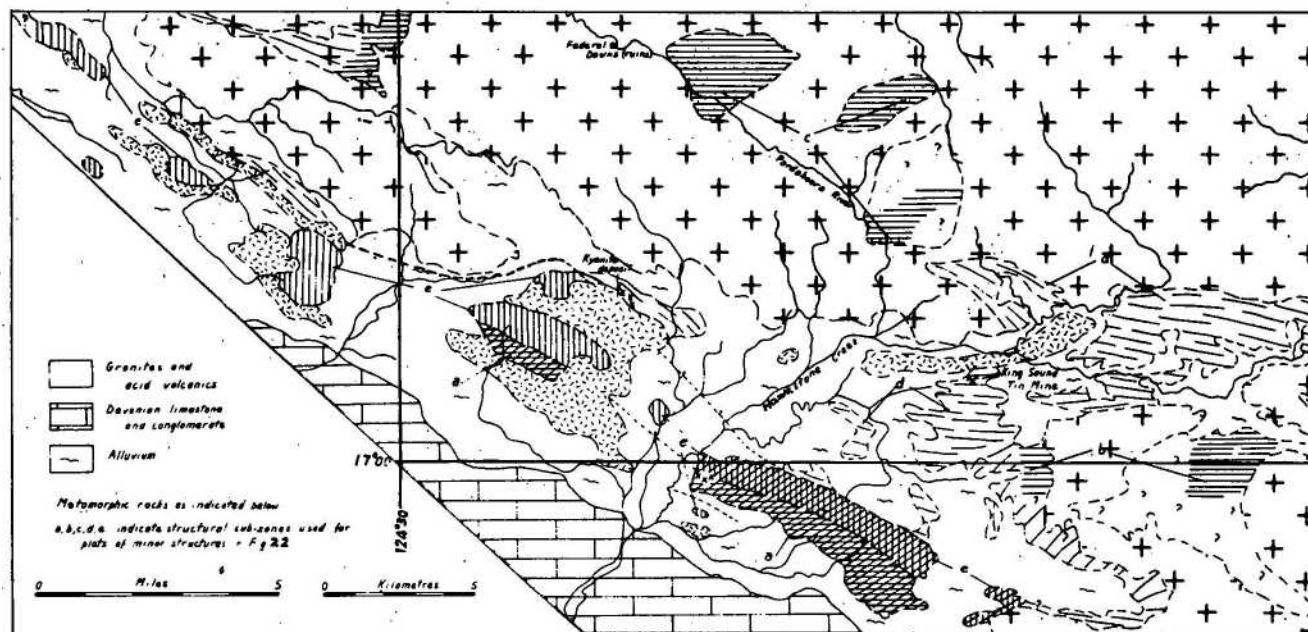
Halls Creek Group Metamorphics

The only metamorphic rocks from the Sheet area to be examined in any detail are those from the Halls Creek Group. They show evidence of at least two phases of metamorphism, an early high temperature low pressure type in which andalusite was developed extensively, and a later higher pressure type in which staurolite, kyanite and garnet were formed, at least partly at the expense of andalusite. A possible intermediate phase is evidenced locally by the presence of chloritoid.

Not all parts of the southwest corner have been affected by the same episodes of metamorphism, and where the same episodes have operated, they have done so with different intensities. Six main metamorphic zones can be recognised in the southwestern corner of the Charnley Sheet area. The distribution of these zones in the Charnley Sheet area, and in the adjacent parts of the Yampi and Lennard River Sheet areas are shown in Fig. 20. These zones are

1. Andalusite-chloritoid zone lying mainly in the catchment area of the Pardaboora River.
2. Sericite phyllite zone to east and west of King Sound Tin Mine.
3. Andalusite zone to south and southeast of King Sound Tin Mine.
4. Garnet zone lying immediately southwest of Hawkstone Creek kyanite deposit.
5. Andalusite-staurolite kyanite zone to the southwest of and parallel to the garnet zone.
6. Kyanite zone of the Hawkstone Creek kyanite deposit.

The metamorphic mineral assemblages of four of these zones are given in Table 11. Those from the other two have not been examined microscopically and are thus not included. Minor accessory minerals namely tourmaline, zircon, sphene and opaque oxides which are unrelated to the metamorphic conditions are omitted from the assemblages in this table.



----- Boundaries of metamorphic zones - - - - - Geological boundaries - - - - - Phyllite cleavage in low grade rocks

==== Andalusite |||| Gneiss |||| Staurolite x x x Kyanite Chloritoid

● Amphibole

Fig.20: Metamorphic Zones - southwestern corner of Charnley Sheet Area and adjoining parts of Lennard River and Yampi Sheet Areas.

TABLE 11 Metamorphic Assemblages

<u>Specimen No.</u>	<u>Assemblage</u>
<u>ANDALUSITE-CHLORITOID ZONE(NORTHERN INLIERS)</u>	
66.16.1001	(Andalusite) ¹ -chloritoid-?cordierite-biotite-sericite-muscovite-chlorite-quartz.
67.16.1026	(Andalusite) ² -chloritoid-muscovite-biotite-sericite-chlorite-quartz.
67.16.1027	Andalusite ² -muscovite-sericite-biotite-quartz.
67.16.1028	Muscovite-biotite-quartz.
67.16.1029	(Andalusite) ¹ -andalusite ² -chloritoid-muscovite-biotite-quartz.
67.16.1030	(Andalusite) ¹ -andalusite ² -chloritoid-muscovite-chlorite-biotite-quartz.
67.16.1062	(Andalusite) ¹ -chloritoid-sericite-biotite-plagioclase-quartz.
67.16.1063	Chloritoid-biotite-sericite-quartz-andalusite.
<u>GARNET ZONE (a) Pelites</u>	
66.16.1016	Garnet-muscovite-sericite-biotite-chlorite-?plagioclase-quartz.
67.16.0339	Garnet-muscovite-biotite-oligoclase-quartz.
<u>(b) Calcareous Psammites</u>	
66.16.1003	Hornblende-plagioclase-quartz.
16.16.1005(a)	Garnet-plagioclase (An ₃₂)-hornblende-clinozoisite-quartz.
(b)	Hornblende-clinozoisite-plagioclase-quartz.
<u>ANDALUSITE-STAUROLITE-KYANITE ZONE</u>	
67.16.0340	(Andalusite) ¹ -staurolite-kyanite-muscovite-biotite-quartz.
67.16.0341	(Andalusite) ¹ -staurolite-kyanite-muscovite-sericite-quartz.
67.16.0342	(Andalusite) ¹ -kyanite-staurolite-muscovite-biotite-quartz.
66.16.1013	Staurolite-(andalusite) ¹ -muscovite-biotite-quartz.
<u>KYANITE ZONE</u>	
66.16.1010	Kyanite-dumortierite
66.16.1011	Kyanite-?paragonite
66.16.0301	Corundum-sericite
67.16.1042	Kyanite-corundum-topaz
67.16.1040	Muscovite-kyanite-topaz
67.16.1043	Kyanite-muscovite-quartz
67.16.1041	Muscovite-quartz
67.16.1032	Muscovite-biotite-quartz

Notes: Parentheses round a mineral name indicate that it has been either partly or wholly pseudomorphed by other minerals.

1 indicates first generation andalusite; 2 indicates second generation andalusite.

1. Andalusite-chloritoid zone: Rocks of this zone are mostly andalusite-bearing phyllite, schist and hornfels with well-preserved bedding. Cleavage, developed locally, is of variable trend; lineations plunge to east and southeast. In many parts of these inliers andalusite is recognisably pseudomorphed by a mica in hand specimen. In thin section it is commonly seen to be completely pseudomorphed by sericite and chloritoid, or by biotite, chlorite and muscovite, but patches of these minerals retain the original form of the replaced (chiastolitic) andalusite. In some specimens a second generation of clear, fresh andalusite is present in addition to the pseudomorphed chiastolite.

Since these rocks occur in inliers (probably roof pendants) completely surrounded by granite the possibility of contact metamorphism must be considered. If contact metamorphism has been responsible for the development of andalusite then some variation in the assemblage might be expected with increasing distance from the contacts. No such variation have been noted in first generation andalusite although rocks up to 1 mile from granite contacts have been examined in these inliers. However, most specimens with fresh (second generation) andalusite come from localities within about 1600 feet (500 m) of granite contacts, and thus andalusite could possibly have formed as a result of contact metamorphism. Evidence from other specimens is conflicting: of two specimens collected about 1 mile from the contact of the most easterly inlier one contains fresh andalusite, and one specimen from within a few yards of the margin of the middle inlier contains no fresh andalusite but has abundant chloritoid.

