1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

NABBERU

WESTERN AUSTRALIA

SHEET SG/51-5 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
1:250 000 OR 4 MILE SCALE

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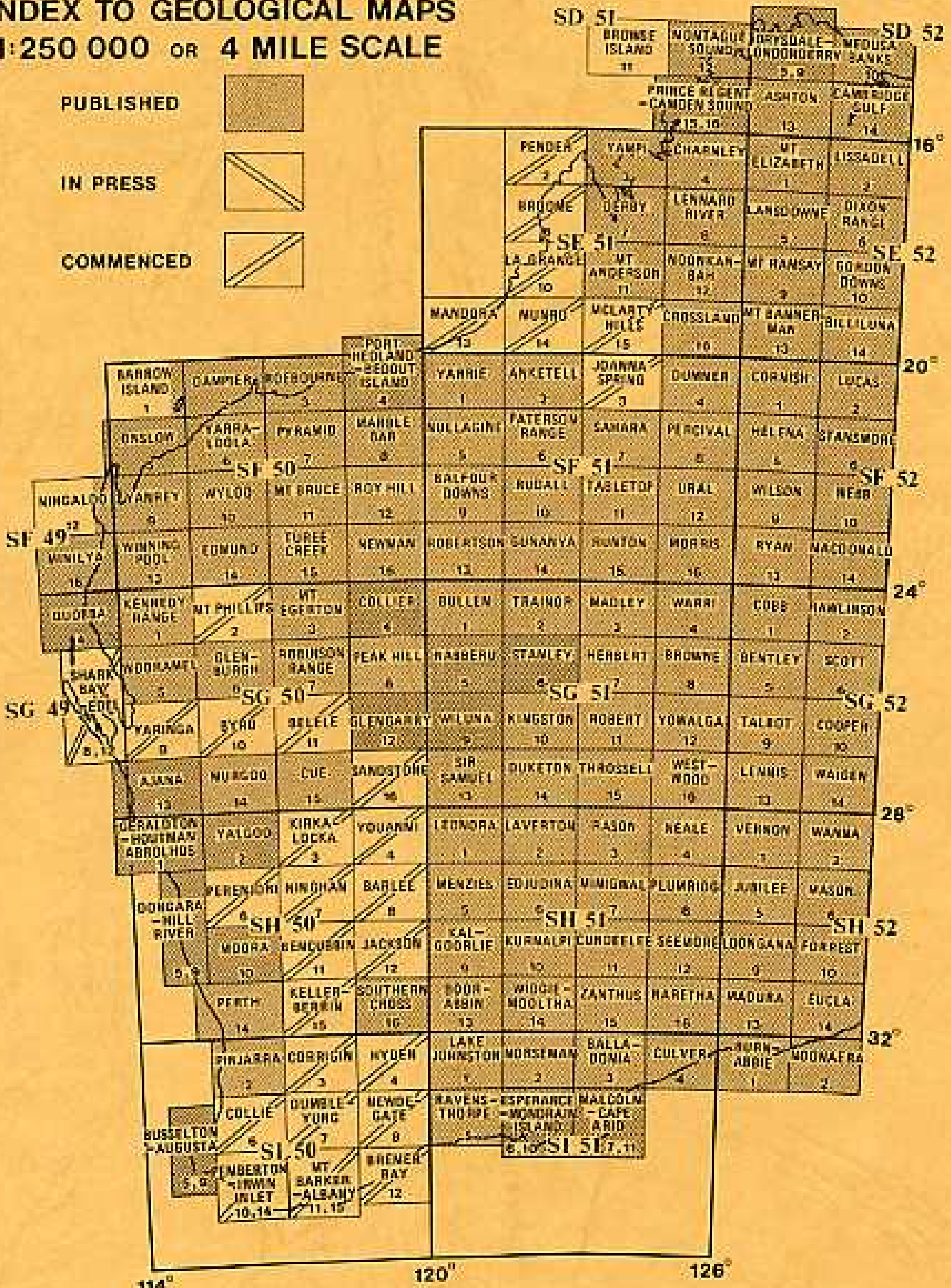

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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NABBERU

WESTERN AUSTRALIA

SHEET SG/51-5 INTERNATIONAL INDEX

COMPILED BY J. A. BUNTING, A. T. BRAKEL AND
D. P. COMMANDER

PERTH, WESTERN AUSTRALIA 1982

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DEPARTMENT OF MINES, WESTERN AUSTRALIA
Minister: The Hon. P. V. Jones, M.L.A.
Under-Secretary: D. R. KELLY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
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Explanatory Notes on the Nabberu Geological Sheet

Compiled by J. A. Bunting, A T. Brakel and D. P. Commander

INTRODUCTION

GENERAL

The NABBERU* 1:250 000 sheet, reference SG 51-5 of the International Series, is bounded by latitudes 25°00′S and 26°00′S and longitudes 120°00′E and 121°30′E. The sheet takes its name from Lake Nabberu (see Appendix for co-ordinates of localities).

The small permanent population is engaged in the pastoral industry at Granite Peak and Marymia Stations. Parts of Cunyu, Neds Creek, New Springs, Millrose, Lorna Glen and Earaheedy Stations also fall within the sheet. A small transient population is engaged in mineral exploration, vermin control and kangaroo shooting.

Graded gravel roads from Wiluna cross the southwest and southeast corners of the sheet. Elsewhere, access relies on station or mineral exploration tracks, many of which require four-wheel-drive vehicles, especially after heavy rain. The Canning Stock Route, established between 1906 and 1909, crosses the sheet from southwest to northeast, and is the only access to the northeast corner. Away from the tracks, vehicle access is good on sheetwash and flood plains, but difficult in rocky hills. On sand plain, travel is hampered by dunes and spinifex.

The climate is semi-arid; the mean annual rainfall is between 200 and 240 mm, but unreliable, and the area is subject to drought as well as localized short-term floods. The wettest period is December to May. Annual potential evaporation is between 2 400 and 2 800 mm. January, with an average maximum of 38°C and minimum 23°C, is the hottest month; July, with an average maximum of 20°C and minimum 6°C, is the coolest.

PHYSIOGRAPHY, DRAINAGE AND VEGETATION

For the purpose of this report, the physiography (Fig. 1) is divided into three: (1) degradational areas, (2) intermediate areas, and (3) aggradational areas.

Degradational: All those areas of relatively high relief, such as hills, breakaways, and cuestas, and their associated talus deposits are considered to be degradational. Relief is generally less than 100 m, although it reaches 300 m in the Carnarvon Range. The highest point is Mount Methwin (903 m). Resistant rocks, such as quartz arenite and iron-formation, commonly form cuestas where the rocks are gently dipping (Frere Range, Verscher Range), or elongate hills and ridges where they are more steeply dipping. Low, rounded hills are characteristic of Archaean rocks and shaly Proterozoic sediments, low breakaways of rocks that are weathered or lateritized.

*Names of 1:250 000 sheets are given in upper case, to distinguish them from localities of the same name.

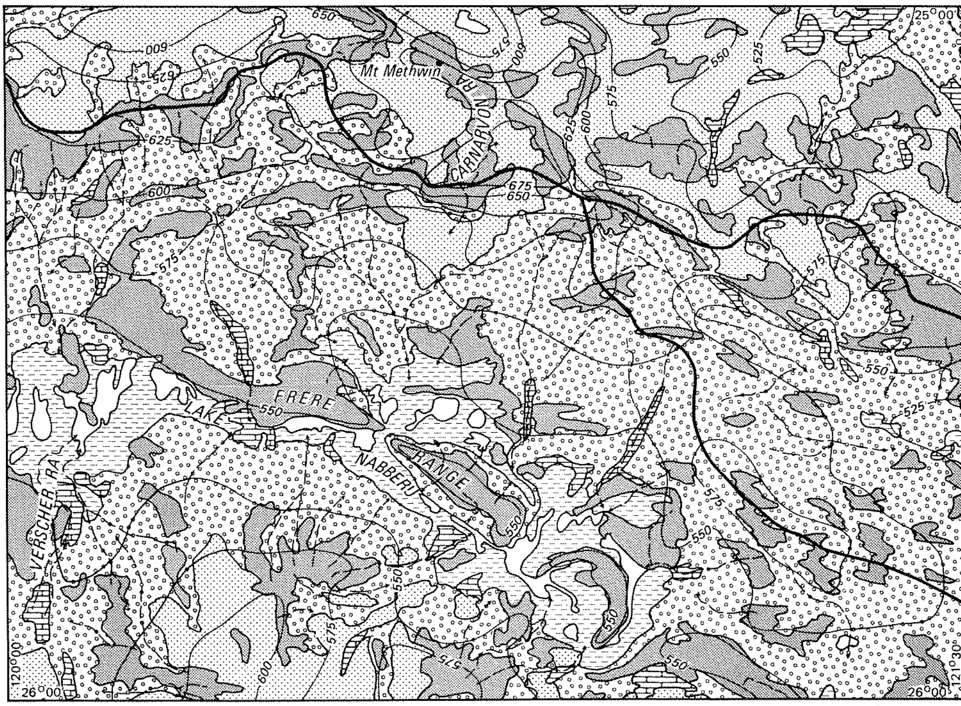


FIGURE 1 GSWA 17582

PHYSIOGRAPHY AND DRAINAGE

NABBERU SHEET SG 51-5

0 10 20 30 km

REFERENCE

DEGRADATIONAL AREAS

1 Upland areas, low hills, cuestas, duricrust-capped mesas and associated pediments

INTERMEDIATE AREAS (material derived from 1)

2a Flat sheetwash plains and valley floors consisting of colluvium and alluvium

2b Eolian sandplain, with patchy cover of longitudinal dunes

AGGRADATIONAL AREAS (material derived from 1and 2)

3a Flat, bare salt-lake surface

3b Dunes and sheets of eolian and alluvial material marginal to salt-lakes and in major valley floors

3c Calcrete filled valley floors, low lying with hummocky surface

Ephemeral drainage

Drainage divide

-525- Topographic contour in metres

Intermediate: Intermediate areas can be subdivided into two units: (a) sheetwash plains and valley floors, and (b) eolian sandplain. Unit (a) includes flat or bare mulga-covered plains of colluvium and alluvium, which have broad, ill-defined drainages characterized by thick vegetation. Eolian sandplain occurs over granitoid rocks and Middle Proterozoic sediments, but is largely absent from areas underlain by the Earaheedy Group and Archaean greenstone belt. The sandplain is gently undulating, and, particularly over Bangemall Group rocks, contains abundant, spinifex-covered, longitudinal and chain dunes up to 10 m high and several kilometres long.

Aggradational: Aggradational areas are low-lying (elevations generally between 520 and 550 m), and represent the infilled trunk drainages of the Cretaceous-Tertiary palaeodrainage system (van de Graaff and others, 1977). The most conspicuous of these is the Lake Nabberu system, which once flowed east-southeast towards Lake Carnegie, but which now terminates in the lakes surrounding the Teague Ring structure. Drainage in the eastern part of the sheet is east-southeast into Lake Carnegie, but in the northeast corner is easterly and northerly into the Lake Burnside—Lake Disappointment system.

