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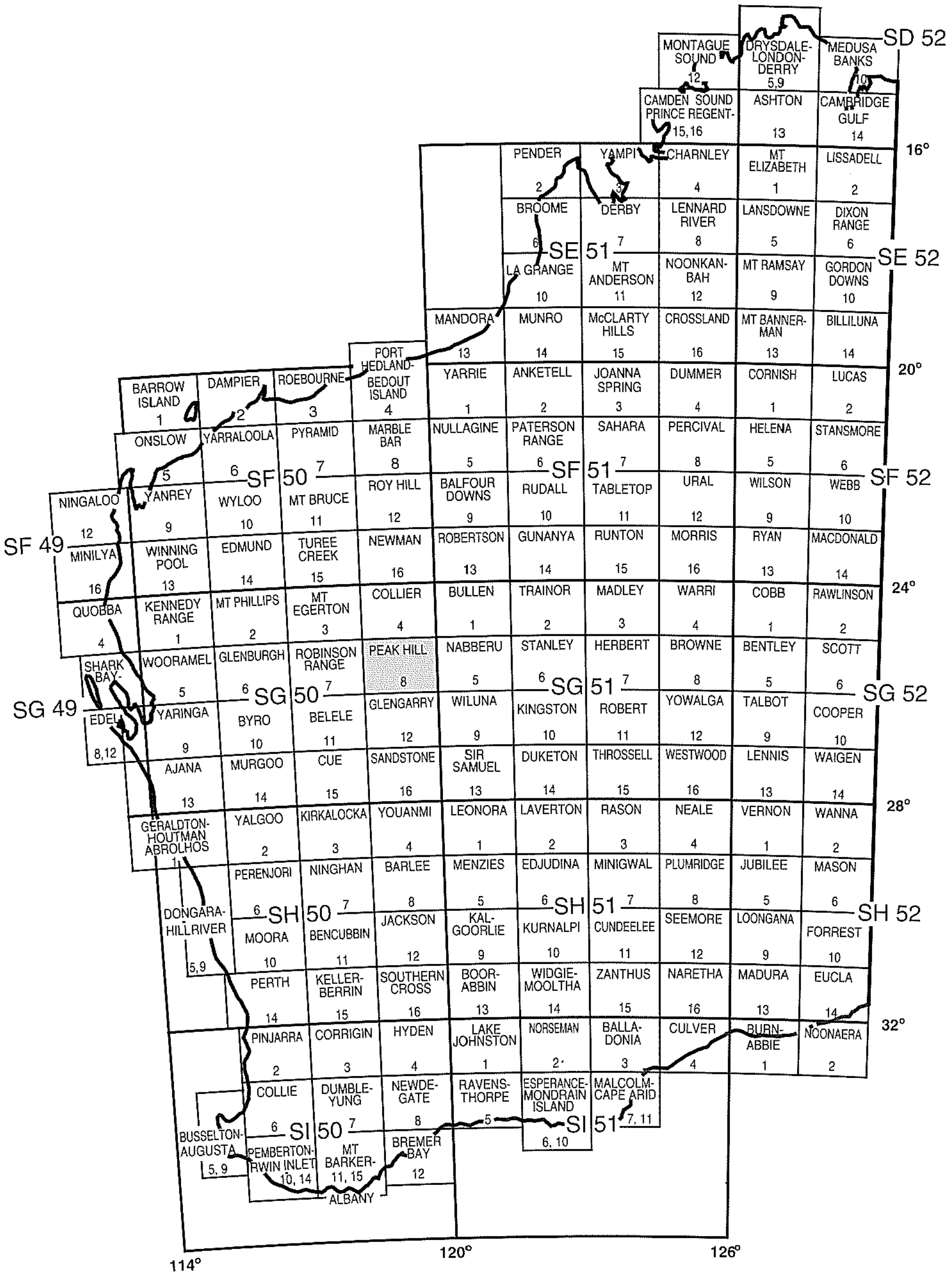
GEOLOGY OF THE DOOLGUNNA 1:100 000 SHEET

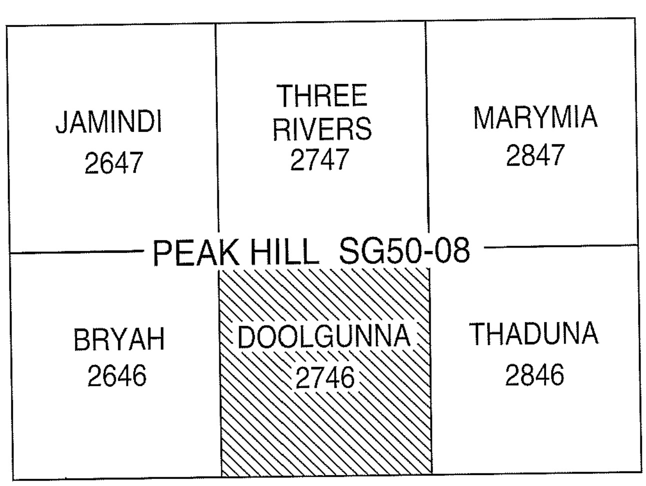
by N. G. Adamides

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY





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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE DOOLGUNNA 1:100 000 SHEET

by
N. G. Adamides

Perth 1998

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Cover photograph:

Thickly bedded granite-derived quartz wacke of the Doolgunna Formation, 4.3 km east of John Bore

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Geology of the Doolgunna 1:100 000 sheet

by

N. G. Adamides

The DOOLGUNNA[1] 1:100 000 map sheet (SG50-08-2746) is located about 750 km northeast of Perth and is bound by latitudes 26°00'S and 26°30'S and longitudes 119°00'E and 119°30'E (Fig. 1). The sheet derives its name from a homestead that is centrally located in the map area. Main access is provided by the Great Northern Highway. Unsealed tracks, mainly along fence lines, provide access to other parts of the area. The old unsealed Thaduna mine[2] haulage road connects the Great Northern Highway with the eastern parts of the map area. The track joining Doolgunna and Diamond Well Homesteads is also in good condition, and a well-preserved track runs westward past Peak Hill Bore towards Quartz Bore.

One of the earliest accounts of the area around DOOLGUNNA is that of Talbot (1920), who, between 1912 and 1914, examined the ground as part of a broader geological reconnaissance. MacLeod (1970) carried out detailed geological mapping of the PEAK HILL 1:250 000 sheet and established some of the currently accepted stratigraphic units. However, Gee (1979, 1987) was mainly responsible for the stratigraphic nomenclature that, with minor modifications, is used in this work.

Hall and Goode (1975) included the area as part of the Nabberu Basin, which was subsequently subdivided into the Earaheedy, Glengarry, and Padbury Sub-basins (Bunting et al., 1977). Later investigations highlighted the unconformable relationships between the sequences defined by the three sub-basins, and the Glengarry Sub-basin was elevated to basin status (Gee and Grey, 1993).

The map area was included in a regional geochemical sampling program that covered the PEAK HILL 1:250 000 sheet. The results of the program are presented in Subramanya et al. (1995).

The climate of the area is arid with long hot summers and mild winters. Annual rainfall ranges from 200 to 300 mm — mainly the effect of cyclonic storms in summer and depressions in winter. Evaporation from a free water surface in the study area reaches up to 3000 mm/y.

DOOLGUNNA was mapped during the field season (April–October) of 1994 as part of a new mapping initiative aimed at the re-examination of Proterozoic sedimentary basins.

Physiography and vegetation

The present physiography is the result of a protracted period of lateritization, uplift, and erosion that has affected most of Western Australia since the Tertiary. These processes produced a broad plateau (the Great Plateau of Jutson, 1934) that was subsequently eroded and dissected. The topography has a generally low relief, with mean elevation of about 550 m. More resistant units form ridges and hills with elevations up to 640 m.

A significant physiographic feature of DOOLGUNNA is the extensive sandplain that occupies much of the southern and southeastern part of the map sheet, and mostly overlies areas of granite. The sand is eolian, consisting of ferruginous quartz derived from the underlying laterite profile, and accumulates in the form of seif dunes. These dunes are aligned in a predominantly northeasterly orientation, reflecting the prevailing winds (Jutson, 1934). Another major feature is the alluvial floodplain that marks the northward-flowing branch of the Gascoyne River. This is characterized by extensive development of groundwater calcrete — a crypto-crystalline mixture of opaline silica and carbonate that forms by precipitation below the watertable under conditions of low, irregular rainfall and high evaporation (Hocking and Cockbain, 1990).

Areas of outcrop show varying physiographic characteristics in keeping with their mineralogical and textural character. Shallow breakaways, commonly only a few metres high, form over areas of granite. Saprolitic and silicified caprock, a remnant of the older regolith, is exposed high in the breakaways, with less-weathered rock at the base. Locally, rounded tors of predominantly fresh granite stand out above the ground surface. A similar mesa-type topography of laterite-capped break-aways characterizes areas occupied by the Doolgunna Formation and, to a lesser extent, the Thaduna Formation. Higher relief, locally with deeply incised valleys, is a feature of the silicified volcanic units of the Narracoota Formation in the northwestern part of DOOLGUNNA,

[1] Capitalized names refer to 1:100 000 and 1:250 000 map sheets.
[2] Coordinates of localities mentioned in the text are shown in Appendix 1.

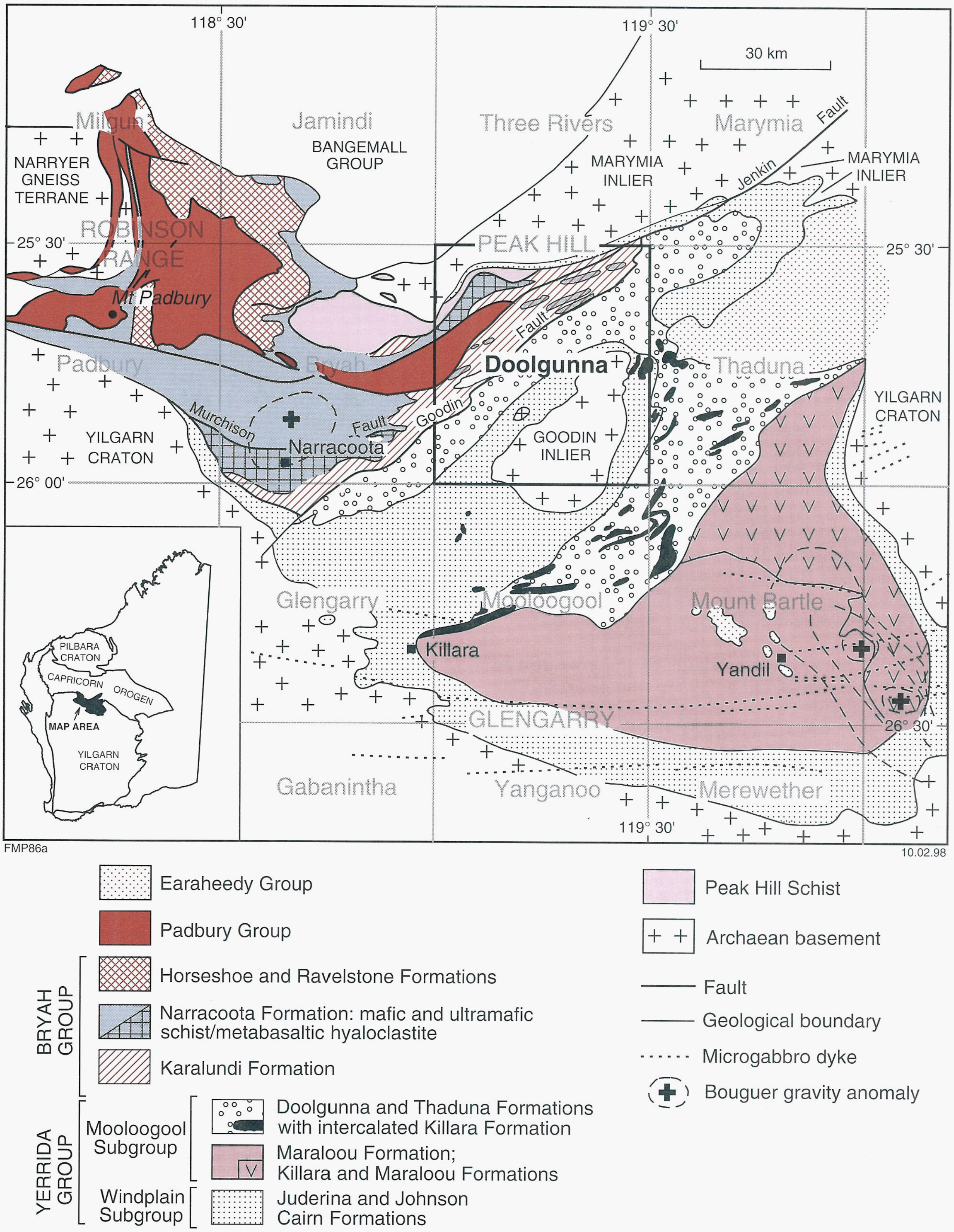

Figure 1. **Map showing the location of DOOLGUNNA and the main tectono-stratigraphic features of the Glengarry Basins (modified from Pirajno et al., 1995)**

with joint and foliation patterns controlling the drainage pattern. In the same area, the quartz-rich units of the Robinson Range Formation form resistant ridges that outline the Robinson Syncline.

