BmR Campactus
copy 3

REPORT 153

The older Precambrian geology of the Lennard River 1: 250 000 Sheet Area, Western Australia

D. C. GELLATLY, J. SOFOULIS, G. M. DERRICK and C. M. MORGAN

DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
DEPARTMENT OF MINES, WESTERN AUSTRALIA
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 153

The older Precambrian geology of the Lennard River 1:250 000 Sheet Area, Western Australia

D. C. GELLATLY, J. SOFOULIS*, G. M. DERRICK and C. M. MORGAN

*Geological Survey of Western Australia

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA, 1974

DEPARTMENT OF MINERALS AND ENERGY

MINISTER: THE HON. R. F. X. CONNOR, M.P.

SECRETARY: SIR LENOX HEWITT, O.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

ACTING DIRECTOR: L. C. NOAKES

ASSISTANT DIRECTOR, GEOLOGICAL BRANCH: J. N. CASEY

DEPARTMENT OF MINES, WESTERN AUSTRALIA
MINISTER: THE HON. A. MENSAROS, M.L.A.
UNDER SECRETARY: G. H. COOPER

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DIRECTOR: J. H. LORD

Published for the Bureau of Mineral Resources, Geology and Geophysics by the Australian Government Publishing Service

ISBN 0 642 00822 1

MANUSCRIPT RECEIVED: MARCH, 1971

REVISED MANUSCRIPT RECEIVED: JANUARY, 1973

ISSUED: OCTOBER, 1974

Printed by Graphic Services Pty Ltd, 60 Wyatt Street, Adelaide 5000

CONTENTS

TABLES

FIGURES

SUMMARY

The Lennard River Sheet area lies in the West Kimberley Division in the northern part of Western Australia. The older Precambrian rocks described in this Report underlie the Carpentarian Kimberley Basin sediments and range in age from ?Archaean to early Carpentarian.

The oldest rocks in the Sheet area are the Halls Creek Group, a series of flysch sediments and minor acid volcanics of ?Archaean age that have been strongly folded and metamorphosed in the greenschist and locally in the almandine-amphibolite facies. They were intruded in pre-Carpentarian time by the Woodward Dolerite and the Wombarella Quartz-Gabbro (both of which have been metamorphosed together with the Halls Creek Group), and probably also by the Kongorow Granite and Richenda Microgranodiorite.

The Whitewater Volcanics (of Lower Proterozoic or early Carpentarian age) consist of quartz and feldsparphyric rhyodacite tuffs and lavas. They overlie the Halls Creek Group unconformably and are intruded by high-level stratiform quartz feldspar-porphyries and granites (Bickleys and Mount Disaster Porphyries and Mondooma Granite) and by later granites. The later granites comprise the porphyritic Lennard Granite, the non-porphyritic McSherrys Granodiorite, and minor occurrences of leucocratic and locally muscovitic types (Mount Amy Granite and Dyasons Granite) that may have been derived from the former types by fractionation.

Several periods of folding are represented along northeast, southeast, and northwest plunging axes. Major faults in the area are mainly northwest-trending transcurrent faults that are a continuation of those of the East Kimberley. The main metamorphism apparently antedates the Whitewater Volcanics. Zonal distribution of andalusite, chloritoid, staurolite, garnet, and sillimanite has been mapped. Locally sillimanite-bearing metamorphics have undergone anatexis to produce potash feldspar-sillimanite gneisses.

Economic minerals that have been worked in the area include gold, mica, and corundum. Minor amounts of galena, cassiterite, stibnite, and copper minerals have been reported from the older Precambrian rocks. Water from surface pools, shallow bores, and wells is used for cattle.

INTRODUCTION

Location

The Lennard River 1:250 000 Sheet area SE/51-8 lies between latitudes 17° and 18°S, and longitudes 124°30′ and 126°E. It falls within the Kimberley Land Division of the northern part of Western Australia. The southeast and northwest corners of the Sheet area are 255 km and 95 km, respectively, from the port of Derby.

Object

The work described in this Report is part of a program of regional reconnaissance mapping at a scale of 1:250 000 carried out jointly by the Geological Survey of Western Australia (GSWA) and the Bureau of Mineral Resources (BMR), and designed to map all the Precambrian rocks of the Kimberley region. Since the program started 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, and Gordon Downs. In addition, the 'younger Precambrian' rocks of the Kimberley Basin in the Charnley and Lennard River Sheet area have been mapped.

This Report provides a preliminary description of the 'older Precambrian' rocks, i.e. the Lamboo Complex (granites, volcanics, porphyries, gabbro, and dolerite) and Halls Creek Group sediments (and metasediments) of the King Leopold Mobile Zone lying within the Lennard River Sheet area. A few previously undescribed post-Precambrian units will also be described in this Report. The Precambrian rocks of the Oscar Range are described in Derrick & Gellatly (1971).

The results of the mapping program are or will be published in four Bulletins; Bulletin 106, East Kimberley (Dow & Gemuts, 1969); Bulletin 107, Lamboo Complex (Gemuts, 1971); Kimberley Basin (Plumb, in prep.); and West Kimberley (Gellatly, Sofoulis, & Derrick, in prep.). In addition, Explanatory Notes, which briefly describe the geology of each 1:250 000 Sheet area, are being published.

This Report and similar reports on the Yampi (Sofoulis et al., 1971) and Charnley (Derrick et al., 1974) 1:250 000 Sheet areas and the Oscar Range of the Lennard River Sheet area will form the basis of the West Kimberley Bulletin.

Access

Access to the Sheet area from the port of Derby is provided by a formed earth and gravel road which runs via Yammera Gap and Inglis Gap to Mount House station in the northeast corner of the Sheet area, and extends eastwards for 50 km to Glenroy station in the Lansdowne Sheet area. The Derby/Fitzroy Crossing section of the Great Northern Highway gives access to the southern part of the Sheet area. This section of the Highway is now mostly sealed.

Napier Downs homestead, in the northwest of the Sheet area, and Mount House homestead are 130 and 225 km by road from Derby, respectively. Numerous graded station tracks, and minor subsidiary tracks, particularly numerous in the southwestern corner of the Sheet area, radiate from the homesteads to yards and watering points. All roads, especially station tracks, are likely to be impassable at times during the wet season.

Mount House and Leopold Downs stations are serviced fortnightly by a local air service. Infrequently used airstrips suitable for light aircraft are located at Napier Downs, and at Mount Hart Outcamp near Inglis Gap. In addition, Fitzroy Crossing, about 40 km southeast of Leopold Downs, has a twice-weekly air service.

Population and industry

Permanently inhabited homesteads in the area are Napier Downs, Mount House, Silent Grove, Fairfield, Leopold Downs, Ellendale, Blina, and Calwynyardah. The Rocks homestead, 5 km southwest of Mount Gladys, is inhabited intermittently. The estimated population of the Sheet area is about 300.

The only major industries in the area are sheep and cattle raising. Sheep raising is confined to Blina, Ellendale, and Calwynyardah properties, and cattle raising to the remainder. A detailed analysis of the cattle and sheep industry is given by Thomas (1964). Maintenance of the Great Northern Highway and the Mount House beef road provides semi-permanent or seasonal employment for road gangs of up to 50 men. Employment for a few men is provided by grading of station tracks, pest control, and prospecting.

Climate

The Lennard River Sheet area has a semi-arid monsoonal climate, with well defined wet and dry seasons. Most of the area lies between the 500 and 750 mm rainfall isohyets, which trend approximately east. Rainfall recorded in the Sheet area ranges from an annual average of 355 mm at Fairfield station to 685 mm at Napier Downs. Most rain falls during the period December to March, and sporadic rain in November and April. The rain is derived from thunderstorms and cyclones which are developed from low-pressure areas centred over northern Australia during the summer months. At Napier Downs in March 1966, 330 mm of rain were recorded in 11 hours from a cyclone.

The dominant climatic influence during the dry season is a high-pressure system with prevailing easterly winds and little cloud. The days are warm and the nights cool. Higher parts of the Sheet area near Mount House experience frosts in July. Average minima during the dry months April to October range from 7 to 18°C, and maxima 24 to 35°C. Relative humidity is low. During the wet summer months, minimum temperatures are near 24° and maximum temperatures 32 to 38°C, with high relative humidity. November is generally the hottest month, and July the coldest. Further detailed information is available in Fitzpatrick & Arnold (1964).

Vegetation and pasture

Vegetation and pastures of the Sheet area were described in detail by Speck & Lazarides (1964).

Tree growth decreases from north to south and reflects the rainfall distribution. The tree layer is open; snappy gum (*Eucalyptus brevifolia*) is ubiquitous, and annual sorghum grasses and spinifex are abundant. Baobab trees are common along sandy watercourses.

Tall stands of cane grass are common around Napier Downs and along the levee banks of the major rivers in the area, particularly the Barker River. Most of the levee banks and plains along the rivers also support large river gums (*Eucalyptus papuana*), paperbark, smaller species of *Bauhinia* and *Acacia,* and a rich assortment of tall perennial grasses.

Present investigation

Most of the area was mapped on foot using four-wheel-drive vehicles for transport. A helicopter was used in the more inaccessible areas.

The following aerial photographs and maps were used:

1. Vertical aerial photographs—1:50 000 scale; 1949 photography by RAAF
2. Topographic base maps at 1:50 000 scale
3. Topographic map at 1:250 000 scale, compiled by the Royal Australian Survey Corps in 1962 and 1963
4. Airphoto mosaics at 1:63 360 scale compiled by the W.A. Department of Lands and Surveys
5. Airphoto mosaic at 1:250 000 scale, compiled in 1950 by the Commonwealth Division of National Mapping, Department of Minerals and Energy
6. Geological map of the Lennard River Sheet (First Edition) at 4 miles to 1 inch, produced in 1956 by the Bureau of Mineral Resources
7. Topographic map at 4 miles to 1 inch by W.A. Department of Lands and Surveys
8. Geological map of the Kimberleys (10 miles to 1 inch) (Harms, 1959).

Previous work

The Palaeozoic geology of the region has been described by Guppy, Lindner, Rattigan, & Casey (1958), and by Playford & Lowry (1966). The Precambrian has been briefly described by Guppy et al. (1958). The Precambrian of the Lennard River Sheet area is included in unpublished comprehensive work on the geology of the Kimberley Division (Harms, 1959). Most other reports deal with small mineral deposits and give only generalized accounts of the geology.

Previous investigations of general geology. The earliest report on the area was by Hardman (1884), who mentioned 'Cambro-Silurian' granite near Mount Amy near the Barker River, and andalusite and garnet schists along the southwestern part of the King Leopold Range.

Many of the creeks, rivers, and mountains in the area were named by Hann (1901) who prospected for gold at Mount Broome. Some of the features he named include Bell Creek, Mount House, Mount Clifton, and Lady Forrest Range. Brief reference was made by Hann to the volcanics near Mount House and to the large whalebacks of granite along the Barker River.

Maitland (1902) described quartzite and sills of dolerite from the King Leopold Range, and thought they were Cambrian. In later reports generalized reference was made to the same rocks by Maitland (1907, 1928), Wade (1924), and Blatchford (1929). By 1929 the Kimberley Group rocks were confidently assigned to the Precambrian.

General reports on the geology of the area were made by Jack (1906), who mentioned the auriferous rocks of the Mount Broome area, slates in the Oscar Range, and the subterranean water flow at Tunnel Creek. Rocks collected by Fitzgerald in 1905-6 included samples of granite and leucitite which were reported on by Fitzgerald (1907) and Farquharson (1920). Farquharson suggested that the unusual leucitite specimens could have come from the East Indies. Wade (1936) traversed from the Napier Range to the King Leopold Range and collected granite from Hann's Hole on the Barker River. He noted dolerite dykes near Fairfield Gap (McSherrys Gap), and compared the deformed conglomerates of the Oscar Range to those from the Goldfields area of Western Australia. Leucitite specimens collected by Wade were described by Wade & Prider (1940) and Prider (1960). A generalized account of porphyrite dykes, granite, acid breccia, gneiss, and schist in the Mount Broome/Richenda River area is given in Finucane (1938, 1939).

The Precambrian was briefly mentioned by Kraus (1941) and Teichert (1941) in reports for Caltex Oil Company. Teichert spoke of rapid subsidence of the Precambrian in pre-Devonian time. Kraus recorded quartzite, schist, and basic igneous rocks at Mount Wilson, and thought that this hill and the Oscar Ranges were low rises on a pre-Devonian peneplain.

A number of basic rocks from the north Kimberley were studied by Edwards (1943). They were collected by Fitzgerald (1907) and Maitland & Gibson, who were attached to the surveying party of Brockman & Crossland (1901). Three specimens from basic dykes in the Mount Joseph/Barker River area were described by Edwards as ophitic two-pyroxene dolerite. The geological map with specimen localities in Edwards (1943) is after Easton (1922).

The first comprehensive account of the geology of the basement complex and the overlying Kimberley Group was given by Harms (1953, 1959) who redefined the sedimentary succession of Guppy et al. (1958), described the Elgee Siltstone and Pentecost Sandstone, renamed the Hart Basalt Hart Dolerite (defined, Gellatly, Derrick, & Plumb, 1974), and noted the more important features of the metamorphics, granites, and porphyries of the basement complex.

General accounts of the geology, stratigraphy, and physiography of the Precambrian of the Sheet area are included in Guppy et al. (1958), Veevers (1958), and Veevers & Wells (1961). The report of the regional geography and physiography of the Kimberley region by Jutson (1950) has been supplemented by more detailed work by CSIRO (Speck et al., 1960, 1964). Gravity and aeromagnetic reconnaissance surveys of the Fitzroy/Canning Basin by BMR show the distribution and broad physiography of the basement complex beneath the Palaeozoic cover (Quilty, 1960; Flavelle & Goodspeed, 1962).

Precambrian stratigraphy, correlation, and subdivision have been discussed by the Geological Survey of Western Australia (1966), Horwitz (1966), and Trendall (1966), whose concepts of subdivision differed from those outlined by Dunn et al. (1966).

References to economic geology. Mineral locality maps of Western Australia for 1899 and 1903 show a copper deposit near the junction of the Barker and Lennard Rivers, and tin near the Lennard River headwaters. These were described later by Maitland & Jackson (1904), and the copper deposit proved to be the Mondooma show in the Yampi Sheet area. The same deposits and the Narlarla lead show were mentioned by Simpson & Gibson (1907).

The Narlarla lead deposit, located in Devonian rocks at the Barker River Gorge, was first described by Woodward (1907) who stated that leases were taken up as early as 1900, but were later abandoned. Numerous references to the minerals of the Narlarla deposit have been made by Simpson (1939), Prider (1941), and Carrol (1945), and the geology and genesis have been discussed by Finucane & Jones (1939), Prider (1945), Halligan (1964), and by Hutton (1965) who carried out a detailed study in the immediate vicinity of the mine.

Emery deposits in the Richenda River/Mount Broome area were reported by Simpson (1919, 1920) and Forman (1942). Minerals from the deposits, especially corundum and diaspore, were described by Stillwell (1942). The gold-bearing reefs and tin-bearing pegmatites of the Mount Broome/Richenda area were investigated by Finucane (1938, 1939), who also reported on Gussy's mica show on the Barker River (Finucane & Jones, 1939). This mica deposit also received attention from Matheson (1944), Simpson (1952), Harms (1953, 1959) and Sofoulis (1967). Harms (1959) also reported minor showings of lead and copper elsewhere in the Sheet area.

During the 1950s a prospecting lease was held by the Western Mining Corporation Ltd over much of the Yampi basement area, extending to the Barker River, but no mineral deposits or showings are indicated on the company map of this area (Woodall, 1957). A geochemical survey of the West Kimberley basement complex by Pickands Mather International has been completed, but results are not available.

Water supply for some West Kimberley cattle stations was investigated by Woodward (1908). A number of bore sites were selected near Mount House and immediately to the southwest of the Oscar Range by Berliat (1953). Further hydrological work has been undertaken during the present survey.

PHYSIOGRAPHY

The landforms of the Lennard River Sheet area are grouped together into four physiographic provinces, comprising 13 subprovinces (Fig. 1). The Kimberley Plateau and the Kimberley Foreland fall within the North Kimberley Division of Jutson (1950); the others, the Lamboo Hills and the Fitzroy Plains, are included in Jutson's Fitzroyland Division.

Only three of the 13 subprovinces, the Lennard Hills, the Halls Creek Ridges, and the Napier Plains, are underlain by the older Precambrian rocks. For completeness a brief account is given of the others. The physiographic nomenclature used here is based on that of Wright (1964), and is part of a systematic nomenclature applicable to the whole Kimberley region (Dow & Gemuts, 1969; Plumb, in prep.; Gellatly, Sofoulis, & Derrick, in prep.).

Lamboo Hills Province

This province occupies the central belt of the Halls Creek and King Leopold Mobile Zones (Traves, 1955, p. 90) and extends from near Dunham River in the East Kimberley to the Townsend River in the Yampi 1:250 000 Sheet area. In the West Kimberley it consists of three subprovinces, the Lennard Hills, Halls Creek Ridges, and Napier Plains.

The *Lennard Hills* subprovince is a series of bouldery tors and whaleback hills with smooth exfoliation surfaces (Fig. 2a). The hills consist of erosion-resistant granite and acid porphyry, and are separated by narrow alluvium-filled valleys and sandy pediments.

Elevation ranges from about 90 to over 300 m; local relief is about 150 m. The tops of most hills appear to coincide with a dissected, gently sloping surface which ranges from 300 m above sea level immediately south of the King Leopold Range to about 250 m near the Fitzroy Ranges. Residuals of flat-lying lateritized grits and conglomerate southwest and south of Millie Windie Gap are probably

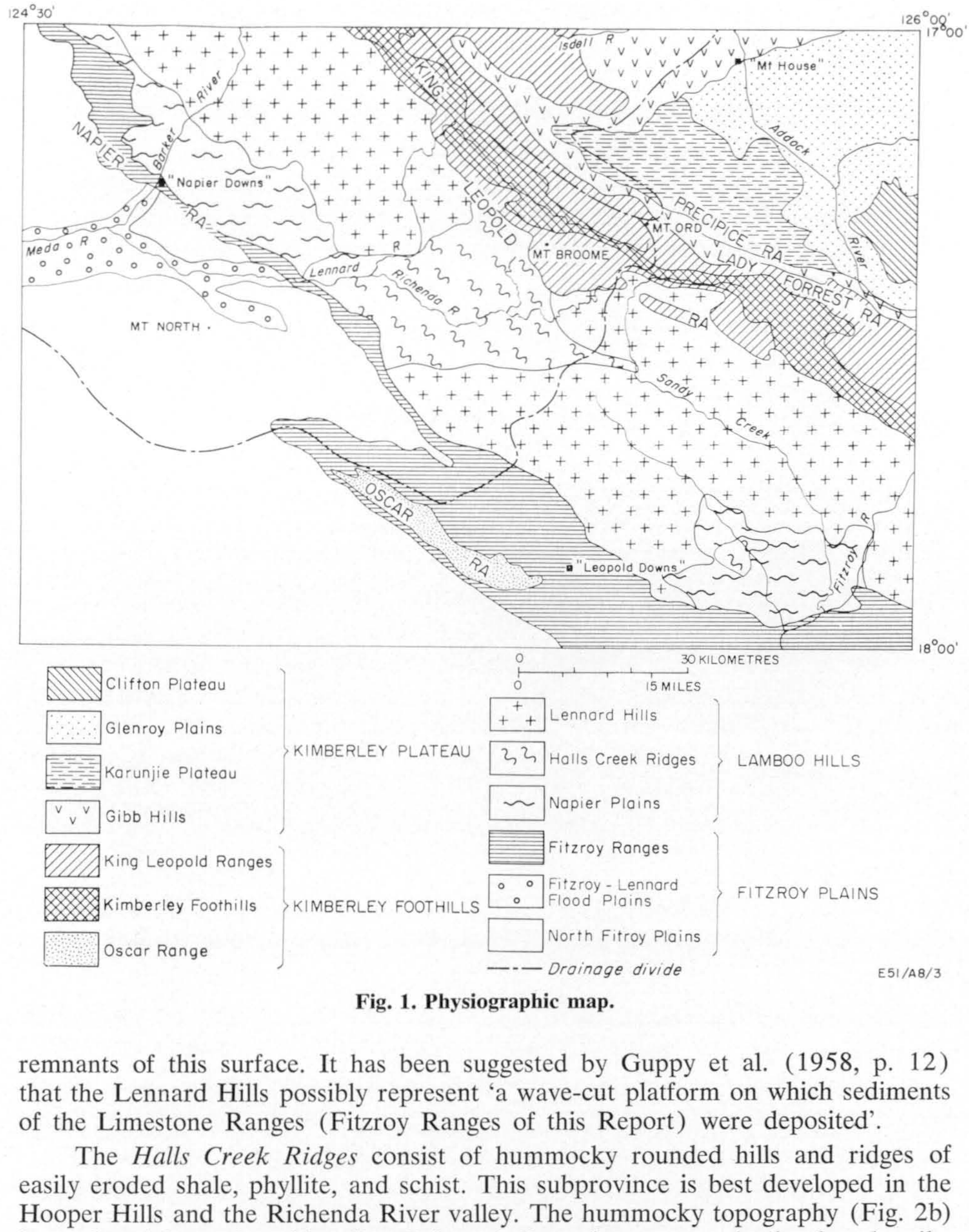


Fig. 1. Physiographic map.

remnants of this surface. It has been suggested by Guppy et al. (1958, p. 12) that the Lennard Hills possibly represent 'a wave-cut platform on which sediments of the Limestone Ranges (Fitzroy Ranges of this Report) were deposited'.

The *Halls Creek Ridges* consist of hummocky rounded hills and ridges of easily eroded shale, phyllite, and schist. This subprovince is best developed in the Hooper Hills and the Richenda River valley. The hummocky topography (Fig. 2b) is produced by active sidewall gullying of discontinuous, poorly developed strike valleys. Breaching of the strike ridges by such gullying is partly responsible for the unique drainage pattern of the subprovince (see Drainage). Elevations of the ridges are relatively uniform, and range from about 250 to about 300 m near the King Leopold Range. Relief is generally from 15 to 60 m.

The *Napier Plains* are best developed immediately northeast of the Napier Range, and along the Fitzroy River in the southeast. The plains consist of a broad expanse of black and sandy soil underlain chiefly by older Precambrian rocks which

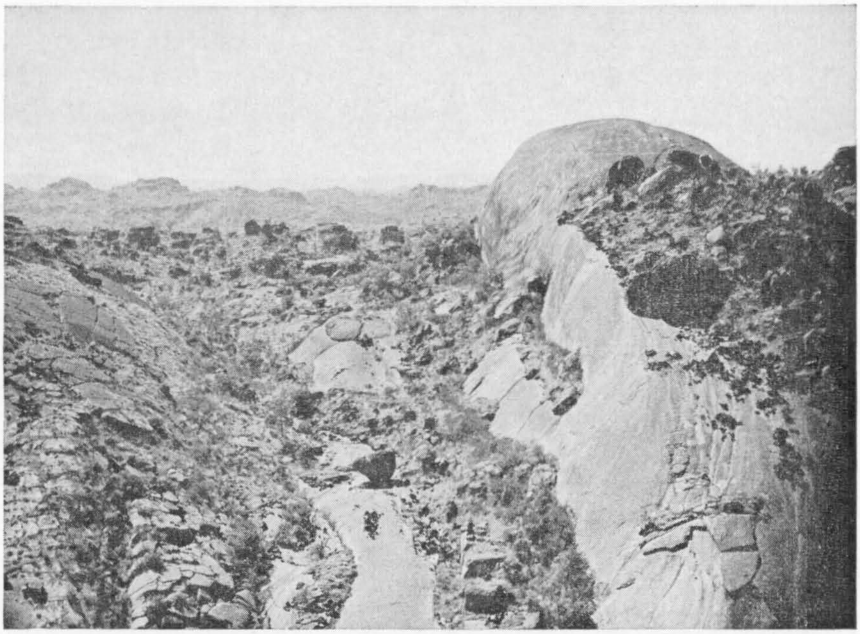


Fig. 2a. Lennard Hills. Whalebacks of Lennard Granite; 20 km east of Big Spring Bore. M529

form small isolated hills. Remnants of Devonian rocks, e.g. Prairie Hill, project from the plains in the Fitzroy River area. The plains are probably the result of eluvial and alluvial accumulation of sand and other sediments deposited by the major rivers in the area, the Barker, Lennard, and Fitzroy. This accumulation has been assisted by the natural limestone barriers which lie at right angles to the stream courses, and which have also contributed material to the plains.

Kimberley Plateau Province

This province contains four subprovinces.

The *Clifton Plateau* is an extensive mesa, about 500 m above sea level, formed by resistant sandstone of the Mount House Group. The Plateau is about 120 m above the *Glenroy Plains* which are underlain by less resistant shale and siltstone of the group.

The *Karunjie Plateau* is underlain mainly by sandstone and some siltstone. Gently dipping cuestas are the most common physiographic form. This plateau is generally flanked by the *Gibb Hills*, a series of rounded knobbly basalt hills interspersed with areas of black and red soil. The slopes of the hills are commonly terraced owing to the alteration of gently dipping lava flows and more resistant sandstone interbeds.

Kimberley Foreland Province

The most striking subprovince is the *King Leopold Ranges* which form a high rugged marginal abutment to the Kimberley Plateau Province. Massive peaks and cuestas consisting of sandstone are common forms; elevations range up to 900 m above sea level (e.g. Mount Broome, Mount Ord), and relief is up to 300 m.

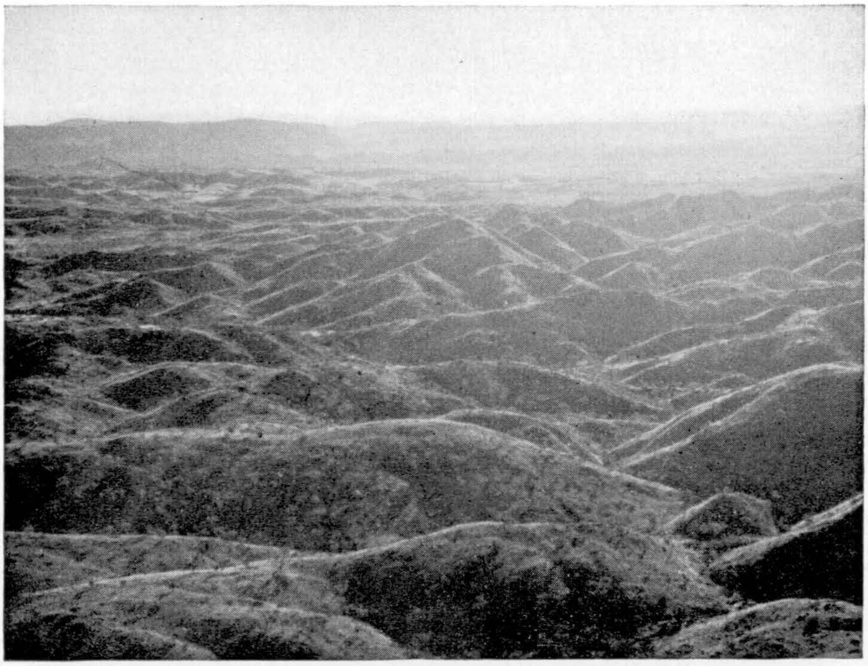


Fig. 2b. Halls Creek Ridges. Aerial view showing typical hummocky topography; 10 km southeast of Blackhill yard. GA996

The *Kimberley Foothills* are intimately associated with the King Leopold Ranges and are characterized by hogback-and-valley topography. Many valleys are underlain by sills of Hart Dolerite. The *Oscar Ranges* show similar hogback development. Maximum elevations of 250 to 300 m are similar to those in the Lamboo Hills. Relief is up to 120 m.

Fitzroy Plains Province

The *Fitzroy Ranges* subprovince consists of Devonian rocks which form broken karst topography with intervening black soil, and massive continuous walls of limestone which rise 30 to 60 m above the *North Fitzroy Plains*. The plains are mostly broad, gently undulating sandy areas covered with thick 'pindan' scrub and lateritic ironstone. The *Fitzroy-Lennard Flood Plains* are broad tracts of alluvium up to 10 m thick bordering the Fitzroy and Lennard Rivers.

Drainage

Three major river systems lie within the Sheet area; the Fitzroy, the Isdell, and the Meda and its tributaries, the Barker and the Lennard. The catchment areas are about 9800, 900, and 7200 km^2, respectively.

The divides of these river systems radiate from Mount Ord, the highest point in the area (Fig. 1). The northwestern extension of the Lady Forrest Range forms the divide between the Isdell and Meda River catchments; the divide between the Isdell and Fitzroy River catchments follows the southern edge of the Precipice Range, and from there trends northeastwards across almost featureless plains of the Kimberley Plateau. The divide between the Meda and Fitzroy catchments trends irregularly southwestwards and westwards, cutting across both the geological structure and the various physiographic subprovinces, demonstrating the lack of geological control of drainage in the southwestern part of the Sheet area.

The tributary streams and the headwater reaches of the major rivers in the King Leopold Range are controlled closely by the local geology. However, the middle and lower reaches of the major rivers are apparently independent of geology; thus the Barker, Lennard, and Fitzroy Rivers all cut across the regional 'grain' or trend of the Lamboo Hills and Fitzroy Ranges. All three are obsequent streams where they break through the King Leopold Ranges, but are consequent and slightly degrading from there to the Fitzroy Ranges. Beyond the Fitzroy Ranges to the south and southwest the rivers are slightly aggrading, with broad alluvial flood plains.

The pattern suggests that the drainage in the southwestern part of the Sheet area is superimposed, and may have developed on a relatively even, old erosion surface. On the other hand, the close geological control of drainage in the King Leopold Range points to drainage development dependent on geological structure and lithology. Different erosion levels can be recognized within the King Leopold Ranges, which suggests that drainage in the ranges may also be incised. Minor exceptions are Baobab Creek and part of Walsh Creek, which cut across the southern margin of the Precipice Range and are only partly controlled by geology.

Within the Lamboo Hills the tributaries of three major rivers are generally subsequent and controlled by whaleback, fault, joint, and foliation trends, which are predominantly northwest. A linear drainage pattern results, such as that developed immediately north of Mount Joseph. Sandy Creek is a major tributary of the Fitzroy River controlled entirely by shear zones in basement rock. The upper reaches of the Lennard River also appear to be fault-controlled.

The Richenda River is a major tributary of the Lennard, and drains chiefly the Halls Creek Ridges. It is a meandering stream which alternately parallels and transects the strike ridges and valleys of the area. The major tributaries of the Richenda are also meandering streams which flow northeast and southwest across the strike or 'grain' of the basement shales and phyllites. The minor tributaries are subsequent, and generally flow along the strike valleys.

All rivers are seasonal; they flow mainly during the wet season, and occasionally for short periods after heavy rainfall at other times. Waterholes (mainly rock pools) are common in most rocky parts of the Lennard Hills and King Leopold Range, but are rare and impersistent elsewhere. Billabongs are common in the flood-channel distributaries of the Fitzroy River and the Meda River, but are rare or absent elsewhere.

STRATIGRAPHY (Table 1)

Precambrian, Palaeozoic, Mesozoic, and Cainozoic rocks are exposed in the Lennard River 1:250 000 Sheet area. In this Report only the older Precambrian rocks (i.e. those that underlie the Proterozoic Kimberley Basin succession), associated Cainozoic rocks, and igneous intrusives cutting the older Precambrian are described.

Ages of the Precambrian units in the Sheet area are tentatively based on

Ages assigned to rock units have been modified by Plumb & Derrick (in press) in accordance with new data obtained since preparation of the Lennard River 1:250 000 geological map and this Report. The Lamboo Complex, Speewah and Kimberley Groups, and the Hart Dolerite are now assigned to the Lower Proterozoic.—Ed.

TABLE 1. STRATIGRAPHY OF LENNARD RIVER 1:250 000 SHEET AREA — OLDER PRECAMBRIAN AND ASSOCIATED PHANEROZOIC ROCKS

Era	*Period*	*Group*	*Rock Unit*	*Map Symbol*	*Thickness (m)*	*Lithology*	*Physiographic Expression*
CAINOZOIC	QUATERNARY		Alluvium	Qa		River silt, sand and gravel	River banks and flood-plains. Gullying common
CAINOZOIC	UNDIFFERENTIATED CAINOZOIC		Travertine (Caliche)	Czt	Superficial		Platforms and low ridges
			Residual black soil	Czb		Dark grey heavy textured clayey soil with well developed cracks when dry	Large to small treeless plains. Rough surface owing to shallow depressions and grass tussocks. Local relief up to 0.5 m
			Other residual soils	Czs		Red-brown to yellow sandy soils. Contain abundant quartz pebbles when overlying granite	Slightly undulating scrub covers plains
			Boulder Gravels	Czg		Sand, and well rounded boulders and cobbles of quartz sandstone	River terraces up to 15 m above present river beds
	TERTIARY		Pisolitic Ironstone	Tp	1-2	Ferruginous sandstone and ferruginous pisolite, and nodules with rock fragments in sandy ferruginous matrix	Thin capping over former peneplained land surface in SW and over flat-topped granite hills S of Millie Windie Gap
							UNCONFORMITY
MESOZOIC	JURASSIC OR TERTIARY		Fitzroy Lamproite	Jf		Massive leucite lamproite and agglomerate, volcanic ash, and pipe flow-breccia. Chalcedony coatings common	Mt North is a prominent hill; most others form low outcrops
PALAEOZOIC	DEVONIAN TO PERMIAN		Unnamed Sandstones	D-Pc		Cobble and boulder conglomerate, quartz grit, and quartz sandstone	Small mesas
		Carboniferous, Permian and Triassic described by Guppy et al. (1958); Devonian by Playford & Lowry (1967); Kimberley Group by Plumb (in prep.); Oscar Range succession by Derrick & Gellatly (1971)					
							UNCONFORMITY

TABLE 1—Continued

Distribution	*Stratigraphic Relations*	*Remarks*
Along all creeks; particularly in the Lennard, Barker and Fitzroy Rs and Sandy Cr valleys		
On W Napier Ra and NW of Oscar Ra at Morown yard and Palm Spring		Developed on Devonian calcareous formations
Widespread; Fairfield Valley, parts of Oscar Plateau, near Mimosa and Andersons Bores, E and W of Napier Downs, W of Mt House	Superficial sediments	Typically developed over calcareous formations, Carson Volcanics, and Hart Dolerite; also locally over areas with deep soil development
Throughout the area. Very extensive in SW		
Between Millie Windie Gap and Sandy Cr. Limited occurrence	Overlie Lennard Granite	Probably equivalent to Warrimbah Conglomerate
Scattered outcrops of pisolitic ironstone from Lennard R to Calwynyardah H.S. and of ferruginous sandstone between Millie Windie Gap and Sandy Cr		Used extensively in SW for formed roads
Mt North, Mt Percy, 81-Mile, Old Leopold Hill, Prairie Hill East, McKinrick Hill, Mt Rose, and Big Spring	Intrude Proterozoic granites and volcanics and Palaeozoic and Mesozoic sediments up to the Triassic	Volcanic necks and inclined plugs. Flow structures seen at Mt North, Old Leopold Hill, and Prairie Hill East. Possibly Eocene in age
2-15 km S of King Leopold Ras between Millie Windie Gap and Richenda Gorge	Unconformable on Lennard Granite. Capped by lateritic pisolitic ironstone.	

TABLE 1. STRATIGRAPHY OF LENNARD RIVER 1:250 000 SHEET AREA—OLDER PRECAMBRIAN AND ASSOCIATED PHANEROZOIC ROCKS

Era	*Group*	*Rock Unit*	*Map Symbol*	*Thickness (m)*	*Lithology*	*Physiographic Expression*
PROTEROZOIC	LAMBOO COMPLEX	Mount Amy Granite	Ƥbka		Grey-pink non-porphyritic coarse to medium leucocratic biotite granite, commonly aplitic. Generally homogeneous, and muscovite-bearing	Low rounded hills and rock pavements
		Dyasons Granite	Ƥbky		Leucocratic medium to fine even-grained biotite granite with abundant mesocratic schlieren	Broad irregular whalebacks and rounded bouldery hills
		Lennard Granite	Ƥbkl		Grey leucocratic coarse porphyritic biotite granite. Abundant large tabular feldspar phenocrysts characteristic. Marginal muscovitic phases present locally. Non-porphyritic in places	Rounded whalebacks, low rock pavements, and rough stony hills
		Chaneys Granite	Ƥby		Coarse leucocratic biotite granite, adamellite, or rarely granodiorite. Mostly porphyritic, but becomes less porhpyritic towards SE	Rounded whalebacks, low domes and pavements, and rough stony hills
		McSherrys Granodiorite	Ƥblkm		Grey mesocratic medium to coarse porphyritic to even-grained biotite-hornblende-granodiorite, tonalite, minor adamellite, and quartz gabbro	Low soil-covered rises and small dark boulder-strewn hills and knobs
		Lerida Granite	Ƥbl		Grey to pink-grey porphyritic biotite granite with euhedral phenocrysts of pale green feldspar and quartz. Phenocrysts of pale pink feldspar present locally	Low rugged hills with rectilinear drainage pattern. Sandy pediments developed locally
		Mondooma Granite	Ƥbko		Pale grey porphyritic biotite granite and micro-granite. Contains prominent bipyramidal quartz phenocrysts and 2 to 3 mm feldspar phenocrysts	Variable; rugged rocky hills and low poorly exposed pediplains
		Mount Disaster Porphyry	Ƥbkd		Dark grey to pale pink-grey porphyritic biotite micro-granite and micro-granodiorite. Contains phenocrysts of quartz, K feldspar, and plagioclase. K feldspars characteristically exceed 25 mm in length	Mostly prominent hills and tors

TABLE 1—Continued

Distribution	*Stratigraphic Relations*	*Remarks*
Scattered outcrops around Mt Amy, Dromedary yard, 19 km E of Tunnel Bore, 6 km N of Lily Hole yard	Intrudes Whitewater Volcanics. Probably intrudes Lennard and Kongorow Granites	Locally associated with McSherrys Granodiorite
Narrow E-trending belt E of Dyasons Cr and isolated patches near headwaters of Hoopers Cr	Intrudes McSherrys Granodiorite and Lennard Granite. Intruded by Mount Amy Granite	
Extensive NW of Lennard R, N of Scrutons Hole, and between Diamond Gorge and Brices yard	Intrudes Halls Creek Group, Wombarella Quartz Gabbro, and Whitewater Volcanics. Intruded by Kongorow Granite, possibly also by Mount Amy Granite	Lateral extension of Chaneys Granite of Lansdowne Sheet area. Similar to parts of Bow River Granite of East Kimberley
Small area in extreme SE near Granite Hill	Possibly intrudes Lerida Granite	
SE-trending plutons in the central SE and far NW	Intrudes Halls Creek Group, Whitewater Volcanics, and possibly also Bickleys Porphyry. Intruded by Lennard Granite and Dyasons Granite	Small dark granodioritic and granitic xenoliths common. Abundant aplite dykes characteristic
Extreme SE margin	Intrudes Whitewater Volcanics. Other relations uncertain	Mainly granodioritic; composition similar to McSherrys Granodiorite
NW margin near Duncan R	Intrudes Mount Disaster Porphyry in Yampi and Charnley Sheet areas; intrudes Whitewater Volcanics; intruded by Lennard Granite	Mostly similar to Bickleys Porphyry, but groundmass coarser-grained
NW of Inglis Gap and around Ord Gap	Intrudes Halls Creek Group and Whitewater Volcanics. Intruded by Mondooma Granite. Other relations uncertain	Distinguished from Bickleys Porphyry by its large phenocrysts

TABLE 1—Continued

Era	*Group*	*Rock Unit*	*Map Symbol*	*Thickness (m)*	*Lithology*	*Physiographic Expression*
PROTEROZOIC	LAMBOO COMPLEX	Bickleys Porphyry	Ꝑbb		Dark to light grey quartz feldspar porphyry and porphyritic microgranite	Rounded and moderately rugged boulder-strewn hills
		White-water Volcanics	Ꝑw		Undifferentiated rhyodacitic ash-flow tuff, greywacke-conglomerate, and arkose; minor rhyodacite lava	
			Ꝑwa	ca. 4800	Massive crystal-rich rhyodacite ash-flow tuff; minor agglomerate	
			Ꝑwp	ca. 3500	Massive crystal-poor rhyodacite ash-flow tuff; minor crystal-rich tuff	Rugged boulder-strewn hills with dark-toned photo-pattern. Ꝑws has banded appearance owing to well developed bedding
			Ꝑwb	ca. 3000	Dacitic and minor rhyodacitic biotite-rich ash-flow tuff	
			Ꝑws	ca. 1500	Bedded rhyodacite tuff; minor tuffaceous siltstone, sandstone, and conglomerate	
						UNCONFORMITY
		Richenda Micro-granodiorite	Ꝑbkr		Medium-grained grey, generally non-porphyritic biotite micro-granodiorite; minor biotite-hornblende microgranodiorite and micro-tonalite	Prominent serrated hills with localized areas of black vegetation-free boulder scree
		Kongorow Granite	Ꝑbkk		Foliated dark grey porphyritic biotite-rich granite. Locally with xenoliths and remnant gneissic bands	Rounded whalebacks, low rock pavements, and rough stony hills
		Wombarella Quartz-Gabbro	Ꝑbkw	ca. 1300	Biotite and orthopyroxene-bearing quartz gabbro and quartz norite; also biotite-hornblende-pyroxene-bearing tonalite and porphyritic micro-tonalite	Quartz-gabbro forms small range of hills with arcuate ridges; tonalite forms low-lying hummocky areas
		Woodward Dolerite	Ꝑbd	Up to 1500	Dark green and greyish green amphibolitized dolerite; commonly porphyritic with phenocrysts up to 25 mm. Minor altered peridotite	Forms prominent ridges. Has dark grey smooth-toned photo-pattern
?ARCHAEAN	HALLS CREEK GROUP	Undifferentiated	Ah	Probably 6000	Grey phyllitic siltstone and greywacke; chloritoid, andalusite, staurolite, kyanite and garnet-mica schist; minor quartz-feldspar biotite gneiss (sillimanite-bearing locally) and grey pebbly sericitic quartz sandstone	Hummocky hilly topography with closely spaced minor streams

TABLE 1—Continued

Distribution	*Stratigraphic Relations*	*Remarks*
W and SE of Ord Gap; around Old Leopold yard	Intrudes Whitewater Volcanics	Similar to crystal-rich tuffs of Whitewater Volcanics
WNW of Mt Broome; between McSherrys Gap and Kurrajong Bore; The Twins; between Millie Windie and Diamond Gorge; scattered outcrops along Sandy Cr	Unconformable on Halls Creek Group; near-basal conglomerates contain cobbles of Woodward Dolerite. Intruded by Bickleys and Mount Disaster Porphyries, and Mondooma Granite; also by Lennard and Mount Amy Granites and McSherrys Granodiorite	Probably mainly ash-flow tuffs: Ɇws may contain ash-fall tuffs. Lavas probably rare. Most tuffs characterized by crystal fragments. Eutaxitic textures rarely preserved
Near Blackhill yard and about 8 km W of Richenda Gorge; scattered outcrops	Intrudes Halls Creek Group; locally occurs in close association with Kongorow Granite	Intruded by dykes and a cone sheet of rhyolite
Similar to that of Lennard Granite. Main outcrop around Kongorow Pool. Rare in SE	Intrudes Halls Creek Group and Wombarella Quartz-Gabbro. Phases of Kongorow Granite intrude Lennard Granite	Commonly garnet-bearing. Probably derived in part through anatexis of Halls Creek Group
Quartz-gabbro lies SW, and main tonalite outcrop E and SE of Stumpys Jumpup	Quartz-gabbro and tonalite show evidence of two-magma relations and are contemporaneous. Quartz-gabbro intruded by Kongorow and Lennard Granites	Tonalite cut by numerous aplopegmatite dykes
Mainly between Scrutons Hole and Blackhill yard. Scattered outcrops in most other areas of Halls Creek Group	Intrudes Halls Creek Group. Occurs as cobbles in conglomerate near base of Whitewater Volcanics	Corundum developed locally at contact with Halls Creek Group
Richenda R/Mt Broome Cr area, Hooper Hills, and Hawkstone Cr; scattered outcrops along Sandy Cr and near Lennard R Gorge. Extensive under soil cover between Winjana Gorge and Hawkstone Cr	Intruded by Woodward Dolerite, Kongorow and Lennard Granites, Richenda Microgranodiorite and McSherrys Granodiorite; overlain by Whitewater Volcanics	Gneisses near Mt Joseph are metasedimentary and locally anatectic; those N of Kurrajong yard may be sheared granites or granitized sediments

isotopic age determinations of correlative rocks of the East Kimberley (Bofinger, 1967) and about 50 specimens of igneous and metamorphic rocks from the West Kimberley (Bennett & Gellatly, 1970).

