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The Older Precambrian Geology of the Lennard River 1:250,000 Sheet Area SE 51-8, Western Australia

by

D.C. Gellatly, J. Sofoulis, G.M. Derrick, and C.M. Morgan*
(Geological Survey of Western Australia)*

THE OLDER PRECAMBRIAN GEOLOGY OF THE LENNARD RIVER 1:250,000 SHEET AREA, SE 51-8, WESTERN AUSTRALIA

by

D.C. Gellatly, J. Sofoulis,[1] G.M. Derrick, and C.M. Morgan

([1]Geological Survey of Western Australia)

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SUMMARY

The Lennard River Sheet area lies in the West Kimberley Division in the northern part of Western Australia. The older Pre-cambrian rocks of the Sheet area, 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 have been intruded in pre-Carpentarian times by the Woodward Dolerite and the Wombarella Quartz Gabbro,(both of which have been metamorphosed along 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. These later granites comprise the porphyritic Lennard Granite, and 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.

Strong folding along northeast, southeast and northwest plunging axes has affected the area; several periods of folding are represented. 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 pre-dates 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 intermittently comprise gold, mica, and corundum. Minor amounts of galena, cassiterite, stibnite, and copper minerals have also been reported from the older Precambrian rocks. Water from surface pools, shallow bores, and wells is used for watering cattle.

INTRODUCTION

Location

The Lennard River 1:250,000 Sheet area, SE51-8, lies between latitudes 17° and 18° south and longitudes 124°30' and 126° east. It falls within the Kimberley Land Division of the northern part of Western Australia. The southeastern and north-western corners of the Sheet area are 160 miles and 60 miles, respectively, from the port of Derby.

Object

The work described in this report is part of a programme of regional reconnaissance mapping at a scale of 1:250,000 carried out jointly by the Geological Survey of Western Australia and the Bureau of Mineral Resources, and designed to map all the Precambrian rocks of the Kimberley region. Since the programme commenced in 1962, the following Sheet areas have been mapped: Montague Sound, Drysdale-Londonderry, Medusa Banks, Prince Regent-Camden Sound, Ashton, Cambridge Gulf, Mount Elizabeth, Lissadell, Lansdowne, Dixon Range, Mount Ramsay, 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 treated in this report. The remaining Precambrian rocks of the Lennard River Sheet area, those of the Oscar Range, and those of the Kimberley Basin will be described in a further report (Gellatly and Derrick, in prep.).

The results of the mapping programme will be published in four Bulletins describing the "Precambrian Geology of the Kimberley Region"; Bulletin 106, East Kimberley (Dow and Gemuts, ~~1968~~ in prep); Bulletin 107, Lamboo Complex (Gemuts, ~~1968~~ in prep); Kimberley Basin (Plumb, in prep.); and West Kimberley (Gellatly, Sofoulis, and Derrick, in prep.). In addition, Explanatory Notes describing briefly the geology of each 1:250,000 Sheet area will be published.

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

Access

Access to the Sheet area from the port of Derby is provided by two main roads: a formed earth and gravel road that leads, by way of Yammera Gap and Inglis Gap, to Mount House Station in the northeastern corner of the Sheet area, and extends eastwards for 30 miles to Glenroy Station in the Lansdowne Sheet area; and the Derby-Fitzroy Crossing section of the Great Northern Highway, which gives access to the southern part of the Sheet area. This section of the Highway is now mostly sealed.

Napier Downs homestead, in the northwestern part of the Sheet area, and Mount House homestead, are 80 and 140 road miles from Derby, respectively.

Access within the area is provided by numerous graded station tracks, and by minor subsidiary tracks that radiate from the homesteads to yards and watering points. These tracks are particularly numerous in the southwestern corner of the Sheet area.

All roads are likely to be impassable at times during the wet season. This applies particularly to station tracks.

Mount House and Leopold Downs Stations are serviced fortnightly by a local DC-3 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 25 miles 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, 3 miles southwest of Mount Gladys, is inhabited only intermittently. The total 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 lies within a region which has semi-arid monsoonal climate, with sharply defined "wet" and "dry" seasons. The area lies mostly between the 20 inch and 30 inch rainfall isohyets, which trend approximately east-west. Rainfall recorded in the Sheet area ranges from an annual average of 14 inches at Fairfield Station to 27 inches at Napier Downs. Most of the rain falls during the period December to March, but sporadic rains also occur 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, 13 inches of rain were recorded in 11 hours from such 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 45° to 65° F, and maxima from 75° to 95° F. Relative humidity is low. During the wet summer months minimum temperatures are near 75° and maximum Temperatures 90° to 100° F, with high relative humidity. November is generally the hottest month, and July the coldest. Further detailed information is available in Fitzpatrick and Arnold (1964).

Vegetation and Pasture

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

In general the tree growth decreases from the north to the south of the area and reflects the rainfall distribution. The tree layer is open; snappy gum (E. brevifolia) is ubiquitous, together with abundant annual sorghum grasses and spinifex. 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 (E. papuana), paper-bark, smaller species of bauhinia and acacia, and a rich assortment of tall perennial grasses.

Present investigation

Geological mapping was carried out by five geologists - the four authors and R.A. Farbridge.* 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 air photographs and maps were used;

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

* W.A. Geological Survey

PREVIOUS WORK

The Palaeozoic geology of the region has been described by Guppy, Lindner, Rattigan, and Casey (1958), and Playford and Lowry (1960). The Precambrian has been described only very briefly by Guppy et al., (1958). The Precambrian of the Lennard River Sheet area is included also in Harms' (1959) unpublished comprehensive work on the geology of the Kimberley Division. 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 the presence of "Cambro-Silurian" granite near Mount Amy, near the Barker River, and andalusite and garnet schists along the south-western 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 them to be 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 also 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 from the Sheet area; these 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 were also collected by Wade, and were reported on by Wade and Prider (1939), 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 the Caltex Oil Company. Teichert spoke of rapid subsidence of the Precambrian in pre-Devonian times. Kraus recorded the presence of 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). These rocks were collected by Fitzgerald (1907) and by geologists Maitland and Gibson, who were attached to the surveying party of Brockman and 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' report is after Easton (1922).

The first comprehensive account of the geology of the basement complex and the overlying Kimberley Group sediments was given by Harms (1953, 1959). He redefined the sedimentary succession of Guppy et al., (1958), defined the Elgee Siltstone and Pentecost Sandstone, renamed the Hart Basalt the Hart Dolerite, 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 and Wells (1961). The report on regional geography and physiography of the Kimberley region by Jutson (1950) has been supplemented by more detailed reports of the CSIRO (Speck et al., 1960, 1964). Gravity and aeromagnetic reconnaissance surveys of the Fitzroy-Canning Basin by the Bureau of Mineral Resources show the distribution and broad physiography of the basement complex beneath the Palaeozoic cover (Quilty, 1960; Flavelle and 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 differ 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 a tin occurrence near the Lennard River headwaters. These were described later by Maitland and 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 and 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 and 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 on 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 and Jones, 1939). This mica deposit also received attention from Matheson (1944), Simpson (1952), Harms (1953, 1959) and, most recently, Sofoulis (1967). Harms (1959) also reported on minor showings of lead and copper elsewhere in the Sheet area.

During the 1950's a prospecting lease was held by the Western Mining Corporation over much of the Yampi basement area, extending to the Barker River, but no mineral deposits or showings are indicated on the company's map of this area (Woodall, 1957). A geochemical survey of the West Kimberley basement complex by Pickands Mather International is nearing completion, but results are not yet 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 south-west of the Oscar Range by Berliat (1953). Further hydrological work has been undertaken during the present survey.

PHYSIOGRAPHY

Introduction

The landforms of the Lennard River Sheet area are grouped together into four physiographic provinces comprising a total of thirteen subprovinces (Fig. 1). Of the four provinces, two, namely 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.

Of the thirteen subprovinces, only three, 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 and Gemuts, in prep; Plumb, in prep; Gellatly, Sofoulis, and 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 locally by sandy pediments.

Elevation ranges from about 300 feet to over 1000 feet; local relief is about 500 feet. The tops of most hills appear to coincide with a dissected gently sloping surface which ranges from 1000 feet above sea-level immediately south of the King Leopold Range to about 800 feet near the Fitzroy Ranges. Residuals of flat-lying lateritised grits and conglomerate southwest and south of Millie Windie Gap are probably 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".

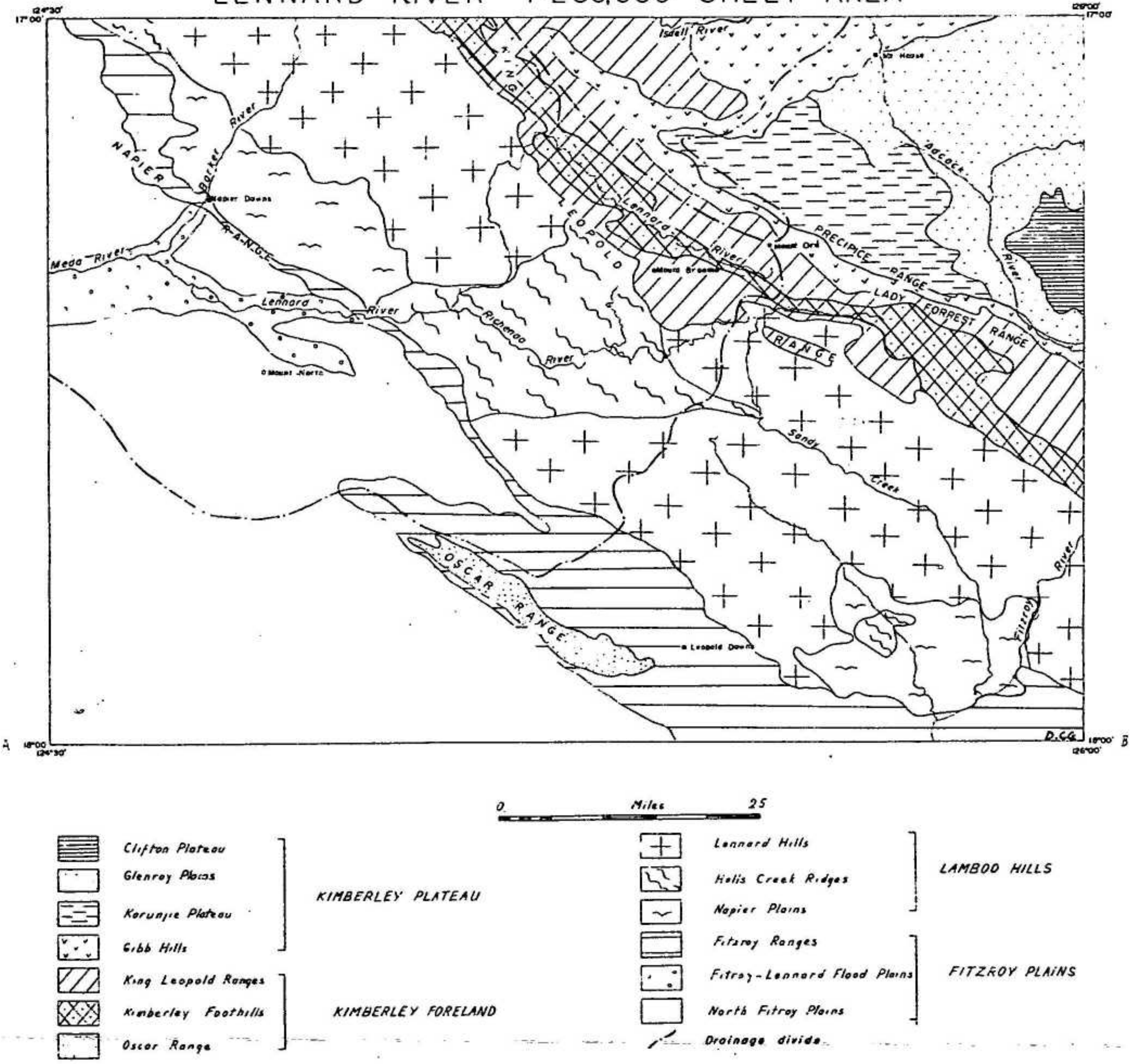
The Halls Creek Ridges consist of hummocky rounded hills and ridges of easily eroded shale, phyllite, and schist. This subprovince is best developed in the Hooper Hills and the Richenda River valley. The hummocky topography (Fig. 2b) is produced by active side-wall gullying of discontinuous, poorly-developed 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 850 feet to about 1000 feet near the King Leopold Range. Relief is generally from 50 to 200 feet.

The Napier Plains are best developed immediately north-east of the Napier Range, and along the Fitzroy River, in the south-east of the Sheet area. The Plains consist of a broad expanse of black and sandy soil, and are underlain chiefly by older Precambrian rocks which 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 etc., deposited by the major rivers in the area, the Barker, the Lennard, and the 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.

FIGURE I

PHYSIOGRAPHIC MAP

LENNARD RIVER 1:250,000 SHEET AREA



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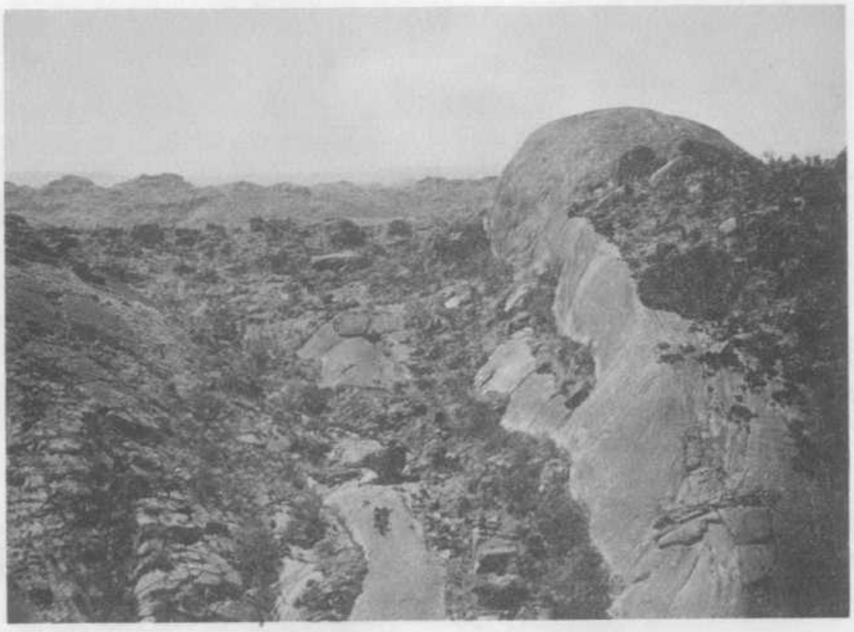

Fig. 2(a). Lennard Hills. Whalebacks of Lennard Granite, 12 miles east of Big Spring Bore. GMD

Fig. 2(b). Halls Creek Ridges. Aerial view showing typical hummocky topography; six miles southeast of Blackhill Yard. DCG

Kimberley Plateau Province

This province contains four sub-provinces.

The Clifton Plateau is an extensive mesa, about 1700 feet above sea-level, formed by resistant sandstone of the Mount House Group. The Plateau is about 400 feet 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 lesser amounts of 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 alternation 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 3000 feet above sea level (e.g., Mount Broome, Mount Ord), and relief is up to 1000 feet.

The Kimberley Foothills are intimately associated with the King Leopold Ranges and are characterised by hogback-and-valley topography. Many of the valleys are underlain by sills of Hart Dolerite. The Oscar Ranges show similar hogback development (Fig. 3b). Maximum elevations, of 800-1000 feet are similar to those in the Lamboo Hills. Relief is up to 400 feet.

Fitzroy Plains Province

The Fitzroy Ranges subprovince consists of Devonian rocks, which form broken karst topography with intervening circles of black soil, and massive continuous walls of limestone which rise 100 to 200 feet above the North Fitzroy Plains. These plains are mostly broad and gently undulating sandy areas covered with thick "pindan" scrub and lateritic ironstone. The Fitzroy-Lennard Flood Plains are broad tracts of alluvium up to 40 feet thick bordering the Fitzroy and Lennard Rivers.

Drainage:

Three major river systems lie within the Sheet area. These are the Fitzroy, the Isdell, and the Meda, together with its tributaries, the Barker and the Lennard. The catchment areas of these are about 3800, 350, and 2800 square miles, respectively.

The divides of these river systems radiate from Mount Ord, the highest point in the area (see Fig. 1). The north-western 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 north-eastwards across almost featureless plains of the Kimberley Plateau. The divide between the Meda and Fitzroy catchments trends irregularly south-westwards and westwards, cutting across both the geological structure and the various physiographic subprovinces, demonstrating the lack of geological control of drainage in the south-western 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 south-west the rivers are slightly aggrading, with broad alluvial flood plains.

The pattern suggests that the drainage in the south-western 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 recognised 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 the three major rivers are generally subsequent, and are controlled by whaleback, fault, joint, and foliation trends, which are predominantly north-west. 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 north-east and south-west 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.

INTRODUCTION TO STRATIGRAPHY

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 isotopic age determinations (Bofinger, 1967) of correlative rocks of the East Kimberley. About 50 specimens of igneous and metamorphic rocks have been collected from the West Kimberley for isotopic age determination. Work on these started only recently, and results are not yet available.

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 recognised in the West Kimberley are a continuation of those described from the East Kimberley (Dow et al., 1964; Dow and Gemuts, in prep; Gemuts, in prep.). The nomenclature of most of the intrusives of the East Kimberley, however, 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., in prep.). The stratigraphy of the older Precambrian rocks is summarised 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 times by the Woodward Dolerite and the Wombarella Quartz Gabbro, both of which have been metamorphosed along 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.

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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 IN FEET	LITHOLOGY	PHYSIOGRAPHIC EXPRESSION	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
CAINOZOIC	QUATERNARY		Alluvium	Qa		River silt, sand and gravel	River banks and flood plains. Gullying common	Along all creeks; particularly in the Lennard, Barker and Fitzroy River and Sandy Creek valleys.		
CAINOZOIC	UNDIFFERENTIATED CAINOZOIC		Travertine (Caliche)	Czt	Superficial		Platforms and low ridges	On western Napier Range and north-west of Oscar Range at Morown Yard and Palm Spring		Developed on Devonian calcareous formations.
			Residual black soil	Czb		Dark grey heavy textured, clayey soil with well developed cracks when dry	Large to small treeless plains. Rough surface due to shallow depressions and tussocks of grass. Local relief 1-2 feet.	Widespread; Fairfield Valley, parts of Oscar Plateau, near Mimosa and Anderson's Bores, east and west of Napier Downs, west of Mount House	Superficial deposits	Typically developed over calcareous formations, Carson Volcanics and Hart Dolerite: also locally over areas with deep soil development
			Other residual soils	Czs		Red-brown to yellow sandy soils. Contain abundant quartz pebbles when overlying granite	Slightly undulating scrub covers plains	Throughout the area. Very extensive in the south-west.		
			Boulder Gravels	Czg		Sand, and well rounded boulders and cobbles of quartz sandstone	River terraces up to 50 feet above present river beds.	Between Millie-Windie gap and Sandy Creek. Limited occurrence.	Overlie Lennard Granite.	Probably equivalent to Warrimbah Conglomerate.
	TERTIARY		Pisolitic Ironstone	Tp	2 to 6 feet	Ferruginous sandstone, and ferruginous pisolites and nodules with rock fragments in sandy ferruginous matrix.	Thin capping over former peneplained land surface in southwest of Sheet area, and over flat topped granite hills south of Millie Windie Gap.	Scattered outcrops of pisolitic ironstone from Lennard River to Calwynyardah H.S. and of ferruginous sandstone between Millie Windie Gap and Sandy Creek.		Used extensively in the south-west for constructing formed roads.
					UNCONFORMITY					
MESOZOIC	JURASSIC		Fitzroy Lamproite	Jf		Massive leucite lamproite and agglomerate, volcanic ash, and pipe flow-breccia. Chalcedony coatings common.	Mount North is a prominent hill; most others form low outcrops.	Mount North, Mount Percy, 81-mile, Old Leopold Hill, Prairie Hill East, McKinrick Hill, Mount 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 Mount North, Old Leopold and Prairie Hill East.
PALAEOZOIC	DEVONIAN TO PERMIAN		Unnamed Sandstones	D-Pc		Cobble and boulder conglomerate, quartz grit and quartz sandstone	Small mesas	One to ten miles south of King Leopold Ranges between Millie Windie Gap and Richenda Gorge	Unconformable on Lennard Granite. Capped by lateritic pisolitic ironstone.	

Carboniferous, Permian and Triassic described by Guppy et al., (1958); Devonian by Playford and Lowrie (1967); Kimberley Group by Plumb (in prep.); Oscar Range succession by Gellatly and Derrick (in prep.)

UNCONFORMITY

ERA	PERIOD	GROUP	ROCK UNIT	MAP SYMBOL	THICKNESS IN FEET	LITHOLOGY	PHYSIOGRAPHIC EXPRESSION	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
PROTEROZOIC		LAMBOO COMPLEX	Mount Amy Granite	Ᵽbka		Grey-pink non-porphyritic coarse to medium-grained leucocratic biotite granite, commonly aplitic. Generally homogeneous, and muscovite-bearing.	Low rounded hills and rock pavements	Scattered outcrops around Mount Amy, Dromedary Yard, 12 miles east of Tunnel Bore, 4 miles north of Lily Hole Yard	Intrudes Whitewater Volcanics. Probably intrudes Lennard and Kongorow granites.	Locally associated with McSherry's Granodiorite
			Dyason's Granite	Ᵽbky		Leucocratic medium to fine-grained, even-grained biotite granite, with abundant mesocratic schlieren	Broad irregular whalebacks and rounded bouldery hills	Narrow east-trending belt east of Dyason's Creek and isolated patches near the headwaters of Hooper's Creek.	Intrudes McSherry's Granodiorite and Lennard Granite. Is intruded by Mount Amy Granite.	
			Lennard Granite	Ᵽbkl		Grey leucocratic coarse-grained porphyritic biotite granite. Abundant large tabular feldspar phenocrysts are characteristic. Marginal muscovitic phases are present locally. Non-porphyritic in places.	Rounded whalebacks, low rock pavements and rough stony hills	Extensively distributed north-west of the Lennard River, north 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 Chaney's Granite of the Lansdowne area. Similar to parts of Bow River Granite of the East Kimberley.
			Chaney's Granite	Ᵽby		Coarse leucocratic biotite granite, adamellite, or rarely granodiorite. Mostly porphyritic, but becomes less porphyritic towards the south-east.	Rounded whalebacks, low domes and pavements, and rough stony hills	Restricted to small area in the extreme south-east near Granite Hill.	Possibly intrudes Lerida Granite	
			McSherry's Granodiorite	Ᵽbkm		Grey mesocratic medium to coarse-grained 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.	Southeast trending plutons in the central south-eastern and far north-western parts of the Sheet area.	Intrudes Halls Creek Group, Whitewater Volcanics and possibly also Bickleys Porphyry. Intruded by Lennard Granite and Dyason's Granite.	Small dark granodioritic and granitic xenoliths are common. Abundant aplite dykes characteristic.
			Lerida Granite	Ᵽbl		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	Extreme southeast margin of Sheet area.	Intrudes Whitewater Volcanics. Other relationships uncertain.	Mainly granodioritic; compositionally similar to McSherry's Granodiorite.
			Mondooma Granite	Ᵽbko		Pale grey porphyritic biotite granite and microgranite. Contains prominent bipyramidal quartz phenocrysts and 2 to 3 mm feldspar phenocrysts	Variable; rugged rocky hills and low poorly exposed pediplains.	Northwest margin of area, near Duncan River.	Intrudes Mount Disaster Porphyry in Yampi and Charnley; intrudes Whitewater Volcanics, and is intruded by Lennard Granite.	Mostly similar to Bickleys Porphyry, but groundmass coarser-grained.
			Mount Disaster Porphyry	Ᵽbkd		Dark grey to pale pink-grey porphyritic biotite microgranite and microgranodiorite. Contains phenocrysts of quartz, K feldspar and plagioclase. K feldspars characteristically exceed 1 inch in length.	Mostly prominent hills and tors.	Northwest 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 the large size of the phenocrysts.
			Bickleys Porphyry	Ᵽbb		Dark to light grey quartz feldspar porphyry and porphyritic microgranite.	Rounded and moderately rugged boulder strewn hills.	West and southeast of Ord Gap; around Old Leopold Yard.	Intrudes Whitewater Volcanics.	Similar to crystal-rich tuffs of Whitewater Volcanics.

