

1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

# MOUNT EGERTON

## WESTERN AUSTRALIA



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

# **MOUNT EGERTON**

## **WESTERN AUSTRALIA**

SHEET SG50-3 INTERNATIONAL INDEX

COMPILED BY P. C. MUHLING, A. T. BRAKEL, AND A. W. DAVIDSON



PERTH, WESTERN AUSTRALIA 1978

**DEPARTMENT OF MINES, WESTERN AUSTRALIA**

Minister: The Hon. A. Mensaros, M.L.A.

Under-Secretary: B. M. Rogers

**GEOLOGICAL SURVEY OF WESTERN AUSTRALIA**

Director: J. H. Lord

# Explanatory Notes on the Mount Egerton Geological Sheet

*Compiled by P. C. Muhling, A. T. Brakel, and A. W. Davidson*

## INTRODUCTION

The Mount Egerton (SG50-3) 1:250 000 sheet is bounded by latitudes 24° and 25°S and longitudes 117° and 118° 30'E. It is located in the North-West Division of Western Australia, and lies principally within the tectonic unit called the Bangemall Basin, but also covers some of the Gascoyne Province.

The present regional survey is the first systematic geological mapping to be undertaken of the Mount Egerton Sheet area and involved P. C. Muhling, and A. T. Brakel (1973), and A. W. Davidson (1973). The petrological work for these notes was done by J. R. Drake and W. G. Libby.

Most of the region is cattle or sheep grazing country. Two major roads which cross the region are alternative routes between Meekatharra and Onslow. Station tracks allow access to most of the region but areas south of Pingandy and Mount Vernon, and around Mount Egerton are difficult to reach; tracks have been made into some of these areas since 1974. The nearest towns are Paraburdoo, Meekatharra, and Gascoyne Junction, all outside the sheet area.

The only mining activity has been for alluvial and reef gold from the Mount Egerton diggings and variscite from near Mount Deverell. Small subeconomic deposits of manganese are known.

### *Rock nomenclature*

In these notes, the grain size of sedimentary rocks is classified by the Wentworth Scale (Pettijohn 1954). Sandstones are classified according to Williams, Turner and Gilbert (1954) as follows. Sandstone having over 10 per cent fine matrix is termed wacke, while that with less than 10 per cent fine matrix is arenite; sandstone in which over 90 per cent of the detrital grains are quartz is termed quartz arenite.

## PREVIOUS INVESTIGATIONS

The earliest geological work in the Mount Egerton sheet area was the collection, from the headwaters of the Lyons River, of specimens which were described by Huddleston (1883). The area was crossed by Giles in 1876, who travelled in a northeasterly direction from Mount Egerton (misidentified by him as Mount Labouchere) to Gorge Creek at its junction with the Ashburton River which he then traced upstream.

Geological reports by Woodward (1891, 1912) contain brief references to the area, and Woodward (1911) describes the Mount Egerton gold diggings in some detail. Talbot (1926) made a geological traverse along the eastern part of the sheet area and on the adjacent Collier Sheet. Johnson (1949, 1950), in association with R. A. Hobson, produced a map which includes a narrow belt of country along the southern margin of the Mount Egerton Sheet. The other published investigations relate to manganese deposits on Woodlands and Mulgul Stations. Blatchford (1928) first gave an account of these deposits, and they have been further reported on by Owen (1953), and de la Hunty (1954, 1963).

A gravity map at 1:250 000 scale of bouguer anomalies has been produced by the Bureau of Mineral Resources.

The region has recently been investigated for base-metal deposits by mineral exploration companies, and some of this work is still continuing.



## PHYSIOGRAPHY

The sheet area lies to the west of the continental divide in the region of external drainage (Mulcahy and Bettenay 1972). The country consists mostly of rugged strike ridges and broad valleys along which the main drainages lie. The physiography can be divided into uplands, colluvial slopes and plains, and main drainages.

Uplands in the north and south of the sheet area (Fig. 1) which are chiefly dissected rocks of the Bangemall Group, are separated by a zone of broad valleys and strike ridges extending diagonally across the sheet area from near the north-west corner. These form southward-dipping cuestas in the north. Elsewhere, long strike ridges cut by narrow steep-sided valleys, are common. The highest point, Mount Egerton, rises 994 m above sea level or about 500 m above the floor of the Lyons River Valley. Minor upland areas are on the igneous and metamorphic terrain of the Gascoyne Province in the southwest and south of the sheet area. Here, undulating quartz-covered mounds, dissected by narrow, shallow gullies occupy the lower areas over granitic rocks. Irregular hills of metasediments rise to about 50 m above this low land.

The largest colluvial slopes and plains fringe the major drainages, and most are in the broad valleys of the Lyons River and the Lyons River North. In the south of the area extensive colluvial slopes (mostly sheet-wash plains) slope southward to the Gascoyne River.

The drainage systems are those of the Ashburton, Gascoyne, and Lyons Rivers (Fig. 1). The main valleys contain extensive deposits of alluvium and calcrete. Streams flow only after heavy rain, though pools are present for most of the year. The Ashburton River drains most of the northern upland areas and is a broad sandy watercourse with extensive, dissected benches of calcrete and colluvium (hardpan). The Lyons River flows northwestward in broad valleys, and varies from incised channels to braided streams and local swamps. Its main tributary, the Frederick River, flows through the northwestern corner of the sheet area. The Jeeaila River, and most streams draining the northern uplands within the Lyons River catchment dissipate before reaching the Lyons River.

## GASCOYNE PROVINCE

Metamorphic rocks of the Gascoyne Province form a basement to the Bangemall Group in the southwest of the sheet area and are exposed in the cores of a number of anticlines in the Bangemall Group between Waldburg and Mulgul. Two terrains are recognized: an older one of sheared granitoid and gneiss (*Pgn*), and a younger one of schist (*Plm*) and granitoid (*Pg*). Between the two, a fault-bounded metasandstone (*Psq*), crops out.

## OLDER GNEISS AND GRANITOID

These occur in the southern part of the outcrop of pre-Bangemall Basement. The gneisses are medium, even-grained, quartz-feldspar rocks containing bands rich in biotite. Feldspar megacrysts are a minor constituent. Four km west from Let In well, the gneiss contains calc silicate bands about 5 m thick, comprising tremolite, epidote, sphene, quartz, and calcite. A few widely scattered amphibolite bands contain hornblende, calcic andesine, and epidote. Metamorphism belongs to the amphibolite facies.

Within the gneisses are bands of quartzite (*Pqm*) and quartz-muscovite rocks (*Pls*) up to 200 m wide, both of which were probably well-sorted sandstones. These crop out as eastward-trending strike ridges, and are broadly parallel with the gneissic banding. Most have a foliation of muscovite and elongate quartz grains parallel to the gneissic banding. Quartz-muscovite-biotite schist (2 km southeast from White



FIGURE 1  
**PHYSIOGRAPHIC FEATURES**  
 MT EGERTON SHEET SH 50-3

0 20  
 km

Well) have been intruded by granitoid. It is not known whether these meta-sedimentary rocks are the same age as the gneisses, or were laid down unconformably on the gneisses, and infolded during later deformation and metamorphism.

Granite, adamellite and subordinate grandodiorite intrude the gneiss. These granitoids are fine to coarse grained, and may be either even grained or porphyritic. Both biotite and muscovite are common accessory minerals. Quartz-feldspar-muscovite pegmatities, some with black tourmaline, are intrusive into granitoids, gneisses and schists. Primary flow orientation of feldspar and biotite is present within the plutons. The interpreted shape of the plutons is shown in Figure 2.

Both the granitoid and gneiss have cataclastic foliations, and have been partially recrystallized. Rounded and fractured feldspars, recrystallized quartz mosaics and trails of biotite are common. These rocks are protomylonite and mylonite gneiss in the classification of Higgs (1971). The plagioclase has been altered to sericite or saussurite in both gneisses and granitoids, and this may be a regional, low-grade metamorphism later than the intrusion of the granitic rocks.

### YOUNGER SCHIST AND GRANITOID

The younger group of rocks of the Gascoyne Province are phyllite and schist (*Plm*) and granitoid (*Pg*). They crop out in the northern part of the main segment of pre-Bangemall basement, and also in the core of the anticline centered on the Egerton mining centre. The schists are composed of quartz, muscovite, and biotite; and probably were interbedded wacke, arenite, and shale. Sedimentary bands with original detrital grains are preserved in places. Many phyllites are actually phyllonites (Higgs 1971) because they show fine sericite growth along cleavage planes and retrogression of coarser muscovite flakes. The metasediments within the anticline centred on the Egerton mining centre are mostly phyllites, and sedimentary structures are more clearly visible than in the schists to the west.

Metagabbro (*Edo*) has intruded the schists after folding and before intrusion of the granitic rocks. Relict igneous textures are well preserved. The metagabbro 2.5 km northeast from Mount Remarkable bore shows a mineral layering which may be primary.

Granitoid (*Eg*) occurs in a group of easterly trending plutons. They are even grained or porphyritic, and commonly contain biotite, muscovite, and tourmaline. These rocks are slightly sheared, or partially recrystallised adamellite and granite, but are not as intensely sheared as the granitoid that intrudes the gneiss. Primary flow orientations of feldspar and biotite are well developed near pluton margins. At the edges of the plutons lit-par-lit zones with alternate layers up to 50 m wide of schist and granitoid are classified as migmatite (*Ein*).

The schists in the western area show evidence of at least two episodes of metamorphism followed by a period of shearing. Deformation with associated metamorphism produced folded trails of elongate quartz and magnetite grains. These textures have been overprinted by post kinematic metamorphism which has produced porphyroblasts of muscovite and tourmaline. This overprinting is developed best in zones close to granitic plutons, but is also present elsewhere. Both events probably took place in greenschist or lower amphibolite facies conditions. These rocks have been again sheared resulting in conversion of muscovite to sericite.