The Precambrian rocks described in this report are assigned to the ?Archaean and Proterozoic (probably Lower Proterozoic and possibly Carpentarian) subdivisions of Dunn et al. (1966), and to the Archaean and Lower Proterozoic according to the Precambrian subdivisions of Horwitz (1967).

The older Precambrian rock units recognized in the West Kimberley are a continuation of those described from the East Kimberley (Dow et al., 1964; Dow & Gemuts, 1969; Gemuts, 1971). However, the nomenclature of most of the intrusives of the East Kimberley has not been retained for the West Kimberley because of lithological variations and because of distance of separation. Definitions of rock units restricted to the West Kimberley are included in this report (Appendix 1) and in the report on the Yampi Sheet area (Sofoulis et al., 1971). The stratigraphy of the older Precambrian rocks is summarized in Table 1.

The oldest rocks in the Sheet area are the Halls Creek Group, a series of eugeosynclinal (flysch) sediments and minor acid volcanics of ?Archaean age. These have been intruded in pre-Carpentarian time by the Woodward Dolerite and the Wombarella Quartz-Gabbro, both of which have been metamorphosed together with the Halls Creek Group. The Kongorow Granite, part of which appears to have been derived from the Halls Creek Group through anatexis, and may have undergone garnet-grade metamorphism, is tentatively assigned, together with the closely associated Richenda Microgranodiorite, to an early (pre-Carpentarian) period of granite intrusion.

The extensively developed Whitewater Volcanics, a series of predominantly ash-flow sheets, unconformably overlie the Halls Creek Group and are intruded by later granitic rocks. These comprise two distinct suites, high-level intrusive quartz-feldspar porphyries (Bickleys Porphyry and Mount Disaster Porphyry) and plutonic intrusives, mainly Lennard Granite, McSherrys Granodiorite, and associated derivatives.

The Whitewater Volcanics have been tentatively correlated with the Cliffdale Volcanics in the Northern Territory, which define the base of the Carpentarian System (Dunn et al., 1966), but the age of the Whitewater Volcanics is at present recorded as being 1823 m.y. (Bofinger, 1967), which places them below the base of the Carpentarian (1800 m.y.). They are regarded as being 'Lower Proterozoic or Carpentarian' as are the granites that intrude the Whitewater Volcanics.

The intrusive rocks of the King Leopold and Halls Creek Mobile Zones, as well as the Tickalara Metamorphics of the East Kimberley, have long been grouped together as the Lamboo Complex (Matheson & Guppy, 1949). The term Lamboo Complex as used by Dow et al. (1964) excludes the Whitewater Volcanics which were placed stratigraphically above the Lamboo Complex. As most granites of the West Kimberley (and this is also true of the East Kimberley) are now known to intrude the Whitewater Volcanics, we suggest that the term Lamboo Complex should embrace all the igneous rocks in the Kimberley that postdate the Halls Creek Group and antedate the Kimberley Basin succession.

We further suggest an informal grouping of the rock units into an early Lamboo Complex comprising the pre-Whitewater Volcanics intrusives (Woodward Dolerite, Wombarella Quartz-Gabbro, Kongorow Granite, and Richenda Microgranodiorite); a middle Lamboo Complex comprising the Whitewater Volcanics and associated high level intrusives (Bickleys Porphyry, Mount Disaster Porphyry, and Mondooma Granite), and a late Lamboo Complex comprising the post-Whitewater Volcanics plutonic intrusives (Lennard Granite, McSherrys Granodiorite, etc.).

These groupings are based on field relations, and the placing of certain units is at present tentative. Minor revisions may be required when isotopic age determinations are completed.

ARCHAEAN

Halls Creek Group

The Halls Creek Group is the oldest unit in the Sheet area. It consists of greywacke, shale, siltstone, and minor acid volcanics which have been strongly folded, and metamorphosed to greenschist and almandine-amphibolite facies assemblages. The distribution of the various metamorphic assemblages is shown in Figure 16.

The term Halls Creek Group was first used by Matheson & Guppy (1949) for rocks, originally termed the Halls Creek Metamorphics (Finucane, 1939), from which they had separated the McLintock Greenstones. Traves (1955) could not differentiate the Halls Creek Group and the McLintock Greenstones and included both in a redefined Halls Creek Metamorphics; Harms (1959) extended this term to the West Kimberley. Because most of the Halls Creek Group sediments, particularly in the East Kimberley, are little altered, Dow et al. (1964) preferred the term Halls Creek Group.

The Halls Creek Group was first partly subdivided by Ruker (1961) working in the Saunders Creek area near Halls Creek, and was further subdivided by Smith (1963), and by Dow et al. (1964) who recognized seven formations. In a revised subdivision of the group, Gemuts (1965) recognized only four formations: Ding Dong Downs Volcanics, Saunders Creek Formation, Biscay Formation, and Olympio Formation. In the West Kimberley the Halls Creek Group has not been subdivided into constituent formations, although gneiss and sandstone are shown as local lithological subdivisions on the accompanying map. Most of the group in the West Kimberley is tentatively correlated with the Olympio Formation of the East Kimberley, although minor remnants of the Saunders Creek Formation may also be present.

Stratigraphic relations

The base of the Halls Creek Group is not exposed. The group is overlain unconformably by the Whitewater Volcanics. Contacts within the area are everywhere conformable or appear to be, but proof of an unconformity is provided by the presence of cobbles of Woodward Dolerite in a thin basal conglomerate in the Whitewater Volcanics (Fig. 8b).

The group is intruded by the Kongorow and Lennard Granites, McSherrys Granodiorite, Richenda Microgranodiorite, Woodward Dolerite, and dolerite dykes.

Field occurrence

The Halls Creek Group occupies an extensive area west and southwest of Mount Broome, and extends northwest in a poorly exposed belt 10 km wide to the northwestern corner of the Sheet area. Minor outcrops are found up to 8 km southwest of Lennard River Gorge, in the Hooper Hills, and in a narrow belt 30 km long extending southeast from Mount Rose along Sandy Creek.

The total area underlain by the Halls Creek Group is about 1700 km^2. The thickness exposed probably exceeds 6000 m in the Richenda River area. Elsewhere only lesser thicknesses are preserved.

The topography of the Halls Creek Group is a distinctive hummocky type resulting from the easily eroded nature of the rocks, the development of strong cleavage commonly cross-cutting bedding, the general absence of resistant beds, and the close spacing of minor streams.

The Halls Creek Group forms roof pendants within and between granite batholiths. The rocks are strongly folded and cleaved, thus their large-scale structure is uncertain. Doming of the granites either during or after intrusion has produced synforms parallel to the margins of some roof pendants.

Lithology

The Halls Creek Group consists of typical eugeosynclinal flysch sediments and their metamorphic equivalents. Phyllitic shale, siltstone, and greywacke predominate and are interbedded with minor sandstone, rhyolite and rhyolitic tuff, limestone, and rare clay-pellet conglomerate.

A generalized stratigraphic section is given below for the Richenda area, where the folding is less intense and approximate thicknesses can be estimated. Thicknesses have been calculated from aerial photographs.

Bedding in the Halls Creek Group is preserved extensively. Other sedimentary structures, which are rare, include graded bedding, cross-laminated ripples, elongate and bulbous flute-casts, and load-flute-casts. In the metamorphosed rocks with bedding preserved, apparent reversals of graded bedding have developed because the fine-grained argillaceous tops of the graded units have recrystallized as coarse-grained decussate muscovite.

Outcrops of pebbly quartz sandstone form a discontinuous belt on the south-western flank of a large intrusion of Lennard Granite some 3 to 6 km east of Mount Rose. This sandstone, about 30 m thick, consists of scattered pebbles of vein quartz up to 40 mm in diameter in a poorly-sorted matrix of coarse rounded to subangular quartz grains and soft white flaky interstitial sericite (derived from shearing of ?feldspars).

Most rocks have been metamorphosed to the greenschist and almandine-amphibolite facies. Metamorphics range from low-stress types with andalusite and staurolite, through chloritoid, garnet, kyanite, and sillimanite-bearing assemblages to high-stress types in which the earlier formed minerals, especially andalusite, chloritoid, and garnet, have been wholly or partly altered through retrograde metamorphism. In an area west of Mount Joseph, sillimanite-bearing schists and gneisses have been partly melted, mobilized, and recrystallized to form streaky porphyroblastic anatectic granitic gneisses containing both sillimanite and potash feldspar (see chapter on metamorphism).

The Halls Creek Group shows little contact metamorphism by granites; in most places decussate muscovite is developed within about 15 m of the contacts.

Petrography

Petrographic notes given here are in part summarized and modified from Scott (1966).

TABLE 2. GENERALIZED SECTION OF HALLS CREEK GROUP
(Waggon Flat to Richenda Gorge)

Whitewater Volcanics with basal conglomerate
Probable unconformity

Approximate thickness (m)	*Halls Creek Group*
1350	Phyllite: grey sericite phyllite and phyllitic siltstone with thin interbeds of rhyolitic tuff
200	Woodward Dolerite (ca. 1200 m) with thin interbeds of phyllite. Total thickness of phyllite ca. 213 m
1200	Phyllite: sericite phyllite and minor greywacke with thin interbeds of porphyritic rhyolite and rhyolitic tuff; intruded by Richenda Microgranodiorite
750+	Greywacke: massive grey greywacke and minor phyllite and quartzite; thin sills of Woodward Dolerite; intruded by Richenda Microgranodiorite. ....Fault (Correlation of beds uncertain)
600 to 900	Phyllite: grey sericite phyllite and psammitic phyllitic schist with thin marble interbeds. ....Transcurrent fault (Correlation of beds uncertain)
2450+	Phyllite and schist: grey sericite phyllite and psammitic muscovite schist with rare thin beds of amphibole-bearing quartzite; andalusite-chloritoid-staurolite schists to south near Waggon Flat; apparent thickness is about 4800 m but sequence is probably repeated by folding. ....Contact with granite (possibly faulted)

Typical low-grade metamorphics from a locality about 10 km northeast of Blackhill yard are described as protoquartzite and flaggy silty sandstone. The protoquartzite (66.16.0120) is a poorly sorted rock consisting of 1 mm detrital quartz grains (75%) showing sutured grain boundaries, with a finer-grained groundmass of quartz, plagioclase (An_{30-35}), sericite, and accessory tourmaline, pale pink rounded zircon, rutile, opaques, and carbonate.

The silty sandstone (66.16.0119) is very fine-grained (max. grain-size 0.22 mm) and poorly sorted, and consists of small angular grains and elongate splinters of quartz (70%) and plagioclase (5%) in a fine-grained matrix of biotite, sericite, chlorite, and accessory opaques, tourmaline, and zircon. The fabric of the rock is essentially a primary feature which is due to the parallel orientation of quartz splinters. It contains conspicuous 2 mm 'pseudo-organic' spherical nodules consisting of a central spot of goethite surrounded by a zone rich in intergranular films of secondary biotite and iron oxide. A coarser variant of this rock is a typical subgreywacke except for the development of biotite. The clastic material is mainly quartz (70%) and fresh plagioclase (5%); the matrix consists of biotite-sericite-epidote.

An example of one of the carbonate beds is a phlogopite-quartz marble (66.16.0133) containing 0.1 to 0.6 mm grains of carbonate (75%), abundant 0.5 mm plates of foxy red-brown phlogopite (and possibly also biotite) (20%) and minute quartz grains (5%) along with accessory muscovite, clinozoisite, ilmenite, and sphene. Associated with the carbonate rocks are dark grey phlogopite-rich siltstones. A specimen (66.16.0132) consists of 0.5 mm plates of phlogopitic biotite (35%) in a fine-grained (0.02 mm) quartz-sericite matrix studded with small prismatic grains of ?clinochlore and minute platy opaque grains. The dark micas in both these rocks have random orientation and contain numerous small inclusions; they possibly formed through alteration of chloritoid.

Among the more highly metamorphosed rocks, hornblende-bearing quartzites represent metamorphosed slightly calcareous sandstones.

Thin acid volcanic interbeds in the upper part of the succession consist of scattered 1 to 2 mm phenocrysts of quartz (commonly embayed) and sericitized feldspar in a very fine-grained sericitic matrix (66.16.0131).

A notable feature of the pelitic rocks of the Halls Creek Group, especially some of those in the Hooper Hills and near Billyara yard, is the abundance of green-brown tourmaline. This mineral is most prominent in the thermally metamorphosed bedded rocks, but is also present in their more sheared schistose equivalents. The tourmaline in these rocks probably is a result of the original composition of the rocks, but in view of its localized distribution and the presence of tourmaline-bearing granites in the vicinity, a metasomatic origin for it cannot be precluded.

LOWER PROTEROZOIC

Early Lamboo Complex

Woodward Dolerite

Sills of amphibolitized dolerite, commonly porphyritic, and minor ultrabasic rocks that intrude the Halls Creek Group in the Lennard River Sheet area are referred to as the Woodward Dolerite. They are characterized by their metamorphic grade (greenschist facies), in places their porphyritic texture, and by their occurrence exclusively within the Halls Creek Group.

Field occurrence

In the Lennard River Sheet area Woodward Dolerite crops out principally between the Richenda and Lennard Rivers, and in a narrow belt extending southeastwards from the Richenda River to Sandy Creek. Scattered outcrops are also present to the west of the Lennard River, about 10 km north of Mount Joseph. Outcrops are mainly narrow, and extend for about 10 km or more along strike, but the main outcrop in the Richenda Valley is up to 2 km wide and extends for 50 km. The total area of outcrop of the Woodward Dolerite is about 100 km^2.

The Woodward Dolerite forms prominent round-topped bouldery ridges that have an even dark grey tone on aerial photographs. The ridges are commonly sinuous owing to folding.

The Woodward Dolerite occurs exclusively as sills that are concordant with the bedding of the enclosing Halls Creek Group but cut across the prevailing cleavage. The sills are strongly folded and have steep dips. In the Richenda area up to seven separate sills averaging about 250 m thick are separated from each other by only 30 to 90 m of sediment. In most other localities only one sill is present.

The sills consist of dark greenish grey, medium to coarse amphibolitized dolerite (Figs 3a, b). There is a complete gradation from non-porphyritic varieties through types with sporadic 5 to 10 mm plagioclase phenocrysts to highly porphyritic types in which 25 mm plagioclase phenocrysts make up about 50 percent of the rock. In one locality near the upper contact of the main sequence in the Richenda area abundant euhedral plagioclase phenocrysts up to 200 mm across

Fig. 3a. Porphyritic Woodward Dolerite with 40 mm plagioclase phenocrysts; near the top of the second-lowest sill, 3 km north-northeast of Blackhill yard. M1001/1

Fig. 3b. Woodward Dolerite with 150 mm plagioclase phenocrysts. The porphyritic rocks form thin concordant lenses near the upper contact of the topmost sill; 7 km north of Blackhill yard. M1001/3

have been found. A porphyritic phase with 2 to 3 mm phenocrysts of hornblende (replacing original pyroxene) is present in one of the sills.

The basal sill in the Richenda area consists entirely of non-porphyritic amphibolitized dolerite that appears to be more mafic than other sills, but does not contain ultramafic accumulates. Leucocratic pods about 5 m by 3 m within the dolerite consist of massive pale grey quartz-feldspar aggregates cut by thin quartz veinlets, and are interpreted as altered xenoliths.

Thin strongly folded sheets of biotite-hornblende diorite in the area about 3 km southeast of the Richenda Microgranodiorite are tentatively referred to the Woodward Dolerite, but differ from it principally in containing moderate amounts of biotite.

Most sills show large-scale layering of porphyritic and non-porphyritic varieties. Hornblende phenocrysts are confined to thin upper contact marginal facies and to the lower parts of the sills. Plagioclase phenocrysts on the other hand are found in layers near the upper contacts of the individual sills, and also near their bases. A measured section (Table 3) of a single sill (the second from the bottom) from the Richenda area illustrates this distribution of porphyritic and non-porphyritic varieties. Further measured sections of Woodward Dolerite are given in Appendix 2.

TABLE 3. SECTION OF A SINGLE SILL OF WOODWARD DOLERITE

(For full section see Appendix 2)

Locality 10 km east-northeast of Blackhill yard

Approximate thickness (m)	*Lithology*
	Overlain by further sills of amphibolitized dolerite
90	Phyllite: grey biotite-rich pelitic phyllite
8	Amphibolite: dark greyish green massive medium-grained porphyritic amphibolite; abundant 3 mm hornblende phenocrysts
18	Amphibolite: massive medium to coarse porphyritic amphibolite with abundant 25 to 30 mm plagioclase phenocrysts; phenocrysts make up about 50% of the rock
42	Amphibolite: massive coarse-grained non-porphyritic amphibolite
44	Amphibolite: massive medium-grained porphyritic amphibolite; containing abundant 3 mm hornblende phenocrysts and scattered phenocrysts and glomeroporphyritic aggregates of plagioclase up to 40 mm
10	Amphibolite: massive medium-grained porphyritic amphibolite with 3 mm hornblende phenocrysts
Total 212	
67	Phyllite: dark grey finely cleaved phyllitic shale
	(underlain by sill of amphibolitized dolerite)

Contact relations

Contacts with the enclosing Halls Creek Group phyllites are sharp and concordant with bedding. Cross-cutting relations have not been observed.

The Woodward Dolerite is nowhere found intruding the Whitewater Volcanics, and cobbles of Woodward-type amphibolite, including feldsparphyric varieties, are present locally in near-basal conglomerates of the Whitewater Volcanics which are thus taken to be younger than the dolerite. The Woodward Dolerite is cut by the Richenda Microgranodiorite and the Lennard Granite.

Contact metamorphism is restricted to slight hornfelsing of siltstone and the development of decussate muscovite in feldspathic greywacke near the base of the sills. Sedimentary beds between the sills show only slight spotting of pale brown isotropic material and localized development of chloritoid. Garnetiferous hornblende and ?cordierite-bearing psammites have been found about 1 km from the contact of the Woodward Dolerite about 3 km north of Blackhill yard, but are probably products of regional metamorphism rather than of contact metamorphism by the dolerite. The Richenda River corundum occurs in Halls Creek Group phyllite at the base of a sill of Woodward Dolerite, and may be in part the result of contact metamorphism. It is probably significant that at Hawkstone Creek, kyanite-corundum similarly occurs in phyllite near the base of a sill of Woodward Dolerite.

Petrography (based partly on Scott, 1966)

Specimens from the Woodward Dolerite show variations in their mineralogical composition depending on both their position in the sequence and on their metamorphic grade. The original variations, other than variations in phenocryst content noted in hand specimen, are largely obscured by mineralogical and textural changes resulting from metamorphism. Variations in metamorphic grade are reflected by the type of amphibole present and by the state of alteration of plagioclase.

Rocks from near Blackhill yard show the highest metamorphic grade found in the Woodward Dolerite of this sheet area. They consist mainly of fresh recrystallized plagioclase (An_{40-45}) and pale green hornblende, and minor amounts of black opaque oxide and sphene. Relict ophitic textures are present in specimens with 3 mm hornblende phenocryst pseudomorphs. Plagioclase phenocrysts, present only in one specimen sectioned, are partly altered to small grains of clinozoisite and contain scattered inclusions of elongate hornblende and sheaves of actinolite. The composition of unaltered patches of plagioclase is about An_{25-30}.

In contrast, specimens from the eastern part of the same sill (mostly from near the Richenda River) show a less well developed relict ophitic texture. They consist of a very pale green actinolite partly altered to chlorite, and plagioclase (ca. An_{45} where fresh) which is mostly wholly or partly altered to a fine-grained aggregate of chlorite, zoisite, and clinozoisite. Groundmass plagioclase is only partly altered. Accessory minerals are calcite, quartz, sphene, and opaque oxides.

One specimen (R66.16.0118) from near the Mount Broome Emery occurrence contains spherical 1 mm patches of clinozoisite that resemble small amygdales. This specimen and one from the Richenda River section (R66.16.0114) are very fine-grained (groundmass grainsize ca. 0.3 mm), but the majority are coarse-grained with the average length of groundmass plagioclase laths about 1 to 1.5 mm.

A number of small ultramafic pods containing hypersthene, found in the Sandy Creek area, are probably part of the Woodward Dolerite.

Discussion

Most evidence suggests that the Woodward Dolerite is intrusive rather than extrusive. Features suggesting intrusion are the moderately coarse grainsize (in most specimens), and in particular that of the plagioclase phenocrysts, and the fact that there is evidence of phenocryst fractionation. Features suggesting a possible extrusive origin include the fine grainsize of certain specimens, the presence of possible amygdales in one specimen, the lateral persistence of thin sedimentary interbeds, and the apparent absence of contact metamorphism at the upper contacts.

The petrographic similarity of rocks from the various sills and the fact that similar phenocryst fractionation trends are noted in several of them suggest that each sill has differentiated as a separate entity, and that the composition of the magma has differed only slightly from one sill to another. The basal sill appears to be slightly more mafic than the others, but the difference is not great. The mechanisms causing differentiation may have included gravitational settling and floating, convection currents, and composite intrusion.

The distribution of hornblende phenocrysts (after pyroxene) near the top of one of the sills (Table 3) and throughout its lower half suggests that pyroxene had crystallized out before intrusion and was localized in the chilled marginal facies, and in the lower half of the sill through crystal settling.

Plagioclase phenocrysts on the other hand are mostly concentrated in the upper parts of the sills, and have probably floated upwards in the magma. In other sills plagioclase phenocrysts appear to have sunk. The upward concentration is evidenced partly by an increase in the size of the phenocrysts and partly by an increase in their abundance. Thus near the upper contacts of some of the sills plagioclase phenocrysts form about 40 to 50 percent of the rock. A similar accumulation of plagioclase phenocrysts near the top of a thick sill of Woodward Dolerite has been noted in the Charnley 1:250 000 Sheet area. This type of feldspar fractionation is unusual since in most other basic masses, e.g. Skaergaard (Wager & Deer, 1939) plagioclase is considered to have sunk along with, but more slowly than, pyroxene and olivine. Sinking of plagioclase in layered basic masses is generally considered to have been assisted by convection currents. Bottom accumulation of plagioclase in certain sills of the Woodward Dolerite may have been caused by this mechanism.

A further hypothesis, suggested by Dr K. R. Walker (pers. comm.), is that composite intrusion of porphyritic and non-porphyritic magmas could have played a part. This could explain anomalies such as the apparent fractionation of plagioclase phenocrysts both upwards and downwards in the same sill, and would also obviate the need to postulate gravitational fractionation and convection currents, or both, in sills only 45 m thick.

Wombarella Quartz-Gabbro (New name)

The type area for the Wombarella Quartz-Gabbro is in the Lennard River 1:250 000 Sheet area about 3 km southwest of Stumpys Jumpup on the Derby/Mount House road. At this locality (2712E, 28338N) the main mass forms a small layered lopolith about 5 km across. The principal rock types are a dark grey orthopyroxene and biotite-bearing quartz-gabbro, a porphyritic microtonalite, and metamorphosed equivalents. The Wombarella Quartz-Gabbro is characterized macroscopically by the presence of prominent biotite and the pale blue-grey colour of the plagioclase, and microscopically by the presence of orthopyroxene. These features distinguish it from the other basic rocks in the area.

Quartz Gabbro

Field occurrence

Outcrops of the Wombarella Quartz-Gabbro are found in the type area and in several small outlying hills to the south and southeast. These hills may be parts

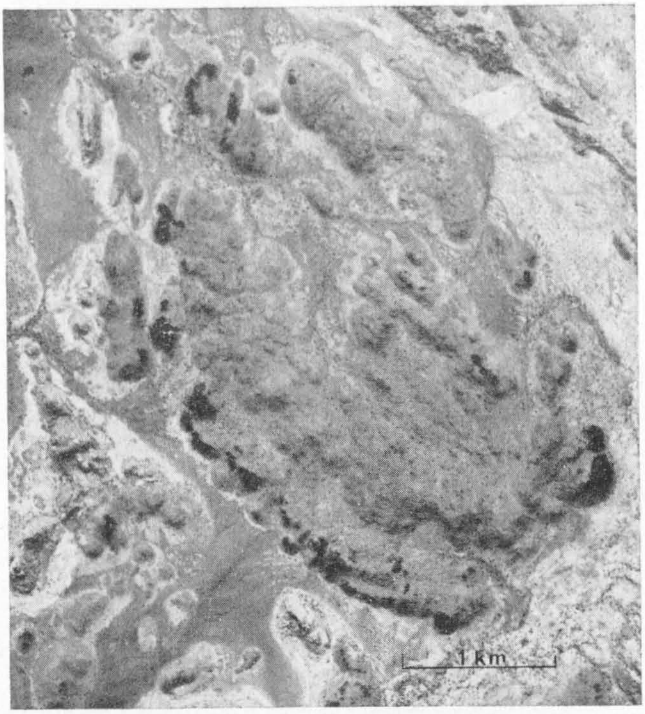


Fig. 4a. Vertical aerial photograph of small lopolith of Wombarella Quartz-Gabbro showing arcuate strike ridges that parallel the layering. Light-toned hills surrounding the mass are granite.

Fig. 4b. Banding in Wombarella Quartz-Gabbro. The mesocratic leucocratic top of a gravity-differentiated band is overlain by the mesocratic base of the overlying band. The contact between the two is sharp and planar; 3 km southwest of Stumpys Jumpup. G9712

of the main mass or offshoots from it. The total extent of the outcrops is about 25 km^2.

The quartz-gabbro crops out as prominent rocky hills which rise to about 100 m above the surrounding plains. On aerial photographs they show a dark grey tone, with patches of black unweathered rock. The photo-pattern is similar to that of the Hart Dolerite (Fig. 4a).

The lopolith is elliptical in outcrop and 5 km long by 3 km wide. The long axis of the ellipse trends southeast, parallel to the trend of the King Leopold Mobile Zone. Large-scale layering in the lopolith has dips inclined towards the northeast at 25 to 80°. The average dip is about 45°. These layers, of which there are four, form semi-elliptical strike ridges. The calculated thickness of the layered mass is 1300 m. The four main layers, each about 300 m thick, grade upwards from a relatively melanocratic basal facies to a more leucocratic upper facies.

Within the main layers, subsidiary small-scale layering or banding is present. This banding is formed by repetition of units which grade from a dark-coloured base to a light-coloured top. Contacts between the upper parts of the banded units and the base of the overlying units are sharp and planar (Fig. 4b). Banding appears to be most pronounced in the upper part of layer 1 and the lower part of layer 2. With the limited amount of work done it was not possible to determine the thicknesses of the individual bands. A general thickness of 10 to 30 m seems likely.

Streaky gneissic banding (as defined by Harker, 1951) is found locally in rocks of the basal layer and also in some of the outlying hills (Fig. 5a). It occurs as small lenticles and bands of material about 10 mm to 50 mm thick, either lighter or darker than the enclosing rock. In places these streaky rocks contain small-scale isoclinal folds. Apart from this streaking the quartz-gabbro shows no signs of deformation, but tonalite on its eastern margin is strongly sheared.

In hand specimen the quartz-gabbro is a dark grey medium to coarse non-porphyritic massive rock with prominent small flakes of red-brown biotite. Feldspar is very pale grey, and pyroxenes show the 'greasy-brown' colour normally associated with granulite-facies rocks. Quartz is prominent in some specimens, e.g. from the topmost rocks of layer 2, but is not evident in all hand specimens.

Contact relations

In several places on its southern margin quartz-gabbro has been observed in contact with tonalite. The tonalite commonly encloses xenoliths of quartz-gabbro which are variously rounded or angular. Contacts between the main mass of quartz-gabbro and the tonalite are irregular, and small tongues and veins of tonalite commonly intrude the quartz-gabbro. In one locality pillows of quartz-gabbro 0.5 to 1 m across are partly surrounded by thin tongues of tonalite, and the individual pillows are cut by thin veinlets of tonalite (Fig. 5b). The tonalite shows flow alignment of feldspar phenocrysts parallel to the pillow margins, and the pillows themselves show a decrease in grainsize from the centre towards the margins, indicating chilling of the quartz-gabbro against the tonalite. These relations are similar to those described by Blake et al. (1965) who interpreted them as indicating chilling of basic magma against acid magma. The inference here is that the quartz-gabbro and the microtonalite magmas are contemporaneous and probably genetically related.

Near its southern margin 2 km north of Wombarella Creek, the Wombarella Quartz-Gabbro is cut by veins of non-porphyritic leucocratic granite derived from

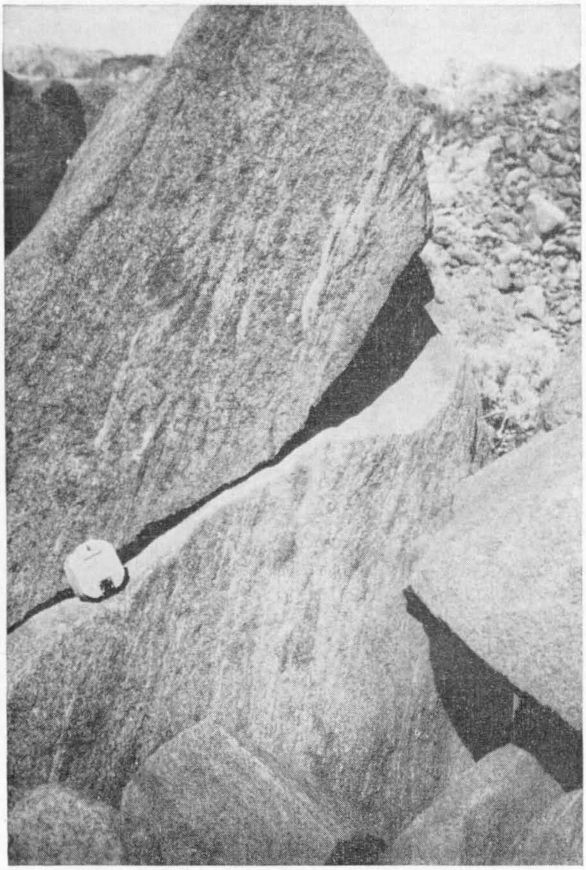


Fig. 5a. Streaky gneissic banding in quartz-gabbro, southern margin of Wombarella intrusions. Note the presence of both light and dark schleiren, and of minor folds; 3 km southwest of Stumpys Jumpup. G9727

adjacent Lennard Granite. It is also found as fragmented xenoliths in Kongorow Granite (type B), but in the same general area thin dykes of fine-grained basic rock, apparently offshoots of the quartz-gabbro, intrude a more coarsely porphyritic variant of the Kongorow Granite, and a xenolith of the latter has been formed in quartz-gabbro. The Wombarella Quartz-Gabbro is thus older than the Lennard Granite and parts of the Kongorow Granite, but is younger than other variants of the Kongorow Granite.

Petrography

In thin section the Wombarella Quartz-Gabbro is mostly medium-grained with an average grain diameter of 1.2 mm, and with a hypidiomorphic-granular texture. It consists essentially of plagioclase, quartz, clinopyroxene, orthopyroxene, amphibole, and biotite; apatite and magnetite are accessory. The quartz-gabbro ranges in composition from hornblende-quartz norite to biotite-hornblende-quartz-gabbro, and possibly to tonalite. Because of strong zoning the average composition of the plagioclase cannot be determined from thin sections, and R.I. determinations on fused plagioclase will be required. Modes given in Table 4 illustrate the compositional variations.

Fig. 5b. Pillow of quartz-gabbro in contact with tonalite, southern margin of Wombarella intrusion. The pillow is veined by tonalite and is chilled against it. The tonalite shows flow-banding parallel to the margins of the pillow; 3 km southwest of Stumpys Jumpup. G9719

TABLE 4. MODES OF ORTHOPYROXENE-BEARING ROCKS FROM THE WEST KIMBERLEY

	1	2	3	4	5	6	7
Plagioclase	50.8	47.0	56.7	44.9	49.9	24.5	57.9
Quartz	3.7	13.4	3.8	7.4	7.1	0.9	2.3
Orthopyroxene	15.9	2.2	5.1	7.6	7.7	8.6	20.3
Clinopyroxene	10.6	17.8	10.6	15.1	13.5	5.2	12.7
Amphibole	5.0	6.1	14.7	9.2	11.3	0.4	0.8
Biotite	13.4	13.0	7.5	14.4	9.6	1.9	4.4
Magnetite	0.3	0.2	1.4	0.9	0.7	0.6	1.5
Apatite	0.3	0.3	0.1	0.5	0.3	tr.	0.1
	100.0	100.0	100.0	100.0	100.1	42.1	100.0

1. Hornblende quartz-norite from the basal part of the intrusion (LR 4-61-18; R 66-16-0046); 2708 E, 28334 N.
2. Biotite-hornblende quartz-gabbro from the topmost part of layer 2 (LR 4-61-25; R 66-16-0054); 2714E, 28340 N.
3. Hornblende-biotite quartz-gabbro, a light-coloured rock from the top of the differentiated band in layer 2 (LR 4-61-24(a); R 66-16-0052); 2714 E, 28340 N.
4. Biotite-hornblende quartz-gabbro, a dark-coloured rock from the base of the overlying band in layer 2 (LR 4-61-24(b); R 66-16-0053); 2714 E, 28340 N.
5. Average quartz-gabbro (1-4).
6. Little Gold River Porphyry (norite) from the Lansdowne 1:250 000 Sheet area; the minerals listed occur as phenocrysts in a cryptocrystalline groundmass (LA 15-63-4); (R 64-16-71); 4805 E, 27430 N.
7. Little Gold River Porphyry; phenocryst percentages recalculated to 100%.

(Rock names given are based on percentage limits of Johannsen, 1939).

Plagioclase occurs as fresh tabular euhedral to subhedral grains up to 2 mm long, with well developed albite twinning and strong zoning. Composition ranges from about An_{70} in the cores of crystals in the more basic rocks to about An_{35} on the margins of crystals in the more acid rocks. Individual crystals commonly show a range of 15 percent An from core to margin. Strong dispersion in some of the strongly zoned crystals results in lack of complete extinction and parts of the crystals show dark blue-grey and brown interference colours. Small to large interstitial grains of quartz are present in all specimens. Three types of pyroxene are present: (a) clinopyroxene (diallage) forming large anhedral grains which show finely developed lamellar twinning, and are partly altered to, and partly surrounded by, a pale green-brown amphibole; (b) colourless to very pale pink orthopyroxene forming elongate subhedral prisms with a finely laminated streaky appearance; and (c) small fresh euhedral to subhedral equant grains of clinopyroxene. Amphibole is a green-brown hornblende that appears to be both primary and an alteration product of clinopyroxene. Large strongly pleochroic foxy red-brown poikilitic plates of biotite commonly surround a core of opaque magnetite.

The crystallization sequence deduced from textural relations appears to have been plagioclase and pyroxene(a); pyroxene(b); pyroxene(c); magnetite; biotite; hornblende; quartz.

Compositional variations from the base of the intrusion to the top are complicated by both layering and banding but the following general trends can be discerned:

(1) The ratio of light minerals to dark minerals increases
(2) Quartz content increases
(3) The ratio of orthopyroxene to clinopyroxene decreases
(4) Hornblende content decreases
(5) Biotite content increases

Discussion

The Wombarella Quartz-Gabbro is an unusual rock type which, apart from the closely associated hypersthene-bearing tonalite phase, is related to only one other rock mass in the Kimberley region—the Little Gold River Porphyry in the Lansdowne 1:250 000 Sheet area (Gellatly et al., 1974).

The Little Gold River Porphyry is a fine-grained dark grey rock with small phenocrysts of plagioclase, orthopyroxene, clinopyroxene, quartz, and magnetite surrounded by coronas of small biotite flakes. A modal analysis of this rock, recalculated in terms of only the phenocrysts, shows remarkable similarities to the Wombarella Quartz-Gabbro, especially to the basal quartz-norite. The Little Gold River Porphyry is possibly comagmatic with the Wombarella Quartz-Gabbro, and differs from it only in lack of differentiation consequent upon much more rapid crystallization.

The crystallization sequence in individual specimens of the Wombarella Quartz-Gabbro shows a close parallel to the modal variations noted from bottom to top of the intrusion; these variations are considered to have resulted from crystal fractionation.

There is a gradual layer-by-layer change in the bulk composition of the rock as well as a gradation within each layer. It is possible that each of the four successive layers represents a fresh injection of magma, and that each successive magma differed slightly from the previous one in having lost some of the more basic components by crystal settling before intrusion.

The banding is probably due to differential crystal settling in situ. Further modal analyses are necessary to test this hypothesis.

The streaky gneissic banding is possibly due to localized inhomogeneities in the magma at the time of intrusion. Such inhomogeneities could have arisen in three ways: (1) through mixing of tonalite magma with a normal norite magma (unlikely because of temperature differences and the evidence of chilling of the basic magma against the acid); (2) through incomplete assimilation of xenoliths; (3) through derivation of the magma by anatexis of pre-existing granulite-facies rocks.

The composition of the magma was unusual in that it was apparently magnesium-rich (hypersthene) but also silica-rich (quartz). Such a composition could not have arisen as a result of normal fractionation of a basic magma because the acid residual tends to be iron-rich. The unusual composition of the Wombarella magma must be left unexplained until chemical analyses are available.

Tonalite

Outcrops of tonalite on the eastern margin of the lopolith, and of porphyritic microtonalite about 5 km east and northeast of the quartz gabbro lopolith have been provisionally included with the Wombarella Quartz-Gabbro because of their close association in the field and because of the presence of orthopyroxene in the microtonalite. The microtonalite is extensively sheared and recrystallized, and resembles some of the recrystallized biotite-bearing Whitewater Volcanics. The sheared microtonalite can, however, be distinguished from the volcanics by the abundant aplopegmatite dykes in it.

Field occurrence

The microtonalite occupies an area of about 15 km^2 and forms low rounded northwest-trending faults and joints. It has an even grey tone on aerial photographs, with thin light-coloured streaks indicating the acid dykes.

The form of the microtonalite is uncertain, but photo-interpretation of the southeastern corner of the intrusion suggests that it forms a thick sheet dipping northeastwards at 30 to 40° conformably with the local joint direction of the enclosing Lennard Granite.

In hand specimen the fresh microtonalite is grey with conspicuous 2 mm phenocrysts of pyroxene and plagioclase. The altered types are dark grey medium-grained mesocratic biotite-rich containing 2 to 3 mm phenocrysts of pale purple quartz, and have a strong gneissic foliation.

Aplopegmatite veins and dykes occur in the tonalite, but not in the surrounding Lennard Granite. They are mostly vertical, 150 mm to 1 m wide, strike 120°, and are parallel to the foliation in the microtonalite. They consist of a fine to medium saccharoidal aggregate of quartz, white and pale cream feldspar, and minor biotite; scattered crystals and aggregates of cream potash-feldspar (up to 75 mm) and rare quartz (up to 25 mm) form the pegmatitic phase.

Contact relations

Along its northern margin the microtonalite is interbanded (on a scale of many tens of metres) with the Lennard Granite, but it is uncertain which is the earlier. In the scattered hills to the south of the Wombarella lopolith, veins of tonalite have been observed cutting Kongorow Granite, and the main tonalite mass, if related to these veins, would thus postdate the Kongorow Granite. Elsewhere the microtonalite is intruded by veins of Kongorow Granite, and thus appears to be intermediate in age between the different phases of the Kongorow Granite.

Petrography (Summarized from Peers, 1966a)

In thin section one specimen of massive microtonalite consists of phenocrysts of plagioclase, hypersthene with coronas of magnetite, and biotite in a fine-grained groundmass of quartz and plagioclase, minor potash-feldspar, and randomly oriented plates of biotite.

The foliated microtonalite consists of phenocrysts of microcline, plagioclase, and highly strained quartz in a groundmass of quartz, feldspar, biotite, minor ilmenite, sphene, epidote, muscovite, and apatite. The epidote is associated with biotite which is usually well oriented; the ilmenite is bordered by sphene.

Discussion

Although two types of microtonalite have been described, all gradations between them are found. It appears that the change from the massive to the foliated variety is the result of mild regional metamorphism rather than shearing alone.

The aplopegmatites within the microtonalite are foliated and are concentrated mainly in the foliated rocks. This suggests that deformation has allowed injection of the pegmatite-forming fluids along the foliation while it was developing, or at least before the final movements.

The presence of orthopyroxene is unusual in the igneous rocks of the area, and because of this the microtonalite is correlated with the Wombarella Quartz-Gabbro which also contains orthopyroxene. However, it should be noted that the minor amounts of tonalite associated with the quartz-gabbro do not contain orthopyroxene. Thus, if the two tonalitic magmas were related, it would appear that two distinct fractionation trends (possibly owing to different depths of fractionation) are represented.