On the other hand all specimens containing chloritoid in the area are found within 1600 feet (500m) of contacts and both specimens from about 1 mile from the contacts contain no chloritoid. In addition there appears to be consistent inverse relationship between chloritoid content and distance from the nearest contact. Further evidence for possible effects of contact metamorphism in these inliers is the co-existence in some rocks of chloritoid and biotite, which are generally considered to be mutually exclusive in regional metamorphism. The co-existence of these two minerals may be explained by the fact that specimens containing them come from within 1600 feet (500m) of granite

contacts and that chloritoid and biotite have previously been reported from contact metamorphics (Albee, 1965).

2. Sericite-Phyllite Zone These rocks are only slightly metamorphosed and are characterised by sericite which defines a strong east-west cleavage. Well developed bedding-cleavage lineations plunge steeply to east-southeast and are thus similar in trend to those in the inliers. No thin sections of rocks from this zone have been examined. The zone grades locally into rocks with altered andalusite.

3. Andalusite Zone (south and southeast of King Sound Tin Mine) The extent of this zone is only partly known. Structurally it is characterized by a cleavage and lineation that parallel almost exactly those in the sericite phyllite zone to the north. Andalusite within the zone is invariably altered to a mica. Traces of staurolite have been noted in one locality in this zone.

4. Garnet Zone Rocks of this zone are well cleaved muscovite schists containing garnet and generally also slender elongate staurolite crystals. The zone is more extensive in the Lennard River Sheet area (where staurolite is almost invariably present) and also extends into the Yampi Sheet area (staurolite absent). The garnet zone has a west-northwest trending cleavage and two strong lineations, one plunging to the southeast and the other to the southwest. Both lineations, at least in part must post-date the formation of garnet since pressure shadows on garnets are locally elongated in both of these directions. Inclusion trains in garnets are straight, but are oblique to the cleavage of the rock suggesting that the garnets have been rotated after, but not during growth.

Calcareous psammites found a short distance west of the Hawkestone Creek kyanite deposit occur within the garnet zone but do not necessarily belong to the same metamorphic subfacies. The rocks are characterized by both garnet and an amphibole, and have equivalents (but of slightly low metamorphic grade) in the Lennard River Sheet area. These rocks probably belong to the amphibolite facies but this is uncertain as the amphibole is pale in colour and may have actinolitic affinities.

5. Andalusite-Staurolite-Kyanite Zone This zone, which parallels the garnet zone and lies on its southwest flank, is notable for the evidence it provides of two-phase metamorphism. No exposures of rocks of this zone have been found in the Charnley Sheet area but abundant detrital andalusite and staurolite indicate that it is well developed 2 miles (3.5 km) southwest of the kyanite deposit. Most of the information on this zone comes from its extension in the Lennard River Sheet area. A small outcrop of garnet-bearing schist to the south of this zone (about $1\frac{1}{2}$ miles (3 km) south of Hawkstone Creek Yard) suggests that the andalusite-staurolite-kyanite zone is a narrow belt within a more extensive area of garnet-bearing rocks.

The principal characteristics of this zone are the presence of large crystals of (altered) chiastolite (up to 10 cm long and 3 cm across), of thick short prismatic ("stubby") staurolite crystals, and of well preserved bedding. Lineations plunge mainly to south and are similar in trend to those in the adjacent garnet zone. Alignment of andalusite parallel to this lineation has been noted in one outcrop. Kyanite is present only as microscopic crystals in pseudomorphs after andalusite, and its extent in this zone is unknown.

In thin section the chiastolites of this zone are seen to be completely pseudomorphed by an assemblage of muscovite, kyanite and staurolite. In addition staurolite occurs as discrete porphyroblasts and as minute elongate grains closely associated with small flakes of biotite which define the cleavage. Many rocks of this zone contain discrete porphyroblasts of biotite up to 2 mm which commonly cut across the cleavage. These porphyroblasts have poikilitic margins containing abundant small quartz inclusions and are generally bordered by small scattered staurolites. It has been suggested (Gellatly et al., 1968) that similar transgressive biotite porphyroblasts in Halls Creek Group rocks of the Lennard River Sheet area have been derived from pre-existing chloritoid. Since chloritoid is generally considered to be replaced by staurolite with increasing metamorphism, the presence of small staurolites bordering the biotite porphyroblasts tends to support the suggestion that biotite has developed at the expense of chloritoid. In some specimens (e.g. 67160340) the porphyroblasts have been sheared out to form thin tabular grains but are still closely associated with small staurolites.

6. Kyanite Zone: The unusual mass of kyanite-rich rocks forming the Hawkestone Creek kyanite deposit apparently lies within the zone of low grade sericite phyllites, but is very close to the garnet isograd. Even if the deposit lies within the greenschist facies, as seems likely (sericite phyllite is the host rock for the kyanite bands), it is probable that the assemblages within it conform with those formed elsewhere during the second metamorphic episode, since kyanite may form in the upper greenschist facies in place of pyrophyllite. The abundant evidence for replacement of andalusite by kyanite and by micaceous minerals suggests that the initial metamorphism affecting the deposit was essentially the same as elsewhere in the area.

This leaves unexplained two main features, namely the abundance of topaz locally within the deposit, and the unusual concentration of aluminous minerals. The presence of topaz is curious and the only explanation that can be offered is that it is the result of metasomatism, either through concentration of F and OH already present in the schists or through introduction of these constituents from nearby granites. The unusually high concentration of topaz in the deposit is probably a direct result of the great amount of alumina there prior to the metasomatism. The role of alumina in the formation of topaz was merely to fix the volatile F- ion in an insoluble form.

The great concentration of aluminous minerals of the kyanite deposit has its parallel in the Richenda River corundum deposit in the Lennard River Sheet area. It is probably significant that both deposits occur at the contacts of Halls Creek Group pelites with the Woodward Dolerite. Also both occur at the lower contacts of the respective sills. A similar occurrence of corundum-rich rocks (whose origin has not been masked by the effects of subsequent metamorphism) has been described from Argyllshire by Smith (1965) who interprets the high concentration of alumina as the residue after selective removal from the pelites of a granitic melt as a result of contact metamorphism by the dolerite.

Thus one may envisage here a three stage process: first, formation of an aluminous residuum (possibly corundum) through selective fusion and removal from the pelites of a granitic fraction; secondly, the first of the two episodes of regional metamorphism causing andalusite

to develop in the deposit and then, thirdly, the alteration of andalusite to kyanite, to corundum + sericite etc. The incoming of fluorine probably post-dated both metamorphisms since topaz has replaced kyanite which in turn previously replaced andalusite.

Effects attributable to retrograde metamorphism include the breakdown of kyanite to diaspore, and of andalusite to a mica (muscovite or pyrophyllite). These reactions require minor movement of material either within the rock or into the rock. Similarly late stage small-scale movement of material is evidenced by veins of kyanite and chloritoid within the kyanite deposit and of concentrations of tourmaline and dumortierite along microfractures in kyanite-bearing rocks.

Discussion

The metamorphic history of the Halls Creek Group rocks under discussion is similar to that in the Richenda River area of the Lennard River Sheet area, where an initial high temperature-low pressure phase ("Buchan-type") metamorphism in which andalusite was developed, was followed by a high temperature-high pressure phase (Barrovian) metamorphism characterized by the incoming of garnet (and locally kyanite) and by the destruction of bedding. In both areas staurolite was developed both as an alteration product of andalusite, and also in association with garnet in rocks that retain no trace of the effects of the first phase of metamorphism. It is probably that in both areas chloritoid was formed in the waning stages of the first metamorphism and was subsequently altered to biotite (with or without minor staurolite) during the second. Fresh chloritoid is confined almost entirely to inliers within the granites of the Charnley area where it is possible that it has developed as a result of contact metamorphism. Alternatively the second metamorphism could post-date the granites which might then have "protected" the inliers from the second metamorphism, and prevented the alteration of chloritoid to biotite which took place elsewhere in the area. The former explanation is the more likely.