Numerous species of vegetation are characteristic of specific physiographic units. The most abundant of the bigger shrubs is mulga (*Acacia aneura*), which is present in almost all habitats and commonly associated with broad-leaf acacia species. Eucalypts, mainly river red gums (*Eucalyptus camaldulensis*), line the major watercourses. Species of eremophila, particularly Wilcox bush (*Eremophila forrestii*), are abundant as an understorey to the mulga on richer soils and are commonly associated with species of the cassia group, particularly crinkled cassia (*Cassia helmsii*) and white cassia (*Cassia luerssenii*). Spinifex (*Triodia* sp.) and scattered low mallee (*Eucalyptus* sp.) characterize the sandy plains. Several species of everlasting daisies associated with larger annuals (Purple mulla mulla, Cotton bush) make colourful displays during spring. Detailed accounts of arid plants in Western Australia, including the DOOLGUNNA region, are contained in Mitchell and Wilcox (1988).

Geological setting and stratigraphic relationships

DOOLGUNNA is situated within volcano-sedimentary basins that formed in the early Proterozoic during the oblique collision between the Yilgarn and Pilbara Cratons (Horwitz and Smith, 1978; Tyler and Thorne, 1990; Myers, 1993). Recent mapping has shown that DOOLGUNNA covers parts of two tectono-stratigraphic domains: the Bryah and Padbury Basins to the west, and the Yerrida Basin to the east. The stratigraphy of the area is presented in Table 1. The tectonic contact between the Bryah and Yerrida Basins extends through DOOLGUNNA in a northeasterly direction (Fig. 2).

The Yerrida Group includes rock types interpreted to have been deposited within a sag basin (Juderina and Johnson Cairn Formations of the Windplain Subgroup). The sag phase was followed by a rift phase, during which rocks of the Mooloogool Subgroup (comprising the Thaduna, Doolgunna, and Maraloou Formations and associated mafic rocks of the Killara Formation) were deposited.

Table 1. Stratigraphy of the Yerrida, Bryah, and Padbury Basins

Basin/Group		*Formation/Member*	*Rock types*
PADBURY BASIN (peripheral foreland basin)			
Padbury Group		Millidie Creek	sericitic siltstone, chloritic siltstone, BIF, dolomitic arenite
		Robinson Range	ferruginous shale, BIF
		Wilthorpe	quartz-pebble conglomerate
		Beatty Park Member	mafic siltstone/wacke
		Heines Member	polymictic conglomerate
		Labouchere	turbidite sequence (quartz wacke, siltstone)
~ ~ ~ *Unconformable contact — in many places tectonized* ~ ~ ~			
BRYAH BASIN (rift succession)			
Bryah Group		Horseshoe	BIF, wacke, shale
		Ravelstone	quartz-lithic wacke
		Narracoota	mafic–ultramafic volcanic rocks and dykes, tuffs, and intercalated sedimentary rocks
		Karalundi	conglomerate, quartz wacke
~ ~ ~ *Faulted contact* ~ ~ ~			
YERRIDA BASIN			
Yerrida Group			
Mooloogool Subgroup (rift succession)		Maraloou	black shale, siltstone, carbonate
		Killara	aphyric mafic lavas and intrusives
	Intercalated	Doolgunna	diamictite, arkosic sandstone, siltstone, shale
		Thaduna	lithic wacke, siltstone, shale, minor arkose
Windplain Subgroup (sag-basin succession)		Johnson Cairn	siltstone, shale, carbonate, minor lithic wacke
		Juderina	arenite, conglomerate, minor carbonate
		Bubble Well Member	silicified carbonate with evaporite units
		Finlayson Member	arenite
~ ~ ~ *Unconformity on Yilgarn Craton* ~ ~ ~			

Modified from Pirajno et al. (1996)

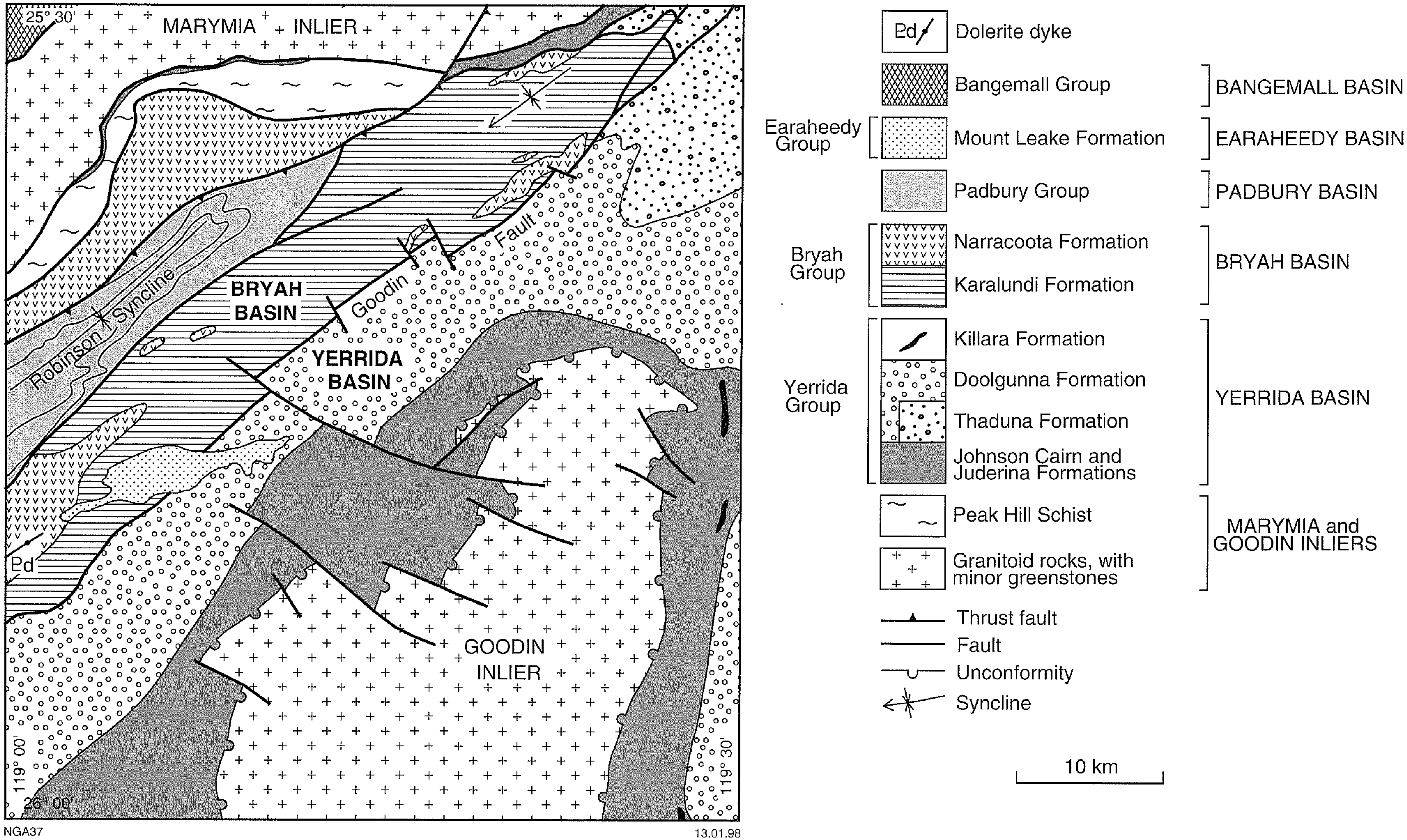

Figure 2. Simplified tectonic sketch of DOOLGUNNA

The Bryah Group covers portions of the northwestern part of DOOLGUNNA. Its members are metamorphosed to greenschist facies and complexly deformed. On DOOLGUNNA these rocks are represented by the Karalundi Formation and the mafic volcanic rocks of the Narracoota Formation.

The Padbury Group is represented by the folded banded and granular iron-formation of the Robinson Range Formation and the thin-bedded turbiditic shales and wackes assigned to the Heines Member of the Wilthorpe Formation. Minor outcrops of shaly rocks in the central parts of the Robinson Syncline are considered part of the Millidie Creek Formation. The group is interpreted to be part of a foreland basin that unconformably overlies the rocks of the Bryah Group (Martin, 1994; Occhipinti et al., 1995).

DOOLGUNNA contains parts of two Archaean inliers: the Marymia and Goodin Inliers. Folded sedimentary rocks of the Yerrida, Bryah, and Padbury Groups occupy the area between the two inliers, where they are locally unconformably overlain by outliers of the Earaheedy Group. Mildly deformed sedimentary rocks of the Bangemall Basin occupy a small portion of the northwestern corner of the map area, and are in faulted contact with the granite of the Marymia Inlier.

Archaean

Goodin Inlier

Archaean granite (*Age*)

The Goodin Inlier is the most southerly of the two Archaean basement highs that are exposed on DOOLGUNNA. It is dominated by granitoid rocks, which form isolated outcrops occupying much of the south-eastern part of the map, and is mostly covered by eolian sand. A series of east-southeasterly trending dykes, presumed to be of Proterozoic age, cut the granite and are themselves truncated by the unconformity with the overlying Proterozoic sequence.

Most of the granite is massive. Foliated varieties are only rarely observed (such as in the area 7 km south of No. 10 Well) and are characterized by almost complete destruction of feldspars, recrystallization of quartz into polycrystalline aggregates, and preservation of muscovite. Sericitic and quartzose Archaean metasedimentary rocks are mainly in the form of slivers tectonically enclosed within the granite.

The inlier comprises medium- to coarse-grained monzogranite to syenogranite (*Age*). Textures vary from equigranular to porphyritic, with an average grain size of 4–5 mm and phenocrysts of potassium feldspar commonly reaching 4 cm in length. The rock is locally affected by strong kaolinization, and cut by quartz veining (associated with shearing) and coarse muscovite (up to several centimetres long). This is probably suggestive of late-stage hydrothermal activity related to granite emplacement. Dominant minerals are alkali feldspar, plagioclase, muscovite, biotite, and quartz. Apatite and zircon are common accessories, and ilmenite and titanomagnetite are common opaque phases. Euhedral fluorite and minor amounts of allanite were identified in a sample of syenogranite (AMG 263342[1]).

A Sensitive High-Resolution Ion Microprobe (SHRIMP) age determination on monzogranite of the Goodin Inlier from near Granite Bore (AMG 274329) indicates a crystallization age of 2624 ± 8 Ma (Nelson, 1997).

Marymia Inlier

Archaean granite (*Agf, Age, Aba, Aci*)

The Marymia Inlier is exposed in the northern part of DOOLGUNNA. It is in tectonic contact with the quartz arenite of the Juderina Formation to the southeast. In the northwestern corner of the sheet the Marymia Inlier is in either tectonic or unconformable contact with the sedimentary rocks of the Bangemall Group.

A generally well defined foliation characterizes much of the outcrop of granitoid rocks of the Marymia Inlier, in contrast to the mostly undeformed granite of the Goodin Inlier. The foliation is particularly pronounced in the northwestern parts of the map sheet, decreasing eastward. The deformation has also affected enclosed mafic dykes, which are locally schistose. The abundance of gneissic textures in the west has led Gee (1987) to correlate these rocks with the Yarlarweelor Gneiss Belt on ROBINSON RANGE.