ERA	PERIOD	GROUP,	ROCK UNIT	MAP SYMBOL	THICKNESS IN FEET	LITHOLOGY	PHYSIOGRAPHIC EXPRESSION	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
PROTEROZOIC		LAMBOO COMPLEX	Whitewater Volcanics	Ꝑw		Undifferentiated rhyodacitic ash-flow tuff, greywacke-conglomerate, and arkose; minor rhyodacite lava.	Rugged boulder-strewn hills with dark-toned photo-pattern. Ꝑws has banded appearance due to well developed bedding.	West-northwest of Mount Broome; between McSherry's Gap and Kurrajong Bore; The Twins; between Millie Windie and Diamond Gorge; scattered outcrops along Sandy Creek	Lies unconformably 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 McSherry's Granodiorite	Probably mainly ash-flow tuffs: Ꝑws may contain ash-fall tuffs. Lavas are probably rare. Most of the tuffs are characterized by the presence of crystal fragments. Eutaxitic textures are rarely preserved.
				Ꝑwa	ca.16,000	Massive crystal-rich rhyodacite ash-flow tuff; minor agglomerate				
				Ꝑwp	ca.12,000	Massive crystal-poor rhyodacite ash-flow tuff; minor crystal-rich tuff.				
				Ꝑwb	ca.10,000	Dacitic and minor rhyodacitic biotite-rich ash-flow tuff				
				Ꝑws	ca. 5,000	Bedded rhyodacite tuff; minor tuffaceous siltstone, sandstone, and conglomerate.				
						U N C O N F O R M I T Y				
			Richenda Microgranodiorite	Ꝑbkr		Medium-grained grey, generally non-porphyritic biotite microgranodiorite; minor biotite-hornblende micro-granodiorite and micro-tonalite	Prominent serrated hills with localized areas of black, vegetation-free boulder scree	Near Blackhills Yard and about 5 miles west 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.
			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	Similar to that of Lennard Granite. Main outcrop around Kongorow Pool. Rare in southeastern part of sheet area.	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.
			Wombarella Quartz Gabbro	Ꝑbkw		Biotite and orthopyroxene-bearing quartz gabbro and quartz norite; also biotite-hornblende-pyroxene-bearing tonalite and porphyritic micro-tonalite.	The quartz-gabbro forms a small range of hills with arcuate ridges; the tonalite forms low-lying hummocky areas	The quartz-gabbro lies south-west, and the main tonalite outcrop to the east and southeast of Stumpys Jump Up	The quartz-gabbro and the tonalite show evidence of two-magma relationships; and are contemporaneous. The quartz-gabbro is intruded by Kongorow and Lennard Granites	The tonalite is cut by numerous aplo-pegmatite dykes.
			Woodward Dolerite	Ꝑbd	Up to 5000 feet	Dark green and grey green amphibolitized dolerite; commonly porphyritic with phenocrysts up to 1 inch. Minor altered peridotite.	Forms prominent ridges. Has dark grey smooth-toned photo-pattern	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.
?ARCHAEAN		HALLS CREEK GROUP	Undifferentiated	Ah	Probably 20,000	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	Richenda River - Mount Broome Creek area, Hooper Hills and Hawkestone Creek; scattered outcrops along Sandy Creek and near Lennard River Gorge. Extensive under soil cover between Windjana Gorge and Hawkestone Creek	Intruded by Woodward Dolerite, Kongorow and Lennard Granites, Richenda Microgranodiorite and McSherry's Granodiorite; overlain by Whitewater Volcanics.	Gneisses near Mount Joseph are metasedimentary and locally anatectic; those north of Kurrajong Yard may be sheared granites or granitized sediments.

The extensively developed Whitewater Volcanics, a series of predominantly ash-flow sheets, overlie the Halls Creek Group, unconformably and are intruded by later granitic rocks. These comprise two distinct suites, viz., 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 thus regarded as being of "Lower Proterozoic or Carpentarian" age. Similarly, granites that intrude the Whitewater Volcanics may be assigned the same age.

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 and 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 post-date the Halls Creek Group and pre-date the Kimberley Basin succession.

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

These groupings are based on field relationships, 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

Introduction

The Halls Creek Group is the oldest unit in the Sheet area. It consists of greywacke, shale, siltstone, and minor acid volcanics that 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 and 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 partially subdivided by Ruker (1961) working in the Saunders Creek area near Halls Creek, and was further subdivided by Smith (1963), and Dow et al., (1964) who recognised seven formations. In a revised subdivision of the Group Gemuts (1965) recognised 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 Relationships

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 apparently so, 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 7 miles wide to the northwestern corner of the Sheet area. Minor outcrops are found up to 5 miles southwest of Lennard River Gorge, in the Hooper Hills, and in a narrow belt 20 miles long extending southeast from Mount Rose, along Sandy Creek.

The total area underlain by the Halls Creek Group is about 650 square miles. The thickness exposed probably exceeds 20,000 feet in the Richenda River area. Elsewhere only lesser thicknesses are preserved.

The topography of the Halls Creek Group is a very distinctive hummocky type that results from the easily eroded nature of these 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, and 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 of the roof pendants.

Lithology

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

A generalised 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 air 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 2 to 4 miles east of Mount Rose. This sandstone, about 100 feet thick, consists of scattered pebbles of vein quartz up to 1½ inches in diameter in a poorly-sorted matrix of coarse rounded to sub-angular quartz grains and soft white flaky interstitial sericite (derived from shearing of feldspars?).

TABLE 2 GENERALISED SECTION OF HALLS CREEK GROUP

(Waggon Flat to Richenda Gorge).

Whitewater Volcanics with basal conglomerate

---------------------------Probable unconformity------------------------

Approximate thickness (feet)	Halls Creek Group
4,400	Phyllite: grey sericite phyllite and phyllitic siltstone with thin interbeds of rhyolitic tuff.
700	Woodward Dolerite (ca. 4000 ft) with thin interbeds of phyllite. Total thickness of phyllite ca. 700 feet.
4,000	Phyllite: sericite phyllite and minor greywacke with thin interbeds of porphyritic rhyolite and rhyolitic tuff; intruded by Richenda Microgranodiorite.
2,500 +	Greywacke: massive grey greywacke and minor phyllite and quartzite; thin sills of Woodward Dolerite; intruded by Richenda Microgranodiorite ....Fault (Correlation of beds uncertain)
2,000 to 3,000	Phyllite: grey sericite phyllite and psammitic phyllitic schist with thin marble interbeds. ....Transcurrent fault (Correlation of beds uncertain).
8,000 +	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 16,000 feet but sequence is probably repeated by folding. ....Contact with granite (possibly faulted)

Most of the 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 partially melted, mobilised, and recrystallised 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 50 feet of the contacts.

The metamorphics of the Halls Creek Group are described in more detail in the chapter on metamorphism. The unmetamorphosed and slightly metamorphosed types are described briefly below.

Petrography

Petrographic notes given here are in part summarised from Scott (1966), with modifications.

Typical low grade metamorphics from a locality about 5 miles 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 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; and have 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 1-2 mm phenocrysts of quartz (commonly embayed) and sericitised 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 localised distribution and the presence of tourmaline-bearing granites in the vicinity a metasomatic origin for it cannot be precluded.

Discussion

The monotonous greywacke and siltstone lithology of the Halls Creek Group is typical of a eugeosynclinal sequence. Quartzite and limestone are rare and make up less than 1% of the total sequence. The appearance of acid volcanics near the top of the sequence is also a characteristic feature of geosynclinal deposits. Sedimentary structures, although rarely preserved on account of metamorphism, also point to this type of deposition.

The sandstones near Mount Rose are problematical in that they are found on only one side of a syncline, and near the top of the exposed sequence. Lithologically they resemble the Saunders Creek Formation of the Halls Creek area. If the sandstones of the Mount Rose area are lateral equivalents of the Saunders Creek Formation then there must have been substantial erosion of the Saunders Creek Formation prior to deposition of the younger beds of the Halls Creek Group. Alternatively they could represent a basal sandstone facies of the Olympio Formation. If so, their position, apparently near the top of the Halls Creek Group sequence, would imply rapid thinning of the Group towards this locality, and the presence here, at least temporarily, of a shoreline.

The age of the Halls Creek Group is rather uncertainly given as 2700 m.y., based on Rb/Sr isotopic age determinations on a pegmatite intruding the Group in the East Kimberley (Bofinger, 1967). The metamorphism affecting the Group has been dated at 1960 m.y. in the East Kimberley.

The Whitewater Volcanics are not demonstrably unconformable on the Halls Creek Group in the Lennard River Sheet area, but an apparent unconformity has been noted in the Lansdowne area (Gellatly et al., 1965). The presence of a conglomerate containing cobbles of Woodward Dolerite at the base of the Whitewater Volcanics is indicative of an unconformity, but the time interval represented by any such break is uncertain. On the basis of stratigraphic relationships throughout the Kimberley region, the time interval between the Whitewater Volcanics and the Halls Creek Group would appear to be much less than the 740 m.y. suggested by the age determinations, because, whereever a contact is preserved, the Volcanics rest on the Olympio Formation, the topmost one of the Group, and nowhere on lower horizons. Further isotopic age determinations are needed.

LOWER PROTEROZOIC

WOODWARD DOLERITE

Introduction

The name Woodward Dolerite has been proposed by Gemuts (in prep.) for extensive sills and dykes of amphibolitised basic and ultrabasic rocks that intrude the Halls Creek Group, mainly in the south-eastern part of the Mount Ramsay Sheet area and the western part of the Gordon Downs Sheet area. The reference locality is the Woodward Range in the Mount Ramsay Sheet area.

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

Field Occurrence

Outcrops of the Woodward Dolerite in the Lennard River Sheet area occur principally between the Richenda and Lennard Rivers, and in a narrow belt extending south-eastwards from the Richenda River to Sandy Creek. Scattered outcrops are also present to the west of the Lennard River, a few miles north of Mount Joseph. Outcrops are mainly narrow, and extend for about a mile or more along strike, but the main outcrop, in the Richenda valley, is up to 1½ miles wide, and extends for 30 miles. The total area of outcrop of the Woodward Dolerite is about 40 square miles.

The Woodward Dolerite forms prominent round-topped, bouldery ridges that have an even dark grey tone on air photographs. The ridges are commonly sinuous due 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 800 feet thick are separated from each other by only 100 to 300 feet of sediments. In most other localities only one sill is present.

The sills consist of dark green-grey medium to coarse-grained amphibolitised dolerite. There is a complete gradation from non-porphyritic varieties, through types with sporadic ¼ inch to ½ inch plagioclase phenocrysts to highly porphyritic types in which 1 inch plagioclase phenocrysts make up about 50% of the rock. In one locality near the upper contact of the main sequence in the Richenda area abundant euhedral plagioclase phenocrysts up to 8 inches across 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 amphibolitised dolerite that appears to be more mafic than other sills, but does not contain ultramafic accumulates. Leucocratic pods about 15 feet by 10 feet occur within the dolerite; they 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 2 miles 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 halves of the sills. Plagioclase phenocrysts on the other hand are found partly in layers near the upper contacts of the individual sills, and partly 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.

Contact Relations

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

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

TABLE 3

SECTION OF A SINGLE SILL OF WOODWARD DOLERITE

(For full section see Appendix 2)

Locality 6 miles east-north-east of Blackhill Yard

Approx. Thickness (feet)	Lithology
	Overlain by further sills of amphibolitised dolerite
304	Phyllite: grey biotite-rich pelitic phyllite
27	Amphibolite: dark grey-green massive medium-grained porphyritic amphibolite; abundant 3 mm hornblende phenocrysts
59	Amphibolite: massive, medium to coarse-grained porphyritic amphibolite with abundant 1 inch to 1¼ inch plagioclase phenocrysts; phenocrysts make up about 50% of the rock.
141	Amphibolite: massive, coarse-grained non-porphyritic amphibolite
147	Amphibolite: massive, medium-grained porphyritic amphibolite; containing abundant 3 mm hornblende phenocrysts and scattered phenocrysts and glomeroporphyritic aggregates of plagioclase up to 1½ inches.
30	Amphibolite: massive medium-grained porphyritic amphibolite with 3 mm hornblende phenocrysts
Total 404	
223	Phyllite: dark grey finely cleaved phyllitic shale
	(underlain by sill of amphibolitised dolerite).

Fig. 3(a) Porphyritic Woodward Dolerite with 1½ inch plagioclase phenocrysts near top of second lowest sill 2 miles north-northeast of Blackhills Yard.
DCG

Fig. 3(b) Woodward Dolerite with six-inch plagioclase phenocrysts. The porphyritic rocks form thin concordant lenses near the upper contact of the topmost sill; 4½ miles north of Blackhills Yard.
DCG

Contact metamorphism is slight and is restricted to slight hornfelsing of siltstone and the development of decussate muscovite in feldspathic greywacke near the base of the sills. Also, sedimentary beds between the sills show only slight spotting (of pale brown isotropic material) and localised development of chloritoid. Garnetiferous hornblende and ?cordierite-bearing psammites have been found about ½ a mile from the contact of the Woodward Dolerite about 2 miles north of Blackhills 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 phyllites at the base of a sill of Woodward Dolerite, and may be in part the result of contact metamorphism. It is probably significant that the Hawkestone Creek kyanite-corundum deposit similarly occurs in phyllites near the base of a sill of Woodward Dolerite.

Petrography*

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 recrystallised plagioclase (An_{40-45}) and pale green hornblende, with 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}.

* Based partly on (Scott 1966)

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 around 1 mm 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 grain-size of certain specimens and 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 in this sill pyroxene had crystallised out prior to intrusion, and was localised 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% 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 and 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 possibly 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/or convection currents in sills only 150 feet thick.

WOMBARELLA QUARTZ-GABBRO (New Name)

Introduction

The type area for the Wombarella Quartz-Gabbro is in the Lennard River 1:250,000 Sheet area about 2 miles southwest of Stumpy's Jump-Up on the Derby-Mount House road. At this locality (2712E, 28338N) the main mass forms a small layered lopolith about 3 miles 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 characterised 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 of it. These hills may be parts of the main mass or may be offshoots from it. The total extent of the outcrops is about 9 square miles.

The Quartz-Gabbro crops out as prominent rocky hills that rise to about 300 feet above the surrounding plains. On aerial photographs they show a dark grey tone patterned with patches of black unweathered rock. The photo-pattern is similar to that of the Hart Dolerite. (Plate 4a)

The lopolith is elliptical in outcrop and 3 miles long by 2 miles wide. The long axis of the ellipse trends southeast, i.e., parallel to the trend of the King Leopold Mobile Zone. Large-scale layering in the lopolith has dips inclined towards 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 4,300 feet. The four main layers, each around 1000 feet thick, grade upwards from a relatively melanocratic basal facies to a more leucocratic upper facies.

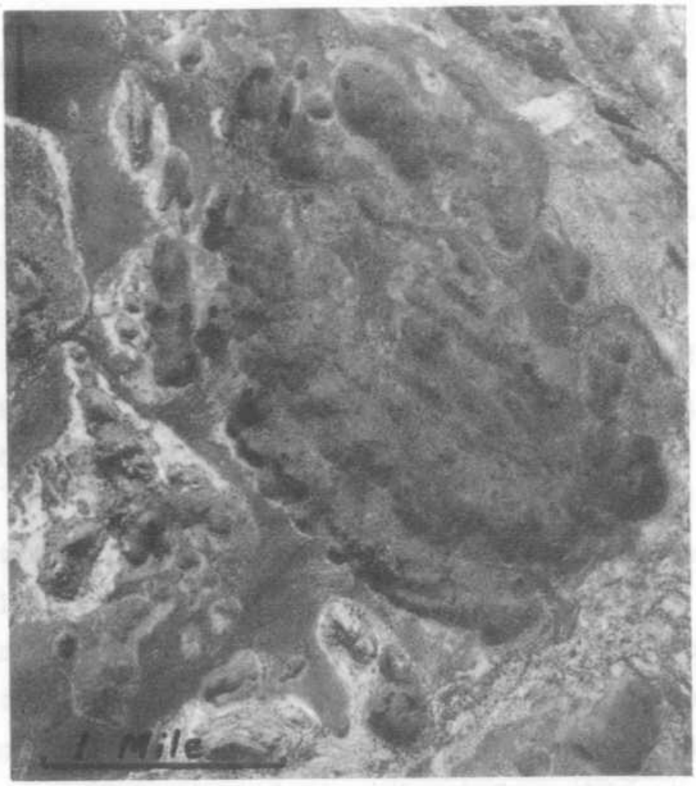


Fig. 4(a) Vertical aerial photograph of small lopolith of Wombarella Quartz-Gabbro showing arcuate strike ridges that parallel the layering. Light-toned hills surrounding the mass are granite.

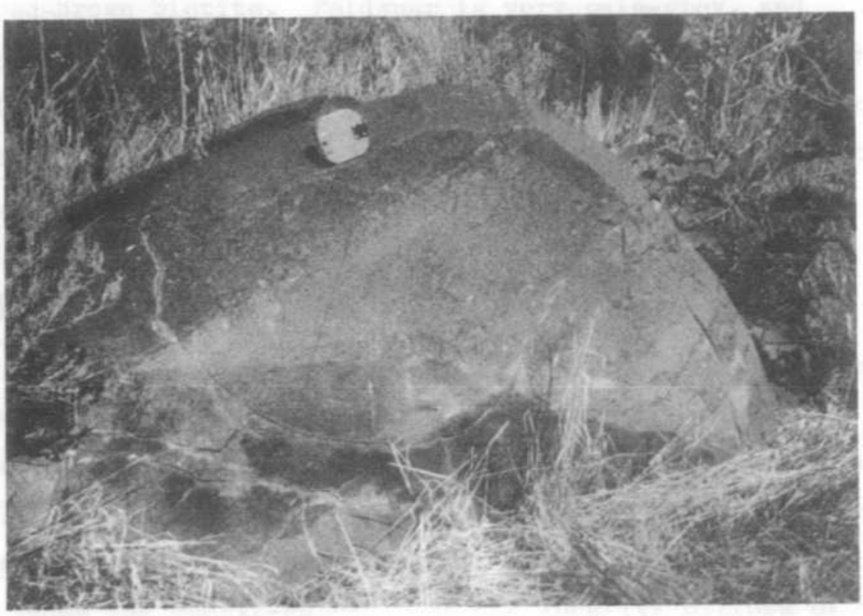


Fig. 4(b) Banding in Wombarella Quartz-Gabbro. The mesocratic leucocratic top of a gravity-differentiated band is overlain by the mesocratic base of the overlying band. The contact between the two is sharp and planar 2 miles southwest of Stumpys Jump Up. DCG

Within the main layers, subsidiary small-scale layering or banding is present locally. This banding is formed by repitition 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 so far it was not possible to determine the thicknesses of the individual bands. A general thickness of 30 to 100 feet 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 (Plate 5a). It occurs as small lenticles and bands, about ½ inch to 2 inches thick, of material either lighter or darker in colour than the enclosing rock. In places these streaky rocks contain small-scale isoclinal folds. Apart from this streakiness 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-grained 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 Relationships

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 2 to 3 feet across are partly surrounded by thin tongues of tonalite, and the individual pillows are cut by thin veinlets of tonalite

(Plate 5b). The tonalite shows flow alignment of feldspar phenocrysts parallel to the pillow margins, and the pillows themselves show a decrease in grain-size from the centre towards the margins, indicating chilling of the quartz-gabbro against the tonalite. These relationships are similar to those described by Blake et al., (1965) who interpret 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 are genetically related.

Near its southern margin 1 mile north of Wombarella Creek the Wombarella Quartz-Gabbro is cut by veins of non-porphyritic leucocratic granite derived from 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 an offshoot from 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 earlier than the Lennard Granite and parts of the Kongorow granite, but is later than other variants of the Kongorow Granite.

Petrography

In thin section the Wombarella Quartz-Gabbro is mostly medium-grained with an average grain diameter (a.g.d.) 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. * Modes given in Table 4 illustrate the compositional variations.

* Footnote. 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.

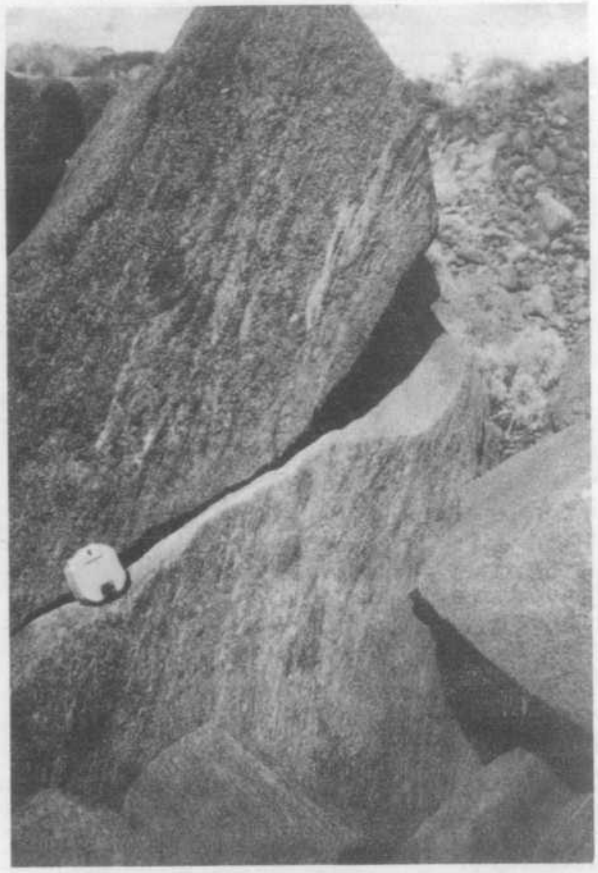


Fig. 5(a) Streaky gneissic banding in quartz-gabbro, southern margin of Wombarella intrusion. Note the presence of both light and dark schlieren, and of minor folds. 2 miles southwest of Stumpys Jump Up. DCG

Fig. 5(b) 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. 2 miles southwest of Stumpys Jump Up. DCG

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% An from core to margin. Strong dispersion in some of the strongly zoned crystals results in lack of complete extinction: instead of extinguishing parts of the crystals show dark blue-grey and brown interference colours. Quartz is present in all specimens as small to large interstitial grains. 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) clinopyroxene, occurring as small fresh euhedral to subhedral equant grains. Amphibole is a green-brown hornblende that appears to be both primary and an alteration-product of clinopyroxene. Biotite occurs as large strongly pleochroic foxy red-brown poikilitic plates that commonly surround a core of opaque ore (?magnetite).

The crystallisation sequence deduced from textural relationships 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 the presence of 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

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	15.0	6.1	14.7	9.2	11.3	0.4	0.8
Biotite	3.4	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 basal part of intrusion (LR 4-61 - 18; R 66-16-0046); 2708 E, 28334 N.

2. Biotite-hornblende quartz-gabbro: from topmost part of layer 2 (LR 4-61 -25; R 66-16-0054); 2714E, 28340 N.

3. Hornblende-biotite quartz-gabbro : light-coloured rock from top of differentiated band in layer 2 (LR 4-61-24(a); R 66-16-0052); 2714 E, 28340 N.

4. Biotite-hornblende quartz-gabbro: dark-coloured rock from base of overlying band in layer 2 (LR 4-61-24(b); R66-16-0053); 2714E, 28340N.

5. Average quartz-gabbro (1-4)

6. Little Gold River Porphyry (norite) (Lansdowne 1:250,000 Sheet area): minerals listed occur as phenocrysts in a cryptocrystalline groundmass, (LA 15-63-4); (R64-16-71); 4805E, 27430 N.

7. Little Gold River Porphyry: phenocryst percentages recalculated to 100%.

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

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., 1965).

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 prior to 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 residua tend 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 3 miles east and north-east 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 it contains.

Field Occurrence

The microtonalite occupies an area of about six square miles and forms low, rounded, north-west trending faults and joints. It has an even grey tone on air 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 degrees conformably with the (local) joint direction of the enclosing Lennard Granite.

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

Aplo-pegmatite veins and dykes occur in the tonalite, but not in the surrounding Lennard Granite. They are mostly vertical, 6 inches to 3 feet wide, strike 120^{o}, and are parallel to the foliation in the microtonalite. They consist of a fine to medium-grained saccharoidal aggregate of quartz, white and pale cream feldspar, minor amounts of biotite; scattered crystals and aggregates of cream potash-feldspar (up to 3 in.) and rare quartz (up to 1 in.) form the pegmatitic phase.

Contact Relationships

Along its northern margin the microtonalite is interbanded (on a scale of hundreds of feet) 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 post-date 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 the two 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 aplo-pegmatites 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 due to differing 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 two miles 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)

Introduction

The Kongorow Granite is a complex suite of porphyritic mesocratic granite and minor gneiss and migmatite which 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, 2842 N), where several varieties of this 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 Jump Up, around Joseph Yard, and in the Sandy Creek area.