Similarly the second generation of andalusite noted could be the result of a second phase of regional thermal metamorphism or could be due to contact metamorphism by granite. Since all the specimens with fresh, second generation andalusite come from within 1600 feet (500m) of granite contacts it is more likely that it is a product of contact metamorphism.

As has been noted above it is unnecessary to invoke special conditions, such as alumina metasomatism suggested by Derrick & Morgan (1966), for the development of the kyanite deposit and its contained mineral assemblage, other than the pre-existence of alumina rich-rocks. The principal parageneses found within the deposit can then be explained by superimposition of the two metamorphisms that have affected the rest of the area, and by localised fluorine metasomatism.

The exact P-T conditions responsible for the metamorphisms are a little uncertain in view of the wide variety of experiment-based interpretations of the aluminium silicate P-T diagram. If the triple point be taken at about 620°C and 5.5 Kb as suggested by E.J. Essene (pers. comm.) then the temperature has been almost entirely less than this (and greater than 430°C since andalusite and kyanite were developed rather than pyrophyllite), and the main difference between the two metamorphisms has been largely one of pressure, with the pressure of the first metamorphism probably below about 5Kb and that of the second probably above about 5.5 Kb.

STRUCTURE

Introduction

The Charnley Sheet area lies mainly within the structurally stable Kimberley Block. The southwestern corner, including the King Leopold Ranges is part of the highly deformed King Leopold Mobile Zone. There is no definite boundary between these two units; instead the boundary is gradational and is determined by the northeastwards decrease in the intensity of deformation in the Kimberley Basin sediments. Because of the thick arenaceous sequence in the King Leopold Ranges structures there resemble more closely those in the Kimberley Block than those in the Mobile Zone and they are thus described along with those of the Kimberley Block. The southern margin of the King Leopold Mobile Zone is obscured by Devonian and later sediments of the Canning Basin and probably lies some distance to the southwest of the southwestern corner of the Sheet area.

The Kimberley Block is characterised by folding along two main trends - northeast and west-northwest. The west-northwest folds truncate the northeast ones and are later than them. Folds within the Mobile Zone are more varied in their trend; southeast plunging folds predominate.

Faults in the area trend mainly north, northwest, or northeast and are probably related to the main transcurrent fault system of the Kimberleys although only minor transcurrent movement has been recorded in the Charnley Sheet area.

FOLDS.

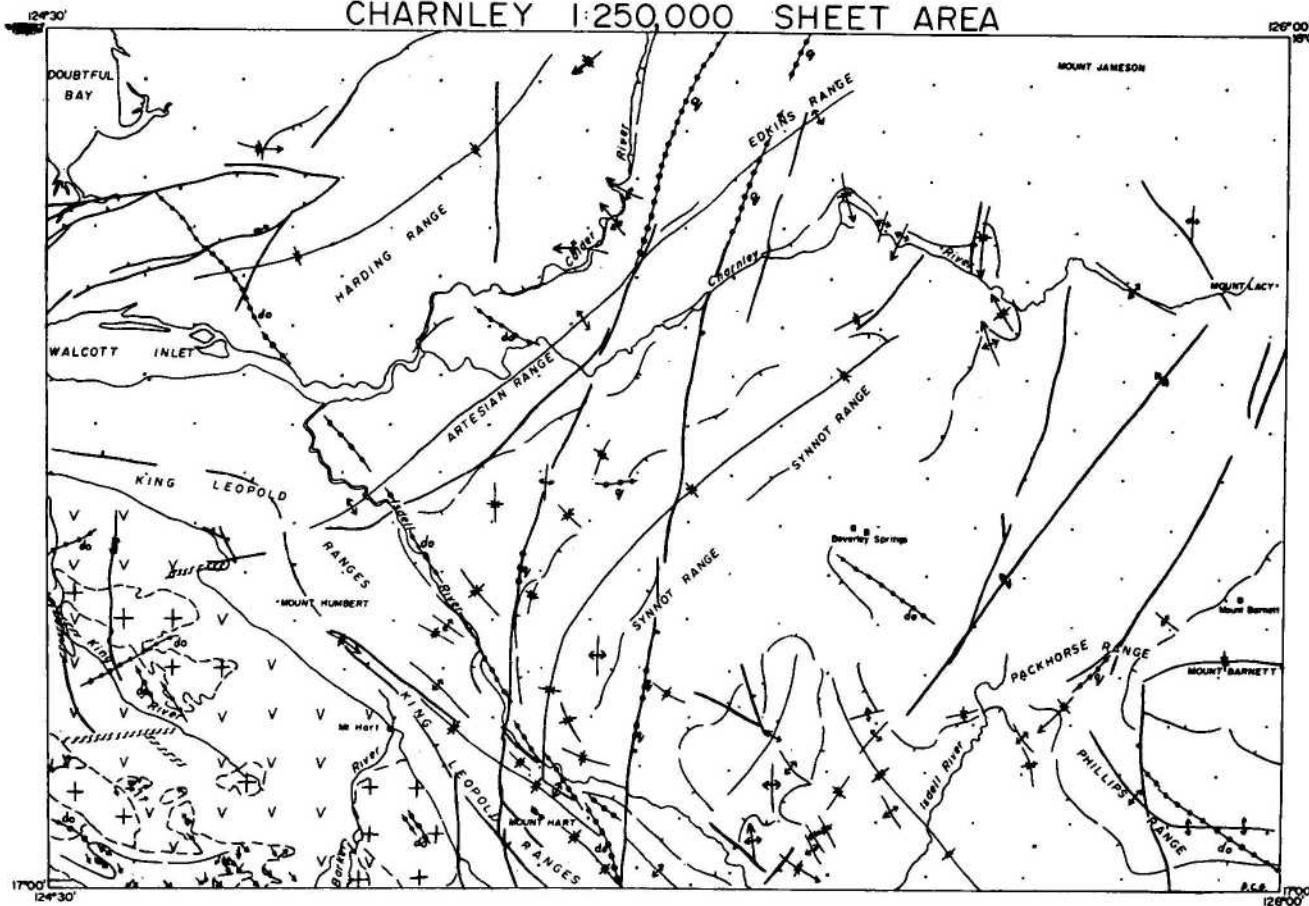
King Leopold Mobile Zone

The only major folds discernible in the King Leopold Mobile Zone are an east-southeast plunging syncline and anticline outlined by the main outcrop of Woodward Dolerite in the extreme southwest corner of the Sheet area.

Figure 21.

STRUCTURAL MAP

CHARNLEY 1:250,000 SHEET AREA



- Phanerozoic sediments
 - Carpentarian to Adelaidean
 - + Granites
 - v Acid volcanics and high level intrusive porphyries
 - Halls Creek Group (folded sediments and metamorphics)
- Carpentarian to ?Archean

- Geological boundaries
 - ↗ Anticline
 - ↘ Syncline
 - Fault
 - Transcurrent Fault
- Major Folds

- * Anticline
 - ↗ Syncline
 - ↘ Drag-fold
 - Lineation or microfold
 - Shear zones
 - Trend and dip direction of bedding
 - Diorite and quartz dykes (do, q)
- Minor Folds

Figure 21.

Minor folds and associated lineations are abundant in the Halls Creek Group, and lineations of trend similar to some of those in the Halls Creek Group (but not associated with discernible folds) are found in the granites. Lineations in the older Precambrian rocks of the Sheet area may be classified into bedding-cleavage intersections, cleavage-cleavage intersections (including crenulation microfolds) elongate pressure shadows on garnets, preferred linear orientation of metamorphic minerals, mineral grain lineations in sheared granite and in flow foliated granite, and fault plane striations. The predominant types are cleavage-bedding intersections and cleavage-cleavage intersections. The latter predominate in garnet staurolite and kyanite bearing schists that have been affected by the second metamorphic episode whereas cleavage-bedding intersections predominate in rocks that have largely escaped the second metamorphism. The trends of minor structures in the older Precambrian are shown in Fig. 22.