The aggradational areas consist of three physiographic elements: (a) bare salt lakes, containing saline clay, which collect shallow saline water after heavy rain; (b) dunes and sheets of eolian and alluvial material marginal to salt lakes and containing numerous small claypans; and (c) calcreted valley floors, in which low mounds of rubbly calcrete are separated by soil-filled depressions. In some areas, the valley calcrete is being eroded by present-day drainage, leaving remnants of calcrete above the newly eroded valley floor.

Vegetation communities correspond closely to physiographic units. Stony Hills support low mulga *(Acacia aneura)* scrub and other small shrubs. Sheetwash plains and floodplains contain low woodland of mulga and a ground cover of grasses, whereas the larger watercourses support lines of large eucalypts along the banks. The marginal areas around salt lakes are characterized by halophytes such as saltbush *(Atriplex)*, bluebush *(Kochia)*, and samphire *(Artrocnemum)*. Sandplain is dominated by spinifex *(Triodia)*, scattered mulga, shrubs and small mallees *(Eucalyptus)*.

SUMMARY OF GEOLOGY

The stratigraphy of the sheet is summarized in Table 1. Most of NABBERU is occupied by Early Proterozoic sedimentary rocks of the Nabberu Basin. A shallow-water sequence of sandstone, iron-formation, chert, shale and carbonate belonging to the Earaheedy Group, overlies, probably unconformably, an older sequence of sandstone, wacke and shale in the Glengarry Sub-basin and Troy Creek inlier.

In the southern part of the sheet, the Early Proterozoic rocks unconformably overlie Archaean greenstone belts and granitoid rocks along the northern margin of the Yilgarn Block. In the northwest, the Earaheedy Group unconformably overlies granitoid rocks of the Marymia Dome.

Middle Proterozoic rocks occupy the northern part of the sheet. Two sequences are present: a lower sequence, the Scorpion Group, which consists of sandstone, shale and carbonate; and an upper sequence, part of the Bangemall Basin, which consists of sandstone and a small amount of shale. An unconformity probably separates the two Middle Proterozoic sequences.

Small outliers of Permian glacigene and fluviatile rocks occur in the southeast corner of the sheet.

TABLE 1. STRATIGRAPHIC SUMMARY OF PRE-CAINOZOIC UNITS

Age	*Group*	*Formation*	*Map Symbol*	*Lithology*	*Thickness (m)*	*Distribution*	*Remarks*
Lower Permian		PATERSON FORMATION	*Paf*	Poorly sorted sandstone, minor conglomerate and siltstone	10	Outliers in SE part of sheet	Fluviatile and fluvioglacial
Proterozoic			*b*	Dolerite, fine- to medium-grained, rare granophyre	1-50	Glengarry Sub-basin, Teague Structure and Bangemall Basin	Sill-like intrusions
		CALYIE SANDSTONE	*ᵽMy*	Quartz sandstone, minor conglomerate	?1000+	Carnarvon Range to NE corner	Abundant large-scale cross-bedding along southern side of distribution
Middle Proterozoic (ca. 1.1 b.y.)	Bangemall Group	WONYULGUNNA SANDSTONE	*ᵽMw*	Quartz sandstone, with shale and siltstone in northwest corner	800+	Between Mount Methwin and NW corner	Separated from Calyie by Backdoor Formation on COLLIER, but laterally continuous with Calyie in NE NABBERU
		COONABILDIE FORMATION	*ᵽmx*	Fine-grained quartz sandstone, silstone and shale		NE corner	More extensive on STANLEY where it is 1 100 m thick
	Scorpion Group		*ᵽo*	Quartz sandstone, siltstone, dolomite, minor lithic sandstone and polymict conglomerate	10 000?	NE corner	Unconformable beneath Bangemall Group; part of more extensive sub-surface basin to NE?
		WONGAWOL FORMATION	*ᵽEo*	Fine-grained arkosic sandstone	5	Core of syncline, NE side Teague Structure	Basal part of 2 000 m thick sequence on STANLEY
		PRINCESS RANGES QUARTZITE	*ᵽEp*	White quartz arenite, minor clayey sandstone and siltstone	250-300	East-central part of sheet and Teague Structure	
Early Proterozoic (ca. 1.7-2.0 b.y.)	Earaheedy Group	WANDIWARRA FORMATION	*ᵽEw*	Quartz sandstone and shale, locally glauconitic	500-1 500	Extensive in central and eastern part of sheet	In places includes Windidda Formation equivalent
		WINDIDDA FORMATION	*ᵽEd*	Limestone, shale, minor jasperoidal chert and carbonate-clast conglomerate	0-1 000?	SE part of sheet	Thickest in SE where it is largely unexposed; grades laterally into Wandiwarra
		FRERE FORMATION	*ᵽEf*	Granular and banded iron-formation, hematitic shale, chert, shale, minor stromatolitic carbonate	1 300	Extensive exposure enclosing central part of sheet	Highly ferruginous, locally ore-grade, in northern and western parts

Early Proterozoic (ca. 1.7-2.0 b.y.)	Earaheedy Group	YELMA FORMATION	*PEy*	Quartz arenite, shale, phyllite, chert, minor stromatolitic carbonate	10-1 000	Extensive exposure in N part of sheet, patchy in S part	Unconformable on crystalline basement. Thickest in N, thinnest in SE
		FINLAYSON SANDSTONE	*PGf*	Quartz arenite, shale, minor chert and chert breccia	450?	SW corner	Part of Glengarry Sub-basin. Unconformably overlain by Earaheedy Group
		Unassigned	*Plx*	Shale, phyllite, sandstone, minor chert, carbonate, iron-formation; schistose in north	(2 000+)?	NE corner	Possible equivalent of rocks in Glengarry Sub-basin
Precambrian			*pЄg*	Granitoid rocks, including syenitic rocks in Teague Structure		NE corner and Teague Structure	Unconformably overlain by Earaheedy Group
Archaean (ca. 2.5-2.7 b.y.)			*Ag*	Various granitoid rocks, mainly adamellite, some hornblende quartz monzonite		SW part of sheet	
			As	Metasediments, fine-grained, schistose		SW corner and south central part of sheet	Intruded by Archaean granitoid rocks
			Ai	Banded iron-formation			
			Af	Metamorphosed felsic volcanic rocks			
			Ab	Metabasalt, fine-grained, locally hornfelsed			

PREVIOUS INVESTIGATIONS

In 1874, the explorer, John Forrest, crossed the sheet from southwest to northeast, naming Sweeney Creek, Frere Range, Kennedy Creek, Windich Spring, Pierre Spring, and various hills in the Carnarvon Range.

The first geological reports were by Talbot (1910, 1920), who recognized unconformities at the base of the Bangemall Group ("Nullaginian" in Talbot's nomenclature) and between the Lower Proterozoic rocks and the Yilgarn Block. However, he mistakenly identified another unconformity corresponding to the southern edge of the Stanley Fold Belt, which led to the belief that the undeformed rocks south of this line were equivalent to the "Nullagine" rocks.

Talbot's interpretation remained on State geological maps until the 1966 edition, when all the Proterozoic sediments in this area were included in the Middle Proterozoic. This interpretation was in vogue (Daniels and Horwitz, 1969; Sanders and Harley, 1970; Geological Survey of Western Australia, 1975) until the major unconformity between the Nabberu Basin and Bangemall Basin sequences was "re-discovered" by Hall and Goode (1975) and Horwitz (1975 a and b). Hall and Goode (1975) proposed stratigraphic subdivisions of the Nabberu Basin sequence, which were modified slightly and formally defined as the Earaheedy Group by Hall and others (1977). The regional geology of the Nabberu Basin has recently been described by Bunting and others (1977), Horwitz and Smith (1978) and Hall and Goode (1978).

Adjoining 1:250 000 geological sheets which have been published or are in press are PEAK HILL (McLeod, 1970), BULLEN (Leech and Brakel, 1978), STANLEY (Commander and others,1979), and WILUNA (Elias and Bunting, 1979).

In 1975 the present survey commenced with a brief reconnaissance by J. A. Bunting and A. T. Brakel, and a few traverses along the northern boundary by R. E. J. Leech. The rest of the sheet was mapped in 1976 by J. A. Bunting and D. P. Commander (Archaean and Nabberu Basin), and A. T. Brakel (Scorpion Group and Bangemall Basin).

ARCHAEAN

GREENSTONE BELTS

Two small Archaean greenstone belts occur in the southern part of the sheet (Table 1). Both are covered by laterite and poorly exposed.

The western belt, which is near Cunyu woolshed, is predominantly mafic. The few small outcrops of fresh rock are of fine-grained, massive metabasalt. In thin section, the metabasalt is a sub-ophitic intergrowth of primary, zoned plagioclase (?andesine), clinopyroxene, sparse quartz, and subordinate secondary epidote, pumpellyite and chlorite. Grade of metamorphism is, therefore, very low, and accords with the low grade in the Wiluna greenstone belt to the south (Binns and others, 1975; Elias and Bunting, 1979). Two small outcrops of deeply weathered, cleaved metapelite west of the Merrie Range are probably close to the eastern side of this belt.

Southeast of Bridle Face Outcamp, a small greenstone belt wedges out southwards along a major fault between two bodies of quartz monzonite. Metabasalt is contact metamorphosed to an irregular aggregate of plagioclase, quartz, diopside, and sparse epidote and spongy garnet. Felsic volcanic rocks, probably originally dacitic, have been statically recrystallized to a fine-grained mosaic of quartz, plagioclase, and either hornblende or diopside. Phenocrysts of quartz, plagioclase, and, occasionally, an altered mafic mineral are common.

A quartz-magnetite banded iron-formation is interbedded with cleaved metapelite 6 km east of Bridle Face Outcamp.

GRANITOID ROCKS

Medium- to coarse-grained adamellite, consisting of roughly equal amounts of quartz, oligoclase and microcline, and minor chloritized biotite, is the dominant granitoid between Bridle Face Outcamp and the western edge of the sheet. Locally, the rock may be fine grained; and near White Well, a coarse, porphyritic variety contains microcline phenocrysts. A steeply dipping gneissic or cataclastic foliation is present near the greenstone belts, but elswhere there is only a very weak primary foliation. No contact relationships with the greenstone belts are seen, but in view of relationships in other parts of the Yilgarn Block, it is presumed that the adamellite intrudes the greenstone belts.

Southeast of Bridle Face Outcamp, two bodies of hornblende-quartz monzonite intrude the greenstone belt. Both bodies, which are separated by a faulted wedge of greenstone, have the same mineralogy, but slightly and consistently different textures. Each consists of quartz (up to 20 per cent), plagioclase (albite to oligoclase), perthitic microcline, and green hornblende (rarely with clinopyroxene cores). The hornblende is euhedral, but the prisms in the western body are stumpier than those in the eastern body. It generally forms about 10 per cent of the rock, but

TABLE 2. CHEMICAL ANALYSES

GSWA Sample No.	*46521*	*46522*	*46523*
SiO_2 per cent	66.7	63.9	68.3
Al_2O_3	15.5	16.0	14.9
Fe_2O_3	2.3	2.7	1.8
FeO	1.29	1.35	1.42
MnO	0.07	0.09	0.07
MgO	0.99	1.33	1.79
CaO	2.50	2.65	2.72
K_2O	4.2	4.2	4.1
Na_2O	5.39	5.82	4.58
TiO_2	0.45	0.51	0.29
P_2O_5	0.28	0.31	0.19
H_2O^+	0.40	0.44	0.51
H_2O^-	0.07	0.05	0.03
F	0.13	0.12	0.08
TOTAL	100.27	99.47	100.78
Ba ppm	2100	1900	1200
Rb ppm	110	100	150
Sr ppm	1600	1600	750
Th ppm	45	35	25
U ppm	2	<1	3

All analyses by Government Chemical Laboratories, Perth.