The topographic expression of the Kongorow granite varies according to its geological setting -- whether it is associated with Lennard Granite or Halls Creek Group. Where it is associated with Lennard Granite it forms large rounded northwest-trending whalebacks with relief of about 350 feet. Where it is emplaced in Halls Creek Group it forms low hills, stony rises, bare rock pavements, and scattered inselbergs.

<u>Macroscopic Appearance and Lithological Variations</u>. The Kongorow Granite is generally foliated, coarse to fine-grained, grey, and biotite-rich. It is mostly porphyritic with discrete tabular and ovoid feldspar phenocrysts 1 cm to 5 cm across of alkali feldspar, and lesser amounts of smaller plagioclase phenocrysts, commonly sericitised. Phenocrysts comprise from 1 percent 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:

<u>Type A</u>: This 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.

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

<u>Type C</u>: is a coarsely porphyritic biotite granite with abundant 2 cm to 3 cm tabular alkali feldspar phenocrysts, and 2 cm to 10 cm ovoid alkali feldspar phenocrysts. Small garnets are present. This type occurs along the Mount House road, about a ½ mile north of Stumpys Jump Up.

Fig. 6(a) Kongorow Granite (type D) intrusive into Lennard Granite. Kongorow phenocryst decrease in size toward margin and show moderately good flow foliation parallel to it. A small xenolith of Lennard Granite near hammer point. 3½ miles west-northwest of Stumpys Jump Up. J.S.

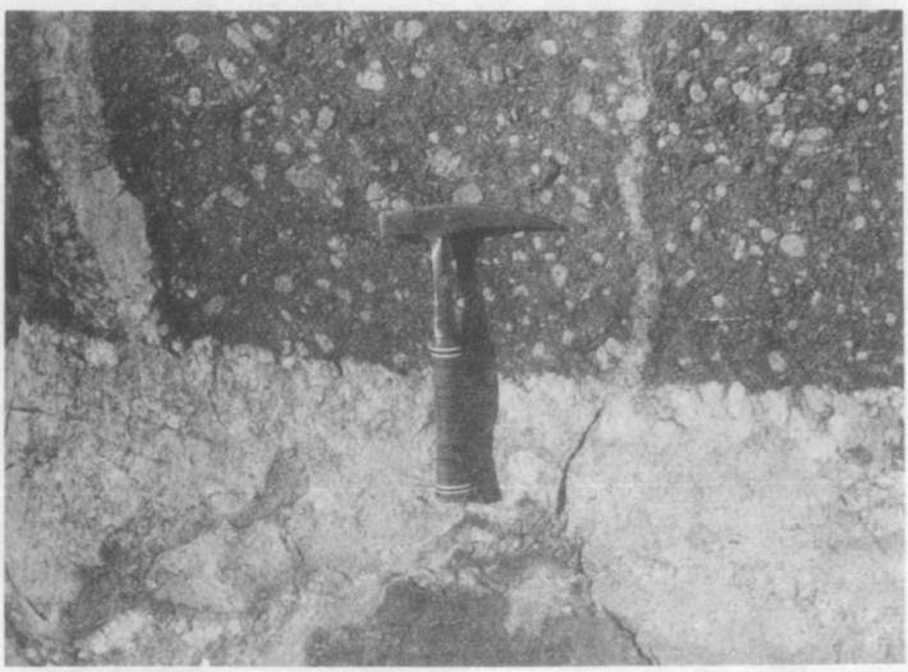


Fig. 6(b) Kongorow Granite (type C) intruded by Mount Amy Granite. Numerous veins of Mount Amy Granite penetrate Kongorow Granite, and there is a pegmatitic marginal phase of Mount Amy Granite up to 1 foot thick at the contact. 3 miles northwest of Stumpys Jump Up. J.S.

Type D: is a dark grey fine to medium-grained 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., 4 miles southeast of Stumpys Jump Up.

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 type D. The texture of this type is shown in Figure 6a. The phenocrysts are usually euhedral, and average from 1 cm. to 5 cm long. Muscovite is an accessory mineral. The rock contains a number of xenoliths, and at one locality forms a dyke with narrow chilled margins.

No contacts between these various Kongorow Granite types have 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 Relationships

The Kongorow Granite was intruded intermittently over a considerable period; relationships 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, aplo-pegmatite veins, and dolerite dykes. Contact relationships with the Wombarella Quartz Gabbro, the Whitewater Volcanics and the Lennard Granite indicate that some types of Kongorow Granite predate both these units, whereas other types post-date them.

1. Contacts with Lennard Granite. Near Kongorow Pool the Kongorow Granite (type A) contains large lenticular xenoliths of Lennard Granite, and is also intruded by veins of possible Lennard Granite (Fig. 7a). A dyke of Kongorow Granite (type D) intrudes also 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 3½ miles west-northwest of Stumpys Jump Up. Pegmatitic marginal phases of Mount Amy Granite at this locality pass into finer-grained granite within a foot 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 Jump Up. 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, 1 mile north of Wombarella Creek, type B Kongorow Granite contains fractured and 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.

Fig. 7(a) 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. J.S.

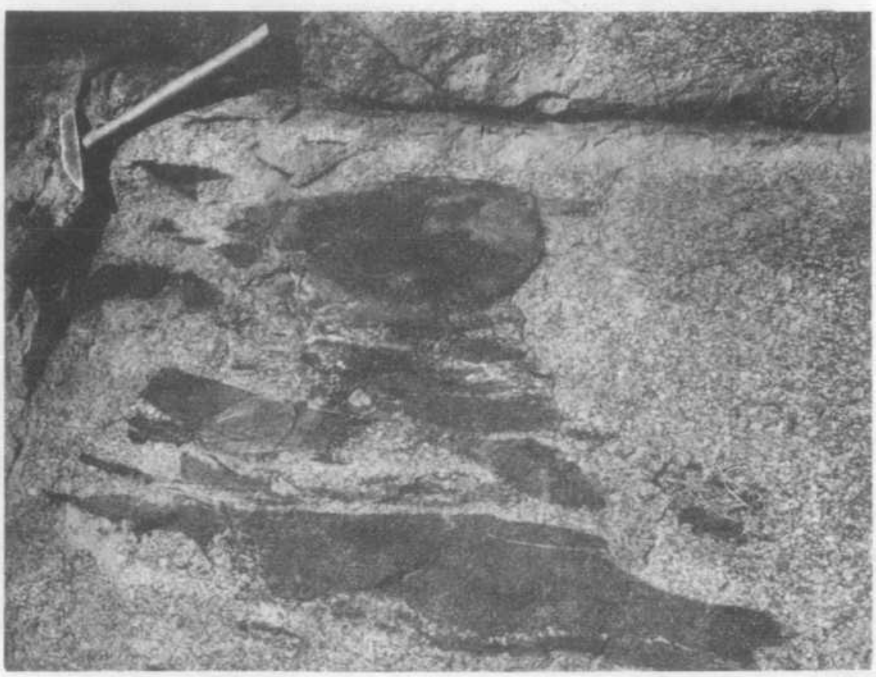


Fig. 7(b) Kongorow Granite (type B) containing xenoliths of Wombarella Quartz Gabbro. Near main road 1 mile north of Wombarella Creek. DCG

The dominant constituents of the Kongorow Granite suite are:

Microcline, which is generally the predominant phenocryst mineral, is microperthitic, and commonly forms a cuneiform intergrowth with quartz along the contact between phenocryst and groundmass (e.g., L.R. 5-86-10). In some instances (e.g., 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 sericitised, and commonly shows strain-effects (e.g., L.R. 3-45-1, L.R. 3-95-9). It may also be extensively sericitised especially along margins (e.g., L.R. 4-61-1e), and myrmekitic intergrowths are common. Locally the plagioclase is andesine (e.g., 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 (e.g., 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 (e.g., L.R. 3-45-1). Magnetite, hematite, secondary calcite, and irregular patches of garnet were noted in some examples (e.g., L.R. 4-61-1e). The groundmass is composed of an irregular interlocking mosaic of quartz, microcline, plagioclase, and biotite, all of extremely variable grain size.

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). There, porphyroblastic migmatites and non-migmatitic gneisses, containing sillimanite, potash feldspar, and garnet, have been derived through partial melting and mobilisation (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)

Introduction

The name Richenda Microgranodiorite has been given to biotite microgranodiorite that crops out near the Richenda River and south of Wombarella Creek, and 4 miles 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 south-eastern corner of the Yampi 1:250,000 Sheet area. The reference area is near the Richenda River, 1 mile 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, 1 mile northeast of Blackhill Yard, about 5 miles west-southwest of Richenda Gorge, and 4 miles south of Wombarella Yard. The total area of outcrop is about 6 square miles.

The microgranodiorite forms prominent serrated hills with localised areas of black-weathering, vegetation-free boulder scree.

In the Richenda River area the microgranite forms two small stocks, the larger one with a circular outcrop plan, and the smaller with its outcrop elongated eastwest, approximately parallel to the strike of the enclosing Halls Creek 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 800 feet 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 north-east 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 seen to be an even-grained rock with a hypidiomorphic-granular texture and an average grain-size of about 0.5 mm. It consists essentially of quartz, plagioclase, potash feldspar, and biotite with 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 relationship; 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.

WHITEWATER VOLCANICS

Introduction

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 and Smith (1961) and Branch (1966), who define the terms ash flow tuff, welded tuff, etc. To distinguish further between some of the rocks the non-genetic terms crystal-rich tuff and crystal-poor tuff have been introduced.

Field Occurrence

The Whitewater Volcanics occur 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 "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 due to strong jointing.

The volcanics form steeply dipping sheets in the northwest with dips generally exceeding 60°; locally the sequence is overturned (e.g., 4 miles east of Mac's Jump Up, and in the Sandy Creek Area). Near Scrutons Hole dips are 30° or less; here and throughout the southeastern parts 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 cryptocrystalline 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 around 40,000 feet.

Four informal stratigraphic units are distinguished:

	Unit	Map Symbol
4.	Massive crystal-rich rhyodacite ash-flow tuff; minor agglomerate. (ca. 16,000 ft.)	Pwa
3.	Massive crystal-poor rhyodacite ash-flow tuff; minor crystal rich tuff. (ca. 12,000 ft.)	Pwp
2.	Dacitic and minor rhyodacitic biotite-rich ash-flow tuff (ca. 10,000 ft.)	Pwb
1.	Bedded rhyodacite tuff; minor tuffaceous siltstone, sandstone, and conglomerate (ca. 5,000 ft.)	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 of these units are probably present.

1. Bedded rhyodacite tuffs and sediments. This basal sequence is characterized by rapid alternations 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 feet to 90 feet thick. They occur at the base of the volcanics (e.g., west of Mount Broome) and up to 700 feet above the base (e.g., 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 Mac's Jump Up, and are similar to crystal-poor types, except that they contain from 5 to 10 percent of 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 present, but are rare.

3. <u>Crystal-poor rhyodacite tuffs</u>. These are generally massive, dark grey, black, pale pink, and pale green 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 8 miles 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. <u>Crystal-rich rhyodacite tuffs</u>. Crystal-rich tuffs extend from Lennard River Gorge northwest to the Sheet boundary. These are dark grey or green-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 10 inches across of dense tuff or fine-grained acid lava set in a fine-grained tuffaceous matrix (Fig. 9b). The fragments define a near-vertical tectonic foliation.

Contact Relationships

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 Whitewater Volcanics-Halls Creek Group unconformity has been discussed previously (see page 25). The unconformity with the overlying Speewah Group is well displayed 8 miles 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 7 miles east of Hanns Hole, and northwest of Mount Eliza. Near Hanns Hole the granite is locally transgressive, and microgranitic and highly porphyritic at the contact, with localized development of pegmatite; the Volcanics are indurated.

Porphyritic Lennard Granite and associated pegmatite intrude the Volcanics 6 miles east of J.O. 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), but the granite locally veins the Volcanics. The margin of the granite is pegmatitic or microgranitic for at least 6 feet 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 sub-parallel 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 Mac's Jump Up.

Tongues and veins of Mount Disaster Porphyry intrude the Volcanics near Ord Gap and in the Duncan River area. Also, a large intrusive sheet of Mount Disaster Porphyry truncates bedding of the Whitewater Volcanics 7 miles east of Mac's Jump Up.

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 around 10 percent in some of the crystal-poor tuffs. The dacitic and rhyolitic tuffs are mostly crystal-poor. The average grain-size of the phenocrysts ranges from 4 mm to 1 to 2 mm.

Plagioclase is usually a zoned calcic oligoclase or andesine, and is saussuritised to varying degrees. Many of the grains are broken. Quartz shows the characteristic form of the beta variety, and 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. Some non-perthitic microcline grains are also present. Grain margins are corroded by the siliceous matrix. Mafic minerals present are biotite and chlorite. These occur as ragged lenticular aggregates, and are responsible for the discontinuous banding present in some hand specimens. The biotite is green or brown, and is associated with iron oxide, or ilmenite with kelyphytic rims of sphene. Some of the biotite aggregates probably represent altered mafic phenocrysts.

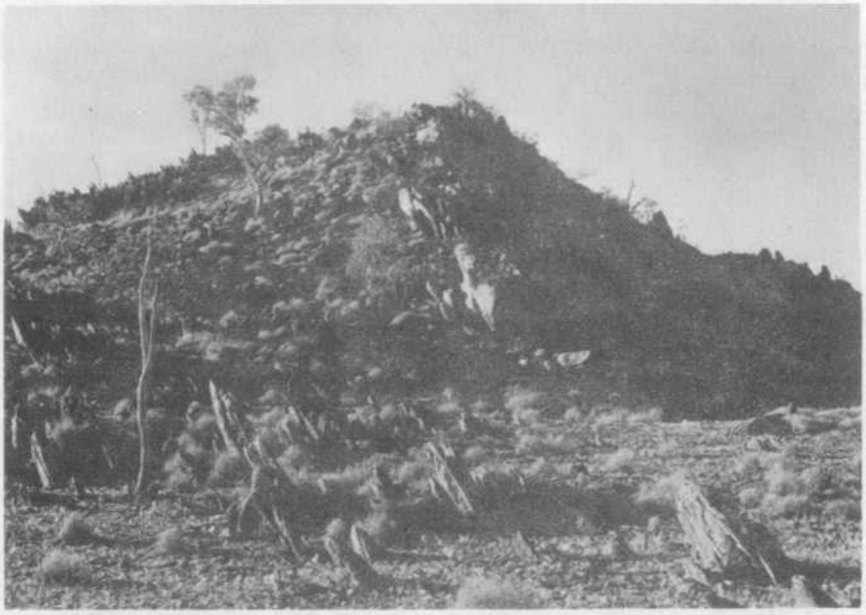


Fig. 8(a) Rock strewn hills with rounded outcrops and 'tombstone' slabs typical of Whitewater Volcanic terrains (Pwa) 1 mile southeast of Scrutons Hole. G.M.D.

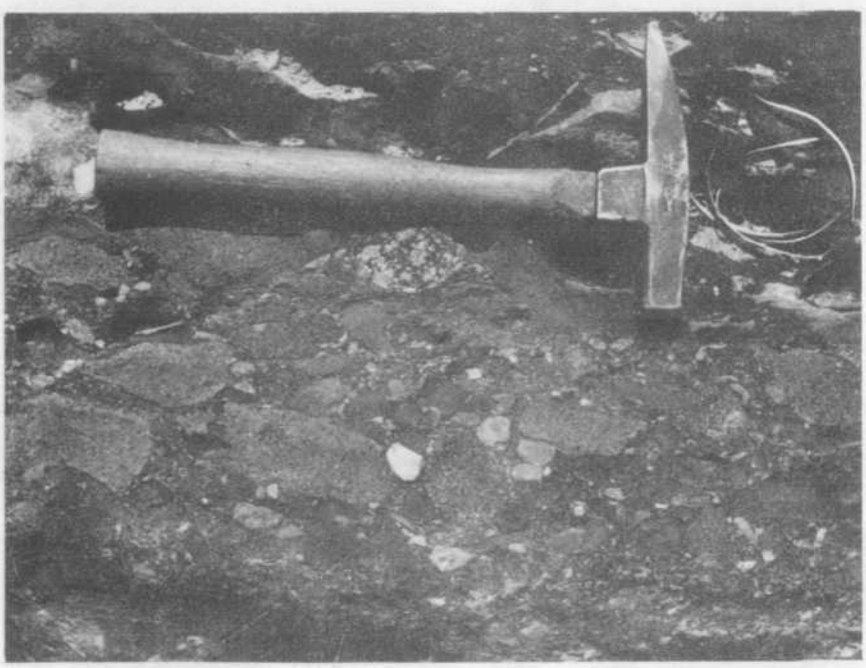


Fig. 8(b) Cobble conglomerate near base of Whitewater Volcanics 4 miles southeast of Scrutons Hole. Note cobbles of porphyritic ?Woodward Dolerite below hammer shaft.

The matrix is a granular mosaic (average grain-size .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 are seen to 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 (see 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 twining 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 and 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 the volcanics in the Mount Ramsey Sheet area were deuterically altered lavas. In the Lennard River Sheet area we think 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 volcanoclastic sheets over large areas and distances, such as in the northwest, where they cover an area at least 8 miles wide and 20 miles long, and the occurrence of thick units of massive non-bedded material.

Pumice fragments, considered by Ross and 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) has 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 suggests 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 and 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.

Fig. 9(a) Whitewater Volcanics underlain by Lennard Granite. Granite is locally transgressive but generally the contact parallels Whitewater bedding. Margin of granite is fine-grained with localised pegmatitic patches for at least 6 feet from contact, and represents a chilled zone. 1 mile east of Scrutons Hole. G.M.D.

Fig. 9(b) Coarse agglomerate associated with fine-grained tuffaceous rocks. Part of Whitewater Volcanics sequence (Bwa). Sequence also intruded at this locality by Mount Disaster Porphyry. Mt Hart track 3 miles north-east of Dromedary Yard. G.M.D.

Age Relationships

Contact relationships 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 relationships (i.e., 1845 m.y. for granite, 1823 m.y. for volcanics; Bofinger, 1967). An isotopic age determination programme to elucidate this problem is in progress.

BICKLEYS PORPHYRY

Introduction

Bickleys Porphyry was named after Bickleys Creek, in the Lansdowne Sheet area. (Gellatly et al., 1965).

Field Occurrence

Bickleys Porphyry 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 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-grained 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 semi-continuous quartz "lacework" typical of deeper-seated granites.

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

Contact Relationships

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 south-east, 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.

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

In the Lansdowne 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 relationships 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 presence of the fragments suggests 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 micrographic 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 Sheet area. 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

Introduction

The Mount Disaster Porphyry (Sofoulis et al., 1968) 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 south-west 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., 1965) and its equivalent, the Mondooma Granite (Sofoulis et al., 1968) 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 3 to 5 mile 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 55 square miles.

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 the Whitewater Volcanics, Mondooma Granite, and Bickleys Porphyry. The photopattern 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 and 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 50 feet wide, along which sericite schist, quartz veins and reefs up to 3 feet 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 grain-size.

At Inglis Gap the Mount Disaster Porphyry occurs adjacent to the unconformity between the Lamboo Complex and Speewah Group, and is heavily kaolinized. Near Ord Gap, fault movement along this 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 (.5 cm to 2 cm) and opaque white or pale green and cream plagioclase (to 3 cm) in a grey-green fine to medium-grained 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 Relationships

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

Contacts with Whitewater Volcanics (a) A small stock of Mount Disaster Porphyry intrudes banded Whitewater Volcanics 5 miles east of Macs Jump Up 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 4 miles west of Inglis Gap phenocrysts of the Porphyry show a diminution in grain-size, 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 inches of the contact.

At a sharp contact between Bickleys Porphyry and Mount Disaster Porphyry three miles 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. 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 inclusions of quartz. Quartz phenocrysts are commonly intergrown with the potash feldspar along the margins and along fracture planes. Large quartz phenocrysts up to 1.5 cm long show resorption embayments.

The [illegible] is relatively coarse-grained with a.g.d. 0.3mm. 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 relationships 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 after Mondooma Yard in the Yampi Sheet area (Sofoulis et al., in prep) occurs as small scattered roof pendants up to 300 feet across in massive Lennard Granite, in the far north-west of the Sheet area. In general these 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 will be given in a report on the geology of the Charnley Sheet area (Derrick, et al., in prep.).

LERIDA GRANITE

Introduction

The name Lerida Granite (Gellatly et al., 1965) is derived from Lerida Gorge, in the southwest corner of the adjoining Lansdowne Sheet area. The mass extends north-westwards on to 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. It occurs in an irregular northwest trending belt, about 6 miles wide, crossed by the Fitzroy River and 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. 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 distinct

Contact Relationships

The Lerida Granite intrudes the Whitewater Volcanics about 5 miles north and three miles 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 relationships. 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) show that granodiorite is the most common rock type; tonalite also occurs. All varieties contain variable amounts of amphibole, probably actinolite.

The mineral composition is similar to that of McSherry's Granodiorite (q.v.). Plagioclase is generally more altered; some of biotite shows a deeper red-brown pleochroism; and rare actinolite grains contain cores of brown hornblende.

Discussion

The Lerida Granite is compositionally similar to McSherry's Granodiorite. The age relationships and modes of origin suggested for that mass also apply to the Lerida Granite. It has some textural similarities to Mount Disaster Porphyry, and the two are gradational locally, e.g., in the southwest corner of the Lansdowne Sheet area.

McSHERRY'S GRANODIORITE (New Name)

Introduction

McSherry's Granodiorite is named from McSherry's Gap, immediately northwest of the type area for the Granodiorite. The Granodiorite is a composite intrusion, and comprises diorite, tonalite, granodiorite, adamellite, and granite.

It resembles Kongorow and Lerida Granites in being moderately mafic, but differs from them compositionally and in being essentially non-porphyritic.

Field Occurrences

Extent and Location of Outcrop: The main mass of Granodiorite crops out discontinuously in a triangular area with apices at McSherry's 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-west fault. Smaller bodies of McSherry's 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 170 square miles.

Topographic expression and Photo Pattern: Differences in the topographic expression and photo pattern of McSherry's Granodiorite are well illustrated in the main mass near McSherry's Gap. Immediately east of this 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 eastwards.

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 McSherry's Gap the foliation parallels the strike of the Halls Creek Group, and may be a flow foliation.

Lithology

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

Large areas of the granodiorite are homogeneous (e.g., east of Tunnel Bore), but elsewhere the granodiorite is markedly inhomogeneous. Quartz may form large pegmatoidal patches (e.g., 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 percentage of biotite, ranges from 10 percent to 35 percent. Some varieties of granodiorite are rich in amphibole (e.g., near McSherry's 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 1 inch to 3 feet 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 Relationships

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

Halls Creek Group: McSherry's Granodiorite is in contact with Halls Creek Group phyllite east of McSherry's Gap and immediately south of Millyie Hill. Near McSherry's Gap and near Millyie Hill contact metamorphosed phyllites contain decussate muscovite but only within about 10 feet 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: Eight miles east-south-east of Tunnel Bore the Granodiorite intrudes Whitewater Volcanics with a sharp contact. The Volcanics show a 6-inch zone of hornfels, and the Granodiorite is enriched in biotite at the contact. In other localities (e.g., 5 miles 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 due to reconstitution of original biotite. Four miles north of Kurrajong Yard xenoliths similar to Whitewater Volcanics and to Bickleys Porphyry are metamorphosed, recrystallized, and partly assimilated.

Lennard Granite: McSherry's Granodiorite is intruded by Lennard Granite at Hanns Hole, at the head of Hoopers Creek, five and eight miles southeast of Scrutons Hole, and seven miles 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. 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

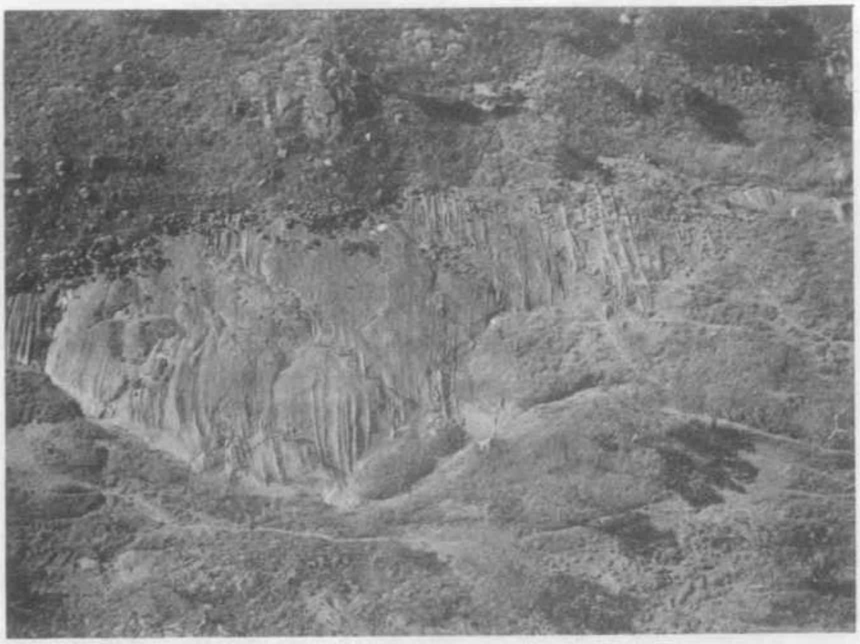


Fig. 10a Sub-parallel aplite dykes veining McSherrys Granodiorite; aerial view, 6 miles north-east of Christmas Bore. Distance across photo about 250 feet. G.M.D.