In rocks which have been affected by the first metamorphism, but which escaped the principal effects of the second metamorphism, lineations and minor folds have steep plunges to east and southeast (Fig. 22 b,c,d,) whereas rocks that have been strongly deformed during the second metamorphism (Fig. 22 a, e) have lineations that plunge mainly to south-southeast and south-southwest. This is similar to the structural pattern in the central part of the Lennard River Sheet area where the initial structures plunge northeast and those associated with the second metamorphism plunge southeast (Gellatly, et al. 1968). Thus it appears that the pattern of development of minor structures in the older Precambrian of the Charnley Sheet area can be related to that, in the Lennard River Sheet area. The only difference is that the two sets of Charnley structures differ in azimuth from their Lennard River counterparts. The variations in stress systems responsible for this difference must have pre-dated the development of structures in the Carpentarian rocks of the mobile zone since structural trends in these rocks are uniform in both areas.

Figure 22. Minor Structures in the Older Precambrian Rocks.

All diagrams are lower hemisphere equal area projections.

In all diagrams: Lineations and minor fold axes

x Poles to cleavage

- (a) Lineations and poles to cleavage in andalusite-staurolite zone. The circled point indicates preferred linear orientation of andalusite porphyroblasts.
- (b) Lineations and poles to cleavage in andalusite zone to south and southeast of King Sound Tine Mine.
- (c) Lineations, minor fold axes, and poles to cleavage in Halls Creek Group inliers to the north of Hawkstone Creek and the Pardaboora River.
- (d) Lineations, minor fold axes, and poles to cleavage in low grade phyllites around and to the east of King Sound Tin Mine.
- (e) Lineations and poles to cleavage in garnet zone. Circled points indicate linear development of pressure shadows on garnets. Tie lines connect lineations on the same cleavage plane.
- (f) Lineations and poles to cleavage in intrusive and extrusive acid igneous rocks. Circles indicate poles to flow foliation.

Figure. 22.

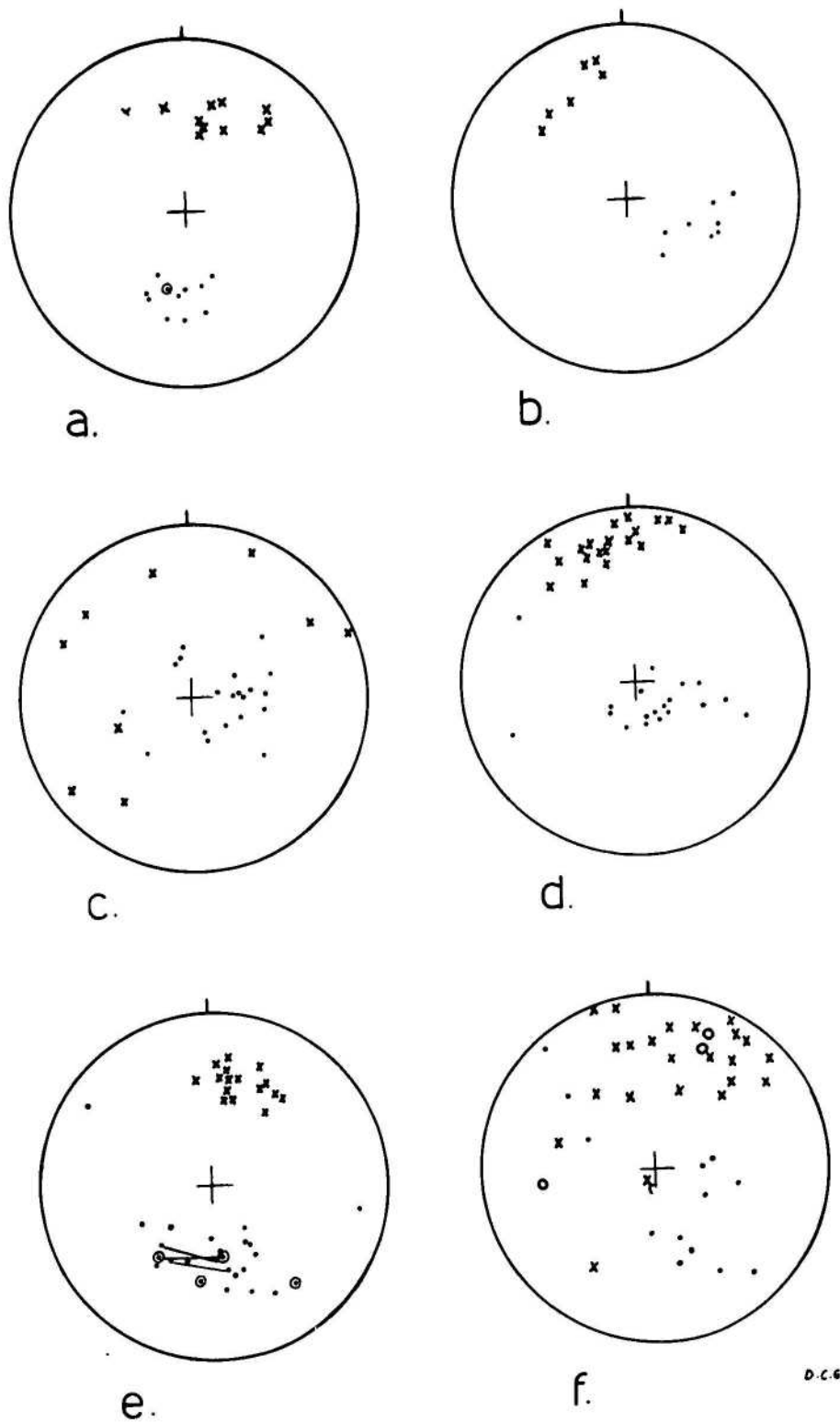


Fig. 22. Minor Structures in the Older Precambrian Rocks.

Northwest-trending Faults.

The principal faults of northwest trend are found in the southwestern corner of the Sheet area. In the Isdell Range near Mount Hart, one west-northwest trending fault has caused sinistral transcurrent displacement of a pair of dolerite dykes. Similarly a north-trending fault near Junction Hill is sinistrally offset, possibly by northwest transcurrent faults. However, another fault of this trend has an associated dextral drag fold which plunges steeply to the southeast. In the granites, faults of this trend are expressed as shear zones which probably reflect transcurrent movement, but the sense of movement is unknown. It is probable that the sense of transcurrent movement on these faults cutting the Preambrian is sinistral - the sense of the only actual displacement noted (in Kimberley Basin rocks). Such a displacement would agree with the observed direction of transcurrent movement in faults of this trend in the Lennard River Sheet area.

Northeast-trending Faults.

Faults which belong to the northeast-trending group have trends that vary from a few degrees east of north to a few degrees north of east. The principal faults with these trends are found northwest of Mt Barnett, and south of Doubtful Bay where a prominent graben is present. Movement appears to have been mainly vertical. Displacements are small except on the northern margin of the graben where one fault has a throw of about 3000 feet (900 metres) and where the maximum total displacement of the deepest part of the rift is 6000 feet (1800 m.).

Together with faults in the eastern part of the Yampi Sheet area the norther boundary fault of this graben forms part of an arcuate fault system with a radius of about 25 miles (40 km) and with its centre about 10 miles north-northwest of Mount Humbert.

Near Mount Humbert an east-trending fault has caused a small vertical displacement of Speewah Group rocks but is expressed as a shear zone in the older Precambrian and one other shear zone of this trend is present a few miles to the southwest. These features suggest that faults of this system may be partly related to transcurrent faults which have been subsequently reactivated.

It is interesting to note that faults of this group in the eastern part of the Sheet area trend north-northeast and are parrallel to the major transcurrent faults of the East Kimberley.

JOINTS

Most rocks of the area are very strongly jointed. Major joints (visible on air photographs) are particularly abundant, and well displayed as a result of preferential erosion, in the King Leopold Sandstone and in the granites.

There main trends are present (1) northwest to north-northwest, (2) northeast to east-northeast, and (3) north-south. In general these trends parallel those of the faults. The principal exception is that joints of the northwest-trending group do not coincide exactly in trend with the northwest faults, and as was noted above one west-northwest transcurrent fault displaces joints infilled by dolerite dykes.

An unusual feature is the presence in the granite west of Mount Matthew of arcuate joints with trends that swing from a few degrees east of north, round to northwest. No explanation for this is apparent.

Dyke Trends

Basic dykes in the area are sparse and follow two main trends northwest and east-northeast. The latter trend is found only in the granites and the former is more common in the Kimberley Basin rocks. A notable feature is the extent of the northwest dykes. Two individual dyke systems can each be traced intermittently for about 70 miles (110 km). One of these dykes terminated against the northern boundary fault of the graben south of Doubtful Bay and is thus considered to be later than the fault.