### SIGNIFICANCE OF METAMORPHIC AND PLUTONIC ROCKS

The Gascoyne Province rocks are older than the unconformably overlying Bangemall Group of age about 1.1 - 1.0 b.y. (Compston and Arriens 1968, Gee, de Laeter and Drake 1976). The lower grade of metamorphism of the schists compared with the gneisses, and the low degree of shearing in the granitic rocks that intrude the schists, indicate that the schists are younger than the gneiss and granitoid.

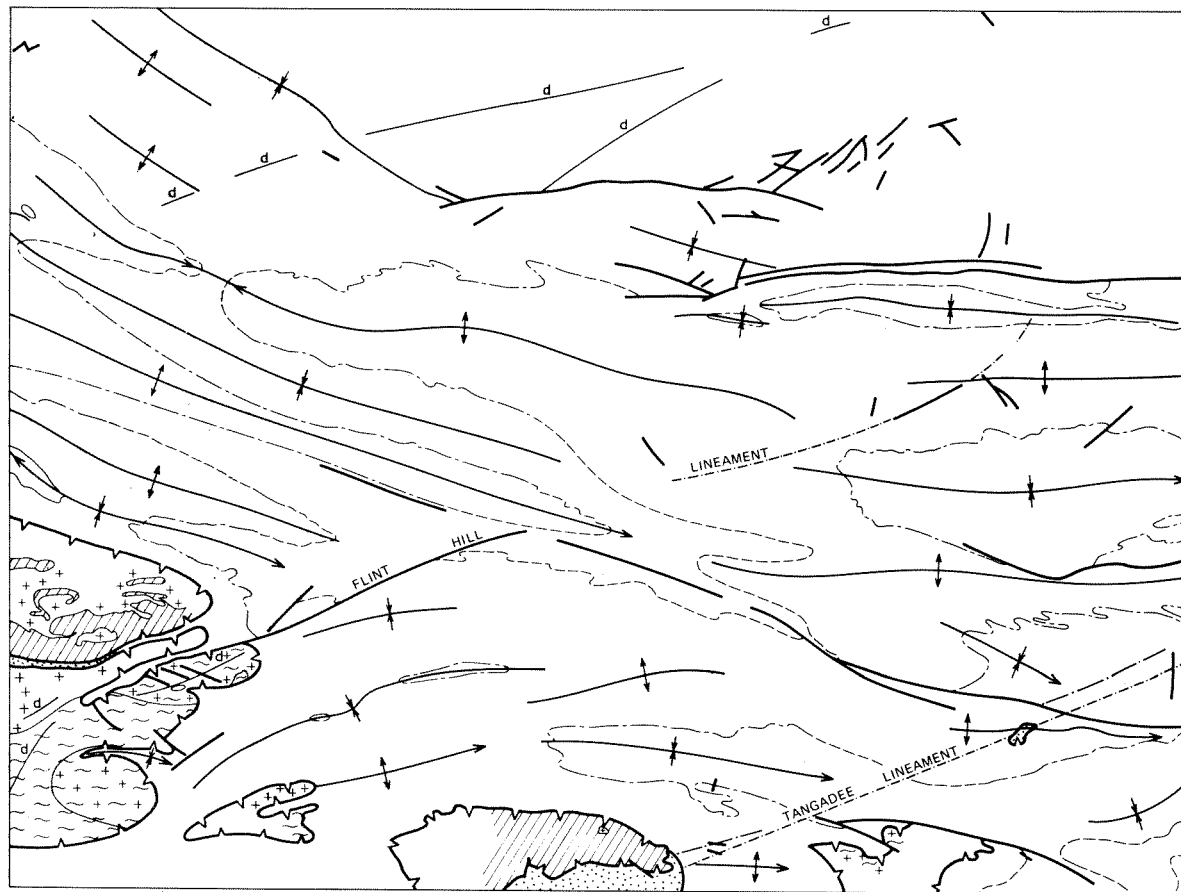
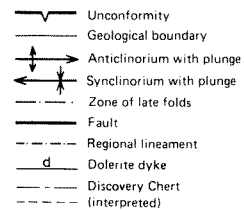
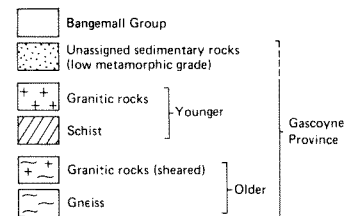


FIGURE 2

**STRUCTURAL INTERPRETATION**

MT EGERTON SHEET SG 50-3

 0 20  
 km


Similar schists are intruded by similar granites throughout the Gascoyne Province and these granites have been dated around 1.626 b.y. (de Laeter 1976).

This younger group is Early Proterozoic. The structural style and lithologies of the schists are similar to those of the Wyloo Group (Daniels 1969), but also could relate to the Padbury Group (Barnett 1975). Clasts of zircon, tourmaline, quartz, feldspar, and muscovite in the schists are ultimately of igneous or metamorphic origin and were probably derived from the older gneissic group, which may have been basement to the schists.

The older gneiss and granitoid may be the continuation of the belt of Archaean rocks (age 2.8 to 3.1 b.y., Arriens 1971) which extends from Perth (Wilde 1975) to Yalgoo (Muhling and Low 1973). All these rocks display similarities in metamorphic grade, structure and gross lithology. This correlation accords with the observations (J. Baxter, pers. comm) of similar high-grade metamorphic rocks on the Byro Sheet area. An alternative view that the gneisses formed by Proterozoic metamorphism and migmatization of Archaean or Early Proterozoic rocks has been suggested by Daniels (1975).

## UNASSIGNED ROCKS

A number of occurrences of schistose conglomerate, cleaved-arenite, and shale occur, either infolded into the metamorphic rocks of the Gascoyne Province, or below clearly assigned Bangemall Group rocks. Their stratigraphic significance is uncertain, but they are part of the Bangemall Group basement, and are therefore treated here for convenience.

### *In the Metamorphic Basement*

A narrow band of schistose metasandstone up to one km wide lies at the boundary of the older and younger terrains. The contacts on either side of the band are shear zones. Conglomerate zones contain deformed pebbles of quartz, quartzite, quartz-tourmaline rock, and granite. A foliation due to muscovite alignment has developed, and this is cut by a crenulation cleavage which trends southeastward and continues into the sheared granitoid and gneiss. In the less deformed areas, vertically dipping cross-bedding sets up to 1 m thick, are present. The metasandstone has had a simpler structural and metamorphic history than the enclosing rocks, and probably unconformably overlies them, being located by structural reactivation at the site of an older unconformity. It is probably a fluvial deposit accumulated in a local basin controlled by fracturing in the basement prior to the main subsidence which produced the Bangemall Basin. Gently dipping sandstones of the Bangemall Group unconformably overlie the metasandstone.

### *Beneath the Bangemall Group*

Fine grained quartz wacke, siltstone and fine to medium-grained, moderately sorted arenite crop out in the core of the anticline 16 km west from Mulgul homestead. These steeply dipping rocks have a weak cleavage expressed by fractures, aligned sericite, and kinked muscovite grains which is not developed in the immediately overlying, gently dipping Bangemall Group. This sequence may be part of the Lower Proterozoic Padbury Group (Barnett 1975) which occurs in the Robinson Range Sheet area.

Cleaved arenite (*Lsn*), and siltstone and shale with minor dolomite (*Ess*), crop out on the south side of the anticline centred on the Egerton mining centre. They unconformably overlie quartz-muscovite phyllites and schists, but their relation to the Bangemall Group is unknown. The arenite is medium grained, and has cross-bedding and ripple marks. The shale is thicker and more uniform than any in the Bangemall Group. The cleavage in the arenite and shales, together with the more intense folding within the arenite unit, contrast with the gently dipping Bangemall Group on the north limb of the anticline. An unconformable relationship is postulated.

## STRUCTURE OF THE GASCOYNE PROVINCE

The older and younger terrains show folding along easterly, northwesterly, and northeasterly trends. In the older gneissic area the dominant trend of the gneissic foliation is eastward. Bands are parallel and dip steeply, indicating a period of regional, isoclinal folding along eastward-trending axes. Later tight mesoscopic folds are mostly along northwestward-trending axes. Quartzites within the gneisses are folded along eastward-trending axes. Still later folds of both major and minor scale have northwestward and northeastward-trending axes.

In the older terrain both the granitoid and the gneisses have been cut by at least three cataclastic foliations. The first trend parallels the boundary with the immediately overlying Bangemall rocks where the contact dips steeply, as in the area northwest from K 17 bore. The second is parallel to the boundary with the metasandstone band (*Psq*), and may be due to faulting along this boundary. The third is a regional feature which trends between 090° and 130°; it is most evident in the gneisses, and may itself represent more than one period of deformation.

In the younger terrain of schists and granitoid, the schists show two main fold trends. One is of probable eastward-trending, regional isoclinal folds. This direction is also reflected by the easterly trend of the long axes of the plutons which have intruded after, and probably controlled by, these folds. The other fold trend is shown by tight major folds with northwestward-trending axes. The plutons are late to post-tectonic with respect to both these fold periods. The late tectonic intrusion is suggested by northwestward-trending folds in early nebulitic phases of the pluton. Post-tectonic intrusion is indicated by discordance of magmatic foliations with the major folds.

The axes of regional folds of phyllites near the anticline which is centred on the Egerton mining centre probably trend eastward. Later minor folds plunge northeast.

## BANGEMALL BASIN

### STRATIGRAPHY OF THE BANGEMALL GROUP

The Bangemall Group occupies approximately ninety per cent of the sheet area. The stratigraphic sequence is shown in Table 1.

The chief lithologies are shale, siltstone, quartz sandstone, dolomite, chert, and conglomerate. All units except the basal Tringadee Formation are marine. The sequence from the Ullawarra Formation upwards has a simple, laterally persistent stratigraphy. In the lower half of the sequence, lensing and interfingering of units is common, although the Discovery Chert is continuous, and is the best marker horizon in the sequence. Facies changes in the lower half of the sequence are thought to be the result of an interplay between the lateral migration of contrasting adjacent environments, and varying clastic input (Brakel and Muhling, 1976).