The lithology is mainly foliated (*Agf*) and unfoliated (*Age*) biotite monzogranite, with subordinate leucocratic varieties. Quartz forms a significant component in sutured, polygonized, and deformed aggregates. Feldspars are strongly altered; they are clouded with, and partly replaced by, alteration minerals including sericite, epidote, clinozoisite, chloritized biotite, minor amounts of carbonate, and microcrystalline sphene. Biotite and minerals of the epidote group define the foliation in the schistose varieties.

Mylonitic quartz–clinozoisite–amphibole–mica rock is exposed in a stream section at AMG 022741. The rock is in a strongly foliated zone with quartz veining parallel to the foliation, and consists of very fine quartz-rich and hornblende–clinozoisite-rich layers with the folia defined by abundant microcrystalline white mica. The mica wraps around broken and rotated crystals of clinozoisite and hornblende, indicating that these minerals pre-date the deformation. Undulatory quartz is strongly attenuated parallel to the foliation.

An outcrop of banded mylonitic chert, mafic schist, and foliated mafic amphibolite (*Aba*), located at AMG 067744, represents part of a greenstone belt.

[1] Localities are specified by the Australian Map Grid (AMG) standard six-figure reference system whereby the first group of three figures (eastings) and the second group (northings) together uniquely define position, on this sheet, to within 100 m.

Banded iron-formation (BIF — *Aci*) is present and is typically complexly folded in semi-continuous, tectonically dismembered units. The rock consists of well-developed layers of polygonized quartz and coarse lepidoblastic hornblende (up to 2 mm in length), associated with abundant euhedral magnetite. Deformation lamellae in the quartz are in oblique orientation to the mineral layers. Retrogressive metamorphism is suggested by thin zones of cataclasis, with the formation of fine biotite at the expense of amphibole.

Peak Hill Schist (*ÆP*p)

The Peak Hill Schist on DOOLGUNNA is restricted to the northwestern part of the map sheet, where it extends in an arcuate belt around the major outcrop of the Narracoota Formation, from Quartz Bore to the area east of No. 3 Well. This rock unit (Occhipinti et al., 1997) includes assemblages previously mapped in the Juderina, Doolgunna, and Karalundi Formations by Gee (1987) that have complex relationships involving tectonic interleaving, as evident on the adjacent BRYAH (Pirajno and Occhipinti, 1998).

The Peak Hill Schist tectonically overlies the granitoid rocks of the Marymia Inlier. The contact is marked by a sequence of white, strongly indurated quartzites about 20 m thick that are probably tectonized equivalents of the Finlayson Member of the Juderina Formation (*ĿYjf*). These rocks are locally thick bedded (up to 1.5 m) with minor flaggy interbeds, and show ripple marks and parallel laminations. They are intensely tectonized with isoclinal intrafolial folds and are locally associated with thin bands of muscovite–biotite schist. The quartzite is extensively recrystallized and locally mylonitic. Quartz forms almost all of the rock, but traces of microcline and possible cordierite were observed.

Structurally above the basal quartzite is a sequence of quartz–sericite schist (*ÆP*p) up to 500 m thick. This unit is exposed in stream sections in the area 9 km northwest of Gale Well, where it resembles the arkosic wackes of the Doolgunna Formation. The schist consists of alternating layers of quartz and coarse-grained sericite. The quartz lenticles are composed of polycrystalline aggregates with sutured grain boundaries. The matrix consists entirely of interlocking crystals of white mica, up to 0.4 mm in length, preferentially oriented parallel to the quartz lenticles.

Scattered through the quartz–sericite schist are bands of strongly brecciated cherty quartzite, represented by lenticular outcrops up to 30 m long and 15 m thick. These are interpreted as mylonite zones (Pirajno and Occhipinti, 1998), and are the lateral equivalents of similar units exposed on BRYAH. Outcrops are slickensided, with abundant disrupted and semi-continuous cherty bands consisting of grey, fine-grained, granular-textured quartzite dusted with minute pyrite crystals. Some blocks contain well-defined ?microbial laminations.

Proterozoic

Mafic dykes (*Ŀd*)

A series of east-southeasterly trending mafic dykes (*Ŀd*) traverse the granite of the Goodin Inlier. They are brownish black in outcrop with well-developed, generally blocky jointing and poorly developed spheroidal weathering. They are mostly vertical but have been affected by tectonism subsequent to emplacement. They have only been observed in the granitoid rocks.

The dykes exhibit a distinctive mineralogy consisting of strongly pleochroic hornblende in the form of finely crystalline or massive concentrations associated with secondary quartz. Textures vary from ophitic to subophitic, and comprise intergrowths of amphibole and euhedral plagioclase with a grain size of 1–2 mm. The plagioclase is commonly completely unaltered, existing both as phenocrysts and as a constituent of the groundmass, and is often zoned with compositions ranging from andesine to labradorite. In places the plagioclase is completely altered to sericite. Minor amounts of biotite are present and sphene is a common accessory mineral. Quartz is present in variable amounts and commonly exhibits a myrmekitic intergrowth with plagioclase. Original opaque minerals of the ilmenite–titanomagnetite group are completely replaced by fine-grained granular leucoxene and iron oxides.

Yerrida Group

Windplain Subgroup

Juderina Formation, Finlayson Member (ĿYjf)

The name 'Juderina Formation' was originally assigned by Gee (1979, 1987) to outcrops near Juderina Bore on PEAK HILL to differentiate them from similar rocks that were assigned to the Finlayson Formation. Later work (Gee and Grey, 1993) demonstrated that the Finlayson and Juderina Formations are correlatives and they compose the basal unit of the Glengarry Basin. The name 'Finlayson Sandstone Member' was applied by Gee and Grey (1993) to the basal quartz arenite, with 'Juderina Formation' being used for the main part of the formation. The Finlayson Sandstone Member was subsequently renamed the Finlayson Member (Occhipinti et al., 1997), and this terminology is used in this work.

The Finlayson Member of the Juderina Formation (*ĿYjf*) unconformably overlies Archaean basement in several areas around the Goodin Inlier, and forms a series of linear outcrops commonly disrupted by faulting. Dips are generally moderate (20–40°) and away from basement rocks. There is no basal conglomerate at the contact with the Archaean granitoid rocks, and the generally planar nature of the unconformity surface has been interpreted as indicative of peneplanation prior to the deposition of the quartz arenite (Hall and Goode, 1978).

The rocks of the Juderina Formation comprise cream-coloured and well-bedded, massive or laminated quartz

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Figure 3. Ripple-marked quartz arenite from the Finlayson Member of the Juderina Formation, 3 km north of Juderina Bore. The lens cap is 5.5 cm in diameter

arenite with abundant sedimentary structures including symmetrical and asymmetrical ripple marks (Fig. 3), herring-bone structures, and trough cross-stratification. Parallel laminations are commonly marked by red-brown ferruginous staining. There is little lithological variation throughout the area.

The arenite is mostly composed of well-sorted, moderately packed, medium-grained quartz grains that are commonly cemented by quartz, showing crystallographic continuity. Minute sericite scales are scattered throughout the matrix or around grain boundaries. Rounded zircons are common and, more rarely, there are traces of detrital muscovite. The interbedded siltstone units are characterized by subangular quartz grains set in a matrix of poorly crystalline kaolinite–illite clays with lesser amounts of sericite.

In the Dingo Bore area the quartz arenite is in two main units, about 50 m in total thickness. These are separated by a band of dark-grey, cherty mudstone associated with silica-cemented quartz arenite, chert breccia, and minor amounts of purplish brown shale. Quartz and cryptocrystalline, colloform-banded opaline silica pseudomorphs after halite are present in this unit. The overall lithology and sedimentary structures of the formation suggest a shallow-marine (possibly intertidal) environment with occasional periods of desiccation.

Johnson Cairn Formation (ĿYc)

The type area for the Johnson Cairn Formation (named after the Johnson Cairn Shale of Gee, 1987) is located northeast of Thaduna mine on MARYMIA, where the type sequence comprises varicoloured iron-rich shale associated with graded silty layers and carbonate beds. A probable lateral extension of the type sequence is represented by poorly exposed laminated siltstones in the area of No. 6 Bore. However, the most extensive outcrops on DOOLGUNNA are located around Centre Pool Bore, with smaller outcrops east of No. 10 Well and in the Ruby Bore area.

In the Centre Pool Bore area the Johnson Cairn Formation (*ĿYc*) conformably overlies the Juderina Formation and is disconformably overlain by the Doolgunna Formation. A thickness of 150 m for the Johnson Cairn Formation is estimated by Gee (1987) around the Goodin Inlier. However, the outcrop pattern suggests that it may be considerably thicker. The Johnson Cairn and Doolgunna Formations may grade into each other, east and southeast of the Goodin Inlier.

The Johnson Cairn Formation in the Centre Pool Bore area is represented by a sequence of laminated grey siltstones weathering to a reddish brown colour (Fig. 4), with minor arenaceous turbidite beds. Lateritic weathering commonly gives rise to a characteristic chocolate

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Figure 4. Laminated argillaceous siltstone from the Johnson Cairn Formation, in the Centre Pool Bore area

coloured rubble. Individual siltstone beds average 15 cm in thickness. The laminae are parallel, with slight undulations and local flame structures. There are also thin beds of dolomite and dolomitic siltstone averaging 20–30 cm in thickness. These commonly display a pisolitic to nodular texture. Such features have been interpreted by Gee (1987) as diagenetic caliche nodules that grew in carbonate muds. Typical Johnson Cairn siltstone consists of minor amounts (5%) of subangular quartz and chert in a matrix of illitic clays and finely dispersed ferruginous opaque minerals.

Mooloogool Subgroup

Thaduna Formation (ᴇYt)

The Thaduna Formation is well exposed in the area of Thaduna mine on THADUNA, where it is represented by about 1000 m of turbidite beds (Blockley, 1968). On DOOLGUNNA, outcrops of this formation are confined to the northeastern corner of the map sheet, where they are in tectonic contact with the Karalundi Formation of the Bryah Group.

The Thaduna Formation (*ᴇYt*) is dominantly a turbidite sequence with abundant graded, coarse-grained arenaceous wackes interbedded with thin, sandy and silty wacke units with parallel and convolute laminations (Fig. 5). Both singly and multiply graded layers are present. The rocks are commonly exposed on breakaways, where they have a characteristic purplish grey colour due to the presence of iron oxides. They commonly include lithic clasts up to several centimetres in diameter, mixed with abundant rip-up clasts.

The lithic fragments are composed of sericitic siltstone, with local iron oxides and subangular to subrounded quartz grains and minor amounts of chert. The matrix is hematitic and composed of sericitic and illitic clays and fine-grained quartz. Outcrops are deeply weathered, and there is little evidence of preservation of primary igneous minerals. However, samples of drillcore from the Thaduna mine contain abundant detrital epidote, clinopyroxene, and fragments of mafic volcanic rock, intermixed with sedimentary components.

A possible correlation between the Thaduna Formation and the Doolgunna Formation is based on their common turbiditic origin and similar stratigraphic position. Interfingering relationships between the two formations have been noted on THADUNA (Pirajno and Adamides, 1997).