TECTONIC HISTORY

The tectonic history of the Sheet area is summarised in Table 12.. The information on the age relationships of various events on which this table is based are given in various sections of the text dealing with the rock units concerned. Evidence for the relative ages, of events if not available from the Charnley Sheet area, has been taken from other areas, particularly from the Lennard River Sheet area.

Some of the more important points of the tectonic history of the Charnley area are that the relationships between principal early periods of folding and the two main metamorphisms, which were a little uncertain from evidence in the Lennard River area, have now been confirmed. Also, the relative age of the Woodward Dolerite prior to both metamorphisms has now been established.

Evidence from the adjoining sheet areas that the main transcurrent fault movements took place before deposition of the Kimberley Basin rocks, and that much of the faulting in these rocks is due to reactivation of old fractures has been further substantiated, although a second (post-Kimberley Group) period of transcurrent movement is also represented.

ECONOMIC GEOLOGY

There are no mines operating in the area at present, but the King Sound tin-tungsten deposits were worked briefly during 1911-13. During the course of the recent survey a small kyanite deposit was located in the area. Other minerals of possible economic interest in the area include scorodite (ferric arsenate) andalusite, fluorite, and possible bauxitic laterite. Development of small deposits in the area is hampered by the absence of water except during the wet season. Groundwater is exploited at present by only seven operating bores and wells, but considerable potential exists for development.

METALS

Tin and Tungsten

King Sound Tin Mine: A deposit of cassiterite, wolframite and scorodite in thin quartz veins in the catchment area of Hawkestone Creek has been known since 1907 (Woodward 1909) but the exact location has never been recorded. The deposit was worked during 1911-1913, but development consisted only of shallow pits and trenches. There is no record of the amount of concentrates produced. The occurrence was mentioned briefly by Campbell (1909). It has been described in detail by Blatchford (1914) and summarised by Simpson (1948), and by Finucane (1939) who made a detailed map of the deposit.

The ore-bearing veins crop out on the top of a 200 feet high narrow ridge of phyllite at 2457 E, 28613 N, about 6 miles (10 km) east-northeast of Hawkestone Creek Yard. A geological sketch map of the locality is included in Fig. 23.

Two main sub-parallel veins have strike 285° , dip 85° S, and follow the cleavage of the Halls Creek Group phyllites. They extend for 300 feet (100 m) and 550 feet (170 m) respectively, with an average thickness of 20 cm, and carry most of the tin and tungsten mineralisation. Thin anastomosing branches of both principal veins, and thin westerly extensions of the main south vein contain some scorodite but have no appreciable cassiterite or wolframite. Assays of vein material listed by Blatchford (1914) and Finucane (1939) indicate average contents of 1.54% SnO_2 and 0.55% WO_3 . In addition to the above minerals arsenopyrite and scheelite have been discovered by Mr. J. Stewart, a local prospector, in one vein at the eastern end of the ridge (Harms 1959). Examination under short wave U.V. light of specimens of mineralized rock from the other veins during the recent survey revealed no further scheelite and it thus appears that scheelite in the King Sound tin deposits is both rare and localised in its occurrence.

ERA	DEPOSITION	IGENOUS EVENTS	TECTONIC EVENTS	METAMORPHISM	REMARKS
CAINOZOIC	Alluvium; coastal muds and sands		MAJOR PERIOD OF EROSION UPLIFT.		Formation of soils and laterite
	Deposition of Devonian - Permian sediments.	-	-	-	Only in extreme south-west
PALAEOZOIC			Transcurrent west-northwest faulting	-	-
		-	Folding along shallow-plunging northwest and southeast axes.	Low grade, largely dynamic metamorphism.	Glaucophane locally in Carson Volcanics; amphibolite and andalusite granofels in Yampi area.
ADEL-ADEAN	Deposition of Mount House Group including glacial rocks.	-		-	-
		-	Gentle folding along shallow-plunging northeast axes.	-	e.g. Synnot Range syncline.
CARPETARIAN		Intrusion of late dolerite dykes	-	-	Related at least in part to Hart Dolerite.
		Intrusion of Hart Dolerite	-	-	Rafting of sediment along north trending fractures in Lansdowne Sheet areas.
C			Faulting: northeast and north faults and joints formed.	-	-
	Deposition of Speewah and Kimberley Groups.	(Extrusion of Carson Volcanics)	-	-	-
Z		UNCONFORMITY	MAJOR PERIOD OF EROSION		Complete removal of Whitewater Volcanics locally.
		-	Transcurrent faulting	-	Shear zones developed in granites
O		-	Folding along steep-plunging southeast axes.	Mild metamorphics of some dolerite dykes.	Foliation and lineation developed in granites
		Intrusion of early dolerite dykes?	-	-	-
T		Intrusion of Lennard, Mount Amy and Kongorow Granites	-	-	-
		Intrusion of Mount Disaster Porphyry and Mondooma Granite.	-	-	-
E		Extrusion of Whitewater Volcanics	-	-	-
		UNCONFORMITY	PERIOD OF EROSION		Cobbles of Woodward Dolerite in conglomerates near base of Whitewater Volcanics in Lennard River Sheet area.
O			Folding along steep south-south-west and southwest axes.	Garnet and kyanite grade metamorphism.	Strong cleavage developed.
			Folding along steep east and south-east axes.	Andalusite and staurolite low stress metamorphism.	-
ARCHAEOAN	Deposition of Halls Creek Group sediments.	Intrusion of Woodward Dolerite			

The mineral paragenesis has been studied both in the veins in situ and in excavated lumps taken from the veins. A remarkably consistent sequence is present with scorodite invariably forming the wall zone of the veins and quartz the core; cassiterite tends to be concentrated preferentially in or close to the scorodite wall zone and wolframite is mostly disseminated in the quartz core (Fig. 23b, c).

The occurrence of scorodite as an early mineral in the paragenetic sequence infers that it is primary and is at first sight at variance with the prediction by Blatchford (1914) that the scorodite would give way to arsenopyrite at depth, a prediction based apparently on the assumption that scorodite is not a primary mineral in the veins but is a product of post-depositional surface oxidation. Its presence as a primary mineral at the present level of erosion suggests that either excess oxygen was present in the mineralizing solutions or that the veins were emplaced into an oxidizing (near surface?) environment. Interpretation of the surface zoning of individual veins suggests that scorodite would persist in depth, rather than give way to arsenopyrite, but would tend to decrease in abundance that cassiterite would initially increase slightly in abundance and then decrease; and that wolframite would increase slightly.

Silent Valley Tin Prospect: The exact location of this prospect has not been recorded previously and it was not located during the recent survey. Subsequent description of the locality by the discoverer, J. Stewart, suggests that it is located at 2465 E, 28648 N - about 3 km. north-northeast of the King Sound Tin Mine. Harms (1959) gives the locality as 8 km northeast of King Sound Tin Mine.

In Silent Valley Harms (1959) reports small pockets of cassiterite-bearing wash containing up to 3 lbs of cassiterite to the dish, and larger quantities of wash under about 3 feet (1 m) of alluvium that carry about one ounce of cassiterite to the dish. The wash has been traced to thin quartz leaders containing cassiterite on their walls and to thin seams of cassiterite in greisen. The veins are apparently within Mondooma Granite close to the contact with Halls Creek Group phyllite.

The deposit has been worked intermittently by Mr. Stewart. Harms (1959) reports that other small alluvial deposits of cassiterite are present in a stream to the northwest of Silent Valley.

Copper etc.