#### *Tringadee Formation (Pme)*

The Tringadee Formation is discontinuous on the basal unconformity. Thicknesses vary greatly and range up to an estimated 1650 m in the anticline between Tringadee Bore and the Resolution Synclinorium.

It consists dominantly of medium and coarse-grained arenites interbedded with granule, pebble, cobble, and boulder conglomerates. Most of the arenites are pebbly, and contain small amounts of feldspar which in a few places comprise 25 per cent of the rock. Clasts in the conglomerates are mostly derived from the underlying basement rocks, and include vein quartz, gneiss, quartzite, schist, quartz-tourmaline rock, and pegmatite.

TABLE 1. STRATIGRAPHIC COLUMN

	Age Group	Map Symbol	Formation	Lithology	Thickness (m)	Remarks
CAINOZOIC	Quaternary	<i>Qra</i>		Alluvium: Unconsolidated sand, silt and gravel deposited by streams.		Good aquifer
		<i>Qrg</i>		Colluvium: unconsolidated sand, silt, gravel and rubble deposited by sheet wash. Minor wind blown sand.		
UNCONFORMITY						
	Quaternary and/or Tertiary	<i>Cza</i>		Hardpan: Consolidated colluvium and alluvium. Minor silcrete.	30 ±	Wiluna Hardpan
		<i>Czk</i>		Calcrete, in places replaced by chalcedony; kankar	22 ±	Good aquifer where not dissected
		<i>Czl</i>		Laterite: massive, pisolitic and detrital iron oxides	3 ±	
		<i>Czd</i>		Chalcedonic caprock on Proterozoic dolomite	2 ±	
UNCONFORMITY						
PROTEROZOIC	Upper and/or Middle Proterozoic	<i>d</i>		Dolerite in dykes		At least two generations present
		<i>q</i>		Quartz veins		
		<i>b</i>		Dolerite in sills		

	Age	Group	Map Symbol	Formation	Lithology	Thickness (m)	Remarks
PROTEROZOIC	Middle Proterozoic	Bangemall	<i>Emq</i>	Kurabuka Formation	Shale, siltstone, minor dolomite	1500	
			<i>Emn</i>	Mount Vernon Sandstone	Sandstone	240	
			<i>Ems</i>	Fords Creek Shale	Shale, minor sandstone and siltstone	1300-1900	
			<i>Emsj</i>	Jeeaila Sandstone Member	Sandstone, with subordinate shale	60-80	
			<i>Emc</i>	Coodardoo Formation	Sandstone, minor siltstone and shale	0-60	
			<i>Emu</i>	Curran Formation	Shale	250	
			<i>Eml</i>	Ullawarra Formation	Shale, siltstone, and minor dolomite	650	Extensively intruded by dolerite
			<i>Emv</i>	Devil Creek Formation	Dolomite and shale	0 to 800 +	
			<i>Emd</i>	Discovery Chert	<i>Chert, subordinate shale</i>	50-125	Laminated rocks, wavy bedding common
			<i>Emj</i>	Jillawarra Formation	Shale, siltstone, minor chert and dolomite	0-1 300	
			<i>Emk</i>	Kiangi Creek Formation	Sandstone, shale, subordinate dolomite and minor conglomerate,	0-1 800	Stromatolites in one dolomite member
			<i>Emkg</i>	Glen Ross Shale Member	Shale	125-525 +	
			<i>Emi</i>	Irregully Formation	<i>Dolomite, dolomitic shale, shale and minor sandstone</i>	0-2 000	Stromatolites present
			<i>Eme</i>	Tringadee Formation	Sandstone with conglomerate lenses	0-1 650	Lenticular basal formation of Bangemall Group
			<i>Emt</i>	Top Camp Dolomite equivalent	Shale, dolomite and Sandstone	2 500	Stromatolites present. Equivalent to all units below Fords Creek Shale

#### PROBABLE UNCONFORMITY



	Age Group	Map Symbol	Formation	Lithology	Thickness (m)	Remarks
PROTEROZOIC	Lower or Middle Proterozoic	<i>Ess</i>		Brown shale slate, minor dolomite	1 070 +	} Relation to <i>Esi</i> , <i>Esq</i> is unknown
		<i>Esn</i>		Cleaved sandstone quartzite, some cleaved conglomerate	230	
		<i>Esq</i>		Metasandstone, moderate to well sorted. Locally conglomeratic	?500	Faulted boundaries. Probably unconformable on <i>Eg</i> , <i>Elm</i> , <i>Egn</i>
		UNCONFORMITY				
		<i>Eg</i>		Porphyritic and even grained granite and adamellite		Intrudes <i>Elm</i> and <i>Edo</i>
	Lower Proterozoic	<i>Edo</i>		Metagabbro and dolerite		Intrudes <i>Elm</i>
		<i>Ein</i>		Migmatite—mixture of granitic rocks and schists		
		<i>Elm</i>		Quartzmuscovite schist		Meta-morphosed wacke siltstone and shale
Padbury	<i>Esi</i>		Cleaved Siltstone wacke and chert		Unconformable beneath Bangemall Group	
	<i>Eqm</i>		Quartzite and muscovite quartzite		Isolated bands in gneisses and sheared granitic rocks	
	<i>Els</i>		Quartzmuscovite and muscovite schist		Meta-sandstones. Probably unconformable on <i>Egn</i>	
	<i>Egn</i>		Gneiss, amphibolite sheared granitic rocks		Probably Archaean sheared and meta-morphosed in Proterozoic. May include Proterozoic granitic rocks.	

Planar cross-bedding is common in the sandstone. Fine-grained arenite and siltstone interbeds are rare near the base, but increase in frequency towards the top of the formation where lenses of dolarenite and fine-grained dolomite appear. The formation shows an upward decrease in average grain size, although coarser grained lithologies are interbedded even at the higher levels. The unit appears to pass conformably upward into the dolomitic Irregully Formation.

Most of the Tringadee Formation is believed to have been deposited subaerially, but the dolomitic members indicate periods of marine incursions, which heralded the marine conditions prevailing for the rest of Bangemall Group sedimentation.

#### *Irregully Formation (Emi)*

Except where it overlies the Tringadee Formation, the Irregully Formation lies unconformably on the metamorphic and granitic rocks of the basement complex.

It consists mainly of dolomite, shale, and siltstone with minor sandstone and conglomerate. The dolomite may be grey, dark brown, yellow brown, buff, and white on exterior surfaces, but is pink, dark grey and light grey internally. It is well bedded, finely laminated and microcrystalline; laminations are conspicuous on weathered surfaces. Cubes of goethite and hematite, varying from less than 1 mm to 20 mm on edge, presumably pseudomorphs after pyrite, are abundant, and clusters of cubes forming nodules 50 mm in diameter have been found. Breccia of fine-grained dolomite slabs and pebbles in a matrix of sand-sized dolomite grains, occurs rarely. The only known limestone occurs 10 km west-northwest of Staten Hill as light-grey laminations and small pods in the dolomite. Grey shale and siltstone, including micaceous varieties, and those with a carbonate cement, are also common in the Irregully Formation. Minor sandstone members with dolomite cement are present. Small columnar stromatolites occur 26 km west of Waldburg and 20 km west of Mulgul.

Considerable interfingering takes place between the Irregully Formation and the overlying Kiangi Creek Formation, such that one formation is in part the lateral equivalent of the other. For mapping purposes, the top of the Irregully Formation is regarded as the base of the lowest laterally persistent sandstone unit. Sandstone lenses lower in the sequence are thus members of the Irregully Formation, whereas higher dolomites are mapped as members of the Kiangi Creek Formation. Difficulties arise where lateral persistence of sandstones is uncertain, such as 20 km west of Mulgul. In the Candolle Syncline and 10 km west-northwest of Staten Hill, no sandstone is present in the sequence and the Irregully Formation is overlain by the Jillawarra Formation. The dolomites occupying the cores of anticlines and synclines in the central and eastern regions of the sheet area have been assigned to the Irregully Formation, but their stratigraphic level is uncertain.

#### *Kiangi Creek Formation (Pmk)*

The Kiangi Creek Formation overlies the Irregully Formation, except east-southeast of the Egerton gold mine, where it probably unconformably overlies pre-Bangemall rocks, and at the southwest end of the Resolution Synclinorium, where it may directly overlie the Tringadee formation.

The chief rock types are quartz arenite, shale and siltstone, but minor dolomite members are widespread. Typical arenites are medium grained, well sorted with a small feldspar component, which in rare cases exceeds 20 per cent. Tourmaline is a common accessory. Bedding planes are irregular and frequently a metre or more apart. Most arenites do not show cross-bedding, though it is locally abundant. The rock commonly resembles quartzite, because of silica cement which is probably secondary. In dissected areas, such as the headwaters of Glen Ross Creek, the unit is soft, white and clayey. The arenites vary from fine to coarse grained;

scattered quartz pebbles and lenses of quartz conglomerate are present. Such conglomerates occur in the Lyons River Anticline and the West Creek district. Thick manganese staining is present on outcrops of sandstone and shale 17 km north of Woodlands and 22 km north-northwest of Mulgul.

The interbedded shale and siltstone are light grey to brown, micaceous, and crop out poorly. The proportion of shale and siltstone ranges from 5 to 70 per cent, and local variations in shale content can be rapid. In the Mount Vernon Syncline, a thick partly silicified shale member which contains isolated pods of laminated dolomite and some copper staining, has been named the Glen Ross Shale Member. The dolomite members of the Kiangi Creek Formation are similar to those of the Irregularly Formation. A small member south of the manganese deposit north of Woodlands contains cumulate-type stromatolite columns 50 to 100 mm wide and 300 mm high. The dolomite in the area east of Mount Egerton has much interbedded arenite. A chert bed occurs in Staten Hill.