Doolgunna Formation (ᴇYd, ᴇYdm)

The Doolgunna Formation, named after Doolgunna Homestead, is developed over a broad northeasterly trending belt extending from the area west of Centre Pool Bore to the area east of John Bore. Less extensive outcrops are present in the southeastern part of the map

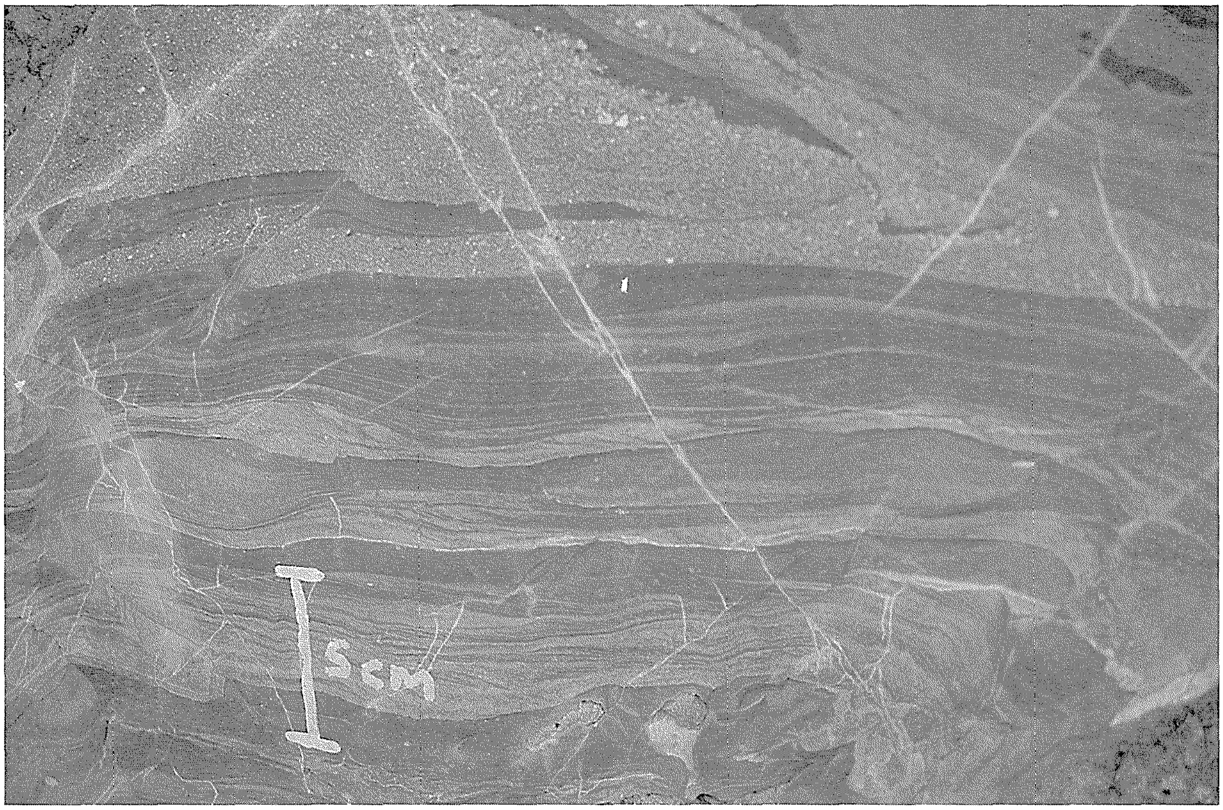

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Figure 5. Soft-sediment deformation structures and isoclinal folding in the Thaduna Formation, 8 km northeast of No. 8 Bore

sheet. Gee (1987) separated the Doolgunna Formation into a lower sandstone member and an upper arkosic member. Recent mapping has not supported this subdivision on DOOLGUNNA, and the formation has been mapped as one unit (*P̲Yd*) with only the conglomeratic member (*P̲Ydm*) mapped separately. This latter unit lies in the middle of the formation and is confined to the area northwest of the Goodin Inlier. A total thickness of about 5 km was estimated by Gee (1987) for the Doolgunna Formation in the area northwest of the Goodin Inlier. This area was the site of the thickest turbidite deposition and the formation thins considerably away from this inlier.

The Doolgunna Formation is typically an arkosic turbidite sequence consisting of whitish arenaceous wacke beds commonly averaging 1 m in thickness, but locally up to 3 m in thickness. Rocks are orange-brown on the weathered surface and locally capped by silcrete. The beds consist of upward-fining sequences with rip-up clasts. There is evidence of intense scouring in the lower parts and laminated facies at the upper levels. Angular to subrounded clasts, mainly of quartz and up to several centimetres across, are enclosed in an unsorted kaolinite-rich matrix.

The arkosic turbidite of the Doolgunna Formation consists of angular quartz and equal proportions of microcline, potassium feldspar, and plagioclase set in a matrix of fine-grained kaolinite and sericite or hydromuscovite clays. Clastic micas are locally preserved. More mature wacke is also present, and dominated by quartz with subordinate kaolinized feldspar in a clay matrix.

The basal unit of turbidites exposed 8 km west of Centre Pool Bore (AMG 013252) is overlain by a succession of diamictites, possibly up to 300 m thick, which contain large blocks commonly reaching tens of metres in size. The blocks include banded (?microbial) chert; grey, well-sorted, silica-cemented, fine- to medium-grained quartz arenite; quartz arenite breccia; and laminated arenite. These blocks are enclosed in a white, sheared, silty matrix and are interpreted as olistoliths deposited in a deepening trough. These units have been designated *P̲Ydm* on the geological map. Associated bands of fine-grained granule conglomerate that locally exhibit inverse-to-normal grading suggest a genesis by debris-flow processes.

A series of outcrops of diamictite (*P̲Ydm*) in the area 2 km south-southwest of Mount Leake Bore are probable correlatives with the zone of olistoliths. Three separate bands are exposed and may represent repetition by isoclinal folding. The best exposed band is 100 m thick, with blocks commonly up to 3 m in diameter enclosed in a fine-grained, sheared, unsorted matrix. The blocks are rounded, suggesting some transport (Fig. 6), and consist mainly of chert breccia comprising intermixed angular and rounded fragments of grey chert in a fine-grained, unsorted matrix of similar composition. They are unlike any other rock types exposed on DOOLGUNNA.

Figure 6. Rounded block of chert breccia in an unsorted matrix from the Doolgunna diamictite, 2 km south-southwest of Mount Leake Bore

However, they have sedimentological and lithological similarities to the Bubble Well Member of the Juderina Formation (Occhipinti et al., 1997), and may be derived from this unit.

The lithology of the Doolgunna Formation in the southeastern corner of the map sheet is distinctly different from the rest of the area. Outcrops in this area (centred around AMG 470230) are dominated by well-bedded (average thickness of 40 cm), grey arenaceous wacke with minor amounts of interbedded grey, laminated siltstone and local granule-stone. The wacke consists of strained subangular to subrounded quartz clasts with minor amounts of chert, feldspar, and lithic fragments in a kaolinitic–sericitic matrix. The sparse feldspar grains are altered to clays. The increased abundance of lithic fragments in these rocks, compared to the typical wackes of the Doolgunna Formation, suggests contribution from diverse sources.

Killara Formation (EYk, EYkd)

The Killara Formation (*EYk*) consists of mafic volcanic rocks, basaltic lavas (that are locally amygdaloidal), dolerite sills, and chertified laminated sedimentary rocks. The formation is best developed on MOUNT BARTLE (Dawes and Le Blanc Smith, 1997) and THADUNA (Pirajno and Adamides, 1997) where it is estimated to be over 1 km thick. Outcrops of the Killara Formation are restricted to the central-eastern and southeastern parts of DOOLGUNNA, and are mainly represented by sills.

The intrusive rocks (*EYkd*) outcrop as dark, greenish grey dolerite, weathering in a blocky or spheroidal fashion. In the area east-southeast of No. 10 Well (AMG 497488), a medium- to coarse-grained dolerite has a locally developed autoclastic breccia structure and is cross-cut by dykes of fine-grained dolerite–basalt (possibly representative of later magma surges).

Rocks of the Killara Formation display textures that vary from subophitic to microporphyritic and intersertal. The rocks contain plagioclase laths that are commonly altered to a mixture of chlorite and clinozoisite, and augitic clinopyroxene in the form of corroded anhedral crystals mostly altered to a fibrous tremolitic amphibole. Plagioclase is locally albitized and clouded with inclusions of fine chlorite and clinozoisite. The alteration of plagioclase appears to be a non-pervasive, partly fracture-controlled process, and original plagioclase (andesine to labradorite) is preserved in places. The matrix is completely altered to a mixture of quartz, chlorite, and clinozoisite. Coarse subhedral opaque minerals are present as corroded crystals and are variably altered to titanite. The degree of alteration varies with grain size, with fine-grained mafic rocks showing almost total replacement by alteration minerals.

In the area southeast of No. 10 Well (AMG 493494), mafic rocks of the Killara Formation intrude the Johnson Cairn Formation and are spatially associated with vesicular basalt, tuff, and chert. This association of basalt, tuff, and chert is lithologically very similar to rocks of the Bartle Member of the Killara Formation (Occhipinti et al., 1997) that are thought to be related to the closing stages of the Killara igneous episode. The tuffs are characterized by fine-scale textures suggestive of aqueous transport (current lamination), and consist of fragments of fresh plagioclase and blades of tremolitic amphibole in a matrix of fine-grained cherty silica, flattened pumice fragments, and dusty iron oxides. Massive chert, spatially associated with the tuffaceous rocks, exhibits a recrystallized polygonal texture and is intergrown with acicular iron hydroxides after hematite, with cavities commonly filled by fine, colloform or radiating chalcedony. Recrystallization generally obscures the textural features of the tuff and chert. However, relict pyroclastic features, such as shards, are well preserved in places. The association of tuffs and basalts within the sedimentary rocks of the Johnson Cairn Formation implies sedimentation coeval with vulcanicity in this area.

Bryah Group

Karalundi Formation (ᏢAk, ᏢAka, ᏢAks, ᏢAkc)

The Karalundi Formation is described by Gee (1987) as a mixed sequence of clastic carbonate, chert, and tuff associated with ferruginous sandstone (*ᏢAk*). However, Bunting (1986) described it as a dominantly shaly sequence with minor amounts of quartz wacke, chert, tuff, and carbonate. This reflects the lithological variability of this unit.

The Karalundi Formation is exposed in a north-easterly trending belt through DOOLGUNNA. Its contact with the Heines Member of the overlying Wilthorpe Formation is inferred to be tectonic, based on an interpretation of aeromagnetic images and the presence of quartz veining. Its contact with the Doolgunna Formation is defined by the Goodin Fault (Fig. 2) — a major discontinuity that is very pronounced on both aeromagnetic and Landsat images. This fault marks the contact between the Bryah and Yerrida Groups.

The formation has been subdivided into three mappable units: arenaceous and conglomeratic rocks (*ᏢAka*); siltstone and shale (*ᏢAks*); and fine siliciclastic rocks and cherts (*ᏢAkc*). The major part of the formation on DOOLGUNNA is a mixed sequence of fissile, sericitic and hematitic siltstone and shale. These fine-grained rocks locally contain exotic blocks of varying sizes. Blocks include fine- to medium-grained, massive quartz arenite with poorly defined parallel laminations in their upper parts, but mostly devoid of any sedimentary structures. Other blocks consist of quartz arenite similar to that of the Finlayson Member of the Juderina Formation. There are also blocks of pebble beds, coarse-grained ferruginous arenite, and deformed quartz conglomerate (Fig. 7) folded in conformity with the host shale.

The arenite units are moderately sorted and well packed, consisting mainly of quartz and lesser amounts of chert clasts with varying degrees of roundness. The quartz clasts show sutured boundaries and deformation lamellae, but are not strongly recrystallized. The grains are surrounded by minor iron oxide. More iron-rich quartz arenite (commonly coarse grained and poorly sorted) contains interstitial, fragmentary, corroded and rounded detrital magnetite.

The pattern of association of quartz arenite and pebble beds within a shaly sequence persists throughout most of the map area. This suggests that the Karalundi Formation may be a deep-water lateral facies of a rift sequence in which olistoliths and debris flows contributed the coarse clastic material to a dominantly shaly sequence. The origin of the olistoliths is enigmatic, but partial derivation from the Yerrida Group as a result of basin inversion is suggested by some blocks that show characteristics of the Juderina Formation. Shales in the immediate vicinity of the arenite blocks are commonly sandy, suggesting that the olistoliths may have been in a semi-consolidated condition at the time of emplacement.

Dark-grey, massive, hematitic jasper outcrops in the area of John Bore (around AMG 359645). The rocks are characterized by a conchoidal fracture and have a dyke-like form within cleaved shale. They are cut by veins of coarsely crystalline micaceous hematite and quartz. Smaller blocks of the same rock type are present nearby. The rock is made up of crudely colloform, euhedral, or massive hematite with interstitial quartz in a recrystallized mosaic. Quartz fills syneresis cracks in the jasper and locally shows outlines of opaque minerals overprinted by the recrystallization. Fine-grained acicular hematite is intermixed with the quartz or forms more massive accumulations. These outcrops have been interpreted as products of hydrothermal exhalative processes related to volcanic activity (Gee, 1987).