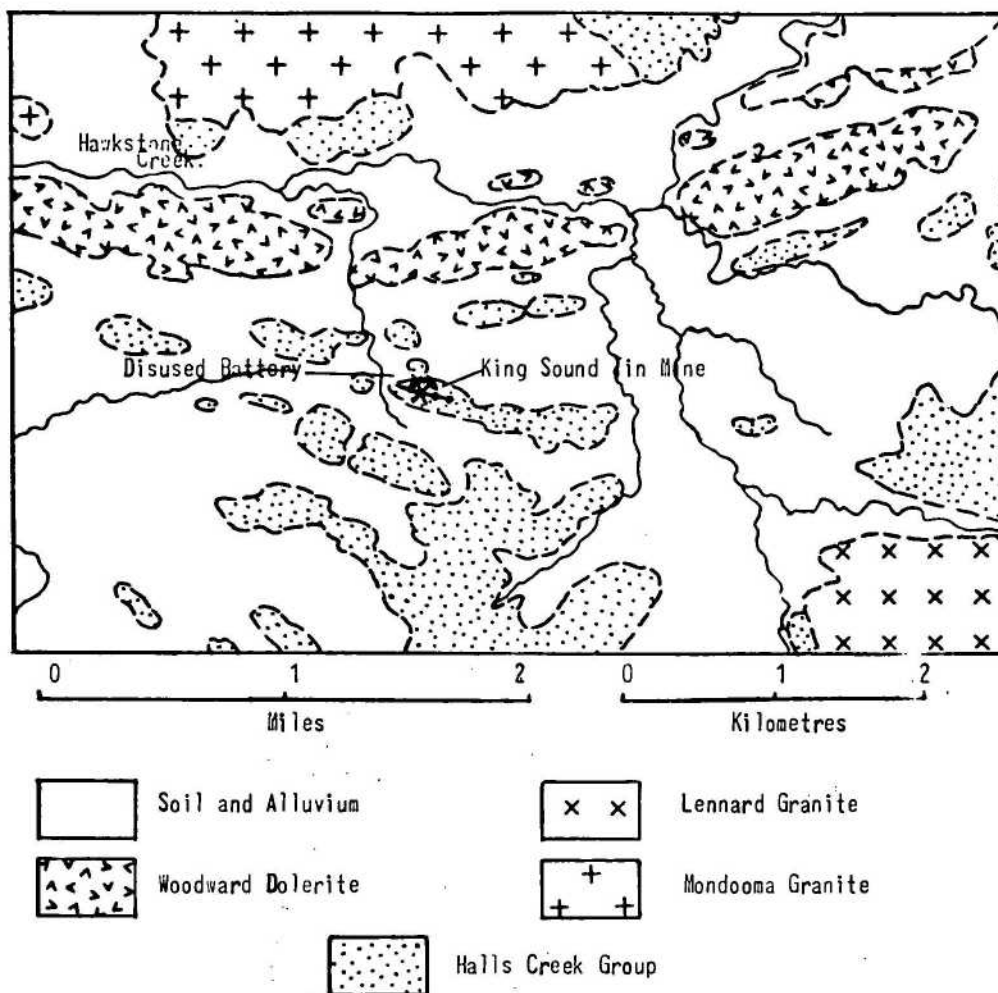
In most parts of the Kimberley region specks of chalcopyrite are common in the basal 250 feet (80 m) of the Carson Volcanics, and also found locally in the topmost (tuffaceous) beds. As yet no economic concentrations have been found. However, in view of the recent discovery of silver-lead-gold-copper mineralization in a fault zone in Hart Dolerite near Kununurra, (reported on ^{by} Sofoulis, 1968) faults traversing both the Carson Volcanics and the Hart Dolerite in the Charnley Sheet area (and other areas in the Kimberley region where these formations occur) warrant detailed prospecting for these metals. Silicified faults are probably the best prospecting targets.

Fluorescent Acid Intrusives: All rock specimens collected were examined under short wave ultra violet light as a possible guide to mineralization. Several granitic rocks exhibiting fluorescence were analysed spectrographically. Only one of these specimens came from the Charnley Sheet area. This specimen was one of Mount Disaster Porphyry from 2560E, 28606N: it contains Sn 4 ppm; W 20 ppm; Mo 5 ppm; Cu 12 ppm; Pb 100 ppm; Zn 25 ppm. As in most of the other fluorescent rocks the only anomalous metal content is that of lead, although three specimens from the Yampi Sheet area also contain anomalous tin values (20 to 80 ppm).

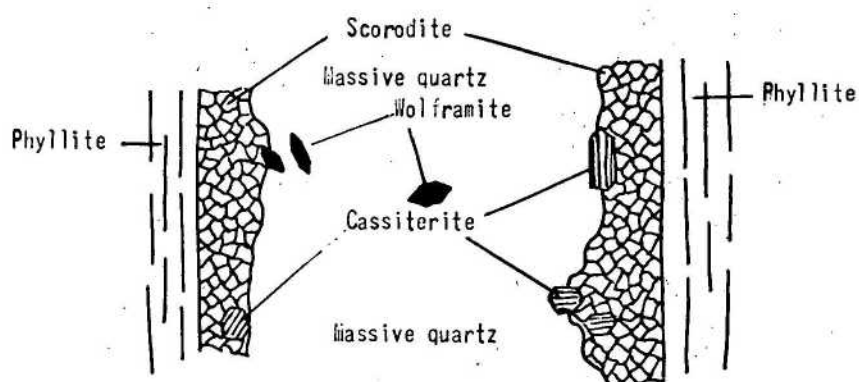
NON-METALLIC MINERALS

Kyanite

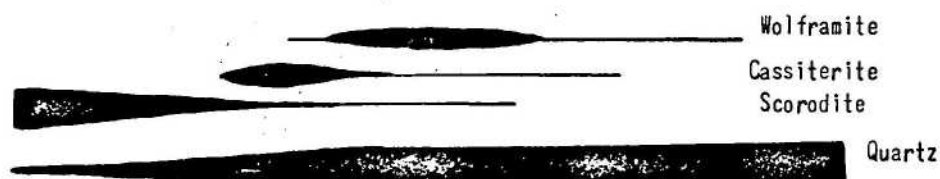
Hawkestone Creek Kyanite Prospect: This has been described in detail by Derrick and Morgan (1966). It consists of a number of poorly exposed lenses and boulder trains of kyanite rock, kyanite schist, kyanite-topaz rock, vein kyanite and some corundum-rock, enclosed by phyllite of the Halls Creek Group, and by the Woodward Dolerite. Topaz was not noted in the report by Derrick and Morgan; it forms dense grey chert-like masses in the northwest part of the deposit, and contains abundant small metacrysts of kyanite.



(a). Locality Map - King Sound Tin Mine.



(b). Field sketch of quartz vein showing mineral distribution.



(c) Diagrammatic crystallisation sequence.

These kyanite crystals are replaced in some instances by fine-grained massive topaz.

Chemical analyses of kyanite and corundum rock are contained in Appendix. 2. These show silica values (for all but the corundum rock) from 35% to 37% and alumina values from 53.8% to 60.4%. For comparison topaz contains about 32% silica and 56% alumina. These values for kyanite compare favourably with the U.S. National Stockpile Specification listed in Appendix 2, although there is probably an excess of alkali in the Kimberley material. However Report 13/67 of the Government Chemical Laboratories of Western Australia states that neither locally produced kyanite in America nor imported Indian sillimanite conform fully to the stockpile specifications, which apparently are too stringent for general application.

Samples of pale blue fibrous kyanite and grey kyanite aggregates were submitted for S.G. determination. Results are as follows: blue kyanite - 3.48, 3.39, 3.57, 3.56, 3.59, 3.59 (average 3.53): grey kyanite - 3.64, 3.61, 3.62, 3.62, 3.50, 3.73 (average 3.62): corundum rock - 3.58, 3.54, 3.63 (average 3.58): topaz - 3.51, 3.51, 3.52 (average 3.51).

The higher density of the grey kyanite is probably due to abundant microscopic inclusion of ? magnetite and rutile, which also account for the colour difference. The relatively low specific gravity of the corundum rock is due to a substantial pyrophyllite-sericite content.

No full-scale refractory test has been carried out on the Hawkstone Creek kyanite material. The pyrometric cone equivalent of massive kyanite rock from this prospect to 1820°C-1835 °C (Orton Cone No 37-38,). After texturing the sample was off white in colour, vitrified, with a matte lustre (AMD L Report CEL852/67).

Reserves have been estimated to be 18,000 tons of kyanite rock per vertical foot, over an area of 200,000 square feet (Derrick and Morgan, 1966). Although this area is possibly an overestimate, the tonnage available would be quite high grade (60% Al_2O_3 or greater) because of the corundum present. Probably between 1000 and 2000 tons of kyanite rock are present as loose boulders scattered over the hill. Reserves at depth are unknown.