The formation interfingers with the overlying Jillawarra Formation, such that the two are laterally equivalent in part, while in some areas this lateral substitution is complete with one of the formations locally absent. The upper boundary of the Kiangi Creek Formation is taken as the top of the highest major sandstone bed, although where such a unit lenses out, for example 5 km east of Coolina yards, interbedded shales pass into identical beds, then classified as shales of the Jillawarra Formation.

#### *Jillawarra Formation (Pmj)*

The Jillawarra Formation, a newly recognised stratigraphic unit, consists dominantly of grey, white, brown, and black shale and mudstone, together with some minor chert, dolomite, and sandstone. The shale and mudstone are usually silty and contain abundant detrital muscovite. In the less dissected areas, the rock resembles chert, probably because of surface silicification. Cubic crystal moulds, usually less than 10 mm on edge, are plentiful in some beds. Many contain powdery iron oxides, and are probably after pyrite, however some may be after halite. Smaller, elongate crystal moulds filled with clay are locally abundant, and may be after gypsum.

The most extensive chert member has a strike length of at least 25 km, and occurs near the top of the formation in the Lyons River Anticline. Two others lie at different levels in the sequence on the northern side of the Hells Doorway Syncline. Although many chert-like beds appear at the surface, some are silicified shale and mudstone; others, which are indistinguishable in appearance from the younger Discovery Chert, are probably primary cherts.

Sandstone members vary from fine-grained wacke to medium or coarse-grained arenite. The thickest member is the prominent quartz arenite close to the top of the formation in the Lyons River Anticline. The only dolomite members, apart from rare, 10 mm thick bands, occur north and west of Woodlands.

The formation is named after Jillawarra bore on Mulgul Station, and has been traced to the southern boundary of the Edmund Sheet. The shale at the base of the Discovery Chert at Mount Palgrave in the Edmund Sheet area may be its equivalent.

The stratigraphic position of the rocks north of Hilberry Well is uncertain. They have been mapped as Jillawarra Formation because of lithological similarities to the chert, shale, and sandstone sequence of this formation in the neighbouring Lyons River Anticline. This interpretation requires a fault south of the anticline, which may be the extension of a fault known to exist under the superficial cover 5 km northeast of Woodlands. Alternatively the rocks in the area belong to the Ullawarra Formation.

### *Discovery Chert (Emd)*

This is a distinctive, remarkably persistent chert unit which forms the best marker horizon in the Bangemall Group. Its most striking lithology is black, massive chert, which can be homogeneous in appearance or characterized by diffuse, light-coloured laminations that are planar, wavy or contorted. Porous laminae, probably representing weathered pyritic laminae, are present. Usually a streaky texture can be seen in the rock with a hand lens. Major bedding units are generally 100 to 300 mm thick and are irregularly wavy. The more massive chert is underlain and overlain by well-bedded, lighter coloured chert, which is fissile and splintery in places. Interbedded shale may be present. While the massive cherts may be primary cherts, the more thinly bedded rocks may pass into shale at depth. There are slump structures in places, for example where Glen Ross Creek cuts through the formation on the southern limb of the Mount Vernon Syncline.

Cubic crystal moulds, presumably after pyrite, are wide-spread. Possible gypsum moulds also occur in several localities. Marshall (1968) has reported acritarch microfossils from the formation.

The upper and lower contacts of the formation are transitional over a thickness of about 3 m or less. As the main chert horizon is approached, thin chert bands appear in the adjacent shale or fine-grained sandstone, increasing in frequency and thickness, and wavy bedding, if present, becomes more pronounced.

In the eastern end of the Lyons River Anticline two chert units similar to each other, are separated by shale. The upper, and by far most extensive unit, is regarded as the Discovery Chert.

### *Devil Creek Formation (Emv)*

This is predominantly a dolomite and silty shale sequence, with occasional siltstone and fine-grained sandstone. The dolomite is similar to the finely laminated, microcrystalline dolomite of the Irregularly Formation, although some grains are up to 1 mm across. Cross-bedding, is uncommon, but low angle, small to medium-scale troughs and planar foresets, as well as climbing ripples, are locally abundant. Erosional scours up to 100 mm deep are present at the western end of the Mount Vernon Syncline. Rare dolarenites (sandstones composed of dolomite grains), occur in the Berala Syncline northeast of Cooradarra well. Southwest of Corner Camp bore in the Range Creek Syncline, there is a breccia consisting of thin slabs of fine-grained dolomite up to 300 mm long in coarse grained dolarenite with a carbonate cement. A few oolite bands, up to 10 mm thick, have been found. Stromatolites are absent.

The shale, siltstone and fine-grained sandstone beds are white, yellow, brown, pale green, and purplish brown. Small load casts on the bedding surfaces are wide-spread. Some of these rocks have a dolomitic cement, and contain layers of dolomite a few millimetres thick. The proportion of shale to dolomite in the Devil Creek Formation is laterally and vertically variable, a characteristic well displayed in the Range Creek Syncline. Southwest of Mulgul a thick basal shale member is below the dolomite.

Cubes and nodules of hematite after pyrite up to 5 mm across are abundant, especially in the dolomite beds. Fresh pyrite in dolomite occurs rarely.

The Devil Creek Formation is laterally and vertically transitional with the overlying Ullawarra Formation, and the boundary between the two is taken as the top of the youngest major dolomite member, or where the proportion of dolomite falls below 10 per cent in a thinly bedded sequence. However, this is not always easy to define where lateral facies changes are rapid and not photo-interpretable. Dolomite is absent and the Devil Creek Formation is therefore missing: east of Jillawarra

bore, in the Berala Syncline north of Narrinja bore, in the northwest part of the Mount Vernon Syncline, and west of Mount Sanford. In the last area, the lensing-out of the formation is visible in outcrop.

#### *Ullawarra Formation (Eml)*

The Ullawarra Formation, which is in part laterally equivalent to the Devil Creek Formation, is composed chiefly of shale, siltstone and fine-grained arenite. These are grey, brown, maroon, cream white, or pale green, and are silty, well bedded, and usually laminated. Alternating thin-bedded maroon and cream shales are common. Load casts may be abundant. Minor interbeds consist of wacke, claystone, dolomite and chert. Most of the wacke is in the Hells Doorway Syncline. Pyrite moulds are not numerous. The dominant rock type in the Berala Syncline, is a hard, grey or white quartzose siltstone which grades into fine-grained sandstone. This rock typically breaks into blocky rubble. It may be laminated, massively bedded, or cross-stratified.

The formation in the Berala Syncline and northwest corner of the sheet area contains a large number of dolerite sills in comparison with other formations of the Bangemall Group. This is also a feature of the Ullawarra Formation in the Edmund Sheet area (Daniels, 1969).

Lateral facies changes with the Devil Creek Formation are due to varying proportions of dolomite. Where the Devil Creek Formation is absent, the Ullawarra Formation comes to overlie the Discovery Chert. A sandstone that caps Mount Sanford was mapped as part of the Ullawarra Formation, but it may be equivalent to the Mount Vernon Sandstone if the Curran and Coodardoo Formations are missing in this area. In that case, fine-grained deposition would be continuous to the top of the Fords Creek Shale.

#### *Curran Formation (Emu)*

The Curran Formation is a distinctive light-weathering unit of shale, mudstone and chert, which is dark grey when fresh. Some of the rock has a distinctive white speckled appearance. At its most easterly point the unit is faulted out by the westernmost branch of the Mount Vernon Fault system, but just west of the fault, it starts to lose its distinctive appearance, and begins to merge with shale above and below. It is overlain by the Coodardoo Formation in the western half of its outcrop area, and by the Fords Creek Shale farther east.

#### *Coodardoo Formation (Emc)*

The Coodardoo Formation consists mainly of medium-grained, moderately sorted, purple-grey, quartz arenite which is poorly bedded, and which locally contains ripple marks and shale fragments. Fine-grained arenite and wacke, are interbedded with micaceous mudstone and shale.

The formation is transitional with both the Fords Creek Shale and Curran Formation, due to a gradual decrease in the proportion of sandstone. It occurs only in the northwest corner of the map area, and lenses out from the succession farther east. It is better sorted than in the Edmund sheet area where it is dominated by greywacke (Daniels 1969).

#### *Fords Creek Shale (Ems)*

The overlying Fords Creek Shale consists of a thick sequence of green micaceous shale and bedded silty mudstone with lesser arenite, and rare wacke, black shale and chert. The fine-grained rocks weather brownish, white, or buff colours, resembling shale in the lower formations. The arenite members which are numerous northeast of Dooley Downs, generally have a low feldspar content, and contain impressions of shale fragments. Flute molds and ripple marks occur on some bedding surfaces. The most important arenite member has been named the Jeeaila

Sandstone Member, and is a prominent cliff-forming unit outlining folds in the northwest corner of the sheet area. It can be traced 90 km to the east-southeast where it is cut off by the Mount Vernon fault system.

Near the top of the formation the frequency of thin sandstone interbeds increases, forming a transition zone 10 m thick with the overlying Mount Vernon Sandstone.

#### *Mount Vernon Sandstone (Emn)*

This unit was previously regarded as the basal member of the Kurabuka Formation (Daniels, 1969), but has now been elevated to formation status because of its significant thickness, and its importance as a marker unit. It forms prominent ridges bounded by cliffs. It is dominantly a hard, well-sorted, medium-grained quartz arenite with a low feldspar component. Angular fragments of fine-grained sandstone and siltstone up to 100 mm in length, are widespread and locally abundant. Ripple marks, flute molds, groove casts and cross-bedding are common. Cross-bedding in a herringbone arrangement in widely separated localities indicates periodic reversals of current directions which suggest of tidal action. Individual beds are massive, and range from 0.2 to 1.5 m in thickness.

#### *Kurabuka Formation (Emq)*

The Kurabuka Formation is composed mainly of green and dark greenish grey shale and mudstone, which weather to olive, khaki, brown and maroon colours. Thin micaceous siltstone beds are present, but, unlike the Fords Creek Shale, interbedded sandstone bands are rare. Near the base, white shale, siltstone and cherty rock are common. The chert is laminated, has wavy bedding, and is probably a silicified shale.