Limited outcrops of cherty rock types (*ᏢAkc*) southeast of No. 11 Well (AMG 087442) consist of laminated hematitic chert that is locally brecciated and cemented by quartz. These rocks may also be chemical precipitates associated with volcanic activity.

Narracoota Formation (ᏢAn, ᏢAnb, ᏢAnd)

The most extensive outcrops of the Narracoota Formation (*ᏢAn*) lie in an arcuate belt in the northwestern part of the map area, where they form steep, deeply dissected hills rising up to 100 m above the surrounding country. The outcrop tapers off towards the east where, in the area of Red Bore, it is represented by a series of narrow belts of volcanic rocks intercalated with the sedimentary units of the Karalundi Formation. In the Quartz Bore area the Narracoota Formation consists of fine-grained, greenish grey, strongly indurated basaltic lavas that are commonly cleaved; and more massive, unfoliated medium-grained dolerite.

NGA52 27.1.98

Figure 7. Tectonized quartz conglomerate from the Karalundi Formation, 5 km northeast of John Bore. The lens cap is 5.5 cm in diameter

Well-developed schistosity, commonly in two conjugate directions, has resulted in sharp, spine-like outcrops. Chlorite schist has developed along zones of intense deformation and shearing. The dominant cleavage direction ranges from northeasterly to easterly, with zones of high schistosity correlated with shear zones and faults in the adjacent sedimentary rocks. An autoclastic texture is common, with blocks of lava set in a matrix of identical composition. Pillow structures, some well preserved, are scarce and characterized by absence of vesicularity in the pillow margins.

Although medium-grained mafic intrusives (*ĿAnd*) are widespread, they are generally too small to map. Deformation obscures contact relationships with surrounding rocks. They commonly form massive resistant cores that contrast with the highly cleaved lavas.

Near John Bore (AMG 358661) there is a zone of volcanic breccia (*ĿAnb*) containing angular fragments of various igneous rock types. Clasts up to several centimetres in size are set in a glassy igneous matrix. Chertified tuff and basalt lavas are spatially associated with this unit.

Petrographically, the volcanic rocks show partly preserved textures varying from ophitic and subophitic to intersertal. Grain size reaches up to 2 mm in the coarser varieties, and is 0.1–0.2 mm in the fine-grained types. The assemblages are dominated by secondary minerals of the chlorite, epidote, and amphibole groups with original phases only rarely preserved. Plagioclase is commonly replaced by a dark, fine-grained aggregate of clinozoisite or a quartz–chlorite–clinozoisite assemblage. Clinopyroxene is commonly replaced by tremolite–actinolite, and early phenocryst phases are replaced by aggregates of quartz, chlorite, and clinozoisite. The chlorite forms sheaf-like aggregates and shows a characteristic anomalous brown birefringence. The groundmass is altered to a mixture of chlorite and clinozoisite, and ilmenite is replaced by a microcrystalline aggregate of leucoxene. Fine trails of microcrystalline titanite are common in the groundmass. Some vesicles are filled by quartz and prehnite, with a rim of clinozoisite. Well-formed crystals of epidote are associated with clinozoisite, or infill vesicles, veinlets, and nests in the groundmass.

Veins within the volcanic rocks contain epidote, clinozoisite, chlorite, calcite, fibrous amphibole, and clays. Late-stage veinlets of pumpellyite cross-cut earlier assemblages. Albite formed during vein paragenesis, and is also a product of the albitization of plagioclase. Quartz is universally present in the alteration paragenesis, either as a vesicle-filling mineral, or interstitially to the other alteration minerals. Pillow margins show an intersertal texture, with microphenocrysts of mafic minerals in a glassy matrix completely altered to quartz, chlorite, and clinozoisite.

Thin tuffaceous units are locally intercalated with the volcanic sequence, and consist of alternating fine- and coarse-grained layers of crystal fragments (up to 0.2 mm in length) of amphibole and quartz in a matrix of quartz, epidote, and clinozoisite. Individual bands are laterally discontinuous in the scale of the thin section. The rocks are interpreted as crystal tuffs, probably water-laid.

Padbury Group

The Padbury Group (Occhipinti et al., 1997) consists of the Wilthorpe, Robinson Range, and Millidie Formations. Martin (1994) proposed that deposition of the lower Padbury Group occurred in a foreland basin during the closure of the Bryah Basin. Iron formations were deposited on a progradational shallow-marine shelf. On DOOLGUNNA the Padbury Group is represented by the Millidie Creek and Robinson Range Formations, and the Heines Member of the Wilthorpe Formation.

Wilthorpe Formation, Heines Member (ᴇPwh)

The type area of the Heines Member of the Wilthorpe Formation on BRYAH is represented by an upward-fining sequence, with a basal polymictic conglomerate followed by finer grained sandy and shaly rocks (Pirajno and Occhipinti, 1998). Rocks assigned to the Heines Member on DOOLGUNNA probably represent the upper part of the formation.

On DOOLGUNNA the Heines Member (*ᴇPwh*) is represented by a sequence of poorly exposed schistose rocks about 7.5 km northwest of Doolgunna Homestead. They consist of siltstone with a considerable amount of fissile, sericitic, possibly carbonaceous shale, and subordinate arenaceous quartz wacke. In the wacke, subangular to rounded quartz, commonly strained and showing incipient recrystallization, is associated with lithic fragments of shale, chert, recrystallized sericitic quartz siltstone, and minor amounts of ferruginous siltstone. The matrix is commonly ferruginous, foliated, and composed of sericite and kaolinite.

Robinson Range Formation (ᴇPr, ᴇPrg, ᴇPri)

Outcrop of the Robinson Range Formation defines the Robinson Syncline (Fig. 2) in the northwestern part of DOOLGUNNA, forming ridges with rounded relief rising above the surrounding topography. Much of the outcrop is covered by scree. The formation consists of interbedded shale, granular iron-formation, and subordinate BIF with a combined thickness of about 1000 m. These rocks are significant in that they represent the first area of extensive granular (Superior-type) iron-formation to be recognized outside North America (Goode et al., 1983).

Granular iron-formation (*ᴇPrg*) typically consists of beds, up to 1 m thick, of fine- to medium-grained, granular-textured ferruginous arenite, commonly dark brown to black in outcrop. The arenite consists of an intimate mixture of siliceous material and granular iron oxides. Beds are separated by ferruginous laminated shale. Thinner siliceous bands show pinching and swelling along strike. Intraclasts of jasperlitic chert, up to a few centimetres in length, are locally observed.

Typical granular iron-formation texture consists of euhedral magnetite, either as single crystals or clusters of crystals, 10–30 microns in length, in a matrix of granular recrystallized quartz. This matrix contains a variety of allochems mainly consisting of jasper, and euhedral magnetite partly or totally replaced by hematite (martitized). Abundant ellipsoidal jasper peloids of densely packed hematite platelets, 5–10 microns in length, are found in a matrix of recrystallized quartz. The textures are compatible with deposition in shallow water, above wave-base, with the peloidal texture providing evidence of disruption of freshly deposited layers (Goode et al., 1983).

Banded iron-formation (*ᴇPri*) is exposed on the northern limb of the Robinson Syncline, where it has individual bedding units up to 30 cm thick. Laminae are defined by alternations of fine-grained, sandy to silty siliceous material and black ferruginous bands. Thickness of individual laminae ranges from less than 1 mm to 1 cm. Local interlayers of cherty BIF are commonly discontinuous along strike, with a flattened elliptical outline passing laterally into continuous laminae (Fig. 8). Similar features elsewhere have been attributed to diagenetic deformation (Findlay, 1994).

The BIF consists of alternating millimetre-scale silica-rich and magnetite-rich layers. The magnetite is euhedral, enclosed in a matrix of cherty silica, and commonly rimmed by hematite. Cherty layers are lenticular and laterally discontinuous. Some laminae show current cross-stratification defined by dusty iron oxides. Secondary colloform goethite, associated with lepidocrocite, fills cavities. There are local interlaminations of magnetite-rich layers with hematite–lepidocrocite assemblages. The petrographic characteristics of both the granular iron-formation and BIF are in many respects similar to those in the Frere Formation of the Earaheedy Basin (Hall and Goode, 1978; Goode et. al, 1983).

The fine-grained rock types in the Robinson Range Formation are typically laminated argillaceous siltstones, weathering to a brown colour, interbedded with slightly ferruginous cherts (*ᴇPr*). They show gradations into, and interfingering relationships with, the BIF. Microscopic examination reveals a well-defined foliation with abundant oriented sericitic flakes and local scattered tourmaline needles.

Millidie Creek Formation (ᴇPm)

In its type section on BRYAH the Millidie Creek Formation (*ᴇPm*) is represented by a thick sequence of shale, dolomite, and sandstone (Gee, 1987). On DOOLGUNNA the formation is in the core of the Robinson Syncline (Fig. 2),

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Figure 8. Disrupted and discontinuous laminae in cherty iron-formation from the Robinson Range Formation, 5 km south of Quartz Bore

where it consists of fissile, light-grey, silty shale interbedded with massive hematitic and locally limonitic siltstones and minor amounts of granular iron-formation. The rocks are folded in conformity with the other units of the Padbury Group.

Earaheedy Group

Mount Leake Formation (ⱣEl)

The Mount Leake Formation (*ⱣEl*) has been assigned to the Earaheedy Group on the basis of well-defined unconformable contacts with the underlying rocks of the Yerrida and Bryah Groups. It is here interpreted as an outlier of the Earaheedy Basin, and correlated with the basal unit of the Earaheedy Group — the Yelma Formation. Supporting evidence is provided by stromatolitic chert containing possible *Asperia digitata* (Grey, 1995) close to the basal unconformity on the western slopes of Mount Leake. Geochronological evidence from the Mount Leake Formation, derived from detrital zircon dating (Nelson, 1997), suggests a maximum depositional age of 1785 ± 11 Ma.

The Mount Leake Formation has a maximum thickness of about 50 m, and rests unconformably on the tectonized and folded Doolgunna and Karalundi Formations. At the type locality, on Mount Leake (AMG 165470), this contact is marked by a 7 m-thick sequence of ferruginous breccia, possibly a palaeoregolith, overlain by a massive siliceous, extensively chertified bed about 10 m thick. Further west the contact with the underlying Karalundi Formation is marked by a complex sequence of chert breccia with interbedded coarse-grained quartz arenite and fine pebble-rich beds, indicative of a shallow-marine or fluvial environment.

The typical rock type of the Mount Leake Formation is a cream-coloured, thin-bedded and cross-stratified, well-sorted quartz arenite commonly containing small rounded glauconite grains. Mud chips and ripple marks are widespread on bedding surfaces, suggesting shallow-water deposition. A shallow-water environment is also supported by the presence of a lithofacies with peloidal texture, probably derived from a carbonate precursor (Fig. 9).