Metamorphosed Quartz-Gabbro and Tonalite

Metamorphosed equivalents of the Wombarella Quartz-Gabbro and its associated tonalite are found in scattered hills about 3 km south-southwest of Wombarella yard. Apart from some shearing, the macroscopic appearance of the rocks here is similar to that of rocks in the type area. All variations are found from mesocratic hornblende and biotite-bearing types to leucocratic plagioclase-cummingtonite rock and gneissic garnetiferous biotite tonalite. Gradations are found between the various rock types, especially between the tonalite and the quartz-gabbro. Thin transgressive garnet-bearing acid veins are also present. The original banding is outlined by repetitive strike ridges of slightly different lithologies, but contacts between the ridges are rarely exposed. Undoubted igneous banding has been noted in one part of the outcrop. Apart from the plagioclase-cummingtonite rock mentioned above, no petrographic work has been done on these rocks.

Kongorow Granite (New name)

The Kongorow Granite is a complex suite of porphyritic mesocratic granite and minor gneiss and migmatite and is associated with the Halls Creek Group and Lennard Granite throughout the Sheet area.

The name is taken from Kongorow Pool on the Barker River (2570E, 2842N), where several varieties of the granite are exposed. The various porphyritic granites mapped collectively as Kongorow Granite probably range in age from the time of the Halls Creek Group metamorphism (early Lamboo Complex) to the main phase of post-Whitewater Volcanics granite emplacement (late Lamboo Complex).

Field occurrence

Extent and location of outcrop. The Kongorow Granite is confined mostly to the area between Joseph yard and the eastern side of the Van Emmerick Range. The main exposures are those flanking the Barker River near Kongorow Pool, with extensions northwest to the Sheet boundary and southeast to near Wombarella Creek; other exposures are northwest of Macs Jumpup, around Joseph yard, and in the Sandy Creek area.

The topography on the Kongorow Granite varies. Where it is associated with Lennard Granite it forms large rounded northwest-trending whalebacks with relief of about 100 m. Where it is emplaced in Halls Creek Group it forms low hills, stony rises, bare rock pavements, and scattered inselbergs.

Macroscopic appearance and lithological variations. The Kongorow Granite is generally foliated, coarse to fine, grey, and biotite-rich. It is mostly porphyritic with discrete tabular and ovoid alkali feldspar phenocrysts 1 to 5 cm across, and lesser amounts of smaller plagioclase phenocrysts, commonly sericitized. Phenocrysts comprise from 1 to over 25 percent of the rock.

Aligned xenoliths, feldspar phenocrysts, and biotite flakes commonly give rise to a pronounced gneissose texture. A tectonic lineation plunging southeast at about 45 to 60° is defined by quartz rodding and biotite streaking.

Several varieties of Kongorow Granite are found in the Sheet area, but are not differentiated on the accompanying map. These are:

Type A is a foliated sparsely porphyritic or porphyroblastic and moderately mesocratic biotite granite with alkali feldspar phenocrysts up to 6 cm. The granite contains small garnets, gneissic remnants, and migmatite. It is best developed near Kongorow Pool, where it contains numerous dioritic and granitic xenoliths and is associated with a porphyritic medium-grained gneissic granite.

Type B is a foliated moderately mesocratic biotite granite. It is partly porphyritic, with 0.5 to 1 cm elongate phenocrysts of alkali feldspar which are anhedral and less prominent in deformed varieties. Small garnets are present. This type crops out near the Mount House road, about 2 km north of Wombarella Creek, where it is associated with a more coarsely porphyritic type.

Type C is a coarsely porphyritic biotite granite with abundant 2 to 3 cm tabular alkali feldspar phenocrysts, and 2 to 10 cm ovoid alkali feldspar phenocrysts. Small garnets are present. This type occurs along the Mount House road, about 1 km north of Stumpys Jumpup.

Type D is a dark grey fine to medium granite with moderately abundant well oriented tabular phenocrysts mainly 0.5 to 1 cm long. Garnet has not been observed, but could be present. This variety occurs as dykes cutting Lennard Granite, e.g. 6 km southeast of Stumpys Jumpup.

In the Sandy Creek area the Kongorow Granite is less common than in the northwest. It forms small masses of grey porphyritic biotite granite similar to type A and, to a lesser extent, to type D. The texture of this type is shown in Figure 6a. The phenocrysts are usually euhedral and average 1 to 5 cm long. Muscovite is an

Fig. 6a. Kongorow Granite (type D) intrusive into Lennard Granite. Kongorow phenocryst decrease in size toward the margin and show moderately good flow foliation parallel to it. A small xenolith of Lennard Granite is near the hammer point; 5 km west-northwest of Stumpys Jumpup.

Fig. 6b. Kongorow Granite (type C) intruded by Mount Amy Granite. Numerous veins of Mount Amy Granite penetrate Kongorow Granite, and there is a pegmatitic marginal phase of Mount Amy Granite up to 0.3 m thick at the contact; 5 km northwest of Stumpys Jumpup.

accessory mineral. The rock contains a number of xenoliths, and at one locality forms a dyke with narrow chilled margins.

Contacts between these various Kongorow Granite types have not been seen, and gradations probably exist between all of them. Types A and B generally form large whalebacks, but differ markedly in phenocryst size. Type C, which forms low domes and pavements, resembles type A but contains many more phenocrysts than type A, in addition to having rare ovoid phenocrysts that are absent in A.

Contact relations

The Kongorow Granite was intruded intermittently over a considerable period; relations with the other rock units of the Lamboo Complex are thus variable.

The Kongorow Granite intrudes the Halls Creek Group, and is intruded by Mount Amy Granite, aplopegmatite veins, and dolerite dykes. Contact relations with the Wombarella Quartz-Gabbro, the Whitewater Volcanics, and the Lennard Granite indicate that some types of Kongorow Granite antedate both these units, whereas other types postdate them.

1. *Contact with Lennard Granite.* Near Kongorow Pool the Kongorow Granite (type A) contains large lenticular xenoliths of Lennard Granite, and is intruded by veins of possible Lennard Granite (Fig. 7a). A dyke of Kongorow Granite (type D) also intrudes Lennard Granite (Fig. 6a). Phenocrysts within the Kongorow Granite decrease in size toward the contact, and show flow foliation parallel to it, and the dyke contains a small xenolith of Lennard Granite. Grainsize of the Lennard Granite remains coarse to the contact. A similar dyke intrudes Lennard Granite in the Sandy Creek area.

2. *Contact with Mount Amy Granite.* Kongorow Granite (type C) is intruded by Mount Amy Granite 5 km west-northwest of Stumpys Jumpup. Pegmatitic marginal phases of Mount Amy Granite at this locality pass into finer-grained granite within 30 cm or so of the contact, and there are numerous apophyses of Mount Amy Granite intruding Kongorow Granite (Fig. 6b).

3. *Contact with Wombarella Quartz-Gabbro.* Kongorow Granite (type C) intrudes the tonalite phase of the Wombarella Quartz-Gabbro near Stumpys Jumpup. The contact is sharply defined; phenocrysts within the granite diminish in size close to the contact, and show a moderately good flow foliation parallel to it. Thin dykes of Kongorow Granite which penetrate the tonalite commonly trend parallel with the contact (and tonalite foliation) and separate thin bands and 'horses' of tonalite.

Near the main road 2 km north of Wombarella Creek, type B Kongorow Granite contains fractured veined xenoliths of Wombarella Quartz-Gabbro (Fig. 7b). The Kongorow Granite elsewhere, however, is cut by dykes of Wombarella Quartz-Gabbro.

Petrography

The Kongorow Granite ranges in composition from biotite granite to hornblende granodiorite. It is almost invariably porphyritic, with large phenocrysts of potash-feldspar and smaller ones of plagioclase in a groundmass consisting essentially of quartz, microcline, plagioclase, and biotite. Texturally the rocks are allotriomorphic granular; a general parallelism of elongated feldspar phenocrysts, biotite flakes, and locally hornblende produces a distinct foliation.

The dominant constituents of the Kongorow Granite suite are:

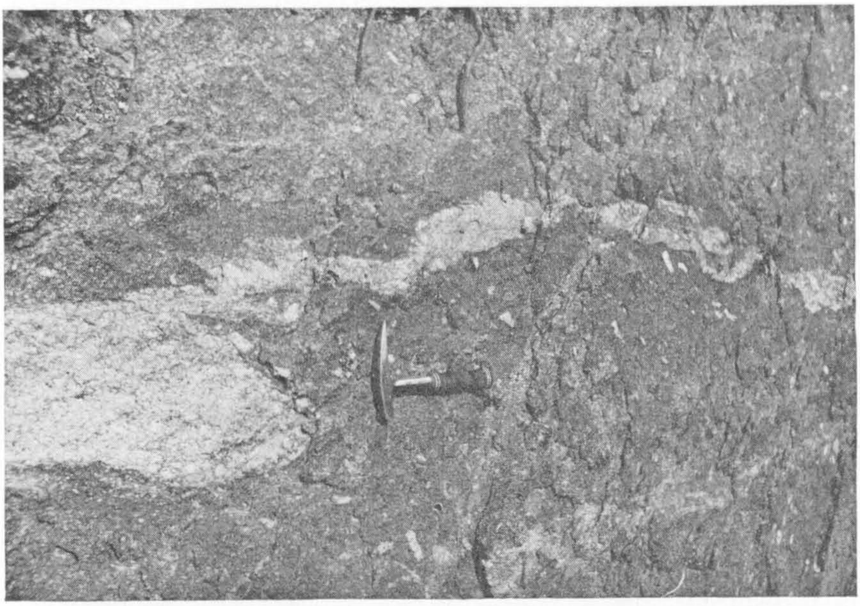


Fig. 7a. Sparsely to moderately porphyritic Kongorow Granite (type A) veined by possible Lennard Granite near Kongorow Pool. The Lennard Granite truncates flow foliation, and is locally contaminated along its margins by the assimilation of Kongorow Granite.

Fig. 7b. Kongorow Granite (type B) containing xenoliths of Wombarella Quartz-Gabbro; near the main road 2 km north of Wombarella Creek.

Microperthitic microcline is generally the predominant phenocryst mineral and commonly forms a cuneiform intergrowth with quartz along the contact between phenocryst and groundmass (L.R. 5-86-10). In some instances (L.R. 3-93-18) microcline occurs only in the groundmass and forms a mosaic with plagioclase and quartz. Plagioclase is usually oligoclase, irregularly zoned and lightly sericitized, and commonly shows strain-effects (L.R. 3-45-1, L.R. 3-95-9). It may also be extensively sericitized especially along margins (L.R. 4-61-1e), and myrmekitic intergrowths are common. Locally the plagioclase is andesine (L.R. 5-86-10) in anhedral grains slightly altered to sericite. Quartz forms large and small irregular grains, commonly with patchy or undulose extinction. Biotite is generally abundant, and comprises up to 10 percent or more of the total rock. The flakes are arranged parallel to the foliation and commonly wrap around phenocrysts. Pleochroism is strong, with X = olive green and Z = dark olive green. Aggregates of laths containing secondary carbonate are common (L.R. 4-61-1e). Hornblende is rare and forms ragged strongly pleochroic blades usually associated with biotite. Accessories comprise sphene, stumpy euhedral apatite, zircon, granular epidote, and ilmenite as irregular grains rimmed by sphene (L.R. 3-45-1). Magnetite, hematite, secondary calcite, and irregular patches of garnet were noted in some examples (L.R. 4-61-1e). The groundmass is composed of an irregular interlocking mosaic of quartz, microcline, plagioclase, and biotite, all of variable grainsize.

Discussion

Certain phases of the Kongorow Granite, especially type D, are definitely later than the Lennard Granite and thus represent one of the latest phases of acid igneous activity in the area, but the age of the main mass of Kongorow Granite (type A) is uncertain. In particular, the question as to whether it is earlier or later than the Whitewater Volcanics is unsolved because no contacts with the volcanics have been observed. Because of the widespread occurrence of garnet and metasedimentary relics in this type and in types B and C, they appear to be closely related to the Halls Creek Group in their origin, and are thus probably of pre-Whitewater age.

A possible link is provided by gneisses in the Mount Joseph area (see Metamorphism) where porphyroblastic migmatites and non-migmatic gneisses containing sillimanite, potash-feldspar, and garnet have been derived through partial melting and mobilization (rheomorphism) of Halls Creek Group schists. These gneisses, which resemble texturally the early porphyritic phases of the Kongorow Granite, become structureless and intrusive locally. Widespread development of magma from Halls Creek Group rocks at depths slightly greater than those represented by rocks now exposed could have given rise to much, if not all, of the Kongorow Granite.

Richenda Microgranodiorite (New name)

The name Richenda Microgranodiorite has been given to biotite microgranodiorite that crops out near the Richenda River and south of Wombarella Creek, and 6 km west-northwest of Mount Joseph, in the Lennard River 1:250 000 Sheet area. It occurs as small stocks and lenses intruding the Halls Creek Group. Small outcrops of the microgranodiorite are also found in the southeastern corner of the Yampi 1:250 000 Sheet area. The reference area is near the Richenda River, 2 km northeast of Blackhill yard. The microgranodiorite differs from most other acid intrusives in the West Kimberley in being non-porphyritic and medium-grained. It contains more biotite than Dyasons Granite.

Field occurrence

The principal exposures of the Richenda Microgranodiorite are found in the vicinity of the Richenda River, 2 km northeast of Blackhill yard, about 8 km west-southwest of Richenda Gorge, and 6 km south of Wombarella yard. The total area of outcrop is about 15 km^2.

The microgranodiorite forms prominent serrated hills with localized areas of vegetation-free boulder scree that is black when weathered.

In the Richenda River area the microgranite forms two small stocks, the larger with a circular outcrop plan, and the smaller with its outcrop elongated eastwards approximately parallel to the strike of the enclosing Halls Greek Group. The contacts are sharp and markedly transgressive. There has been very little deflection of the strike of the surrounding sediments, and only very slight contact metamorphism which has resulted in the development of decussate muscovite in the sediments. The microgranodiorite also forms small lenticular intrusions south of Wombarella Creek, and lenses and veins west-northwest of Mount Joseph. In both these areas the rock is very friable and is intimately associated with Kongorow Granite. In the latter area it occurs in rheomorphic migmatites that have given rise to gneissic Kongorow-like granites.

Rare flow foliation in the main outcrop dips inward towards the centre of the intrusion and is parallel to the contacts of, and flow foliation within, a cone-sheet of rhyolite some 250 m thick that cuts the stock.

In hand specimen the rock is a pale grey even-grained biotite-bearing granitic rock. Coarse-grained variants are present locally, but medium-grained types predominate. It locally contains 2 mm phenocrysts of biotite and quartz and rare small biotite-rich xenoliths.

Contact relations

The Richenda Microgranodiorite cuts Halls Creek Group sediments and is itself cut by late northwest-trending dolerite dykes and by a northeast-trending rhyolite dyke. The microgranodiorite truncates an outcrop of Woodward Dolerite, but the contact is obscured by soil cover.

Petrography

In thin section the Richenda Microgranodiorite is an even-grained rock with a hypidiomorphic-granular texture and an average grainsize of about 0.5 mm. It consists essentially of quartz, plagioclase, potash-feldspar, and biotite and minor accessory zircon, rare apatite and garnet, and secondary muscovite and clinozoisite.

Quartz occurs as 0.1 to 0.2 mm anhedral grains forming aggregates of up to 1 mm. Plagioclase forms thick tabular euhedral crystals strongly zoned from An_{38} to An_{22}. It shows partial alteration (especially in the cores of crystals) to discrete grains of muscovite and clinozoisite. Potash-feldspar is a microcline which forms large scattered poikilitic crystals enclosing plagioclase and biotite. Yellow-brown biotite occurs as discrete 0.5 mm grains with strongly pleochroic haloes around radioactive inclusions, or as smaller flakes forming 3 mm aggregates. Epidote is common along biotite cleavage planes. Garnet occurs in one slide as a single poikiloblast associated with clinozoisite and biotite, and is probably a xenocryst.

Discussion

Whereas most of the larger granites (especially Lennard and Chaneys Granites) in the West Kimberley appear to have been intruded diapirically and to have pushed aside the enclosing sedimentary and volcanic host rocks, the Richenda Microgranodiorite has sharply truncated the surrounding beds of the Halls Creek Group. This feature, plus the lack of contact metamorphism, suggests a process of quiet emplacement with possible subsidence of the displaced country rock.

The close association with Kongorow Granite, especially in the area west of Mount Joseph, suggests a genetic relation; both may have been derived at least partly through rheomorphism of the Halls Creek Group. The occurrence of garnet and of small biotite-rich xenoliths in the Richenda Microgranodiorite tend to support this.

Middle Lamboo Complex

Whitewater Volcanics

A sequence of acid volcanic rocks in the East Kimberley was called the Whitewater Formation by Smith (1963), after Whitewater Well in the Dixon Range Sheet area, and subsequently renamed Whitewater Volcanics by Dow et al. (1964).

Petrographic nomenclature used here is that of Ross & Smith (1961) and Branch (1966), who defined the terms ash flow tuff, welded tuff, etc. To distinguish further between some of the rocks, non-genetic terms crystal-rich tuff and crystal-poor tuff have been introduced.

Field occurrence

The Whitewater Volcanics crop out in a broad discontinuous northwest-trending belt adjacent to the King Leopold Ranges; a narrow belt extending southeast from Mount Rose along Sandy Creek; and scattered exposures along the southeastern margin of the older Precambrian between Tunnel Bore and Mount Wilson.

The volcanics are generally more resistant to weathering than the granites and form moderately rugged topography, particularly in the northwest and near Millie Windie Gap. Hills are closely spaced and boulder-strewn. In areas of shearing the hills are more elongate and less outstanding, and in places of 'tombstone' outcrop is common (Fig. 8a). The photo-pattern of the volcanics is not everywhere distinctive; it is generally dark-toned, with a 'broken' appearance owing to strong jointing.

The volcanics form steeply dipping sheets in the northwest with dips generally exceeding 60°; locally the sequence is overturned (e.g. 6 km east of Macs Jumpup, and in the Sandy Creek area). Near Scrutons Hole dips are 30° or less; here and throughout the southeastern part of the Sheet area the volcanics form narrow downwarped belts between, and envelopes round, the granite plutons.

Lithology and thickness

The Whitewater Volcanics consist of dark to pale grey and rare pink-brown quartz feldspar porphyry and feldspar porphyry, interpreted as welded ash flow, ash fall, crystal and lapilli tuffs; porphyritic lavas; and minor intercalations of agglomerate, siltstone, sandstone, and conglomerate. The dominant lithologies are a fragmental crystal-rich tuff consisting of phenocrysts and phenocryst fragments with little or no fine-grained matrix, and a crystal-poor tuff in which a crypto-crystalline or fine-grained matrix predominates over phenocrysts and phenocryst fragments. The two groups tend to be distinct, but a few specimens bridge the textural gap between them. The crystal-rich porphyries are probably ash-flow and ash-fall tuffs, whereas the crystal-poor varieties may include both tuffs and porphyritic lavas. The crystal-poor varieties predominate in the lower parts of the sequence, whereas the upper part consists almost exclusively of crystal-rich tuffs.

Most of the tuffs are of rhyodacitic or dacitic composition; rhyolitic tuffs are rare. A few are quartz-poor and approach andesite in composition.

The total thickness is uncertain because of the structureless nature of the tuffs and the consequent lack of reliable dip data. The thickness exposed is probably about 12 000 m.

Four informal stratigraphic units are distinguished:

		Map Symbol
4.	Massive crystal-rich rhyodacite ash-flow tuff; minor agglomerate (ca. 4800 m)	*Pwa*
3.	Massive crystal-poor rhyodacite ash-flow tuff; minor crystal rich tuff (ca. 3500 m)	*Pwp*
2.	Dacitic and minor rhyodacitic biotite-rich ash-flow tuff (ca. 3000 m)	*Pwb*
1.	Bedded rhyodacite tuff; minor tuffaceous siltstone, sandstone, and conglomerate (ca. 1500 m)	*Pws*

This generalized composite sequence is best displayed in the area between Mount Broome and the Barker River. Because of discontinuity of outcrop the Whitewater Volcanics have not been subdivided in the southeast, where remnants of all these units are probably present.

1. *Bedded rhyodacite tuffs and sediments*. This basal sequence is characterized by rapid alterations of rock types, mainly tuff (both crystal-rich and crystal-poor), siltstone, sandstone, and conglomerate. The tuffs are well banded, and may be air-fall rather than ash-flow types. The banding is due mainly to bedding and compaction. Tuffaceous siltstone is interlayered with conglomerate and tuff. In many places the tuffs are sheared and phyllitic, and difficult to separate from metasediments of the Halls Creek Group, which they overlie concordantly.

The conglomerates contain pebbles, cobbles, and boulders of tuff, vein quartz, quartzite, dolerite, and spotted phyllite, all of which resemble rocks from the underlying Halls Creek Group and Woodward Dolerite (Fig. 8b). The conglomerates range from a few metres to 30 m thick. They are found at the base of the volcanics (west of Mount Broome) and up to 200 m above the base (in the Sandy Creek area). Minor arkose and pelites associated with the conglomerate commonly are recrystallized to laminated fine-grained feldspathic quartzite and sericite schist. Near Mount Broome the sediments are finely laminated and display graded and current bedding.

2. *Biotite-rich dacitic and rhyodacitic tuffs* occur immediately east-northeast of Macs Jumpup and are similar to crystal-poor types, except that they contain

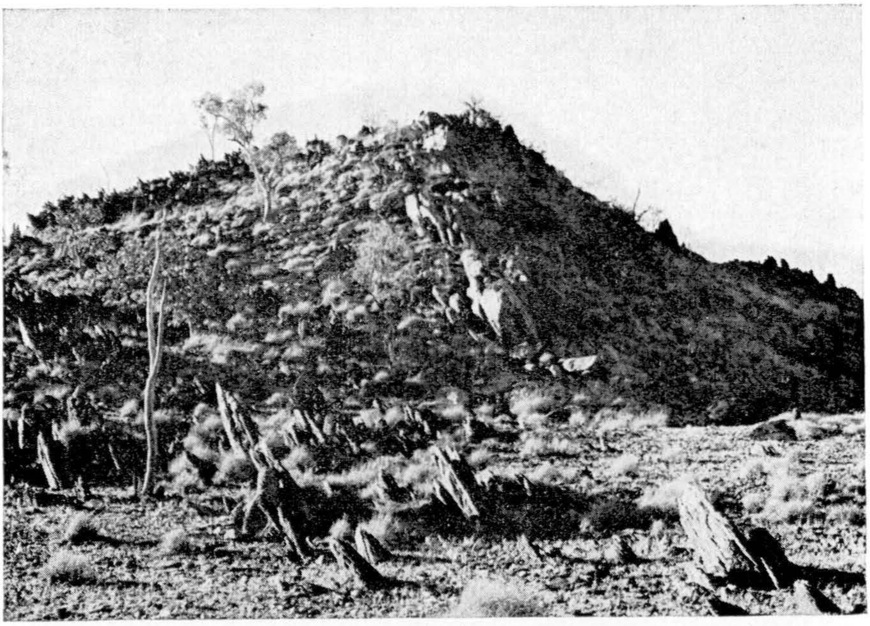


Fig. 8a. Rock-strewn hills with rounded outcrops and 'tombstone' slabs typical of Whitewater Volcanics terrain; 2 km southeast of Scrutons Hole.

Fig. 8b. Cobble conglomerate near the base of the Whitewater Volcanics 6 km southeast of Scrutons Hole. Note cobbles of porphyritic ?Woodward Dolerite below the hammer shaft.

5 to 10 percent biotite. They are dark grey where fresh. Pale green plagioclase and rare quartz are the usual phenocrysts. Biotite streaks up to 8 mm long are evident on weathered surfaces, and commonly wrap around some of the phenocrysts. Lithic fragments up to 4 cm long are rare.

3. *Crystal-poor rhyodacite tuffs.* These are dark grey, black, pale pink, and pale green generally massive aphanitic rocks which contain scattered phenocrysts and fragments of glassy quartz and off-white feldspar. The crystals range from 1 mm to over 1 cm, and usually form less than 50 percent of the rock. Narrow discontinuous mafic lenticles are visible on weathered surfaces. The main outcrop extends from the Lennard River northwest to beyond Dromedary yard. Minor outcrops of crystal-poor tuff 13 km northeast of Dromedary yard apparently overlie the crystal-rich tuffs. In the Christmas Bore area alternations of quartz-rich and quartz-poor tuff bands are evident.

4. *Crystal-rich rhyodacite tuffs.* Crystal-rich tuffs extend from Lennard River Gorge northwest to the Sheet boundary. They are dark grey or greenish grey where fresh, and usually contain over 50 percent of crystals or crystal fragments of quartz, feldspar, and biotite. The glassy blue-grey quartz grains commonly show bipyramidal high-temperature crystal form. Potash-feldspar is usually pink or cream, and plagioclase cream to pale green. Biotite forms small black lustrous flakes and rarely exceeds 2 percent of the rock. Small lithic fragments up to 5 mm also occur throughout the unit. The matrix is pale grey and siliceous, but is not always evident on freshly broken surfaces.

The rocks are generally massive, but show a tectonic foliation in most areas. They are difficult to separate from the subvolcanic high-level intrusives—Bickleys Porphyry, Mount Disaster Porphyry, and Mondooma Granite. Along shear-zones all varieties of tuff are usually altered to phyllonitic quartz-mica schist.

Agglomerate is present locally along the Mount Hart track. It consists of angular to subrounded fragments up to 250 mm across of dense tuff or fine-grained acid lava set in a fine-grained tuffaceous matrix (Fig. 9a). The fragments define a near-vertical tectonic foliation.

Contact relations

The Whitewater Volcanics overlie the Halls Creek Group unconformably, and are overlain unconformably by the Speewah Group. They are intruded by at least three separate granite types and by granite porphyry.

The unconformity with the overlying Speewah Group is well displayed 13 km northwest of Mount Broome, where the base of the O'Donnell Formation overlaps progressively lower beds of the Whitewater Volcanics and lies unconformably on the Halls Creek Group.

Lennard Granite intrudes the volcanics 11 km east of Hanns Hole, and northwest of Mount Eliza. Near Hanns Hole the granite is locally transgressive, and micrograniti c and highly porphyritic at the contact, with localized development of pegmatite; the volcanics are indurated.

Porphyritic Lennard Granite and associated pegmatite intrude the volcanics 10 km east of Jo Hill. At the contact, which is sharp and slightly cross-cutting, the granite is even-grained and shows a narrow chilled margin.

Near Scrutons Hole where dips are low (30°), the contact with the Lennard Granite is parallel to the bedding in the volcanics and appears conformable

Fig. 9a. Coarse agglomerate associated with fine-grained tuffaceous rocks. Part of the Whitewater Volcanics sequence. The sequence is also intruded at this locality by Mount Disaster Porphyry; Mount Hart track 5 km northeast of Dromedary yard.

Fig. 9b. Whitewater Volcanics underlain by Lennard Granite. The granite is locally transgressive, but generally the contact parallels Whitewater bedding. The margin of the granite is fine-grained with localized pegmatitic patches for at least 2 m from the contact and represents a chilled zone; 2 km east of Scrutons Hole.

(Fig. 9b), but the granite locally veins the volcanics. The margin of the granite is pegmatitic or microgranitic for at least 2 m from the contact, and represents a chilled zone. Sheet jointing in the granite parallels the plane of the contact.

Mount Amy Granite intrudes crystal tuff near the Fitzroy River. The contact is transgressive, but is subparallel to the foliation in the volcanics which are recrystallized near the contact. Mount Amy Granite also intrudes Whitewater Volcanics near Millie Windie Gap and north of Macs Jumpup.

Tongues and veins of Mount Disaster Porphyry intrude the volcanics near Ord Gap and in the Duncan River area. In addition, a large intrusive sheet of Mount Disaster Porphyry truncates bedding of the Whitewater Volcanics 11 km east of Macs Jumpup.

Contacts between the volcanics and McSherrys Granodiorite are variously sharp or gradational. At some sharp contacts in the Tunnel Creek area the granodiorite becomes enriched in mafic minerals, and narrow hornfels zones are present in the volcanics.

Xenoliths of fine-grained volcanics in Bickleys Porphyry near Ord Gap suggest that the volcanics are older than the porphyry.

Petrography

The majority of samples from the Whitewater Volcanics are tuffs of rhyolitic, rhyodacitic, and dacitic composition. All are porphyritic; the percentage of phenocrysts and phenocryst fragments (mainly quartz, plagioclase, potash-feldspar, and rare altered biotite) ranges from more than 50 percent in the crystal-rich tuffs to about 10 percent in some of the crystal-poor tuffs. The dacitic and rhyolitic tuffs are mostly crystal-poor. The average grainsize of the phenocrysts ranges from 4 mm to 1 to 2 mm.

Plagioclase is usually a zoned calcic oligoclase or andesine, and is saussuritized to varying degrees. Many of the grains are broken. Beta quartz is the most common phenocryst. The fragments and splinters are generally clear, angular, and embayed, and show zones of recrystallization along microfracture planes. In sheared specimens many unbroken phenocrysts are flattened or augen-like. Potash feldspar is commonly microperthitic and unaltered, but some non-perthitic microcline grains are also present. Grain margins are corroded by the siliceous matrix. Mafic minerals present are biotite and chlorite. They occur as ragged lenticular aggregates and are responsible for the discontinuous banding in some hand specimens. The biotite is green or brown, and is associated with iron oxide, or ilmenite with kelyphytic rims of sphene. Some biotite aggregates probably represent altered mafic phenocrysts.

The matrix is a granular mosaic (average grainsize .05 to 1 mm) of quartz, plagioclase, and potash feldspar. Sericite flakes are common. Rare pink zircon and apatite are accessories. Vitroclastic textures are visible in only a few specimens and are not well preserved.

Sheared volcanic rocks in the Tunnel Creek area are represented by phyllonitic quartz-biotite schists. In thin section they consist of granular quartz, olive-green biotite, muscovite, and some epidote and feldspar.

The conglomerates in the volcanic sequence near Sandy Creek contain numerous pebbles and boulders of sedimentary and igneous material (Fig. 8b). The matrix is dark and consists of quartz (50 to 60%) which forms fine-grained granular mosaics containing scattered larger grains of quartz with recrystallized margins; actinolite (30 to 35%), which forms sheaves of acicular crystals, clots, or discontinuous lamellae; plagioclase (4%), partly saussuritized and showing albite twinning and abundant dusty inclusions; biotite (1 to 3%), pleochroic from pale fawn to brown and intimately associated with actinolite; clinozoisite/epidote (1 to 2%), scattered through the matrix; accessory ilmenite grains with coronas of sphene; and hydrothermal veins up to 2 mm wide of coarse epidote and calcite.

The absence of chlorite and the presence of both biotite and actinolite indicate that the conglomerate has been recrystallized in the quartz-epidote-albite-biotite sub-facies of the greenschist facies (Turner & Verhoogen, 1960, p. 537). This slightly higher than usual metamorphic grade is probably due to contact metamorphism by adjacent granite.

Discussion

The Whitewater Volcanics were considered by Gellatly et al. (1965) and Dow et al. (1964) to be mainly ash-flow tuffs, whereas Roberts et al. (1965) thought that the volcanics in the Mount Ramsay Sheet area were deuterically altered lavas. In the Lennard River Sheet area we think that the bulk of the Whitewater Volcanics are ash-flow tuffs, and that true lavas (as indicated by vesicular zones, frothy flow tops, basal flow breccia, etc.) are extremely rare.

The field evidence for ash-flow origin is the uniformity of volcaniclastic sheets over large areas and distances such as in the northwest where they cover an area at least 13 km wide and 32 km long, and the occurrence of thick units of massive non-bedded material.

Pumice fragments, considered by Ross & Smith (1961) as diagnostic of ash-flows, are not recognizable in the Whitewater Volcanics. However, most of the volcanics show discontinuous lenticles and dark chloritic or biotitic streaks which are possibly devitrified and metamorphosed pumice or other lithic fragments.

The microscopic evidence for an ash-flow origin is based mainly on the presence of fragmental phenocrysts and crystal chips and splinters. Diagnostic eutaxitic textures are not well developed because of recrystallization and mild metamorphism.

Trendall (1967) pointed out that shards, flow textures, broken phenocrysts, etc., may all appear in both lavas and ash-flows, and that no single textural feature is indisputable. He suggested that subaqueous bulk flow of acid volcanic material, made highly mobile by superheated steam, is a means of producing sequences similar to the Whitewater Volcanics. The presence of sediments in the Whitewater Volcanics lends some support to this concept, but as the sediments are near the base and constitute less than 1 percent of the Whitewater Volcanics, the subaqueous bulk flow concept is not applicable to the formation as a whole.

The crystal-rich varieties of tuff, which occur at the top of the sequence, indicate a general increase in the degree of crystallization of the magma from which the ash-flows were derived (Ratte & Steven, 1967). The high-level intrusive porphyries (Bickleys Porphyry, Mondooma Granite, Mount Disaster Porphyry) which in places are difficult to separate from crystal-rich tuff are almost certainly genetically related to them and probably represent intrusive equivalents of the same magma.

Age relations

Contact relations in the Lennard River Sheet area show that the Whitewater Volcanics are older than the Lennard and Chaneys Granite (Bow River Granite equivalents). However, age determinations in the East Kimberley indicate reverse relations (1845 m.y. for granite, 1823 m.y. for volcanics; Bofinger, 1967), although reassessment of field data shows that the volcanics are intruded by the granites in the East Kimberley also (Plumb, pers. comm.).

Bickleys Porphyry

Bickleys Porphyry was named after Bickleys Creek in the Lansdowne Sheet area (Gellatly et al., 1974).

Field occurrence

It extends into the southeastern part of the Lennard River Sheet area from the adjacent Lansdowne Sheet area, but the major exposures continue only as far as the Fitzroy River. The porphyry also crops out sporadically north of the Bigelleas yard and in the area around Kurrajong Bore.

It forms rounded and moderately rugged boulder-strewn hills which, because of lack of soil and vegetation, appear dark grey or black on aerial photographs. In zones of shearing the exposures are less upstanding.

The porphyry is generally massive and markedly less foliated than associated granites and volcanics. This suggests that the porphyry is younger than the major periods of deformation in the mobile zone, or is less susceptible to deformation. The unit forms small domed intrusive sheets.

In hand specimen the porphyry is dark to light grey, coarse to medium, and generally porphyritic. Quartz forms the most obvious phenocrysts, though feldspars and biotite also occur as phenocrysts. The groundmass is microcrystalline. Discrete quartz phenocrysts characteristically show bipyramidal crystal form, but within a suite of specimens gradations exist between this type and the semicontinuous quartz 'lacework' typical of deeper-seated granites.

Bickleys Porphyry resembles the crystal-rich tuffs of the Whitewater Volcanics; locally the micrograniitic texture and massive form of the porphyry are distinctive, but in many places the two units are indistinguishable.

Contact relations

Bickleys Porphyry is intruded by the Chaneys and Lennard Granites and possibly also by the Mount Disaster Porphyry. It apparently intrudes Whitewater Volcanics.

In the southeast near Old Leopold yard, a dyke of Chaneys Granite cuts Bickleys Porphyry. The contact between the two masses here is marked by a profusion of quartz veins and aplite and pegmatite dykes.

At a sharp contact near Ord Gap, Mount Disaster Porphyry shows a reduction in phenocryst size, suggestive of chilling, against Bickleys Porphyry. The contact dips gently southwest and indicates that Bickleys and Mount Disaster Porphyries may be stratiform. Elsewhere contacts between the two are gradational.

In the Lansdowne Sheet area highly sheared crystal-poor Whitewater Volcanics give way along strike to less deformed Bickleys Porphyry, and the latter becomes finer-grained towards the contact. These relations suggest that Bickleys Porphyry is the younger unit and is probably intrusive.

Petrography

Quartz up to 4 mm is the most common phenocryst. It characteristically shows bipyramidal form, but is commonly fractured. Plagioclase phenocrysts (An_{25} to An_{40}) are subhedral, but fragments of euhedral crystals are also present. Most grains show oscillatory zoning, some normal, and some reversed zoning, and have a strongly saussuritized core. Potash-feldspar is subhedral and microperthitic. Characteristic zones of quartz inclusions are present at the grain margins. Biotite is red-brown and quite fresh, and contains numerous zircon and apatite inclusions. A common associate is green hornblende. The groundmass is siliceous, and has corroded and embayed most of the phenocrysts and crystal fragments. The fragments suggest that the phenocrysts were disrupted during intrusion. The microscopic features which help distinguish Bickleys Porphyry from some of the Whitewater Volcanics are the holocrystalline and microgranitic groundmass, fresh ?primary biotite flakes, marginal quartz inclusions in potash feldspar, and the presence of rare orthopyroxene. Much of the amphibole may have been derived from the orthopyroxene.

Discussion

The bipyramidal quartz phenocrysts which are typical of much of Bickleys Porphyry are high-temperature forms, and their association with strongly zoned plagioclase suggests rapid cooling at a relatively high level in the crust. Gradations between the bipyramidal quartz form and the irregular quartz form of most granites reflect changes in cooling history, and probably indicates crystallization in progressively deeper crustal environments.

Bickleys Porphyry is equivalent to the Mondooma Granite which crops out in the Yampi and Charnley Sheet areas. The Mondooma Granite does not everywhere show the bipyramidal quartz typical of Bickleys Porphyry, but outcrop form, composition, and lithology are generally similar.

Mount Disaster Porphyry

The Mount Disaster Porphyry (Sofoulis et al., 1971) is essentially a biotite-bearing porphyritic microgranite characterized by large potash feldspar phenocrysts, and is found in the Lennard River, Charnley, and Yampi Sheet areas. It occurs also in the southwest corner of the Lansdowne Sheet area, where it was originally described as a coarse-grained variant of Bickleys Porphyry.

It has affinities with Bickleys Porphyry (Gellatly et al., 1974) and its equivalent, the Mondooma Granite (Sofoulis et al., 1971), both of which are high-level intrusives associated with Whitewater Volcanics.

Field occurrence

The Mount Disaster Porphyry crops out immediately southwest of the King Leopold Ranges in a 5 to 8 km wide belt extending northwest from the Lennard River to the Sheet Boundary, and as elongate southeast-trending outcrops between Ord Gap and the Fitzroy River. Total area of outcrop is about 140 km^2.

The Mount Disaster Porphyry forms rugged bouldery hills and low rocky exfoliation pavements interspersed with sandy areas, or less commonly steep sided hills and dissected plateaux. It usually forms the lower ground when associated with Whitewater Volcanics, Mondooma Granite, and Bickleys Porphyry. The photo-pattern of Mount Disaster Porphyry resembles that of the Whitewater Volcanics and some parts of the Lennard Granite.

The porphyry occurs as thick intrusive sheets and small stocks. The sheets of Mount Disaster Porphyry are generally subparallel to banding in the Whitewater Volcanics, and overlie the crystal-rich tuffs of the Whitewater Volcanics. A porphyry with prominent white feldspar phenocrysts and dark grey to black fine-grained groundmass that occurs extensively along parts of the Mount Hart track is probably a variant of the lighter-coloured more coarsely crystalline Mount Disaster Porphyry, and forms a steep-sided flat-roofed body intrusive into Whitewater Volcanics.

The Porphyry is cut by numerous fault and shear zones up to 15 m wide, along which sericite schist, quartz veins, and reefs up to 1 m wide are developed. At some contacts with Whitewater Volcanics and Bickleys Porphyry it appears chilled, as phenocrysts are smaller than usual and groundmass darker, reflecting the smaller grainsize.

At Inglis Gap the Mount Disaster Porphyry occurs adjacent to the unconformity between the Lamboo Complex and the Speewah Group, and is heavily kaolinized. Near Ord Gap, fault movement along the unconformity has caused intense shearing in the porphyry and the development of phyllonite containing quartz augen.

Lithology

In hand specimen the porphyry is usually a light grey porphyritic rock consisting of prominent euhedral phenocrysts of white to pink potash feldspar (up to 4 cm), blue-grey or clear quartz (0.5 to 2 cm) and opaque white or pale green and cream plagioclase (up to 3 cm) in a greyish green fine to medium groundmass of quartz, feldspar, chlorite, and biotite. Streaky flow banding in the rock is emphasized by the curving of biotite-rich layers around dimensionally oriented phenocrysts.

Contact relations

The Mount Disaster Porphyry intrudes the Whitewater Volcanics. It is intruded by the Lennard Granite in the Charnley Sheet area (Gellatly et al., 1969). Relations with Bickleys Porphyry are uncertain.

Contact with Whitewater Volcanics. (a) A small stock of Mount Disaster Porphyry intrudes banded Whitewater Volcanics 8 km east of Macs Jumpup along the Mount House road. The porphyry shows chilled margins and has a flow foliation parallel to the contact. At one point the porphyry forms irregular sheets and dykes which intrude and truncate the bedding of the Whitewater Volcanics; (b) at a sharp contact between Mount Disaster Porphyry and Whitewater Volcanics (crystal-rich ash-flow tuff) on the main road 6 km west of Inglis Gap, phenocrysts of the porphyry show a diminution in grainsize, their long axes parallel to the contact. A slight enrichment in biotite is also evident, and large feldspars are developed locally in the Whitewater Volcanics at or within a few centimetres of the contact; (c) at a sharp contact between Bickleys Porphyry and Mount Disaster Porphyry

5 km west of Ord Gap, the only noticeable change at the contact is a reduction in phenocryst size in the Mount Disaster Porphyry, which suggests that it is the younger rock; (d) southeast of Ord Gap patches and streaky bands of Mount Disaster Porphyry appear in Bickleys Porphyry. These patches, which are probably partly digested xenoliths, usually have gradational boundaries with Bickleys Porphyry. This apparent conflict of age relations suggests that they may be coeval.

Petrography (summarized from Peers, 1966a, b)

In thin section the Mount Disaster Porphyry consists of prominent phenocrysts of potash feldspar, plagioclase, and quartz set in a fine-grained groundmass which comprises 40 to 50 percent of the rock. Sodic plagioclase is the most abundant phenocryst and occurs as anhedral to subhedral grains up to 1 cm. Internal saussuritization has partly or wholly altered the plagioclase to a fine-grained aggregate of sericite, zoisite, epidote, quartz, albite, and green biotite. Potash feldspar is comparatively unaltered and forms prominent euhedral to subhedral and slightly rounded phenocrysts up to 3 cm across. It consists of microcline-microperthite showing incipient cross hatching, and containing 1 to 2 mm inclusions of oligoclase and 0.2 mm potash feldspar along the margins and along fracture planes. Large quartz phenocrysts up to 1.5 cm long show resorption embayments.