46521 Hornblende-quartz monzonite Lat. 25°57′20″ Long. 120°47′20″

46522 Hornblende-quartz monzonite Lat. 25°57′20″ Long. 120°46′10″

46523 Hornblende-quartz monzonite Lat. 25°57′40″ Long. 120°42′50″

can form up to 20 per cent. Large crystals of sphene and allanite are abundant. The high grade of contact metamorphism in the adjacent greenstones and the lack of any tectonite fabric in the quartz monzonite suggest a high-level post-tectonic intrusion. The mineralogy and chemistry (Table 2), which indicate a rock of alkaline affinities, suggest a relationship with the post-tectonic alkaline granitoids (Mount Boreas suite) elsewhere in the northeast Yilgarn Block (Bunting and Williams, 1976).

?ARCHAEAN INLIERS.

In the northwest part of the sheet and in the Teague Ring Structure, the granitoid rocks are lithologically similar to Archaean types, but their age cannot be stated with certainty.

The predominant rock in the northwest part of the sheet (Marymia Dome) is a medium- to course-grained adamellite (*p€gb*) which is very similar to the Archaean granitoids further south. It has a weak, northeast-trending tectonic foliation. In the northwest corner, the adamellite is finer grained and more strongly foliated (*p€ge*). The adamellite is unconformably overlain by the Yelma Formation of the Earaheedy Group, a relationship best seen 24 km south of Marymia. However, on COLLIER, some 30 km northwest of Marymia, granitic rocks of the Marymia Dome intrude metasediments which may be equivalent to Lower Proterozoic rocks in the Glengarry Sub-basin (Brakel and others, 1978). It is probable that the Marymia Dome is a composite structure containing granitoid rocks of various ages.

The Teague Ring Stucture consists of a core of granitic and syenitic material, which is, in turn, surrounded by a ring syncline in rocks of the Earaheedy Group. The granitic rocks (*p€g*) are all weathered, and their exact nature is not clear. Medium- and course-grained varieties are present, and in places, there is a gneissic foliation. The syenitic rocks (*p€gs*) contain up to 20 per cent quartz, and at one locality the syenite is quartz free. Grain-size varies from medium to very coarse. Perthitic alkali feldspar is always more abundant than plagioclase. The main mafic mineral is green aegirine-augite, rarely with a core of pale greyish-green clinopyroxene.

The granitic rocks in the Teague Ring Structure are probably overlain unconformably by the Yelma Formation. The quartz syenite is not seen within a kilometre or so of the sedimentary rocks, and, although it intrudes the granitic rocks, its age relationship with the sediments is not known for certain. Therefore, although the granitic rocks can be tentatively assigned to the Archaean, the age of the quartz syenite is less certain. Lithologically the quartz syenite is similar to late Archaean quartz syenites elsewhere in the Yilgarn Block (Bunting and Williams, 1976), but preliminary results of Rb-Sr geochronology indicate that the Teague syenites may be Early Proterozoic (de Laeter, pers. comm.).

The origin of the Teague Ring Structure is discussed later in these notes.

PROTEROZOIC

NABBERU BASIN

Troy Creek Beds

In the northeast part of the sheet, below the lowest continuous arenite of the Yelma Formation, is a mixed group of rocks, here termed the Troy Creek Beds, the age and relationships of which are not clear. Rock types include shale, phyllite, quartz sandstone, and rare, thin bands of chert and carbonate. Chlorite-muscovite schist, 1 km south of Mount Davis, contains millimetre-thick bands of magnetite octahedra. Banded iron-formation is interbedded with phyllite 10 and 15 km east of Mount Davis.

The commonest rock is a brown, maroon or purple cleaved shale which becomes more phyllitic northwards. Near the northern limit of exposure, south of Willy Willy Bore the phyllite (here almost a schist) displays an older, folded foliation (S_1) cut by a later planar foliation (S_2). Small garnets (now largely weathered out) are wrapped around by S_2, which in hand specimen is the dominant foliation. A later crenulation cleavage (S_3) is present in some samples. To the south, both S_1 and S_2 decrease in intensity until finally, in the vicinity of Troy Creek, only a moderate S_2 cleavage remains. The S_2 cleavage is the dominant and earliest cleavage in the overlying Earaheedy Group; it is followed only by a weak S_3 crenulation. While not conclusive, this structural sequence and the high metamorphic grade suggest an unconformable relationship between the Troy Creek Beds and the Yelma Formation.

On stratigraphic, lithological, and structural grounds, the Troy Creek Beds probably correlate with the axial sequence in the Glengarry Sub-basin (Bunting and others, 1977).

Glengarry Sub-basin sequence

The Glengarry Sub-basin forms the western part of the Nabberu Basin. Only the basal unit, the Finlayson Sandstone, occurs on NABBERU, and that in the southwest corner of the sheet.

Finlayson Sandstone: The Finlayson Sandstone lies unconformably on Archaean rocks and is probably overlain unconformably by the Earaheedy Group. To the west, the Finlayson Sandstone is conformably overlain by the Maraloou Formation and the axial sequence of the Glengarry Sub-basin (Bunting and others, 1977).

Two sandstone units are present in the formation: a lower unit, about 50 m thick, in the Verscher Range, and an upper unit about 100 m thick, in the vicinity of Mount Paterson. Between these two, there is about 300 m of largely unexposed fine-grained sandstone and flaggy shale. Thin (<5 m) silicified chert bands underlie both of the thick sandstone units. The sandstone is a white to pale-grey, supermature quartz arenite which has ripple marks and trough-style cross-bedding. Similar white quartz arenite in the Merrie Range has been included in the Finlayson Sandstone because of its lithological similarity, although it might equally well be part of the Yelma Formation.

Black microbanded chert from below the arenite at the northeast end of the Verscher Range contains an abundant microfauna, mainly algal filaments (K. Grey, pers. comm.).

Earaheedy Group

The Earaheedy Group (Hall and others, 1977), about 6 000 m thick and occupying most of the eastern part of the Nabberu Basin, is a shelf facies of shale, sandstone, limestone, chert and granular iron-formation. The top two formations, the Kulele Limestone and the Mulgarra Sandstone, are not present on NABBERU.

Isotopic ages of 1 590 and 1 710 m.y. have been obtained from glauconite in the Yelma Formation in the southeast Nabberu Basin (Preiss and others, 1975), and an age of 1 685 m.y. has been reported from glauconite in the Wandiwarra Formation on KINGSTON (Horwitz, 1975b).

Yelma Formation: The Yelma Formation is the basal unit of the Earaheedy Group. It is a predominantly clastic unit which unconformably overlies granitic rocks and other Lower Proterozoic sediments.

The formation consists of quartz arenite and shale, and minor chert, carbonate and conglomerate. Chert in the southern and northwestern part of the sheet contains sparse stromatolites, is commonly brecciated and resilicified, and is therefore, probably, a silicified carbonate. Lenses of stromatolitic limestone are interbedded with sandstone east of Bridle Face Outcamp and southeast of No. 10 Bore.

In the southern part of the sheet, the formation is only 30 to 50 m thick. Over the Marymia Dome, the thickness varies from a few tens of metres to several hundred. The basal unconformity is well exposed west of the Rabbit Proof Fence, 23 km south of Marymia, where the basal unit is a cleaved shale containing minor arkosic sandstone. Twenty-four kilometres west of Mount Methwin, the formation is 500 m thick, and consists of conglomerate, quartz arenite, and phyllite. The conglomerate contains sub-rounded quartz pebbles in an arkosic matrix. Conglomerate in a similar sequence 5 km south of Mount Methwin contains pebbles of grey shale.

On the eastern side of the sheet, the formation is probably about 1 000 m thick. It consists of two quartz arenite units, with locally abundant trough-style cross-bedding, separated by about 300 m of shale.

Frere Formation: The Frere Formation is a sequence about 1 300 m thick, composed of dominantly ferruginous chemical sediments, fine-grained clastics, and minor carbonates. Iron-formation members, each between 10 m and 50 m thick, form a series of parallel ridges in the Frere Range and south of Mount Cecil Rhodes. The formation lies conformably beneath the Windidda or Wandiwarra Formations.

The type section of the Frere Formation is taken immediately west of Mount Teague (Hall and others, 1977), where the middle part of the section, about 200 m, is very well exposed. A comparable section 2 to 3 km west of Snell Pass is shown in Figure 2. Nowhere is a complete section exposed: consequently the figure given for the total thickness on NABBERU is an estimate only.

Each iron-formation member consists of alternate beds of hematitic shale and granular iron-formation. The ratio, granular iron-formation : hematitic shale, varies considerably, but is generally between 1:1 and 2:1. Individual granular beds attain a thickness of 1 m, but are generally between 50 and 300 mm thick. Wavy and lenticular bedding is common. Thin bands ($<$20 mm thick) of grey, finely crystalline chert occur at the top and bottom of some granular beds. The granular texture is usually peloidal, occasionally brecciated, rarely oolitic. The peloids are rounded, sub-spherical grains consisting of chert with varying amounts of red hematitic dust (jasper) and specular hematite. Breccia fragments (intraclasts) are usually iron-rich and occasionally cherty. The fragments are usually angular, but the smaller ones grade into peloids in some cases; they represent the brecciation of penecontemporaneously deposited iron-formation and chert. Ooliths show only a vague concentric layering, and are not as abundant as they are to the southeast of NABBERU. Both peloids and ooliths range in size from 1 to 2 mm. Breccia fragments may be up to several centimetres across, but are generally less than 10 mm. Peloids, ooliths and fragments are all enclosed in a finely crystalline chert matrix.

The granular iron-formation is comparable with the Superior-type iron-formation of North America (Gross, 1965; Dimroth and Chauvel, 1973). The textures indicate a shallow-marine environment (Goode and Hall, 1976), in which periods of turbulence alternated with periods of quiescence. Small-scale washout structures in the iron-formation indicate some current action.

Banded iron-formation is not common, but is significant as an indicator of an increase in water depth. At Mount Cecil Rhodes, banded iron-formation displays a highly disrupted form of wavy bedding, possibly due to complex sedimentary boudinage and load deformation. Chert mesobands alternate with microbanded iron-rich mesobands. South of Murgurra Pool, near the top of the Frere Formation, there is a layer of chert-poor iron-formation which displays undisturbed banding on centimetre scale or less. It is about 200 m thick, and passes laterally into granular iron-formation.

Between the members of iron-formation, and accounting for over half the total thickness of the Frere Formation in the type area, are shale members, which are poorly exposed in valleys between the main iron-formation ridges. The shale lying between the top arenite of the Yelma Formation and the lowest iron-formation is included in the Frere (Hall and others, 1977). The shales are typically buff, pink or white, finely laminated, and show small-scale cross-lamination. Thin chert bands occur sparsely within the shale.