Bangemall Group

Rocks of the Bangemall Group are confined to the extreme northwestern part of DOOLGUNNA. The Group unconformably overlies the Glengarry (now Yerrida and Bryah) and Earaheedy Groups (Brakel and Muhling, 1975). Williams (1990) proposed a two-fold subdivision with an older sequence (Edmund Subgroup) in the west, and a younger sequence (Collier, Manganese, and

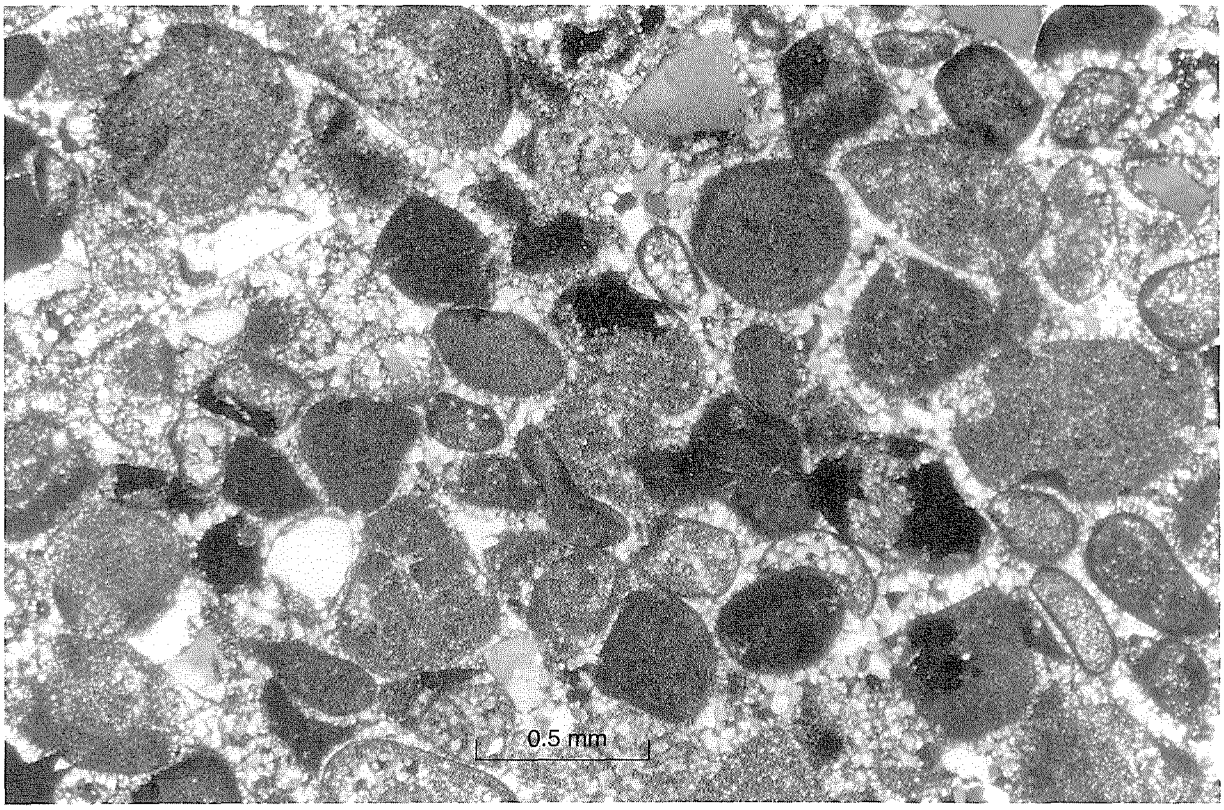

Figure 9. Peloidal textures in chertified carbonate from the Mount Leake Formation. GSWA 120531, crossed polars

Kahrban Subgroups) in the east. On DOOLGUNNA, only rocks of the Collier Subgroup are exposed. They are characterized by gentle dips and open, shallow-plunging folds.

Backdoor Formation (PMb)

The Backdoor Formation (*PMb*) is represented by thin-bedded and finely laminated, buff and light-grey siltstone commonly with hematitic staining. Beds show open-style folds with northeast-trending axial planes and shallow to horizontal plunges. The contact of the Backdoor Formation with the overlying Calyie Formation is exposed at AMG 049776, where thin-bedded argillaceous siltstone grades conformably into quartz siltstone with fine, parallel and trough laminations. The rocks are locally intruded by dolerite sills, although there are none in the mapped area.

Calyie Formation (PMy)

The base of the main quartz arenite unit of the Calyie Formation (*PMy*) is marked by a zone of interbedded siltstone and thin quartz sandstone. The quartz arenite is well bedded, light grey, and silica cemented, with widespread mud-chip moulds on bedding planes. It is locally interbedded with quartz siltstone. The arenite is fine grained, well sorted, and well packed, with a distinct bimodal distribution of grains.

Cainozoic

Mapping of most of the Cainozoic units is mainly based on morphological and photogeological expression. Relics of the old lateritic duricrust (*Czl*) are commonly preserved in breakaways. This laterite consists of generally massive or brecciated ferruginous material, and is separated from the fresh bedrock beneath by an intermediate saprolitic zone. It is distinguishable from the spatially limited and commonly fault-controlled ironstone (*Czli*), which may be related to mineralization. The saprolitic zone is rarely greater than a few metres thick. The lateritic duricrust degrades into a mixture of laterite fragments, pisolites, and soil, that is particularly well developed on aprons at the base of the laterite mesas (*Czf*).

Areas adjacent to outcrop are commonly covered by coarse colluvium (*Czc*) comprising rock fragments mixed with laterite and soil. The size of the fragments decreases and soil content increases with distance from the outcrop. This unit merges at lower levels with the floodplain deposits (*Cza*). The latter are commonly characterized by vegetation groves that have a characteristic pattern on aerial photographs. This is a result of the adjustment of the vegetation to the patterns of sheet flow on gentle slopes (Mabbutt, 1963) and is distinct from the smooth photogeological pattern of the coarse colluvium (*Czc*). Floodplain deposits surround and merge with channels of active transport (*Qa*) or locally terminate in topographic lows, forming claypans (*Qac*). A special type of colluvium, derived from quartz veins, consists predominantly of quartz mixed with subordinate rock fragments (*Czcq*).

Areas overlying granite are typically covered by a thick layer of red-brown sand (*Czs*), commonly in the form of dunes. This sand is the end product of lateritization of the underlying granite. Coarse quartzofeldspathic sand (*Czg*) locally overlies granite and is the product of mainly mechanical fragmentation. Silcrete (*Czz*) forms a siliceous duricrust over deeply weathered rock, and is composed of angular quartz grains in a fine-grained siliceous matrix. Calcrete (*Czk*) — a cryptocrystalline mixture of opaline silica and carbonate — lines the major areas of drainage.

Igneous geochemistry

Pirajno et al. (1995) identified distinct chemical differences between the Narracoota and Killara Formations. Rare-earth element patterns and major-element distribution suggest that the mafic rocks of the Narracoota Formation have a more primitive chemistry than those of the Killara Formation. These differences have been interpreted (Pirajno et al., 1995) as indicative of an oceanic setting for the Narracoota Formation and a continental setting for the Killara Formation. Hynes and Gee (1986) favoured a continental rift setting for the Narracoota Formation, with rifting probably taking place in a subduction zone environment.

A small number of rock samples were analysed from DOOLGUNNA. Samples were from the Narracoota Formation, the mafic dykes that intrude the Archaean granite of the Goodin Inlier, and one sample came from an intrusive rock within the Bangemall Group. Analyses were carried out by the Chemistry Centre of Western Australia. Major elements were analysed using X-ray fluorescence spectrometry (XRF), and trace elements determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Analytical results are presented in Appendix 2.

Samples from the Narracoota Formation range from basaltic komatiite to calc-alkaline basalt (Fig. 10). Samples from the Killara Formation occupy the tholeiite field. The sample from the Bangemall Group, and most of the samples from the Proterozoic dykes that intrude the granite, plot in the high-iron tholeiite field.

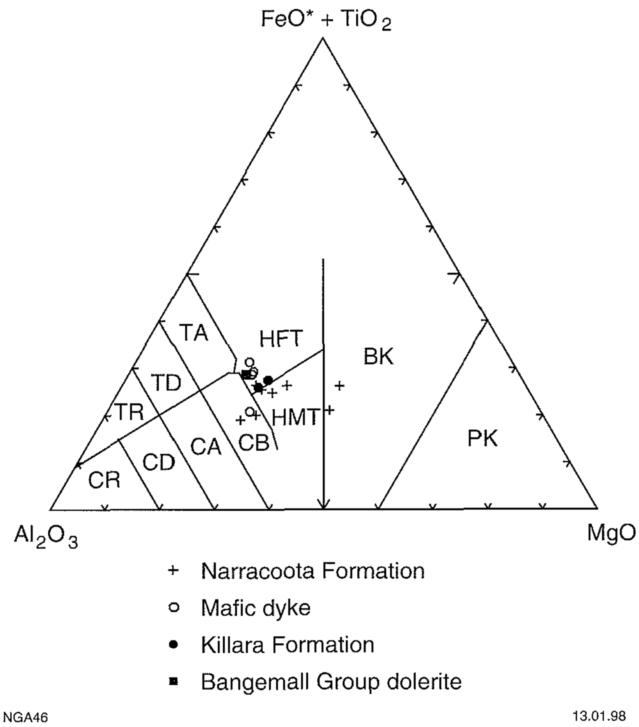

Figure 10. Jensen (1976) cation plot of igneous assemblages from DOOLGUNNA. The line separating the tholeiitic from the calc-alkaline field is shown. HFT: high-iron tholeiite, HMT: high-magnesium tholeiite, CB: calc-alkaline basalt, BK: basaltic komatiite. FeO* is total iron recalculated as FeO. Refer to Jensen (1976) for description of other fields

Deformation and metamorphism

The structural pattern on DOOLGUNNA is dominated by a major synclinorium — the Glengarry Fold Belt (Gee, 1987) — broadly centred between the Goodin and Marymia Inliers. The rocks are relatively undeformed in the area around the Goodin Inlier, but become more strongly deformed in the vicinity of the Robinson Syncline. The increased deformation is marked by increasing schistosity in the argillaceous rocks.

In the areas around the Goodin Inlier, the quartz arenites of the Juderina Formation are deformed in a brittle manner similar to the underlying granite. The structural pattern is characterized by block faulting. Higher in the sequence the sedimentary rocks of the Johnson Cairn and Doolgunna Formations are extensively folded with fold axes oriented east-northeast. These folds are outlined by the diamictite unit northwest of the Goodin Inlier. The same type of folding, associated with dip reversals, is present in the Thaduna Formation, with common development of a strong axial-plane cleavage in the shales. Quartz arenite units within argillaceous rocks of the Karalundi Formation also define folds along northeasterly trending axes.

The iron formations of the Padbury Group are typically steeply dipping, with common isoclinal folding. Minor folds plunge at moderate angles towards the southwest, parallel to the axial plane of the Robinson Syncline. They are associated with transposed bedding and the development of an axial-plane fracture cleavage in the iron formations and a slaty cleavage in the shaly rocks.

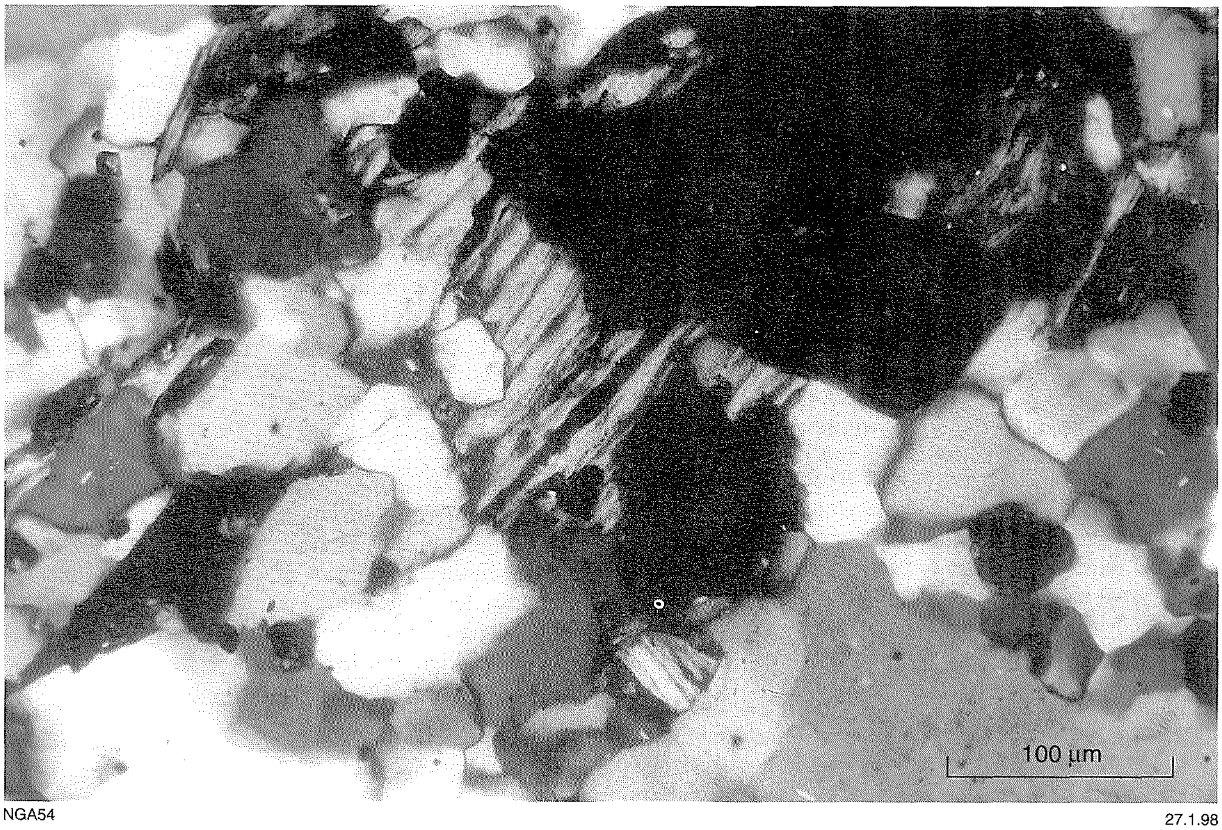

Figure 11. Chlorite with well-developed cleavage, associated with quartz, in recrystallized granular iron-formation from the Robinson Range Formation. GSWA 120585, crossed polars

On DOOLGUNNA the granitoid rocks of the Marymia Inlier typically have a gneissic foliation and abundant mylonitic zones, particularly in the western part. The dominant foliation in granitoid rocks trends northeast, with local open-style folding along similarly trending axes. The latter may be related to the same folding episode that affected the rocks of the Bangemall Group.