The groundmass is relatively coarse-grained with average grainsize 0.3 mm. It consists of quartz, microcline plagioclase, and minor sericite, clinozoisite, olive-green biotite, epidote, euhedral zircon, chlorite, sphene, skeletal ilmenite (altered to leucoxene), apatite, and calcite.

Discussion

The Mount Disaster Porphyry is the most readily recognizable acid igneous rock of the area. It is distinguished from the Whitewater Volcanics, Bickleys Porphyry, and Mondooma Granite by its large phenocrysts, and from the porphyritic granites by its fine-grained groundmass.

Although the main masses of Mount Disaster Porphyry are found as thick inclined sheets concordant with, and overlying, the topmost part of the Whitewater Volcanics, transgressive veins and stocks of porphyry lower in the volcanic sequence indicate that the porphyry is intrusive.

The close association with Bickleys Porphyry indicated by the conflicting age relations is paralleled by a similar close association between Mount Disaster Porphyry and Mondooma Granite in the Charnley Sheet area.

Mondooma Granite

The Mondooma Granite, named from Mondooma yard in the Yampi Sheet area (Sofoulis et al., 1971), occurs as small scattered roof pendants up to 90 m across in massive Lennard Granite in the far northwest of the Sheet area. In general the roof pendants are erosion-resistant and form the tops of isolated granite knobs surrounded by sand plain.

The roof pendants are metamorphosed porphyritic microgranite and granite, with pyramidal phenocrysts of quartz, tabular alkali feldspar, and clotted biotite. The groundmass is siliceous and appears hornfelsed.

The Mondooma Granite has been separated from Bickleys Porphyry, which it closely resembles, on account of distance of separation and the more granitic character of the Mondooma Granite in Charnley and adjoining Sheet areas.

A detailed petrographic account of the Mondooma Granite is given in a report on the geology of the Charnley Sheet area (Gellatly et al., 1969).

Late Lamboo Complex

Lerida Granite

The name Lerida Granite (Gellatly et al., 1974) is derived from Lerida Gorge in the southwest corner of the adjoining Lansdowne Sheet area. The mass extends northeastwards into the Lennard River Sheet area. In composition it is similar to McSherrys Granodiorite.

Field occurrence

The Lerida Granite crops out in the southeast corner of the Lennard River Sheet area in an irregular northwest-trending belt, about 10 km wide, crossed by the Fitzroy River and by the Sandy Creek shear zone.

The Lerida Granite is porphyritic, coarse-grained, and biotite-rich. It contains scattered phenocrysts of potash feldspar up to 3 cm, quartz up to 1 cm, and abundant plagioclase phenocrysts about 3 to 4 mm across. Locally the potash feldspar and quartz phenocrysts increase in abundance, and the rock resembles the Mount Disaster Porphyry. Xenoliths are common. In the southeast the plagioclase crystals appear cream-green and highly altered, and the biotite is ragged and altered to green chlorite. To the northwest the feldspars are less altered, and the biotite is dark and occurs in clots.

Contact relations

The Lerida Granite intrudes the Whitewater Volcanics about 8 km north and 5 km southeast of Jo Hill. The contacts are sharp and locally transgressive. Contact effects are limited to a narrow zone of recrystallization in the volcanics.

Contacts with Chaneys and Lennard Granites do not provide conclusive answers on relations. Aplite and pegmatite generally increase in abundance in all three granites near the contacts. Xenoliths and mafic minerals in the Lerida Granite generally decrease towards the contacts.

Contacts with Bickleys Porphyry are also uninformative. They are marked by much inhomogeneity, and quartz and aplite veins are common.

Petrography

Modal analyses (Table 5) shows that granodiorite is the most common rock type; tonalite is also present. All varieties contain variable amounts of amphibole, probably actinolite.

The mineral composition is similar to that of McSherrys Granodiorite (q.v.) but the plagioclase is generally more altered, biotite shows a deeper red-brown pleochroism, and rare actinolite grains contain cores of brown hornblende.

Discussion

Age relations and modes of origin suggested for McSherrys Granodiorite also apply to the Lerida Granite. It has some textural similarities to Mount Disaster

Porphyry, and the two are gradational locally in the southwest corner of the Lansdowne Sheet area.

McSherrys Granodiorite (New name)

McSherrys Granodiorite is named from McSherrys Gap. The granodiorite is a composite intrusion comprising diorite, tonalite, granodiorite, adamellite, and granite.

It resembles Kongorow and Lerida Granites in being moderately mafic, but differs from them compositionally and texturally.

Field occurrences

Extent and location of outcrop. The main mass of granodiorite crops out discontinuously in a triangular area with apices at McSherrys Gap, Scrutons Hole, and Mount Wilson. This area is embayed by a large stock of Lennard Granite around Brices yard. The northern boundary follows an east-trending fault. Smaller bodies of McSherrys Granodiorite crop out discontinuously along the northern margin of the Sandy Creek shear zone, and northwest of the Barker River near Hanns Hole. The total area of outcrop of the granodiorite in the Sheet area is about 440 km^2.

Topographic expression and photo-pattern. Differences in the topographic expression and photo-pattern of McSherrys Granodiorite are well illustrated in the main mass near McSherrys Gap. Immediately east of McSherrys Gap and Tunnel Bore the granodiorite forms moderately rugged topography; the main landforms are tors, broken whalebacks, and low boulder-strewn hills. Relief increases farther east.

The granodiorite is poorly exposed around Pigeon Creek, Kurrajong Bore, and Mount Hill where it forms rolling spinifex-covered downs with sporadic low whalebacks and boulder-strewn rises. Here the photo-pattern is soft-toned and grey with superimposed fine dendritic drainage. Elsewhere the granodiorite pattern is dark, broken, and generally unfoliated or granular.

Form and structure. The form of the intrusion is not known. It is probably a large irregular stock whose shape has been modified by stoping of country rock and by younger intrusions. The only broad structure evident is a foliation which generally trends southeast and is probably due to regional deformation. Near McSherrys Gap the foliation parallels the strike of the Halls Creek Group and may be a flow foliation.

Lithology

McSherrys Granodiorite is generally dark grey, coarse to medium, even-grained to porphyritic, and more mafic than any other granitic rock type in the Sheet area.

Large areas of the granodiorite are homogeneous (east of Tunnel Bore), but elsewhere the granodiorite is markedly inhomogeneous. Quartz may form large pegmatoidal patches (near Millyie Hill), phenocrysts, or intergranular material. Biotite, the chief mafic mineral in the granodiorite, usually forms aggregates of small flakes, or less commonly large discrete flakes. The modal percentages of biotite ranges from 10 to 35. Some varieties of granodiorite are rich in amphibole (near McSherrys Gap and Millyie Hill), and the colour index in these usually exceeds 40. Plagioclase is white, grey, or pale creamy green. Zoning is recognizable in the hand specimen because of differential weathering of adjacent zones.

Small oriented xenoliths of fine-grained amphibole-rich diorite are common throughout most of the granodiorite. Inclusions of phyllite and acid volcanics are less common. The presence of xenoliths affects the composition. Where they are sparse or absent the host rock is generally more mafic probably because of assimilation of the xenoliths. Where they are present but have not been assimilated it is relatively more leucocratic.

Aplite dykes with localized pegmatitic phases are characteristic of the mass. They range from 25 mm to 1 m thick, and in places form dyke swarms (Fig. 10a). Many contain pegmatitic intergrowths and tourmaline-rich segregations.

Bands of quartz-feldspar-biotite gneiss are common to the northeast of the main mass and may represent either metamorphosed Halls Creek Group or sheared granodiorite. They range from finely banded varieties to augen gneiss containing feldspar porphyroblasts up to 1.5 cm. Granitic veining and *lit-par-lit* structures are evident in places.

Contact relations

McSherrys Granodiorite is younger than the Halls Creek Group and Whitewater Volcanics, and probably younger than Bickleys Porphyry. It is older than Dyasons Granite and Lennard Granite. Dolerite dyke swarms of at least two ages intrude McSherrys Granodiorite, particularly in the McSherrys Gap/Tunnel Creek/Mount Hill area.

Halls Creek Group. McSherrys Granodiorite is in contact with Halls Creek Group phyllite east of McSherrys Gap and immediately south of Millyie Hill. Near McSherrys Gap and near Millyie Hill contact metamorphosed phyllites contain decussate muscovite but only within about 3 m of the contact. At both localities the granodiorite is enriched in biotite and actinolite-hornblende near the contact, where tonalite, diorite, or, rarely, quartz gabbro are developed; these grade into granodiorite away from the contacts.

Whitewater Volcanics. 13 km east-southeast of Tunnel Bore the granodiorite intrudes Whitewater Volcanics with a sharp contact. The volcanics show a 150 mm zone of hornfels, and the granodiorite is enriched in biotite at the contact. In other localities (8 km east of Tunnel Bore) the contact zone is complex and all gradations between the granodiorite and volcanics are evident. The latter generally show marked spotting owing to reconstitution of original biotite. About 6 km north of Kurrajong yard xenoliths similar both to Whitewater Volcanics and to Bickleys Porphyry are metamorphosed, recrystallized, and partly assimilated.

Lennard Granite. McSherrys Granodiorite is intruded by Lennard Granite at Hanns Hole, at the head of Hooper Creek, and 13 km southeast of Scrutons Hole, and 11 km east of Kurrajong Bore. At Hanns Hole mesocratic and highly sheared granodiorite is intruded by and interbanded with Lennard Granite. Abundant veins of quartz, aplite, and pegmatite cut the granodiorite. At the other localities, contacts are strongly sheared and the Lennard Granite contains angular and rounded xenoliths of granodiorite (Fig. 10b). Lennard Granite becomes finer-grained and less porphyritic towards the contact, and both rock types are veined by quartz, aplite, and pegmatite. Areas of great inhomogeneity up to 300 m wide border the

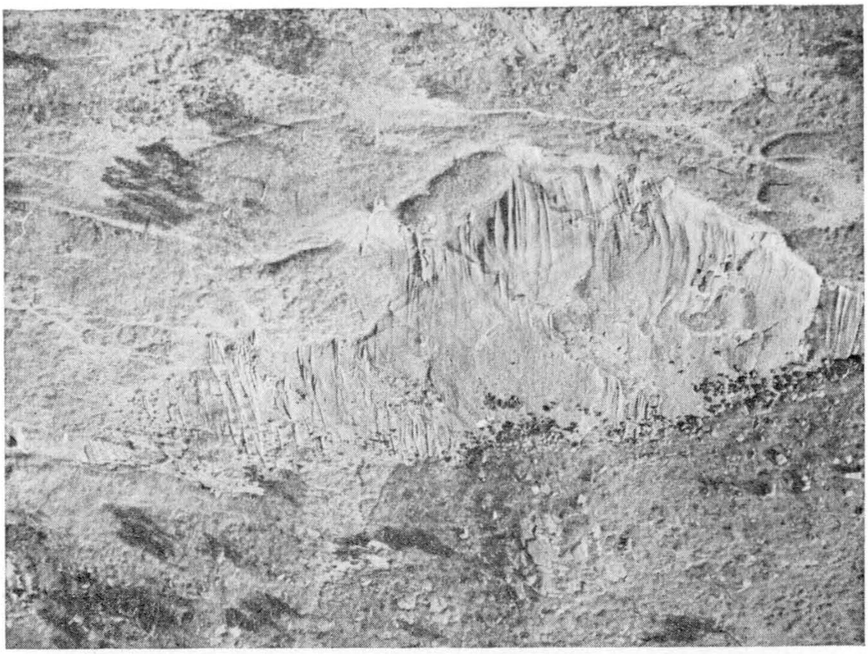


Fig. 10a. Subparallel aplite dykes veining McSherrys Granodiorite; aerial view 10 km northeast of Christmas Bore. Distance across photo about 75 m.

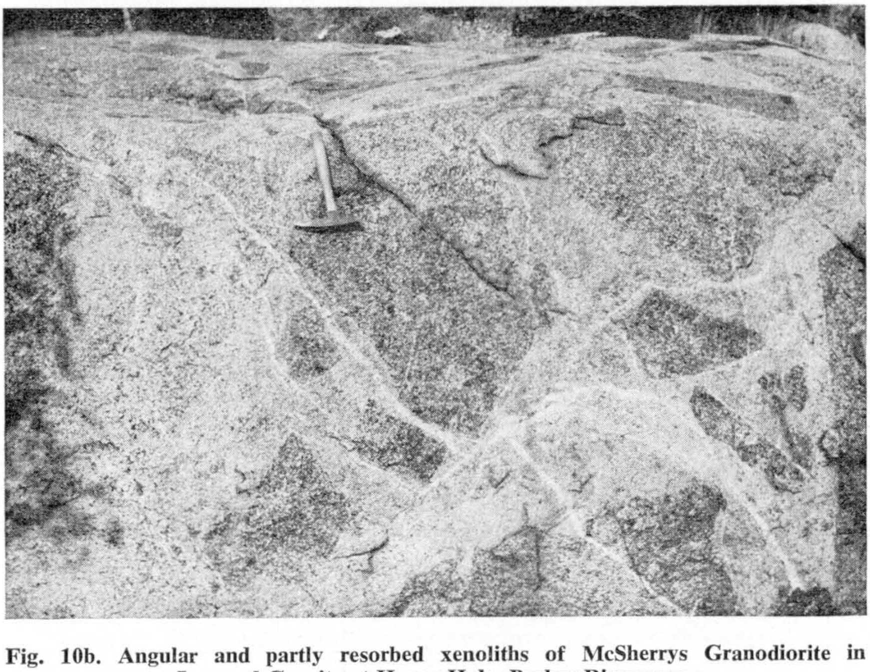


Fig. 10b. Angular and partly resorbed xenoliths of McSherrys Granodiorite in Lennard Granite at Hanns Hole, Barker River area.

sheared contact zones and porphyritic Lennard Granite is interbanded with a more leucocratic granite. The bands are highly contorted, and phenocrysts of feldspar define a sinuous flow foliation. A mesocratic granular quartz-feldspar-biotite rock, common in these zones, e.g. at Hooper Creek, is intermixed with the granodiorite as contorted bands, lenses, and interfingering tongues. It forms bodies up to 10 m long which display small-scale folding.

Dyasons Granite. Several large bodies and dykes of this mass intrude McSherrys Granodiorite. The dykes are leucocratic porphyritic granite 0.3 m to 10 m wide. They cut the granodiorite 5 km southwest of Scrutons Hole, and in a broad belt at the headwaters of Hooper Creek.

Petrography

The granodiorite is generally coarse to medium and shows a hypidiomorphic or allotriomorphic granular texture in thin section.

Quartz occurs as large anhedra up to 4 mm and as granular mosaics with grains up to 0.5 mm across. The mosaics generally border the larger grains, which in sheared rocks are slightly elongate. All quartz is clear and has slightly uneven extinction. Some composite grains are 1 cm or more in diameter. Plagioclase ranges in grainsize from 1 to 4 mm. Grains are generally subhedral, strongly zoned from about An_{40} to An_{20}, and form albite and pericline twins. Sodic rims are common, and albite is present in some rocks. Andesine-oligoclase predominates, but labradorite (An_{64}) is present in one specimen. Saussuritization is variable; in some cases, only the sodic rim of large plagioclase grains remains unaltered. Rare antiperthite occurs in one specimen. Potash feldspar is a microcline microperthite though the cross-hatched twinning is only developed in patches. It forms fields up to 5 mm across which enclose euhedral plagioclase and biotite, or occurs as anhedral interstitial grains 1 to 2 mm across. Carlsbad twinning is common. The grains are clear and generally unaltered, and in some cases are partly replaced by petaloid myrmekite growths. The myrmekite is best developed between potash feldspar grains and at potash feldspar plagioclase interfaces. It occurs most commonly in those rocks with more than 10 percent potash feldspar. Biotite, like quartz, occurs in two distinct grainsizes. Large subhedral to anhedral flakes 1 to 3 mm long are common, and so are aggregates containing flakes 0.2 to 0.6 mm long. Pleochroism ($X =$ pale straw, $Y = Z =$ orange-brown) is strong, and in some samples the general brown colour shows a green component. Abundant small acicular ?rutile inclusions are arranged at 60° angles in the cleavage planes. Biotite grains poikilitically enclose quartz and contain inclusions of apatite, zircon, and ilmenite with sphene. Epidote is a common associate and appears to have replaced the biotite which is also partly altered to chlorite. In sheared rocks the biotite flakes are deformed or form stringers which wrap around quartz or feldspar augen. Amphibole is a pale green actinolite with $X =$ pale fawn, $Y = Z =$ pale apple green. Stronger-coloured varieties are less common with $X =$ yellow brown, $Y =$ brown-green and $Z =$ olive green. It forms subhedral prismatic crystals up to 2 mm long, or decussate patches of finer grainsize; $2V = 80°$, and Z to C is 16 to 20°. The grains are twinned and contain plagioclase and quartz grains poikilitically. In some rocks the amphibole has corroded biotite, but regular boundaries between biotite and amphibole are common. In some rocks the cleavage-planes contain brown iron oxide films. Accessories are mainly epidote, apatite, zircon, ilmenite, sphene, and rare calcite and red-brown limonitic material.

The aplite and pegmatite in McSherrys Granodiorite range from leucocratic granite to granodiorite. Most aplites show typical saccharoidal texture. Many pegmatites are coarsely graphic. One pegmatite 5 km north of Kurrajong Bore consists entirely of graphically intergrown plagioclase (An_{25}) and quartz. Alkali feldspar is present only as small antiperthitic blebs in plagioclase.

Compositional variations are shown in Table 5. Rocks 24 and 26 (Millyie Hill contact) and 167 and 168 (McSherrys Gap contact) are rich in mafic minerals. The amphibole-bearing rocks (24 and 168) have a colour index greater than 40. Contact rocks in which amphibole is absent (26, 167) have a biotite content of 30 percent, which is considerably higher than the average biotite content (19%) of rocks away from contacts (e.g. 163, 164, 29). In the contact-zones amphibole and biotite contents vary antipathetically. Near contacts with the Whitewater Volcanics the granodiorite is richer in potash feldspar than usual (180, 183, 185), and at contacts with Lennard Granite, McSherrys Granodiorite is granodiorite or tonalite in composition.

Discussion

Many features suggest that McSherrys Granodiorite is a contaminated mass. These include (a) the tonalite-granodiorite compositional range, (b) abundant xenoliths in various stages of recrystallization and assimilation, and (c) marginal inhomogeneity near contacts with older rock types.

The biotite-rich margins of the granodiorite reflect the incorporation of argillaceous xenoliths of the Halls Creek Group, whereas the amphibole-bearing areas of the mass are probably a result of absorption of more calcareous xenoliths of the same group. Xenoliths elsewhere in the mass are not recognizably metasedimentary and range from granite to diorite. Older dolerites (Woodward Dolerite) have possibly been a source of many of the dioritic xenoliths.

The masses of graphic plagioclase aplite and pegmatite north of Kurrajong Bore are similar to those detailed by Wilson (1938) in the Kopaonik Granodiorite in Yugoslavia, where similar sodic rocks are considered to be late, relatively cold representatives of the parent magma which, having lost its volatile constituents, crystallized without assimilation of, or reaction with, the wall rocks. The sodic aplopegmatite magma is assumed to be poorer in soda and alumina than the computed parent magma because of volatile loss.

Wilson also found evidence of alkali transfer at the granodiorite margins, i.e. the granodiorite enriched the intruded and assimilated sediments in sodium and these in turn supplied potassium to the granodiorite, causing the local development of potash feldspar porphyroblasts. At the margins of McSherrys Granodiorite there is no obvious large-scale soda enrichment of the Halls Creek Group, although the belt of gneiss (?paragneiss) near the Granite Range is granodioritic in composition. In addition, large potash feldspar crystals occur locally in McSherrys Granodiorite; these could have developed in the way suggested by Wilson (1938). However, it appears more probable that any potash metasomatism in McSherrys Granodiorite has contributed instead to the development of the abundant, possibly endogenous, aplite dykes.

Chaneys Granite

Chaneys Granite crops out southeast of the Fitzroy River and forms part of a large mass extending from the Lansdowne and Mount Ramsay Sheet areas. The

TABLE 5. MODAL ANALYSES—McSHERRYS GRANODIORITE AND LERIDA GRANITE

Field Number	24	26	27	28	29	163	164	166	167	245	249	250	251	27	181	168	180	181	182	183	185	83	85	96
Quartz	21	34	31	31	33	23	34	32	29	34	29	28	28	11	5	18	25	20	25	25	30	25	30	25
Plagioclase	35	31	36	43	37	31	35	42	40	32	39	34	39	10	45	30	15	40	35	30	30	53	40	50
K feldspar	—	2	12	2	12	22	12	—	1	17	3	18	18	37	—	10	30	1	—	30	20	—	20	15
Biotite	17	30	17	16	18	20	18	25	30	17	20	10	10	40	10	35	30	22	25	15	20	20	10	8
Amphibole	25	—	4	7	—	3	—	—	—	—	8	10	5	1	40	7	—	17	15	—	—	2	—	2
Accessories	2	2	Tr	1	Tr	1	1	1	Tr	—	Tr	Tr	Tr	1	—	—	—	Tr	Tr	Tr	—	—	Tr	Tr
Plagioclase Composition	An64 An40	45 28	36	25	28	37	37	37 28	20 15	38 27	40 30	23	45	ca 28	27	28	25	39	36	2	5	45	—	—
Rock Name (Johanssen)	T	QT	GD	T	GD	A	GD	T	T	GD	T	GD	GD	GX	TXor MTX	GD	G	T	T	A	A	T	GD	GD

24, 26, 29	McSherrys Granodiorite, Millyie Hill area
163, 164, 166, 167, 168, 180, 183	McSherrys Granodiorite, Tunnel Creek area
181, 182, 185, 83, 85	McSherrys Granodiorite, Sandy Creek area
96	McSherrys Granodiorite, Barker River area
27, 28	Lerida Granite, Fitzroy River area
245, 249, 250, 251	Lerida Granite, Lansdowne Sheet area

QT = quartz tonalite — (224 P)
T = tonalite — (228 P)
MT = melatonalite — (238 P)
GD = granodiorite — (227 P)
A = adamellite — (226–"7" P)
G = granite — (226 P)
(X = xenolith)
Figures in parentheses are Johannsen numbers.

granite was named from Chaneys yard in the Mount Ramsay Sheet area, where the name was given to an even-grained mesocratic granodiorite or tonalite similar to McSherrys Granodiorite or the Violet Valley Tonalite (Roberts et al., 1965). In the Lansdowne Sheet area the term was applied to a coarse-grained leucocratic granite similar to the Lennard Granite, and it is this rock type which extends into the Lennard River Sheet area.

To maintain continuity between the Lennard River Sheet area and the Lansdowne Sheet area the name Chaneys Granite has been used for the granite from the Lansdowne area to the Fitzroy River. The boundary in the Fitzroy River area between the Lennard and Chaneys Granites is therefore artificial, but necessary as it is desirable to restrict the use of the term Chaneys Granite because of its double meaning.

We hope to clarify these matters in the West Kimberley 1:500 000 Sheet and Bulletin (Gellatly et al., in prep.). For the present Report the petrology and petrography of the Lennard Granite apply also to Chaneys Granite.

Lennard Granite (New name)

The Lennard Granite is a distinctive coarse-grained porphyritic leucocratic biotite granite which crops out extensively in the Lennard River Sheet area. It is probably equivalent to parts of the Bow River Granite of the East Kimberley (Dow & Gemuts, 1969; Gemuts, 1971).

The reference area for the Lennard Granite is 11 km southeast of Stumpys Jumpup (284 E, 2838 N).

Field occurrence

The Lennard Granite is the most extensive acid intrusive in the area. It crops out northwest from the Fitzroy River to the Richenda Gorge and Brices yard, and in a narrow belt extending northwest from the Lennard River to beyond Hanns Hole on the Barker River. Individual intrusions range from small plugs to large lenticular stocks and small batholiths up to 40 km long and 15 km wide.

The Lennard Granite forms smooth exfoliated whalebacks, blocky steep-sided ridges, and rugged or knobbly undulating hills, locally interspersed with, or separated by, sandy pediments and alluvial tracts. Drainage has a rectangular pattern controlled by joints.

Relief seldom exceeds 180 m and is generally less than 100 m. East of Richenda Gorge granite hilltops and small laterite-capped mesas stand at 150 to 180 m above river levels and are probably remnants of an earlier erosion surface.

Lithology

In fresh exposures, typical Lennard Granite is a mottled grey-white leucocratic coarse-grained porphyritic rock characterized by large feldspar phenocrysts 10 to 50 mm across, set in a coarse to medium groundmass of quartz and feldspar with minor biotite (Fig. 11a).

The phenocrysts commonly have irregular ovoid shapes and constitute over 50 percent of the rock. Where phenocrysts are less abundant they are tabular and generally have a primary orientation parallel to aligned xenoliths and to contacts. The Lennard Granite includes granodioritic and adamellitic phases which are generally finer-grained and less porphyritic, or even-grained.

Fig. 11a. Typical texture of Lennard Granite, showing variations in phenocryst density; Granite Hill area.

Fig. 11b. Lennard Granite cutting McSherrys Granodiorite and containing xenoliths of it at Hanns Hole, Barker River area.

Xenoliths in varying stages of assimilation are common near some of the contacts. Quartz veins, aplites, and pegmatites are present locally.

Contact relations

Lennard Granite intrudes Halls Creek and Whitewater Volcanics and is itself intruded by the Mount Amy Granite. Most contacts trend northwest. Many are sheared, e.g. phyllonites are developed 6 km southeast of Dromedary yard at the contact of Lennard Granite with Whitewater Volcanics.

Contact with Halls Creek Group. Where it intrudes the Halls Creek Group the Lennard Granite commonly shows chilled margins, but locally retains a coarse porphyritic texture to knife-sharp contacts.

Near the Lennard River, metamorphics in contact with the Lennard Granite are locally altered to hornfels in a zone 0.5 to 1 m wide, containing large feldspar porphyroblasts. Metamorphosed and metasomatized xenoliths, which are common towards the margins of the granite and are generally aligned parallel to the contacts, show similar porphyroblastic selvedges a few centimetres wide. Locally, assimilation of xenoliths of schist and minor amphibolite has produced hybrid rocks.

In the Hooper Hills, where the contact is knife-sharp and transgressive, contact metamorphism of the metasediments is limited to local development of muscovite flakes and recrystallization of tourmaline. Small xenoliths of phyllite, mica schist, and biotite-rich basic to intermediate rock are present in the granite. The granite retains its coarse porphyritic texture right to the contact and contains more aplite and pegmatite than usual.

Contact with Whitewater Volcanics. Lennard Granite intrudes Whitewater Volcanics north of Mount Eliza and along Sandy Creek and Pandanus Creek. The granite is transgressive, shows marginal chilling, and contains volcanic xenoliths. Elsewhere the granite is coarse and porphyritic right up to sharp contacts. Apart from local transgressive relations most of the contacts are controlled by bedding of the Whitewater Volcanics. Locally they are faulted and may have been initially fault-controlled, e.g. 6 km southeast of Dromedary yard. Small-scale interlayering has produced migmatites of granite and biotite-rich acid volcanics.

At some contacts (e.g. Pandanus Creek 6 km south of Bigelleas yard) the granite, although chilled marginally, is inhomogeneous and contains irregular patches of aplite and pegmatite. At other contacts (e.g. 5 km south of Dromedary yard) feldspar porphyroblasts are developed in the volcanics.

Contact with Mount Amy Granite. Lennard Granite is locally intruded by Mount Amy Granite, particularly along schistose zones or along contacts between Lennard Granite and other granitic or metamorphic rocks.

Contact relations with McSherrys Granodiorite (Fig. 11b) and Kongorow Granite are referred to in the descriptions of those units.

Petrography (from Peers, 1966a, 1967)

The granite is coarse-grained and porphyritic and consists essentially of feldspars, quartz, and biotite. The phenocrysts, which are generally 2 cm or more across, consist of microcline containing minor perthitic plagioclase.

Microcline (ca. 40%) is unaltered. Microcline phenocrysts are microperthitic. In the matrix microcline forms small anhedral grains. Plagioclase (ca.

15%) is oligoclase which forms distorted mildly sericitized grains. Locally medium-grained quartz (ca. 35%) forms bands of interlocking mosaics, parallel to biotite flakes and rock foliation. Biotite (ca. 7%) is pleochroic with X = pale yellow, Y = greenish brown and Z = dark brown. It is partly altered to chlorite and commonly associated with minor muscovite. Pleochroic haloes surround included zircons. Accessories include zircon, epidote, apatite, and sphene. The groundmass is a mosaic of quartz, microcline, and plagioclase of variable grainsize. Quartz-feldspar intergrowths are common. The texture is allotriomorphic granular with a distinct foliation imported by the alignment of phenocrysts and biotite flakes.

Discussion

The Lennard Granite is uniform over wide areas. Significant variations are found adjoining metamorphosed sediments of the Halls Creek Group, where muscovite or biotite becomes prominent and is probably due to contamination of the granite with pelitic material. Other variations within the granite are attributed to assimilation of xenoliths.

The association of the normal porphyritic Lennard Granite with more even-grained granites in complex stocks suggests that the later phases (adamellite and granodiorite) became successively enriched in plagioclase by differentiation of the normal Lennard Granite magma.

Xenolith swarms

Xenolith swarms occur in the Lennard Granite in the Sandy Creek area about 13 km south of Millie Windie Gap. These swarms occur in three zones which appear to be collinear and extend discontinuously in an east-west direction for about 6 km. The zones vary in width from 3 to 15 m, but their boundaries are gradational. Most xenoliths are lenticular or oblate and up to 300 mm across. A few larger ones up to 10 m across occur at the western extremity of the zones.

Most of the xenoliths are granodioritic or dioritic; some are probably gabbroic. They are similar to the rock types present in McSherrys Granodiorite, which crop out near the western end of the xenolith zones. Some xenoliths show subophitic texture typical of dolerite and may have been derived from the Woodward Dolerite which crops out immediately south of the swarm.

The granite containing the xenoliths is coarse-grained and patchily porphyritic, and tends to be richer in mafic minerals than elsewhere. It is foliated, and most of the xenoliths are parallel with, or actually define, this foliation (Fig. 12). Many of the xenoliths show an irregular reaction border with the enclosing granite.

Discussion

This occurrence is considered to be a xenolith swarm rather than an agmatite because of the lack of intimate veining and intrusion of country rock which is typical of agmatite. It is possible that this zone was agmatitic at an earlier stage, but the aligned and generally rounded xenoliths are not now typical of agmatite.

It appears that McSherrys Granodiorite, and to a lesser extent Woodward Dolerite, have provided most of the xenolithic material. The Halls Creek Group may have contributed material as well, but the xenoliths in general show a lack of regular banding. The increase in size of the xenoliths from east to west is probably due to more complete brecciation and disruption of McSherry Granodiorite towards the east, resulting in greater numbers of smaller xenoliths.

The xenolith swarm indicates that McSherrys Granodiorite is intruded by Lennard Granite. This is consistent with observations elsewhere in the Sheet area. At many of these localities Lennard Granite is enriched in xenoliths near the contact, but not to the extent observed in the Sandy Creek locality.

Dyasons Granite (New name)

Dyasons Granite is named from Dyasons Creek which flows along the southwest margin of the granite near the centre of the Sheet area. The reference area is the Granite Range (320E, 279N).

Field occurrence

Dyasons Granite extends for about 30 km in a discontinuous belt 5 km wide, east-southeast of Waggon Flat. It forms irregular stocks, large dykes, and veins associated with other granites of the Lamboo Complex.

The granite forms moderately rugged bouldery ridges and large exfoliated whalebacks with intervening sandy pediments. Along many of the ridge tops it occurs only as an erosion-resistant dyke, and is probably less extensive than photo-patterns indicate. It has a light-toned photo-pattern similar to that of Lennard Granite, but distinct from the darker-toned McSherrys Granodiorite that commonly borders it.

Fig. 12. Xenolith swarm in Lennard Granite; Sandy Creek area, 13 km south of Millie Windie Gap.

Lithology

Dyasons Granite is a leucocratic medium-grained, typically even-grained pale blue-grey granite containing 5 to 10 percent biotite.

Generally it is massive or only slightly foliated; the foliation mostly trends northwest. Near an extension of the Sandy Creek shear zone in the Granite Range, the mass is very strongly foliated and sheared in an easterly direction. The sense of shear movement in this area is sinistral. Small mesocratic and melanocratic xenoliths are present, and in the Granite Range these have been drawn out to discontinuous mafic schlieren.

Contact relations

Contact with Halls Creek Group. Dyasons Granite is faulted against the Halls Creek Group along the northern edge of the Granite Range. The granite intrudes and partly incorporates a band of quartz-feldspar-biotite-gneiss (possibly granitized Halls Creek Group) immediately south of the Granite Range. Tongues of the granite penetrate along the gneissic foliation.

Contact with McSherrys Granodiorite. Blocks and xenoliths of McSherrys Granodiorite are incorporated in the stocks and larger dykes of Dyasons Granite. Some of the blocks are over 2 km^2 in area. At most contacts abundant dykes of granite up to 10 m wide intrude the granodiorite.

Contact with Lennard Granite. No contacts between stocks of Dyasons Granite and Lennard Granite have been observed, but a dyke of Dyasons Granite cuts Lennard Granite 5 km southwest of Scrutons Hole, showing that Dyasons Granite is younger.

Contact with Mount Amy Granite. Mount Amy Granite intrudes Dyasons Granite east-southeast of the Granite Range. At this locality Dyasons Granite intrudes McSherrys Granodiorite, and both are cut by dykes, veins, and very small stocks of aplite and graphic pegmatite related to the Mount Amy Granite.

Petrography

Dyasons Granite ranges from leucocratic granite to granodiorite. Estimated modal analyses are as follows:

Specimen No.:	0230	0231	0232
Grid Reference	336E, 2785N	3275E, 2789N	341E, 2784N
quartz	45	40	35
plagioclase	40	25	25
alkali feldspar	10	32	35
biotite	5	3	4
accessories	trace	trace	1

The granite is medium to coarse and slightly porphyritic. Quartz forms composite grains and fine-grained granular mosaics. Plagioclase in all specimens is andesine; compositions range from An_{32} to An_{48}. Most grains are subhedral, fresh or slightly saussuritized, and have normal zoning. Potash feldspar is microperthitic and shows only limited microcline-type twinning. Many grains show marginal bleb-like inclusions of quartz. Myrmekite is abundant in all samples and is developed mainly at interfaces between potash feldspar grains, where it forms petaloid growths replacing part of the host feldspar. Biotite is strongly pleochroic with

X = pale straw and Y = Z = deep olive green-brown. The anhedral flakes are scattered throughout the rock and rarely form aggregates. Accessory minerals are generally associated with biotite and include epidote, sphene, zircon, calcite, muscovite, and iron ore.

Discussion

Dyasons Granite is similar to Mount Amy Granite, but the latter is mostly muscovite-bearing. The close spatial relations with McSherrys Granodiorite suggest that the two may be related.

Mount Amy Granite (New name)

The Mount Amy Granite is named from Mount Amy, a granite whaleback near Stumpys Jumpup. The reference area for this unit is 8 km northeast of Mount Amy at 2700E, 28460N.

Field occurrence

Small masses of Mount Amy Granite are exposed sporadically between the Fitzroy River and the Barker River. They range from aplite dyke complexes 400 m wide, to stocks and plugs of muscovite granite up to 10 km^2. The total exposed area of Mount Amy Granite is about 30 km^2.

The topographic expression of these bodies is mainly a function of their size; the larger masses form whalebacks and other exposures form low rounded hills and rock pavements.

Lithology

A number of rock types have been included in the Mount Amy Granite. The most extensive type is fine to coarse biotite-muscovite granite which forms small stocks at and near Mount Amy and Hanns Hole. It is usually grey to pale pink, leucocratic, even-grained or locally porphyritic, and strongly sheared. The presence of muscovite is distinctive.

A second type forms veins, dykes, sheets, and small plugs of aplite and pegmatite, e.g. near McKinrick Hill in the Sandy Creek Shear Zone, and immediately north of Kurrajong Bore. Locally they contain tourmaline and books of muscovite up to 25 mm in diameter.

Contact relations

Mount Amy Granite intrudes all other granitic rocks of the Lamboo Complex. The veins, sheets, and dykes show sharp contacts with older rocks, but the contacts of the stocks are commonly gradational.

Streaky xenoliths of older granite are common in the stocks and larger dykes of the Mount Amy Granite. Shearing of aplite vein complexes has resulted in an apparent interbanding of Mount Amy Granite and Lennard Granite near Stumpys Jumpup.

Petrography (summarized partly from Peers, 1966a, b.)

Muscovite Granite. The larger stocks of Mount Amy Granite consist of biotite and muscovite granite which is locally porphyritic. Most of the specimens examined are strongly foliated and contain quartz, microcline, plagioclase, biotite, and muscovite. Quartz and feldspars of phenocrysts are poorly defined because of marginal replacement by the groundmass. Quartz forms phenocrysts with undulose extinction and finely granular margins, and fine-grained lenticular aggregates in the groundmass. Narrow veinlets of quartz also fill fractures in microcline phenocrysts which are abundant and range from 2 to 5 mm. The microcline is microperthitic. Myrmekite is developed at the grain boundaries. Plagioclase, usually saussuritized oligoclase, forms elongate phenocrysts and granular aggregates associated with quartz in the matrix. Biotite and muscovite form discontinuous stringers which define the foliation in the sheared rocks. The biotite shows yellow-brown pleochroism, and is intergrown with muscovite which contains numerous dark fine-grained inclusions along cleavage planes. Zircon, sphene, epidote, and apatite are rare accessory minerals.

Aplite. These are mostly fine to medium-grained, granitic or adamellitic in composition, and show allotriomorphic granular texture. They are highly leucocratic and contain only traces of biotite. Unlike the muscovite granites, most of the dyke rocks are unsheared or only slightly strained. Grainsize ranges from 0.5 to 2.5 mm. Quartz forms mainly granular mosaics which are interstitial to anhedral patches of microperthitic microcline and plagioclase. Plagioclase (An_{12} to An_{30}) is heavily saussuritized and clouded with fine dusty pale red-brown inclusions. The potash feldspar in places forms composite grains in which intergranular albite is in optic orientation with the perthitic plagioclase. Some myrmekite is developed at potash feldspar interfaces. Muscovite forms clear fresh grains which are slightly deformed or broken.

Aplopegmatite masses near Kurrajong Bore differ from others in the Sheet area in texture and composition. They are graphic granodiorite and consist of intergrown quartz and coarse-grained clouded plagioclase (An_{25}) which contains small quartz blebs and small irregular fields of potash feldspar.

Discussion

The Mount Amy Granite is confined to zones of faulting or shearing within major batholiths, and to the margins of these batholiths. Generally the stocks occur in the sheared zones and the dykes and veins at the batholith margins. The aplites and pegmatites are probably magmatic differentiates of earlier granites, especially the Lennard Granite and McSherrys Granodiorite. The muscovite granites, however, are not all differentiates or late-stage intrusions. Some may be zones of recrystallization in Lennard Granite in which muscovite has developed as a result of contamination, or breakdown of potash feldspar and quartz, or both. The relations noted in some areas suggest localized movement of the rock mass after development of muscovite.

The Mount Amy Granite is the youngest intrusive phase in the Lamboo Complex, with the possible exception of the masses of graphic granodiorite near Kurrajong Bore. These graphic rocks differ both in texture and composition from most other occurrences of Mount Amy Granite, and may be allied to McSherrys Granodiorite.

Equivalents of the Mount Amy Granite are Mulkerins Granite in the Lansdowne Sheet area (Gellatly et al., 1974) and the Mount Ramsay Sheet area (Roberts et al., 1965), and 'muscovite granite' in the Lissadell Sheet area (Dunnet & Plumb, 1964) in the East Kimberley.

Unnamed Acid Rocks

A small exposure of adamellite porphyry about 50 m across crops out 10 km southeast of Scrutons Hole, but is not shown at 1:250 000 scale. It is significant because it resembles Mount Disaster Porphyry and intrudes Lennard Granite (Figs. 13a, b).

The porphyry contains large light-coloured euhedra of alkali feldspar up to 4 cm long. The matrix is fine-grained, biotite-rich, and dark. In hand specimen it resembles the Mount Disaster Porphyry and parts of the Kongorow Granite. It is sheared, but shows a relict flow foliation and a fine-grained border zone which ranges up to 300 mm wide, but is absent in places. This border zone is characterized by both a fine-grained matrix and a lower phenocryst content.

Petrography

In a specimen from the centre of the intrusion, phenocrysts form about half the rock (by modal analysis). Fragments of plagioclase and quartz phenocrysts suggest autoclasis. Potash feldspar (15%) grains are euhedral and range from 4 to 40 mm. They are microperthitic microcline and are commonly corroded and embayed by the siliceous matrix. They usually contain small subhedral inclusions of plagioclase. Plagioclase (15%) phenocrysts, 2 to 4 mm, are subhedral and commonly glomeroporphyritic. They show reversed as well as normal zoning; average composition is An_{42}. Quartz (15%) phenocrysts are augen-like and show granulated margins. Biotite (4%) occurs as large rounded or lenticular grains which are shredded near the margins. The matrix (50%) is a granular aggregate of quartz, plagioclase, sericite, and fine-grained biotite. The grainsize is approximately 0.2 mm.

The chilled marginal phase contains potash feldspar, plagioclase, and quartz phenocrysts, most of which are slightly smaller than those further from the contact. Biotite phenocrysts are rare. The plagioclase grains are noticeably glomeroporphyritic and show little or no disruption. The matrix contains biotite, quartz, plagioclase, decussate patches of pale green amphibole, and abundant zoisite.

The rocks are porphyritic microadamellites, though the groundmass of each is granodioritic.

Discussion

The field evidence (transgressive contact, chilled margin, flow foliation, etc.) shows that this rock is intrusive and younger than the Lennard Granite. Microscopic features such as the strong twinning, zoning and euhedral nature of plagioclase suggest that the intrusion is a high-level type (Vance, 1960). The fragmentary nature of many of the phenocrysts suggests autoclasis during intrusion.

The lithology and composition of the intrusion suggest affinity with the Mount Disaster Porphyry. However, the latter is known to be older than Lennard Granite whereas this dyke is younger than Lennard Granite. This suggests at least two periods of porphyry intrusion separated by a period of granite intrusion.

Unnamed Basic Rocks

A number of small basic and ultrabasic lenses crop out immediately north of Sandy Creek, 15 km southwest of Scrutons Hole, and in McSherrys Granodiorite 8 km north of Kurrajong yard and 20 km east of McSherrys Gap. These are only 15 to 30 m across, and are not shown at 1:250 000 scale.