There is a steady increase, from eastern KINGSTON to western NABBERU, in the thickness of the iron-formation members at the expense of shale; Hall and Goode (1978) give iron-formation: shale ratios of 1:9 in the east rising to 8:2 in the west.

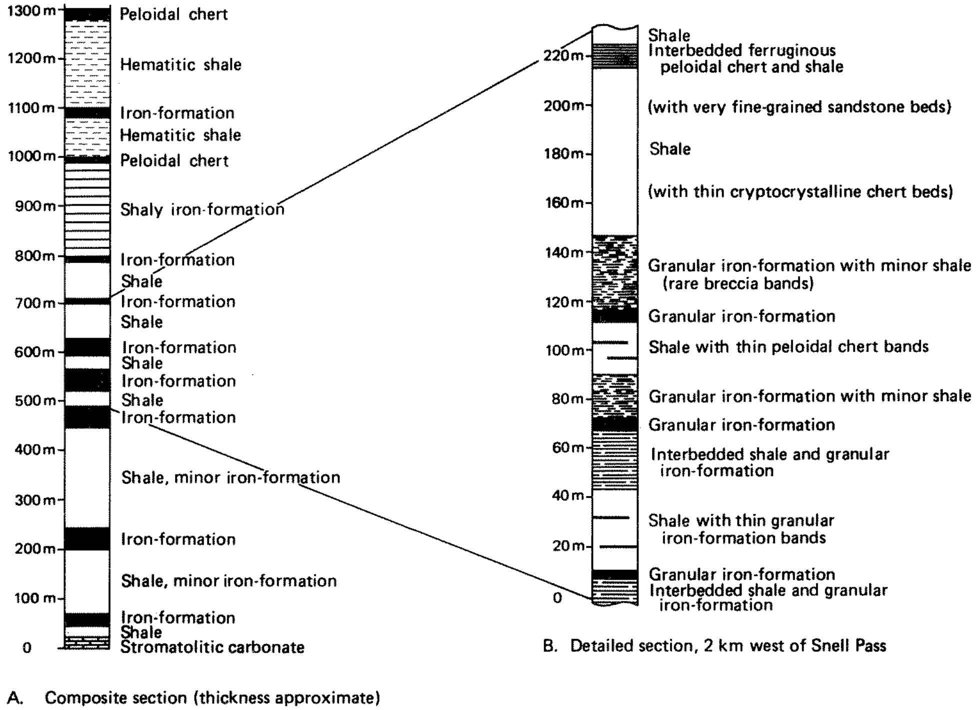


FIGURE 2 : Frere Formation stratigraphy

Carbonate lenses occur at two localities in the Frere Formation. Southeast of Sweetwaters Well, at the base of the formation, is a carbonate band, about 10m thick, which contains abundant stromatolites. At least three stromatolite forms are present: broad domal forms, large columnar forms, and small, divergent branching forms. Other stromatolitic carbonate lenses occur at this stratigraphic level between the Yelma and Frere Formations on KINGSTON (Bunting, 1977) and DUKETON (Bunting and Chin, 1975; Preiss, 1976).

Northeast of Simpson Well, a limestone lens, 35m thick, occurs about 500m above the base of the sequence (the exact distance is not known because of poor exposure and structural complexity). The carbonate is pale grey to white, and has been recrystallized to a sparry calcite. Fifteen metres above the base of the limestone lens is a band containing fresh pyrite cubes, and small, faint, branching stromatolites. Twenty-five metres from the base, a band, 2m thick, contains columnar stromatolites similar to those at Sweetwaters Well. The carbonate near the top has been partly replaced by chert.

South of Oxbys Well, is a pale grey-green chert that is variously massive (cryptocrystalline), granular, banded or brecciated. The chert is virtually iron-free, and is very similar to the chert that marks the top of the Frere Formation on KINGSTON (Bunting, 1977). Around the western closure of the sub-basin (in the vicinity of Hawkins Knob) and along the northern margin (from Miss Fairbairn Hills to Mount Cecil Rhodes), the stratigraphy and lithology of the Frere Formation are obscured by low-grade metamorphic recrystallization and supergene iron enrichment, and weathering. During metamorphism, plastic-style deformation and flattening of peloids were accompanied by replacement of chert and hematite by progressively coarser quartz and euhedral magnetite. In the interbedded shale, a strong cleavage developed, accompanied by the growth of fine muscovite. A later crenulation is common in the area between Ivan Well and Mount Cecil Rhodes.

Windidda Formation: At its type section on KINGSTON, the Windidda Formation is a carbonate and shale unit about 1 200m thick, which conformably overlies the Frere Formation, and is disconformably overlain by the Wandiwarra Formation (Hall and others, 1977). The typical Windidda Formation is poorly represented on NABBERU because of various facies changes, which are shown schematically in Figure 3. East-southeast from Oxbys Well, an intermittent carbonate band 20m thick extends for 10 km. The carbonate is pink to grey sparry calcite with occasional domal stromatolites up to 100 mm high. The carbonate is interbedded with, and overlies, jasperoidal granular iron-formation, and in places forms a mixed rock in which jasper peloids are embedded in a carbonate matrix. The underlying iron-formation is similar to those in the Frere Formation, but is probably a local facies variant of the Windidda Formation. The carbonate is overlain, possibly disconformably, by shale and quartz arenite of the Wandiwarra Formation.

In the north and northwest part of the sheet, carbonate rocks are largely absent, and the Frere Formation passes directly into shale which is indistinguishable from that in the Wandiwarra Formation.

Wandiwarra Formation: The Wandiwarra Formation consists of clastic rocks ranging from coarse sandstone to shale. The sandstone is a moderately well-sorted, pale-grey, ferruginous quartz arenite, which locally contains glauconite pellets. Sedimentary structures include shaly or sandy intraclasts, ripple marks, cross-beds, and rarely, flute casts. The sandstone occurs as bands up to 10 m thick, which form low, rubbly hills and cuestas.

Shale, containing thin, fine-grained sandstone beds, is the dominant rock type, and crops out as low breakaways. It is typically maroon, buff, or white, and generally deeply weathered. In the northern part of the sheet, it is strongly cleaved.

East-southeast of Oxbys Well, medium-grained, mature quartz arenite at the base of the formation is probably a transgressive strand-line deposit marking the disconformity with the underlying Windidda Formation. Elsewhere in the sheet, there was apparently continuous clastic sedimentation conformably above the Frere Formation. The lower part of the Wandiwarra Formation in these areas is, therefore, the lateral equivalent of the Windidda Formation (Figure 3). The thickness of the formation, therefore, varies from about 500 m to perhaps 1 500 m.

The conformable passage into the overlying Princess Ranges Quartzite is best exposed southwest of Cockatoo Well. Here, flat-laminated shale and thin (< 1 m) glauconitic quartz arenite and wacke beds, which display slump, flame, and clastic dyke structures, pass upwards into a unit of lenticular bedded shale and quartz arenite. The arenite in this upper unit contains some cross-bedding and ripple marks (including symmetrical and linguoid varieties). This passes upwards into the more continuous, and thicker, mature quartz arenite of the Princess Ranges Quartzite. This transition represents a regressive sequence.

Princess Ranges Quartzite: This fine- to coarse-grained clastic formation lies conformably between the Wandiwarra and Wongawol Formations, and is 250-300 m thick. In the ring syncline of the Teague Ring Structure west of Cockatoo Well, it consists of mature, medium-grained, white quartz arenite in bands up to 10 m thick, separated by white micaceous siltstone containing thin fine-grained quartz arenite bands. The quartzite bands are thick-bedded, and show 10 to 20 mm bedding lamination. Sedimentary structures are abundant, and include trough cross-bedding, ripple marks (mostly symmetrical, and including some with wavelengths in excess of 1 m), sandy intraclasts, and vermiform flute or load casts. The quartz arenite is typically clean, white, well sorted, and has well-rounded grains cemented by

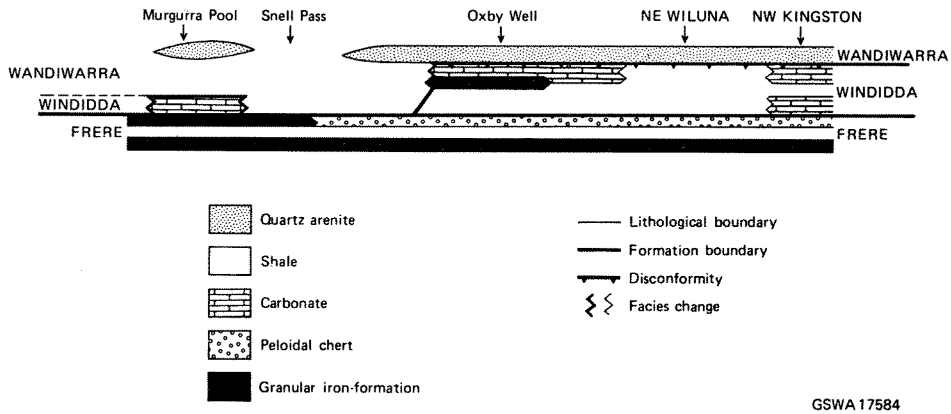


FIGURE 3 : Diagrammatic relationships of stratigraphic units, Murgurra Pool to northwest Kingston

authigenic silica in optical continuity with the overgrown grain. Accessory glauconite and tourmaline may be present. Rhomboid, ferruginous spots, up to 30 mm long, form up to 30 per cent of the rock, and are probably weathered-out rhombs of calcite cement.

Outside the Teague Ring Structure, in the main part of the sub-basin, the formation is less well exposed, and its internal stratigraphy is unknown.

Wongawol Formation: Only one small outcrop of the Wongawol Formation was noted on NABBERU, and that is in the core of the ring syncline 6 km west-southwest of Cockatoo Well. The outcrop is of dark brown-grey, fine-grained sandstone. As well as quartz and clay minerals, the sandstone contains abundant feldspar, glauconite, mica and chlorite. The thin bedding is disturbed by ball-and-pillow structures.

Only the basal few metres are exposed here, although on STANLEY and KINGSTON the total thickness is possibly 2 000 m (Hall and others, 1977).

SCORPION GROUP

The Scorpion Group is a sedimentary sequence that underlies the Bangemall Group and is in faulted contact with deformed sediments of the Nabberu Basin. No formations within the group can be defined at present, but the lithological units mapped could form the basis of a future formal subdivision.

The estimated thickness of the exposed Scorpion Group (10 000 m) is about ten times greater than that of the immediately adjacent Bangemall Group. This suggests that it is not a facies variation of the basal Bangemall Group. An apparent structural discordance between the Scorpion Group and the overlying Bangemall Group suggests an unconformable relationship. It may correlate with the Cornelia Sandstone or Yeneena Group on TRAINOR (Brakel and Leech, 1979), and could represent the margin of an extensive Middle Proterozoic basin beneath the eastern part of the Bangemall Basin.