The contact between the Marymia Inlier and the basal orthoquartzite of the Juderina Formation is characterized by intense deformation associated with mylonitization and intrafolial folding. This is consistent with strong compressional stresses from the southeast, which resulted in the overthrusting of the orthoquartzite onto the Archaean granite, possible tectonic interleaving in the Peak Hill Schist – Marymia granite contact, and fracture cleavage in the mafic igneous rocks of the Narracoota Formation. Chloritic schists occupy well-defined zones of high-strain deformation in the latter rocks. The structural pattern may be interpreted as the result of the development of longitudinal normal faults during extension in the basins, followed by their reactivation and reversal of movement.

Metasedimentary rocks show varying degrees of generally low-grade burial metamorphism in the form of weak recrystallization of the clay matrix. Argillaceous rocks of the Johnson Cairn Formation are dominated by illite in the form of matted acicular microcrystalline aggregates. The arkosic wackes of the Doolgunna Formation have kaolinite as the predominant clay mineral. Sericite, indicative of slightly increased metamorphic grade, is present in rocks of the Yerrida Group from the Mount Leake area.

The iron formations of the Padbury Group are variably recrystallized, with replacement of fine-grained ferruginous material by crystalline iron oxide (either fine, platy hematite or magnetite) and general recrystallization of the siliceous fraction. Quartz grain-size ranges from 0.02 mm in the finer grained, weakly metamorphosed types, to 0.2 mm in the coarser grained, recrystallized varieties. Chlorite was observed locally (Fig. 11), along with small amounts of biotite or stilpnomelane infilling fractures and overgrowing pre-existing phases.

At least two periods of deformation are identified in the rocks of the Peak Hill Schist. Foliation, defined by coarse alternations of quartz and white mica, is locally crenulated, with reorientation of mica flakes parallel to the crenulation direction. The association of muscovite and biotite in these rocks, and the presence of cordierite, suggest that conditions of metamorphism were probably about 350°C and 4 kbar (Bucher and Frey, 1994). Mylonites in the same formation show well-formed pyrite porphyroblasts and scattered sericite, in a matrix of sutured or polygonized quartz.

The association of metamorphic minerals in the volcanic rocks of the Narracoota Formation is characteristic of the lower greenschist facies, and represents a typical assemblage observed in metabasites. The style of alteration in the mafic rocks of the Killara Formation is similar to, but generally not as pervasive as, that in the main outcrop of the Narracoota Formation. Albitized plagioclase (commonly clouded with inclusions of clinozoisite and chlorite) and amphibolitized clinopyroxene are associated in a matrix of granular clinozoisite, quartz, chlorite, and epidote. These assemblages are consistent with metamorphic conditions of about 300°C and 3 kbar (Bucher and Frey, 1994).

The mafic dykes that intrude the granite in the Goodin Inlier are metamorphosed under static, probably hydrous, conditions with plagioclase retaining its igneous zoning and the pyroxene completely altered to strongly pleochroic amphibole. Metamorphic grade is in the lower greenschist facies.

The BIF within the Archaean granitoid rocks of the Marymia Inlier is coarsely recrystallized and characterized by alternating quartz- and hornblende-rich layers with abundant euhedral magnetite. The association is typical of metamorphism to middle greenschist facies.

Economic geology

Iron ore

Iron-ore deposits within the Robinson Range Formation (Sofoulis, 1970) form numerous small bodies of hematite, hematite–goethite, and goethite. They were formed by supergene enrichment caused by leaching of silica at or below the plateau surface. This leaching left residual hematite in the iron formation, which has recrystallized to massive hematite ore. Such zones are generally restricted in area, with the largest extending only 300 m along strike. The hematite ores have grades of up to 61.9% iron, and total reserves for the whole of the Robinson Syncline are estimated by Sofoulis (1970) at 24 Mt.

Road metal

Road metal is quarried from volcanic rocks of the Narracoota Formation at Noonyereena Hill.

Groundwater

Extensive areas of calcrete form good aquifers, and are a source of water suitable for livestock. Major deposits of calcrete are present in the Gascoyne River channel, which runs in a northerly direction in the area of the Doolgunna Homestead. The calcrete may be up to 15 m thick and has high porosities capable of yielding large quantities of groundwater.

Concentrations of alluvial gravels in major river channels are additional potential reservoirs for groundwater. Shear zones within the volcanic rocks and granite provide limited quantities of groundwater. Quartz veins, generally defining fault zones, have sometimes proved to be good aquifers, with groundwater held in joints and fractures (Allen and Davidson, 1982).

Groundwater salinity ranges from 500 to 3000 mg/l, with the quality of water better close to places of intake and deteriorating towards the calcrete areas. In general, salinity varies from fresh to brackish in areas of external drainage, and brackish to saline in areas of internal drainage (MacLeod, 1970).

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Appendix 1

Gazetteer of localities

Locality	*Latitude (S)*	*Longitude (E)*	*AMG(E)*	*AMG(N)*
Centre Pool Bore	25°59'03"	119°05'16"	709000	7124400
Diamond Well Homestead	26°11'17"	119°32'12"	753500	7101000
Dingo Bore	25°58'33"	119°12'41"	721400	7125100
Doolgunna Homestead	25°41'16"	119°13'34"	723400	7157000
Gale Well	25°36'14"	119°09'28"	716700	7166400
Granite Bore	25°53'44"	119°15'34"	726350	7133900
John Bore	25°37'15"	119°20'20"	734850	7164200
Juderina Bore	25°52'53"	119°12'03"	720500	7135600
Mount Leake	25°46'44"	119°09'32"	716500	7147000
Mount Leake Bore	25°49'41"	119°08'45"	715100	7141600
No. 3 Well	25°33'25"	119°13'25"	723400	7171500
No. 6 Bore	25°31'25"	119°20'07"	734700	7175000
No. 8 Bore	25°36'08"	119°25'49"	744100	7166100
No. 10 Well	25°43'53"	119°25'45"	743700	7151800
No. 11 Well	25°47'03"	119°02'47"	705200	7146600
Noonyereena Hill	25°35'03"	119°12'44"	722200	7168500
Peak Hill Bore	25°38'25"	119°08'55"	715700	7162400
Quartz Bore	25°38'07"	119°03'21"	706400	7163100
Red Bore	25°32'14"	119°19'25"	733500	7173500
Ruby Bore	25°43'16"	119°20'28"	734900	7153100
Thaduna mine	25°30'29"	119°42'40"	772500	7176000

Appendix 2

Geochemical analyses of mafic rocks from DOOLGUNNA

Sample no.	*120549*	*120550*	*120566*	*120593*	*120630*	*120655*	*120659*	*120663*
AMG(E)	*709110*	*709190*	*734201*	*707343*	*722750*	*709556*	*725500*	*721500*
AMG(N)	*7163260*	*7162721*	*7165328*	*7160447*	*7168750*	*7171000*	*7133985*	*7130270*
Rock unit	*Narracoota*	*Narracoota*	*Narracoota*	*Narracoota*	*Narracoota*	*Mafic dyke*	*Mafic dyke*	*Mafic dyke*
Mg no.	*58.36*	*58.69*	*51.88*	*66.87*	*49.66*	*56.82*	*41.43*	*44.99*
				Weight percent				
SiO_2	50.60	51.60	49.70	49.80	52.00	49.10	52.20	52.50
TiO_2	0.48	0.34	0.73	0.51	0.79	0.52	0.91	0.82
Al_2O_3	16.00	15.50	14.90	12.80	14.00	16.00	13.70	13.80
Fe_2O_3	3.16	2.81	2.72	2.63	2.80	0.76	3.91	3.52
FeO	4.43	5.55	7.90	7.08	7.38	7.70	8.27	7.90
MnO	0.12	0.14	0.18	0.16	0.17	0.14	0.18	0.18
MgO	5.72	6.44	6.26	10.70	5.48	6.19	4.68	5.08
CaO	14.10	10.90	12.60	10.60	10.80	14.70	10.90	11.40
Na_2O	1.50	2.52	1.71	1.63	2.27	1.25	1.52	1.55
K_2O	0.32	0.26	0.31	0.14	0.39	0.02	0.32	0.42
P_2O_5	0.06	0.02	0.06	0.05	0.07	0.05	0.07	0.07
H_2O	2.67	3.09	2.36	3.09	2.64	2.90	2.15	2.07
CO_2	0.22	0.26	0.22	0.16	0.22	0.11	0.11	0.22
Total	**99.38**	**99.43**	**99.65**	**99.35**	**99.01**	**99.44**	**98.92**	**99.53**
				Parts per million				
Cr	392	422	66	678	116	412	64	127
Ni	138	183	121	327	81	154	64	73
Sc	31	32	11	34	38	30	34	32
V	181	216	268	227	261	203	293	281
Pb	2.9	<0.5	4.8	<0.5	<0.5	1.0	3.1	5.0
K	2 656	2 158	2 573	1 162	3 238	166	2 656	3 487
Rb	17.9	4.6	9.9	0.6	9.5	<0.5	18.8	39.2
Ba	110	80	412	48	60	62	743	167
Sr	141	139	119	123	101	127	166	120
Nb	2.8	3.3	4.1	0.5	4.4	2.7	5.8	5.7
Zr	70.9	33.8	47.0	44.3	67.3	40.6	82.5	69.6
Ti	2 877.6	2 038.3	4 376.4	3 057.5	4 736.1	3 117.4	5 455.5	4 915.9
Y	1.4	14.8	20.3	14.7	19.3	10.8	39.4	21.0
Th	2.1	<0.5	1.3	<0.5	<0.5	<0.5	<0.5	<0.5
U	0.2	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
La	14.7	<0.5	6.1	5.3	4.8	3.0	25.7	6.7
Ce	21.6	0.6	4.6	1.8	3.6	1.6	32.0	8.3
Ag	10.2	<0.1	0.3	<0.1	11.8	<0.1	0.8	<0.1
As	<0.5	<0.5	2.1	<0.5	<0.5	<0.5	<0.5	<0.5
Au (ppb)	7.0	3.0	3.0	<2	<2	2.0	<2	<2
Be	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Bi	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	<0.5	<0.5
Cd	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Co	29	36	37	43	36	34	42	40
Cu	93	88	129	85	74	59	94	102
Ga	5.7	4.7	0.5	4.7	5.6	6.3	6.3	5.5
Li	10	6	8	8	12	10	3	4
Mo	1.2	0.5	0.6	0.4	0.4	0.4	0.4	0.3
Pd (ppb)	<2	<2	<2	<2	<2	<2	<2	<2
Pt (ppb)	3	<2	9	<2	<2	2	<2	<2
Sb	29.7	11.5	4.4	6.8	4.6	2.3	1.8	1.1
Sn	7.4	2.9	2.7	1.5	0.9	0.7	<0.5	<0.5
W	13.9	7.7	3.3	5.1	4.5	3.1	3.3	2.2
Zn	59	66	88	76	77	56	91	91