At the top of the formation in the region south of Mount Vernon homestead, minor bands of carbonate 100 to 150 mm thick are present.

#### *Top Camp Dolomite (Pmt)*

The name Top Camp Dolomite, introduced by Halligan and Daniels (1964) in the Turee Creek sheet area, was later abandoned and replaced by several formations (Daniels 1966) in the Edmund sheet. The Top Camp Dolomite continues from the Turee Creek sheet into the Mount Egerton sheet, but at present its constituent units cannot be correlated with stratigraphic units south of the basin axes, and naming has been deferred. The Top Camp Dolomite is equivalent to all the Bange-mall Group formations below the Fords Creek Shale, and rests unconformably on the Bresnahan Group and Lower Proterozoic Ashburton Formation just north of the Mount Egerton sheet.

The basal unit on the Mount Egerton sheet is yellow-brown, pink, or white, fine-grained dolomite, varying from massive to faintly bedded. It is overlain by grey, pale brown, or olive shale and siltstone with some interbedded black cherty rock and minor lenses of sandstone. This is overlain by dolomitic shale, and dolomite similar to the basal dolomite, and then a distinctive unit of fine-grained quartz arenite which crops out poorly but forms an extensive scree of blocky slabs. Current ripples, flute molds, groove casts and current lineations are abundant within it, and shale fragments and lenses of dolomite with algal laminations are present. At the top of the sequence below the overlying Fords Creek Shale, interbedded dolomite, shale and dolomitic shale are developed. This dolomite is faintly laminated and contains numerous stromatolites near Pingandy Creek.

#### *Basic Igneous Rocks*

Sills more than 100 m thick, and up to 80 km long commonly intrude the Bange-mall Group. They are generally concordant with the bedding but may vary rapidly in thickness and cross-cut the bedding in jumps of up to 100 m. Xenoliths of wall rock are rarely present. The Fords Creek Shale in the Mount Vernon region

contains two intrusive sheets which gradually and completely transgress the formation. The intrusives occur preferentially in shale, siltstone and chert, but are uncommon in sandstone units. Dolerite sills are absent from the Tringadee, Irregularly and Coodardoo Formations, while the greatest concentration occurs in the north-western part of the Ullawarra Formation. Sills are also concentrated in the Kurabuka Formation in the Mount Vernon region, and the Discovery Chert and Curran Formation have sills persistently associated with them. In general there is a decrease in abundance of sills from west to east. Contact metamorphism of the adjacent rocks is slight. In the Berala Syncline major quartz veins occur close to or within dolerite. Intrusion preceded folding of the Bangemall Group.

A number of mafic dykes about one to two metres in width are present. The largest extends for 10 km, south of the Jeeaila River Fault. Dykes are most common in the shale units on the northern flank of the basin and in the granitic rocks of the southwestern district.

At least two, possibly three generations of dykes are present. Some, including the largest, may be feeders to the sills, while others cut through folds, faults and sills and thus postdate the folding.

## STRUCTURE OF THE BANGEMALL GROUP

The dominant regional structure of the Bangemall Group is an arcuate, south-eastward to eastward trending synclinorium that is a direct continuation of the Edmundian folds (Daniels 1966). The major synclinal zones in the south of the Mount Egerton sheet area trend northeastward to eastward, and form a subordinate structural axis of the Bangemall Basin. These synclinal zones are separated by a west-northwestward trending zone of basement arches in the Mount Phillips sheet area.

Folds within the Bangemall Group are mostly concentric in style, and dips vary from horizontal to vertical with a few overturned fold limbs. Slaty cleavage is developed only in tight folds, and metamorphism is extremely low grade.

### *Lineaments*

The Flint Hill Lineament (Brakel and Muhling, 1976) is a zone of faulting extending east-northeastward from Flint Hill where it is associated with a narrow tongue of the Bangemall Group overlying the Gascoyne Province. To the northeast, in the Teano Range, it is a prominent photolineament, which can be related to a fault. A facies change in the Jillawarra Formation is present where the Flint Hill lineament intersects the nose of the Lyons River anticline. The lensing out of the sandstone of the Kiangi Creek Formation northwest of Staten Hill may also be related to this lineament.

The Tangadee Lineament (Brakel and Muhling, 1976) is a line of basement inliers on both Mount Egerton and Collier sheet areas which marks the change from eastward-trending folds to dome and basin style folds of variable trend. Associated with the lineament is a zone of folds trending east-northeastward.

The styles and trends of the regional folds together with the lineaments (Fig. 2) can be used to define four structural provinces (Brakel and Muhling, 1976). The northern province contains the gently south-dipping limb of the main synclinorium in the north of the sheet area. The southern boundary of this province is the change from gentle dips to relatively tight folds along the axes of the main synclinorium. The Mount Vernon fault system lies on this boundary. Within the western and central part of the sheet is the western province with relatively tight folds trending southeastward to eastward. The Tangadee Lineament marks the eastern boundary between this province and the eastern province which is characterised by dome and basin style folds. The relatively tight folds trending northeastward to

eastward between the Flint Hill and Tangadee Lineaments lie within an intermediate province. There is a broad zone where folds of this province converge with folds of the western province and the northern boundary between the two provinces is arbitrary.

### *Faults*

The main trends of faults are eastward, east-northeastward east-southeastward, and northeastward. Minor faults trend northward and northwestward.

Three large eastward-trending reverse faults are in the central and eastern part of the sheet area. The Jeeaila River Fault is a moderate-angle, reverse fault. The fault plane, dipping about 40° southward is exposed near Gorge Creek, where the Fords Creek Shale has been thrust over the Mount Vernon Sandstone. The fault truncates east-southeastward-trending folds which become more numerous and overturned close to the fault plane.

The northern limb of the Mount Vernon Syncline is truncated by two parallel reverse faults, each at least 40 km long, which possibly link with a major eastward-trending fault on the Collier sheet area (Brakel and others, 1978). The northern fault separates gently dipping Kurabuka Formation from a ridge of steeply dipping, locally overturned Mount Vernon Sandstone. The fault plane probably dips vertically at the surface. The southern fault is inferred from the stratigraphy. Minor thrust faults exposed in a gorge in Glen Ross Creek suggest these two faults are also thrusts, possibly splayed from the one primary thrust at depth. At the western end of the major faults is a system of splay and tear faults which may continue under colluvium to the west. Slickensides on minor thrusts associated with the Jeeaila River and Mount Vernon Faults indicate the last movement was on a north-easterly trend.

East-southeastward-trending faults are not exposed, but are inferred from the stratigraphy. In each case the south block has apparently moved upward, and all are concentrated in the zone of anticlines and synclines which is the continuation of a zone of basement highs in Mount Phillips Sheet area.

The most prominent east-northeastward-trending faults lie on the Flint Hill Lineament. There is an apparent sinistral displacement east of Glen Ross Creek.

Northeastward-trending faults are concentrated near the east end of the Jeeaila River Fault. The fault planes are silicified, dip 60° southeastward and are cut by the Jeeaila River Fault.

Most of the eastward and east-southeastward-trending faults are reverse faults, and many may be thrusts. Some of the faults penetrate basement, but some may flatten at depth to become surfaces of detachment within the Bangemall Group or between the basement and its cover. If there is such a decollement surface, the present structures within the Bangemall Group may be the result of gravity sliding of sediments off basement highs which have been elevated by block faulting, or off the Gascoyne Province to the south.

## **CAINOZOIC GEOLOGY**

### *Chalcedonic cap rock (Czd)*

In the southern half of the sheet area, small areas of white to buff chalcedonic rock form a capping on the Bangemall Group dolomites. The chalcedony is probably related to silcrete and the silicification of other rocks. An outcrop 26 km west of Waldburg contains outlines of stromatolites.

### *Laterite and ferruginous deposits (Czl)*

These deposits are either massive, pisolitic or clastic. The massive ironstone is composed dominantly of goethite, but contains lesser amounts of limonite and hematite, and forms caps over leached and deeply weathered bedrock. One



example of relict textures, probably after dolerite, was seen in the leached zone but most ironstone capping occurs on mudstone or shale. The pisolitic variety is generally underlain by a pallid zone in mudstone. Some deposits of transported pebbles of coarse sand which have been recemented by goethite and limonite, directly overlie unleached shale. Both massive and clastic types may incorporate clasts of vein quartz and sedimentary rock.

Laterite generally forms knobs with steep slopes. In the Range Creek Syncline, elongate, branching ironstone bodies lie across valleys and hills, independently of the present topography. They have the form of dendritic drainages, and may represent ancient streams which flowed to the northeast. Massive ironstone has been found over silcrete, and pisolitic laterite has been observed over hardpan, but there may have been more than one period of laterite formation.

#### *Hardpan and silcrete (Czc)*

Hardpan is partially consolidated colluvium; the deposits occur as dissected remnants of talus aprons on valley sides in the Ashburton drainage system, and form vertical or overhanging cliffs. Elsewhere they occur in the banks of incised water-courses, and probably extend under much of the younger colluvium. Maximum thickness is estimated to be over 30 m.

It is orange, or reddish-brown, and consists of a sand, pebbles, and cobbles, in a finer grained, ferruginous clay matrix. The deposits in large creeks are cemented older alluvium, consisting of bedded, cross-bedded, and imbricated water-worn gravel. Palaeocurrent directions accord with present stream directions.

Bettenay and Churchward (1974) called this unit the Wiluna Hardpan, and suggest a Late Tertiary or Early Quaternary age. Brewer and others (1972) concluded it was formed from colluvium with a high proportion of lateritic debris that had been eroded from an older laterite or hardpan.

Silcrete occurs mostly as sporadic outcrops in the eastern half of the sheet area, and is considered to be a silica replacement of bedrock and hardpan. Most silcrete outcrops are too small to show on the map. The rock is composed of white to pale-brown aphanitic silica, which in the vicinity of sandstone bedrock contains quartz grains. Silicified hardpan has been observed.