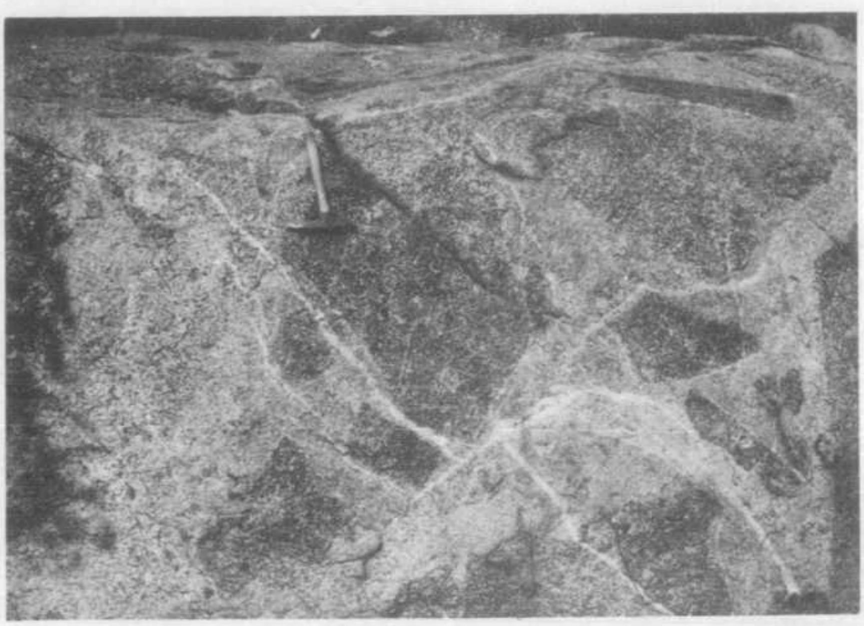


Fig. 10(b) Angular and partly resorbed xenoliths of McSherrys Granodiorite in Lennard Granite, Hanns Hole, Barker River area. CMM inhomogeneity up to 1000 feet wide border the sheared contact-zones, and porphyritic Lennard Granite is interbanded with a more leucocratic granite. The bands are highly contorted, and phenocrysts of feldspar define a sinuous flow foliation. A mesocratic granular quartz-feldspar-biotite rock, common in these zones, e.g., at Hoopers Creek, is intermixed with the granodiorite as contorted bands, lenses, and interfingering tongues. It forms bodies up to 40 feet long which display small-scale folding.

Dyasons Granite: Several large bodies and dykes of this mass intrude McSherry's Granodiorite. The dykes are leucocratic porphyritic granite from 1 foot to 30 feet wide. They cut the Granodiorite three miles southwest of Scrutons Hole, and in a broad belt at the headwaters of Hoopers Creek.

Petrography

The granodiorite is generally coarse to medium-grained, 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 grain-size from 1 to 4 mm. Grains are generally subhedral, well-twinned on albite and pericline laws, and strongly zoned from abour An_{40} to An_{20}. 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 patchily developed. It forms fields up to 5 mm across which enclose euhedral plagioclase and biotite, or occurs as anhedral interstitial grains 1-2 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 grain-sizes. Large subhedral to anhedral flakes 1-3 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 2mm long, or decussate patches of finer grain-size; $2V \doteq 80^{\circ}$, 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 amphibole cleavage-planes contain brown iron oxide films. Accessories are mainly epidote, apatite, zircon, ilmenite, and sphene; and rare calcite and red-brown limonitic material.

The aplite and pegmatite present in McSherrys Granodiorite range from leucocratic granite to granodiorite in composition. Most aplites show a typical saccharoidal texture. Many pegmatites are coarsely graphic. One pegmatite 3 miles 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 all 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 (e.g., 180, 183, 185) and at contacts with Lennard Granite, McSherrys Granodiorite is granodiorite or tonalite.

Discussion

Many features suggest that McSherrys Granodiorite is a contaminated mass. These include (a) the tonalite-granodiorite compositional range, (b) abundant xenoliths throughout the mass, in various stages of recrystallization and assimilation, and (c) marginal inhomogenity 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 (e.g., 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 parallel 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 aplo-pegmatite magma is assumed to be poorer in soda and alumina than the computed parent magma because of volatile loss.

TABLE 5 MODAL ANALYSES - McSHERRY'S GRANODIORITE AND LERIDA GRANITE

	MEASURED															ESTIMATED								
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	2 5	39	36	2	5	45	-	-
Rock Name (Johanssen)	T	QT	GD	T	GD	A	GD	T	T	GD	T	GD	GD	GX	TXor M TX	GD	G	T	T	A	A	T	GD	GD

24, 26, 29 McSherry's Granodiorite, Millyie Hill area

163, 164, 166, 167, 168, 180, 183 McSherry's Granodiorite, Tunnel Creek area

181, 182, 185, 83, 85 McSherry's Granodiorite, Sandy Creek area

96 McSherry's 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.

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. Also, 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

This granite occurs southeast of the Fitzroy River and forms part of a large mass extending from the Lansdowne and Mount Ramsay Sheet areas. The granite was named after 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 on to the Lennard River Sheet.

Application of the name Chaneys Granite has been extended from the Lansdowne area as far as the Fitzroy River, to maintain continuity between the Lennard River Sheet and the already-published Lansdowne Sheet. The boundary in the Fitzroy River area between the Lennard and Chaneys Granites is therefore an artificial one, but necessary, as it is desirable to restrict the usage 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)

Introduction

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

The reference area for the Lennard Granite is 7 miles southeast of Stumpys Jump Up (284 E 2838 N).

Field Occurrence

The Lennard Granite is the most extensive acid intrusive in the area. It predominates northwest from the Fitzroy River to the Richenda Gorge and Brices Yard, and also 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 25 miles long and 10 miles wide.

The Lennard Granite forms smooth exfoliated whalebacks, blocky, steepsided 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 600 feet and is generally less than 350 feet. East of Richenda Gorge granite hill tops and small laterite-capped mesas stand at 500 to 600 feet 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, from a $\frac{1}{2}$ inch to 2 inches across, set in a coarse to medium grained groundmass of quartz and feldspar with minor biotite (Fig. 11a).

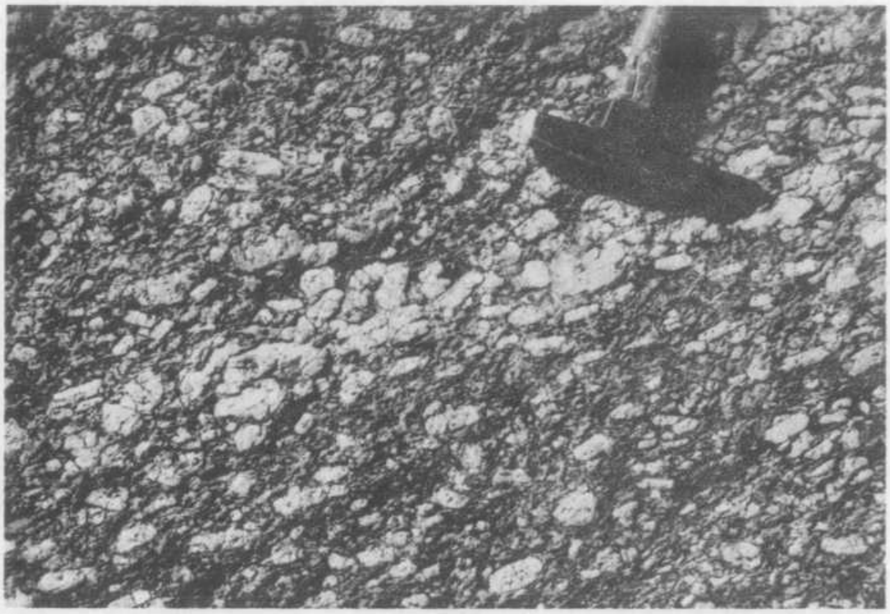


Fig. 11(a) Typical texture of Lennard Granite, showing variations in phenocryst density, Granite Hill area. CMM

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

The phenocrysts commonly have irregular ovoid shapes and comprise over 50% 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 markedly porphyritic, or even-grained.

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

Contact Relationships

Lennard Granite intrudes Halls Creek Group and Whitewater Volcanics and is itself intruded by the Mount Amy Granite. Most contacts trend northwest. Many are sheared, e.g., phyllonites are developed 4 miles southeast of Dromedary Yard at the contact of Lennard Granite with Whitewater Volcanics.

Contacts 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 over a zone 2 to 3 feet wide containing large feldspar porphyroblasts. Metamorphosed and metasomatised xenoliths, which are common towards the margins of the granite and are generally aligned parallel to the contacts, show similar porphyroblastic selvedges a few inches 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 Creeks. 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 relationships 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., 4 miles southeast of Dromedary Yard. Locally small-scale interlayering has produced migmatites of granite and biotite-rich acid volcanics.

At some contacts (e.g. Pandanus Creek, 4 miles south of Bigelleas Yard) the granite, although chilled marginally, is inhomogeneous and contains irregular patches of aplite and pegmatite. At other contacts (e.g., 3 miles south of Dromedary Yard) feldspar porphyroblasts are developed in the volcanics.

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 and Kongorow granite are referred to in the descriptions of these 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 sericitised grains. Medium-grained quartz (ca. 35%) forms interlocking mosaics locally in bands 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 grain size. Quartz-feldspar intergrowths are common. The texture is allotriomorphic granular with a distinct foliation imparted by the alignment of phenocrysts and of 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 more prominent and are 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 8 miles south of Millie Windie Gap. These swarms occur in three zones which appear to be collinear, and which extend discontinuously in an east-west direction for about four miles. The zones vary in width from 10 feet to 50 feet, but their boundaries are gradational. Most xenoliths are lenticular or oblate and up to 12 inches across. A few larger ones up to 30 feet 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 crops 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 (see 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 in character 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 McSherrys 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.

Fig. 12 Xenolith swarm in Lennard Granite, Sandy Creek area, 8 miles south of Millie Windie Gap.

DYASONS GRANITE (New Name)

Introduction

Dyasons Granite is named after 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, 320 E, 279N.

Field Occurrence

Dyasons Granite extends in a discontinuous belt 3 miles wide east-southeast of Waggon Flat for about 20 miles. 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 which commonly borders it.

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 east-west 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 Relationships

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.

McSherrys Granodiorite. Blocks and xenoliths of McSherry's Granodiorite are incorporated in the stocks and larger dykes of Dyasons Granite. Some of the blocks are one square mile in area. At most contacts abundant dykes of granite up to 40 feet wide intrude the granodiorite.

Lennard Granite. No contacts between stocks of Dyasons Granite and Lennard Granite have been observed, but a dyke of Dyasons Granite cuts Lennard Granite 3 miles southwest of Scrutons Hole, showing that Dyasons Granite is younger.

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 of these 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	tr	tr	1

The granite is medium to coarse-grained, and is 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 of the 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 relationship with McSherrys Granodiorite suggests that the two may be related.

MOUNT AMY GRANITE (New Name)

Introduction

The Mount Amy Granite is named after Mount Amy, a granite whaleback near Stumpys Jump Up. The reference area for this unit is 5 miles 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 a $\frac{1}{4}$ mile wide, to stocks and plugs of muscovite granite up to 5 square miles in area. The total exposed area of Mount Amy Granite is about 12 square miles.

The topographic expression of these bodies is mainly a function of their size; the larger masses form whalebacks; 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-grained 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 just north of Kurrajong Bore. They contain locally tourmaline and books of muscovite up to 1 inch diameter.

Contact Relationships

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 Jump Up.

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. Phenocrysts (of quartz and feldspars) 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 very abundant and range from 2mm 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 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. Average grain size ranges from 0.5 mm 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.

Aplo-pegmatite 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, and/or breakdown of potash feldspar and quartz.

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 Mc Sherrys Granodiorite.

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

UNNAMED ACID ROCKS

Introduction

A small exposure, about 150 feet across, of adamellite porphyry occurs 6 miles 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.

The porphyry contains large light-coloured euhedra of alkali feldspar, up to 4 cms long. The matrix is fine-grained and biotite-rich and the colour dark. In hand specimen it resembles the Mount Disaster Porphyry and also parts of the Kongorow Granite. It is sheared, but shows a relict flow foliation and a fine-grained border zone which ranges up to 12 inches wide, but which is absent in places. This border zone is characterized by both a finer-grained matrix and a lower phenocryst contant.

Petrography

In a specimen from the centre of the intrusion, phenocrysts form approximately half of the rock (by modal analysis). Fragments of plagioclase and quartz phenocrysts suggest autoclasis. Potash feldspar

Fig. 13(a) Adamellite porphyry (dark) intruding Lennard Granite, and truncating xenoliths in the Granite. Note the euhedral phenocrysts of alkali feldspar, and the lack of a chilled margin. Sandy Creek area, 6 miles east-southeast of Scrutons Yard.

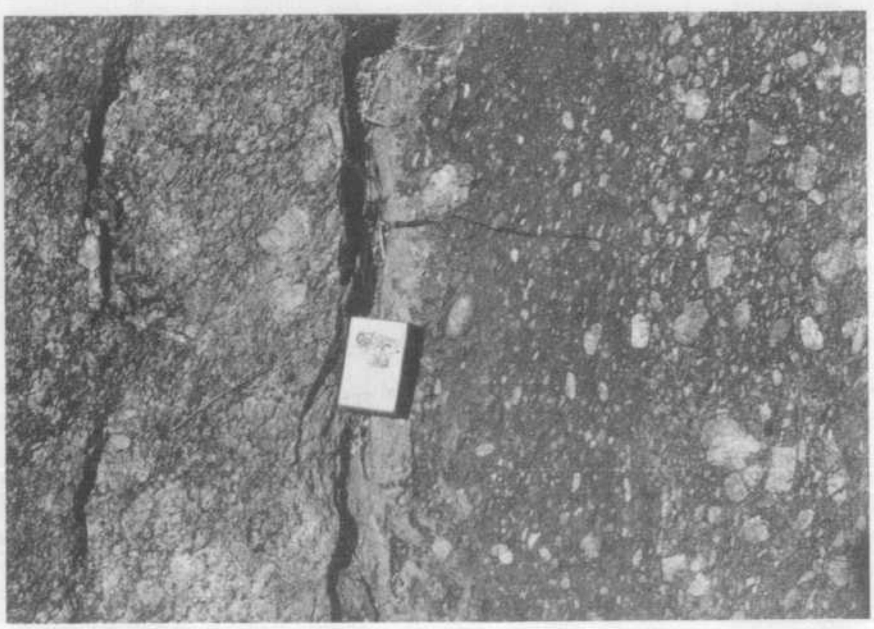


Fig. 13(b) Contact of adamellite porphyry cutting Lennard Granite. Note the slight diminution in size and number of phenocrysts in the chilled margin. Sandy Creek area, 6 miles east-southeast of Scrutons Yard. G.M.D.

(15%) grains are euhedral and range from 4 mm to 4 cm. 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, from 2-4 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 grain-size 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 is rare as phenocrysts. 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 micro-adamellites, though the groundmass of each is granodioritic.

Discussion

The field evidence (transgressive contact, chilled margin, flow foliation etc.) shows this rock to be 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, 1961). 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. The latter however, 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

Introduction

A number of small basic and ultrabasic lenses crop out immediately north of Sandy Creek 8 miles southwest of Scrutons Hole, and in McSherrys Granodiorite 5 miles north of Kurrajong Yard and 12 miles east of McSherrys Gap. These are only 50 to 100 feet across, and are not shown at 1:250,000 scale.

Field Occurrence

In the Sandy Creek locality two of the basic lenses are completely enclosed by Lennard Granite which intrudes them. The lenses are massive and dark, and appear ultrabasic in hand specimen. 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 from pale pink to pale green. (b) A colourless variety which appears fresh and unaltered, characterized by a 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 1961). (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 +ve or -ve. 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%). Biotite (5%) is brown and coarse-grained, 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 granites. The quartz veins range from 1 to 20 feet thick, and trend mainly north-northwest and east. They are up to 5 miles long, and occupy fault zones or joints. In many cases quartz veins up to 1 mile long are arranged en echelon along major fault zones, e.g., 8 miles east of Old Leopold Yard. Generally the quartz is massive, milky and highly fractured, though smoky quartz crystals up to 4 inches 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 2 inches across to reefs ½ mile 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 8 miles 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 2 miles 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

Field Occurrence

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

They occur mainly as dykes, and, to a lesser extent, sheets and very small stocks, and 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 air photos, but dyke swarms e.g., 3 miles north of McKinrick Hill, show a fine trellised photo pattern.

Dykes are from 3 inches to 30 feet thick, but most are about 6 inches. Sheets of aplite crop out in areas up to 3000 square feet or more. The dyke trends are graphically shown in Figure 14. Conjugate dyke systems are present, trending northeast, northwest, and north-south. 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 grain size, but in some cases feldspar crystals up to 8 inches and tourmaline up to 3 inches 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 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.

Contact Relationships

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 6 feet 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 12 inches thick are common in the strongly foliated Lennard and Kongorow Granites four miles north and northwest of Wombarella Yard. These bands are either remnant meta-sedimentary 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 grano-dioritic in composition. Flakes of muscovite and chlorite shreds are common accessories to quartz and potash feldspar. Iron-oxide, garnet and apatite are less common. Further information on aplite petrography has been listed previously (see p.70).

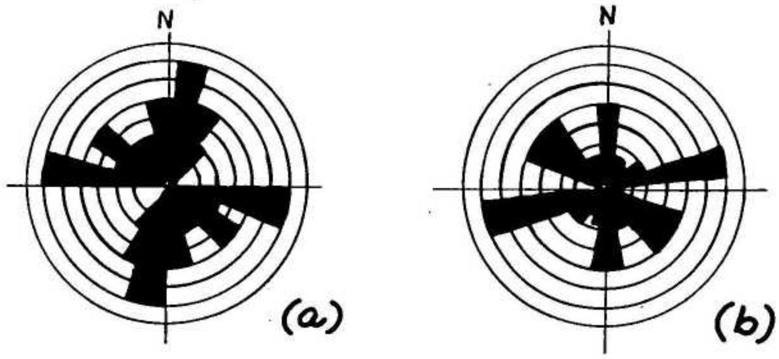
Mineralization

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.

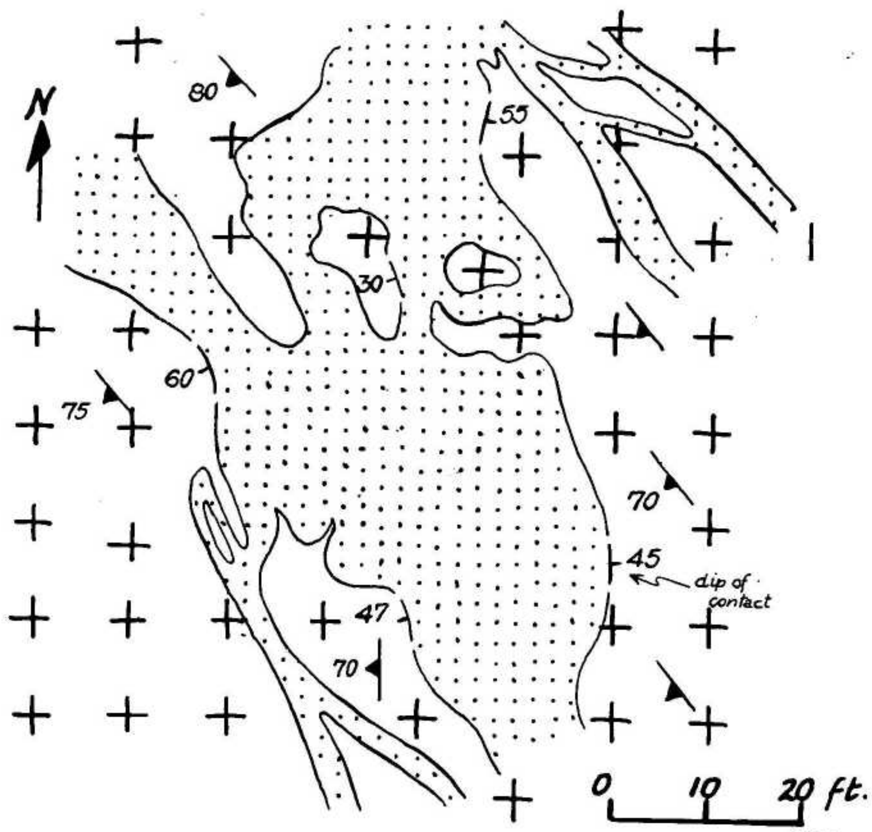
Tourmaline and small books of muscovite are ubiquitous minerals in many of the aplites and pegmatites in the granites. Masses of biotite or phlogopite are associated with tourmaline in metamorphic rocks north of Windjana Gorge. Cassiterite has been recorded by Finucane (1939) from pegmatite in the Dyason's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

FIGURE 14. FEATURES OF APLITE DYKES

1.



2.



1. *Dyke trends: a/ Mc·Sherrys G'diorite*
   b/ Lennard Granite

2. *Dykes and domed sheets of aplite (:::) intruding Lennard Granite, Fitzroy River area. 2 miles north Gardeners Yard*

Discussion

Many large masses of aplite are similar to the fine-grained Mount Amy Granite, and have been referred to that mass where they are mappable 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 occur up to 5 miles 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

Introduction

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, and Lennard Granite and the Halls Creek Group.

The dykes generally form dark resistant ridges of varying height and from 3 to 60 feet wide, or lines of residual boulders on soil plains. Some are continuous for more than 12 miles, but the average continuous length is about 1 to 2 miles. Dyke swarms are particularly abundant in McSherrys Granodiorite, in the area immediately east of McSherrys Gap, where the dykes generally trend north-northwest. Many of them are gently arcuate. They intersect, bifurcate, and vary in thickness along strike. Some show en echelon distribution.

Lithology

The typical dolerite is dark green-grey, fine to coarse-grained, usually 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 dolerites are 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 hornblende, pleochroic green to brown, 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 of dyke rocks cutting the Halls Creek Group 3 miles south of Josephs Yard are similar, except that one contains pigeonite, (2V less than 15°)associated with pale pink titan-augite, (2V $\doteqdot 35^{\circ}$). 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, due to sub-microscopic 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 Relationships

Structure. Few of the dykes are folded, but many are faulted, the most notable examples being the large dykes in the vicinity of Mount Rose and Scrutons Hole. A dyke south-southeast of Scrutons Hole shows sinistral shear displacement of about a half mile. 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 6 miles. Near Mount Hill quartz veins trending approximately east-west have displaced several dolerite dykes dextrally for up to a $\frac{1}{4}$ mile.

East of McSherrys Gap there are notably less dolerite dykes in the Halls Creek Group than in McSherrys Granodiorite, due to differences in ease of fracturing. These differences are well illustrated by the distribution of the large dyke 3 miles 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

Introduction

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

These units excluding Cainozoics are -

Palaeozoic

a. Undifferentiated Devonian-Permian rocks

b. Arkose at Prairie Hill

Mesozoic

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 lamproite occurrences which have been newly discovered and mapped during the present survey, and which occur within or close to the Precambrian belt. One lamproite occurrence, the 81-mile plug, was a new discovery, but is not described here since it is well outside this belt. Similarly, the well known plugs at Mount North and Mount Percy are excluded.

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. The unit crops out as small flat-topped residual outliers (Fig. 15a) in an area one to ten miles south of the King Leopold Ranges, in the vicinity of Mount Broome and Millie Windie Gap. The residuals have irregular outcrop plans and range in area from about 800 square feet to 3 square miles.