The lowest unit of the Scorpion Group is represented by the symbol *Ꝑo(d)*. The dominant rock is pink, buff-weathering, laminated, fine-grained dolomite, interbedded with dolarenite that consists of red to buff dolomite grains and abundant medium to coarse quartz sand. Platy, angular fragments of fine-grained dolomite are present in some dolarenite beds, in places to the extent that the whole rock is dolomite breccia. Stromatolites of *Conophyton,* as well as columnar and broadly domical types, are developed at several levels between Willy Willy Bore and Scorpion Bore. Sandstone beds in the dolomitic sequence are ordinarily medium- to fine-grained, moderately sorted, light grey to pinkish-brown rocks with 10 to 20 per cent feldspar and lithic grains. The lithic component is mostly dolomite. A few beds contain one to two per cent glauconite, and others, platy siltstone fragments. Sandstone dominates the sequence near the base, and above the main dolomite interval. Symmetrical ripple marks of small wavelength, indicative of water only centimentres deep (Tanner, 1971), are preserved.

The middle mapping unit *(Ꝑo(s))* consists of pinkish, yellowish and grey-brown micaceous siltstone and interbeds of shale, and medium- to coarse-grained quartz lithic sandstone and silty sandstone. Some of the sandy beds contain glauconite. Symmetrical ripples of very small wavelength (8 mm) are present.

A higher unit *(Ꞓo(l))* is variable in composition. Near the Salvation Fault are pinkish-brown, poorly sorted conglomerate and sandstone. The conglomerate consists of pebbles, cobbles and occasional boulders of vein quartz, quartzite, slate, schist, and dark-grey sandstone. The accompanying immature sandstone is micaceous, silty, lithic, commonly well bedded, and contains granule and pebble lenses. Northwards, the conglomerates thin and lens out, and the sandstones become better sorted. The distribution of the rock types implies activity on the Salvation Fault before or during the sedimentation. A similar trend to cleaner, well-washed sandstone is apparent going up the sequence to the east. This culminates in a succession of whitish, fine- to medium-grained quartz sandstone and lesser white, micaceous silty shale on STANLEY.

BANGEMALL GROUP

Coonabildie Formation (ꞒMx)

The relation of the Coonabildie Formation to the other Bangemall Group formations is unclear. Although provisionally mapped as conformable below the Calyie Sandstone, and therefore as part of the Bangemall Group, it may be unconformable below the Calyie. Most of the formation lies on adjoining STANLEY (Commander and others, in press), and the only outcrop on NABBERU occurs in the extreme northeast corner, where it is a fine-grained, well-sorted quartz sandstone, which has symmetrical ripple marks and molds of weathered-out siltstone fragments, interbedded with siltstone and shale.

Wonyulgunna Sandstone (ꞒMw)

The Wonyulgunna Sandstone occupies a prominent range, and is a medium- to coarse-grained, moderately sorted quartz sandstone with minor planar cross-lamination. On COLLIER and BULLEN, it is the basal unit of the Bangemall Group, and is separated from the Calyie Sandstone by the intervening Backdoor Formation (Brakel and others, 1978; Leech and Brakel, 1978). However, the Backdoor Formation lenses out at the boundary between BULLEN and NABBERU, and the Wonyulgunna Sandstone becomes indistinguishable along strike from the Calyie Sandstone. An arbitrary boundary between the two has been set at a convenient break in outcrop northwest of Mount Methwin.

Outcrop of the siltstone-shale sequence below the main sandstone interval on BULLEN (Leech and Brakel, 1978) occurs only in the far northwest corner of NABBERU.

Calyie Sandstone (ꞒMy)

The Calyie Sandstone crops out extensively in northern NABBERU. It rests unconformably on pre-Bangemall rocks, and this relationship is exposed 10 km southeast of Mount Methwin. Typically the sandstone is coarse- to fine-grained, well-sorted quartz arenite, and has little or no feldspar. Beds are internally laminated. Siltstone fragments (intraclasts), quartz pebbles, and wave-formed ripples occur locally. Planar cross-bedding in sets up to 250 mm thick is widespread. The thickness of the formation on NABBERU is unknown, but on COLLIER it is 1 250 m (Brakel, Elias and Barnett, 1978).

In the southern Carnarvon Range-Mount Davis area, there is a unit exceeding 60 m thick which contains very large and spectacular cross-bedding. Individual cross-bed sets range in thickness from 0.5 to 8 m, but most are less than 2 m. In longitudinal sections, the foresets are either planar or are asymptotic to the lower bounding surface. In plan or transverse view they are broad, shallow troughs or scoops up to 250 m wide, in which the strike of the foresets changes through 70° of azimuth from side to side. The troughs are scoured into underlying sets with knife-sharp, regular cut-off surfaces at low angles (5° to 20°) to earlier laminations. The foresets (1 to 30 mm thick) are usually coarse-grained, moderately sorted quartz sandstone without feldspar.

The large-scale cross-bedded unit overlies a basal sequence which differs from place to place, but is of three main types:

(1) A thin basal boulder conglomerate containing clasts of vein quartz and shist, which is overlain by laminated sandstone which lacks cross-bedding. The contact with the overlying large-scale cross-bedded unit is scoured to depths of over 1 m. This sequence is exposed in cliffs 1.5 km south of Mount Davis, where it is 40 m thick.

(2) A sequence of sandstone which contains solitary cross-bed sets, ill-defined conglomerate lenses and mono-pebble layers. Near Trig Station M6 the conglomerate contains clasts of vein quartz, quartzite, chert, and older conglomerate which itself contains clasts of granular iron-formation (Frere Formation).

(3) A sequence, exclusively of sandstone, in which symmetrical ripple marks are locally abundant, grades upwards by the increase of thickness and frequency of cross-bed sets, into the overlying large-scale cross-bedded sequence. This is typical of the southwestern end of the Carnarvon Range.

This variable basal sequence probably accumulated in beach and shoreface conditions, but the large-scale cross-bedded unit could record either a subaerial coastal dune system, or a submarine tidal current regimen analogous to that described from the North Sea by Houbolt (1968).

BASIC INTRUSIVE ROCKS

In the southwest corner of NABBERU, medium-grained dolerite intrudes Finlayson Sandstone as sills and irregular sheets, which range from a few metres to at least 50 m thick. Disruption to bedding produces dips up to 25° in the adjacent sandstone. The dolerite consists of a sub-ophitic intergrowth of clinopyroxene and altered plagioclase. Variation within the bodies is rare and slight, and compositional layering is absent. Fine-grained chilled margins occur at the tops of some bodies.

Around the northeastern margin of the Teague Ring Structure are two small dolerite intrusions. One of these, 6 km west of Madmans Outcamp and too small to show at 1:250 000 scale, contains a thin granophyric vein. These dolerite intrusions may be relevant to the formation of the ring structure itself.

Intrusives within the Bangemall Basin occur in the Carnarvon Range and in the Coonabildie Formation in the extreme northeast corner of the sheet. The rock is the same medium-grained tholeiitic dolerite that occurs as sills in adjacent map sheets.

PROTEROZOIC STRUCTURE

Six structural units lie partly or wholly within the sheet. These are the Yilgarn Block, Marymia Dome, Kingston Platform, Stanley Fold Belt, Scorpion Inlier and Bullen Platform (Figure 4).

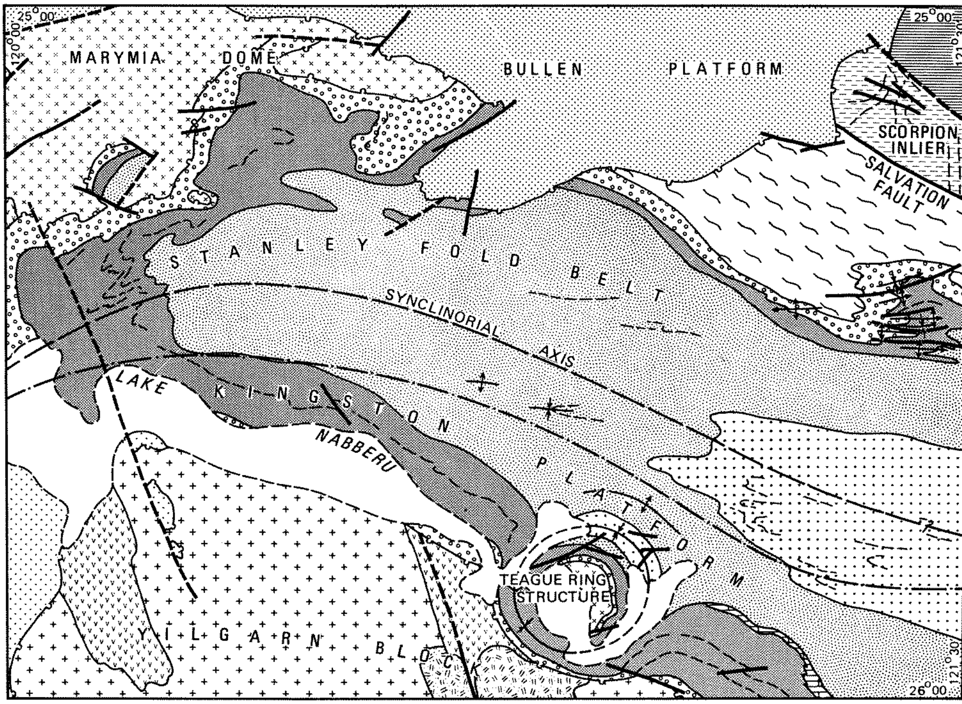


FIGURE 4

GSWA 17585

SOLID GEOLOGY AND STRUCTURE INTERPRETATION

NABBERU SHEET SG 51-5

0 10 20 30 km

REFERENCE

MIDDLE PROTEROZOIC
- CALYIE SANDSTONE, WONYULGUNNA SANDSTONE — BANGEMALL GROUP
- COONABILDIE FORMATION — BANGEMALL GROUP
- SCORPION GROUP

LOWER PROTEROZOIC
- PRINCESS RANGES QUARTZITE — EARAHEEDY GROUP
- WANDIWARRA FORMATION — EARAHEEDY GROUP
- WINDIDDA FORMATION — EARAHEEDY GROUP
- FRERE FORMATION — EARAHEEDY GROUP
- YELMA FORMATION — EARAHEEDY GROUP
- FINLAYSON SANDSTONE
- TROY CREEK BEDS

ARCHAEAN or PROTEROZOIC
- Granitoid rocks

ARCHAEAN
- Hornblende-quartz monzonite
- Granitoid rocks
- Greenstone belt

- Geological boundary
- Fold belt/platform boundary
- Unconformable boundary between tectonic units
- Fault
- Fault, inferred and concealed
- Anticline, with plunge
- Syncline, with plunge
- Bedding trend

BASEMENT UNITS

Yilgarn Block

The Yilgarn Block is the exposed part of an Archaean craton which formed a stable basement upon which the Early Proterozoic sediments were deposited. The dominant north-northwesterly trends of the Yilgarn Block had little effect on Proterozoic deformatation, although two major north-northwest-trending faults may have been re-activated early in the Proterozoic. Both faults, one west of the Merrie Range, and the other cutting the eastern greenstone belt, are continuations of major deep-seated features further south.

Marymia Dome

The Marymia Dome is a complex inlier of Precambrian granitoid rocks, which, in this northeast corner, are predominantly magmatic in character, but which have a weak northeast structural trend. The overlying Earaheedy and Bangemall Groups are usually unconformable on the dome, but in places, the contact is faulted. A quartz-filled fault, 17 km north of Grasscutters Well, near the western boundary of the sheet, is the continuation of a major east-northeast-trending fault that marks the southern margin of the dome on PEAK HILL. Bunting and others (1977) consider that the dome moved upwards and to the south during the Early Proterozoic.