#### *Calcrete and kankar (Czk)*

Calcrete and kankar are similar in appearance, but calcrete occurs as thick valley-fill deposits in the drainages of present-day or ancestral water courses, whereas kankar is a thin superficial deposit unrelated to drainages (Sanders, 1974). Both are white limestones formed by the chemical replacement of valley-fill sediment or soil by precipitation of calcium carbonate from saturated pore water. The material forms low mounds of nodular or massive limestone, which contain small solution sink holes.

In the Ashburton Valley however, calcrete forms a capping at least 22 metres thick on mesas. Replacement of carbonate by chalcedonic and opaline silica in bands that probably mark former water tables is common. Calcrete mesas and flanking dissected terraces at about the same level in the present drainages are thought to outline the cross-sections of ancestral valleys. The two formations may, therefore, have formed at the same time; the calcrete is probably Late Tertiary, or Early Quaternary.

#### *Colluvium (Qrg)*

Colluvium that is related to present erosion consists of unconsolidated sand, silt, gravel and rubble on slopes and outwash plains. It is transported by a sheet wash process. The unit also includes eluvium, alluvium of small streams, and minor wind-blown sand.

### *Alluvium (Qra)*

Alluvium is unconsolidated gravel, sand and silt transported in water-courses. The boundaries with colluvium are gradual and have been determined by photo-interpretation. All areas showing evidence of stream action are regarded as alluvial.

## ECONOMIC GEOLOGY

### GOLD

Between 1910 and 1935, 247 030 g of gold, consisting of 237 372 g of reef gold and 9 258 g of alluvial gold, was won from the Egerton field. Almost two-thirds of this amount was produced between 1936 and 1953, the remainder between 1910 and 1924 (Table 2).

TABLE 2. GOLD PRODUCTION TO 1974

EGERTON CENTRE					
Name of Lease	Ore (t)	Gold (kg)	Alluvial	Dollied	Main Operating Periods
Dorothy.....	91.4	4.012	—	—	1916
Homeward Bound.....	225.1	6.683	—	—	1914-15
Excelsior.....	3.8	0.502	—	—	1911
Full Hand.....	—	—	—	0.602	1923
Hibernian.....	4 480.8	51.625	1.893	0.331	1912-24
Pegasus.....	357.7	25.588	—	—	1937-38
Egerton.....	2153.0	116.805	0.045	6.027	
Wyndham.....	97.5	0.220	—	—	
Mt View Extended.....	—	—	—	0.028	
Sundry Claims.....	152.6	24.613	7.320	0.731	

TOTAL GOLD = 247.03 kg

Figures from Statistics Branch, Mines Department

The Egerton occurrences are in a sequence of metamorphosed wacke, shale, and gabbro. The main mines, Hibernian and Egerton, were on quartz veins near the contact of sheared metagabbro and quartz-muscovite phyllite. Most other prospects, including those of Gaffneys Find Centre were sunk on pyritic quartz veins that are parallel to the schistosity of metasediments. According to Woodward (1911) most of reef gold occurred in short, lenticular, quartz bodies separated by barren ground, and values declined at depth.

### MANGANESE

Manganese staining is common. Significant occurrences are located about 16 km north-northwest of Woodlands homestead, and about 18 km north-northeast of Mulgul homestead. They have been described by Blatchford (1928), Owen (1953) and de la Hunty (1954, 1963).

The Woodlands deposit consists of small bodies that cap an east-west ridge of sandstone, shale, and dolomite of the Kiangi Creek Formation. The bodies are highly ferruginous, and published analyses of three samples indicate manganese contents from 23 to 27 per cent (de la Hunty, 1954). Most bodies vary from 1 to 3 m in thickness, and consist of pyrolusite encrustations which have some radiating fibrous structure. In places, remnant textures indicate that shale has been replaced by manganese and iron minerals. Other types of occurrences have a fragmental texture, suggesting either a hardpan composed of manganiferous debris, or replacement of a pre-existing hardpan. Normal hardpan with scattered pyrolusite pebbles has been found in a watercourse to the south of the Woodlands deposit. The deposits are low grade and small, and too high in iron to be economic under present conditions.

The Mulgul Station deposit occurs as coatings on bedrock near the foot and on the sides of a ridge about 60 m high of shale and sandstone of Kiangi Creek Formation. In the largest body, relict, shaly bedding demonstrating replacement of bedrock by pyrolusite, hematite and goethite can be seen. Thicknesses vary from 0.3 to 2.7 m, and analyses of two samples show values of 46.2 and 34.8 per cent manganese (de la Hunty, 1954). Although the grade appears high, the reserves are too small to justify exploitation in the foreseeable future.

## COPPER

Malachite and atacamite occur in association with the gold-bearing quartz reefs of the Egerton mining centre. Copper staining was first recorded by Woodward (1911), but no mining for copper has taken place.

Chrysocolla with some malachite occurs in a small excavation in dolerite near its contact with shale of the Devil Creek Formation 20 km northwest of Mulgul. Mineralization is associated with an 80 mm-wide quartz vein. The adjacent dolerite is altered to kaolin and yellow-green nontronite.

Green copper staining on bedding and joint surfaces in the Glen Ross Shale Member five km west of Glen Ross Creek in the northern limb of the Mount Vernon Syncline has been investigated by Westfield Minerals (W.A.) N.L., but the copper values rapidly decrease with depth and appear to be due to surface enrichment.

## VARISCITE

The green, hydrated aluminium phosphate, variscite, has been mined from the Jil-lawarra Formation in the southeast corner of the sheet area. It occurs in narrow, fault-controlled veins, less than 100 mm wide, that cut irregularly silicified shale and mudstone between Irregully Formation dolomite and a dolomite member of the Jilawarra Formation. Associated minerals have been described by Bridge and Pryce (1974).

## WATER

Stock and domestic water is drawn from about 180 bores and wells all of which are tapping shallow aquifers (Table 3).

TABLE 3. WELLS AND BORES

<i>Bore or Well (B) (W)</i>	<i>SWL (m)</i>	<i>TD (m)</i>	<i>T.D.S. (mg/litre)</i>	<i>Remarks</i>
<i>Woodlands Station</i>				
Big Bob (B).....		14.05	570	
Yandagully (B).....			530	Colluvium.
Rumble (B).....			490	Colluvium.
Dispute (B).....			1 450	Alluvium. Tank sample.
Saddle (B).....			690	Alluvium and colluvium.
Hells Doorway (B).....				Abandoned.
Cattle Camp (B).....				Kankar and colluvium.
Quandong (B).....				Colluvium (calcrete next to sandstone)
Gnnall (B).....			480	Colluvium. Tank sample.
Little Spring (B).....			760	Colluvium and kankar. Tank sample.
Muddaberri (B).....			450	Scree, colluvium.
L 18 (B).....			480	Scree. Tank sample.
Munjang (B).....			430	Alluvium and colluvium. Tank sample.

<i>Bore or Well (B) (W)</i>	<i>SWL (m)</i>	<i>TD (m)</i>	<i>T.D.S. (mg/litre)</i>	<i>Remarks</i>
Bullrushes (B).....				Alluvium, colluvium and kankar.
Bore Hole Bore.....			540	Colluvium. Tank sample.
Black Tank (B).....				Colluvium.
Ginginjibby (B).....			250	Alluvium & colluvium. Tank sample.
Deep (B).....				Colluvium.
Alan (B).....			1 160	Colluvium and kankar.
Snake (W).....	7.90	12.60	370	Colluvium.
Trig (B).....			660	Alluvium and colluvium. Tank sample.
Groom (W).....	5.00	6.20	1 100	Alluvium over dolerite.
Shearing.....			477	Colluvium. Tank sample.
Shed (B).....				
North (B).....			478	Level ground. Homestead.
Homestead (W).....			367	Level ground.
Shearing Shed (W).....			663	Colluvium.
Tamana (B).....			600	Alluvium.
Wandry (W).....	10.4	11.5	700	Calcrete.
Ten Mile (B).....			600	Colluvium.
Andrews (B).....			800	Colluvium.
The Swamp (W).....	3.5	9.1	620	Calcrete.
Cement Hole (B).....		27.43	510	Colluvium.
Billycan (B).....		32	590	Colluvium. Tank sample
Main Camp (W).....	19.1	22.9	730	Colluvium.
Deep (W).....	26.0	30	710	Colluvium.
Postcutter (B).....			1 290	Colluvium. Tank sample.
Allarans (B).....				Colluvium.
The Gap (B).....			740	Colluvium. Tank sample.
Cork Tree (B).....		31.8	980	Calcrete.
5 Mile (B).....				Colluvium.
2 Mile (W).....	18.2	21.2	760	Colluvium
Tradedy (B).....		20	610	Colluvium. Tank sample
<i>Waldburg Station</i>				
Twin Peak (B).....			416	Alluvium and colluvium.
Downside (B).....				Not operating-alluvium.
Dicks Yard (B).....		25.32		Not operating-dolerite and chert.
Curlys (B).....			650	Alluvium, colluvium, kankar near dolerite.
Waldburg (B).....		27.42	350	Alluvium and colluvium. Tank sample.
Middle Camp (W&B).....	4.50	5.65	320	Alluvium and colluvium into dolerite.
Happy Jacks (B).....			520	Alluvium and calcrete.
Waterhole (B).....			580	Alluvium and kankar.
Tynes (B).....		30.48	1050	Alluvium. Tank sample.
Tribulation (B).....			800	Colluvium. Tank sample.
Patricks (B).....			630	Colluvium, kankar. Tank sample.
Resolution (B).....			400	Colluvium, kankar. Tank sample.
Valentines (B).....			800	Alluvium and colluvium. Tank sample.
Mungil (B).....			500	Alluvium and kankar. Tank sample.
Fotheringham (B).....		41.0		Colluvium not equipped.
Abandoned (B).....		30.48		Weathered granite.