The unit consists of quartz grit, coarse-grained quartz sandstone, quartz granule sandstone and basal conglomerate. This sequence is flat-lying, and overlies Lennard Granite unconformably. The uppermost few feet are ferruginized, and appear on the accompanying map as Tertiary laterite. A measured section of the sequence is as follows:

TABLE 6: Measured section, 3600E, 27970N. Measured with Abney level by G. Derrick

Thickness (feet)	eroded top
15	Quartz grit, kaolinitic, massive, faintly bedded; lateritized at surface.
6	Gritty sandstone, fine to coarse-grained
4	Gritty quartz sandstone, white, with abundant kaolinitic or fine-grained siliceous matrix. Some silica enrichment along small joints.
8	Quartz grit, quartz sandstone, granule sandstone, friable, poorly bedded, some graded bedding; kaolinitic and iron-stained; high porosity.
ca 30	Probably conglomerate: scree-slope covered with rounded boulders (up to 12inches), cobbles and pebbles of quartz sandstone, fine to coarse-grained, white to pale purple and tourmaline-bearing.
	UNCONFORMITY base not exposed
ca 63 Total	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 lithologies of the O'Donnell Formation.

Discussion

This sequence of coarse consolidated gravels, grits and sandstones is probably not an ancient river terrace, since it is 500 feet above the present stream level and at least 400 feet above known ancient terraces in the area. The distribution of the unit suggests

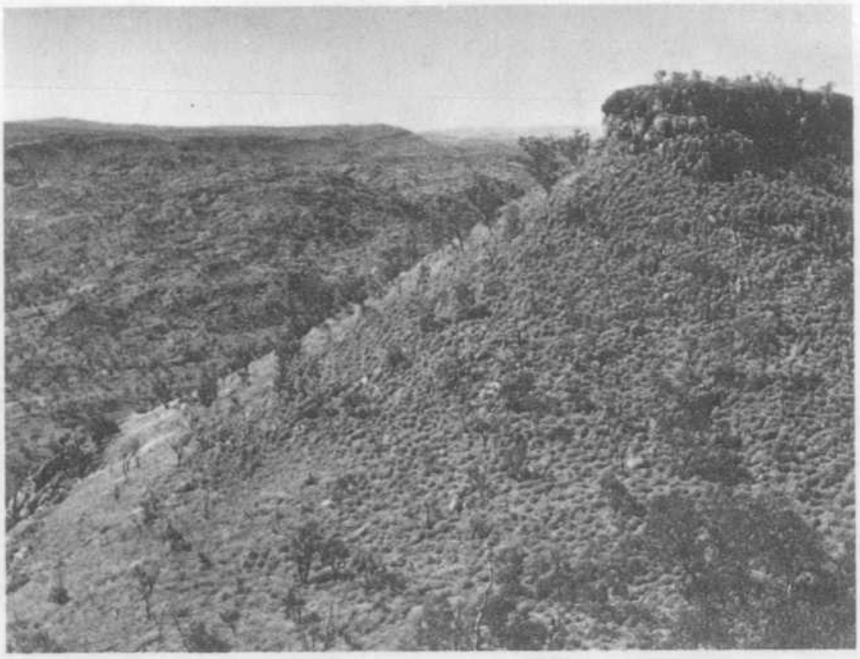


Fig. 15(a) Small residual of lateritised quartz grit (Tp) and conglomerate (D-Pc) in scree slope. Level of residual coincides with tops of granite hills. Sandstone cliffs of the King Leopold Ranges in left background. GMD

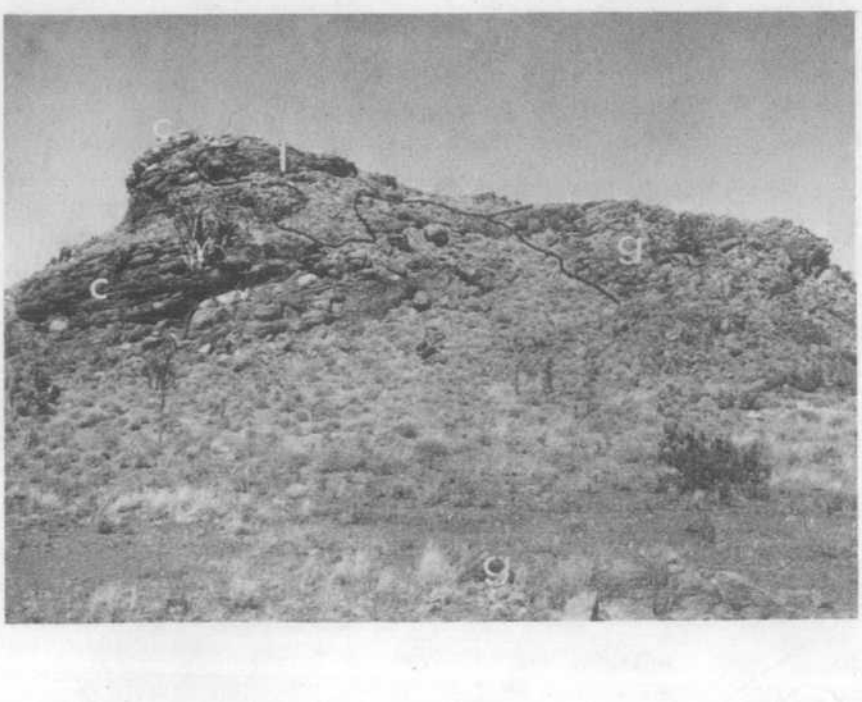


Fig. 15(b) Massive arkose and conglomerate (c) at Prairie Hill, east, overlying granite (g) and intruded by leucitite (l). G. 9612, GMD

At Prairie Hill East, about 2 miles northeast of Prairie Hill, the arkose is intruded by lamproite, of Jurassic age. 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 relationships 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 is older than the 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 7 miles to the south of Prairie Hill, and only soil and alluvium separate the two exposures. The Pillara Limestone is a Devonian back-reef facies, and the distribution of Prairie Hill sequence is in accord with this concept.

MESOZOIC - JURASSIC

LEUCITE LAMPROITES

Introduction

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

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, 3 miles north of Old Leopold yard. The plug shows near-vertical linear and platy flow structure, and sub-horizontal 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 ground mass. 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 1½ miles east of Prairie Hill. It intrudes both Lennard Granite and Devonian sediments which unconformably overlie the granite. A less prominent lamproite crops out near the main plug, and 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 ground mass. 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 100 feet 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 1 inch to 18 inches in diameter, and consist of quartz and feldspar grains, pieces of Whitewater Volcanics and lamproite material.

d. Big Spring

This plug is located in a soil plain about 1 mile east of Big Spring Bore. The only outcrop is a low mound of loose boulder rubble, about 25 feet by 15 feet. 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 unit.

e. Mount Rose Plug

The Mount Rose Plug is located 1½ miles southeast of Mount Rose. It is roughly circular in plan and about 250 feet in diameter.

Flow-foliation near the plug margins generally dips steeply 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 and weathered grey-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 age of the lamproites is Jurassic. Compston (in Prider, 1960) obtained an average value of 145 ± 10 million years, using rubidium-strontium ratios. More recent work by Kaplan et al., (1967) gave a rubidium-strontium age of 150 ± 40 million years, and potassium-argon ratios indicated an Oligocene (32 to 37 million years) age, due possibly to "uplift of the lamproites "from the surrounding peneplain", or possibly to argon loss during weathering.

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 deposits 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 of the Sheet 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 surface deposits, occur around the Hooper Hills, and large barren, vegetation-free areas are common. In the northwest of the Sheet 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, potholed 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 100 feet above the present stream levels, and are generally loosely cemented with ferruginous material. They are possibly outwash gravels from the King Leopold Ranges, and their age is uncertain.

QUATERNARY

Alluvium (Qa) Alluvial deposits that are found along all the major river courses in the area consist of silts, sands, and locally of gravels.

Brown loamy silts form flood-plain deposits flanking the rivers and are commonly well exposed in river banks and erosion gullies. They contain sporadic lenses of coarse grained silty sands and gravels (e.g. on Sandy Creek). Locally, e.g., on the Barker River between Napier Downs and Kongorow Pool, these silts form distinct sandy levees.

Coarse-grained, clean-washed feldspathic and micaceous sands are found in most present-day river beds, especially the Barker, Lennard and Richenda Rivers and Sandy and Hooper Creeks. They are however rare on the Fitzroy River within the Sheet area.

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

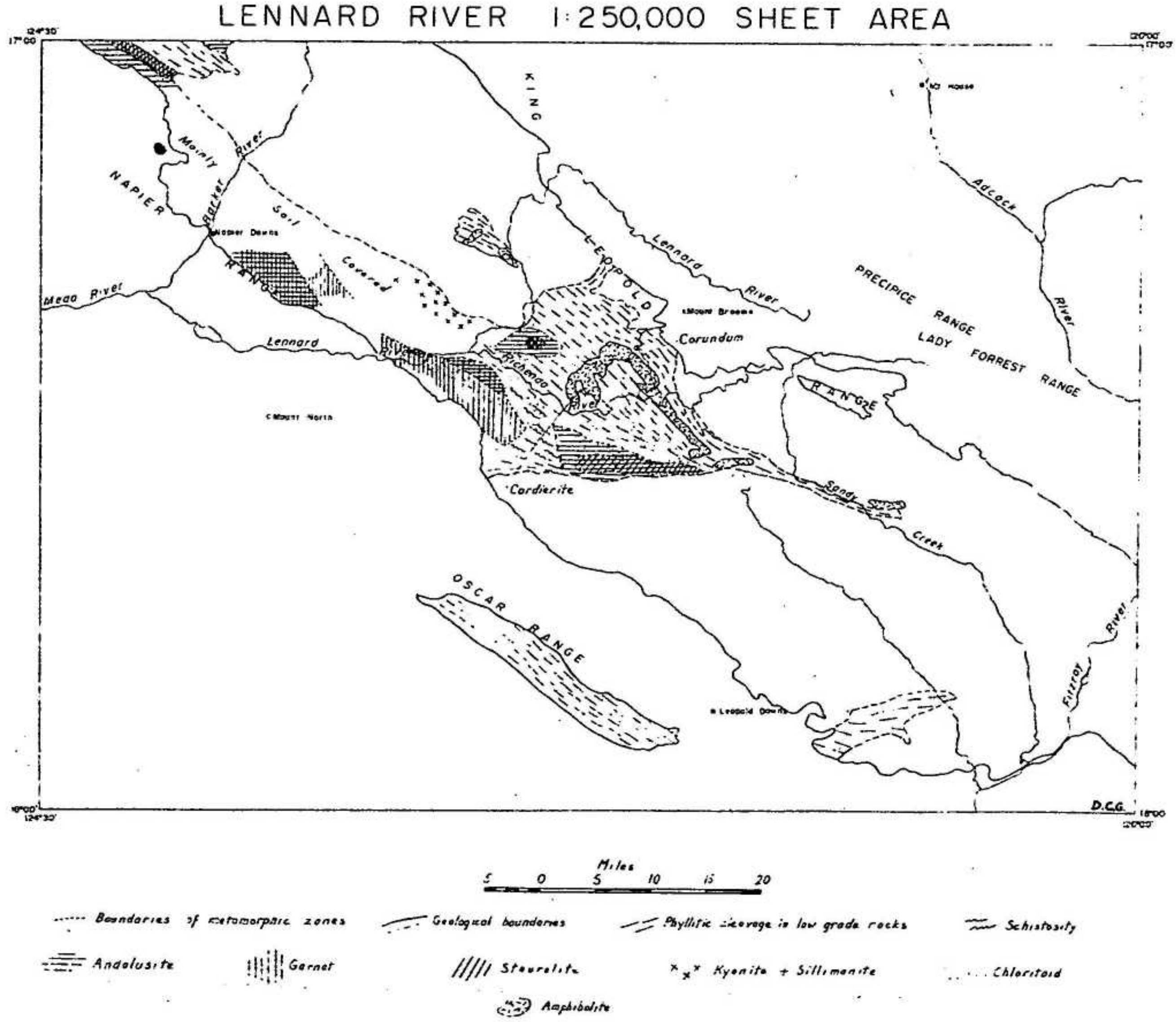
METAMORPHISM

Introduction

In the Lennard River Sheet area the Halls Creek Group has been metamorphosed to varying degrees up to high amphibolite facies. Most of the 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 locally with evidence of intense deformation, e.g., stretching of cobbles in conglomerates in the Oscar Range.

Mineral assemblages within the high and intermediate grade rocks of the Sheet area vary appreciably both across and along strike and reflect local variations in the temperatures and pressures. Relationships 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 followed by moderately high temperature - high pressure, and finally by low temperature - high pressure conditions. Locally two or more phases of elevated temperatures are recognized.

METAMORPHIC ZONES
LENNARD RIVER 1:250,000 SHEET AREA



To accompany Record 1968/126 E51/A8/5

Porphyroblastic potash-feldspar-bearing anatectic gneiss and migmatite near Mount Joseph and gravity-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 in their occurrence 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

(a) 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 south-western 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 one mile 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, since elsewhere in the Sheet there appears to be no direct relationship between metamorphic grade and proximity to granite. There is however a relationship 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; and staurolite is found in both of these environments. These assemblages are listed in Table 7.

(b) 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 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. Also, since 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 non-migmatitic porphyroblastic granodiorite gneiss are found about four miles 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.

TABLE 7 METAMORPHIC ASSEMBLAGES - LENNARD RIVER SHEET AREA

1968/126

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 2 miles north and east of Billyara Yard	1. Garnet - chloritoid - biotite - muscovite - quartz. 2. Garnet - staurolite - biotite muscovite - quartz.	1. Corundum[2] - muscovite[1,2] - biotite - quartz.
Hawkestone 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

NOTES:

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.

Fig. 17(a) Nebulititic potash feldspar and sillimanite-bearing anatectic gneiss; 4 miles west-northwest of Mount Joseph. D.C.G.

Fig. 17(b) Finely banded quartz-feldspar-biotite gneiss intruded by tongues of granodiorite, 7 miles north of Kurrajong Bore. G.M.D.

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.

The non-migmatitic gneisses are massive and commonly show irregular nebulitic flow banding expressed by mafic streaks and lenticles, and by planar distribution of feldspars (Fig. 19a). They are mostly porphyroblastic with scattered ovoid potash feldspar porphyroblasts (up to 2 inches) containing bipyramidal quartz inclusions, tabular 1 to 1¼ inch porphyroblasts of sillimanite, and 2 to 3 inch 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 non-porphyritic granodiorite (similar to McSherrys Granodiorite), of non-porphyritic 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 3 miles long and ¼ mile 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 ½ an inch. It is intruded by tongues of medium-grained granodiorite related to Dyasons Granite (Fig. 19b).

In thin section the finely banded gneiss contains a granoblastic aggregate of quartz, plagioclase (An_{25}) and, very 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 in composition, 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 4 inches long and 1¼ inches across that commonly show 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. About 5 miles southwest of Mount Rose small crystals of pale pink translucent secondary andalusite have been noted in 3-inch diameter pods of altered primary chiastolite. The most intense alteration of andalusite, to pods of coarse-grained, pure white decussate muscovite plus minor corundum, was found mainly on the margins of zones of higher grade metamorphism, e.g., 2 miles east of Hawkestone Creek, and 1 mile north of Billyara Yard, but has also been found near the outer margin of the andalusite zone about 5 miles 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 attributes it to potash metasomatism. However, the Halls Creek Group metamorphics of the Lennard River Sheet area, show no evidence of metasomatism, so that this explanation is unlikely; changes in pressure-temperature conditions were presumably responsible.

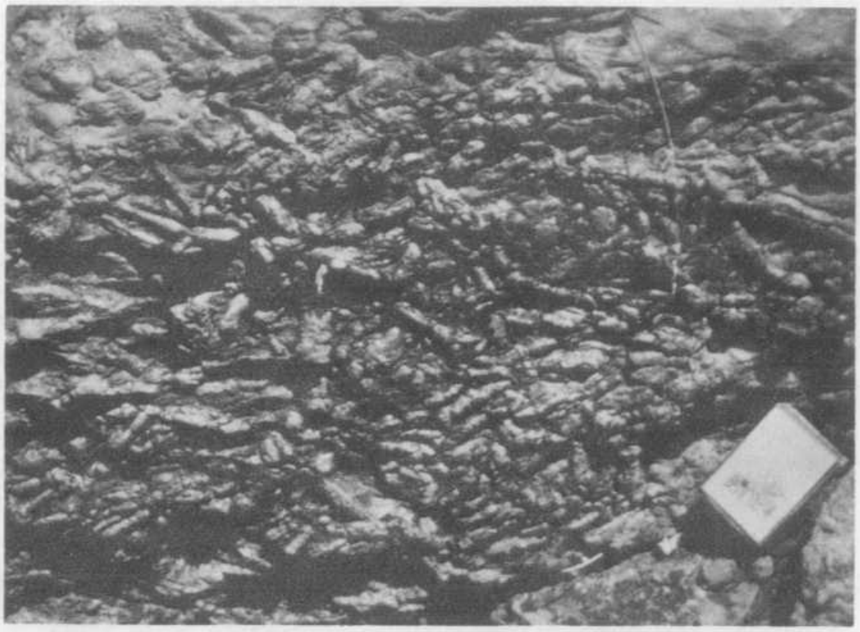


Fig. 18(a) Andalusite pseudomorphs in quartz-mica-schist (Halls Creek Group) six miles north of Mount Behn. DCG

Fig. 18(b) Large pods of corundum, sericite, and biotite (replacing chloritoid) pseudomorphing andalusite in bedded Halls Creek Group metamorphics 5 miles south-southeast of Blackhill Yard. DCG

Stress changes probably played a minor part since alteration of andalusite has taken place extensively in areas in which bedding is well preserved, but changes in hydrostatic pressure due to change in depth of burial may have been important. Experimental data (Ervin and Osborne, 1951) show that in a hydrous environment corundum is stable only above 450°, and gibbsite, boehmite and diaspore below this temperature. This thus 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, 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 to these muscovite-rich lenticles. This breakdown of andalusite,assisted by (if not entirely caused by) deformation, is responsible for the westwards disappearance of andalusite in the vicinity of Dyasons Creek.

Staurolite varies in crystal habit according to the tectonic setting in which it has developed. Those from the eastern-most staurolite zone form short, prismatic crystals up to 2 inches 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 Hawkestone 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 2 miles 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 Hawkestone Creek have sinuous trains of quartz inclusions indicating rotation during growth.

Garnets in the area vary little except in size. They attain a diameter of 2 inches, 3 miles south of Wombarella Yard, but are mostly in the range 1/4 inch to 1/2 inch. Quartz inclusions are common in them, and locally, e.g., ½ mile northwest of Billyara Yard, show classical sinuous trains of quartz inclusions generally interpreted (e.g. Harker, 1951 p. 220-221) as the result of rotation during crystallization.

Garnets that have been marginally, or completely, altered to chlorite (in the Lennard River 2 miles 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 remarkable little alteration, e.g., 3 to 4 miles east of McSherrys Gap a zone of decussate muscovite only 10 feet 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.

Contact metamorphism by the Woodward Dolerite is similarly of low grade and localized in its occurrence. 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 due to the temperature gradient within the contact zone. The origin of the corundum in the Mount Broome area is probably analagous to that of kyanite and corundum at the contact of Woodward Dolerite with the Halls Creek Group near Hawkestone Creek, in the Charnley 1:250,000 Sheet area.

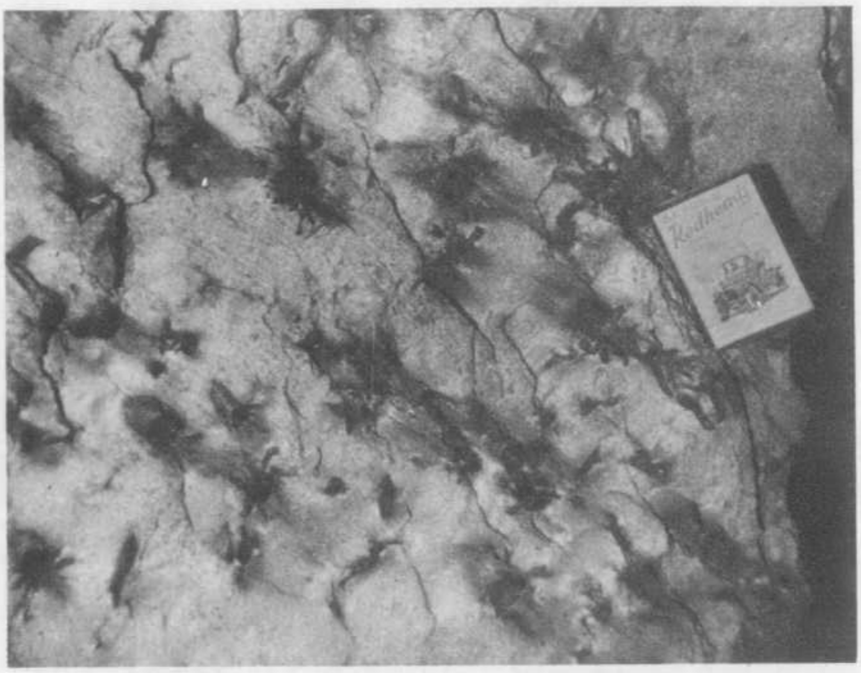


Fig. 19 Garnets surrounded by radiating staurolite crystals in garnet-staurolite-biotite-quartz-muscovite schist 2 miles east of Billyarra Yard. DCG

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 of the thermal type ("Buchan-type" metamorphism). This has been followed by normal 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 states 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

Introduction

The Lennard River Sheet area contains three main structural units: (1) the west-northwest trending King Leopold Mobile Zone (named by Traves, 1955, p.91) flanked on the north by (2) the relatively more stable Kimberley Block, and on the south by (3) 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 Gellatly and Derrick (in prep.) and Plumb (in prep.), and that of the Oscar Range by Gellatly and Derrick (in prep.).

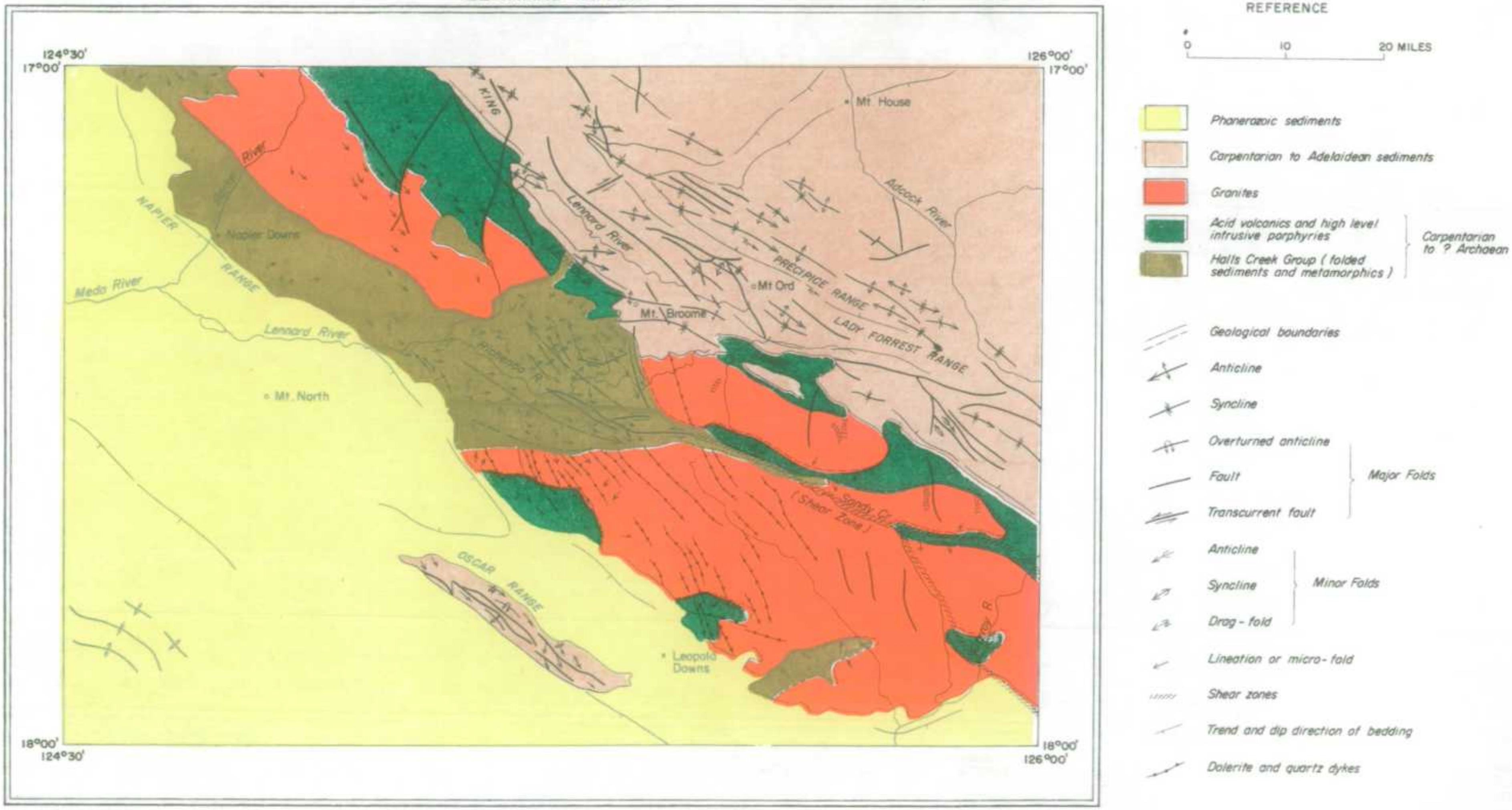
Regional Structure

The limits of the King Leopold Mobile Zone are uncertain. The northern boundary cannot be defined precisely since 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 the dominant one 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 region, north-northeast trending structures are poorly developed, and are 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 to west-northwest or to east-southeast: both of these 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.