KINGSTON PLATFORM

The Kingston Platform and the Stanley Fold Belt are the two structural components of the Nabberu Basin. The boundary between them is taken as the first appearance of minor folds and related slaty cleavage, a line which may represent the buried edge of the stable Yilgarn Craton.

The Kingston Platform is characterized by shallow dips and gentle folds which lack slaty cleavage. It corresponds roughly to the southern side of the synclinorium where the sequence dips very gently to the north and northeast. Average dips increase northward (from 5° in the southeast, to 20° in the vicinity of Murgurra Pool) as the Stanley Fold Belt is approached.

The main folding took place along approximately east-southeast trending axes. The folds are gentle, open, occasionally with slightly steepened southern limbs, but tighter towards the Stanley Fold Belt. A later period of folding has produced small, isolated folds whose axes plunge gently northeast.

In the southwest part of the sheet, gently dipping Finlayson Sandstone of the Glengarry Sub-basin also lies within the Kingston Platform.

Teague Ring Structure

The Teague Ring Structure contains a circular granitic and syenitic core (12 km across) surrounded by a ring syncline (21 km in diameter) in rocks of the Earaheedy Group. The structure is symmetrical about a northeast plane, but steep dips, tight folds, and severe faulting on the northeast side give the structure a pronounced asymmetry about a northwest plane. A polygonal pattern of normal faults around the structure indicate an upward movement of the core. The rock types involved in the structure have been described in the relevant sections of these notes.

Two possible explanations for this unusual structure were advanced by Butler (1974): a meteorite impact (astrobleme) and a diapiric intrusion. Horwitz (1975b) suggested an origin by interference of folds. Bunting and others (1977) suggested cold emplacement of a plug of syenite, at high strain rates, related to the regional stress system.

Several lines of evidence now indicate that the origin of the structure involved shock metamorphism. These include the presence of shatter cones in the iron-formation (D. C. Gellatly, pers. comm.), and deformation lamellae and thin pseudotachylite veins in some granitoid rocks of the core. There is some evidence to relate the ring structure to the regional stress pattern and the occurrence of syenite; thus an origin by meteorite impact, which requires a random event, is unlikely. A more likely origin involves explosive activity associated with the volatile phases of a magma at depth. However, more work remains to be done on the structure before firm conclusions can be reached.

STANLEY FOLD BELT

The Stanley Fold Belt is characterized by moderate to tight folding and conspicuous slaty cleavage. The fold belt has been subdivided into eastern and western parts, separated by an interference zone (Bunting and others, 1977). NABBERU contains the interference zone and part of the eastern zone.

Eastern zone

The eastern zone contains east to east-southeast-trending folds, which become tighter and more asymmetrical to the northeast. The asymmetry is the result of oversteepened, occasionally overturned, long south-dipping limbs, and short, shallowly north-dipping limbs. Near Mount Cecil Rhodes, easterly plunges on these folds have produced S-asymmetry, although this is complicated by a series of east-trending reverse faults. To the west, near Troy Creek, west-plunging folds show Z-asymmetry. This pattern of plunge reversal is repeated elsewhere in this eastern zone, and indicates a later, very open cross-folding. Crenulation of the dominant cleavage in the Troy Creek-Mount Cecil Rhodes area may be related to this cross-folding.

The slaty cleavage in this eastern zone becomes stronger and more schistose towards the northeast, and is the most prominant cleavage throughout the Troy Creek beds below the Earaheedy Group. In most of these older rocks, it is the earliest deformation event, but in an area 15 to 20 km east of Mount Davis, schistose rocks display an earlier foliation (S_1) which was accompanied by the growth of small garnets. Thus, prior to deposition of the Earaheedy Group, a metamorphic front may have existed in the Troy Creek Beds, south of which the rocks escaped the S_1 event.

The metamorphic style in the Stanley Fold Belt is one of dynamic deformation at low metamorphic grades. The presence of chlorite, muscovite, and garnet in the Troy Creek Beds east of Mount Davis indicates a lower greenschist facies of metamorphism. Metamorphism in the main deformation period (S_2) of the fold belt probably did not reach lower greenschist facies.

Interference zone

The western part of the Stanley Fold Belt (on PEAK HILL and GLENGARRY) is characterized by northeasterly structural trends. In western NABBERU in the connecting zone between the eastern and western parts, interference of the two fold trends has produced a dome-and-basin pattern, which is particularly apparent along the unconformity between the Yelma Formation and the underlying granitoid rocks of the Marymia Dome. The pattern is disrupted by a number of faults following the two main structural trends. West of Hawkins Knob, the interfering folds have produced an ellipsoidal outcrop pattern in the iron-formation.

The regional inflection point of the two structural trends coincides with the narrowest part of the Nabberu Basin, where the Marymia Dome and Yilgarn Block are only 35 km apart. This corresponds to the boundary of the Earaheedy and Glengarry Sub-basins, and is a structural culmination caused by a broad, gentle, northwest-trending basement high, called the Wiluna Arch (Bunting and others, 1977).

SCORPION INLIER

The Scorpion Inlier is the structural unit containing the Scorpion Group. The southern side of the inlier is marked by a major normal fault, the Salvation Fault, which has placed unmetamorphosed Scorpion Group against deformed and metamorphosed rocks of the Nabberu Basin. Movement probably started during deposition of the Scorpion Group and had apparently finished before deposition of the basal Bangemall Group.

The Scorpion Group is folded into an open, southeast-plunging anticline which is truncated to the south by the Salvation Fault and unconformably overlain to the north and east by the Bangemall Group.

BULLEN PLATFORM

The Bullen Platform is the gently folded eastern part of the Bangemall Basin. Two intersecting fault trends are apparent—east-northeasterly and east-southeasterly—both of which may reflect reactivation of structural trends in the basement.

PERMIAN

Small outliers of Permian rocks east of Oxbys Well consist of medium- to coarse-grained, poorly sorted sandstone, with some tabular sets of cross-bedding and occasional bands of quartz pebble conglomerate. The planar unconformity surface and the principal bedding planes dip north at about 2°. The sediments, which are only a few metres thick and which are capped by silcrete, are lithologically similar to the fluvial facies of the Early Permian glacigene Paterson Formation in adjacent STANLEY and KINGSTON (Commander and others, 1977; Bunting, 1976) and in the Officer Basin (Lowry and others, 1972).

CAINOZOIC

Mapping of Cainozoic units is based on lithology and morphological expression. The boundary between many units is transitional, and mapped positions are often arbitrary.

CAINOZOIC UNITS

Except for calcrete *(Czk)*, the units under this heading are restricted to the deep-weathering profile. Silcrete *(Czb)* forms a siliceous duricrust on top of deeply weathered granitic, felsic volcanic, sandstone, and Permian rocks, although in many cases it has been omitted from the map in favour of bedrock. It is a hard, white to grey-green rock, consisting of angular to rounded grains (mostly quartz) set in a matrix of microcrystalline silica.

Ferruginous duricrust or laterite *(Czl)* occurs mainly over rocks of the Archaean greenstone belts and Proterozoic dolerite, although it can occur over iron-rich and shaly Proterozoic rocks. It varies from pale-brown pisolitic limonite and goethite, to dark-brown massive hematite and goethite. On ultramafic rocks, the equivalent of laterite is a capping of ferrunginous opaline silica *(Czj)*, which on NABBERU, occurs in only one small exposure southwest of Cunyu woolshed.

Silcrete and laterite generally pass downward into the mottled and pallid zones *(Czo)*, shown on the map as an overprint. In some areas, notably over dolerite west of Verscher Range, the laterite passes directly into fresh bedrock. Deep weathering in the mottled and pallid zones involves the breakdown of feldspar, mica and mafic minerals to form kaolin and iron oxides. Much of the original texture and structure is preserved, and it is usually possible to identify the original rock type.

Calcrete *(Czk)* is a deposit of limestone and opaline silica formed by partial replacement of alluvium in major drainages. It formed after the trunk valleys of the palaeodrainage system had been filled with sediment, probably in the later Tertiary, and is now being eroded in those drainage lines which are still active (e.g. Sweeney Creek). The calcrete may be nodular, massive, or laminated, and is typically cavernous.

QUATERNARY UNITS

Colluvium *(Qc)*, consisting of angular to rounded rock and quartz fragments in loam, occurs marginally to rock outcrops as a scree or thin cover over bedrock. It grades downslope into coalesced alluvial fans and broad sheetwash plains of clay and loam. An iron-cemented colluvium or hardpan occurs as outcrops too small to be mapped, but it underlies large areas of colluvium *(Qc)*. Hardpan adjacent to Frere Formation near Carnarvon Range is a lithified talus of iron-formation, on which laterite has formed.

Alluvium *(Qa)* occurs in broad, ill-defined drainage lines, ranging from small creeks, to wide flood plains in the lower reaches of the drainage system. The deposits are poorly sorted and contain material ranging from clay to pebble size.

Eolian quartz sand *(Qs)* forms extensive sheets over granitic rocks and Middle Proterozoic sandstone. The quartz is well sorted, and has an iron-oxide patina which gives the sand a pale-yellow to red-brown colour. Complex dune systems in the northern part of the sheet originated in a drier period, probably the Late Pleistocene, but have now been fixed by the growth of spinifex and low scrub.

A mixture of ferruginous pebbles and windblown sand *(Qp)* occurs in northeast NABBERU, and is similar to more extensive deposits to the north. The material overlies laterite rises, and forms when sand is blown onto lateritic debris.

Two units related to the salt-lake systems are recognized. Lacustrine clay and silt *(Ql)* containing minor sand, salt and gypsum, forms flat, bare lake floors, which become covered by a few centimetres of saline water after heavy rain. Marginal to the lacustrine unit, and in places covering it, is a mixed unit *(Qg)* containing eolian dunes and sheets of gypsum or quartz sand. Alluvial flats and small claypans are scattered between the dunes.

ECONOMIC GEOLOGY

IRON

The iron-ore potential of the Frere Formation has only recently (1973) been recognized, but at the time of writing no ore bodies have been reported. Zones of hematite and hematite-goethite enrichment occur on the Frere Formation throughout the area, but are concentrated in the Miss Fairbairn Hills area, the Frere Range between Snell Pass and Hawkins Knob, and the ridge that trends northwest from Ivan Well. Hematite occurs as a replacement of jasperoidal peloidal chert and as enriched hematitic shale. Pebbles of enriched peloidal iron-formation occur in conglomerates of the Calyie Sandstone in the Carnarvon Range, indicating a primary enrichment earlier than 1.1 b.y. ago. However, a secondary enrichment related to the Tertiary laterite profile is apparent throughout most of the area. Although grades of over 60 per cent have been reported, the average is much lower, and nowhere is the high-grade material known to be in sufficient quantities to constitute an ore body. Grades tend to be variable over short distances.

URANIUM

Several potential uranium environments occur on NABBERU, although none is considered to be a good prospect. Carnotite is present in calcrete between Fyfe Bore and Kennedy Creek, but a brief exploration programme reported no economically significant mineralization. However, other areas of calcrete are largely unexplored.