<i>Bore or Well (B) (W)</i>	<i>SWL (m)</i>	<i>TD (m)</i>	<i>T.D.S. (mg/litre)</i>	<i>Remarks</i>
<i>Mount Augustus Station</i>				
Genoa (B).....		23.18	527	Colluvial plain.
Woolcott (W).....	7.20	14.10	1850	Tank sample.
Hilberry (W).....	2.60	6.20	925	Creek alluvium-kankar.
Coolingberri (B).....			700	Creek alluvium-kankar.
Edney (B).....			650	Level ground.
Isle (B).....		20.13	550	Level ground.
Cooradarra (W).....	4.2	5.8	2500	Alluvium.
Dingo (B).....			580	Alluvium and calcrete. Tank sample.
Isabel (W).....	5.3	6.0	940	Calcrete.
Kudjinarra (W).....	5.1	8.0	1050	Calcrete. Tank sample.
Calcubary (W).....	3.5	7.3	1000	Calcrete.
Narranja (B).....			605	Calcrete.
Sugarloaf (W).....	21.3	30	825	Sandy laminated siltstone.
Muckinarra (W).....	7.4	8.0	800	Calcrete.
Seventeen Mile (W).....	2.7	14.7	780	Calcrete.
Wittenoom (B).....			840	?Calcrete. Tank sample.
Wittenoom (W).....	7.0	9.2	945	Calcrete.
Bilabiddy (W).....	5.2	7.8	590	Calcrete.
Blue Bush (B).....			530	Calcrete.
Bains Swamp (B).....	5.0		1050	Calcrete.
Othes (W).....	8.7	0.2	770	Calcrete.
Staten (W).....	16.2	17.4	700	Colluvium. Tank sample.
Belang (B).....			620	Colluvium & ?calcrete.
Momma (B).....			600	Calcrete. Tank sample.
Ealing (B).....			830	Colluvium. Tank sample.
Mugger (B).....		31.8		Colluvium.
New Bains Swamp (B) or Gidgee Gum (B).....			862	Colluvium.
<i>Mount Vernon Station</i>				
Ruby (W).....	15.60	16.70	760	Shale & dolerite near Ruby B.
Kemps (B).....	11.50	16.30	920	Bank of creek shale. Near 3 mile well.
Three Mile (W).....	1.30	14.10	180	Creek bank. Dolerite.
Roadside (B).....			900	Calcrete & possible dolerite.
9 Mile (B).....			440	Calcrete and dolerite.
Bronco (B).....			350	Alluvium.
ESR Well No. 16.....	7.00	12.50	4500	Calcrete, silcrete, shale.
Crown Wheel (B) O'Briens.....			1000	Calcrete.
(B) & (W).....	5.5	7.2	1300	Calcrete over ?dolomite.
Top Mill (W).....	2.5	3.9	710	Calcrete.
Glen Ross (W).....	7.0	11.7	590	Silty shale & Siltstone.
Netting Mill (W).....	5.0	10.0	1250	Black Shale.
Homestead (B).....	10.5	28	1100	Level ground.
Stockyard (W).....	3.8	6.6	1040	Shale.
House (W).....	6.5	12.5	1390	Shale.
Beefwood (B).....			1960	Alluvium. Tank sample.
Trouble (B).....				Colluvium—alluvium.
<i>Mount Clene Station</i>				
Muddaveing (B).....			1800	Colluvium and kankar, tank sample.
Bubbaweedarra (B).....		15.24	1800	Colluvium.
Mountain (W).....	6.85	10.05	580	

<i>Bore or Well (B) (W)</i>	<i>SWL (m)</i>	<i>TD (m)</i>	<i>T.D.S. (mg/litre)</i>	<i>Remarks</i>
Bundibudda (B).....			220	Colluvium.
Mt Remarkable (B).....			500	Colluvium.
Tringadee (B).....				Colluvium.
Sullivan (W).....	11.25	14.5	500	Colluvium.
Bottle (B).....			650	Colluvium.
Ten Mile (W).....	23.3	23.5	600	Colluvium over granite.
Five Mile (W).....	18.25	23.45	530	Colluvium.
Mt Egerton (B).....			1230	Colluvium over muscovite schist, tank sample.
<i>Cobra Station</i>				
Weloo (B).....		27.45	300	Bank of creek—colluvium.
<i>Milgun Station</i>				
Havelock (B).....			860	Colluvium and alluvium.
Horse Camp (B).....				Alluvium and colluvium.
Deval (B).....		20.75		Colluvium.
Devalle (B).....			912	Colluvium, tank sample.
Bucardy (W).....	4.50	6.70	1040	Alluvium and colluvium.
Abd Bucardy (W).....	3.25	4.10	1040	Calcrete.
Captain Bore.....		11.60	187	Tank sample.
Turner (B).....			1373	Colluvium. Tank sample.
Duration (B).....			640	Colluvium.
<i>Mulgul Station</i>				
Hannaford (W).....	18.50	21.50		Colluvium and mudstone.
Hardy (W).....	29.50	31.15	1730	Level ground.
Gum (W).....	18.50	20.70	1090	Colluvium and sandstone.
Shed (W).....	8.95	9.60	952	Level ground.
Kangathanna (W).....	7.63	11.33	817	Colluvium and mudstone.
Mountain (W).....	15.53	15.63	600	Calcrete.
White (B).....			520	Alluvium.
Andrews (B).....			350	Colluvium and dolerite.
Mt Hopeless (B).....		22		Level ground.
Jimbamunna (W).....	7.55	13.80	499	Colluvium and alluvium.
Black Hill (B).....				Colluvium and alluvium.
Clifton (B).....			912	Calcrete.
Mulgul Hmstd (W).....	13.10	15.35	787	Colluvium.
5 Mile (B).....			810	Alluvium Colluvium. Tank sample.
ESR W13.....	2.0	7.25	636	Alluvium
Beefwood (B).....			894	Colluvium.
Turner (B).....			676	Calcrete—kankar.
Ryles Camp (B).....				Colluvium and calcrete.
Conanna (B).....			884	Colluvium. Tank sample.
Corktree (B).....				Sheet wash. Dry.
Limestone (B).....				Calcrete.
Toby Soak (B).....			580	?Colluvium. Tank sample.
Old Shed				
War Coolina (W).....	11.1	20.0	900	Calcrete over mudstone.
Middle (W).....	8.1	10.2	890	Calcrete.

<i>Bore or Well (B) (W)</i>	<i>SWL (m)</i>	<i>TD (m)</i>	<i>T.D.S. (mg/litre)</i>	<i>Remarks</i>
<i>Mulgul Station—continued</i>				
West Creek (W).....	7.0	13.5	1430	Calcrete. Tank sample.
Gap Well and Bore.....	10.0	14.5	950	Calcrete over shale.
Hillawarra (B).....				Gentle slope.
Quartzite (W).....	19.1	30	1110	Laminated mudstone and shale.
Relief (B).....			615	?Dolomite. Tank sample.
Junction Bore.....			575	?Calcrete.
Manganese (B).....	26.4	36	880	Calcrete.
Bummer (B).....	14.5	20.7		Shale.
Artesian (B).....				Shales.
Range Creek (B).....			780	Silty shales.
Corner Camp (B).....			980	Calcrete.
Little Jimbamunna (B).....			690	Colluvium. Tank sample.
Teana (B).....			900	Shale. Tank sample.
<i>Mount James Station</i>				
Division (B).....	18.75	27.05	1183	Colluvium over migmatite.
White (W).....	16.25	24.25	1338	Weathered granite.
Recovery (W).....	18.0	24.25	1364	Weathered quartz schists.
Peak (B).....				Near creek, not equipped.
Dead Horse (B).....				Calcrete, gravel and colluvium.
Dingo (B).....				Colluvium over dolomite.
K 17 (B).....		27.43		Dolomite.
Yamagie (B).....			1350	Colluvium on weathered sedi- ments.
Biming (W).....	11.50	13.45	830	Weathered granite.
Gaffney (B).....				Near creek.
Let In (W).....	8.90	10.75	1150	Migmatite.
<i>Dooley Downs Station</i>				
Homestead (W).....			1500	Level ground. Tank sample.
Wilsons (B).....			800	Level ground.
Eden (B).....			1000	Level ground.
Alison (B).....			360	Level ground bank of creek.
Steven (B).....			560	Valley near creek.
Andrew (B).....			450	Alluvium over colluvium.
Drum (B).....			3200	Tank sample.
Frederick (B).....		18.3	1500	Alluvium.
<i>Landor Station</i>				
Old Cairn (W).....	9.20	21.55	1000	Colluvium.
Cairn (B).....			1150	Next to creek.

### *Rainfall*

The average annual rainfall is about 200 mm, and in individual years may vary widely. Potential evaporation is about 2 500 mm per year.

Rainfall on the hilly areas quickly runs into small creeks, but some is retained in rock fractures. Direct rainfall on the clayey gilgai-plains infiltrates very slowly, and most evaporates, or is transpired by vegetation.

### *Surface Water*

The area is drained by tributaries of the Ashburton, Lyons, and Gascoyne Rivers which all flow intermittently. Many semi-permanent or permanent pools in the drainage channels are fed by seepage from fractured rocks. Some of the more permanent pools connect with the water table, and only become dry after exceptionally dry years when the water table drops below base level in the pools.

Springs (soaks) are fed by seepage from surrounding fractured rocks. The rate of discharge from the springs is almost equal to the rate of evaporation plus the rate of consumption by stock, so that they remain as small water holes and seldom flow. There is, however, a good supply of water in Pingandy Spring.

### *Groundwater*

Four major aquifers are connected to a fairly shallow water-table.

Alluvium derived from sandstone and granitic rocks is coarser and more permeable than that derived from fine-grained sediments. The alluvium is probably only 10 to 20 m thick and capable of providing only small supplies.

The broad valleys are surfaced with colluvium of talus and debris from sheet erosion. It consists of poorly sorted sand and pebbles with a high silt and clay content. The thickness varies considerably, but is thought to be between 10 and 50 m. Low yielding bores tap these aquifers.