STRUCTURAL MAP LENNARD RIVER 1:250,000 SHEET AREA



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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 north-easterly dips of the Kimberley Basin sediments away from the older Precambrian of the central part of the Mobile Zone, and by the south-westerly 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. The granites, in general form batholiths elongate parallel to the trend of the Mobile Zone. Within these batholiths individual plutons similarly 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 Hall Creek Group forms roof pendants within or between the major granite plutons. The structure of these 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 north-westwards 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 north-western 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 north-westwards from the Surprise Creek area suggests that the beds young to the northeast.

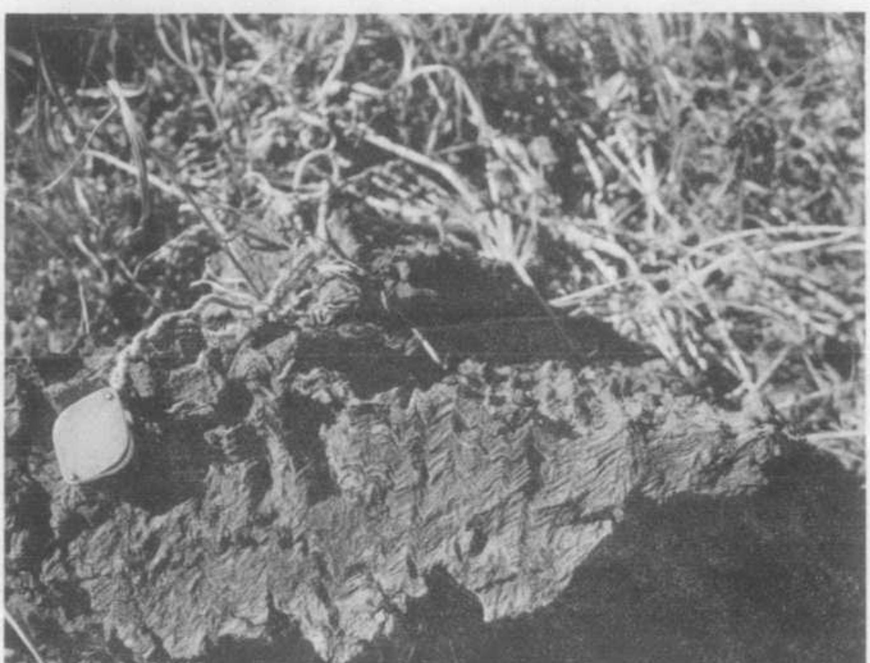
Folds

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 on one or more of these trends.

1. South-southwest plunging and related north-northeast plunging folds are apparently the oldest and are found only in the Halls Creek Group rocks. They are best developed in the area 7 miles 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. The direction of plunge is variously to the south-southwest or to the north-northeast because of later cross-folding about west-northwest plunging axes. Subsequent large scale warping along this north-northeast trend has taken place also in post Kimberley Group times (e.g., Synnot Range Syncline in Charnley 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).

Fig. 21 Contrasted fold styles in the Halls Creek Group
(a) Open style of folding in andalusite-chloritoid-bearing Halls Creek Group, 6 miles south-southeast of Blackhill Yard. These minor folds plunge northeast. DCG



(b) Chevron style crenulation minor folds due to strong cleavage intersecting bedding; andalusite mica schist, 7 miles south-southeast of Blackhill Yard. DCG

Figure 22

Trends of Minor Structures

A. Steeply-plunging west-northwest trending minor structures in Halls Creek Group about 8 miles 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 5 miles southeast of Blackhill Yard. Dots are lineations and microcrenulation folds; crosses are fold axes.

C. Gently plunging fold axes in Speewah Group rocks about 2 miles 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 (see Fig. 23).

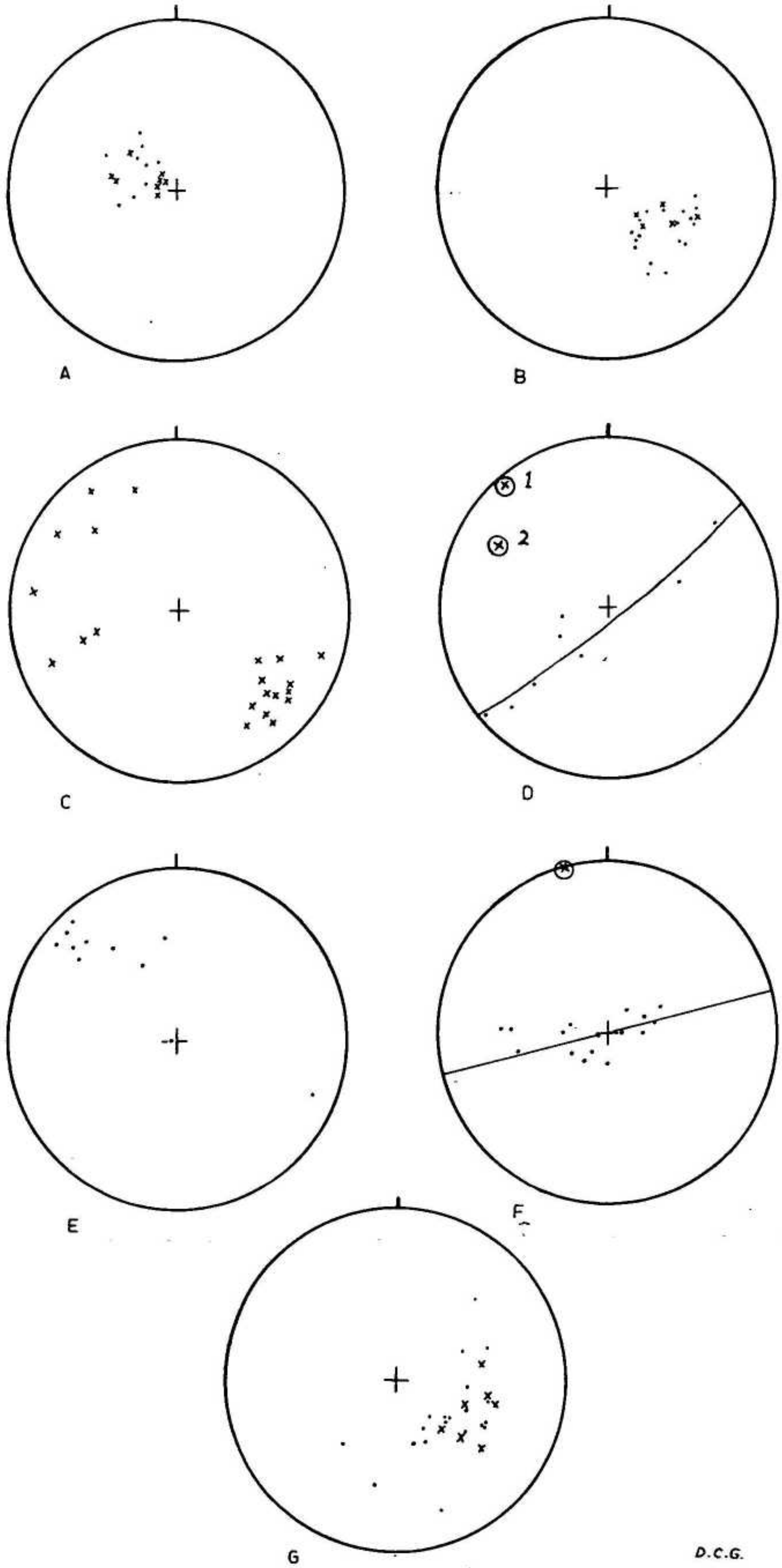
E. Crenulation style lineations in Halls Creek Group near track about 3½ miles west-southwest of Blackhills Yard.

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

G. Minor structures in bedded Halls Creek Group hornfelses about 1 mile northeast of Billyara Yard. Dots are bedding plane intersections; crosses are fold axes and lineations.

TRENDS OF MINOR STRUCTURES

Figure 22



D.C.G.

To accompany Record 1968/126

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2. West-northwest trending folds are found mainly in the Halls Creek Group. Evidence from both the older Precambrian and from the Kimberley Group rocks indicates that the north-northwest plunging folds are distinct from the east-southeast plunging ones, and that the two plunge directions are not the result of refolding of a single system of folds that 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 mostly at about 60° to 300° and can thus be distinguished from post-Kimberley Group northwest plunging folds that 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). Also, cleavage-bedding intersections in the Halls Creek Group about 4 miles 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.

Only the gently plunging minor structures of this trend have been found in the Whitewater Volcanics in the Lennard River area (e.g., 6 miles 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 area (Gellatly, et al., 1965). This suggests that initial folding on steeply plunging west-northwest axes took place prior to the extrusion of the Whitewater Volcanics, and that only local movement on these axes took place after their extrusion.

3. Southeast and east-southeast trending folds and associated minor structures are abundant throughout 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 of upper Adelaidean age. Also, steeply plunging southeast trending lineations are common in the granites, but are apparently absent from the overlying Speewah Group rocks. Thus it appears that at least three periods of folding with this trend are represented in the area.

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 due 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, or locally with an earlier cleavage. Fold axes plunge to southeast or east-southeast at 45° to 50° and axial planes dip to the southwest.

Cleavage

Cleavage is developed throughout the Halls Creek Group rocks 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.

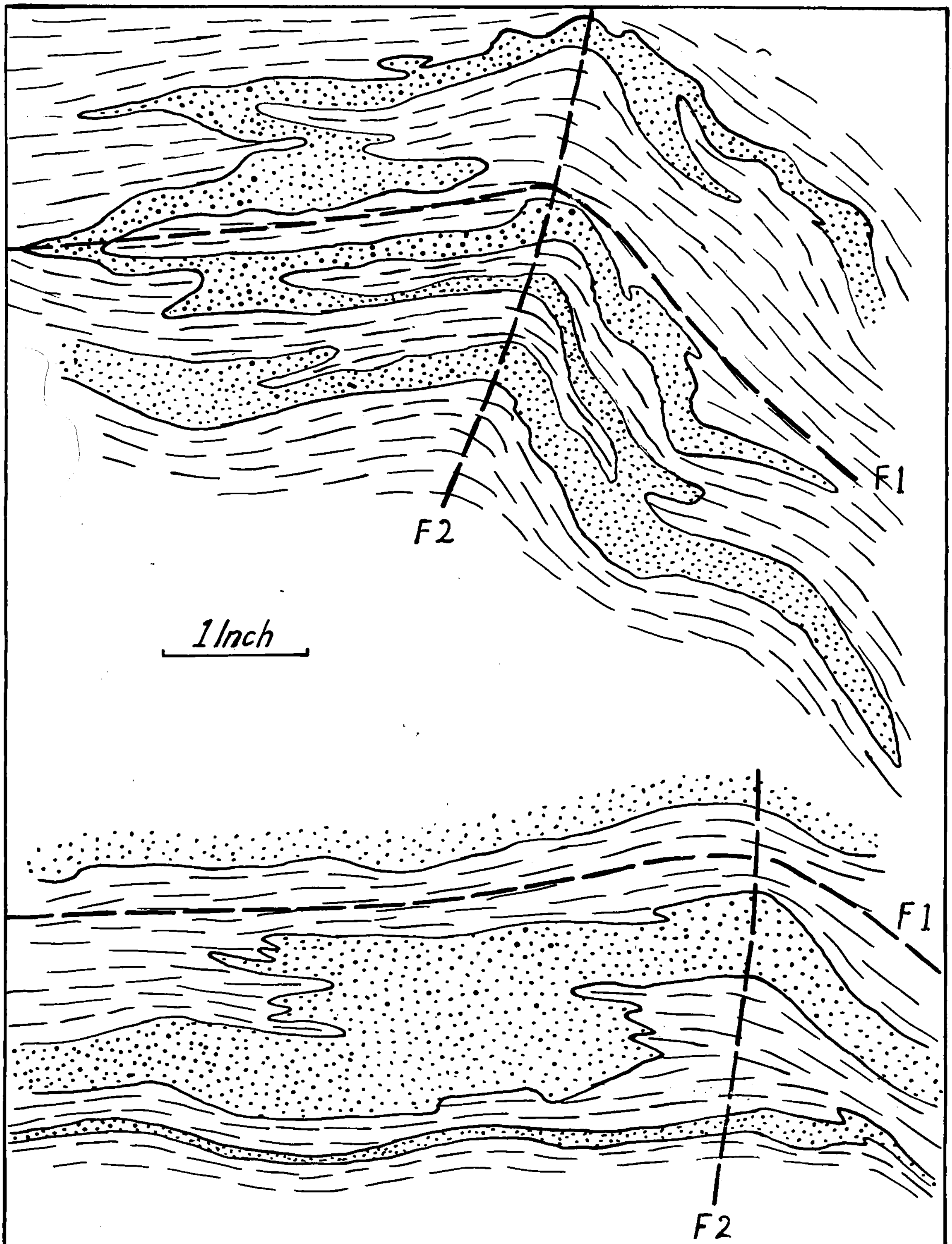


Fig. 23. Refolded isoclinal recumbent minor folds in Halls Creek Group at Dyasons Creek

D.C.G.

In certain localities, especially on Dyasons Creek about a $\frac{1}{2}$-mile from the northern contact of the McSherrys Granite, small-scale isoclinal recumbent folds demonstrate the relationship of cleavage and coincident bedding (Fig. 23). 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 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 post-dates 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 (Fig. 24).

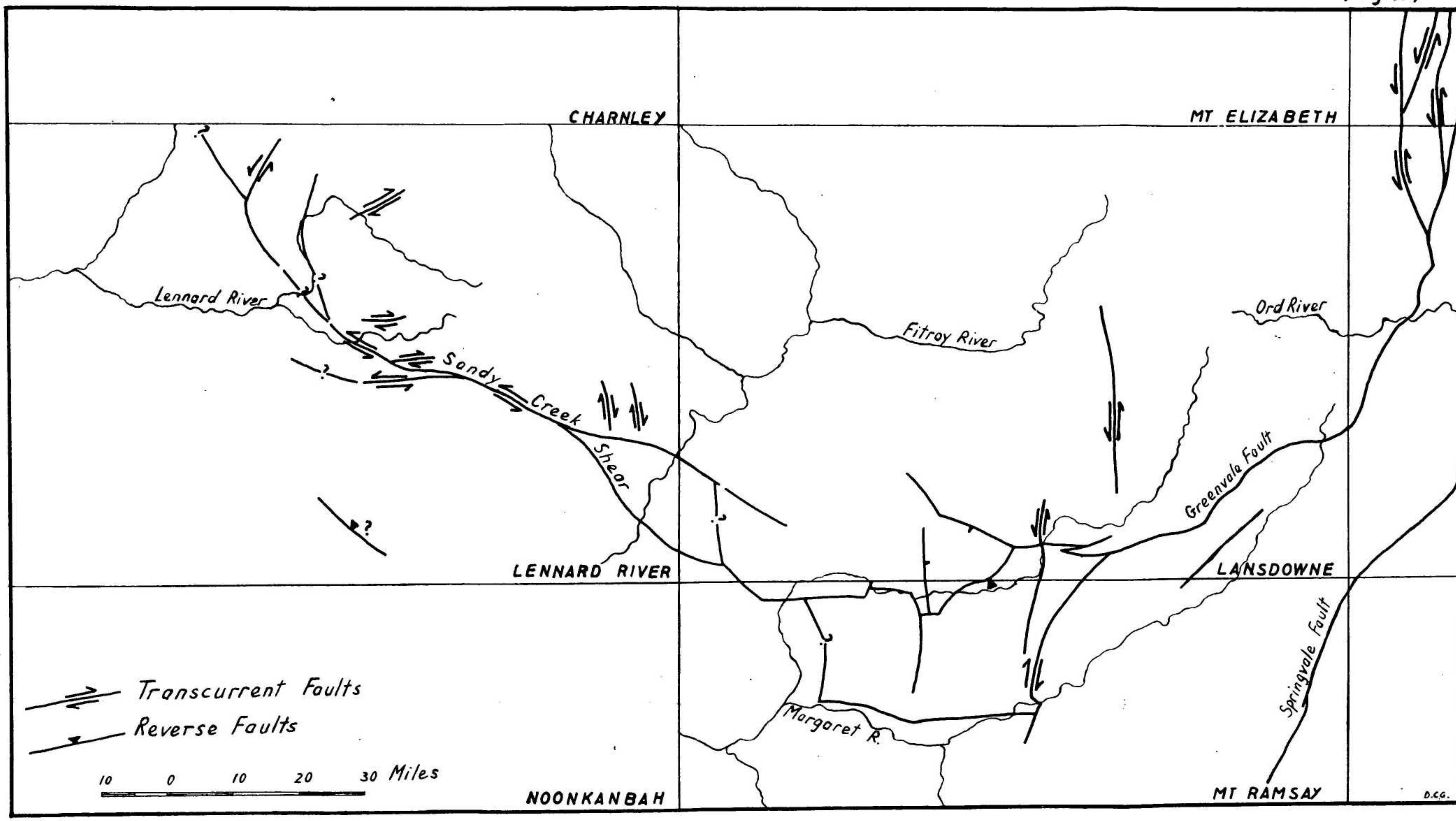
The main fault feature in the Lennard River Sheet area is a west-northwest trending shear zone termed the Sandy Creek Shear Zone. This shear and transcurrent fault system extends from the southeastern corner of the Sheet area to near the northwestern corner, and may possibly extend into the Charnley Sheet area. Along parts of its length this shear system 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 3 miles 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 6 miles. The other north-western 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.

Complimentary transcurrent faults associated with these major shears are well displayed near Coleman's Camp (Fig. 25) and also in the vicinity of the Richenda River corundum deposit. At both localities displacement of sills of Woodward Dolerite enables small movements to be detected. These complimentary shears have dextral displacement and make an angle of about 30° with the principal shear. Accompanying these complimentary 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 Coleman's Camp. They are westward-plunging sinistral drag folds that have near vertical fold axes and a wavelength of about 500 feet.

North-south trending faults and shear zones, found mainly in the granites, especially in the south-eastern part of the Sheet area, are marked by zones of strongly cleaved schistose granite, and show mainly dextral displacement. The cleavage within these north-south 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.,).

Fig. 24.



Principal faults of the Lennard River sheet area showing their relations to those of the East Kimberley.

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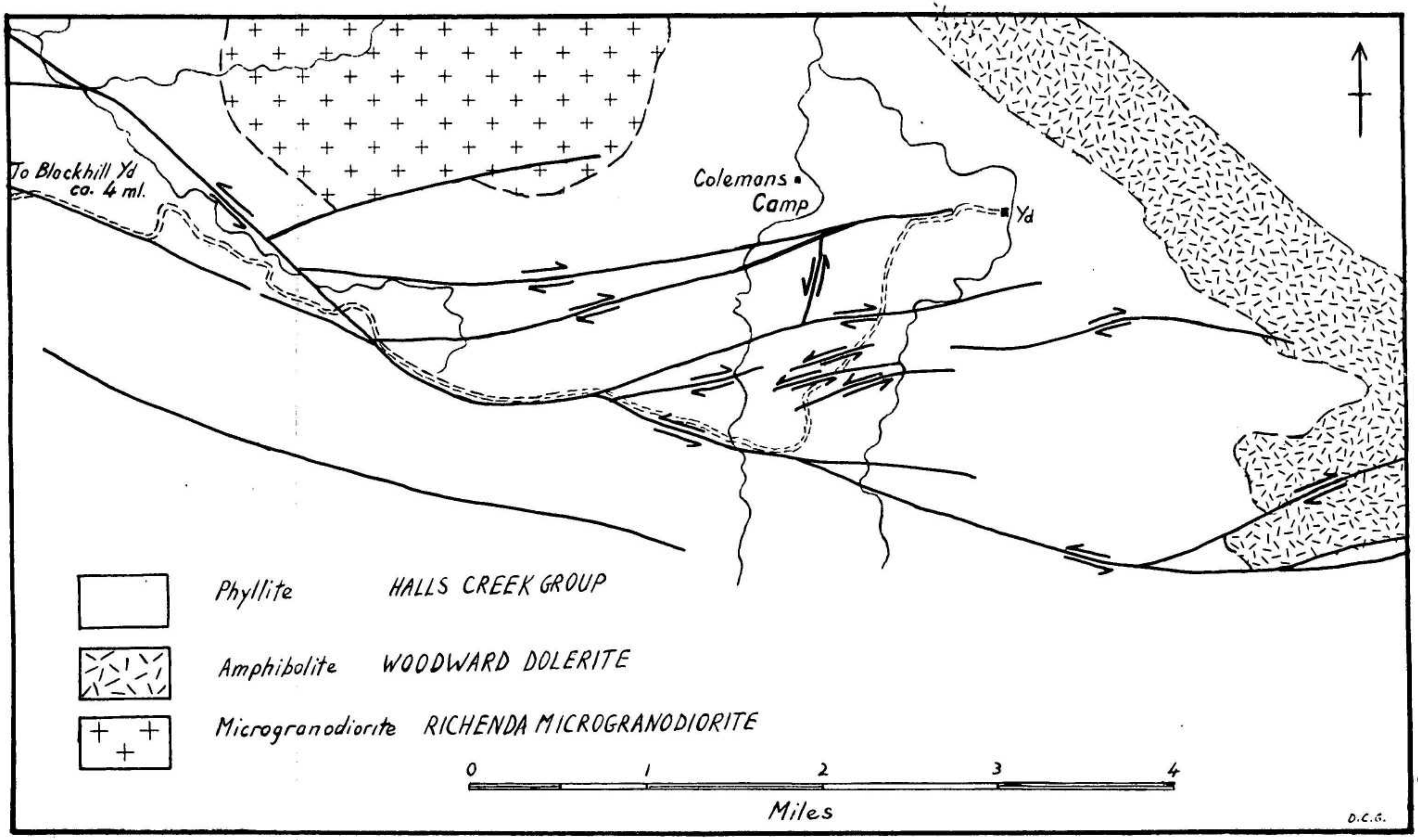

Fig. 25.

TRANSCURRENT FAULT SYSTEM IN THE AREA WEST-SOUTH-WEST OF MT ROSE.

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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 south trend, probably related to the north-south shears.

These joints are either vertical or steeply dipping. In addition a set of low-angle joints that dip gently to north-east 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.

Dykes Trends

The majority of basic dykes in the area 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 on differences of metamorphic grade) with identical trends suggests that the fracture system occupied by the dykes originated prior to their intrusion. If this fracture system is regarded as a tensional one, 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 region closely resembles that of the San Andreas and related faults (e.g., Moody 1966) though the scale and amount of movement in the West Kimberley region are much smaller. Similar tectonics may be inferred, although the whole system of faults in the West Kimberley region cannot be related to a single stress field.

The west-northwest sinistral and east-west dextral shears form a complementary system that could have resulted from east-west compression. The relation of the north-south 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 has probably occurred intermittently throughout the Proterozoic. The main transcurrent movement in the West Kimberley region, however, appears to pre-date the Kimberley Basin sedimentation.

The earliest movements appear to pre-date the Richenda Microgranodiorite and the McSherrys Granodiorite, since 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. Also, the northern margin of McSherrys Granodiorite is a linear, apparently fault controlled feature, but between Daysons 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 pre-dates the Kimberley Basin sedimentation is found a few miles east and northeast of Dromedary Yard, where the contact of Lennard Granite with Whitewater Volcanics shows apparent displacement of about 3 miles, while 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 times, since an eastern branch of the Sandy Creek Shear has deformed O'Donnell Formation sandstones in the Lansdowne Sheet area about 4 miles south of Lindesunjun Waterhole. Post-Kimberley Basin faulting in the West Kimberley region 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 area is summarized in Table 8. This includes events later than the deposition of the Speewah Group, since these are recognizable locally in the older Precambrian. It does not include events that affected the Oscar Range succession, since these cannot be recognized in the older Precambrian, and since they 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

Introduction

There are no mines operating in the area. Minerals produced spasmodically from the region include corundum and emery, cupreous ore, 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) and is not described in this report. Production figures however, 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 covers the older Precambrian rocks of the West Kimberley Goldfield is currently being geochemically prospected for base metals by Pickands Mather International Company Limited.