The Teague Ring Structure is very similar to the Carswell Structure in Canada (Currie, 1969; Ruzicka, 1976) which contains the Cluff Lake uranium deposit. Some exploration has been carried out inside the Teague structure, so far with negative results.

Other potential targets could exist along the unconformity with granitoid rocks in the northwest corner of the sheet, and possibly in the conglomerates of the Scorpion Group along the Salvation Fault.

BASE METALS

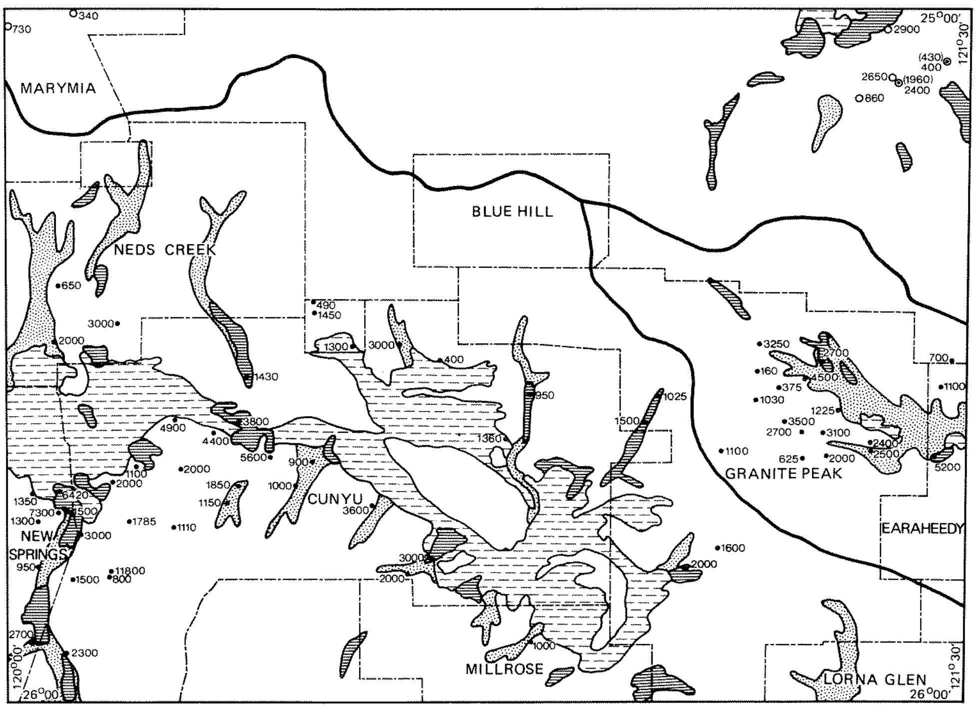
Galena occurs in stromatolitic carbonate rocks southeast of Sweetwaters Well. It forms small clusters of crystals associated with small, branching stromatolites, and in the cores of large domal forms. Dolomite from the domal stromatolitic horizon assayed 460 ppm lead, 70 ppm copper and 65 ppm zinc.

BUILDING MATERIALS

A small quarry 2 km south of Mount Paterson has produced flagstones and slabs used locally in building water troughs and tank foundations. The quarry is in a fissile shale capable of producing slabs up to 1 m across and 20 to 30 mm thick.

GROUNDWATER

Aquifers in superficial deposits supply most of the existing bores and wells, and are the only potential sources of large quantities of usable groundwater. The Proterozoic and Archaean rocks are generally too impervious to make suitable aquifers, although small amounts of water may be obtained from jointed, fractured, or weathered bedrock. The exising bores are about equally distributed between colluvial sheetwash plains, valley alluvium and calcrete.



GSWA 17586

FIGURE 5

WATER RESOURCES

NABBERU SHEET SG 51-5

0 10 20 30 km

REFERENCE

Valley alluvium

Calcrete

Salt lakes and marginal deposits

Bore, well or permanent spring : salinity in mg/L

• (after Sanders and Harley, 1971)

o (by A.T. Brakel, 1975-6)

Drainage divide

Pastoral station boundary

Salinity increases away from the major drainage divides and towards the trunk drainages (Fig. 5). In the lake units, groundwater is too saline for stock use, although some marginal areas may contain brackish water. In many areas, shallow wells produce small supplies of fresh water, whereas deeper bores tap brackish water.

Supplies from colluvial plains, where the bores are commonly situated in small, ill-defined drainages, are usually limited. Valley calcrete and large areas of valley alluvium are the best potential sources of large quantities of groundwater, although salinities in the ranges 1 500 to 5 000 mg/l can be expected. Sanders and Harley (1971) reported on the groundwater potential of the area, and recommended only the valley calcrete from Cunyu Station to the Verscher Range as worthy of further investigation. Most of the other occurrences of valley calcrete are too small or too saline for industrial water supplies, although the calcrete around Murgurra Pool and in the northeast corner of the sheet may have potential.

At the time of the present survey (1976-1977) most bores and wells on Granite Peak station were not functioning. Most rock holes and pools contain water only for short periods after heavy rain. Only Windich Spring and possibly Lake Talbot have permanent supplies of fresh to brackish water.

ACKNOWLEDGEMENTS

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APPENDIX

Co-ordinates of localities mentioned in the text

	Latitude	Longitude
Bridle Face Outcamp	25°48′	120°37′
Carnarvon Range	25°15′	120°42′
Cunyu homestead (WILUNA)	26°01′	120°07′
Cunyu woolshed	25°49′	120°10′
Frere Range	25°34′	120°23′
	to 25°45′	120°32′
Fyfe Bore	25°40′	120°42′
Granite Peak homestead	25°38′	121°21′
Grasscutter Well	25°21′	120°03′
Hawkins Knob	25°27′	120°13′
Ivan Well	25°24′	121°06′
Kennedy Creek	25°38′	120°48′
Lake Nabberu	25°36′	120°07′
	to 25°50′	120°50′
Lake Talbot	25°05′	121°21′
Madmans Outcamp	25°48′	121°04′
Marymia homestead	25°01′	120°07′
Merrie Range	25°44′	120°15′
Miss Fairbairn Hills	25°14′	120°21′
Mount Cecil Rhodes	25°25′	121°26′
Mount Davis	25°13′	121°08′
Mount Methwin	25°05′	120°41′
Mount Paterson	25°44′	120°03′
Mount Teague	25°41′	120°41′
Murgurra Pool	25°32′	120°23′
No. 10 Bore	25°55′	120°49′
Oxbys Well	25°53′	121°08′
Pierre Spring	25°14′	121°06′
Scorpion Bore	25°06′	121°23′
Simpson Well	25°24′	120°05′
Snell Pass	25°43′	120°46′
Sweeney Creek	25°48′	120°39′
Sweetwaters Well	25°35′	120°22′
Troy Creek	25°27′	121°12′
Trig Station M6	25°18′	120°41′
Verscher Range	25°44′	120°05′
Willy Willy Bore	25°08′	121°19′
Windich Spring	25°33′	120°49′

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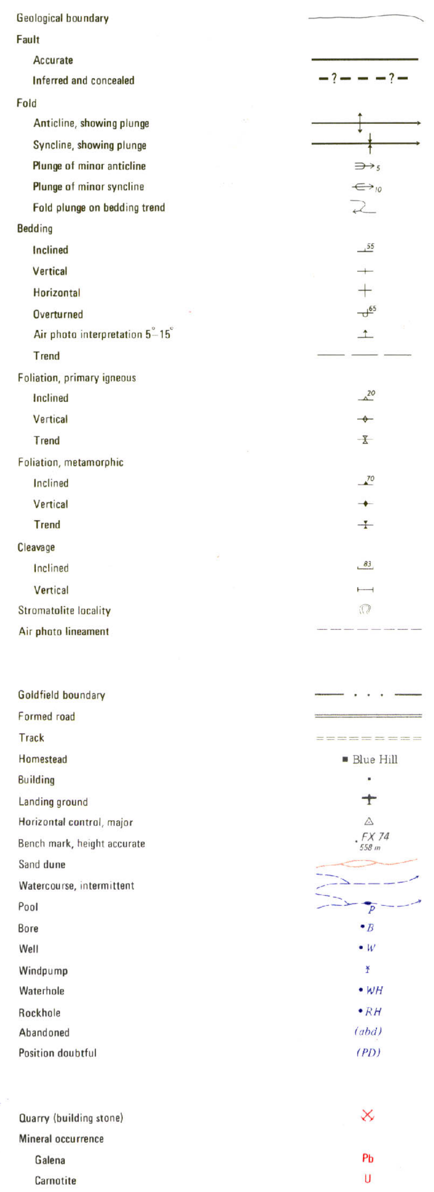
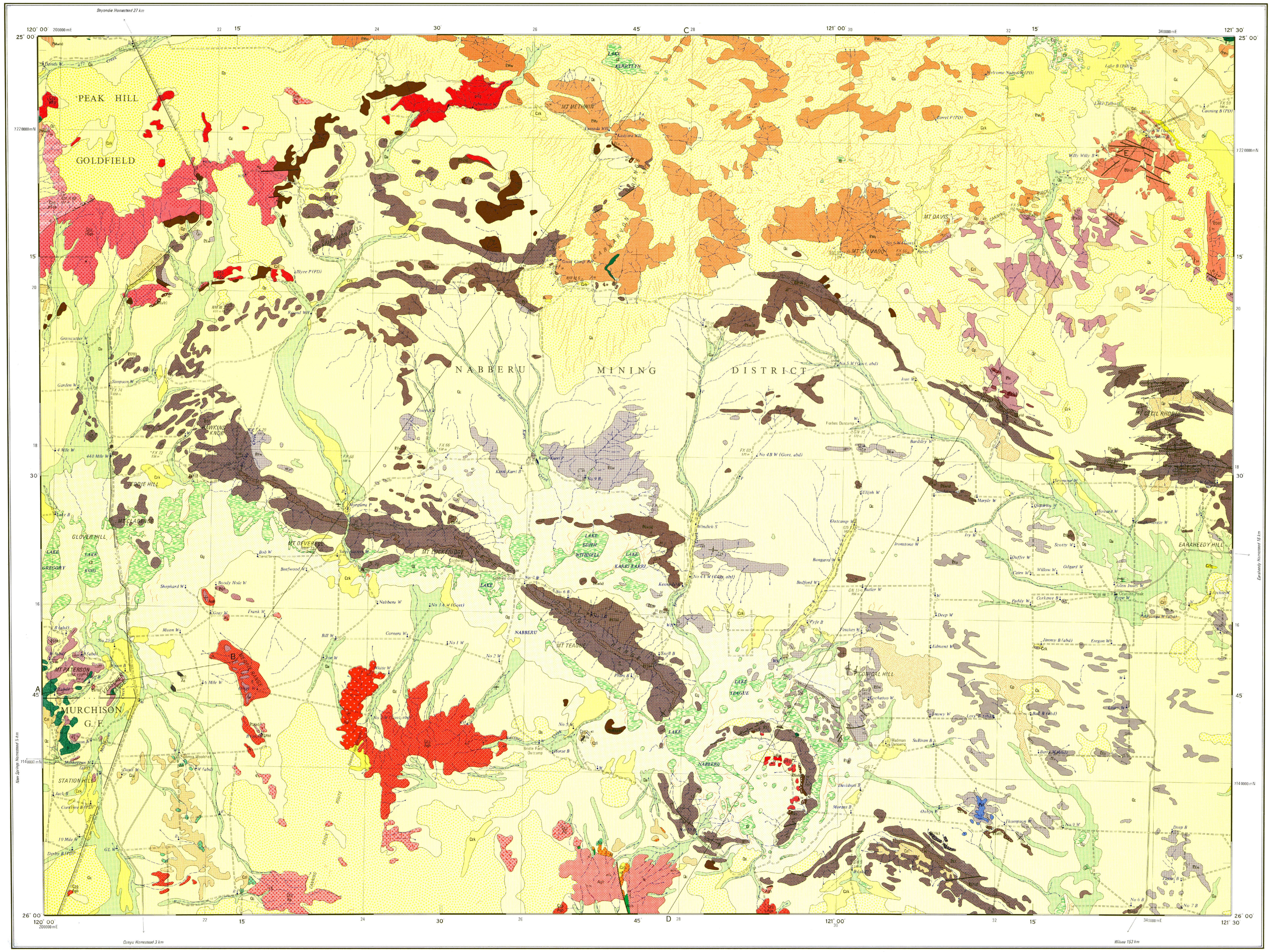
AUSTRALIA 1 : 250 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