Calcrete deposits range in thickness up to 25 m. They generally have a high secondary rock porosity and permeability, and in some areas yield fairly large quantities of groundwater.

Many of the fractured sedimentary rocks, particularly cherts and sandstones, could yield groundwater. Hard-rock drilling would be necessary to sink bores into these aquifers.

### *Groundwater Prospecting*

The most prospective areas are where the alluvium is thickest or where calcrete is present, for example, Hilberry Well at the headwaters of the Lyons River. Other good sites can be located immediately upstream of an upstream-dipping sequence of sedimentary rocks such as at Resolution Bore on Waldburg Station, because the alluvial or colluvial overburden in such places is usually thicker than elsewhere. Exploratory drilling should be continued through the overburden into the underlying rocks to test for fracture porosity.

Most dolomite is fairly tight, and does not contain water. Dolomite may have secondary porosity produced by a network of interconnecting solution channels, and if located below the water table, could hold large quantities of groundwater.

### *Groundwater Quality*

The salinity of the groundwater (Table 3) varies between 200 ppm and 4 500 ppm T.D.S. (parts per million Total Dissolved Solids) but in most areas is less than 1 000 ppm T.D.S. Low-salinity groundwater indicates probable areas of intake or areas of high permeability where the salts have been flushed. Experience elsewhere suggests that the salinity of the groundwater may increase with depth particularly in the fractured-rock aquifers. Throughout the entire area, the salinity should be satisfactory for stock and in most areas suitable for human consumption.



TABLE 4. LOCALITIES MENTIONED IN TEXT

<i>Name</i>	<i>Latitude</i>	<i>Longitude</i>
Berala Syncline.....	24°25'	117°20'
Candolle Syncline.....	24°32'	117°02'
Coolina Yards.....	24°40'	118°16'
Cooradarra Well.....	24°23'	117°07'
Corner Camp Bore.....	24°30'	118°18'
Dooley Downs.....	24°08'	117°07'
Egerton Mining Centre.....	24°56'	117°46'
Glen Ross Creek.....	24°17'	118°13'
Gorge Creek West.....	24°12'	117°59'
Hells Doorway Syncline.....	24°50'	117°50'
Hilberry Well.....	24°34'	117°23'
Jillawarra Bore.....		
K 17 Bore.....	24°51'	117°10'
Let In Well.....		
Lyons River Anticline.....	24°28'	117°20'
Mount Deverell.....	24°58'	118°15'
Mount Egerton.....	24°46'	117°42'
Mount Sanford.....	24°20'	118°29'
Mount Vernon.....	24°09'	118°02'
Mount Remarkable Bore.....	24°57'	117°21'
Mount Vernon Homestead.....	24°14'	118°14'
Mount Vernon Syncline.....	24°20'	118°05'
Mulgul Homestead.....	24°50'	118°28'
Narrinja Bore.....	24°29'	117°23'
Pingandy Creek.....	24°02'	117°48'
Pingandy Spring.....	24°05'	117°41'
Range Creek Syncline.....	24°33'	118°15'
Resolution Synclinorium.....	24°48'	117°25'
Staten Hill.....	24°28'	117°43'
Teano Range.....	24°33'	117°56'
Waldburg.....	24°45'	117°22'
West Creek.....	24°40'	118°10'
Woodlands Homestead.....	24°49'	118°06'

## REFERENCES

- Ariens, P. A.*, 1971, The Archaean geochronology of Australia: Geol. Soc. Aust. Spec. Pub. No. 3, p. 11-24.
- Barnett, J. C.*, 1975, Some probable Lower Proterozoic sediments in the Mount Padbury area: West. Australia Geol. Survey Ann. Rept. 1974, p. 52-54.
- Bettenay, E. and Churchward, H. M.*, 1974, Morphology and stratigraphic relationships of the Wiluna Hardpan in arid Western Australia: Geol. Soc. Australia Jour. V. 21, p. 73-80.
- Blatchford, T.*, 1928, Manganese deposits of the Teano Range and Mt Fraser, Peak Hill Goldfield: West. Australia. Geol. Survey. Ann. Prog. Rept. 1927, p. 117-118.
- Brakel, A. T., and Muhling P. C.*, 1976, Stratigraphy, sedimentation and structure in the Bangemall Basin, Western Australia: Geol. Survey Ann. Rept, 1975, p. 70.
- Brakel, A. T., Elias, M., and Barnett, J. C.*, 1978, Explanatory notes on the Collier 1:250 000 Geological Sheet, Western Australia: West. Australia Geol. Survey. Rec. 1978/8.
- Brewer, R., Bettenay E., and Churchward, H. M.*, 1972, Some aspects of the origin and development of the red and brown hardpan soils of Bulloo Downs, Western Australia: C.S.I.R.O. Division of Soils Technical Paper No. 13.
- Bridge, P. J. and Pryce, M.*, 1974, Magnesian collinsite from Milgun Station, Western Australia: Min. Mag. V. 39, p. 577-9.
- Compston W., and Arriens, P. A.*, 1968, The Precambrian geochronology of Australia: Canadian. Jour. of Earth Sciences, v. 5, p. 561-583.
- Daniels, J. L.*, 1966, Revised stratigraphy, palaeocurrent system and palaeogeography of the Proterozoic Bangemall Group: Geol. Survey Ann. Rept. 1965, p. 48-56.
- 1968, Turee Creek, W.A., 1:250 000 Geological Series: Geol. Survey West. Australia Explan. Notes.
- 1969, Edmund, W.A., 1:250 000 Geological Series: Geol. Survey West Australia Explan. Notes.
- 1975, Gascoyne Province, in Geology of Western Australia: West. Australia Geol. Survey, Mem. 2, p. 107-114.
- Daniels, J. L., and Horwitz, R. C.*, 1969, Precambrian tectonic units of Western Australia: West Australia Geol. Survey Ann. Rept. 1968, p. 37-38.
- de la Hunt, L. E.*, 1954, Report on some manganese deposits in the North-West Division, Western Australia: West. Australia Geol. Survey Ann. Rept. 1952, p. 72-78.
- 1963, The geology of the manganese deposits of Western Australia: West. Australia Geol. Survey Bull 116.
- de Laeter, J. R.*, 1976, Rb-Sr whole rock and mineral ages from the Gascoyne Province: West. Australia Geol. Survey Ann. Rept. 1975, p. 7.
- Gee, R. D., de Laeter, J. R., and Drake J. R.*, 1976, The geology and geochronology of altered rhyolite from the lower part of the Bangemall Group near Tangadee, Western Australia: West. Australia Geol. Survey Ann. Rept. 1975, p. 112.
- Geological Survey of Western Australia*, 1975, Geology of Western Australia: West. Australia Geol. Survey, Mem. 2, p. 541.
- Halligan, R., and Daniels, J. L.*, 1964, Precambrian geology of the Ashburton Valley region, North-West Division: West. Australia Geol. Survey Ann. Rept. 1963, p. 88-96.
- Higgs, M. W.*, 1971, Cataclastic rocks. U.S. Geol. Survey, Prof. Paper 687.
- Hudleston, W. H.*, 1883, Notes on a collection of fossils and of rock-specimens from West Australia, north of the Gascoyne River: Geol. Soc. London Quart. Jour. v. 39, p. 582-595.
- Johnson, W.*, 1949, Progress report on the geology of portion of the North-West Division between latitudes 24°S and 29°S and between longitudes 115°30'E and 118°30'E: West. Australia Geol. Survey. Ann. Rept. 1947, p. 102-110.
- 1950, A geological reconnaissance survey of part of the area included between the limits lot 24°0'S and lat 29°0'S and between long 115°30'E and long 118°30'E including parts of the Yalgoo, Murchison, Peak Hill and Gascoyne Goldfields: West. Australia Geol. Survey Bull. 106.
- Marshall, A. E.*, 1968, Geological studies of the Proterozoic Bangemall Group, N.W. Australia: Princeton University Ph. D. Thesis (unpublished).
- MacLeod, W. N.*, 1970, Peak Hill, W.A.: West. Australia Geol. Survey 1:250 000 Geological Series Explan. Notes.
- Muhling, P. C., and Low, G. H.*, 1973, Explanatory notes on the Yalgoo 1:250 000 Geological Sheet W.A.: West. Australia Geol. Survey Rec. 1973/6 (unpublished).
- Mulcahy, M., and Bettenay, E.*, 1972, Soil and landscape studies in Western Australia. (1) The major drainage divisions: Geol. Soc. Australia Jour. v. 18. p. 349.
- Owen, H. B.*, 1953, Ferruginous manganese deposits, Teano Range, North-West Division W.A.: Australia Bur. Mineral Resources Rec. 1953/25 (unpublished).
- Pettijohn, F. J.*, 1954, Sedimentary Rocks: Harper Bros. N.Y.
- Sanders, C. C.*, 1974, Calcrete in Western Australia: Geol. Survey Ann. Rept. 1973, p. 12-13.

- Talbot, H. W. B.*, 1926, A geological reconnaissance of part of the Ashburton drainage basin: West. Australia Geol. Survey. Bull. 95.
- Wilde, S. A.*, 1974, Explanatory notes on the Perth 1:250 000 Geological Sheet, Western Australia: West. Australia Geol. Survey Rec. 1974/15 (unpublished).
- Williams, H., Turner F. J., and Gilbert, C. M.*, 1954, Petrography: W. H. Freeman and Co San Francisco.
- Woodward, H. P.*, 1891, Geognosy. A general description of the Victoria, Murchison, Gascoyne, Ashburton, Fortescue, Roebourne and De Grey districts: Ann. General Rept. of the Government Geologist for the year 1890 p. 6-12.
- 1911, The Mt Egerton diggings, Peak Hill Goldfield: West. Australia Geol. Survey Ann. Rept. 1910, p. 111-115.
- 1912, Notes to accompany the geological sketch map of the country at the heads of the Ashburton and Gascoyne Rivers: West. Australia Geol. Survey Bull. 48, p. 49-55.