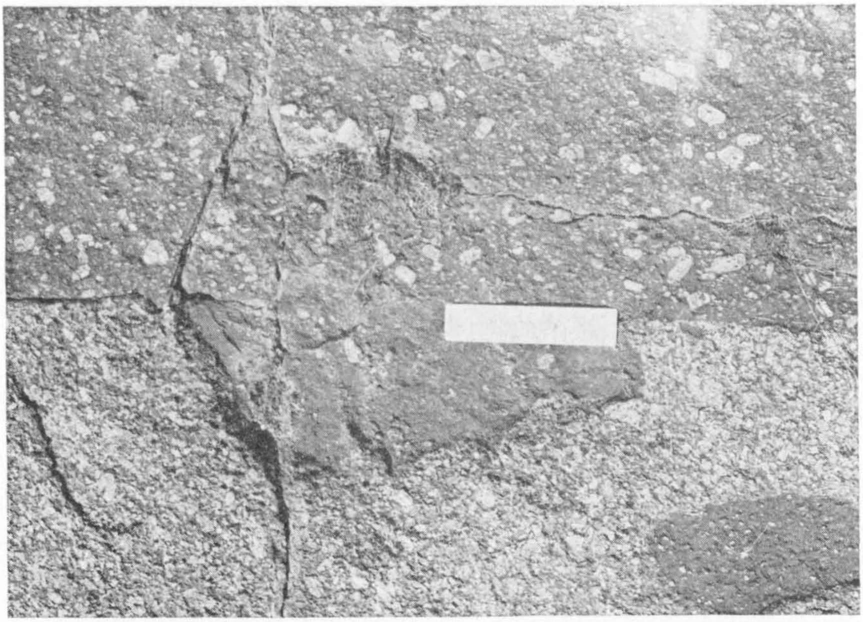


Fig. 13a. Adamellite porphyry (dark) intruding Lennard Granite and truncating xenoliths in it. Note the euhedral phenocrysts of alkali feldspar, and the lack of a chilled margin; Sandy Creek area, 10 km east-southeast of Scrutons yard. M431

Fig. 13b. Contact of adamellite porphyry cutting Lennard Granite. Note the slight diminution in size and number of phenocrysts in the chilled margin; Sandy Creek area, 10 km east-southeast of Scrutons yard. M431

Field occurrence

North of Sandy Creek two basic lenses are completely enclosed by Lennard Granite. The lenses are massive and dark, and in hand specimen appear to be ultrabasic. Amphibole and poikilitic plates of dark mica up to 1.5 cm across are coarsely intergrown, and some opaque oxide is visible.

Petrography

In thin section the major minerals present are amphibole and chlorite. At least two varieties of amphibole are present. One is hornblende with X = pale green fawn, Y = pale orange fawn, Z = pale orange-brown. The other is actinolite, which is less massive and more fibrous than the hornblende. Chlorite occurs as (a) penninite, pseudomorphing large plates of mica which contain abundant dusty ferruginous inclusions. Pleochroism is pale pink to pale green; (b) a colourless variety which appears fresh and unaltered, characterized by low birefringence (.006) positive optical sign, negative elongation, and polysynthetic twinning. Muscovite lenticles are common along cleavage planes. The optical properties suggest rumpfite or prochlorite (Winchell & Winchell, 1951); (c) a fibrous or asbestiform colourless variety with low birefringence, which forms the bulk of the rock and encloses all other minerals poikilitically.

Hypersthene(?) occurs as large pale pink sieve-textured plates, with a low birefringence on prismatic sections; 2V is large and may be positive or negative. In one section anhedral grains of hypersthene occur in the core of a large actinolite crystal. Opaque inclusions are present in amphibole cleavage planes and in the chlorite-rich matrix. A few of the opaque grains have been identified as chromite.

These rocks appear to have been peridotites which have been metamorphosed and hydrothermally altered. They may be xenoliths of Woodward Dolerite, which crops out nearby.

Another basic body in the same area crops out alongside a quartz reef which intrudes Halls Creek Group phyllites. This rock contains abundant plagioclase phenocrysts and is probably part of the Woodward Dolerite, but differs from it in containing graphic intergrowths of quartz and potash feldspar.

The basic pods in McSherrys Granodiorite occur along a shear zone near masses of Dyasons Granite and pegmatite. They are dark green and amphibolitic and consist of green hornblende (40%), andesine An_{32} (40%), and interstitial quartz (15%). Brown coarse-grained biotite (5%) is associated with the hornblende.

The rock is a hornblende tonalite, and its hypidiomorphic granular texture suggests that it is part of McSherrys Granodiorite, and may be related genetically to the mesocratic diorite masses found adjacent to the Halls Creek Group at McSherrys Gap.

Minor Acid Intrusives

Quartz Veins

Field occurrence

Quartz veins and reefs occur throughout the Sheet area and intrude the Halls Creek Group and most of the granite. The quartz veins range from 0.3 to 6 m thick and trend mainly north-northwest and east. They are up to 8 km long and occupy fault zones or joints. In many cases quartz veins up to 2 km long are arranged *en echelon* along major fault zones, e.g. 13 km east of Old Leopold yard. Generally the quartz is massive, milky, and highly fractured, though smoky quartz crystals up to 100 mm long are present in veins cutting the Whitewater Volcanics.

The Halls Creek Group is intruded by quartz reefs and veins which range from small lenticles 50 mm across to reefs 1 km long. Most of the veins are generally conformable with the enclosing sediments and strike mainly east and north-northwest.

Large quartz reefs are common in McSherrys Granodiorite and form prominent razorback ridges, e.g. Mount Hill. These quartz reefs thicken considerably at places of intersection and appear to be fault fillings.

Arcuate quartz reefs up to 12 km long intrude Mount Disaster Porphyry in the northeast near Mount Eliza. These trend north-northeast and fill fault zones. In the southeast, quartz veins are associated mainly with the Lerida Granite and Bickleys Porphyry.

Mineralization

Many of the quartz veins are mineralized, though only slightly. Galena occurs in a quartz gangue 3 km northeast of Bigelleas yard, and northwest of Ord Gap. Gold has been won from the quartz veins in the Halls Creek Group near Mount Broome and Mount Rose (see Economic Geology). Barite and some galena occur in a siliceous fault zone near Dromedary yard, and specular hematite is common in the Oscar Range. Hematite pseudomorphs after pyrite are present in quartz veins cutting McSherrys Granodiorite near Tunnel Bore.

Aplite and Pegmatite

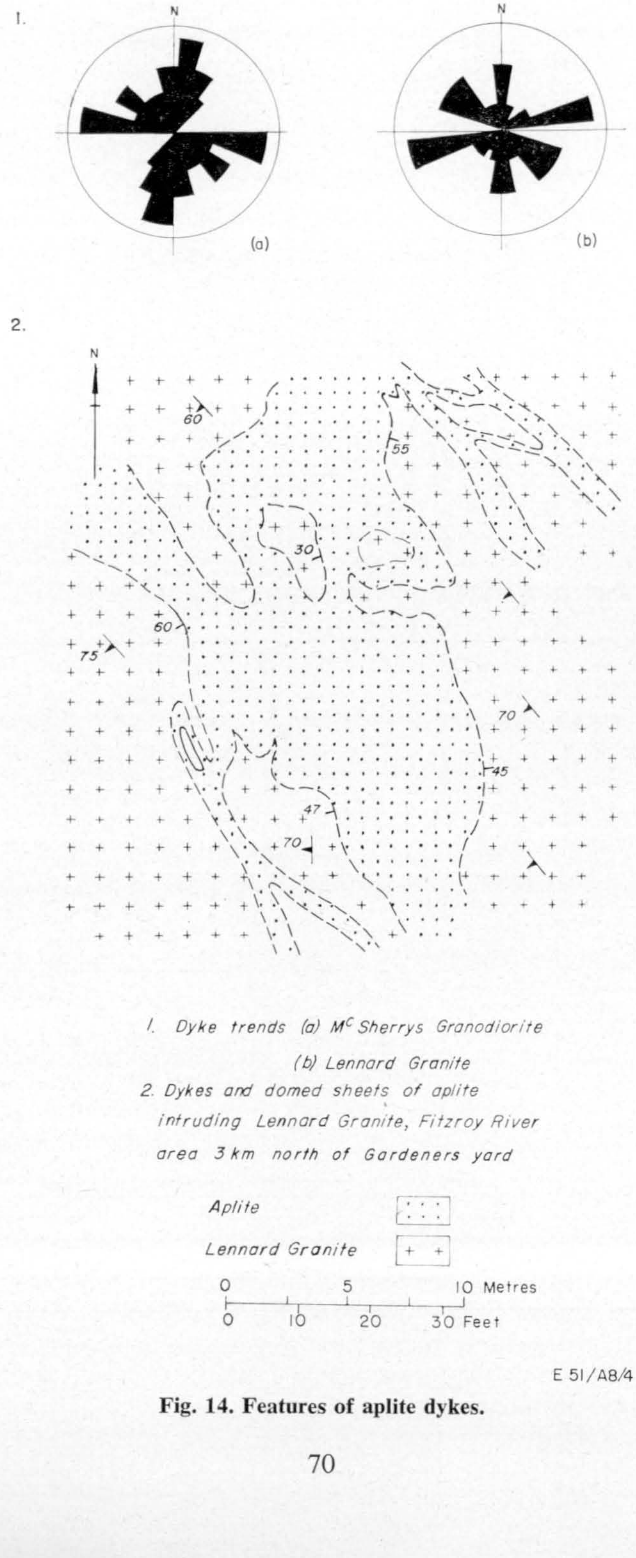
Aplite and pegmatite are associated with nearly all of the Precambrian rocks in the Sheet area, and in most cases represent a final phase of intrusive igneous activity.

They occur mainly as dykes and, to a lesser extent, sheets and very small stocks; they are widespread, particularly in McSherrys Granodiorite and Chaneys, Lennard, and Lerida Granites. They also occur in Dyasons and Kongorow Granites.

Aplites are generally more resistant to weathering than the host rock, but large masses of pegmatite are mostly poorly exposed. Only the larger dykes are visible on aerial photographs, but dyke swarms e.g. 5 km north of McKinrick Hill, show a fine trellised photo-pattern.

Dykes are 75 mm to 10 m thick, but most are about 150 mm. Sheets of aplite crop out in areas up to 280 m^2 or more. The dyke trends are shown in Figure 14. Conjugate dyke systems are present, trending northeast, northwest, and north. The dykes tend to parallel the joint and fault patterns in the host rocks.

The aplites are fine to medium-grained and light-coloured. The pegmatites vary in grainsize, but in some cases feldspar crystals up to 200 mm and tourmaline up to 75 mm in diameter are present. The pegmatites are generally pink and show graphic texture. In most dykes aplite and pegmatite are intimately associated. In some the pegmatite occurs in the centre of the dyke, but in others it occurs at the margins or is rhythmically interbanded with aplite across the dyke. These features are due to both composite intrusion and to variations in rates of crystallization in a single dyke.



E 51/A8/4

Fig. 14. Features of aplite dykes.

Contact relations

Invariably the dykes of aplite and pegmatite show sharp transgressive contacts with the host rocks. In McSherrys Granodiorite north of Kurrajong Bore, bands of aplite or fine-grained granite have assimilated and reacted with volcanic xenoliths, and boundaries are gradational. At least three sets of aplite dyke intrusion are evident in the granodiorite, but in Lennard Granite and others only one or two are present.

Structure

Many of the dykes are folded or faulted on a small scale. In the Sandy Creek shear zone, aplite dykes are faulted in a sinistral sense, with up to 2 m displacement. This reflects the larger-scale shear movements along this zone. Some dykes show tight fold forms, but the dyke and host granite in such cases show little evidence of disruption. This suggests that dyke intrusion and deformation may have occurred while the rocks were only partly solidified.

Quartzo-feldspathic bands up to 300 mm thick are common in the strongly foliated Lennard and Kongorow Granites 6 km north and northwest of Wombarella yard. These bands are either remnant metasedimentary material or, more probably, sheared aplite dykes.

Petrography

Most of the aplites show an allotriomorphic granular, saccharoidal, or graphic texture. The aplites and pegmatites are mainly granitic, but some associated with McSherrys Granodiorite are granodioritic in composition. Flakes of muscovite and chlorite shreds are common accessories to quartz and potash feldspar. Iron-oxide, garnet, and apatite are less common. Additional information on aplite petrography has already been listed on page 65.

Mineralization

Economic minerals are present in pegmatite only at Gussys Mica Mine (see Economic Geology). This pegmatite is coarse-grained, and is broadly conformable with muscovite schist of the Halls Creek Group. It contains large books of muscovite and accessory tourmaline, garnet, and beryl.

Tourmaline and muscovite are ubiquitous in many aplites and pegmatites in the granites. Masses of biotite or phlogopite are associated with tourmaline in metamorphic rocks north of Winjana Gorge. Cassiterite has been recorded by Finucane (1939) from pegmatite in the Dyasons Creek area.

Discussion

Many large masses of aplite are similar to the fine-grained Mount Amy Granite and have been referred to it where they are able to be mapped at 1:250 000 scale. The dykes appear to be the last stage of igneous intrusion and are probably directly related to the granites they intrude. The rare pegmatites that cut the Halls Creek Group are found up to 8 km from the nearest granite and are more likely to have been formed from solutions that were derived from the metasediments rather than from a distant granite source.

Dolerite Dykes

Dolerite dykes are widespread throughout the basement belt of the Sheet area. They are more common in the southeast than in the northwest, and are associated mainly with McSherrys Granodiorite, Lennard Granite, and Halls Creek Group.

The dykes generally form dark resistant ridges of varying height and 1 to 20 m width, or lines of residual boulders on soil plains. Some are continuous for more than 20 km, but the average continuous length is about 2 or 3 km. Dyke swarms are particularly abundant in McSherrys Granodiorite in the area immediately east of McSherrys Gap, where the dykes generally trend north-northwest. Many are gently arcuate, and intersect, bifurcate, and vary in thickness along strike. Some show *en echelon* distribution.

Lithology

The typical dolerite is dark greenish grey, fine to coarse, and even-grained with a subophitic texture. Phenocrysts of plagioclase up to 1 cm occur in some dykes. The dolerite is generally massive and unaltered but locally is sheared and amphibolitized. Minor amounts of pyrrhotite and pyrite are evident in some hand specimens. Most of the more massive dykes show fine-grained chilled margins. Immediately east of Tunnel Bore sheared amphibolite dykes are cut by massive dolerite, which suggests two periods of dyke emplacement. Similarly both amphibolitized and fresh dolerite is found in the Halls Creek Group northeast of McSherrys Gap.

Petrography

Two dykes intruding McSherrys Granodiorite have been examined in thin section. Plagioclase up to An_{52} (labradorite) is generally zoned and saussuritized. The other major constituents are pleochroic green to brown hornblende, and pale green actinolite. Biotite, quartz, and iron oxide are present in small amounts. Large grains of apatite formed up to 20 percent of one specimen. In both rocks the subophitic texture was only moderately preserved. No pyroxene was observed, indicating complete amphibolitization during regional metamorphism.

A suite or dyke rocks cutting the Halls Creek Group 5 km south of Josephs yard are similar, except that one contains pigeonite, (2V less than 15°) associated with pale pink titan-augite (2V about 35°). A pale green pyroxene which borders the titan-augite is possibly a ferro-augite. The proportions of pigeonite and augite could not be determined. In one grain a core of pigeonite was surrounded by augite. The associated plagioclase is andesine An_{45} and forms fresh laths arranged subophitically. Both pyroxene and plagioclase show clouding owing to submicroscopic inclusions. The clouding is generally most intense towards the centre of the crystals and is more evident in the plagioclase. Free quartz is rare but the presence of pigeonite indicates that the dolerites are tholeiitic.

Structural and age relations

Structure. Few of the dykes are folded, but many are faulted, the most notable examples being the large dykes near Mount Rose and Scrutons Hole. A dyke south-southeast of Scrutons Hole shows sinistral shear displacement of about 1 km. If this dyke is part of the dyke east of Mount Rose (which appears likely), then the sinistral shear displacement along the Sandy Creek Shear Zone is about 10 km. Near Mount Hill, east-trending quartz veins have displaced several dolerite dykes dextrally for up to 400 m.

East of McSherrys Gap there are notably less dolerite dykes in the Halls Creek Group than in McSherrys Granodiorite because of differences in ease of fracturing. These differences are well illustrated by the distribution of the large dyke 5 km east of Mount Rose, mentioned previously. This dyke is strongly developed in the granite, but terminates at the granite-Halls Creek Group contact. The fracture along which the dyke was apparently intruded continues into the Halls Creek Group, but contains no dolerite.

The significance of the dyke trends is discussed in the chapter on structure.

Age. Absolute ages for the dolerite dykes have not been established. They are younger than most of the granites, volcanics, and meta-sediments in the Sheet area, and probably belong to at least two periods of intrusion.

The Mount Rose dolerite dyke is unique in that it also intrudes the O'Donnell Formation in the Speewah Group, and the lowermost sill of Hart Dolerite, including granophyre. It does not appear to cut the dolerite sill above the granophyre, and thus could be a feeder dyke for this sill. The occurrence also suggests that the two sills constituting the section of Hart Dolerite in this area are of slightly different ages.

PALAEOZOIC

Although this Report is concerned mainly with the older Precambrian geology, a number of Phanerozoic units intimately associated with the Precambrian belt warrant mention.

Excluding Cainozoics, these units are—

Palaeozoic

a. Undifferentiated Devonian-Permian

b. Arkose at Prairie Hill

Mesozoic or Tertiary

c. Leucite lamproites

Units a and b have not previously been mapped and were photo-interpreted by Guppy et al. (1958) as Proterozoic rocks. Unit c includes only those lamproites which have been newly discovered and mapped during the present survey and which occur within or close to the Precambrian belt.

DEVONIAN—PERMIAN

Unnamed Sandstone (D-Pc?)

Rocks of this unit have not previously been described in reports concerning post-Precambrian geology of the Lennard River Sheet area. The unit crops out as small flat-topped residual outliers (Fig. 15a) in an area 1 to 15 km south of the King Leopold Ranges near Mount Broome and Millie Windie Gap. The residuals have irregular outcrop plans and range in area from about 70 m^2 to 8 km^2.

The unit consists of quartz grit, coarse-grained quartz sandstone, quartz granule sandstone, and basal conglomerate. It is flat-lying and overlies Lennard Granite unconformably. The uppermost few metres are ferruginized, and appear on the accompanying map as Tertiary laterite. A measured section of the sequence is shown in Table 6.

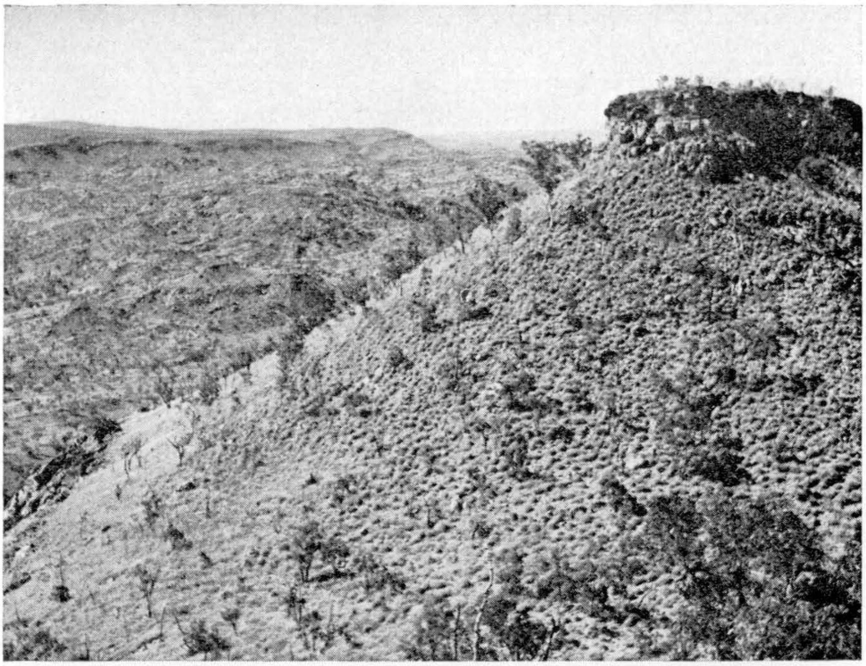


Fig. 15a. Small residual of lateritized quartz grit and conglomerate in scree slope. The level of the residual coincides with the tops of granite hills. Sandstone cliffs of the King Leopold Ranges in left background.

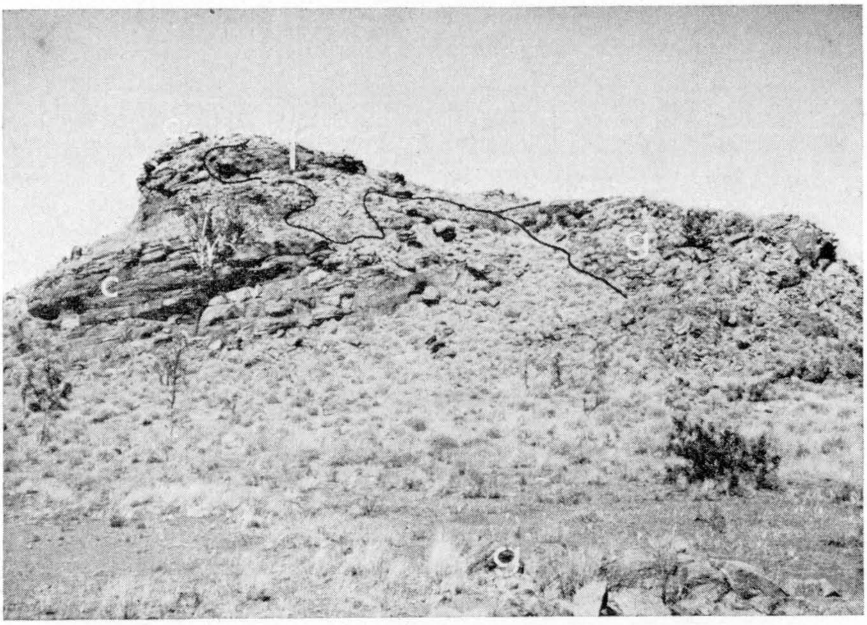


Fig. 15b. Massive arkose and conglomerate (c) at Prairie Hill East, overlying granite (g) and intruded by leucitite (1). G9612.

TABLE 6. MEASURED SECTION OF UNNAMED SANDSTONE AT 3600E, 2797N. MEASURED WITH ABNEY LEVEL.

Thickness (m)	*eroded top*
5	Quartz grit: kaolinitic, massive, faintly bedded; lateritized at surface
2	Gritty sandstone: fine to coarse
1	Gritty quartz sandstone: white, with abundant kaolinitic or fine-grained siliceous matrix. Some silica enrichment along small joints
2	Quartz grit, quartz sandstone, granule sandstone: friable, poorly bedded, some graded bedding; kaolinitic and iron-stained; high porosity
ca. 10	Probably conglomerate: scree-slope covered with rounded boulders (up to 300 mm), cobbles, and pebbles of quartz sandstone, fine to coarse, white to pale purple, and tourmaline-bearing
	UNCONFORMITY
	base not exposed
Total ca. 20	Lennard Granite

The basal conglomerate is not exposed, but the lower half of the scree slope is covered with rounded cobbles and boulders of sandstone which resemble the rocks of the O'Donnell Formation.

Discussion

This sequence of coarse consolidated gravel, grit, and sandstone is probably not an ancient river terrace as it is 150 m above the present stream level and at least 120 m above known ancient terraces in the area. The distribution of the unit suggests that it was continuous over much of the area southwest of the King Leopold Ranges, and the rock types suggest that the unit was probably derived from the ranges.

During Devonian and Permian times the King Leopold Ranges were probably exposed cliffs, while the submerged granitic basement formed an extensive wave-cut platform or shallow shelf (Guppy et al., 1958). Thus, the conglomerate and grit appear to be detritus deposited on this shallow shelf or platform and modified by wave and, to a lesser extent, current action. Conglomeratic material may have been contributed to the shelf by streams and the conglomerate at the base of the unit may be in part a deltaic fanglomerate.

Correlations. No correlations can be made with certainty. However, this unit is possibly equivalent to the extensive flat-lying conglomerates in the Yampi Sheet area which overlie bevelled Proterozoic sandstones. It is also possibly related to the Behn and Van Emmerick Conglomerates, which interfinger with the Devonian reef complex in the central and northwestern Lennard River Sheet area.

(UNKNOWN AGE)

Arkose at Prairie Hill

Prairie Hill is a small prominent rise about 30 m high situated in a broad sandplain immediately east of Hooper Hills. It and two other small rises nearby consist of arkose and were photo-interpreted by Guppy et al. (1958) as part of the Lamboo Complex.

The arkose is red-brown and coarse-grained. The only apparent variation is a change from massive to flaggy parting in the middle of the sequence. It shows graded bedding, but is also current-bedded. Ripple marks are present but are uncommon. The unit is almost flat-lying, and shallow dips of 3° to the north and southwest have been recorded. Rare intraformational overturned cross beds are present.

At Prairie Hill East, about 3 km northeast of Prairie Hill, the arkose is intruded by lamproite. The sediments are metasomatized at the contact and appear dense and green. Conglomerate is also present in this section.

At Prairie Hill East the arkose rests unconformably on the granite (Fig. 15b). Similar relations are assumed to hold for Prairie Hill itself, where soil cover obscures the arkose-granite boundary.

Discussion and correlations

The arkose at Prairie Hill is younger than the surrounding Proterozoic rocks, but older than the Eocene or Jurassic lamproite which intrudes it (Fig. 15b). No fossils were found in the sequence, which has been tentatively correlated with the Pillara Limestone (Playford, 1964). The basal facies of the Pillara Limestone contains arkose, grit, conglomerate, and breccia, and appears lithologically similar to the Prairie Hill exposures. The nearest outcrops of Pillara Limestone are 10 km to the south of Prairie Hill, and only soil and alluvium separate the two exposures. The Pillara Limestone is a Devonian backreef facies, and the distribution of Prairie Hill sequence is in accord with this concept.

MESOZOIC OR TERTIARY

Leucite Lamproites

Potash and magnesia-rich leucite lamprophyres found as volcanic necks and flows of limited extent in the Fitzroy Basin have been described by Wade & Prider (1940) and by Prider (1960) who termed them leucite lamproites. During the 1966-67 mapping program six new plugs were mapped. All except one, the 81-mile plug, intrude exposed Precambrian rocks and are described briefly here. The 81-mile plug and the other new plugs are described in Derrick & Gellatly (1969).

Field occurrence and lithology

a. *Old Leopold Hill.* This plug was located by Harms (1959), but was not mapped in detail until the present survey. It is an inclined plug which intrudes Lennard Granite 5 km north of Old Leopold yard. The plug shows near vertical linear and platy flow structure, and subhorizontal columnar jointing.

The rock is porphyritic and relatively coarse-grained. It contains phenocrysts of altered leucite, diopside, corroded phlogopite, and magnophorite (a K-Mg amphibole) set in a serpentiniferous groundmass. Important accessory minerals include priderite (a potassium rutile), aegirine, and rare sanidine and wadeite (a potassium zircon).

b. *Prairie Hill East.* This is an inclined plug located in extensive soil plains 2 km east of Prairie Hill. It intrudes both Lennard Granite and Devonian sediments which unconformably overlie the granite. A less prominent lamproite near the main plug appears to be a ring dyke. Thin sills of lamproite also intrude the Devonian sediments. In the main plug, platy and linear flow indicate a steep plunge to the southwest. Platy flow at the lamproite margins parallels the contact with the older rocks.

The lamproite is similar to the Old Leopold plug, but contains regular zones which are deficient in phlogopite phenocrysts. In addition, olivine pseudomorphs are present, set in an orange-brown antigoritic groundmass. The ring dyke is poorly exposed, and only phlogopite crystals in a black earthy soil are present.

c. *McKinrick Hill.* McKinrick Hill is a small rise, 30 m high, in the south east of the Sheet area. It consists of strongly jointed lamproite flow breccia filling a steeply plunging pipe which intrudes Whitewater Volcanics. Joint planes in the lamproite form elongate saucer-shaped structures, and have dips ranging from 80° at the pipe margins to 2° at the pipe centre.

The flow breccia is fine-grained and consists of small phenocrysts of talcose material, pseudomorphous after olivine or diopside, and fresh skeletal leucite set in a turbid orange-brown matrix. The fragments range from 25 to 450 mm in diameter and consist of quartz and feldspar grains, pieces of Whitewater Volcanics, and lamproite material.

d. *Big Spring.* The plug is located in a soil plain about 2 km east of Big Spring Bore. The only outcrop is a low mound of loose boulder rubble, about 8 m by 5 m. It is a lamproite breccia containing pale green metamorphosed fragments of Whitewater Volcanics set in a fine-grained agglomeratic, possibly leucitic matrix.

The plug occurs close to outcrops of both the Whitewater Volcanics and the Devonian Pillara Limestone, but appears to contain only fragments of the former.

e. *Mount Rose Plug.* The Mount Rose Plug is located 2 km southeast of Mount Rose. It is roughly circular in plan and about 75 m in diameter.

Flow foliation near the plug margins generally dips deeply inward at angles of 50 to 70°. The Halls Creek Group, which it intrudes, is only slightly metamorphosed and shows no deformation even close to the lamproite.

The plug contains an outer zone of friable, weathered greyish green phlogopite-free leucite rock, and an inner zone containing both coarse phlogopite and diopside phenocrysts. The centre of the plug is not exposed and is covered by black earthy soil and detritus from the phlogopite-bearing lamproite.

Age

The lamproites were considered to be Jurassic. Compston (in Prider, 1960) obtained an average value of 145 ± 10 m.y. using rubidium-strontium ratios. More recent work by Kaplan et al. (1967) gave a rubidium-strontium age of 150 ± 40 m.y., and potassium-argon ratios indicated an Oligocene (32 to 37 m.y.) age, owing possibly to uplift of the lamproites from the surrounding peneplain, or possibly to argon loss during weathering. Recent potassium-argon determinations by Wellman (1972) show the lamproites are of early Miocene age, about 17 to 21 m.y. old.

CAINOZOIC

TERTIARY

Laterite (Tp). A thin laterite capping is present on the Devonian-?Permian sediments which form outlying residuals over the basement near Mount Broome and Millie Windie Gap. Effects of lateritization are poorly developed over this arenite sequence, and are confined to superficial iron enrichment, minor joint silicification, and kaolinite development in the top half of the sedimentary sequence (see Measured Section, Table 6).

Undifferentiated Cainozoic

Soil, sandy soil, colluvium (Czs). These superficial skeletal sediments are developed mainly over the Halls Creek Group and the granitic rocks of the Lamboo Complex. Large expanses of buff to grey loams occur in the southeast along Pigeon, Hoopers, and Sandy Creeks and the flood plains of the Fitzroy River, and in the northwest adjacent to the Lennard and Barker Rivers. Red-brown soils, some with stony surfaces, occur around the Hooper Hills, and large barren vegetation-free areas are common. In the northwest of the Sheet area and in the Sandy Creek area, shearing of the granite has facilitated rock weathering, and pockets of light sandy to gritty soil separate massive boulder outcrops. These soils support only sparse vegetation and abundant large anthills. Colluvium occurs at the base of the King Leopold Ranges, but the outcrop is too narrow to represent at 1:250 000 scale.

Black Soil (Czb). This includes black, grey, and grey-brown clay soils which are developed mainly over basic rocks and limestone, but are also found where deep soils overlie granite and schist. They occur in the southeast near the Fitzroy River and are widespread in areas adjacent to the Napier Range. During the dry season these soils develop large and irregular vertical cracks and a rough pot-holed surface. Calcareous concretions and boulders of dolerite and metamorphics are common in the black soils near Billyara waterhole.

Gravel (Czg). Coarse boulder and cobble gravels form elevated terraces along streams draining southwards from Millie Windie Gap. The coarse gravels are up to 30 m above the present stream levels and are generally loosely cemented with ferruginous material. They are possibly outwash gravels of uncertain age from the King Leopold Ranges.

Quaternary

Alluvium (Qa). Alluvial sediments found along all major river courses in the area consist of silt, sand, and locally gravel.

Brown loamy silt forms flood-plains flanking the rivers and is commonly well exposed in river banks and erosion gullies. The silt contains sporadic lenses of coarse-grained silty sand and gravel (e.g. along Sandy Creek). Locally, e.g. on the Barker River between Napier Downs and Kongorow Pool, the silt forms distinct sandy lenses.

Coarse-grained clean-washed feldspathic micaceous sand is found in most present-day river beds, especially the Barker, Lennard, and Richenda Rivers and Sandy and Hooper Creeks. However, it is rare in the Fitzroy River within the Sheet area.

Gravel is rare and is found principally in minor streams in the Richenda River area, and around Mount Behn and the Van Emmerick Range where coarse cobble gravel derived directly from the Devonian to Permian conglomerate is characteristic. Gravel is also found locally in the Lennard River and in other rivers that include sandstone of the Kimberley Basin succession in their catchment.

METAMORPHISM

In the Lennard River Sheet area the Halls Creek Group has been metamorphosed to varying degrees up to high amphibolite facies. Most rocks belong to low amphibolite or to greenschist facies. Later rocks show only low-grade metamorphism; the Whitewater Volcanics have locally been recrystallized to assemblages containing biotite, and Carpentarian to late Adelaidean rocks have undergone largely dynamic metamorphism producing phyllites with evidence of intense deformation, e.g. stretching of cobbles in conglomerate in the Oscar Range.

Mineral assemblages within the high-grade and intermediate-grade rocks vary appreciably both across and along strike and reflect local temperature and pressure variations. Relations between the various facies and evidence of alteration of early-formed minerals (e.g. andalusite, chloritoid, and garnet) indicate that metamorphism in parts of the area has been polyphase. A general pattern can be recognized indicating that moderately high temperature-low pressure conditions were commonly succeeded by moderately high temperature-high pressure, and finally by low temperature-high pressure conditions. Locally, two or more phases of elevated temperatures are recognized.

Porphyroblastic potash-feldspar-bearing anatectic gneiss and migmatite near Mount Joseph and quartz-feldspar-biotite gneiss south of the Granite Range represent the highest metamorphic grade in the area.

The metamorphic zones recognized in the area are based entirely on the study of pelitic rocks. Impure carbonate-bearing rocks are too rare to be of use in delineating metamorphic zones or facies, but amphibole-bearing rocks could possibly be used in a more detailed study.

Metamorphic zones and assemblages

Pelitic rocks. The principal zones in the higher metamorphic grades in the pelitic rocks are recognized by the assemblages kyanite + sillimanite; garnet + staurolite; staurolite + andalusite; garnet + andalusite; andalusite. Superimposed on these are zones with chloritoid. Throughout the area both andalusite (chiastolite) and chloritoid have been pseudomorphed by other minerals.

The zones of high and intermediate metamorphism (Fig. 16) are erratically distributed, but in general parallel the southwestern margin of the older Precambrian rocks. In the Richenda River area there is a general decrease in grade northwards away from the granite mass to the south, but also a decrease southwards within about 2 km of the granite. The area of highest-grade metamorphism (kyanite + sillimanite) occurs northwest of the Lennard River/Richenda River junction and close to, but not adjacent to, one of the major granite intrusions of the area. The high grade is probably not a result of contact metamorphism, as elsewhere there appears to be no direct relations between metamorphic grade and proximity to granite. There is, however, a relation between the various zones and the degree of deformation; for example, andalusite occurs in areas where bedding has been preserved or only partly destroyed; garnet occurs mainly (but not entirely) in areas of strong deformation where bedding has been destroyed; staurolite is found in both of these environments. These assemblages are listed in Table 7.

Amphibole-bearing rocks. Amphibole-bearing rocks fall into three categories: dolerite dykes; sills of Woodward Dolerite; and beds of amphibole-bearing psammite.

The dolerite dykes are apparently of two or more ages and their degree of metamorphism varies accordingly; some contain fresh pyroxene whereas others are completely amphibolitized. Only extensive sampling could produce reliable information on their metamorphic history. The amphibole present in the Woodward

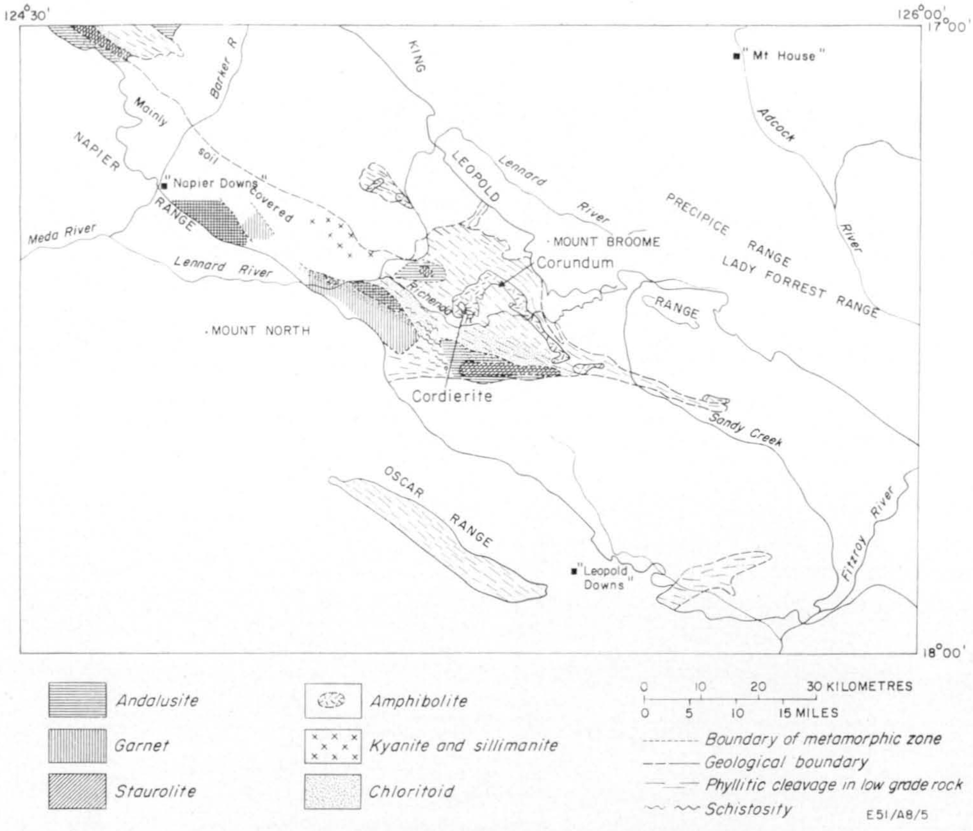


Fig. 16. Metamorphic zones in Precambrian areas.

Dolerite shows minor variations in colour, and presumably also in composition. This could be of use locally, but the Woodward Dolerite is confined to the upper stratigraphic levels of the Halls Creek Group and has not been affected by the higher grades of metamorphism. In addition, as some of the alteration of the Woodward Dolerite may be deuteric, its mineral assemblages may not give a true indication of metamorphic grade.

The amphibole-bearing psammites are widely distributed in the Halls Creek Group and may be sufficiently abundant to be used as indicators of metamorphic grade. The assemblages noted so far in rocks of this type in the Lennard River Sheet area are confined to hornblende-?cordierite-magnetite-quartz-garnet, with or without minor amounts of zoisite; but a compositional range from hornblende-garnet-bearing to hornblende-free clinozoisite-bearing psammites has been noted in rocks of this type from the Inda Ad Series of the Somali Republic (Gellatly, 1961).

Gneiss. Scattered outcrops of migmatite and mobilized nonmigmatic porphyroblastic granodiorite gneiss are found about 6 km west-northwest of Mount Joseph in an area of sillimanite-bearing Halls Creek Group schists, and in a narrow belt immediately south of the Granite Range.

In the Mount Joseph area the gneiss crops out as small irregular masses in ridges of schist, and forms bouldery hillocks similar in outcrop expression to the nearby Kongorow Granite.

TABLE 7. METAMORPHIC ASSEMBLAGES

General locality	*Strongly deformed rocks: bedding mostly destroyed*	*Mildly deformed rocks: bedding mostly recognizable*
Wombarella yard-Joseph yard	1. Garnet—biotite—plagioclase—quartz 2. Garnet—magnetite—plagioclase—?cummingtonite 3. Garnet—kyanite—sillimanite—biotite—cordierite—orthoclase—plagioclase—quartz 4. Garnet—kyanite—sillimanite—biotite—orthoclase—quartz 5. Hornblende—biotite—plagioclase—quartz	
1 to 3 km north and east of Billyara yard	1. Garnet—chloritoid—biotite—muscovite—quartz 2. Garnet—staurolite—biotite muscovite—quartz	1. Corundum—muscovite[1,2]—biotite—quartz
Hawkstone Creek	1. Staurolite—garnet—chloritoid—muscovite—biotite—quartz 2. Garnet—chloritoid—biotite[1,2]—muscovite—quartz	(1. Andalusite (altered)—staurolite—chloritoid—biotite—quartz—muscovite)
North of Mount Behn	1. Andalusite—corundum[2]—sericite[2]—muscovite—biotite—quartz 2. Corundum[2]—muscovite[1,2]—chloritoid—biotite—quartz (3. Garnet—andalusite (altered)—staurolite—biotite—muscovite—quartz) (4. Garnet—chloritoid—biotite—muscovite—quartz)	(1. Garnet—chloritoid—biotite—muscovite—quartz)
East of Dyasons Creek	1. Chlorite—biotite—muscovite—quartz	1. Andalusite—sericite[2]—corundum[2]—biotite[2]—muscovite—quartz 2. Andalusite—corundum[2]—muscovite[2]—biotite[2]—chlorite[2]—quartz 3. Corundum[2]—sericite[2]—biotite[2]—quartz 4. Corundum[2]—sericite[2]—chloritoid—biotite—muscovite—quartz 5. Staurolite—andalusite corundum[2]—muscovite[2]—biotite[2]—quartz 6. Staurolite—biotite[2]—muscovite—quartz 7. Hornblende—garnet—magnetite—?cordierite—quartz 8. Hornblende—garnet—chlorite—zoisite—?cordierite—quartz

[1] Indicates primary mineral.

[2] Indicates a secondary mineral pseudomorphing another.

Parentheses indicate minerals or assemblages noted in the field; others have been identified from thin sections.

The non-migmatic gneisses are massive and commonly show irregular nebulitic flow banding expressed by mafic streaks and lenticles, and by planar distribution of feldspars (Fig. 17a). They are mostly porphyroblastic with scattered ovoid potash feldspar porphyroblasts (up to 50 mm) containing bipyramidal quartz inclusions, tabular 25 to 30 mm porphyroblasts of sillimanite, and 50 to 75 mm patches rich in garnet.