Although no economic deposits have been located, minor showings of Pb, Cu, Zn, 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 will be described in the Record on that area. (Gellatly and Derrick, in prep.).

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

Groundwater which is utilized for the beef-cattle industry is the principal known mineral resource of the area.

METALLIC AND INDUSTRUAL MINERALS

Lead

Macs Jump Up. Galena with minor pyrite, barite, and fluorite was noted in narrow fault zones cutting Whitewater Volcanics near the main road 1 to 2 miles east of Macs Jump Up. Simpson (1951), also reported the occurrence of lead mineralization in rocks of the Lamboo Complex some 12 miles north of the Narlarla Mine. Neither of the deposits are of economic potential.

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TABLE 8 SUMMARY OF TECTONIC HISTORY - OLDER PRECAMBRIAN ROCKS (LENNARD RIVER SHEET AREA)

ERA	DEPOSITION	IGNEOUS EVENTS	TECTONIC EVENTS	METAMORPHISM	REMARKS
PROTEROZOIC			Transcurrent Faulting		
			Folding along shallow-plunging northwest and southeast axes	Low grade, largely dynamic metamorphism	Only phyllite in Lennard River area, but amphibolite and andalusite granofels in Yampi area
			Gentle folding along shallow-plunging northeast axes		e.g. Synnot Range Syncline in Charnley area: weak in Lennard River area.
		Intrusion of late dolerite dykes			Related at least in part to Hart Dolerite
	Deposition of Speewah and Kimberley Groups	(Extrusion of Carson Volcanics)			
	UNCONFORMITY - MAJOR PERIOD OF EROSION				Complete removal of Whitewater Volcanics locally
PROTEROZOIC			Folding along steep-plunging southeast axes	Mild metamorphism: marginal alteration of dolerite dykes	Foliation and lineation developed in granites
		Intrusion of early dolerite dykes			Relative order uncertain
		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			
			Faulting (partly transcurrent?)		Possible fault control of margins of granite 4 miles southeast of Dromedary Yard, and east of McSherrys Gap
		Intrusion of Bickleys and Mount Disaster Porphyries, and Mondooma Granite			
		Extrusion of Whitewater Volcanics			
	UNCONFORMITY - PERIOD OF EROSION				Cobbles of Woodward Dolerite in conglomerates near base of Whitewater Volcanics
		?Intrusion of early phases of Kongorow Granite, and Richenda Microgranodiorite			
			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		
		Intrusion of Wombarella Quartz Gabbro			
		Intrusion of Woodward Dolerite			
			Folding along steep northeast axes	?Metamorphism	Andalusite in rocks with only northeast minor folds
ARCHAEAN	Deposition of Halls Creek Group sediments	Minor acid vulcanicity			

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TABLE 9 MINERAL PRODUCTION LENNARD RIVER 1:250,000 SHEET AREA WEST KIMBERLEY GOLDFIELD

(as reported to Mines Dept., Western Australia to December 1966)

Mineral	Centre	Holding	Name of Lease or Holder	Period	Quantity Long Tons	Metallic Content	Value $ Aust.
Beryl	"Napier Downs Stn" (Probably Stuart's mica-Beryl mine Yampi Sheet area)	Crown Lands	Sundry Persons			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
Cupreous Ore	Patterson Range [1]	P.A.74	Latham A.			Assay Cu%	
				1961	3.10	17.07	254.00
Corundum	Mt. Broome	M.C.38	Clackline Ref.Ltd.	1955	9.15	-	550.00
Emery	Mt. Broome	M.C. 38	Clackline Ref.Ltd.	1955	8.15	-	490.00
	Richenda	T.R.1110H	West. Aust. Govt.	1942	13.00	-	260.00
				Total Emery	21.15	-	750.00
Lead ore & concentrates	Napier Range	M.C.29	Devonian Pty.Ltd.	1948-1955	1844.14	Lead (Long tons) 731.00; Zinc (Long tons) 342.37; Silver (Fine ozs) 13,630.87	93,467.20
	"	"	" "	1964-1966	9015.21	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	10859.35	Lead (Long tons) 2,082.062; Zinc (Long tons) 2,821.72; Silver (Fine ozs) 37,373.13	505,745.40
Mica	Napier Downs Stn	P.A.58 [2]	Stuart J.	1949	lbs 312		9.24
Tin Concentrate	Patterson Range	Sundry Claims [3]	Sundry Persons	1951-1952	tons .30	Tin (Long tons) .23	469.50
	" "	Sundry Claims [3]	Sundry Persons	1955	.13	.09	158.06
				Total Tin	.43	.32	627.56
Wolfram	Napier Range	M.L.146H [3]	Taylors Wolfram Reward	1909-1910	27.00	200.00	240.00
	Napier Range	M.C.28 [3]	Kimberley Metals	1940	1.48	79.68	422.50
				Total Wolfram	28.48	279.68	662.50

1 Locality uncertain possibly Charnley 1:250,000 Sheet area.
2 Probably from Stuarts Mica Mine, Yampi 1:250,000 Sheet area.
3 Probably from King Sound Tin Mine Charnley 1:250,000 Sheet area.

Bigelleas Yard: Galena has been reported from the Bigelleas Yard locality by Guppy et al., (1958), and Harms (1959). The deposit is located 2 miles north of Bigelleas Yard, at the southern end of a razorback about 80 feet high. The razorback cuts foliated biotite granite and trends north-south, while 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 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 three miles northeast of Old Leopold Yard. The reef is 12 to 18 inches wide, and trends north-south for about 1800 feet. Country rock is sheared Chaneys Granite or Bickleys Porphyry.

Copper

Richenda River area.

Blocks of malachite-bearing limonitic gossan up to 2 feet across have been found in a creek bed at 3190E, 28087N, about $\frac{1}{2}$ a mile 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 5 miles 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 70 feet x 13 inches to 134.46 dwt per ton over 13 feet x 18 inches. Most values are less than 10 dwt per ton. These reefs have recently been worked by Mr. J. Stewart who reports the association of antimony (stibnite) with the gold in thin leaders in the area about 1½ miles southwest of Coleman's 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) 4 miles southwest of Mount Broome
(2) Between half and one mile northwest of (1)
(3) Near Mount Rose

During the recent survey corundum was located at (3198 E 28090 N)about 7½ miles southwest of Mount Broome, which is probably the deposit referred to by Forman as being 4 miles southwest of Mount Broome (see Fig. 26). Detrital corundum was also noted in a creek bed about 1 mile west of this locality, but the deposit near Mount Rose was not found.

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* 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.

The deposit examined consists of blocks of massive pale grey corundum rock up to 2 feet 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 1200 feet, 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 $\frac{1}{8}$ inch to $\frac{1}{4}$ inch 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_2 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.

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%	x	x
Margarite	-	-	-	x
Kyanite	6.9	x	-	-
Sillimanite	-	-	x	-
Calcite	-	-	x	-
Grossularite	2.4	-	-	-
Rutile	0.2	x	x	x
Ilmenite	4.9	-	-	-
Iron oxides	-	x	x	-
Carbon	0.5	-	-	-
Grain size		0.2 to 0.5 mm	0.015 -0.045mm	0.65mm
Remarks	Hard and sharp	angular grains	usable as fine abrasive	-

☒ major constituent;
x minor constituent

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.

In view of the small size of the deposit, 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.

GEOLOGICAL SKETCH MAP OF RICHENDA RIVER CORUNDUM DEPOSIT

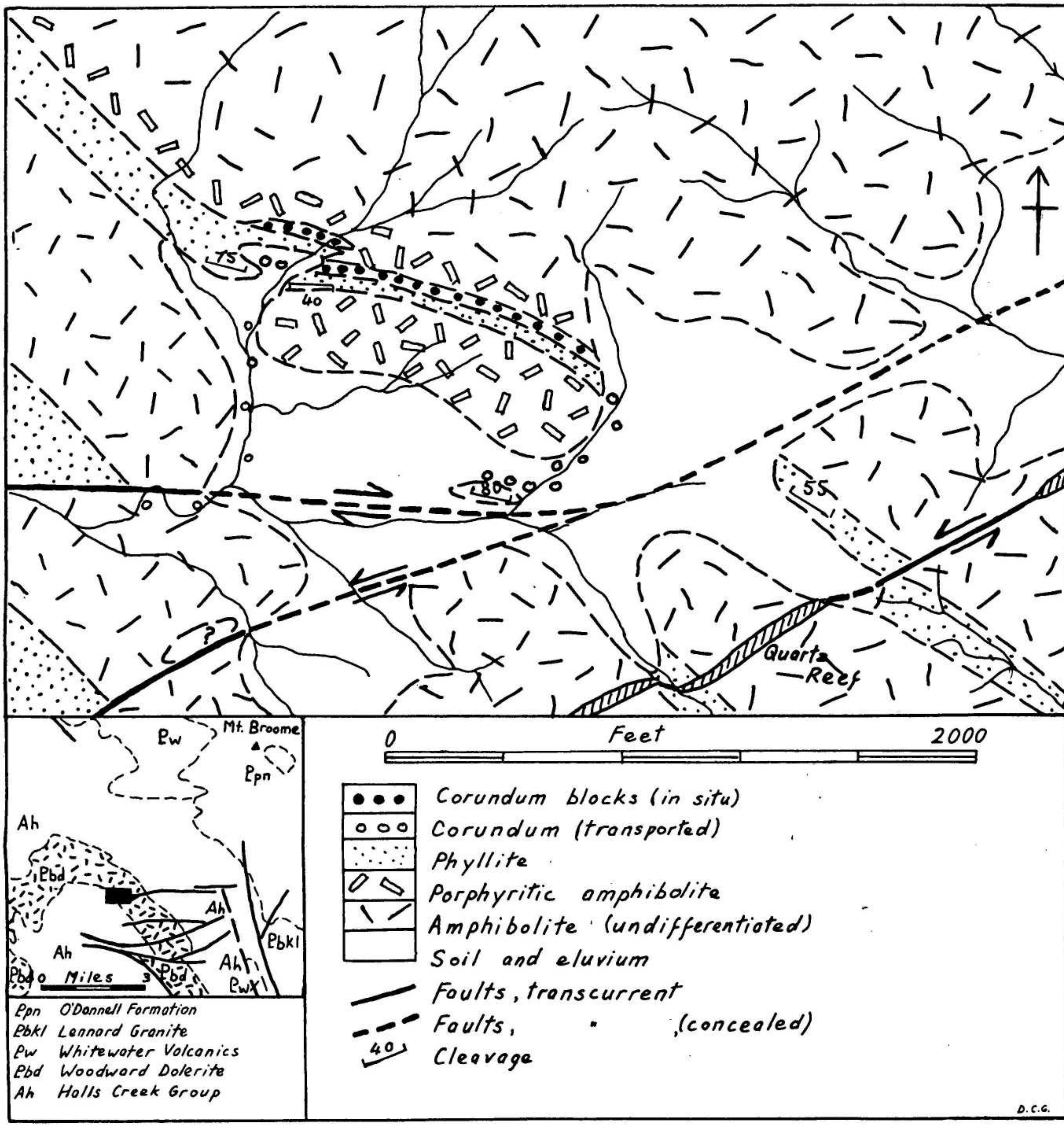

Fig. 26.

In its geological setting at the lower contact of a sill of Woodward Dolerite with low grade Halls Creek Group phyllite, the Richenda River corundum deposits are similar to the Hawkstone Creek kyanite deposits (Derrick and Morgan, 1966). The mineral assemblages are similar (corundum, diaspore and kyanite), the only significant difference being in the relative proportions of the minerals present. In view 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 in the vicinity of Dyasons Creek by Finucane (1939). Both occur near the northern margin of a major granite intrusion (Fig. 27) about 10 and 11 miles respectively east of McSherrys Gap.

The more easterly deposit is a pegmatite dyke in medium-grained leucocratic granite (Dyasons Granite). Finucane (1939) records values of 0.09% SnO_2 over a length of 350 feet and an average width of 14 inches.

The more westerly one consists of tin-bearing gravels in a small creek valley on the north side of Waggon Flat. Finucane reports 734 cu. yards of wash containing 0.12 lbs SnO_2 per cubic yard.

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 Sn concentrations found in the stream sediment samples was 8 p.p.m. There seems little likelihood of economic deposits in this area.

Mica

A pegmatite dyke about 6 miles northeast of Napier Downs Homestead and $1\frac{1}{2}$ miles 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.A.'s 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 and Jones (1939), Simpson (1952), Harms (1959), and Sofoulis (1966). The deposit could yield a small quantity of high grade muscovite.

Harms (1959) recorded abundant muscovite up to 3 inches by 3 inches in pegmatite, from the Mount Joseph area and suggested further prospecting for larger sheets.

Beryl

Small crystals of beryl were noted in the dumps at Gussy's Mica Mine, 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 3 miles 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.

To accompany Record 1968/126.

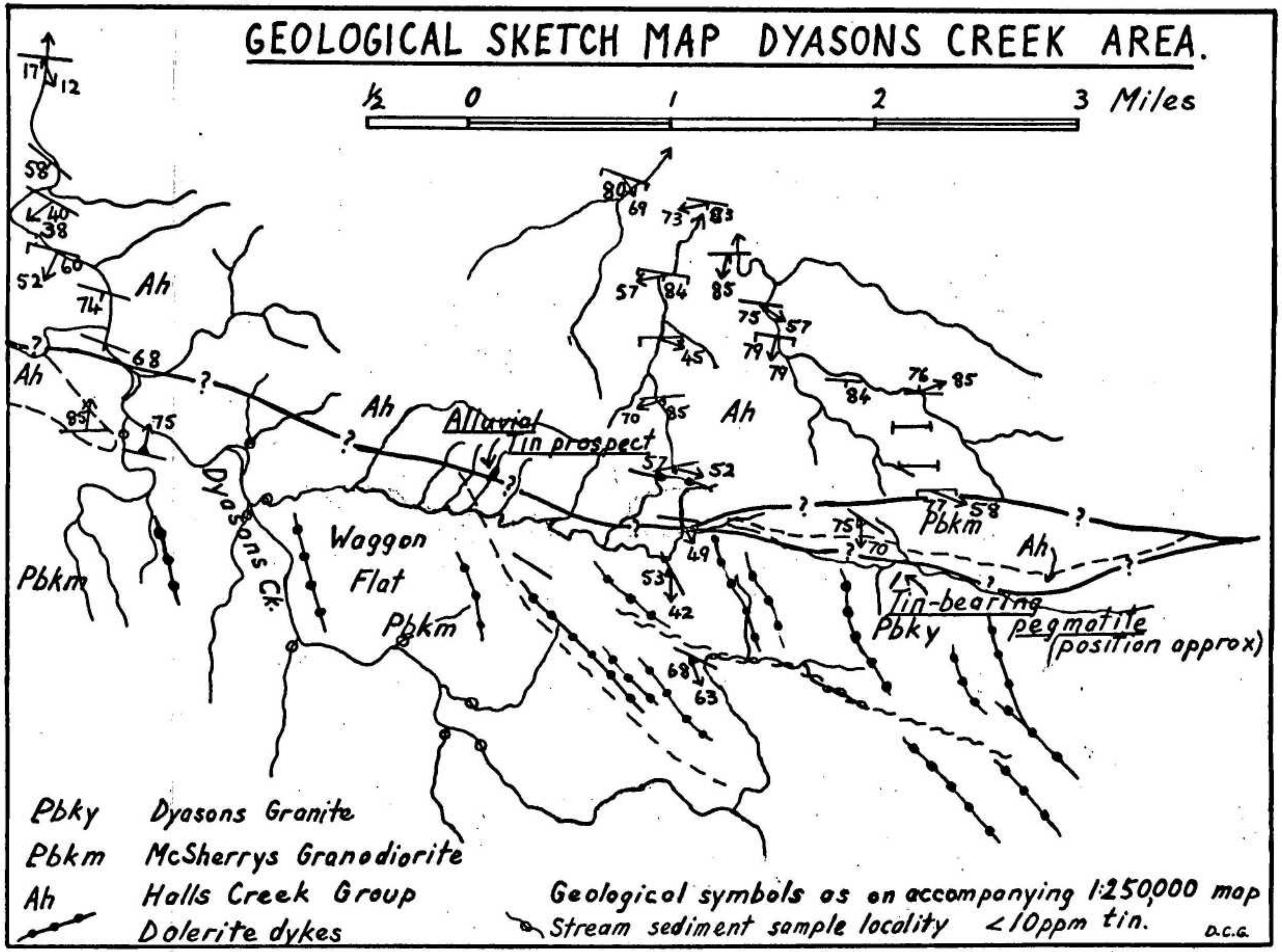

Fig. 27.

E 51/A8/11.

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 analyzed spectrographically for Sn, W, Mo, Cu, Pb and Zn. Slightly anomalous lead values were noted in most of these specimens and slightly anomalous tin values were found in some specimens from the Yampi Sheet area (Sofoulis, et al., 1969). 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. Rept. 2598/67

- indicates 'less than'

CONSTRUCTION MATERIALS

Road Metal is quarried from the Devonian reef complex about 10 miles 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, who have a mobile crushing unit at the site.

The quarry face is now 120 feet wide and 30 feet deep, and the quarry floor rises to surface level approximately 150 feet from the quarry face.

The quarried material consists of thin banded, jointed and blocky crystalline limestone in blocks up to 5 by 4 by 3 feet. This material is crushed and sized and used on road metal in bitumen-sealing operations on the Derby-Fitzroy Crossing road.

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

WATER SUPPLY

Rainfall in the Lennard River Sheet area ranges from 20 inches in the south to 28 inches in the northern part of the area. It is mainly confined to the period November to April. Potential annual evaporation is approximately 100 inches.

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

The area is divided into four hydrological divisions, the 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 of the Sheet area has been discussed by Allen (1966). That of the Fitzroy Plains and Fitzroy Ranges has been described by Guppy et al., 1958), Playford & Lowrie (1967) and further notes 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 water holes, and rock holes 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 sandstones, 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 100 feet. 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 limestones overlie weathered metasedimentary rocks. Reliable supplies have been obtained both from basal Devonian sediments and from metamorphic sandstones.

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APPENDIX I

STRATIGRAPHIC NOMENCLATURE SUBMISSIONS

The following pages document the submissions approved by the Western Australian Sub-Committee (of the Geological Society of Australia) for Stratigraphic Nomenclature, for newly named rock units with type areas lying within the Lennard River 1:250,000 Sheet area. Minor amendments have been made, to bring the submissions up to date with the results of further mapping.

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 Jump Up, and 2 miles south of Wombarella Yard. The quartz-gabbro mass lies to the south-west of the Jump Up and the main tonalite outcrop to the east and south-east 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	2 miles south-west of Stumpys Jump Up (quartz-gabbro-2710E, 28348N), 3 miles east-south-east of Stumpys Jump Up (tonalite - 2783E, 28358N).
Mode of Occurrence	The quartz-gabbro forms a small layered lopolith, elliptical in outcrop, approximately 3 miles by 2 miles. The tonalite forms a small intrusion to the east, whose form is unknown.
Relationships	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 post-date the Quartz Gabbro. The tonalite is cut by numerous aplo-pegmatite dykes.
Distinguishing Features	The basic to intermediate nature of these rocks and the presence of orthopyroxene in them 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 Sheet areas
Derivation of Name	From Kongorow Pool on Barker River, 7 miles north-east of Napier Downs Homestead.
Lithology	A foliated grey-black (mottled) porphyritic biotite-rich granite. Discrete tabular feldspar phenocrysts mostly 1 cm to 5 cms 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 south-eastern part of the Lennard River Sheet area.
Topography	Rounded whalebacks and prominent stocks. Relief to 250 feet. 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, 10 miles east-southeast of Stumpys Jump Up (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 10 miles across. Elsewhere the Kongorow granite occurs mainly as dykes and veins.
Relationships	Locally intrudes Lennard and Chaneys Granites, and Wombarella Quartz Gabbro. Parts of Kongorow Granite probably pre-date these. Intrusive into Halls Creek as large masses and as small discrete bodies. Intruded by quartz, aplite, tourmaline-pegmatite and quartz dolerite dykes.
Distinguishing Feature	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 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 non-porphyritic biotite microgranodiorite; minor biotite-hornblende microgranodiorite and microtonalite. Average grain-size 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 Blackhills Yard and about 5 miles west of Richenda Gorge in the Lennard River Sheet area; also small outcrops about 2 miles 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, 1 mile northeast of Blackhills 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.
Relationships	The Richenda Microgranodiorite cuts Halls Creek rocks and is itself intruded by dykes and a cone sheet of rhyolite. Relations with other types are uncertain, but it probably post-dates Mondooma Granite and McSherrys Granite.
Distinguishing Features	The medium-grained non-porphyritic texture and moderately dark grey colour distinguish this from all other granitic 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	LENNARD GRANITE
Sheet Area	Lennard River, Yampi 1:250,000 Sheet areas.
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 - 3 cms 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 south-western part of the Charnley Sheet area; extensive in the south-eastern part of the Yampi Sheet area, and as far west as Mount Nellie.
Topography	Rounded whalebacks and prominent hills. Relief up to 300 feet. Main masses usually as elongate ridges parallel to regional northwest structural trend. Also as low rock pavements and as rough low stoney hills interspersed with sandy pediments. Dissection and drainage locally controlled by prominent joints.
Reference Area	In the Lennard River Sheet area, 7 miles east-south-east of Stumpys Jump Up (2840E, 28380N).
Mode of Occurrence	As plutonic intrusions up to 15 miles across; outcrops are generally elongate parallel to the trend of the King Leopold Mobile zone.
Relationships	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	McSHERRY'S GRANODIORITE
Sheet Area	Lennard River 1:250,000
Derivation of Name	From McSherry's Gap, near the centre of the Lennard River Sheet area. (2960E, 27920N).
Lithology	Grey medium to coarse-grained porphyritic to even-grained hornblende granodiorite, tonalite, minor adamellite and quartz gabbro.
Distribution	As south-east trending plutons in the central south-eastern and far north-western parts of the Lennard River Sheet area; south-west corner of Charnley Sheet area, and south-east corner of Yampi Sheet area in the vicinity of 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. Vicinity of 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.
Relationships	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 south-eastern 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 McSherry's Granodiorite have been observed on a small scale.
Age	Proterozoic

Name of Unit	DYASONS GRANITE
Sheet Area	Lennard River 1:250,000
Derivation of Name	From Dyasons Creek near the centre of the Lennard River Sheet area.
Lithology	Leucocratic medium to fine-grained, 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	Seven miles east of Dyasons Creek (3230E, 27890N).
Mode of Occurrence	Elongate stocks, dykes
Relationships	Intruded by dolerite dykes and Mount Amy Granite, and intrudes McSherry's Granodiorite.
Distinguishing Features	Leucocratic nature and grain size.
Petrological Affinities	Possibly aplitic derivatives of McSherry's Granodiorite.
Age	Proterozoic

Proposed Name	MOUNT AMY GRANITE
Sheet Area	Lennard River 1:250,000 Sheet Area.
Derivation of Name	From Mount Amy, 2700E, 28402N, which is close to exposures of Mount Amy granite.
Lithology	A grey-pink non-porphyritic coarse to medium-grained leucocratic biotite granite, commonly aplitic. Generally homogeneous, muscovite-bearing and non-foliated.
Distribution	Scattered outcrops around Mount Amy and Dromedary Yard; also about 12 miles east of Tunnel Bore, and about 4 miles north of Lily Hole Yard in the south-eastern part of the Lennard River Sheet area.
Topographic Features	Low rounded hills, rock pavements. Usually flanked by granites more prominent topographically.
Reference Area	In the Lennard River Sheet area, 5 miles northeast of Mount Amy (2760E, 2846N.).
Mode of Occurrence	As small intrusive stocks, cut locally by numerous endogenetic aplite and pegmatite veins.
Relationships	Believed to intrude Lennard and Kongorow granites and is probably one of the youngest granites of the Lamboo Complex. In the south-eastern part of the Lennard River Sheet area, occurs in association with McSherrys Granodiorite and intrudes Whitewater Volcanics.
Distinguishing Features	The leucocratic nature and the non-porphyritic 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.