The kyanite deposit is of little economic significance at present, mainly because of its relatively small size and isolation. Trade requirements in Appendix 1 indicate that the Hawkstone Creek kyanite would be generally acceptable for refractory material and that the topaz, corundum and even pyrophyllite present in the deposit would enhance both alumina content and refractoriness.

Andalusite.

Schists of the Halls Creek Group about 3 miles (5 km) northwest of Hawk Creek Yard contain up to 10% of andalusite (chiastolite) occurring as large individual crystals averaging about 3 to 4 cm by 1.5 cm, and associated with short prismatic staurolites. The andalusite (and staurolite) weather out readily from the schist and are concentrated locally in detrital gravels. At least some of the chiastolite crystals are pseudomorphed by kyanite. If the demand and price for aluminium silicates were adequate for the nearby kyanite deposit to be worked it is possible that these andalusite-bearing schists and the lateral extensions of the same andalusite-staurolite belt to the southeast could provide a substantial additional tonnage of aluminium silicate, but crushing and separating facilities would be required to recover the andalusite, whereas they would probably be unnecessary for the kyanite rock.

Fluorite.

Trace of fluorite have been noted at 2560 E, 28649 N, about 6 miles (10 km) east-northeast of King Sound Tin Mine, in Mondooma Granite close to the contact with Halls Creek Group phyllite, and at 2280E, 28834N about 10 miles (17 km) north-northwest of Hawkstone Creek Yard in a dyke of Mount Disaster Porphyry. These showings are not of direct economic significance, but are of interest in that they indicate the presence of a volatile phase in the sub-volcanic acid intrusives which enhances their mineralizing potential.

Bauxite.

Scattered areas of laterite are present within a radius of 20 miles (35 km) of Beverley Springs homestead. Some may be bauxitic but they have not been sampled in detail. Laterite and lateritic soils overlying the Carson Volcanics, which covers an area of about 10 square miles (25 km), by analogy with that from other Sheet areas to the north and northeast, probably contains areas of bauxitic laterite interspersed with areas of highly ferruginous laterite.

Because of their small size, scattered distribution, and greater distance from the coast than many of the laterite outcrops further north, the laterites of the Charnley area even if they prove to be highly luminous are unlikely to be an economic source of bauxite in the immediate future.

Areas of lateritic soils (Cz1) overlying the Warton Sandstone in the Synnot Range probably include true laterite locally. In other parts of the Kimberley region however, (e.g. Drysdale-Londonderry: Gellatly and Sofoulis, 1966) it has been shown that laterites overlying sandstone are more ferruginous and more siliceous than those overlying basic rocks and are unlikely to be a potential source of alumina.

CONSTRUCTION MATERIALS

Sand and Gravel. Supplies of medium-grained clean quartz sand suitable for use in cement mortar and in concrete are available in most creeks draining the King Leopold Sandstone and the Warton Sandstone which together underlie about 80% of the Sheet area. Sands derived from the granites in the southwest and from the Carson Volcanics would probably be unsuitable on account of their feldspar content and those from the Carson Volcanics also on their iron content.

Deposits of cobble and boulder gravels are present in many places along the main rivers and their principal tributaries but most deposits are of limited extent.

Rock-Fill.

Beneath the zone of surface leaching most of the sandstones in the area (as seen in rocky gorges) are compact and silicified and would probably make suitable rock-fill material ("dimension stone"), as would the igneous rocks of the area with the possible exception of the Lennard Granite, which in places is highly altered.

Road metal.

"Blue metal" for use in the preparation of bitumen-sealed roads could be obtained from the Hart Dolerite, Woodward Dolerite, Carson Volcanics, or the Mondooma Granite. However, there is unlikely to be any demand for this in the Charnley Sheet area in the immediate future. Material for forming and surfacing earth roads is more important at present. Residual soils derived from the Carson Volcanics and from the intermediate granophyric varieties of the Hart Dolerite are suitable for this purpose as are also laterite and residual material derived from it. Shale and siltstone from the Speewah Group and from the Carson Volcanics could be used locally but are inextensive in their occurrence.

DAM SITES

The possible development of hydro-electricity using dams on the Isdell, Charnley and Calder Rivers has been mentioned briefly by Maitland (1921). Good dam sites are present on the Isdell River at 2746E, 29110N (about 7 miles (12 km) north-northwest of trig point T033), and on the Charnley River at 3000E, 29328N, (about 2 miles (3.5 km) down stream from its confluence with Synnot Creek.) In both cases the excellence of the dam site is at least partly outweighed by isolation and by the lack of areas that could be irrigated with the water after its use for power generation.

Generation of electricity by tidal power using the ebb flow of the tide from Walcott Inlet has been mooted in recent years but little preliminary work has been done apart from a brief investigation by Gordon (1964). The principal engineering works in connection with such a scheme would probably be situated entirely in the Yampi Sheet area to the west.

WATER SUPPLY

Surface Water.

Permanent pools are abundant in most water courses that drain areas of King Leopold Sandstone in the north and northwest of the Sheet area and in areas of granite close to the King Leopold Range, but are scarce in areas of Carson Volcanics which form the best grazing land, and are lacking in the extreme southwest of the Sheet area.

Underground Water.

To date there has been little development of underground water, there being only 5 operating bores and two wells in the Sheet area. (Allen, 1966). Details of these and of three unsuccessful bores and wells are given in Table 12. Most of the operating bores are situated in areas underlain by the Carson Volcanics. This is a reflection of three factors (1) that areas underlain by these Volcanics are the best grazing areas (2) that surface water supplies in these areas are inadequate for optimum distribution of stock in relation to grazing potential, (3) that satisfactory supplies of underground water are available in the Carson Volcanics. Flow rates (600 to 1800 g/hr) are adequate for stock watering, and salinities are low.

TABLE 12

WATER BORE AND WELL DATA - CHARNLEY 1:250,000 SHEET AREA

Name	Station	Grid Co-ordinates	G.S.W.A. Reg. No.	Depth (metres)	Static Water Level (metres)	Supply g/hr	Salinity ppm T.D.S.	Aquifer
Plover Hill Bore	Mount House	3543E 28615N	4064-III-1	16	8.7	1800	505	Carson Volcanics
_____(Dud bore)	Mount House	3523E 28662N	4064-III-2	10.7	-	-	-	Carson Volcanics
_____(Dud Bore)	Mount House	3527E 28678N	4064-III-3	11	-	-	-	Carson Volcanics
Herberts Bore	Mount House	3518E 28673N	4064-III-4	19	9.7	1000+	low	Carson Volcanics
Allens Bore	Beverley Springs	3334E 29051N	3964-I-3	12	3	1200	-	Alluvium
Pandanus Bore	Beverley Springs	3387E 29146N	3964-I-4	17	-	1600	-	Alluvium
Tomahawk Bore	Beverley Springs	3342E 28933N	3964-I-5	16	-	600	-	Carson Volcanics
Beverley Springs	Beverley Springs	3385E 29106N	3964-I-1	7	4	660	35	Alluvium
Homestead Well								
_____(Dry Well)	Beverley Springs	3287E 28963N	3964-I-2	-	-	-	-	Carson Volcanics
Mount Hart	Mount Hart	2742E 28827N	-	-	-	-	-	Hart Dolerite
Homestead Well								

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APPENDIX 1SUITABILITY OF HAWKSTONE CREEK KYANITE ROCK
FOR TRADE REQUIREMENTS

The following trade information is from Varley (1965).

Kyanite, andalusite and sillimanite, together with topaz, corundum and dumortierite, are used in the manufacture of refractory bricks, etc. The process involves calcination at around 1500-1600°C to convert these minerals to a mixture of mullite and silica in the ratio 88/12. Depending on grain size, the calcined material is then bonded to form bricks or refractory cements. Most of the material used industrially is in the form of crystal aggregates with grain size from 2 mm to 1 cm.

Sillimanite is advantageous as a starting product, since it requires no calcination before bonding, and suffers from a 16% expansion in the conversion to mullite, but this can be used to offset shrinkage of other refractory material present. In the calcination of topaz, fluorine and water are driven off at 850-900°C, and the problem of fuming fluorides has deterred some manufacturers. However, the fluorine carries with it considerable iron and silica. Topaz has a low permanent expansion, a refractoriness of cone 40 (1875°C), and exerts a marked bonding action at higher temperatures. Pyrophyllite in limited quantities can be used to advantage in refractories, since it, too, acts as a bonding agent at high temperatures.