The migmatites show very irregular banding. They are intimately and randomly mixed with undigested unmobilized remnants of muscovite schist, psammitic biotite schist, and fine-grained amphibolitized dolerite. The migmatites also have inclusions of mafic nonporphyritic granodiorite (similar to McSherrys Granodiorite), nonporphyritic biotite microgranite (similar to Richenda Microgranodiorite), and coarsely porphyritic biotite granite with flow-oriented phenocrysts that locally resembles phases of the Kongorow Granite. These phenocrysts contain small quartz inclusions in their cores, but lack the borders of plagioclase inclusions found extensively in the Kongorow and Lennard Granites.

In the Granite Range area quartz-feldspar-biotite gneiss occurs in a belt 5 km long and 400 m wide between Dyasons Granite and McSherrys Granodiorite. The gneiss is generally finely banded, but grades locally into porphyroblastic gneiss with augen of feldspar up to 15 mm. It is intruded by tongues of medium-grained granodiorite related to Dyasons Granite (Fig. 17b).

In thin section the finely banded gneiss contains a granoblastic aggregate of quartz, plagioclase (An_{25}), and rare potash feldspar. Biotite flakes occur in bands and contain sphene, zircon, and epidote inclusions. Myrmekite is sporadically developed throughout the rock. Porphyroblasts (or porphyroclasts) of plagioclase occur in both the finely banded gneiss and the coarse-grained variety, and in the latter are partly composite.

The gneiss complex is granodioritic and could be either granitized sediments of the Halls Creek Group or sheared granite. If the gneiss is metasedimentary the lack of garnet and recrystallized detrital tourmaline is unusual. If the gneiss is sheared granite, then post-shearing recrystallization has occurred, causing the granoblastic development of quartz and feldspar. No conclusive evidence is available, however, to decide between the two possibilities.

Metamorphic minerals and their reactions

Andalusite (var. chiastolite) is apparently an early mineral in the metamorphic sequence in the area. It forms elongate four-sided prisms up to 100 mm long and 30 mm across and commonly shows typical chiastolite cruciform internal structure. In most thin sections andalusite is partly or wholly altered to an assemblage of muscovite (or sericite), corundum, and minor biotite pseudomorphing chloritoid (Fig. 18 a,b). About 8 km southwest of Mount Rose small crystals of pale pink translucent secondary andalusite have been noted in 75 mm-diameter pods of altered primary chiastolite. The most intense alteration of andalusite to pods of coarse-grained pure white decussate muscovite and minor corundum was found mainly on the margins of zones of higher grade metamorphism, e.g. 3 km east of Hawkstone Creek and 2 km north of Billyara yard, but has also been found near the outer margin of the andalusite zone about 8 km south of Blackhill yard.

The exact conditions responsible for the breakdown of andalusite are unknown. Similar alteration of andalusite to muscovite and corundum has been reported from Yosemite National Park, California, by Rose (1957) who attributed

Fig. 17a. Nebulititic potash feldspar and sillimanite-bearing anatectic gneiss; 6 km west-northwest of Mount Joseph.

Fig. 17b. Finely banded quartz-feldspar-biotite gneiss intruded by tongues of granodiorite; 10 km north of Kurrajong Bore.

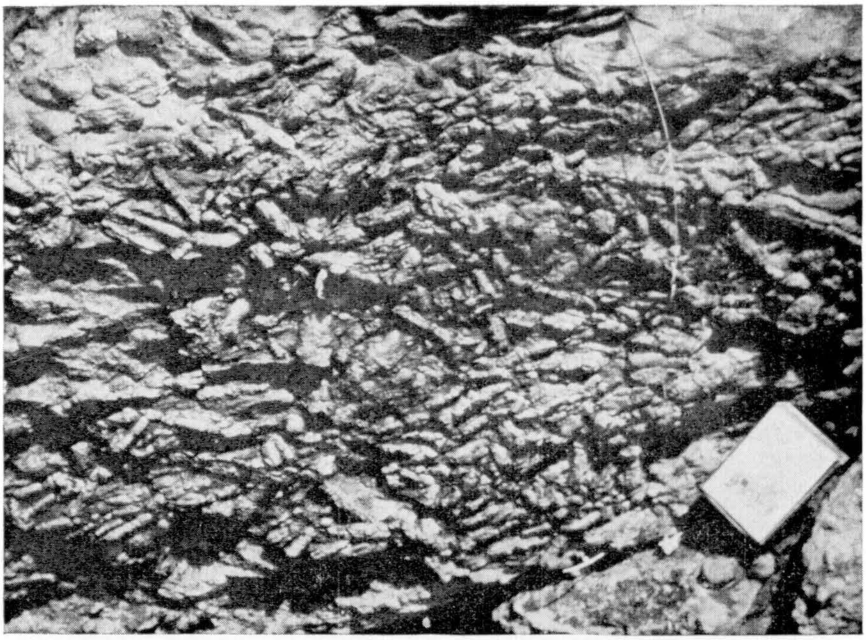


Fig. 18a. Andalusite pseudomorphs in quartz-mica-schist (Halls Creek Group); 10 km north of Mount Behn.

Fig. 18b. Large pods of andalusite partly replaced by sericite and biotite in bedded Halls Creek Group metamorphics; 8 km south-southeast of Blackhill yard.

it to potash metasomatism. However, the Halls Creek Group metamorphics of the Lennard River Sheet area show no evidence of metasomatism, so this explanation is unlikely; changes in pressure-temperature conditions were presumably responsible. Stress changes probably played a minor part as alteration of andalusite has taken place extensively in areas in which bedding is well preserved, but changes in hydrostatic pressure owing to change in depth of burial may have been important. Experimental data (Ervin & Osborne, 1951) show that in a hydrous environment corundum is stable only above 450°, and gibbsite, boehmite, and diaspore below this temperature. This sets a lower temperature limit on the transformation.

With stronger deformation, andalusite is completely altered to muscovite without accompanying corundum, and the only traces that are left are lenticular micaceous patches which are silvery in appearance and unusually rich in muscovite compared with the enclosing rock. All gradations can be traced in the field from undeformed andalusite pseudomorphs of these muscovite-rich lenticles. This breakdown of andalusite, assisted by (if not entirely caused by) deformation, is responsible for the westwards disappearance of andalusite near Dyasons Creek.

Staurolite varies in crystal habit according to the tectonic setting in which it has developed. Those from the easternmost staurolite zone form short prismatic crystals up to 50 mm long with a length/breadth ratio of 2/1 to 3/1. They are found in bedded schists and hornfelses and have probably developed in a non-stress or low-stress environment. Those from the area east of Hawkstone Creek, however, are found in rocks in which bedding has been completely destroyed, and have a slender habit with length/breadth ratio between 4/1 and 6/1. Staurolites from 3 km east of Billyara yard are unusual in that they radiate from a central garnet nucleus (Fig. 19). In thin section all staurolites examined are poikilitically studded with abundant small quartz grains. Those from Hawkstone Creek have sinuous trains of quartz inclusions, indicating rotation during growth.

Garnets vary little except in size. They attain a diameter of 50 mm about 5 km south of Wombarella yard, but are mostly in the range 6 to 15 mm. Quartz inclusions are common in them, and locally, e.g. 1 km northwest of Billyara yard, show classical sinuous trains of quartz inclusions generally interpreted as the result of rotation during crystallization (Harker, 1951, pp. 220-1). Garnets that have been marginally or completely altered to chlorite in the Lennard River 3 km east of Billyara yard suggest retrograde metamorphism, but they are not widely distributed and may be due to localized deformation accompanying falling temperatures.

Chloritoid pseudomorphs occur as thick tabular crystals that are randomly oriented and commonly cut across the schistosity of the rocks. Many of the rocks that contain thin flakes of primary biotite parallel to primary muscovite and defining the schistosity also contain thick tabular biotites that cut across the foliation. These are similar in form to chloritoid (both in hand specimen and thin section) and are tentatively interpreted as biotite pseudomorphs after chloritoid. There is no evidence in this area that chloritoid has developed from staurolite or vice versa.

Contact metamorphism

Contact metamorphism is not well developed in the area. The granites have caused remarkably little alteration, e.g. 5 to 6 km east of McSherrys Gap a zone of decussate muscovite only 3 m wide is developed in Halls Creek Group rocks at the contact with McSherrys Granodiorite. At other granite contacts in the area, e.g. Hooper Hills, there is similarly very little contact metamorphism.

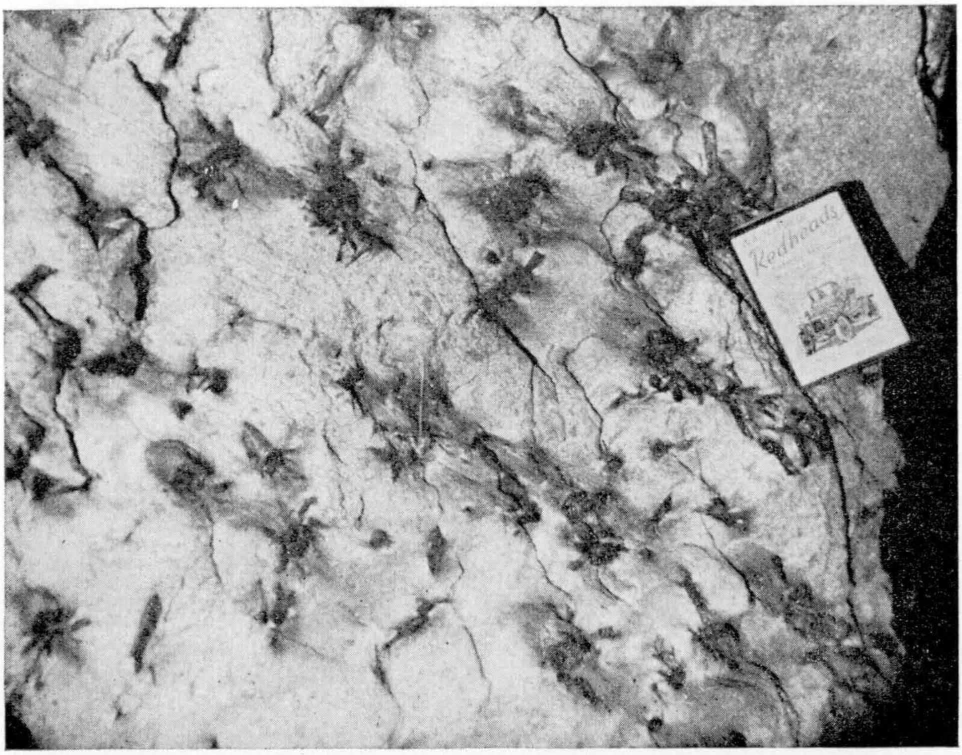


Fig. 19. Garnets surrounded by radiating staurolite crystals in garnet-staurolite-biotite-quartz-muscovite schist; 3 km east of Billyara yard.

Contact metamorphism by the Woodward Dolerite is of low grade and localized. Pelites of the Halls Creek Group mostly show only slight induration close to the dolerite. However, the corundum rock in the area southwest of Mount Broome occurs at or near the contact of the Halls Creek Group with Woodward Dolerite, and the development of corundum is probably due to contact metamorphism accompanied by localized metasomatism owing to the temperature gradient within the contact zone. The origin of the corundum in the Mount Broome area is probably analogous to that of kyanite and corundum at the contact of Woodward Dolerite with the Halls Creek Group near Hawkstone Creek in the Charnley Sheet area.

Discussion

The metamorphic zones recognized in the Lennard River Sheet area are similar in part to the classical Barrovian zones of the Scottish Highlands (Barrow, 1893), except for the widespread occurrence of andalusite and its pseudomorphs. The presence of andalusite and its association with staurolite in a garnet-free area of bedded schists indicates that there has been an early phase of regional metamorphism resulting in the development of garnet, staurolite, kyanite, and sillimanite and also in the breakdown of andalusite to corundum and white mica. The late stages of the main metamorphism were probably retrograde and dominantly dynamic, with development of chloritoid, but subsequent temperature increases have resulted in the conversion of chloritoid to biotite.

STRUCTURE (Fig. 20)

The Lennard River Sheet area contains three main structural units: the west-northwest-trending King Leopold Mobile Zone (named by Traves, 1955, p. 91) which is flanked on the north by the relatively more stable Kimberley Block, and on the south by the gently folded Canning Basin. In this Report the structure of only the older Precambrian rocks of the Mobile Zone is considered. The structure of the younger Precambrian to the northeast will be described by Plumb (in prep.), and that of the Oscar Range was described by Derrick & Gellatly (1971).

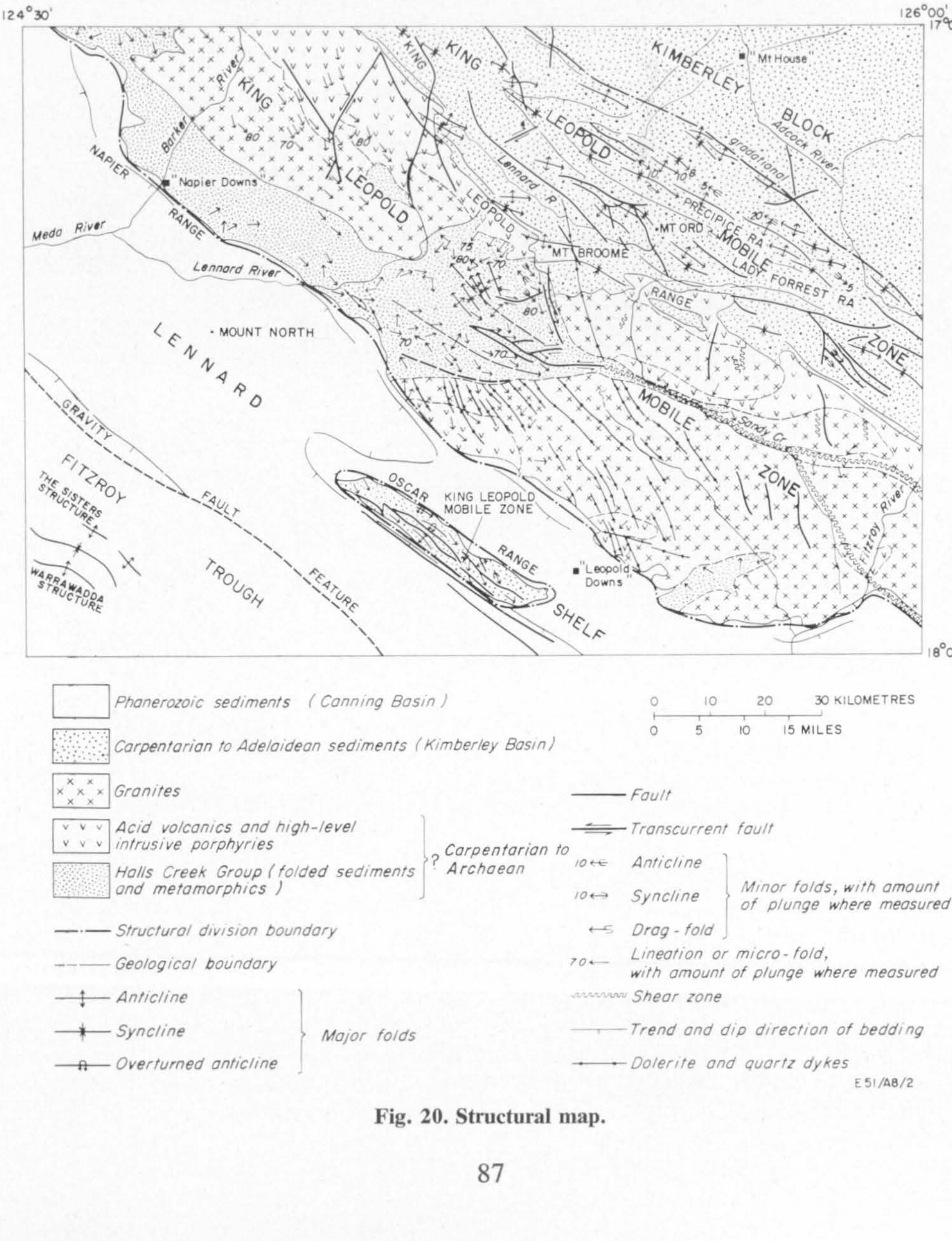


Fig. 20. Structural map.

Regional structure

The limits of the King Leopold Mobile Zone are uncertain. The northern boundary cannot be defined precisely as there is a gradual decrease in the intensity of folding northwards from the mobile zone to the Kimberley Block. No comparable decrease in intensity of folding can be recognized to the south; the most southerly exposed Precambrian rocks (those of the Oscar Range) are intensely folded and show similar fold trends to the Kimberley Basin sediments along the northern flank of the mobile zone. Any southwards decrease in the intensity of folding that might indicate a southern limit to the mobile zone is obscured by the Phanerozoic sediments of the Canning Basin.

The Kimberley region as a whole is characterized by folding and faulting along two main structural trends—west-northwest and north-northeast. The west-northwest trend is dominant in the King Leopold Mobile Zone in the west and the north-northeast trend in the Halls Creek Mobile Zone in the east. In the West Kimberley area, north-northeast-trending structures are poorly developed and prominent only locally, e.g. in the Kimberley Group of the Charnley Sheet area and in the Halls Creek Group southwest of Mount Broome in the Lennard River Sheet area . The west-northwest-trending folds plunge either west-northwest or east-southeast; both plunge directions are considered to be primary.

From evidence of unconformities in the Precambrian sequence of the Mount Ramsay Sheet area to the southeast (Roberts et al., 1965), it appears that movements within the mobile zone and adjacent areas have taken place intermittently from late Archaean to late Proterozoic times. Subsequent fold movements have probably had no perceptible effects on the Precambrian rocks of the region.

The King Leopold Mobile Zone

The general structure of the mobile zone within the Lennard River Sheet area is anticlinal. This is demonstrated by the general northeasterly dips of the Kimberley Basin sediments away from the older Precambrian of the central part of the mobile zone, and by the southwesterly dips of Precambrian rocks of the Oscar Range and of the overlying Phanerozoics. The structure of the older Precambrian rocks of the mobile zone is possibly anticlinorial with a central core of granite plutons and strongly folded Halls Creek Group schists and phyllites, flanked to the northeast and southeast by the Whitewater Volcanics and associated high-level stratiform porphyry intrusions. Generally the granites form batholiths elongate parallel to the trend of mobile zone. Within these batholiths individual plutons show elongation in a west-northwesterly direction.

The Whitewater Volcanics and associated high-level stratiform porphyry intrusions form steeply dipping sheets mostly along the northern flank of the mobile zone, also narrow downwarped belts between and enveloped round the granite plutons.

The Halls Creek Group forms roof pendants within or between the major granite plutons. The structure of the roof pendants is uncertain because of their highly deformed character and the paucity of readily recognizable marker horizons. As far as can be determined, the Halls Creek Group in the Richenda River area forms a complex biplicate anticlinorium of which the northern part (outlined by the Woodward Dolerite) plunges northwestwards and the southern part (inferred from small-scale structures and partly from the distribution of metamorphic facies) plunges to the southeast. The structure of the northwestern extension of this anticlinorium is uncertain, although folds in general parallel the trend of the mobile zone. If increasing metamorphism here is due to increasing depth of burial, then the variation in metamorphic grade suggests younging of the beds to the southwest, i.e. away from the granites which form the core of the anticlinorium. On the other limb of the structure extrapolation northwestwards from the Surprise Creek area suggests that the beds young to the northeast.

Folds

Folding along axes with three main primary plunge directions is recognized within the King Leopold Mobile Zone. These directions are south-southwest, west-northwest, and east-southeast. In the older Precambrian rocks, south-southwest trending folds are confined to the Halls Creek Group. West-northwest plunging folds are found in both the Halls Creek Group and in the Whitewater Volcanics, but are poorly displayed in the latter. Folds plunging east-southeast are common in both rock groups, and the effects of this folding are displayed also in the granites as a strong east-southeast plunging lineation. The relative ages of the main periods of folding are incompletely known, and there has probably been repetition of folding along one or more of these trends.

1. South-southwest and related north-northeast plunging folds are apparently the oldest and are found only in the Halls Creek Group. They are best developed in the area 11 km west of Mount Broome where they predominate over folds of other trends. Because of the lack of suitable marker beds in this area, only small-scale folds have been recognized. Subsequent large-scale warping along this north-northeast trend took place in post-Kimberley Group time (e.g. Synnot Range Syncline in the Charnley Sheet area), but no associated structures are recognized in the older Precambrian rocks.

Minor folds of this system are found almost exclusively in rocks in which bedding is well preserved and they generally display a moderately open style (Fig. 21a).

2. West-northwest-trending folds are found mainly in the Halls Creek Group. Evidence from rocks of the older Precambrian and the Kimberley Group indicates that the north-northwest-plunging folds are distinct from those plunging east-southeast, and that the two plunge directions are not the result of refolding of a single system of folds which originally had only one plunge direction. Evidence for the separate existence of the two fold systems is provided mainly by minor structures, particularly where small-scale folds and crenulations related to each of these trends are found in the same outcrop.

The major folds of this system are best developed in the area north of the Richenda River, where they have caused intense folding of the Woodward Dolerite. These folds plunge steeply at about 60 to 300° and can be distinguished from post-Kimberley Group northwest-plunging folds which have shallow angles of plunge. Cleavages associated with these folds dip steeply to the southwest.

Northwest folds with gently plunging axes have been noted from the Halls Creek Group in Dyasons Creek, where a set of lineated quartz veinlets shows folding of lineations about a northwest axis (Fig. 22D). In addition, cleavage-bedding intersections in the Halls Creek Group about 6 km west-southwest of Blackhill yard similarly plunge gently to northwest. These gently plunging northwest minor structures are possibly the result of post-Kimberley Group folding in the Halls Creek Group rocks.

Fig. 21a. Contrasting fold styles in the Halls Creek Group. Open style of folding in andalusite-chloritoid-bearing Halls Creek Group, 10 km south-southeast of Blackhill yard. These minor folds plunge northeast.

Only the gently plunging minor structures of this trend have been found in the Whitewater Volcanics in the Lennard River Sheet area (e.g. 10 km east-southeast of McSherrys Gap), but steeply plunging west-northwest-trending lineations are prominent in the Whitewater Volcanics in the southwest corner of the Lansdowne Sheet area (Gellatly et al., 1974). This suggests that initial folding on steeply plunging west-northwest axes took place before the extrusion of the Whitewater Volcanics, and that only local movement on these axes took place after their extrusion.

3. Southeast-trending and east-southeast-trending folds and associated minor structures are abundant in most of the Sheet area. They have been found in rocks of the Halls Creek Group unaffected by later phases of the Halls Creek metamorphism, and are common in the rocks of the Oscar Range, some of which may be upper Adelaidean. Steeply plunging southeast-trending lineations are common in the granites, but are apparently absent from the overlying Speewah Group. Thus it appears that there were at least three periods of folding with this trend in the area.

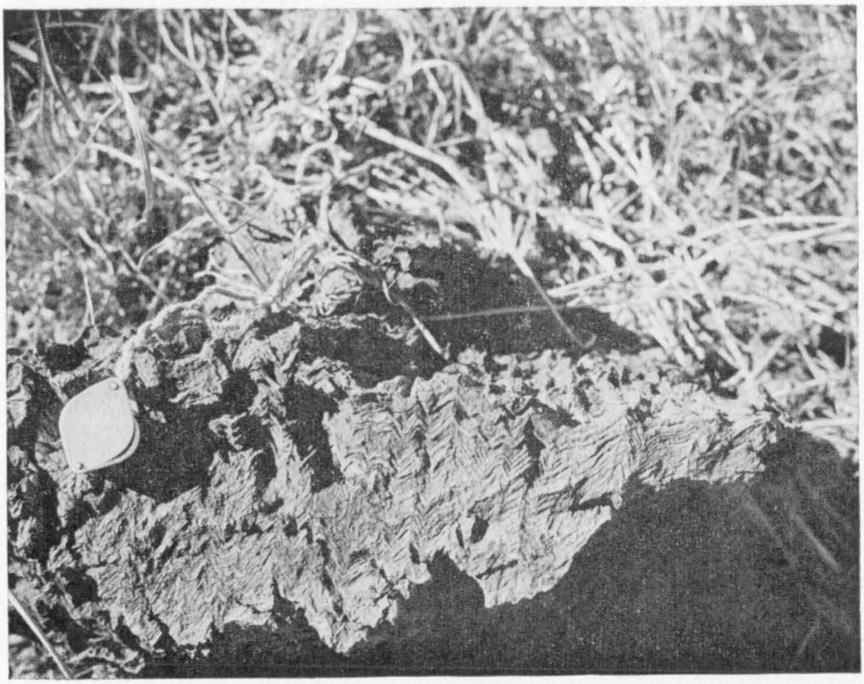


Fig. 21b. Chevron-style crenulation minor folds owing to strong cleavage intersecting bedding; andalusite-mica schist, 11 km south-southeast of Blackhill yard.

The only major folds of this trend recognized are a syncline in the Richenda Gorge/Mount Rose area, and an anticlinorium to the east of Dyasons Creek. The axes of these two structures tend to converge, possibly owing to constriction of the folds by the adjoining granite plutons.

Fold styles of this trend vary; the early ones appear to be mainly tight or isoclinal; later ones in the Halls Creek Group are mainly chevron-style and result from the intersection of cleavage with bedding (Fig. 21b), or locally with an earlier cleavage. Fold axes plunge to the southeast or east-southeast at 45 to 50° and axial planes dip to the southwest.

Cleavage

Cleavage is developed throughout the Halls Creek Group and is locally prominent in the volcanics and granites.

In the sediments all gradations are present from well bedded to strongly cleaved rocks in which bedding has been completely obliterated. In most rocks both bedding and cleavage can be recognized. Generally cleavage cross-cuts bedding, but in many localities cleavage and bedding coincide. Where this is so, bedding is difficult to trace and its identity uncertain because of almost complete obliteration by cleavage. In certain localities, especially on Dyasons Creek about 1 km from the northern contact of the McSherrys Granite, small-scale isoclinal recumbent folds demonstrate the relation of cleavage and coincident bedding. On the limbs of these minor folds, bedding planes have been completely obliterated owing to the development of cleavage, but its former presence is indicated by thin arenaceous layers in the predominantly argillaceous host. These arenaceous layers are generally parallel to the cleavage. Bedding is preserved locally on the crests of folds. By analogy, it is suggested that at other localities in the Sheet area where bedding and cleavage are coincident, this is also due to the presence of isoclinal folding.

Two cleavages have been recorded from many places in the Dyasons Creek/ Richenda River area. Where two cleavages are well developed their intersection generally results in the development of strong crenulation microfolds and lineations, but kink-folds of the style developed from two-cleavage intersections in the area of overfolding and thrusting in the Yampi Sheet area are unknown in the Lennard River Sheet area. Strong crenulations formed through the intersection of two cleavages are characteristic of strongly cleaved rocks in the garnet zones, but are comparatively rare in the andalusite zones.

The ages of the two cleavages relative to the metamorphism are not known with certainty, but slicing of garnets by an intense fracture cleavage indicates that at least one strong cleavage episode postdates the development of garnet, i.e. post-dates the second main phase of metamorphism.

Faults

Major faults in the older Precambrian rocks of the Sheet area are transcurrent and are a continuation of the East Kimberley fault systems, particularly the Greenvale Fault.

The main fault feature in the Lennard River Sheet area is a west-northwest-trending shear zone termed the Sandy Creek Shear Zone. This shear and transcurrent fault system extends from the southeastern corner to near the northwestern corner and may possibly extend into the Charnley Sheet area. Along parts of its length it cuts granites and is expressed only as a zone of highly foliated rocks in which small-scale structures locally indicate the sense of movement, but not the amount, of displacement. In the Mount Rose area sinistral transcurrent movement of 5 km is demonstrated by displacement of the Woodward Dolerite by one of two major north-western extensions of the Sandy Creek Shear Zone. Elsewhere, the shear zone has displaced dolerite dykes by up to 10 km. The other northwestern branch, which forms the northern contact of the main outcrops of McSherrys and Dyasons Granites, also shows sinistral movement (indicated by small-scale sinistral drag folds), but the amount of displacement is unknown.

Complementary transcurrent faults associated with these major shears are well displayed near Colemans Camp and also near the Richenda River corundum deposit. At both localities displacement of sills of Woodward Dolerite enables small movements to be detected. These complementary shears have dextral displacement and make an angle of about 30° with the principal shear. Accompanying these complementary faults and parallel to them are sinistral faults with a smaller displacement. These may be regarded as second-order shears related to the primary shear.

Folds associated with the transcurrent faulting are well developed near Colemans Camp. They are westward-plunging sinistral drag folds that have near vertical fold axes and a wavelength of about 150 m.

North-trending faults and shear zones found mainly in the granites, especially in the southeastern part of the Sheet area, are marked by zones of strongly cleaved schistose granite and show mainly dextral displacement. The cleavage within these north-trending shear zones generally trends about 150°, indicating dextral compressive shear. Small-scale drag folds also indicate dextral movement. These shears are similar in every respect to those cutting the Lennard Granite in the Yampi Sheet area (Sofoulis et al., 1971).

Joints

Joints are prominent throughout the granites of the Sheet area, but are much less prominent in the volcanics and metasediments. The principal trend is west-northwest, with a subsidiary southerly trend probably related to the north-trending shears. The joints are either vertical or steeply dipping. In addition, a set of low-angle joints that dip gently northeast is locally conspicuous, especially in the granites to the northwest of the Lennard River. The joints in the area are probably related to the shear system described above. Many of the major joints in the granites may in fact be faults along which movement cannot be demonstrated.

Dyke trends

Most basic dykes have a general northwest trend, particularly in the McSherrys Gap/Granite Range area where they are most abundant. In the northwest part of the Sheet area the trend is west-northwest. Within the granite outcrops the dykes invariably occupy fault or joint fractures. The presence of two sets of dykes (distinguished by differences of metamorphic grade) with identical trends suggests that the fracture system occupied by the dykes originated before their intrusion. If this fracture system is regarded as tensional, it cannot be readily correlated with the major fault systems of the area. On the other hand, the dykes are parallel to one of the main branches of the Sandy Creek Shear Zone, so that the dyke-filled fractures may represent transcurrent shear fractures with very little displacement. This concept is supported by the fact that some of the dykes have themselves been sheared. The possibility that the dykes infill tensional fractures developed during folding (*ac* joints) appears unlikely because of the paucity of late northeast-trending folds and the absence of dykes normal to the principal fold trends.

In the Halls Creek Group a few dykes occupy west-northwest-trending joints. They commonly parallel either the cleavage of the rocks or bedding, depending on which is the better developed locally.

Fault tectonics

The transcurrent fault pattern of the West Kimberley area closely resembles that of the San Andreas and related faults (Moody, 1966), though the scale and amount of movement in the West Kimberley area are much smaller. Similar tectonics may be inferred, although the whole system of faults in the West Kimberley area cannot be related to a single stress field.

The west-northwest sinistral and east-trending dextral shears form a complementary system that could have resulted from east-west compression. The relation of the north-trending shears to this system is uncertain, although they could represent part of a second-order set of shears related to the Sandy Creek Shear Zone.

Age of faulting

Movement along faults in the area probably occurred intermittently throughout the Proterozoic. The main transcurrent movement in the West Kimberley area, however, appears to antedate the Kimberley Basin sedimentation.

The earliest movements appear to antedate the Richenda Microgranodiorite and the McSherrys Granodiorite as the southern margin of the main plug of Richenda Microgranodiorite is controlled by one of the transcurrent faults, but is not apparently displaced by it. In addition, the northern margin of McSherrys Granodiorite is a linear, apparently fault-controlled feature, but between Dyasons Creek and McSherrys Gap small tongues of unsheared granodiorite diverging from this general linearity produce an irregular contact that has not been faulted. However, strong shearing along the granite margin to the east of Dyasons Creek renewed after intrusion.

Evidence that the main movement antedates the Kimberley Basin sedimentation is found a few kilometres east and northeast of Dromedary yard, where the contact of Lennard Granite with Whitewater Volcanics shows apparent displacement of about 5 km, but the O'Donnell Formation to the north shows no displacement at all. There has, however, been some movement on the transcurrent faults in post-Kimberley Basin time as an eastern branch of the Sandy Creek Shear Zone has deformed O'Donnell Formation sandstone in the Lansdowne Sheet area about 6 km south of Lindesunjun Waterhole. Post-Kimberley Basin faulting in the West Kimberley area includes both vertical and transcurrent displacements and has probably resulted from reactivation of pre-existing lines of weakness.

TECTONIC HISTORY

The tectonic history of the older Precambrian rocks of the Lennard River Sheet area is summarized in Table 8. This includes events later than the deposition of the Speewah Group as these are recognizable locally in the older Precambrian and are of uncertain age.

Because of the large number of fold periods represented and because of repetition of folding along each trend, the ages of the various periods of deformation are at present uncertain, but may be clarified by closer examination of the data collected, particularly those relating to the relative ages of periods of folding and metamorphism.

ECONOMIC GEOLOGY

No mines operate in the area. Minerals produced spasmodically from the region include corundum and emery, copper, mica, tin, wolfram, and beryl. Table 9 lists the total mineral production reported to the W.A. Mines Department to December 1966. The Narlarla lead-zinc mine is located in Devonian rocks (Playford & Lowry, 1966; Halligan, 1964; Gellatly, 1970) and is described in this Report. Production figures are included.

Small showings of other economic minerals have been recorded within the Sheet area, but none appear to be capable of economic exploitation at the present time. T.R. 2686H, which covered the older Precambrian rocks of the West Kimberley Goldfield was geochemically prospected for base metals by Pickands Mather International Company Limited from 1966 to about 1970.

Although no economic deposits have been located, minor showings of lead, copper, zinc, etc., noted during the present survey suggest that more intensive work in the area could be justified. Small base-metal anomalies in the Oscar Range area were described by Derrick & Gellatly (1971).

Numerous quarries developed along the major roads of the area provide road surfacing, ballasting, and construction materials.

Groundwater used for the beef cattle industry is the principal known resource.

Metallic and industrial minerals

Lead

Macs Jumpup. Galena with minor pyrite, barite, and fluorite was noted in narrow fault zones cutting Whitewater Volcanics near the main road 2 to 3 km east of Macs Jumpup. Simpson (1951) also reported lead mineralization in rocks of the Lamboo Complex some 19 km north of the Narlarla mine. Neither deposit is of economic potential.

Bigelleas yard. Galena has been reported from the Bigelleas yard locality by Guppy et al. (1958) and Harms (1959). The deposit is located 3 km north of Bigelleas yard at the southern end of a razorback about 25 m high. The razorback cuts foliated biotite granite and trends northwards, and the quartz veins forming the ridge are arranged *en echelon* and trend south-southeast.

The galena occurs as small (0.2 to 0.4 mm) crystals in thin veinlets which cut a brecciated massive grey-white quartz vein. The mineralized rock was not found *in situ* during the recent mapping, and the extent of the mineralization is not known. One or two old mining buckets and picks suggest some small-scale production, but it appears that the deposit has not been exploited for many years. It is probably similar to the Old Leopold occurrence described by Harms (op. cit.).

Old Leopold (Harms, 1959). A quartz reef with erratically distributed crystals and patches of galena occurs on the east bank of the Fitzroy River about 5 km northeast of Old Leopold yard. The reef is 300 to 450 mm wide and trends northwards for about 500 m. Country rock is sheared Chaneys Granite or Bickleys Porphyry.

Copper

Richenda River area. Blocks of malchite-bearing limonitic gossan up to 0.5 m across have been found in a creek bed at 3190E, 28087N, about 1 km west-southwest of the Richenda River corundum deposit, but their source has not been located. A grab-sample of one of these boulders contains the following (values in ppm);

Cu	Pb	Zn	Co	Ni	Sn	Ag	Au	Mo
10 000	600	2000	5	5	50	25	3	1

Ord Gap area. Specks of copper are widely distributed in shear zones and quartz veins in the Ord Gap/Pandanus Creek area, but no economically significant occurrence has been located.

Gold

Gold occurrences in the area around Colemans Camp about 8 km southeast of the Richenda Gorge have been described by Finucane (1939) under the heading Richenda River Gold Quartz Reefs. The reefs are emplaced in Halls Creek Group phyllites in an area much intruded by Woodward Dolerite. Seven prospects are described with values that range from 0.10 dwt per ton over 20 m x 330 mm to

TABLE 8. SUMMARY OF TECTONIC HISTORY — OLDER

Era	Deposition	Igneous Events
PROTEROZOIC		
		Intrusion of late dolerite dykes
	Deposition of Speewah and Kimberley Groups	Extrusion of Carson Volcanics
	UNCONFORMITY — MAJOR PERIOD OF EROSION	
		Intrusion of early dolerite dykes
		Intrusion of late porphyry dykes ('Unnamed acid rocks')
		Intrusion of Lerida Granite, McSherrys Granodiorite, Lennard, Chaneys, Dyasons, and Mount Amy Granites, and late phases of Kongorow Granite
		Intrusion of Bickleys and Mount Disaster Porphyries and Mondooma Granite
		Extrusion of Whitewater Volcanics
	UNCONFORMITY — PERIOD OF EROSION	
		?Intrusion of early phases of Kongorow Granite and Richenda Microgranodiorite
		Intrusion of Wombarella Quartz-Gabbro
		Intrusion of Woodward Dolerite
ARCHAEAN	Deposition of Halls Creek Group	Minor acid volcanicity

PRECAMBRIAN ROCKS (LENNARD RIVER SHEET AREA)

Tectonic Events	*Metamorphism*	*Remarks*
Transcurrent faulting		
Folding along shallow-plunging northwest and southeast axes	Low-grade largely dynamic metamorphism	Phyllite in Lennard River Sheet area
Gentle folding along shallow-plunging northeast axes		e.g. Synnot Range Syncline in Charnley Sheet area; weak in Lennard River Sheet area
		Related at least in part to Hart Dolerite
		Complete removal of Whitewater Volcanics locally
Folding along steep-plunging southeast axes	Mild metamorphism; marginal alteration of dolerite dykes	Foliation and lineation developed in granites
		Relative order uncertain
		Some andalusite granofels in Yampi Sheet area.
Faulting (partly transcurrent?)		Possible fault control of margins of granite 6 km southeast of Dromedary yard, and east of McSherrys Gap
		Cobbles of Woodward Dolerite in conglomerate near base of Whitewater Volcanics
Folding along steep southeast axes	Garnet and kyanite-sillimanite grade metamorphism, and subsequent retrograde metamorphism	Strong cleavage developed; anatexis causing development of granite magma
Folding along steep southeast axes	Andalusite and staurolite low-stress metamorphism	
Folding along steep northwest axes		
Folding along steep northeast axes	?Metamorphism	Andalusite in rocks with only northeast minor folds

TABLE 9. MINERAL PRODUCTION — LENNARD RIVER

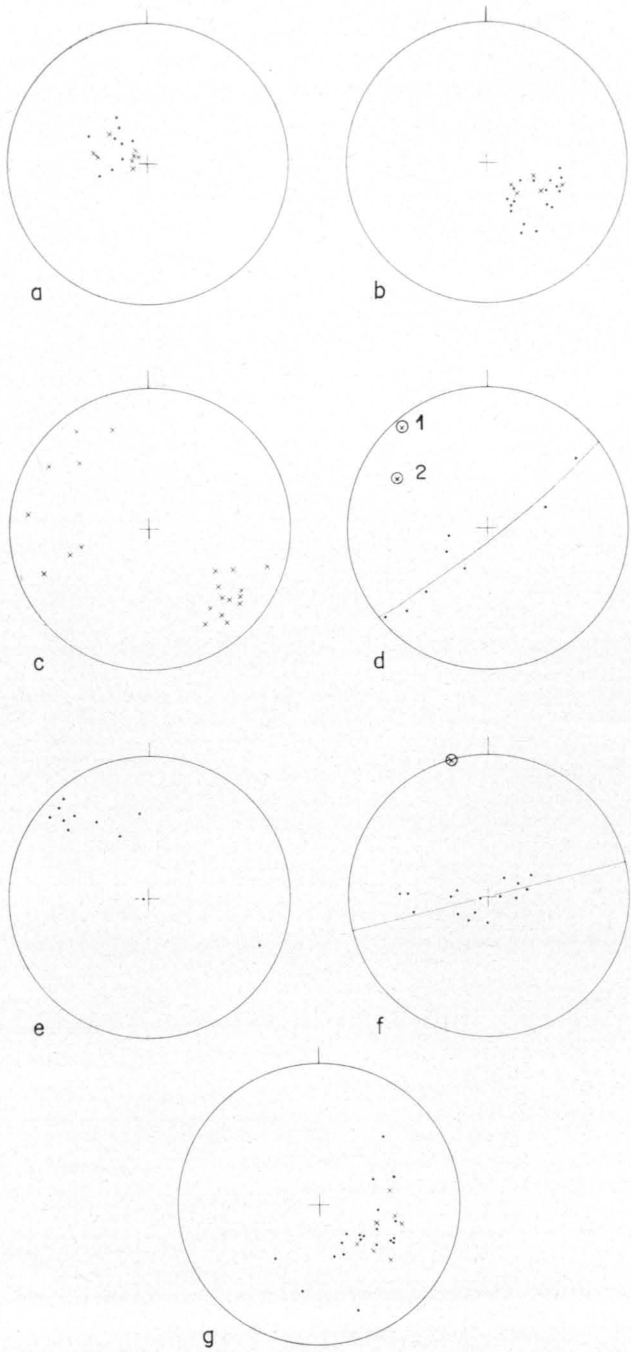
(as reported to W.A. Mines Dept to December 1966)

1968/126

Mineral	*Centre*	*Holding*	*Name of lease or holder*
Beryl	'Napier Downs stn' (probably Stuart's mica-beryl mine in the Yampi Sheet area)	Crown Lands	Sundry Persons
Cupreous Ore	Patterson Ra[1]	P.A.74	Latham A.
Corundum	Mt Broome	M.C.38	Clackline Ref Ltd
Emery	Mt Broome	M.C.38	Clackline Ref Ltd
	Richenda	T.R.1110H	W.A. Govt
	Napier Ra	M.C.29	Devonian Pty Ltd
	Napier Ra	M.C.29	Devonian Pty Ltd
Lead ore & concentrates			
Mica	Napier Downs stn	P.A.58[2]	Stuart J.
Tin Concentrate	Patterson Ra	Sundry Claims[3]	Sundry Persons
	Patterson Ra	Sundry Claims[3]	Sundry Persons
Wolfram	Napier Ra	M.L.146H[3]	Taylors Wolfram Reward
	Napier Ra	M.C.28[3]	Kimberley Metals

1 Locality uncertain, possibly Charnley Sheet area.
2 Probably from Stuarts mica-beryl mine, Yampi Sheet area.
3 Probably from King Sound mine, Charnley Sheet area.