APPENDIX 2

Measured Sections of Woodward Dolerite

W1. Measured section of Woodward Dolerite 8 miles west-southwest of Mount Broome (3155E, 28100N). (Distances paced; measured by D.C. Gellatly).

Thickness (feet)	Phyllite (Halls Creek Group)
- - - - -	- - - - - - - - - - - - - - - - - - - -
214	Amphibolite; fine to medium-grained, non-porphyritic.
40	Amphibolite; fine-grained, porphyritic with $\frac{1}{8}$ in. to $\frac{1}{4}$ in. feldspar phenocrysts.
179	No exposure
719	Amphibolite; medium-grained, non-porphyritic
52	Amphibolite; coarse-grained, porphyritic with $\frac{1}{8}$ in. to $\frac{1}{4}$ in. phenocrysts of amphibole, and $\frac{1}{2}$ in. phenocrysts of feldspar.
195	Amphibolite; coarse-grained, porphyritic with $\frac{1}{8}$ in. to $\frac{1}{4}$ in. phenocrysts of amphibole: amphibole phenocrysts become coarser upwards.
359	Amphibolite; fine-grained non-porphyritic amphibolite
183	Amphibolite; massive, medium-grained, porphyritic with $\frac{1}{4}$ in. to 1 in. feldspar phenocrysts: phenocrysts rare near base of layer and increase in abundance upwards; contact with underlying non-porphyritic amphibolite is apparently sharp.
303	Amphibolite; massive, fine to medium-grained, non-porphyritic.
81	Amphibolite; massive, medium-grained, porphyritic with rare $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.
155	Amphibolite; massive, medium-grained, porphyritic with scattered $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.
89	Amphibolite; massive, medium-grained, non-porphyritic.
230	Amphibolite; massive, medium-grained, porphyritic with abundant $\frac{1}{4}$ in. to 1 in. feldspar phenocrysts.
- - - - -	- - - - - - - - - - - - - - - - - - - -
36	Phyllite; pale-grey, hornfelsed
- - - - -	- - - - - - - - - - - - - - - - - - - -
33	Amphibolite; massive, medium-grained, non-porphyritic

111 <u>Amphibolite</u>; massive, medium-grained, porphyritic with $\frac{1}{4}$ in. to 1 in. feldspar phenocrysts.

174 <u>Amphibolite</u>; massive, fine to medium-grained non-porphyritic

67 <u>Amphibolite</u>; massive, medium-grained, porphyritic with scattered $\frac{1}{4}$ in. to 1 in. feldspar phenocrysts.

327 <u>Amphibolite</u>; massive, medium-grained, non-porphyritic.

317 <u>Amphibolite</u>; massive, medium-grained, porphyritic with scattered $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.

- -

10 <u>Hornfels</u>; very fine-grained, dark grey.

294 <u>Phyllite</u>; grey, biotite rich, pelitic.

- -

27 <u>Amphibolite</u>; massive, medium-grained, porphyritic with abundant 3 mm hornblende phenocrysts.

59 <u>Amphibolite</u>; massive, medium to coarse-grained, porphyritic with abundant 1 in. to $1\frac{1}{4}$ in. feldspar phenocrysts; phenocrysts make up about 50% of the rock.

141 <u>Amphibolite</u>; massive, medium-grained, non-porphyritic.

147 <u>Amphibolite</u>; massive, medium-grained, porphyritic with abundant 3 mm hornblende phenocrysts, and scattered phenocrysts and glomeroporphyritic aggregates of plagioclase up to $1\frac{1}{2}$ inches.

30 <u>Amphibolite</u>; massive, medium-grained porphyritic with 3 mm hornblende phenocrysts.

- -

- -

223 <u>Phyllite</u>; dark grey, finely cleaved, phyllitic shale.

- -

546 <u>Amphibolite</u>; massive, coarse-grained, non-porphyritic; contains large (ca 1 in.) poikilitic feldspars visible in hand specimen; becomes more mafic towards margins.

- -

45 <u>Phyllite</u>

- -

90 <u>Amphibolite</u>; massive, medium-grained, non-porphyritic; contains a pale green amphibole.

15 <u>Amphibolite</u>; strongly cleaved, phyllitic, biotite-bearing, non-porphyritic amphibolite.

- -

Phyllite; strongly cleaved, fine-grained, semi-pelitic, bedded sericite phyllite.

W2. Measured section of Woodward Dolerite, Richenda River, 3 miles west of gorge (3241 E, 28300 N). Distances paced; measured by D.C. Gellatly.

Thickness (feet)	
	- - - - - - - - - - - - - - - - - - - -
	Phyllite; pale grey, hard, flaggy, phyllitic siltstone.
	- - - - - - - - - - - - - - - - - - - -
285	Amphibolite; massive, medium-grained, porphyritic, with $\frac{1}{4}$ in. feldspar phenocrysts.
1023	Amphibolite; massive, medium-grained, non-porphyritic.
396	Amphibolite; massive, medium-grained, porphyritic, with $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.
408	Amphibolite; massive, medium to fine-grained, non-porphyritic.
204	Amphibolite; massive, medium-grained, porphyritic, with abundant $\frac{1}{4}$ in. to 1 in. feldspar phenocrysts.
	- - - - - - - - - - - - - - - - - - - -
321	No exposure
9	Phyllite; pale grey fissile, phyllitic shale
	- - - - - - - - - - - - - - - - - - - -
9	Amphibolite; flaggy, foliated, fine to medium-grained.
63	Amphibolite; massive, coarse-grained, non-porphyritic
108	Amphibolite; Massive, coarse-grained, porphyritic, with scattered $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.
	- - - - - - - - - - - - - - - - - - - -
183	Phyllite; strongly cleaved, flaggy grey phyllitic siltstone and shale.
	- - - - - - - - - - - - - - - - - - - -
27	Amphibolite; massive, non-porphyritic.
63	Amphibolite; massive, porphyritic, with rare 1 in. feldspar phenocrysts.
24	Amphibolite; massive, medium to coarse-grained, non-porphyritic, mafic-rich (ca 75% hornblende)

30   Amphibolite; sheared, flaggy, grey-green.

- -

192   Phyllite; grey-brown, flaggy to fissile, phyllitic siltstone.

- -

213   Amphibolite; massive, medium to coarse-grained, non-porphyritic, mafic-rich (ca 75% hornblende)

63   Amphibolite?; mainly unexposed; traces of sheared amphibolite.

88   Amphibolite; massive, medium to coarse-grained, non-porphyritic, mafic-rich (as above).

- -

Phyllite.

W3. Partial measured section of Woodward Dolerite $4\frac{1}{2}$ miles north-northeast of Blackhill Yard. Distances paced; measured by D.C. Gellatly. (3157E, 28078N).

Thickness (feet)

Axis of syncline; no further exposures.

180   Amphibolite; massive, medium to coarse-grained, porphyritic with $\frac{1}{2}$ in. to $\frac{3}{4}$ in. phenocrysts of feldspar.

80   Amphibolite; massive, medium to coarse-grained, porphyritic with $\frac{1}{8}$ in. phenocrysts of hornblende.

- -

340   Phyllite;

- -

40   Amphibolite; massive, coarse-grained, porphyritic with 1 in. feldspar phenocrysts; pinches out along strike.

285   Amphibolite; massive, medium-grained, non-porphyritic.

135   Amphibolite; massive, coarse-grained, porphyritic, with 1 in. feldspar phenocrysts.

60   Amphibolite; massive coarse-grained with $\frac{1}{8}$ in. hornblende phenocrysts.

- -

240   Phyllite and quartzite.

- -

385	Amphibolite; massive, coarse-grained, non-porphyritic, mafic-rich.
	Phyllite.

W4. Measured section of Woodward Dolerite $2\frac{1}{2}$ miles west-northwest of Mount Rose (3283E, 27986N). Distances paced; measured by D.C. Gellatly.

Thickness (feet)	
	Phyllite; pelitic sericite phyllite with sporadic psammitic interbeds.
51	Amphibolite; massive, fine-grained, non-porphyritic.
90	Amphibolite; massive, fine-grained, porphyritic, with $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.
400	Amphibolite; cleaved, fine-grained non-porphyritic.
15	Phyllite; flaggy, dark-grey, silty phyllite.
450	Amphibolite; massive, medium-grained, porphyritic with $\frac{1}{4}$ in. to 1 in. feldspar phenocrysts.
210	Amphibolite; cleaved, fine-grained, porphyritic, with very rare $\frac{1}{4}$ in. feldspar phenocrysts.
10	Phyllite; fine-grained, indurated silty phyllite
10	Amphibolite; massive, fine-grained, porphyritic with very rare $\frac{1}{4}$ in. feldspar phenocrysts.
4	Phyllite; dark grey indurated phyllitic siltstone and shale.
378	Amphibolite; massive, fine-grained, porphyritic with very rare $\frac{1}{4}$ in. feldspar phenocrysts.
120	Amphibolite; massive, medium-grained, porphyritic with $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.

372 Phyllite; dark grey, laminated, fissile phyllitic shale; minor white phyllitic acid tuff at base.

- -

60 Amphibolite; massive, medium to coarse-grained, non-porphyritic.

120 Amphibolite; massive, medium-grained, porphyritic with $\frac{1}{4}$ in. to $\frac{1}{2}$ in. feldspar phenocrysts.

105 Amphibolite; massive, medium-grained, non-porphyritic

- -

45 Phyllite;

- -

150 Amphibolite; massive medium-grained, porphyritic with abundant 1 in. feldspar phenocrysts; cut by thin discordant acid veins.

20 Amphibolite; massive, medium-grained, highly mafic, porphyritic with 3 mm hornblende phenocrysts.

- -

600 Phyllite.

- -

150 Amphibolite; massive, medium to coarse-grained, non-porphyritic.

- -

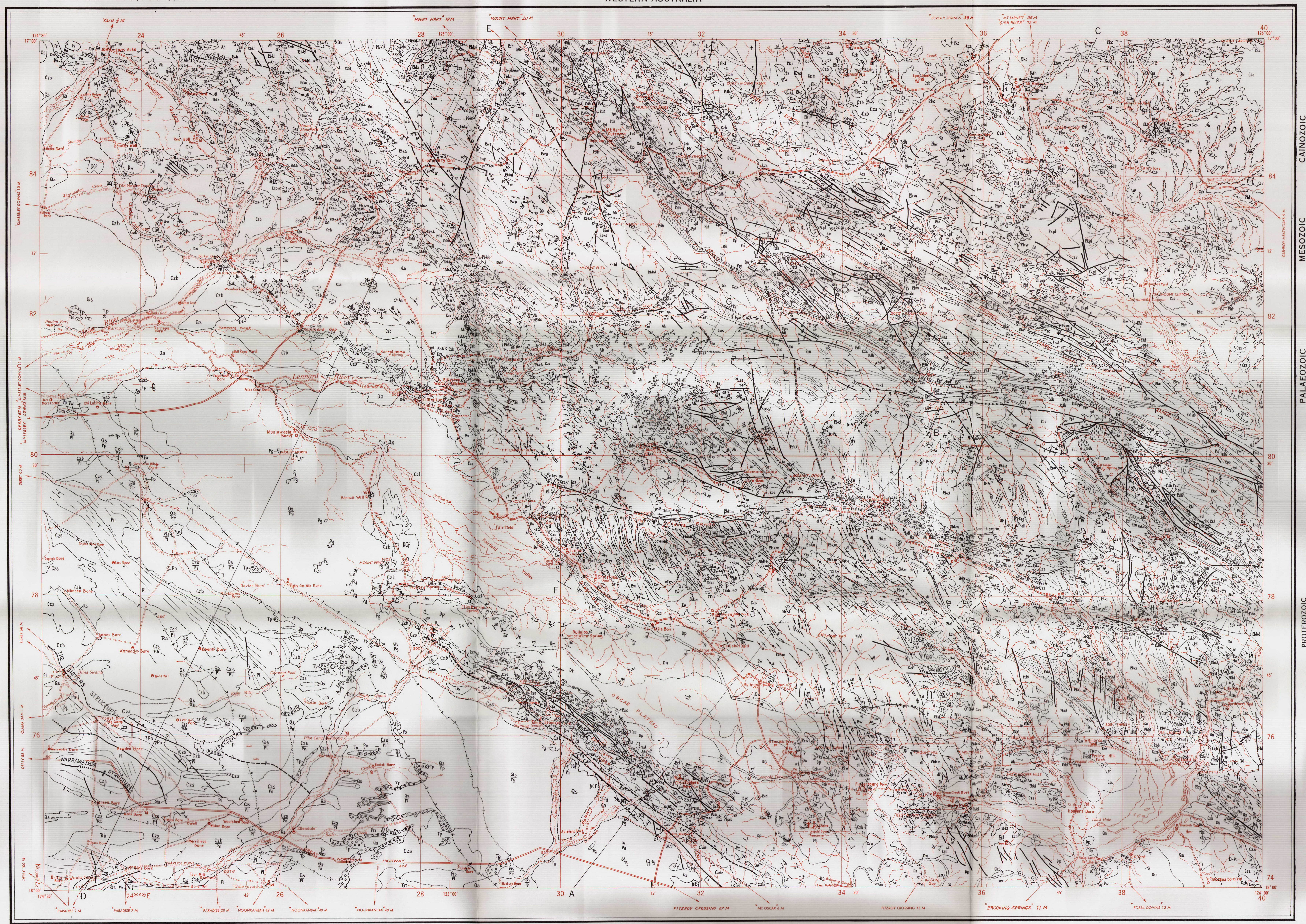
Phyllite; pelitic sericite phyllite with thin psammitic interbeds.

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

LENNARD RIVER

WESTERN AUSTRALIA

SHEET SE 51-8



Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium
			Qs	Windblown sand
	UNDIFFERENTIATED		Czf	Travertine, tufa (caliche)
			Czb	Residual black soil
			Czs	Other residual soils
			Czg	Boulder gravels
	TERTIARY			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; blue-grey shale in bores; marine fauna
PALAEOZOIC	PERMIAN	Liveringa Formation	Pl	Ferruginous, micaceous, silty sandstone and conglomeratic sandstone
		Noonkanbah Formation	Pn	Shale, siltstone, limestone, intraformational conglomerate
		Poole Sandstone	Pp	Micaceous silty sandstone and quartz sandstone
		Grant Formation	Pg	
	DEVONIAN & PERMIAN?		D-Pc	Boulder, cobble and pebble conglomerate, quartz grit and quartz sandstone
	DEVONIAN TO CARBONIFEROUS FAMENNIAN TO TOURNAISIAN	Fairfield Formation	D-Cf	
		Stony Creek Conglomerate	Ds	Conglomerate: pebble, cobble, and boulders of granite, quartz, quartzite, and sheared acid volcanics
	DEVONIAN FAMENNIAN-FRASNIAN	Windjana Limestone	Dw	
		Pillara Limestone	Dp	
		Napier Formation	Dn	
	FRASNIAN?-GIVETIAN?	Van Emmerick Conglomerate	Dv	Boulder, pebble, and cobble conglomerate with arkose matrix
		Bolin Conglomerate	Db	Boulder, pebble, and cobble conglomerate with arkose matrix
PROTEROZOIC	ADELAIDEAN — Mount House Group	Estaughe Formation	Phe	
		Throssell Shale	Pht	
		Traine Formation	Pha	
		Walsh Tillite	Phw	
	ADELAIDEAN OR CARPENTARIAN — Oscar Range Succession	Ninety Seven Mile Beds	Ezn	
		Elimberrie Beds	Ezb	
		Lineasman Beds	Ezl	
		Christopher Beds	Ezc	
		Ellendale Beds	Eze	
		Le Lievre Beds	Ezv	Pale grey quartzite, grey-green and brown phyllite, dark grey-green phyllite
		Mount Wilson Beds	Ezw	Grey to white granule sandstone, gritty feldspathic sandstone and arkose; buff, green and white quartz sandstone
PROTEROZOIC	CARPENTARIAN	Hart Dolerite	Pdh	
	Kimberley Group	Pentecost Sandstone	Pkpu, Pkpl	
		Elgee Siltstone	Pke	
		Warton Sandstone	Pkw	
		Carson Volcanics	Pkc	
		King Leopold Sandstone	Pkl	
	Speewah Group	Luman Siltstone		
		Lansdowne Arkose	Ppn	
		Valentine Siltstone	Ppv	
		Tunganary Formation	Ppt	
		O'Donnell Formation	Ppo	
	LOWER PROTEROZOIC — Lamboo Complex (UNDIFFERENTIATED)	Mount Amy Granite	Pbka	
		Dyasons Granite	Pbky	
		Lennard Granite	Pbkl	
		Chaneys Granite		
		Mc Sherrys Granodiorite	Pbkm	
		Lerida Granite	Pbl	
		Mondooma Granite	Pbko	
		Mount Disaster Porphyry	Pbkd	
		Bickleys Porphyry	Pbb	Grey porphyritic microgranite
		Whitewater Volcanics	Pw	
		Richenda Microgranodiorite	Pbkr	
		Kongorow Granite	Pbkk	
		Wombarella Quartz Gabbro	Pbkw	
		Woodward Dolerite	Pbd	
ARCHAEAN OR LOWER PROTEROZOIC	Halls Creek Group	Undifferentiated	Ah	

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

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, 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 — 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

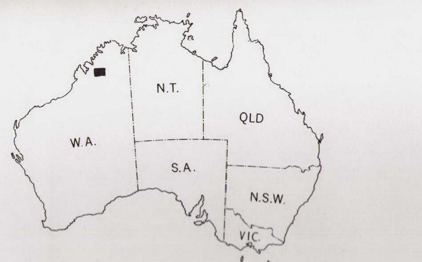
Strike and dip of foliation
Prevailing strike and dip of foliation
Vertical foliation
Strike and dip of foliation with plunge of lineation
Vertical foliation with plunge of lineation
Strike and dip of flow-foliation
Prevailing strike and dip of flow-foliation
Strike and dip of cleavage
Prevailing strike 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 strata and cleavage 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
Measured section
Type section locality
Sample locality for age determination
Dykes ap-aplite, dl-dolerite, peg-pegmatite, q-quartz, gr-granite, amph-amphibolite
Open cut or quarry
Open cut or quarry not being worked
Prospect
•Pb Minor mineral occurrence
Ag Silver
Au Gold
Cu Copper
Cn Corundum

Fe Iron
Fl Fluorite
Mi Mica
Pb Lead
Rc Crushed rock aggregate
Sn Tin
Zn Zinc

Bore
Abandoned bore
Bore - salinity < 2,500 p.p.m.
Saline bore - salinity 2,500 - 10,000 p.p.m.
Saline bore - salinity > 10,000 p.p.m.
Sub-artesian bore
Windpump
Ope 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
Astronomical station
•460' Height in feet
PD Position doubtful

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjuction with the Geological Survey of Western Australia. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Royal Australian Survey Corps. Commonwealth aerial photography. Complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection



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Showing Magnetic Declination

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ANNUAL CHANGE

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

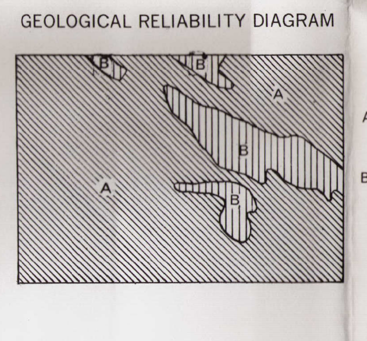
Sections

Cainozoic sediments omitted from sections

Attitude of faults not known; Folding schematic

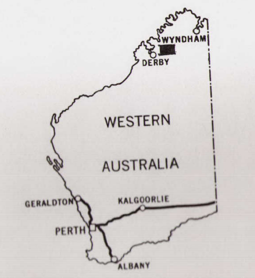
Scale: $\frac{V}{H} = 1$

GEOLOGICAL RELIABILITY DIAGRAM

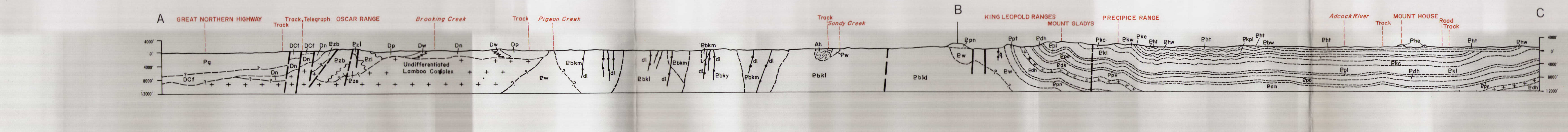


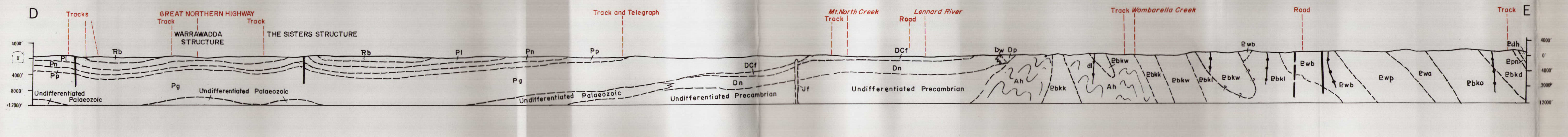
A Detailed reconnaissance - numerous ground traverses and air-photo interpretation

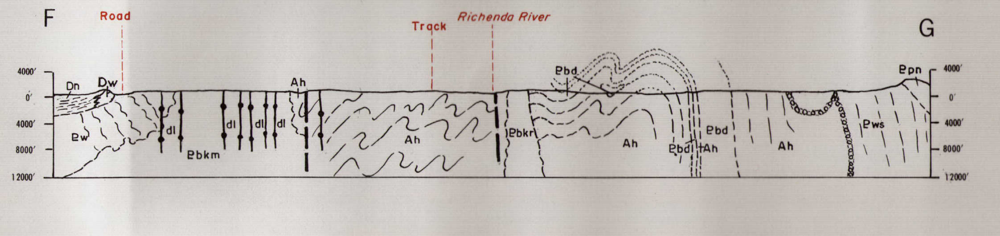
B Reconnaissance - some ground and helicopter traverses and air-photo interpretation



Geology, 1955, by: D.J. Guppy, A.W. Lindner, J.H. Rattigan, J.N. Casey
1963, by: P.E. Playford, D.C. Lowry (G.S.W.A.)
1966-67, by: D.C. Gellatly, G.M. Derrick, K.A. Plumb, C.M. Morgan (B.M.R.)
J. Sofoulis, R.A. Farbridge, A.D. Allan, R. Halligan (G.S.W.A.)
Compiled, 1967, by: G.M. Derrick, D.C. Gellatly, A. Tatarow
Drawn by: A. Tatarow, J. Kopras

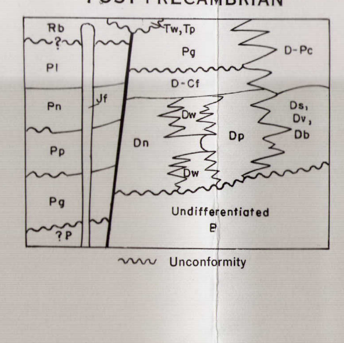






DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

POST PRECAMBRIAN



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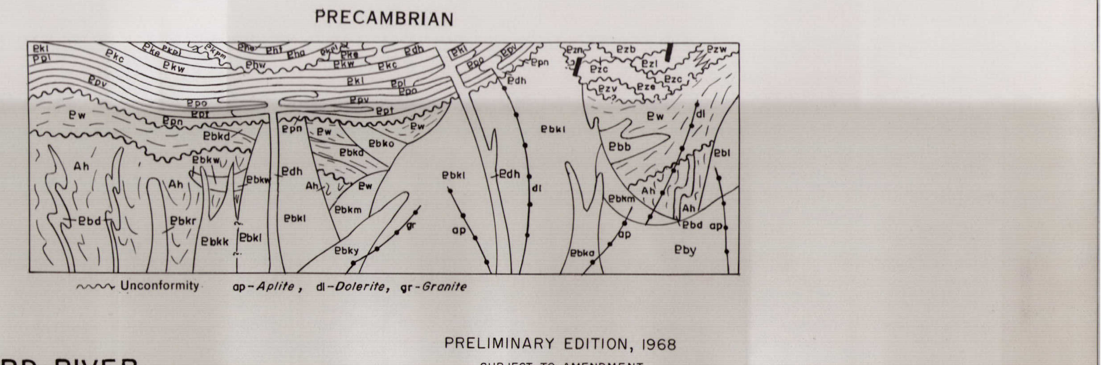

LENNARD RIVER

SHEET SE 51-8

PRELIMINARY EDITION, 1968

SUBJECT TO AMENDMENT

Complimentary