The U.S. stockpile specifications require a raw material minimum grain size of 4.7 mm for the manufacture of refractory bricks and as fine as 100 mesh for refractory cement. Coarse bladed kyanite (with blades from 3 cm long or more) is not very desirable, since it reduces load strength of the final product. Refractoriness is specified as Cone 37 for high alumina (>45% Al_2O_3) bricks.

In general, corundum and topaz are usually regarded as beneficial because they increase the alumina content, but an excess of corundum makes drilling and grinding difficult.

Comparing these requirements with the Hawkstone Creek kyanite, the latter satisfies the refractoriness specifications of cone 37. The topaz and corundum in the deposit would only enhance this figure.

Grainsize of the kyanite is variable, but there are large quantities of crystal aggregates of 2-5 mm grainsize, with scattered zones of bladed material, which probably would be suitable. Corundum and topaz appear to occur in certain areas, and could be selectively mined to enrich any bulk kyanite charge.

APPENDIX 2CHEMICAL ANALYSIS OF ROCKS FROM THE
KYANITE DEPOSIT

The following analyses are taken from AMDL Report AN1852/67 and W.A. Government Chemical Laboratories Report 13/67. For comparison the U.S. Stockpile Specification for kyanite is also listed.

Oxide	1 66160301*	2 1010	3 1011	4 1012	5 1014	6 13031/66+	7 P-27
SiO ₂	18.1	37.5	35.9	37.0	36.0	37.0	Max. 39
Al ₂ O ₃	71.0	55.5	53.8	58.6	60.4	59.4	Min. 59
Fe ₂ O ₃	0.13	0.18	0.19	0.11	0.10	{ 0.76	Max. 0.75
FeO	0.19	0.21	0.08	0.10	0.12		
MgO	0.13	0.44	0.14	0.06	0.05	0.18	} Max. 0.20
CaO	1.78	0.38	2.40	0.15	0.37	0.06	
Na ₂ O	1.58	0.52	1.53	1.00	0.24	0.96	} Max. 0.20
K ₂ O	0.87	1.63	1.33	1.00	2.05	0.30	
H ₂ O+	3.30	1.69	2.45	1.03	0.31	1.34	
H ₂ O-	0.08	0.07	0.21	0.09	0.05	n.d.	
CO ₂	0.02	0.01	0.02	0.04	0.03	n.d.	
TiO ₂	2.35	1.55	1.60	0.44	0.55	0.30	Max. 1.25
P ₂ O ₅	0.25	0.08	0.19	0.02	0.02	n.d.	
MnO	0.01	0.01	0.01	0.01	0.01	n.d.	

n.d. not determined

* BMR Registered Sample Nos

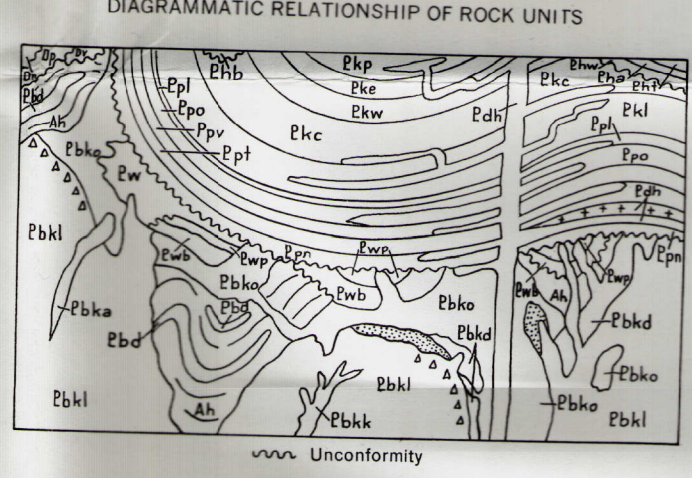
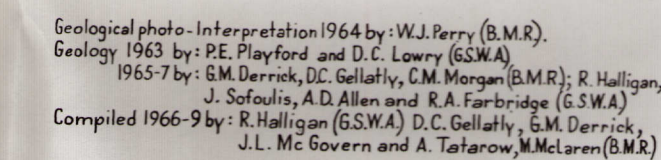
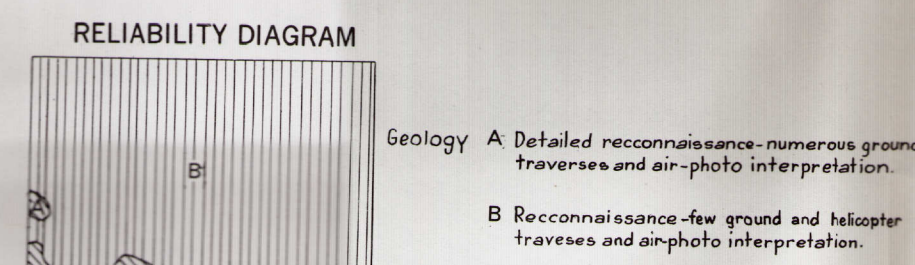
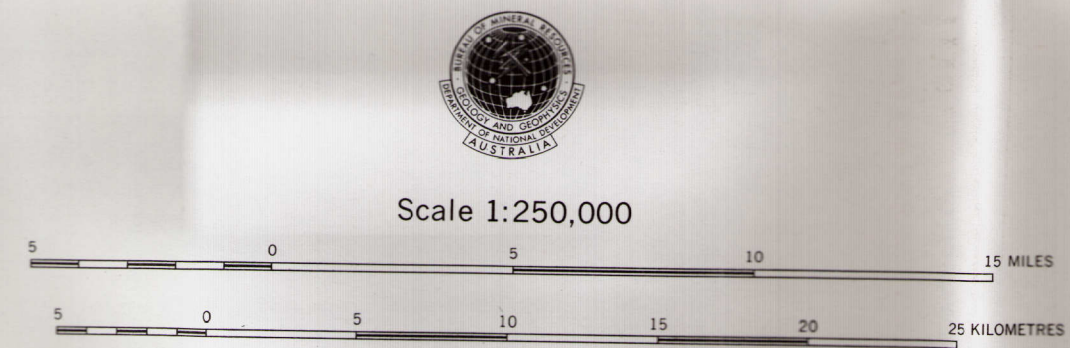
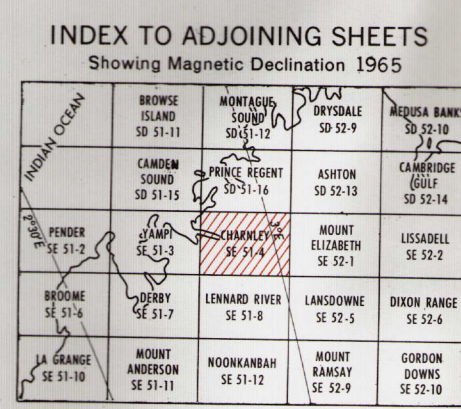
+ W.A. Govt Chemical Laboratories Number

1. Corundum-pyrophyllite-sericite rock - Analyst A. Jorgenson A.M.D.L.
2. Kyanite-tourmaline-dumortierite-pyrophyllite rock. " "
3. Kyanite-pyrophyllite-sericite-diaspore rock (kyanite schist) - Analyst A. Jorgenson A.M.D.L. " "
4. Kyanite rock " " "
5. Kyanite rock " " "
6. Kyanite rock - Analyst J. Sims, W.A. Govt
7. U.S. Stockpile Specification.

APPENDIX 3COMPARISON OF STANDARD TOPAZ DIFFRACTION PATTERN WITH
FINE-GRAINED TOPAZ MATRIX FROM KYANITE-TOPAZ ROCK

dA Standard	dA Kyanite-topaz rock R67161043	I/I _i
3.693	3.69	60
3.195	3.20	65
3.037	3.03	35
2.986	2.98	25
2.937	2.93	100
2.4804	2.48	20
2.3783	2.38	25
2.3609	2.36	45
2.1049	2.10	45
2.0555	2.06	25
1.8691	1.87	25
1.8553	1.86	25
1.6706	1.67	25

plus perfect matches in 17 other peaks with I/I_i less than 20, in the range 3.69 to 1.67.



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