Period	*Quantity (long tons)*	*Metallic content*	*Value* $
		BeO Units	
1949	3.50	38.85	593.40
1960	0.98	11.74	380.40
1961	1.61	17.82	552.40
Total Beryl	6.09	68.41	1 526.20
		Assay Cu%	
1961	3.10	17.07	254.00
1955	9.15		550.00
1955	8.15	—	490.00
1942	13.00	—	260.00
Total Emery	21.15	—	750.00
1948-1955	1 844.14	*Lead (Long tons)* 731.00 *Zinc (Long tons)* 342.37 *Silver (Fine ozs)* 13 630.87	93 467.20
1964-1966	9 015.21	*Lead (Long tons)* 1 351.062 *Zinc (Long tons)* 2 479.35 *Silver (Fine ozs)* 23 742.26	412 278.28
Total lead ore & concentrates	10 859.35	*Lead (Long tons)* 2 082.062 *Zinc (Long tons)* 2 821.72 *Silver (Fine ozs)* 37 373.13	505 745.40
	lbs		
1949	312	*Tin (Long tons)*	9.24
	tons		
1951-1952	.30	.23	469.50
1955	.13	.09	158.06
Total Tin	.43	.32	627.56
1909-1910	27.00	200.00	240.00
1940	1.48	79.68	422.50
Total Wolfram	28.48	279.68	662.50



E 51/A8/6

Fig. 22. Trends of minor structures.

A. Steeply plunging west-northwest-trending minor structures in Halls Creek Group about 13 km west-southwest of Mount Broome. Dots represent lineations; crosses are fold axes.

B. Steeply plunging east-southeast-trending minor structures in Halls Creek Group about 8 km southeast of Blackhill yard. Dots are lineations and microcrenulation folds; crosses are fold axes.

C. Gently plunging fold axes in Speewah Group rocks about 3 km south of Pittard Bluff. Compare with A and B.

D. Lineations in folded quartz veinlets, Dyasons Creek. The lineations are distributed along a great circle, with a gently plunging northwest-trending pole (fold axis) 1. This axis corresponds approximately to 2, which is the axis of nearby recumbent folds (second folds) in the Halls Creek Group.

E. Crenulation-style lineations in Halls Creek Group near a track about 5 km west-southwest of Blackhill yard.

F. Steeply plunging lineations showing evidence of folding about a gently plunging north-northwest axis. The lineations are in deformed dolerite. Same locality as E.

G. Minor structures in bedded Halls Creek Group hornfelses about 2 km northeast of Billyara yard. Dots are bedding plane intersections; crosses are fold axes and lineations.

134.46 dwt per ton over 4 m x 450 mm. Most values are less than 10 dwt per ton. These reefs have recently been worked by Mr J. Stewart who reported the association of antimony (stibnite) with the gold in thin leaders in the area about 2 km southwest of Colemans Camp.

The limited size, sporadic distribution, and moderately low grades of these reefs discourage their exploitation except as small prospects.

Corundum

Corundum occurrences in the Richenda River area have been referred to previously by Simpson (1919, 1920), Forman (1942), and Harms (1959) under the term 'emery',* but the location of these deposits has not been accurately described. Specimens of corundum from the 'Richenda River' and 'Mount Rose' were examined petrographically by Stillwell (1942).

The localities mentioned previously are (1) 6 km southwest of Mount Broome; (2) between 1 and 1.5 km northwest of (1); and (3) near Mount Rose.

During the recent survey corundum was located (at 3198E 2809N) about 12 km southwest of Mount Broome, which is probably the deposit referred to by Forman as being 6 km southwest of Mount Broome (Fig. 23). Detrital corundum was also noted in a creek bed about 2 km west of this locality, but the deposit near Mount Rose was not found.

The deposit examined consists of blocks of massive pale grey corundum rock up to 0.6 m across. No undoubted outcrop was seen, but the boulders, which lie near the crest of a low ridge of amphibolite, are almost in situ. The distribution of corundum boulders suggests that the corundum forms veins or lenses between a thin band of Halls Creek Group phyllite and overlying porphyritic amphibolite referred to the Woodward Dolerite.

The corundum boulder trains have been traced along strike for over 336 m, and are everywhere coincident with, or close to the phyllite-amphibolite contact, which trends east-southeast and dips steeply to the north-northeast.

The corundum rocks are mostly massive and granular; but specimens showing contorted 3 mm to 6 mm interbanding of corundum with ?diaspore are also found. The rocks consist mainly of corundum and diaspore and minor kyanite (Table 10). Rutile and iron oxide are present in small amounts as inclusions in corundum but not in diaspore. A specimen from Mount Rose, described by Stillwell (1942) consisted chiefly of fine-grained corundum, with minor diaspore, sillimanite, calcite and rutile.

The chemical composition of a specimen from the Richenda River (Stillwell, op. cit.) is SiO_2 1.40%; Al_2O_3 92.04%; Fe_2O_3 1.30%; TiO_3 1.90%.

Crushing tests showed that the Richenda River corundum forms angular fragments suitable for use as a coarse abrasive. The Mount Rose material is finely granular and thus unsuitable as coarse abrasive, but could be used as fine-grained or flour abrasive.

The surface tonnage of corundum available from the Richenda River locality was estimated by Forman at 50 to 100 tons. Over the total length of the deposit about 50 tons per foot of depth may be present.

As the deposit is small, it is unlikely to warrant systematic exploitation; but an intensive search along the contacts of the Woodward Dolerite in this area might reveal further occurrences.

* The term 'emery' as applied to these deposits is a misnomer; emery is a granular mixture of corundum and magnetite, whereas this material contains no magnetite.

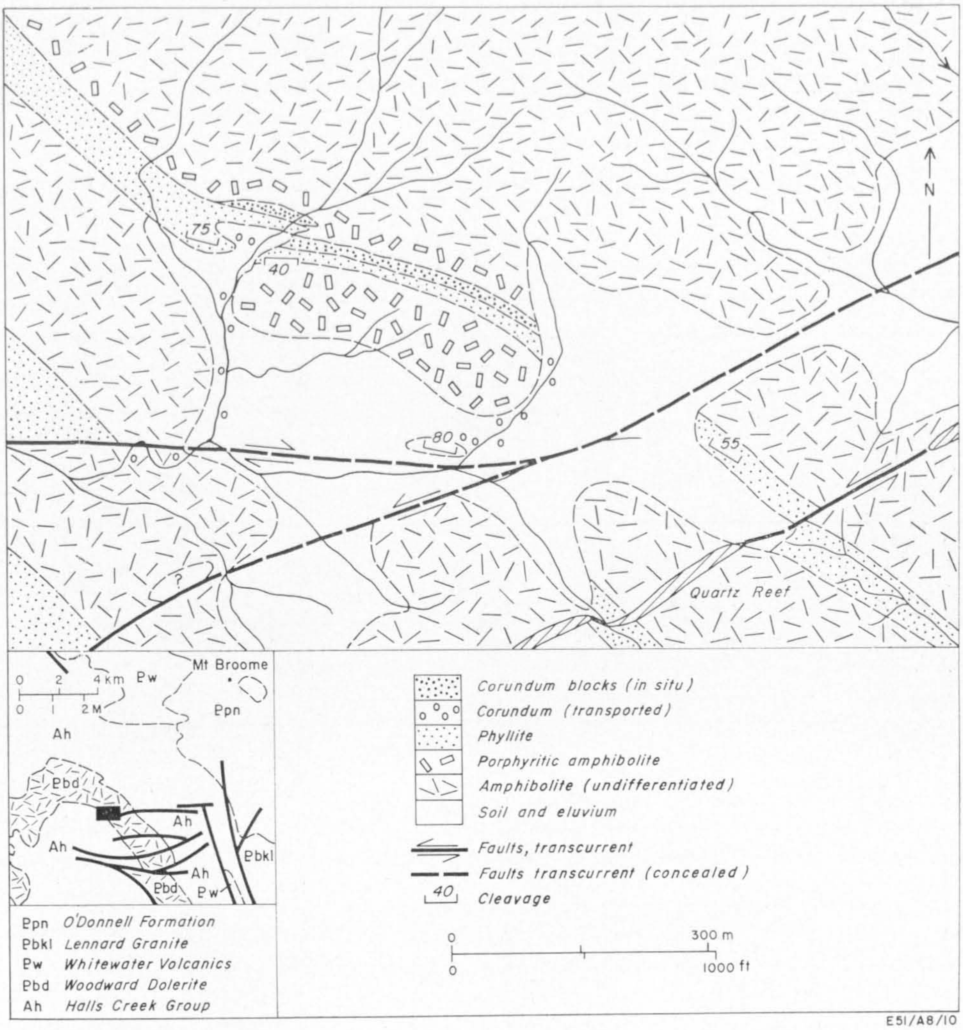


Fig. 23. Geological sketch map of Richenda River corundum deposit.

In its geological setting at the lower contact of a sill of Woodward Dolerite with low-grade Halls Creek Group phyllite, the Richenda corundum deposits are similar to the Hawkstone Creek kyanite deposits (Derrick & Morgan, 1966). The mineral assemblages are similar (corundum, diaspore, and kyanite), the only significant difference being in the relative proportions of the minerals present. Because of the very low metamorphic grade of the country rocks it is probable that intrusion of the Woodward Dolerite has played a prominent part in the genesis of both deposits, but they do not appear to be the products of simple contact metamorphism.

Tin

Tin has been reported from two areas near Dyasons Creek by Finucane (1939). Both occur near the northern margin of a major granite intrusion (Fig. 24) about 16 and 18 km respectively east of McSherrys Gap. The eastern deposit is a pegmatite dyke in medium-grained leucocratic granite (Dyasons Granite). Finucane (1939) recorded values of 0.09% SnO_2 over a length of 100 m and an average width of 350 mm. The western deposit consists of tin-bearing gravels in a small creek valley on the north side of Waggon Flat. Finucane reported 734 cubic yards of wash containing 0.12 lb SnO_2 per cubic yard.

TABLE 10. MODAL COMPOSITIONS OF CORUNDUM-BEARING ROCKS

	1	*2*	*3*	*4*
Locality	1	1	3	1
Reference	Simpson 1920	Stillwell 1942	Stillwell 1942	Scott 1966
Corundum	31.2	ca. 80	△	95
Diaspore	53.9	ca. 20	×	×
Margarite	—	—	—	×
Kyanite	6.9	×	—	—
Sillimanite	—	—	×	—
Calcite	—	—	×	—
Grossularite	2.4	—	—	—
Rutile	0.2	×	×	×
Ilmenite	4.9	—	—	—
Iron oxides	—	×	×	—
Carbon	0.5	—	—	—
Grainsize (mm)		0.2 to 0.5	0.015 —0.045	0.65
Remarks	Hard and sharp	angular grains	usable as fine abrasive	—

△ major constituent
× minor constituent

These two deposits examined by Finucane are of no economic significance, and sand samples collected from tributaries of Dyasons Creek to the southwest of the alluvial deposit failed to indicate any further mineralization. Maximum tin concentration found in the stream sediment samples was 8 ppm. There seems little likelihood of economic deposits in this area.

Mica

A pegmatite dyke about 10 km northeast of Napier Downs homestead and 2 km southeast of Kongorow Pool on the Barker River has been mined previously for sheet muscovite. The deposit, known as 'Gussy's Mica Deposit' and also as 'Kongarrah' or 'Barker Gorge' Mica Mine, was last worked (as P.As 47 and 49) during 1943 to 1944, but the production was not reported. The pegmatite lies close to the contact of the Halls Creek Group with a coarse-grained porphyritic biotite granite (Kongorow Granite) of the Lamboo Complex. The deposit has been described by Finucane & Jones (1939), Simpson (1952), Harms (1959), and Sofoulis (1967). It could yield a small quantity of high-grade muscovite.

Harms (1959) recorded abundant muscovite up to 75 mm by 75 mm in pegmatite from the Mount Joseph area and suggested further prospecting for larger sheets.

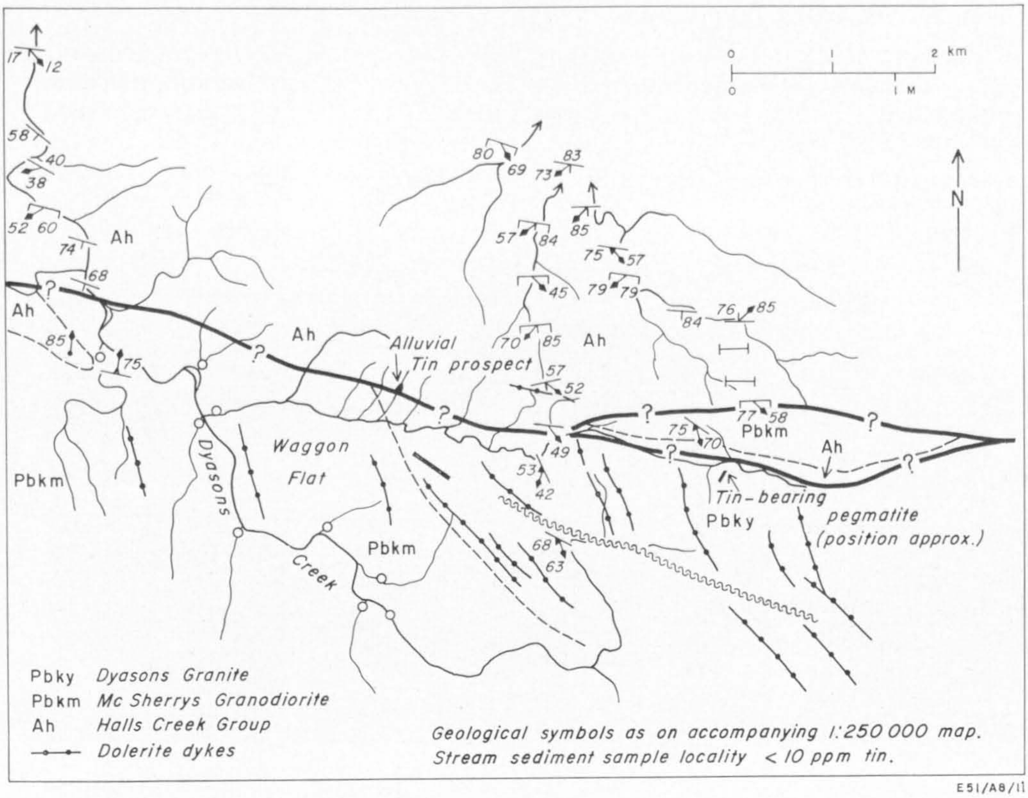


Fig. 24. Geological sketch map, Dyasons Creek area.

Beryl

Small crystals of beryl were noted in the dumps at Gussy's Mica Deposit, and it is possible that some of the 1960-61 beryl production reported from the West Kimberley area was derived from this source.

Pyrite

Minor pyrite mineralization occurs in quartz veins cutting sheared Whitewater Volcanics about 5 km east of Christmas Bore. The pyrite forms small cubic crystals up to 1.5 cm edge, which are scattered through the veins and the adjacent volcanics. The quartz veins also contain chlorite aggregates and fragments of serpentinized phyllonite. In most cases the pyrite is pseudomorphed by hematite, which also occurs as specularite flakes.

Miscellaneous

Barite has been recorded by Harms from Mount Amy. The metamorphic minerals garnet, staurolite, chiastolite, and kyanite are moderately abundant in the Richenda River area and near the Van Emmerick Range, and some material of gem or lapidary quality could be present. The leucite lamproites contain 10 to 12 percent potash, but this could not be economically extracted. However, some lapidary use could be made of opaline silica and mossy chalcedony which are associated with the lamproites. Feldspar is abundant in the area, but not in economic concentrations.

During field mapping, all specimens collected were examined under short-wave ultra-violet light as a guide to mineralization. The few specimens that showed anomalous fluorescence were analysed spectrographically for Sn, W, Mo, Cu, Pb, and Zn. Slightly anomalous lead values were noted in most specimens and slightly anomalous tin values were found in some specimens from the Yampi Sheet area (Sofoulis et al., 1971). Results for specimens from the Lennard River area are given in Table 11.

TABLE 11. SPECTROGRAPHIC ANALYSES OF GRANITIC ROCKS*

Field No.	*Co-ordinates*	*Sn*	*W*	*Mo*	*Cu*	*Pb*	*Zn*
LR 5-88-7	2898E, 28273N	3	—20	3	5	100	20
LR 5-86-8a	2828E, 28238N	4	—20	3	3	150	20
LR 11-59-23b	3435E, 27789N	2	—20	3	20	250	—20
LR 13-47-5a	3820E, 27615N	4	—20	2	5	70	—20

* A.M.D.L. Rep. 2598/67

— indicates 'less than'

Construction materials

Road Metal is quarried from the Devonian reef complex about 15 km west of Leopold Downs near the point where the access road from the Great Northern Highway to Leopold Downs passes through the Devonian limestone hills. The limestone quarry is operated by Australian Blue Metals Limited which has a mobile crushing unit at the site. The quarry face is about 35 m wide and 10 m deep and the quarry floor rises to surface level about 50 m from the quarry face.

The quarried material consists of thin banded, jointed, and blocky crystalline limestone in blocks up to 2 m by 1 m by 1 m. This material is crushed and sized and used as road metal in bitumen-sealing operations on the Derby/Fitzroy Crossing road.

Smaller quarries established along formed roads intermittently supply laterite, river sand, colluvial soil, gravel, limestone, granite, porphyry, and dolerite for road surfacing, road maintenance, and culvert construction.

Water supply

Rainfall in the Lennard River Sheet area ranges from 500 mm in the south to 700 mm in the north. It is mainly confined to the period November to April. Potential annual evaporation is about 2500 mm.

The Fitzroy, Isdell, Barker, and Lennard Rivers constitute the main drainage systems in the area.

The area is divided into four hydrological divisions: Kimberley Plateau, Lennard Hills, Fitzroy Plains, and Fitzroy Ranges. The water supply of the Kimberley Plateau, an elevated region of Proterozoic Kimberley Group rocks in the northwest, has been discussed by Allen (1966). That of the Fitzroy Plains and

Fitzroy Ranges has been described by Guppy et al. (1958), Playford & Lowry (1967), and further notes were given by Farbridge (1967). The Lennard Hills division consists of metasediments of the Halls Creek Group, extrusive Whitewater Volcanics, and intrusive acid porphyries and granitic rocks of the Lamboo Complex.

The alluviated main channels of the Barker, Lennard, and Fitzroy Rivers contain isolated semi-permanent waterholes, and rockholes in the river beds usually contain permanent water. Numerous soaks of water with less than 100 ppm (total dissolved solids) are found at the bases of granitic domes, apparently where eluvium overlies sheet or exfoliation joints.

Fourteen unsuccessful and seven successful bores are known within the Lennard Hills division. The latter derive water from weathered metamorphic sandstone, from granite weathering profiles and from thick sections of alluvium. Unweathered rocks are not expected to contain groundwater except in joint and fracture partings.

In most producing bores only small supplies (less than 10 000 gpd) of low salinity water (300 to 500 ppm total dissolved solids) are obtained; depths seldom exceed 30 m. Available drawdown in these bores is small, and they may become dry during a prolonged drought.

A line of springs occurs on the flanks of the Oscar Plateau, where Devonian limestone overlies weathered metasedimentary rocks. Reliable supplies have been obtained both from basal Devonian sediments and from metamorphic sandstone.

REFERENCES

ALLEN, A. D., 1966—The hydrogeology of the Kimberley Plateau. *Geol. Surv. W. Aust. Rec.* 1966/16 (unpubl.).

BARROW, G., 1893—On an intrusion of muscovite-biotite gneiss in the southeastern Highlands of Scotland, and its accompanying metamorphism. *Quart. J. geol. Soc. London,* 49, 330.

BENNETT, R. B., & GELLATLY, D. C., 1970—Rb-Sr age determinations of some rocks from the West Kimberley region, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1970/20 (unpubl.).

BERLIAT, K., 1953—Report on water supply on Kimberley cattle stations. *Geol. Surv. W. Aust. ann. Rep.* 1951.

BLAKE, D. H., ELWELL, R. W. D., GIBSON, I. L., SKELHORN, R. R., & WALKER, G. P. O., 1965—Some relationships resulting from the intimate association of acid and basic magmas. *Quart. J. geol. Soc. London,* 121, 31-49.

BLATCHFORD, T., 1929—Precambrian in Western Australia. *Geol. Surv. W. Aust. ann. Rep.,* 88.

BOFINGER, V. M., 1967—Geochronology in the East Kimberley region, Western Australia. *ANZAAS, Abs. Vol.* 110-11.

BRANCH, C. D., 1966—Volcanic cauldrons, ring complexes and associated granite of the Georgetown Inlier, Queensland. *Bur. Miner. Resour. Aust. Bull.* 76.

BROCKMAN, F. S., & CROSSLANDS, C., 1901—Report on the exploration of the North-west Kimberley. *Perth, Govt. Printer.*

CARROL, D. C., 1945—Census of West Australian minerals. *W. Aust. Mines Dep., Miner. Resour. Bull.,* 1-4.

DERRICK, G. M., & GELLATLY, D. C., 1969—New leucite lamproite from the West Kimberley, Western Australia. *Bur. Miner. Resour. Aust. Bull.* 125.

DERRICK, G. M., & GELLATLY, D. C., 1971—The Precambrian geology of the Oscar Range Inlier, Lennard River 1:250 000 Sheet area SE/51-8, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1971/61 (unpubl.).

DERRICK, G. M., GELLATLY, D. C., HALLIGAN, R., & SOFOULIS, J., 1969—The geology of the Charnley 1:250 000 Sheet area SE/51-4, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1969/13 (unpubl.).

DERRICK, G. M., & MORGAN, C. M., 1966—The Hawkstone Creek kyanite deposit. *Bur. Miner. Resour. Aust. Rec.* 1966/221 (unpubl.).

DOW, D. B., & GEMUTS, I. V., 1969—Geology of the Kimberley region, Western Australia: The East Kimberley. *Bur. Miner. Resour. Aust. Bull.* 106.

DOW, D. B., GEMUTS, I. V., PLUMB, K. A., & DUNNET, D., 1964—The geology of the Ord River region, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1964/104 (unpubl.).

DUNN, P. R., PLUMB, K. A., & ROBERTS, H. G., 1966—A proposal for time-stratigraphic subdivision of the Australian Precambrian. *J. geol. Soc. Aust.,* 13(2), 593-608.

DUNNET, D., & PLUMB, K. A. P., 1964—Explanatory notes on the Lissadell 1:250 000 Geological Sheet SE/52-2, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1964/70 (unpubl.).

EASTON, W. R., 1922—Report on the North Kimberley district of Western Australia. *W. Aust. Dep. North-West. Publ.* 3. *Perth, Govt Printer.*

EDWARDS, A. B., 1943—Some basalts from the north Kimberley, Western Australia. *J. Roy. Soc. W. Aust.,* 27, 79-94.

ERVIN, G., & OSBORNE, E. G., 1951—The system Al_2O-H_2O. *J. Geol.,* 59, 381.

FARBRIDGE, R. F., 1967—The hydrogeology of the Yampi and Lennard River 1:250 000 Geological Sheets. *Geol. Surv. W. Aust. Rec.* 1967/5 (unpubl.).

FARQUHARSON, R. A., 1920—Petrological determinations. *Geol. Surv. W. Aust. ann. Rep.,* 112.

FINUCANE, K. J., 1938—The Mount Broome area, West Kimberley district. *Aerial geol. geophys. Surv. N. Aust., W. Aust. Rep.* 33.

FINUCANE, K. J., 1939—The Granite Range area, West Kimberley district. *Aerial geol. geophys. Surv. N. Aust., W. Aust. Rep.* 44.

FINUCANE, K. J., 1953—The geological structure of the Kimberley region in relation to mineralization. *In* The geology of Australian ore deposits. *5th Emp. Min. metall. Cong.*, 1, 271-5.

FINUCANE, K. J., & JONES, F. H., 1939—The Barker River area, West Kimberley district. *Aerial geol. geophys. Surv. N. Aust., W. Aust. Rep.* 43.

FITZGERALD, W. V., 1907—Reports on portions of the Kimberleys (1905-6). *W. Aust. parl. Pap.* 6.

FITZPATRICK, E. A., & ARNOLD, J. A., 1964—Climate of the West Kimberley area. *CSIRO, Land Res. Ser.*, 9, 76.

FLAVELLE, A. J., & GOODSPEED, M. T., 1962—Fitzroy and Canning Basin reconnaissance gravity surveys, Western Australia 1952-60. *Bur. Miner. Resour. Aust. Rec.* 1962/105 (unpubl.).

FORMAN, F. G., 1942—Emery deposits—Richenda River area, Kimberley district. *Geol. Surv. W. Aust. ann. Rep. 1941,* 9.

GELLATLY, D. C., 1961—The geology of the area around Dalan, near Elayu, Erigavo district. *Geol. Surv. Somali Republ. Rep.* DCG/7 (unpubl.).

GELLATLY, D. C., 1970—Textures & genesis of lead-zinc ores from Narlarla, West Kimberley region, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1970/117 (unpubl.).

GELLATLY, D. C., & DERRICK, G. M., 1968—Lansdowne, W.A.—1:250 000 Geological Series. *Bur. Miner. Resour. Aust. explan. Notes* SE/52-5.

GELLATLY, D. C., DERRICK, G. M., & PLUMB, K. A., 1965—The geology of the Lansdowne 1:250 000 Sheet area SE/52-5, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1965/210 (unpubl.).

GELLATLY, D. C., SOFOULIS, J., & DERRICK, G. M., in prep.—The Precambrian Geology of the Kimberley Region, Western Australia: West Kimberley. *Bur. Miner. Resour. Aust. Bull.*

GEMUTS, I. V., 1965—Metamorphism and igneous activity in the Lamboo Complex. East Kimberley area, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1965/242 (unpubl.).

GEMUTS, I. V., 1971—Metamorphic and igneous rocks of the Lamboo Complex, East Kimberley region, Western Australia. *Bur. Miner. Resour. Aust. Bull.* 107.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA 1966—Provisional subdivision of the Precambrian in Western Australia, 1966. *Geol. Surv. W. Aust. ann. Rep.* 1965, 46.

GUPPY, D. J., LINDNER, A. W., RATTIGAN, J. H., & CASEY, J. N., 1958—The geology of the Fitzroy Basin, Western Australia. *Bur. Miner. Resour. Aust. Bull.* 36.

HALLIGAN, R., 1964—The Narlarla lead-zinc deposits, Barker River area, West Kimberley district. *Geol. Surv. W. Aust. Rec.* 1964/34 (unpubl.).

HALLIGAN, R., 1965—The Narlarla lead-zinc deposits, Barker River area, West Kimberley goldfield. *Geol. Surv. W. Aust. ann. Rep.* 1964, 97-9.

HANN, F., 1901—Exploration in Western Australia. *Proc. Roy. Soc. Qld.*, 16.

HARDMAN, E. T., 1884—Report on the geology of the Kimberley district, Western Australia. *W. Aust. parl. Pap.* 31.

HARDMAN, E. T., 1885—Report on the geology of the Kimberley district, Western Australia. *W. Aust. parl. Pap.* 34.

HARKER, A., 1951—METAMORPHISM. London, Methuen.

HARMS, J. E., 1953—Summary report—West Kimberley area: B.H.P. prospecting campaign, Kimberleys, W.A. *Broken Hill Prop. Co. Ltd unpubl. Rep.*

HARMS, J. E., 1959—The geology of the Kimberley Division, Western Australia, and of an adjacent area of the Northern Territory. *M.Sc. Thesis, Adelaide Univ.* (unpubl.).

HARMS, J. E., 1964—Geology of the Kimberley Division, Western Australia. *In* Geology of Australian ore deposits, 2nd Edn. *8th Comm. Min. metall. Cong.*, 1.

HORWITZ, R. C., 1966—Analogies in the Precambrian. *Geol. Surv. W. Aust. ann. Rep. 1965,* 46-8.

HORWITZ, R. C., 1967—Provisional subdivisions of the Precambrian in W.A. *Ibid.*, 1966

HUTTON, G., 1965—The Devonian lead-zinc mine, West Kimberley district. *B.Sc. Thesis, Univ. W.A.* (unpubl.).

JACK, R. L., 1906—The prospects of obtaining artesian water in the Kimberley district. *Geol. Surv. W. Aust. Bull.* 25.

JOHANNSEN, A., 1939—A DESCRIPTIVE PETROGRAPHY OF THE IGNEOUS ROCKS, Vol. 1. *Chicago, Univ. Chicago Press.*

JUTSON, J. T., 1950—The physiography (geomorphology) of Western Australia (3rd Edn). *Geol. Surv. W. Aust. Bull.* 95.

KAPLAN, G., FAURE, D., ELLOY, R., & HEILAMMER, R., 1967—Contribution a l'étude de l'origine des lamproites. *Bull. Centre Rech. PAU-SNPA.*, 1(1), 153-9.

KRAUS, P. S., 1941—Geologic and stratigraphic reconnaissance, northwest portion Caltex Concession 7-H Kimberley Division, Western Australia (with comment by C.St.J. Brunner.). *Unpubl. Rep. for Caltex Oil Co.*

MAITLAND, A. GIBB., 1902—Principal results of the year's field operations—Kimberley. *Geol. Surv. W. Aust. ann. Rep.* 1901, 9.

MAITLAND, A. GIBB., 1903—Mineral map of Western Australia. *W. Aust. Dep. Min. ann. Rep. 1902.*

MAITLAND, A. GIBB., 1907—Recent advances in the knowledge of the geology of Western Australia. *Geol. Surv. W. Aust. Bull.* 26, *Rep.* 7.

MAITLAND, A. GIBB., 1928—The volcanic history of Western Australia. *J. Roy. Soc. W. Aust.,* 13, 79-86.

MAITLAND, A. GIBB., & JACKSON, C. F. V., 1904—The mineral production of Western Australia up to the end of the year 1903. *Geol. Surv. W. Aust. Bull.* 16.

MATHESON, R. S., 1944—Mica. *Geol. Surv. W. Aust., Miner. Resour. Bull.* 2.

MATHESON, R. S., & GUPPY, D. J., 1949—Geological reconnaissance in the Mount Ramsay area, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1949/48 (unpubl.).

MOODY, J., 1966—Crustal shear patterns and orogenesis. *Tectonophysics,* 3(6), 499-522.

PEERS, R., 1966(a)—*Geol. Surv. W. Aust. petrolog. Rep.* 104.

PEERS, R., 1966(b)—*Ibid.,* 114.

PEERS, R., 1966(c)—*Ibid.,* 116.

PEERS, R., 1967—*Ibid.,* 152.

PLAYFORD, P. E., & LOWRY, D. C., 1966—Devonian reef complexes of the Canning Basin, Western Australia. *Geol. Surv. W. Aust. Bull.* 118.

PLUMB, K. A., in prep.—Precambrian geology of the Kimberley region, Western Australia: Kimberley Basin. *Bur. Miner. Resour. Aust. Bull.*

PLUMB, K. A., & DERRICK, G. M., in press—Proterozoic geology of the Kimberley to Mount Isa region. *In* Economic Geology of Australia and Papua New Guinea. *Proc. Aust. Inst. Min. Metall.*

PRIDER, R. T., 1941—Hydrozincite from Narlarla, West Kimberleys, Western Australia. *Miner. Mag.,* 26(173), 60-5.

PRIDER, R. T., 1945—Igneous activity, metamorphism and ore formation in Western Australia. *J. Proc. Roy. Soc. W. Aust.,* 39, 44-84.

PRIDER, R. T., 1960—The leucite lamproites of the Fitzroy Basin, Western Australia. *J. geol. Soc. Aust.,* 6(2), 71-118.

PRIDER, R. T., 1965—Noonkanbahite, a potassic batisite from the lamproites of Western Australia. *Miner. Mag.,* 34 (Tilley Vol.), 403-5.

QUILTY, J. H., 1960—Canning Basin aeromagnetic reconnaissance survey, W.A. 1954. *Bur. Miner. Resour. Aust. Rec.* 1960/11 (unpubl.).

RATTE, J. C., & STEVEN, T. A., 1967—Ash flows and related volcanic rocks associated with the Creede Caldera, San Juan Mountains, Colorado. *U.S. geol. Surv. prof. Pap.* 524-H.

ROBERTS, H. G., HALLIGAN, R., & GEMUTS, I. V., 1965—The geology of the Mount Ramsay 1:250 000 Sheet area SE/52-9, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1965/156 (unpubl.).

ROBERTS, H. G., HALLIGAN, R., & PLAYFORD, P. E., 1968—Mount Ramsay, W.A.—1:250 000 Geological Series. *Bur. Miner. Resour. Aust. explan. Notes.* SE/52-9.

ROSE, R. L., 1957—Andalusite and corundum-bearing pegmatites in Yosemite National Park, California. *Amer. Mineral,* 42, 635.

ROSS, C. S., & SMITH, R. L., 1961—Ash flows: their origin, geologic relations and identification. *U.S. geol. Surv. prof. Pap.* 366.

RUKER, R. A., 1961—The Saunders Creek radioactive prospect, Halls Creek district. *Bur. Miner. Resour. Aust. Rec.* 1961/103 (unpubl.).

RUTHERFORD, G. K., 1964—Soils of the West Kimberley area. *CSIRO Land Res. Ser.,* 9, 119-39.

SCOTT, I. F., 1966—A suite of rocks from the Kimberleys. *Aust. Miner. Devel. Lab. Rep.* MP425-67 (unpubl.).

SIMPSON, E. S., 1939—Mineral provinces and metallogenetic epochs in W.A. *J. Proc. Roy. Soc. W. Aust.,* 25, 204-37.

SIMPSON, E. S., 1919—Emery, Richenda River. *Geol. Surv. W. Aust. ann. Rep.* 1918.

SIMPSON, E. S., 1920—Emery, Richenda River. *Ibid.,* 1919, 109-10.

SIMPSON, E. S., 1951—MINERALS OF WESTERN AUSTRALIA, Vol. 2. *Perth, Govt Printer.*

SIMPSON, E. S., 1952—Minerals of Western Australia. *Perth, Govt Printer,* 3, 263.

SIMPSON, E. S., & GIBSON, C. G., 1907—The distribution and occurrence of the base metals in W.A. *Geol. Surv. W. Aust. Bull.* 30.

SMITH, J. W., 1963—Explanatory notes to accompany Gordon Downs 1:250 000 Sheet SE/52-10, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1963/120 (unpubl.).

SOFOULIS, J., 1967—Mica deposits of the West Kimberley area, Western Australia. *Geol. Surv. W. Aust. ann. Rep. 1966.*

SOFOULIS, J., GELLATLY, D. C., DERRICK, G. M., FARBRIDGE, R. A., & MORGAN, C. M., 1971—The geology of the Yampi 1:250 000 Sheet area, SE/51-3 Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1971/1 (unpubl.).

SPECK, N. H., BRADLEY, J., LAZARIDES, M., PATERSON, R. A., SLATYER, R. O., STEWART, G. A., & TWIDALE, C. R., 1960—The lands and pastoral resources of the North Kimberley area, W.A. *CSIRO Land Res. Ser.,* 4.

SPECK, N. H., & LAZARIDES, M., 1964—Vegetation and pastures of the West Kimberley area. *CSIRO Land Res. Ser.,* 9, 140-74.

SPECK, N. H., WRIGHT, R. L., & RUTHERFORD, G. K., 1964—Land systems of the West Kimberley area. *CSIRO Land Res. Ser.,* 9, 24-5.

STILLWELL, F., 1942—Micro-textures of some Australian corundum and emery. *CSIRO mineragr Rep.* 259.

TEICHERT, C., 1941—Observations on the stratigraphy and palaeontology of the Devonian in the country between the Oscar Range and Bugle Gap, West Kimberley Division, W.A. *Caltex (Aust.) Oil Devel. Pty Ltd* (unpubl. rep.).

THOMAS, F., 1964—The pastoral industries of the West Kimberley area. *CSIRO Land Res. Ser.,* 9, 192.

TRAVES, D. M., 1955—The geology of the Ord-Victoria region, Northern Australia. *Bur. Miner. Resour. Aust. Bull.* 27.

TRENDALL, A. F., 1967—*Geol. Surv. W. Aust. petrolog. Rep.* 134.

TRENDALL, A. F., 1966—Towards rationalism in Precambrian stratigraphy. *J. geol. Soc. Aust.,* 13(2), 517-26.

TURNER, F. J., & VERHOOGEN, J., 1960—IGNEOUS AND METAMORPHIC PETROLOGY. *N.Y., McGraw-Hill.*

VANCE, J. A., 1960—Origin of zoning in some igneous plagioclase (abs.). *Bull. geol. Soc. Amer.,* 71(2), 2081.

VEEVERS, J. J., 1958—Lennard River—4-mile Geological Series. *Bur. Miner. Resour. Aust. explan. Notes* SE/51-8.

VEEVERS, J. J., & WELLS, A. T., 1961—The geology of the Canning Basin. *Bur. Miner. Resour. Aust. Bull.* 60.

WADE, A., 1924—Petroleum prospects Kimberley district and Northern Territory. *W. Aust. parl. Pap.* 142.

WADE, A., 1936—The geology of the West Kimberley district of W.A. *Freney Kimberley Oil Co. N.L.* unpubl. Rep.

WADE, A., & PRIDER, R. T., 1940—Leucite-bearing rocks of the West Kimberley. *Quart. J. geol. Soc. London,* 96, 39-98.

WAGER, L. R., & DEER, W. A., 1939—The petrology of the Skaergaard intrusion Kangerdlugssuaq, East Greenland. *Medd. on Gronland,* 105(4).

WELLMAN, P., 1972—Early Miocene potassium argon age for the Fitzroy lamproites of Western Australia. *J. geol. Soc. Aust.* 19(4), 471-4.

WILSON, G., 1938—The evolution of the granodioritic rocks of the south eastern end of the Kopaonik Batholith, Yugoslavia. *Geol. Mag.,* 75, 193.

WINCHELL, A. N., & WINCHELL, H., 1951—ELEMENTS OF OPTICAL MINERALOGY. *N.Y., Wiley.*

WOODALL, R., 1957—The copper prospects of the Little Tarraji area, West Kimberley, Western Australia. *Western Mining Corp. Ltd Rep.* K1112 (unpubl.).

WOODWARD, H. P., 1907—Mineral discoveries at Narlarla in the West Kimberley district. *Geol. Surv. W. Aust. ann. Rep. 1906.*

WOODWARD, H. P., 1908—Boring for artesian water, West Kimberley. *Min. Dep. W. Aust. ann. Rep. 1907.*

APPENDIX I

Name of unit	*WOMBARELLA QUARTZ-GABBRO*
Sheet area	Lennard River 1:250 000.
Derivation of name	From Wombarella Creek, a tributary of the Barker River, Lennard River Sheet area.
Lithology	Biotite and orthopyroxene-bearing quartz gabbro, quartz norite; also biotite-hornblende-pyroxene-bearing tonalite and porphyritic microtonalite.
Distribution	In the Lennard River Sheet area, near Stumpys Jumpup, and 3 km south of Wombarella yard. The quartz-gabbro mass lies to the southwest of the Jumpup and the main tonalite outcrop to the east and southeast of it.
Topography	The quartz-gabbro forms a small range of hills with elliptical concentric ridges; the tonalite forms low-lying hummocky areas.
Reference areas	3 km southwest of Stumpys Jumpup (quartz-gabbro—2710E, 28348N), 5 km east-southeast of Stumpys Jumpup (tonalite—2783E, 28358N).
Mode of occurrence	The quartz-gabbro forms a small layered lopolith, elliptical in outcrop, approximately 5 km by 3 km. The tonalite forms a small intrusion to the east, whose form is unknown.
Relations	The quartz-gabbro and the tonalite show evidence of two-magma relationships and are contemporaneous. Quartz-gabbro is metamorphosed locally to garnet grade. Xenoliths of quartz-gabbro occur in Kongorow and Lennard Granites which thus postdate the quartz-gabbro. The tonalite is cut by numerous aplopegmatite dykes.
Distinguishing features	The basic to intermediate nature of these rocks and the presence of orthopyroxene distinguish them from other igneous rocks of the West Kimberley.
Petrological affinities	Similar to the Little Gold River Porphyry in the Lansdowne Sheet area. No other related rocks are known in the area.
Age	Proterozoic.

Name of unit	*KONGOROW GRANITE*
Sheet area	Lennard River and Yampi 1:250 000.
Derivation of name	From Kongorow Pool on Barker River, 11 km northeast of Napier Downs homestead.
Lithology	A foliated grey-black (mottled) porphyritic biotite-rich granite. Discrete tabular feldspar phenocrysts mostly 1 to 5 cm across, usually microcline or orthoclase with lesser amounts of plagioclase (often sericitized) are characteristic. Parallel arrangement of feldspar and biotite is common and gives the rock a gneissic appearance. Locally has xenoliths and remnant gneissic bands.

Distribution	Scattered outcrops in a broad belt between Mount Joseph and Hawkstone Creek. Rare in southeastern part of the Lennard River Sheet area.
Topography	Rounded whalebacks and prominent stocks. Relief to 75 m. Main masses form elongate bodies parallel to regional west-northwest trend. Also as rough stony hills and low rock pavements interspersed with areas of sandy soils. Drainage subsequent and controlled by joints and foliation trends.
Reference area	In the Lennard River Sheet area, 15 km east-southeast of Stumpys Jumpup (2870E, 28280N).
Mode of occurrence	Main outcrop is a complex plutonic mass probably intrusive into Halls Creek Group sediments. Its outcrop is elongate parallel to the trend of the King Leopold Mobile Zone, and about 15 km across. Elsewhere the Kongorow Granite occurs mainly as dykes and veins.
Relations	Locally intrudes Lennard and Chaneys Granites and Wombarella Quartz-Gabbro. Parts of Kongorow Granite probably antedate these. Intrusive into Halls Creek Group as large masses and as small discrete bodies. Intruded by quartz, aplite, tourmaline-pegmatite, and quartz dolerite dykes.
Distinguishing features	The prominent biotite development and tabular shape of the feldspar phenocrysts distinguish the Kongorow Granite from other porphyritic granites of the Lamboo Complex. Mesocratic and leucocratic gneissic bands locally present within the granite may represent metasomatized Halls Creek Group remnants.
Age	Proterozoic.