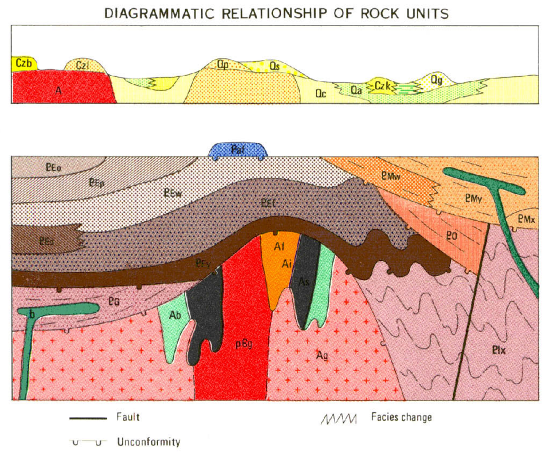
SHEET SG 51-5

SYMBOLS





DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



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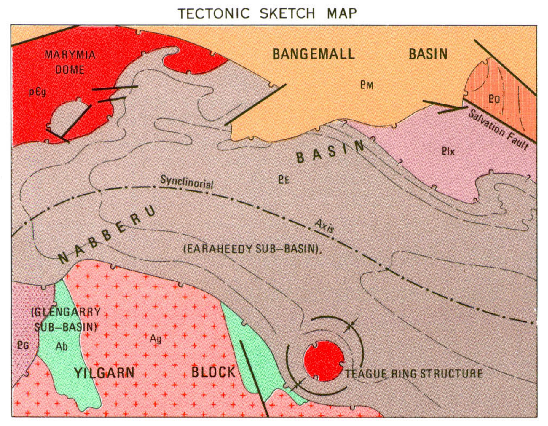

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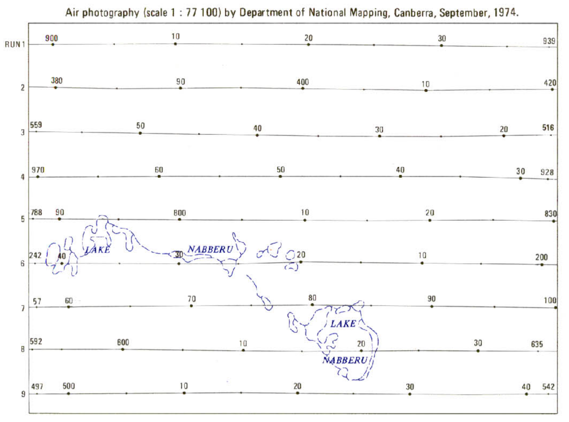
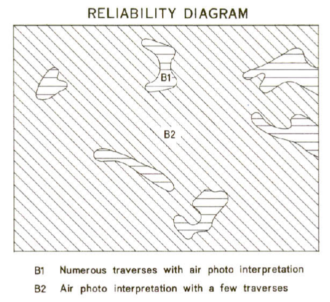


RELIABILITY DIAGRAM



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HON. P.V. JONES, M.L.A.
MINISTER FOR MINES

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Geology by R.E.J. Leech 1975, A.T. Brakel, J.A. Bunting and D.P. Commander 1976, J.A. Bunting 1977

SCALE 1 : 250 000

TRANSVERSE MERCATOR PROJECTION

ZONE 51 AUSTRALIAN MAP GRID

INDEX TO ADJOINING SHEETS

COLLIER SG 50-4	BULLEN SG 51-1	TRAINOR SG 51-2
PEAK HILL SG 50-8	NABBERU SG 51-5	STANLEY SG 51-6
GLENGARRY SG 50-12	WILUNA SG 51-9	KINGSTON SG 51-10

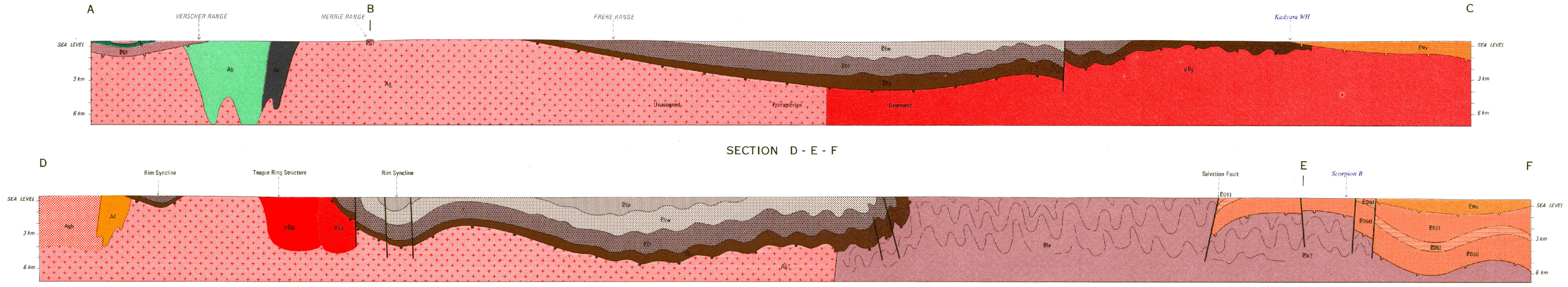
DECLINATION DIAGRAM

DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A - B - C

SECTION D - E - F



REFERENCE

CAINOZOIC — QUATERNARY

- Ql — Lake deposits – clay, silt, sand; saline and gypsiferous
- Qg — Quartz sand and gypsum deposits marginal to salt lakes; eolian
- Qa — Alluvium – poorly sorted clay to pebble deposits in drainage lines and adjacent flood plains
- Qc — Colluvium – quartz and rock fragments in loam; includes hardpan
- Qs — Eolian sand
- Qp — Eolian sand with small laterite pebbles

- Czl — Laterite – massive and pisolitic ferruginous duricrust
- Czb — Silcrete – sub-vitreous siliceous duricrust with angular quartz grains
- Czj — Jasperoidal chalcedony and siliceous limonite deposits over ultramafic rocks
- Czk — Calcrete – massive, nodular and sheet carbonate with minor chalcedony
- Czo — Deeply weathered rock; kaolinized, subsequently ferruginized and silicified in part

PALAEOZOIC — LOWER PERMIAN

- Paf — **PATERSON FORMATION:** poorly sorted sandstone, minor conglomerate and siltstone; dominantly fluviatile or fluvio-glacial

PROTEROZOIC — MIDDLE PROTEROZOIC

- Dolerite sills (both pre- and post-Bangemall Group)

Bangemall Group (ЕМ)

- ЕMy — **CALYIE SANDSTONE**: quartz sandstone, commonly cross-bedded, with minor conglomerate lenses
- ЕMw — **WONYULGUNNA SANDSTONE**: coarse to medium-grained quartz sandstone
- ЕMw(s) — Shale, siltstone and minor sandstone
- ЕMx — **COONABILDIE FORMATION**: fine-grained quartz sandstone, siltstone and shale

Scorpion Group (ЕO)

- ЕO(l) — Lithic, silty sandstone, coarse polymictic conglomerate, quartz sandstone, and shale
- ЕO(s) — Micaceous siltstone with interbeds of shale and sandstone
- ЕO(a) — Quartz sandstone, and siltstone
- ЕO(d) — Dolomite and sandstone; stromatolites in some beds

EARLY PROTEROZOIC

Earaheedy Group (ЕE)

- ЕEo — **WONGAWOL FORMATION**: fine-grained arkosic sandstone
- ЕEp — **PRINCESS RANGES QUARTZITE**: white quartz arenite, minor clayey sandstone and siltstone
- ЕEw — **WANDIWARRA FORMATION**: medium to coarse-grained quartz sandstone and shale, locally glauconitic
- ЕEw(a) — Quartz arenite
- ЕEw(s) — Shale, siltstone, minor fine-grained sandstone
- ЕEd — **WINDIDDA FORMATION**: limestone, shale, minor jasperoidal chert and carbonate-clast conglomerate
- ЕEd(s) — Shaley siltstone
- Granular jasperoidal chert
- ЕEf — **FRERE FORMATION**: granular and banded iron-formation, hematitic shale, chert and shale
- Pale grey-green chert
- Shaley siltstone, minor chert and fine-grained sandstone
- Limestone and dolomite; stromatolitic in part
- ЕEy — **YELMA FORMATION**: quartz arenite, shale, phyllite, minor chert and carbonate
- Quartz arenite
- Shale, phyllite
- Limestone, stromatolitic in part
- Pale grey-green to white chert and chert breccia; replaced carbonate

Glengarry Group (ЕG)

- ЕGf — **FINLAYSON SANDSTONE**: white, pink or pale grey quartz arenite, minor shale
- ЕGf(s) — Shale and fine-grained sandstone, purple and flaggy
- ЕGf(c) — Chert and chert breccia in part black and finely laminated, otherwise pale grey-green to white

- Еlx — **TROY CREEK BEDS**: shale, phyllite, sandstone, minor chert, carbonate and iron-formation; rarely garnetiferous
- Еlx(i) — Banded iron-formation
- Еlx(c) — Chert, grey and massive

- q — Quartz dyke

- pЕg — Unassigned granitoid rocks
- pЕgs — Pyroxene-quartz syenite
- pЕgb — Granite to adamellite; medium to coarse-grained
- pЕge — Granite to adamellite; fine to medium-grained

ARCHAEAN

- Ag — Unassigned granitoid rocks
- Agb — Granite to adamellite; medium to coarse-grained
- Age — Granite to adamellite; fine to medium-grained
- Agl — Granite to adamellite; coarse-grained; porphyritic
- Agh — Hornblende quartz monzonite and hornblende quartz syenite
- As — Metasedimentary rock; fine-grained and schistose
- Ai — Banded iron-formation
- Af — Metamorphosed felsic volcanic rock, with volcanic fragments and/or quartz phenocrysts
- Ab — Metabasalt; fine-grained, massive
- Abh — Mafic hornfels; contact metamorphosed metabasalt

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