Name of unit	*RICHENDA MICROGRANODIORITE*
Sheet area	Lennard River 1:250 000.
Derivation of name	From the Richenda River in the Lennard River 1:250 000 Sheet area.
Lithology	Medium-grained grey generally nonporphyritic biotite microgranodiorite; minor biotite-hornblende microgranodiorite and microtonalite. Average grainsize is about 0.5 mm. Consists of abundant small strongly zoned euhedral plagioclases with subsidiary quartz, microcline, and biotite.
Distribution	The principal exposures are in the Richenda River area near Blackhill yard and about 8 km west of Richenda Gorge in the Lennard River Sheet area; also small outcrops about 3 km northeast of Parderoo Pool in the Yampi Sheet area.

Topography	The Richenda Microgranodiorite forms prominent serrated hills with localized areas of black vegetation-free boulder scree.
Reference area	Richenda River area, 2 km northeast of Blackhill yard, about 125°15′E, 17°28′S.
Mode of occurrence	In the Richenda River area the microgranodiorite occurs as small intrusive stocks cutting Halls Creek Group metasediments. Near Parderoo Pool (Yampi Sheet area) it occurs as a gently dipping sheet surrounded by Mondooma Granite and Lennard Granite.
Relations	The Richenda Microgranodiorite cuts Halls Creek Group rocks and is itself intruded by dykes and a cone sheet of rhyolite. Relations with other types are uncertain, but it probably postdates Mondooma Granite and McSherrys Granite.
Distinguishing features	The medium-grained nonporphyritic texture and moderately dark grey colour distinguish this from all other granite rocks of the West Kimberley area.
Petrological affinities	None recognized in the West Kimberley. It may possibly be related to the Violet Valley Tonalite of the East Kimberley.
Age	Proterozoic.

Name of unit	*McSHERRYS GRANODIORITE*
Sheet area	Lennard River 1:250 000.
Derivation of name	From McSherrys Gap near the centre of the Lennard River Sheet area (2960E, 27920N).
Lithology	Grey medium to coarse porphyritic to even-grained hornblende granodiorite, tonalite, minor adamellite and quartz gabbro.
Distribution	As southeast-trending plutons in the central southeastern and far northwestern parts of the Lennard River Sheet area; southwest corner of Charnley Sheet area, and southeast corner of Yampi Sheet area near the Robinson River headwaters.
Topography	Low soil-covered rises and small dark boulder-strewn hills and knobs.
Reference areas	1. Headwaters of Dyasons Creek, Lennard River Sheet area (3170E, 27880N). 2. Near Mount Hill, Lennard River Sheet area (3510E, 27580N).
Mode of occurrence	Occurs as large and small stocks generally enclosed by other granites. Small pod-like forms not uncommon.

Relations	Possibly intruded by Chaneys and Lennard Granites, though some contacts gradational. Intruded by Mondooma Porphyry in Yampi Sheet area, and by aplite dykes at all localities. Intrudes Halls Creek Group and Whitewater Volcanics.
Distinguishing features	Generally highly mesocratic; small dark granodioritic and granitic xenoliths common. Abundant aplite dykes characteristic. In thin section, tonalitic composition, plagioclase alteration and presence of actinolite-biotite clots are distinctive.
Petrological affinities	Probably equivalent in part to the Lerida Granite in the Lansdowne and southeastern Lennard River Sheet areas. The compositional range within this mass, the sharp to gradational contacts with other rock types, the presence of pale green amphibole, and the abundance of xenoliths suggests that this mass is a product of contamination. Quartz gabbro is developed only near contacts with the Halls Creek Group. Near Hill C70, all gradations between Bickleys Porphyry and McSherrys Granodiorite have been observed on a small scale.
Age	Proterozoic.

Name of unit	*LENNARD GRANITE*
Sheet area	Lennard River and Yampi 1:250 000.
Derivation of name	From the Lennard River which crosses outcrops of the Lennard Granite.
Lithology	A coarse-grained grey leucocratic porphyritic quartz-feldspar-biotite granite with abundant euhedral to subhedral equant potassic feldspar porphyroblasts commonly 2 to 3 cm across. The granite is commonly xenolithic and sometimes foliated and gneissic. Marginal muscovitic phases are present locally.
Distribution	Extensively distributed in the Lennard River Sheet area to the northwest of the Lennard River; sporadic outcrops in the southwestern part of the Charnley Sheet area; extensive in the southeastern part of the Yampi Sheet area, and as far west as Mount Nellie.
Topography	Rounded whalebacks and prominent hills. Relief up to 90 m. Main masses usually as elongate ridges parallel to regional northwest structural trend. Also as low rock pavements and as rough low stony hills interspersed with sandy pediments. Dissection and drainage locally controlled by prominent joints.
Reference area	In the Lennard River Sheet area, 11 km east-southeast of Stumpys Jumpup (2840E, 28380N).
Mode of occurrence	As plutonic intrusions up to 25 km across; outcrops are generally elongate parallel to the trend of the King Leopold Mobile zone.

Relations	Intrusive into Halls Creek Group and Whitewater Volcanics. Intruded by Secure Bay Granite, Kongorow Granite, and Wombarella Quartz-Gabbro; possibly also by Mount Amy Granite. Intruded by quartz, aplite, tourmaline-bearing pegmatite, and by quartz dolerite dykes. Overlain unconformably by Kimberley Group in Yampi Sheet area.
Distinguishing features	The large phenocryst size, the equant shape and abundance of the phenocrysts, and the relatively low biotite content are distinctive.
Petrological affinities	Probably related to the Secure Bay Granite. The Lennard Granite is possibly equivalent to parts of the Bow River Granite of the East Kimberley.
Age	Proterozoic.

Name of unit	*DYASONS GRANITE*
Sheet area	Lennard River 1:250 000. From Dyasons Creek near the centre of the Lennard River Sheet area.
Lithology	Leucocratic medium to fine, even-grained granite with abundant mesocratic schlieren.
Distribution	Crops out in a narrow east-trending belt east of Dyasons Creek, and in isolated localities near the headwaters of Hooper Creek.
Topography	Broad irregular whalebacks and rounded bouldery hills.
Reference area	7 miles (11 km) east of Dyasons Creek (3230E, 27890N).
Mode of occurrence	Elongate stocks, dykes.
Relations	Intruded by dolerite dykes and Mount Amy Granite, and intrudes McSherrys Granodiorite.
Distinguishing features	Leucocratic nature and grainsize.
Petrological affinities	Possibly aplitic derivatives of McSherrys Granodiorite.
Age	Proterozoic.

Proposed name	*MOUNT AMY GRANITE*
Sheet area	Lennard River 1:250 000.
Derivation of name	From Mount Amy (2700E, 28402N) which is close to exposures of Mount Amy Granite.
Lithology	A grey-pink nonporphyritic coarse to medium leucocratic biotite granite, commonly aplitic. Generally homogeneous, muscovite bearing, and non-foliated.

Distribution	Scattered outcrops around Mount Amy and Dromedary yard; also about 20 km east of Tunnel Bore, and about 6 km north of Lily Hole yard in the southeastern part of the Lennard River Sheet area.
Topographic features	Low rounded hills, rock pavements. Usually flanked by granites more prominent topographically.
Reference area	8 km northeast of Mount Amy (2760E, 2846N) in the Lennard River Sheet area.
Mode of occurrence	As small intrusive stocks cut locally by numerous endogenetic aplite and pegmatite veins.
Relations	Believed to intrude Lennard and Kongorow Granites and is probably one of the youngest granites of the Lamboo Complex. In the southeastern part of the Lennard River Sheet area it occurs in association with McSherrys Granodiorite and intrudes Whitewater Volcanics.
Distinguishing features	The leucocratic nature and the nonporphyritic aplitic texture are distinctive.
Petrological affinities	Similar to and probably related to the leucocratic Mulkerins Granite of the Lansdowne Sheet area. May be related genetically to McSherrys Granodiorite in the Lennard River Sheet area.
Age	Proterozoic.

Name of unit	*CHANEYS GRANITE*
Lithology	Coarse-grained non-porphyritic grey biotite granite, commonly foliated and locally sheared. Essentially even-grained, and xenolithic in places.
Distribution	In Mount Ramsay 1:250 000 Sheet near, and to the north of Chaneys Yard, and in Lansdowne Sheet mainly north and northwest of Long Hole Bore. Extends into Lennard River Sheet.
Reference area	At Chaneys Yard (18°08′S, 126°14′E) in Mount Ramsay Sheet area.
Derivation of name	Chaneys Yard (above).
Relations	Near Chaneys Yard forms small stocks. Age relations with other granites uncertain, but apparently intrudes Whitewater Volcanics and is apparently earlier than Mulkerins Granite.
Age	?Proterozoic.
Topography	Low rounded 'Whale-back' outcrops with isolated residual tors.
Diagnostic features	The even-grained nature of this rock and the presence of clear pale grey rather than cloudy blue-grey quartz are diagnostic.

Name of unit	*LERIDA GRANITE*
Lithology	Grey to pink-grey porphyritic biotite granite and granodiorite with euhedral phenocrysts of pale green feldspar, quartz, and biotite. Phenocrysts of pale pink feldspar present locally. Phenocrysts are mainly 0.5 to 1 cm, but sporadic phenocrysts up to 3 cm. Fine-grained biotite-rich xenoliths not uncommon.
Distribution	Southwestern part of Lansdowne 1:250 000 Sheet area from Connors Gap to near Bickleys Creek. Extends into Lennard River Sheet area.
Reference area	Lansdowne-Fitzroy Crossing track about 3 miles (4.8 km) south of Lerida Gorge.
Derivation of name	Lerida Gorge 17°54′S, 126°15′E.
Relations	Apparently intrudes Whitewater Volcanics. Overlain unconformably by O'Donnell Formation. Is intruded by Mulkerins Granite.
Age	?Middle Proterozoic.
Topography	Low steep-sided hills with rectilinear drainage pattern. Sandy pediments developed locally.
Diagnostic features	Pale green colour of feldspar phenocrysts is most characteristic. The grain size of the matrix is slightly coarser than that of Bickleys Porphyry, the phenocrysts are larger and quartz is less abundant.

Name of unit	*MOUNT DISASTER PORPHYRY*
Sheet areas	Yampi, Charnley, Lennard River, and Lansdowne 1:250 000.
Derivation of name	From Mount Disaster in the Yampi 1:250 000 Sheet area (2045E, 29040N).
Lithology	Porphyritic biotite microgranite and microgranodiorite with phenocrysts of quartz (up to 1 cm), and plagioclase and perthitic potash feldspar (both up to 3 cm). The matrix is medium-grained (0.05 mm to 0.5 mm) and consists essentially of quartz, plagioclase, potash feldspar, and biotite.
Distribution	Around Mount Disaster (Yampi); in the southwestern part of the Charnley Sheet area; to the northwest of Inglis Gap, and around Ord Gap in the Lennard River Sheet area; in the southwestern part of the Lansdowne Sheet area.
Topography	Mostly prominent hills and tors.
Reference areas	Mount Disaster (2045E, 29040N) in the Yampi Sheet area and around Inglis Gap in the Lennard River Sheet area (3035E, 28450N).

Mode of occurrence	Occurs as high level, possibly stratiform intrusions. Intrusive dykes and veins of Mount Disaster Porphyry are rare.
Relations	Intrudes Halls Creek Group sediments and Whitewater Volcanics. It is in contact with Bickleys Porphyry, McSherrys Tonalite, Lennard Granite, and Secure Bay Granite, but relations with these are uncertain.
Distinguishing features	The large size of the phenocrysts distinguishes the Mount Disaster Porphyry from Bickleys Porphyry. The relatively fine-grained matrix and the presence of large quartz phenocrysts distinguishes it from other granitic rocks of the West Kimberley Area.
Petrological affinities	Appears to be closely related in space and time to the Whitewater Volcanics and to Bickleys Porphyry.
Age	Proterozoic.

APPENDIX II

MEASURED SECTIONS OF WOODWARD DOLERITE

W1. 13 km west-southwest of Mount Broome (3155E, 28100N). Distances paced.

Thickness (m)	*Phyllite* (Halls Creek Group)
65	*Amphibolite;* fine to medium, nonporphyritic
10	*Amphibolite;* fine-grained, porphyritic with 3 to 5 mm feldspar phenocrysts
55	No exposure
220	*Amphibolite;* medium-grained, nonporphyritic
15	*Amphibolite;* coarse-grained, porphyritic with 3 to 6 mm phenocrysts of amphibole, and 15 mm phenocrysts of feldspar
60	*Amphibolite;* coarse-grained, porphyritic with 3 to 5 mm phenocrysts of amphibole: amphibole phenocrysts become coarser upwards
110	*Amphibolite;* fine-grained nonporphyritic amphibolite
55	*Amphibolite;* massive, medium-grained, porphyritic with 6 to 25 mm feldspar phenocrysts: phenocrysts rare near base of layer and increase in abundance upwards; contact with underlying nonporphyritic amphibolite is apparently sharp
90	*Amphibolite;* massive, fine to medium, nonporphyritic
25	*Amphibolite;* massive, medium-grained, porphyritic with rare 5 to 15 mm feldspar phenocrysts
45	*Amphibolite;* massive, medium-grained, porphyritic with scattered 5 to 15 mm feldspar phenocrysts
25	*Amphibolite;* massive, medium-grained, nonporphyritic
70	*Amphibolite;* massive, medium-grained, porphyritic with abundant 5 to 25 mm feldspar phenocrysts
10	*Phyllite;* pale-grey, hornfelsed
10	*Amphibolite;* massive, medium-grained, nonporphyritic
35	*Amphibolite;* massive, medium-grained, porphyritic with 5 to 25 mm feldspar phenocrysts
55	*Amphibolite;* massive, fine to medium, nonporphyritic
20	*Amphibolite;* massive, medium-grained, porphyritic with scattered 5 to 25 mm feldspar phenocrysts.
100	*Amphibolite;* massive, medium-grained, nonporphyritic
95	*Amphibolite;* massive, medium-grained, porphyritic with scattered 5 to 15 mm feldspar phenocrysts
3	*Hornfels;* very fine-grained, dark grey
90	*Phyllite;* grey, biotite-rich, pelitic
8	*Amphibolite;* massive, medium-grained, porphyritic with abundant 3 mm hornblende phenocrysts
20	*Amphibolite;* massive, medium to coarse-grained, porphyritic with abundant 25 to 30 mm feldspar phenocrysts; phenocrysts make up about 50% of the rock
45	*Amphibolite;* massive, medium-grained, nonporphyritic
45	*Amphibolite;* massive, medium-grained, porphyritic with abundant 3 mm hornblende phenocrysts, and scattered phenocrysts and glomeroporphyritic aggregates of plagioclase up to 40 mm
10	*Amphibolite;* massive, medium-grained, porphyritic with 3 mm hornblende phenocrysts
70	*Phyllite;* dark grey, finely cleaved, phyllitic shale

165	*Amphibolite;* massive, coarse-grained, nonporphyritic; contains large (ca. 25 mm) poikilitic feldspars visible in hand specimen; becomes more mafic towards margins
14	*Phyllite*
25	*Amphibolite;* massive, medium-grained, nonporphyritic; contains a pale green amphibole
5	*Amphibolite;* strongly cleaved, phyllitic, biotite bearing, nonporphyritic amphibolite
Total ca. 1660	including phyllite intercalations
	Phyllite; strongly cleaved, fine-grained, semipelitic, bedded sericite phyllite

W2. Measured section of Woodward Dolerite, Richenda River, 5 km west of gorge (3241 E, 28300 N). Distances paced.

Thickness (m)	
	Phyllite; pale grey, hard, flaggy phyllitic siltstone
85	*Amphibolite;* massive, medium-grained, porphyritic, with 5 mm feldspar phenocrysts
310	*Amphibolite;* massive, medium-grained, nonporphyritic
120	*Amphibolite;* massive, medium-grained, porphyritic, with 5 to 15 mm feldspar phenocrysts
125	*Amphibolite;* massive, medium to fine, nonporphyritic
60	*Amphibolite;* massive, medium-grained, porphyritic, with abundant 5 to 25 mm feldspar phenocrysts
100	No exposure
5	*Phyllite;* pale grey fissile, phyllitic shale
5	*Amphibolite;* flaggy, foliated, fine to medium
20	*Amphibolite;* massive, coarse-grained, nonporphyritic
35	*Amphibolite;* massive, coarse-grained, porphyritic, with scattered 5 to 15 mm feldspar phenocrysts
55	*Phyllite;* strongly cleaved, flaggy grey phyllitic siltstone and shale
10	*Amphibolite;* massive, nonporphyritic
20	*Amphibolite;* massive, porphyritic, with rare 25 mm feldspar phenocrysts
5	*Amphibolite;* massive, medium to coarse, nonporphyritic, mafic-rich (ca. 75% hornblende)
10	*Amphibolite;* sheared, flaggy, greyish green
60	*Phyllite;* grey-brown, flaggy to fissile phyllitic siltstone
65	*Amphibolite;* massive, medium to coarse, nonporphyritic, mafic-rich (ca. 75% hornblende)
20	*Amphibolite?;* mainly unexposed; traces of sheared amphibolite
25	*Amphibolite;* massive, medium to coarse, nonporphyritic, mafic-rich (as above)
Total ca. 1130	including phyllite
	Phyllite

W3. Partial measured section of Woodward Dolerite 7 km north-northeast of Blackhill yard (3157E, 28078N). Distances paced.

Thickness (m)	
	Axis of syncline; no further exposures.
55	*Amphibolite;* massive, medium to coarse, porphyritic with 5 to 20 mm phenocrysts of feldspar
25	*Amphibolite;* massive, medium to coarse, porphyritic with 3 mm phenocrysts of hornblende
105	*Phyllite*
10	*Amphibolite;* massive, coarse-grained, porphyritic with 25 mm feldspar phenocrysts; pinches out along strike
85	*Amphibolite;* massive, medium-grained, nonporphyritic
40	*Amphibolite;* massive, coarse-grained, porphyritic, with 25 mm feldspar phenocrysts
20	*Amphibolite;* massive, coarse-grained with 3 mm hornblende phenocrysts
75	*Phyllite* and *quartzite*
115	*Amphibolite;* massive, coarse-grained, nonporphyritic, mafic-rich
Total ca. 530	including phyllite *Phyllite*

W4. Measured section of Woodward Dolerite 4 km west-northwest of Mount Rose (3283E, 27986N). Distances paced.

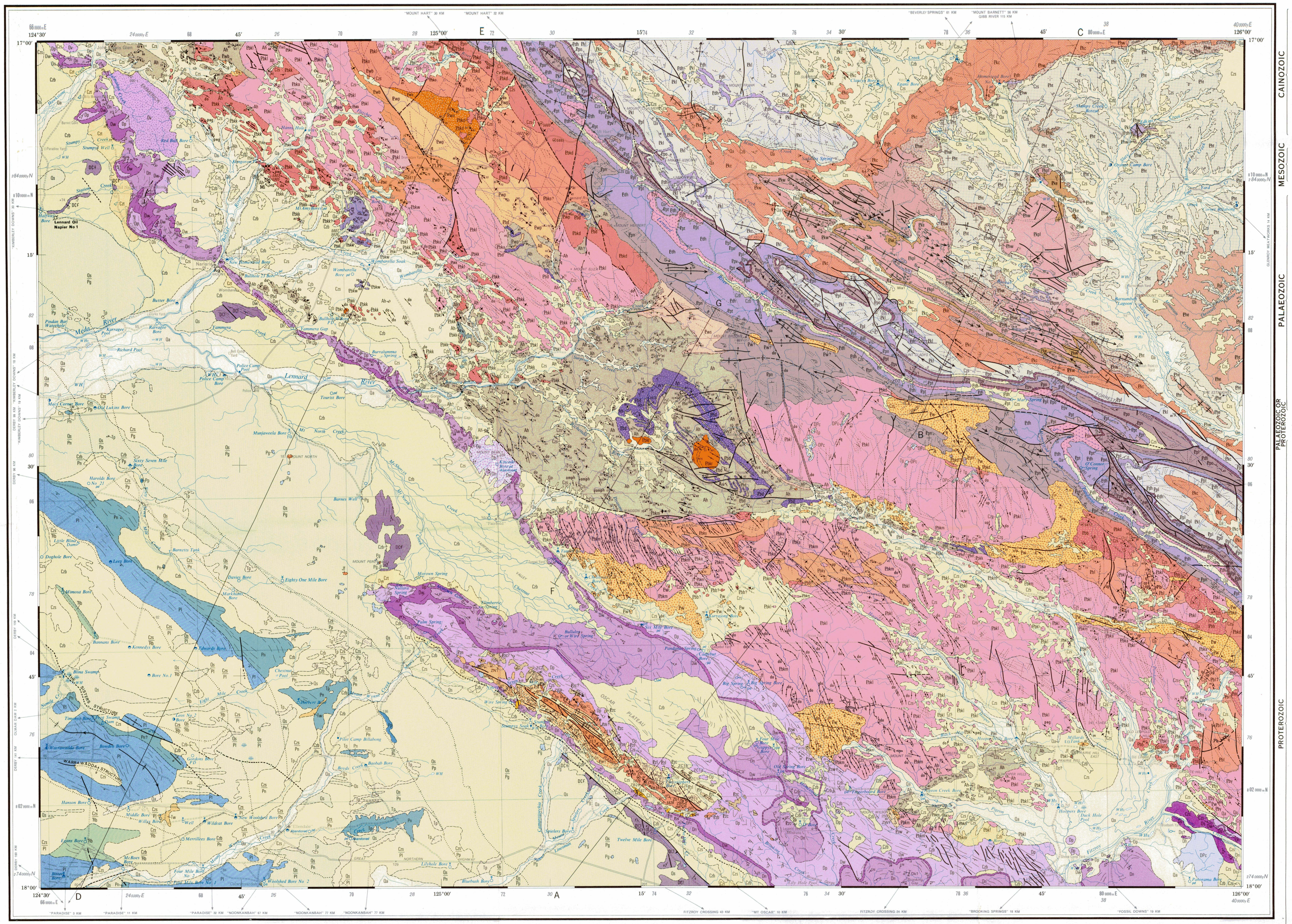
Thickness (m)	
	Phyllite; pelitic sericite phyllite with sporadic psammitic interbeds
15	*Amphibolite;* massive, fine-grained, nonporphyritic
25	*Amphibolite;* massive, fine-grained, porphyritic, with 5 to 15 mm feldspar phenocrysts
120	*Amphibolite;* cleaved, fine-grained, nonporphyritic
5	*Phyllite;* flaggy, dark grey, silty phyllite
135	*Amphibolite;* massive, medium-grained, porphyritic with 5 to 25 mm feldspar phenocrysts
65	*Amphibolite;* cleaved, fine-grained, porphyritic, with very rare 5 mm feldspar phenocrysts
5	*Phyllite;* fine-grained, indurated silty phyllite
35	*Amphibolite;* massive, fine-grained, porphyritic with very rare 5 mm feldspar phenocrysts
1	*Phyllite;* dark grey indurated phyllitic siltstone and shale
115	*Amphibolite;* massive, fine-grained, porphyritic with very rare 5 mm feldspar phenocrysts
35	*Amphibolite;* massive, medium-grained, porphyritic with 5 to 15 mm feldspar phenocrysts
115	*Phyllite;* dark grey, laminated, fissile phyllitic shale; minor white phyllitic acid tuff at base

20	*Amphibolite;* massive, medium to coarse, nonporphyritic
35	*Amphibolite;* massive, medium-grained, porphyritic with 5 to 15 mm feldspar phenocrysts
30	*Amphibolite;* massive, medium-grained, nonporphyritic
15	*Phyllite*
45	*Amphibolite;* massive, medium-grained, porphyritic with abundant 25 mm feldspar phenocrysts; cut by thin discordant acid veins
5	*Amphibolite;* massive, medium-grained, highly mafic, porphyritic with 3 mm hornblende phenocrysts
185	*Phyllite*
45	*Amphibolite;* massive, medium to coarse, nonporphyritic
Total ca. 1020	including phyllite
	Phyllite; pelitic sericite phyllite with thin psammitic interbeds

LENNARD RIVER
WESTERN AUSTRALIA

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

SHEET SE 51-8



Reference

- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Monocline
- Overturned anticline
- Plunge of minor anticline
- Plunge of minor syncline
- Plunge of drag fold
- Plunge of fold axis
- Normal fault, barb on downthrown side
- Fault, attitude unknown (D, U indicate relative movement down, up)
- Transcurrent fault showing relative horizontal movement
- Inclined fault, with dip value
- Shear zone
- Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
- Strike and dip of strata
- Prevailing strike and dip of strata
- Strike and dip of strata with plunge of lineation
- Vertical strata
- Vertical strata with plunge of lineation
- Horizontal strata
- Overturned strata
- Overturned strata, dip unmeasured
- Dip < 5° (air-photo interpretation)
- Dip < 15° (air-photo interpretation)
- Dip 15°-45° (air-photo interpretation)
- Dip > 45° (air-photo interpretation)
- Horizontal strata (air-photo interpretation)
- Trend lines with prevailing dip (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Top of bedding indicated by cleavage and bedding relations
- Top of bedding indicated by graded bedding
- Prevailing dip of strongly deformed strata
- Strike and dip of foliation
- Prevailing strike and dip of foliation
- Vertical foliation
- Strike and dip of foliation with plunge of lineation
- Vertical foliation with plunge of lineation
- Strike and dip of flow-foliation
- Prevailing Strike and dip of flow-foliation
- Strike and dip of cleavage
- Prevailing strike and dip of cleavage
- Strike and dip of cleavage and strata coincident
- Strike and dip of cleavage with plunge of lineation
- Strike and dip of cleavage and strata coincident, with plunge of lineation
- Strike and dip of cleavage and overturned strata
- Vertical cleavage
- Plunge of lineation
- Strike and dip of joints
- Prevailing strike and dip of joints
- Vertical joint
- Glacial striae, with direction of movement
- Current direction from cross-bedding
- Fossil locality
- Y1 Measured section
- ZL1 Type section locality
- 5617 Sample locality for age determination with reference number
- Dykes ap — aplite, do — dolerite, peg — pegmatite, q — quartz, gr — granite, amph — amphibolite
- Petroleum exploration well — dry, abandoned
- Open cut or quarry
- Open cut or quarry not being worked
- Prospect
- • Pb Minor mineral occurrence

Ag Silver	Mi Mica
Au Gold	Pb Lead
Cu Copper	Rc Crushed rock aggregate
Cn Corundum	Sn Tin
Fe Iron	Zn Zinc
Fl Fluorite	

- Bore
- Abandoned bore
- Bore — salinity < 2500 p p m
- Saline bore — salinity 2500–10000 p p m
- Saline Bore — salinity > 10000
- Sub-artesian bore
- Windpump
- Ope Bore equipped with pump engine
- T Water tank
- E Earth tank or dam
- Dam on stream
- WH Water hole
- WH Water hole on stream
- Spring
- Swamp
- Highway
- Road
- Vehicle track
- Landing ground
- "Fairfield" Homestead
- Yd Yard
- Fence
- Telephone line
- Trigonometrical station
- •140 Height in metres, approximate
- pd Position doubtful

Reference

CAINOZOIC

QUATERNARY
- Qa — Alluvium
- Qs — Windblown sand, residual sand
- Czt — Travertine, tufa (caliche)
- Czb — Residual black soil
- Czs — Sand and sandy soil
- Czg — Sand and gravel

TERTIARY
- Tp — Laterite; pisolitic ironstone, ferruginous sandstone
- Warrimbah Conglomerate — Tw — Poorly consolidated boulder beds

MESOZOIC

JURASSIC
- Fitzroy Lamproite — Jf — Leucite-rich volcanic rocks

TRIASSIC
- Blina Shale — Rb — Grey and brown siltstone, shale and sandy shale exposed; bluish grey shale in bores; marine fauna

PALAEOZOIC

PERMIAN
- KAZANIAN TO TARTARIAN: Liveringa Formation — Pl — Ferruginous, micaceous, silty sandstone and conglomeratic sandstone
- ARTINSKIAN: Noonkanbah Formation — Pn — Shale, siltstone, limestone, intraformational conglomerate
- ARTINSKIAN: Poole Sandstone — Pp — Micaceous silty sandstone and quartz sandstone
- SAKMARIAN: Grant Formation — Pg — Massive aqueoglacial unsorted silty sandstone, conglomeratic sandstone, tillite, siltstone, shale, varved rocks

DEVONIAN & PERMIAN?
- DPc — Boulder, cobble and pebble conglomerate, quartz grit and quartz sandstone

DEVONIAN TO CARBONIFEROUS
- FAMENNIAN TO TOURNAISIAN: Fairfield Formation — DCf — Grey to yellow-brown coquinoid limestone, calcarenite, calcareous sandstone, siltstone and shale

DEVONIAN
- Stony Creek Conglomerate — Ds — Conglomerate: pebbles, cobbles, and boulders of granite, quartz, quartzite, and sheared acid volcanics
- FAMENNIAN TO FRASNIAN: Windjana Limestone — Dw — Reef facies: yellow to white, massive, algal and stromatoporoid limestone, dolomitized in part
- FAMENNIAN TO FRASNIAN: Pillara Limestone — Dp — Back-reef facies: yellow to light grey, bedded, stromatoporoid limestone; birdseye limestone, oolite; calcarenite and calcilutite, minor conglomerate, arkosic sandstone
- FAMENNIAN TO FRASNIAN: Napier Formation — Dn — Fore-reef and inter-reef facies: grey to red calcarenite, calcirudite, and megabreccia, in part sandy and silty
- FRASNIAN? TO GIVETIAN?: Van Emmerick Conglomerate — Dv — Boulder, cobble, and pebble conglomerate with arkose matrix
- FRASNIAN? TO GIVETIAN?: Behn Conglomerate — Db — Boulder, cobble, and pebble conglomerate with arkose matrix

PALAEOZOIC OR PROTEROZOIC

PALAEOZOIC OR ADELAIDEAN
- Spielers Volcanics — Pzs — Porphyritic rhyolite ash-flow tuff

PROTEROZOIC

ADELAIDEAN — Mount House Group (UPPER PROTEROZOIC*)
- Estaughs Formation — Phe — Purplish grey fine ferruginous sandstone and micaceous siltstone; white fine quartz sandstone and micaceous sandstone
- Throssell Shale — Pht — Greyish green shale; buff and greyish green fine sandstone interbeds. Basal reddish brown shale and ferruginous sandstone
- Traine Formation — Pha — Green to brown coarse lithic sandstone; minor sandy dolomite and dolomitic sandstone. Scattered glacial erratics
- Walsh Tillite — Phw — Tillite; pink fine pebbly sandstone, pink to brown dolomite. Minor purplish brown siltstone, algal dolomite

ADELAIDEAN OR CARPENTARIAN — Oscar Range Succession (UNDIFFERENTIATED PROTEROZOIC)
- Ninety Seven Mile Beds — Pzn — White to grey quartzite, cobble and boulder conglomerate, phyllite and phyllitic sandstone, amygdaloidal epidotised tholeiitic basalt, chlorite schist, epidotised quartzite, minor tuff, rhyolite
- Elimberrie Beds — Pzb — Quartz and feldspathic sandstone, cobble and boulder conglomerate, grey phyllitic siltstone, greyish brown limestone, ironstone lenses and chert
- Linesman Beds — Pzl — Greyish green and purplish grey siltstone and shale, buff feldspathic sandstone; minor boulder-beds
- Ellendale Beds — Pze — Greyish green to brown phyllitic sandstone and shale, cobble and boulder conglomerate, sheared feldspathic sandstone and minor siltstone, hematite lenses
- Le Lievre Beds — Pzv — Pale grey quartzite, greyish green and brown phyllite, dark greyish green phyllite, quartz sandstone
- Christopher Beds — Pzc — White to purplish grey quartz sandstone, feldspathic sandstone, grey and reddish brown shale and siltstone, pebble conglomerate, altered basic igneous rocks
- Mount Wilson Beds — Pzw — Grey to white granule sandstone, gritty feldspathic sandstone and arkose; buff, green and white quartz sandstone

CARPENTARIAN (LOWER PROTEROZOIC)
- Hart Dolerite — Pdh — Pinkish grey granophyre; Dark grey and greyish green tholeiitic dolerite

Kimberley Group
- Pentecost Sandstone — Pkpm — Middle: Pink and white quartz sandstone, greyish green micaceous shale and grey fine sandstone; purplish brown sandstone at base; Pkpl — Lower: Purplish brown and white quartz sandstone, buff feldspathic sandstone, minor micaceous siltstone
- Elgee Siltstone — Pke — Reddish brown siltstone and greyish green to reddish brown fine feldspathic sandstone; minor arkose, feldspathic and quartz sandstone, mudstone
- Warton Sandstone — Pkw — White and buff quartz sandstone and feldspathic sandstone; minor hematitic siltstone
- Carson Volcanics — Pkc — Tholeiitic basalt, spilite, amygdaloidal basalt; feldspathic sandstone, arkose, micaceous siltstone and subgreywacke; minor tuffaceous agglomerate
- King Leopold Sandstone — Pkl — White, buff and pale purplish brown medium quartz sandstone; minor coarse sandstone and granule sandstone; Conglomerate

Speewah Group
- Luman Siltstone — Ppl — Purplish brown to grey ferruginous micaceous siltstone and fine sandstone
- Lansdowne Arkose — Ppo — Purplish brown, grey and white quartz sandstone and feldspathic sandstone, purplish grey micaceous siltstone, minor fine arkose
- Valentine Siltstone — Ppv — Grey to green flaggy, laminated siltstone; minor fine feldspathic sandstone interbeds
- Tunganary Formation — Ppt — Buff and pale grey feldspathic sandstone and arkose; grey, brown and green siltstone and phyllite; minor shale and ferruginous quartz sandstone
- O'Donnell Formation — Ppn — Grey, white and purplish brown granule sandstone and coarse quartz sandstone; minor phyllite, siltstone, arkose and pebble conglomerate

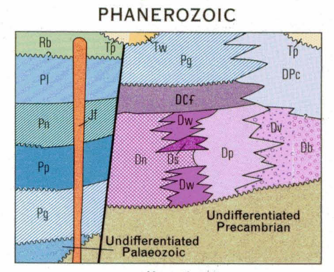
Lamboo Complex
- Mount Amy Granite — Pbka — Grey to pink medium and even-grained biotite granite, muscovite granite, aplite, pegmatite
- Dyasons Granite — Pbky — Leucocratic medium and even-grained grey biotite granite; Gneissic contact zone with xenoliths and net-veining
- Lennard Granite — Pbkl — Leucocratic coarse porphyritic biotite granite; Muscovite granite
- Chaneys Granite — Pby — Leucocratic coarse porphyritic and even-grained biotite granite
- McSherrys Granodiorite — Pbkm — Mesocratic coarse even-grained and porphyritic hornblende granodiorite and tonalite; minor adamellite and quartz gabbro
- Lerida Granite — Pbl — Grey coarse to medium porphyritic granodiorite; minor tonalite
- Mondooma Granite — Pbko — Grey porphyritic microgranite and coarse to medium even-grained granite
- Mount Disaster Porphyry — Pbkd — Coarsely porphyritic pink to grey biotite microgranite and microgranodiorite
- Bickleys Porphyry — Pbb — Grey porphyritic microgranite
- Whitewater Volcanics — Pw — Undifferentiated rhyodacite ash flow tuff, conglomerate, arkose; minor rhyodacite lava; Pwa — Massive crystal-rich rhyodacite ash flow tuff, minor agglomerate; Pwp — Massive crystal-poor rhyodacite ash flow tuff, minor crystal-rich tuff; Pwb — Dacite and minor rhyodacite biotite-rich ash flow tuff; Pws — Bedded rhyodacite tuff; minor tuffaceous siltstone and sandstone; Conglomerate
- Richenda Microgranodiorite — Pbkr — Grey medium and even-grained microgranodiorite, minor hornblende microgranodiorite and microtonalite. Rhyolite cone-sheet
- Kongorow Granite — Pbkk — Coarsely porphyritic grey biotite granite; remnant gneissic bands locally; some granodiorite
- Wombarella Quartz Gabbro — Pbkw — Biotite and orthopyroxene quartz gabbro, quartz norite; Pyroxene tonalite and porphyritic microtonalite
- Woodward Dolerite — Pbd — Dark greyish-green uralitised dolerite, commonly coarsely porphyritic; minor ultramafic patches

ARCHAEAN (ARCHAEAN OR LOWER PROTEROZOIC)
- Halls Creek Group — Ah — Grey phyllitic siltstone and greywacke; chloritoid, andalusite, staurolite, kyanite and garnet-mica schist; Quartz-feldspar-biotite gneiss and migmatite, sillimanite-bearing locally; Greyish blue pebbly sericitic quartz sandstone

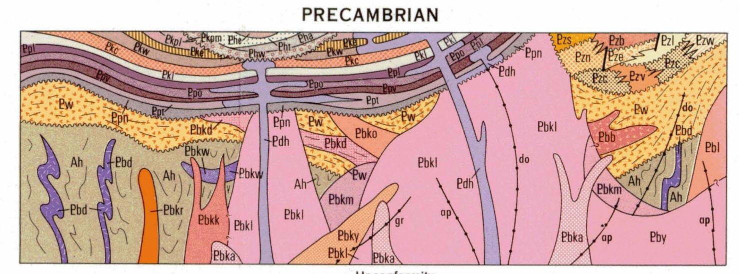
* Subdivisions of the Precambrian time-scale used by the Geological Survey of Western Australia shown in grey

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

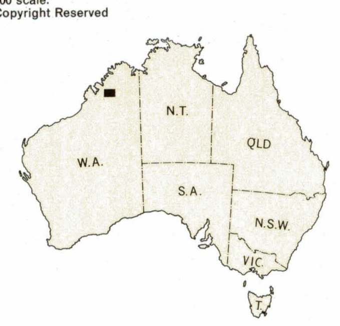
PHANEROZOIC



PRECAMBRIAN



Published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Western Australia. Issued under the authority of the Hon. R. W. Swartz, M.B.E., E.D., Minister for National Development. Base map compiled by the Royal Australian Survey Corps from aerial photography at 1:50,000 scale.



INDEX TO ADJOINING SHEETS
Showing Magnetic Declination 1970

	CAMDEN SOUND SD 51-15	PRINCE REGENT SD 51-16	ASHTON SD 52-13	CAMBRIDGE GULF SD 52-14
PENDER SE 51-2	YAMPI SE 51-3	CHARNLEY SE 51-4	MOUNT ELIZABETH SE 52-1	LISSADELL SE 52-2
BROOME SE 51-6	DERBY SE 51-7	LENNARD RIVER SE 51-8	LANSDOWNE SE 52-5	DIXON RANGE SE 52-6
LA GRANGE SE 51-10	MOUNT ANDERSON SE 51-11	NOONKANBAH SE 51-12	MOUNT RAMSAY SE 52-9	GORDON DOWNS SE 52-10
MUNRO SE 51-14	McLARTY HILLS SE 51-15	CROSSLAND SE 51-16	MOUNT BANNERMAN SE 52-13	BILLILUNA SE 52-14

ANNUAL CHANGE 0°55'W

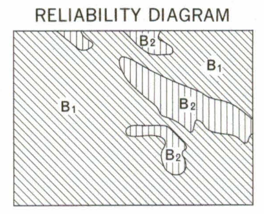
Scale 1:250,000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

GREY NUMBERED LINES ARE 20,000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 51
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20,000 YARD GRID, ZONE 3 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

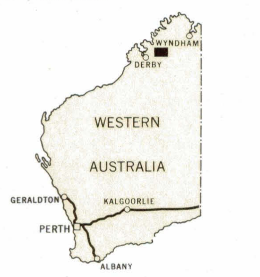
RELIABILITY DIAGRAM



B_1 Detailed reconnaissance: numerous traverses, and air-photo interpretation

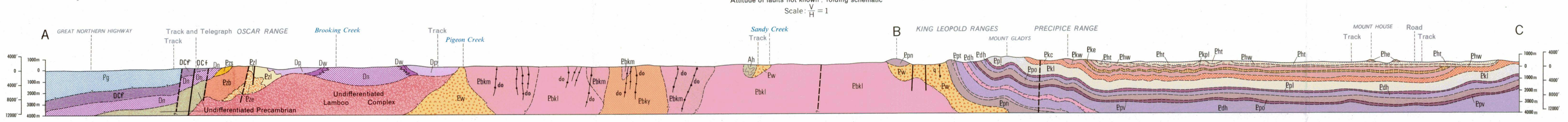
B_2 General reconnaissance: some traverses, and air-photo interpretation

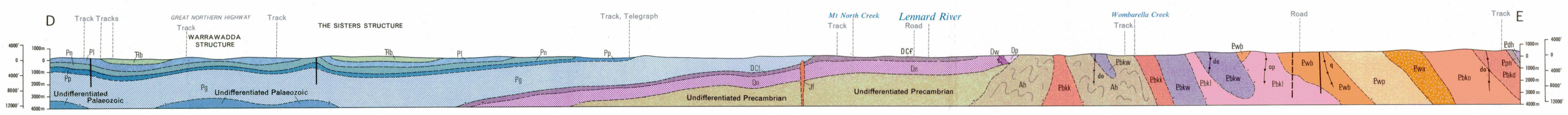
Geology 1948–1952 by D. J. Guppy, A. W. Linder, J. H. Rattigan, J. N. Casey, J. O. Cuthbert, A. B. Clarke
1962–1964 by P. E. Playford, D. C. Lowry (G.S.W.A.)
1966–1967 by D. C. Gellatly, G. M. Derrick, K. A. Plumb, C. M. Morgan (B.M.R.), J. Sofoulis, R. A. Farbridge, A. D. Allen, R. Halligan (G.S.W.A.)
Compiled 1967 by G. M. Derrick, D. C. Gellatly
Drawn by Mercury-Walch Pty. Ltd. Hobart
Printed by Mercury-Walch Pty. Ltd. Hobart

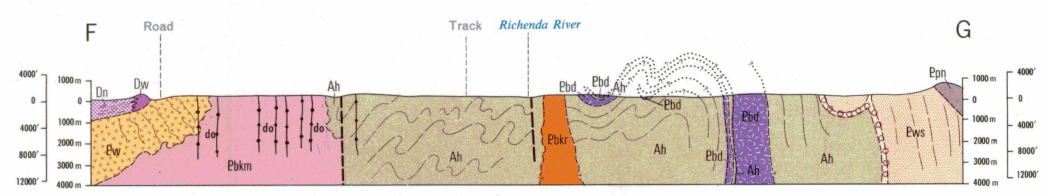


Sections

Cainozoic sediments omitted
Attitude of faults not known : folding schematic
Scale: $\frac{V}{H} = 1$







SECOND EDITION 1971

LENNARD RIVER
SHEET SE 51-8

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or the Geological Survey of Western Australia, Perth.