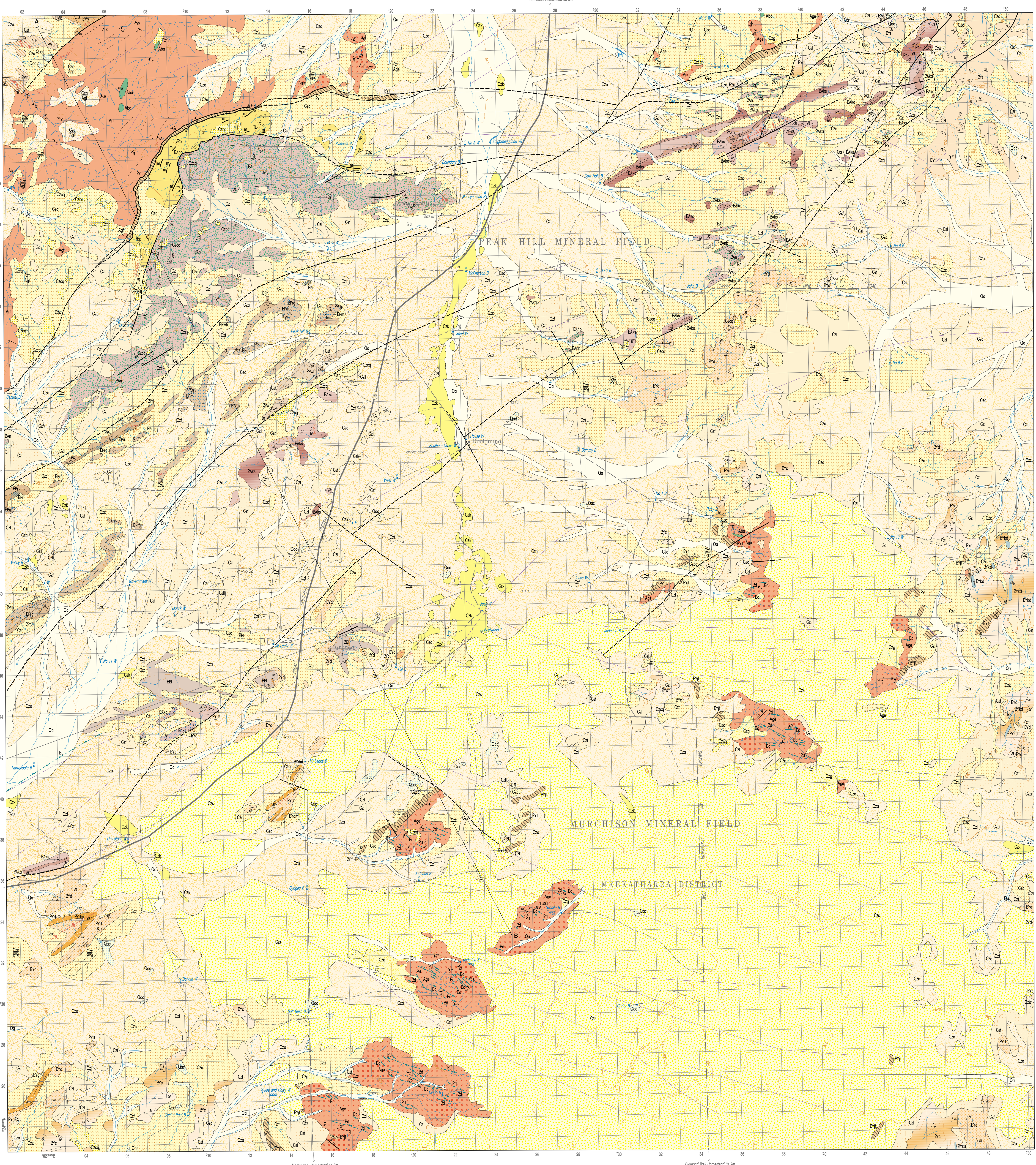
Appendix 2 (*continued*)

Sample no.	*120668*	*120688*	*120692*	*120694*	*120698*	*130903*	*130911*
AMG(E)	*749487*	*739099*	*738903*	*738100*	*735588*	*699680*	*746441*
AMG(N)	*7142982*	*7173927*	*7174351*	*7177500*	*7172781*	*7177047*	*7122107*
Rock unit	*Killara*	*Narracoota*	*Narracoota*	*Mafic dyke*	*Narracoota*	*Bangemall*	*Killara*
Mg no.	*50.54*	*61.21*	*54.45*	*45.59*	*54.60*	*45.37*	*50.17*
				Weight percent			
SiO_2	50.50	48.00	49.00	49.70	48.90	51.90	50.70
TiO_2	0.69	0.53	0.59	0.86	0.60	1.35	0.77
Al_2O_3	14.70	10.50	13.90	14.60	12.80	14.70	14.00
Fe_2O_3	2.86	3.91	3.61	3.12	3.65	2.42	2.65
FeO	7.77	7.46	6.56	8.53	7.06	8.53	8.59
MnO	0.17	0.18	0.16	0.18	0.17	0.15	0.18
MgO	5.93	9.72	6.58	5.33	6.98	4.99	6.20
CaO	11.80	13.60	13.00	11.00	13.70	11.20	11.90
Na_2O	1.46	1.00	1.90	1.71	1.37	1.95	1.48
K_2O	0.17	0.34	0.19	0.54	0.23	0.70	0.55
P_2O_5	0.06	0.04	0.05	0.07	0.05	0.13	0.06
H_2O	3.20	3.90	3.28	3.20	3.48	1.31	2.17
CO_2	0.26	0.15	0.15	0.22	0.11	<0.10	0.15
Total	**99.57**	**99.33**	**98.97**	**99.06**	**99.10**	**99.33**	**99.40**
				Parts per million			
Cr	207	200	120	248	165	101	117
Ni	76	156	143	130	152	122	87
Sc	31	43	24	32	33	12	17
V	246	276	220	306	233	228	243
Pb	3.0	3.6	2.4	4.2	2.2	5.9	2.7
K	1 411	2 822	1 577	4 483	1 909	5 811	4 566
Rb	5.5	5.5	2.0	22.3	4.9	22.5	34.5
Ba	244	63	45	77	36	780	116
Sr	155	110	101	102	108	264	133
Nb	6.0	1.9	3.2	4.4	2.4	7.1	4.9
Zr	63.6	41.0	44.2	67.8	41.5	135.0	66.3
Ti	4 136.6	3 177.4	3 537.1	5 155.7	3 597.0	8 093.3	4 616.2
Y	16.2	12.6	14.5	21.3	14.9	21.1	17.7
Th	<0.5	<0.5	<0.5	<0.5	<0.5	3.9	2.0
U	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
La	6.1	1.0	1.2	3.9	0.8	12.4	7.7
Ce	5.7	3.7	2.5	7.2	2.2	30.2	10.7
Ag	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	21.7
As	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Au (ppb)	2.0	3.0	3.0	<2	3.0	3.0	4.0
Be	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5
Bi	<0.5	<0.5	<0.5	<0.5	<0.5	3.6	14.7
Cd	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1
Co	37	55	42	42	49	44	47
Cu	115	192	164	200	108	125	143
Ga	3.8	5.5	6.6	5.9	6.4	1.3	1.4
Li	23	11	10	12	11	6	4
Mo	0.1	0.2	0.7	0.5	0.4	0.1	0.1
Pd (ppb)	<2	<2	<2	<2	<2	4	<2
Pt (ppb)	3	3	<2	3	4	7	5
Sb	0.8	0.8	3.3	1.1	0.6	0.2	0.2
Sn	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
W	1.1	1.2	8.2	4.4	1.8	2.1	11.2
Zn	85	76	67	87	68	81	84

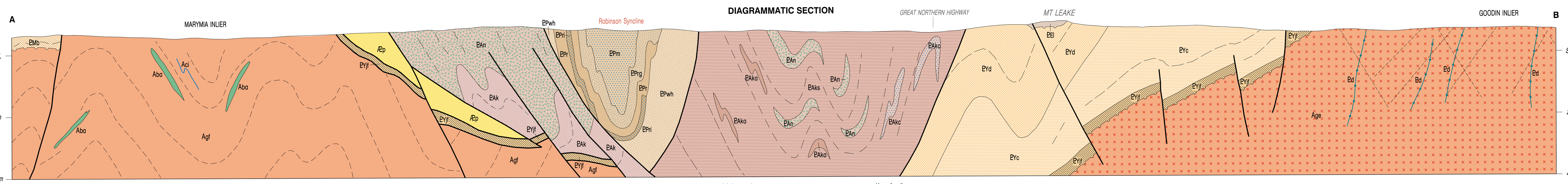
Trace elements in ppm except where stated otherwise

DOOLGUNNA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



DIAGRAMMATIC SECTION



Legend

PHANEROZOIC — CAINOZOIC — QUATERNARY

- Qa — Alluvial deposits — sand and silt in channels and floodplains
- Qac — Clay and silt in claypans

CAINOZOIC

- Cza — Sheetwash deposits — ferruginous clay, silt, and sand as extensive fans
- Czc — Colluvium — gravel, sand, and silt as scree and sheetwash
- Czcq — Quartz vein rubble and debris
- Czk — Calcrete
- Czs — Sandplain deposits — unconsolidated sand; minor silt and clay; includes low, vegetated dunes
- Czz — Silcrete
- Czf — Ferruginized rubble and colluvium — dominantly ferruginized pisolites and nodules, ferruginized rock, and ironstone rubble; degraded lateritic duricrust
- Czg — Sand over granitoid rock — includes quartzofeldspathic sand
- Czl — Lateritic deposits — nodular and pisolitic laterite, and associated debris
- Czli — Ironstone duricrust; massive and rubbly

PROTEROZOIC

- q — Quartz veins
- Ed — Dolerite dykes

Bangemall Group (BANGEMALL BASIN)

- EMy — **CALYIE FORMATION:** quartz arenite, well-bedded
- EMb — **BACKDOOR FORMATION:** laminated siltstone and shale

Earaheedy Group (EARAHEEDY BASIN)

- EEl — **MOUNT LEAKE FORMATION:** quartz arenite and silicified stromatolitic carbonate

Padbury Group (PADBURY BASIN)

- EPm — **MILLIDIE CREEK FORMATION:** ferruginous shale and sandstone; minor granular iron-formation
- EPr — **ROBINSON RANGE FORMATION:** ferruginous shale; locally sericitic; minor granular iron-formation
- EPrg — Granular iron-formation; minor shale
- EPri — Banded iron-formation
- EPw — **WILTHORPE FORMATION:** conglomerate, sandstone, and siltstone (not on map)
- EPwh — **Heines Member:** shale with fine-grained lithic and quartz wacke

Bryah Group (BRYAH BASIN)

- EAn — **NARRACOOTA FORMATION:** metabasaltic lava; locally with pillow structures, dolerite sills, and dykes
- EAnd — Dolerite sills; metamorphosed; hypabyssal facies of EAn
- EAnb — Metabasaltic breccia
- EAk — **KARALUNDI FORMATION:** shale, sandstone, and granule conglomerate; metamorphosed (section only)
- EAka — Sandstone; locally ferruginous, with conglomerate lenses; metamorphosed
- EAks — Shale; metamorphosed
- EAkc — Chert and fine-grained siliciclastic sedimentary rock; metamorphosed

Yerrida Group (YERRIDA BASIN) — Mooloogool Subgroup

- EYk — **KILLARA FORMATION:** undivided mafic igneous rocks and related sedimentary rocks (not on map)
- EYkd — Dolerite sills; hypabyssal equivalent of EYk
- EYd — **DOOLGUNNA FORMATION:** arkosic wacke and siltstone with pebble conglomerate locally
- EYdm — Diamictite: polymictic conglomerate and breccia in arkosic matrix
- EYt — **THADUNA FORMATION:** lithic sandstone, locally coarse-grained; siltstone, and shale

Yerrida Group — Windplain Subgroup

- EYc — **JOHNSON CAIRN FORMATION:** laminated siltstone and shale; minor feldspathic sandstone, local thin dolomite beds
- EYj — **JUDERINA FORMATION:** undivided siliciclastic and carbonate sedimentary rocks (not on map)
- EYjf — **Finlayson Member:** quartz arenite; local siltstone and chert breccia

(MARYMIA and GOODIN INLIERS)

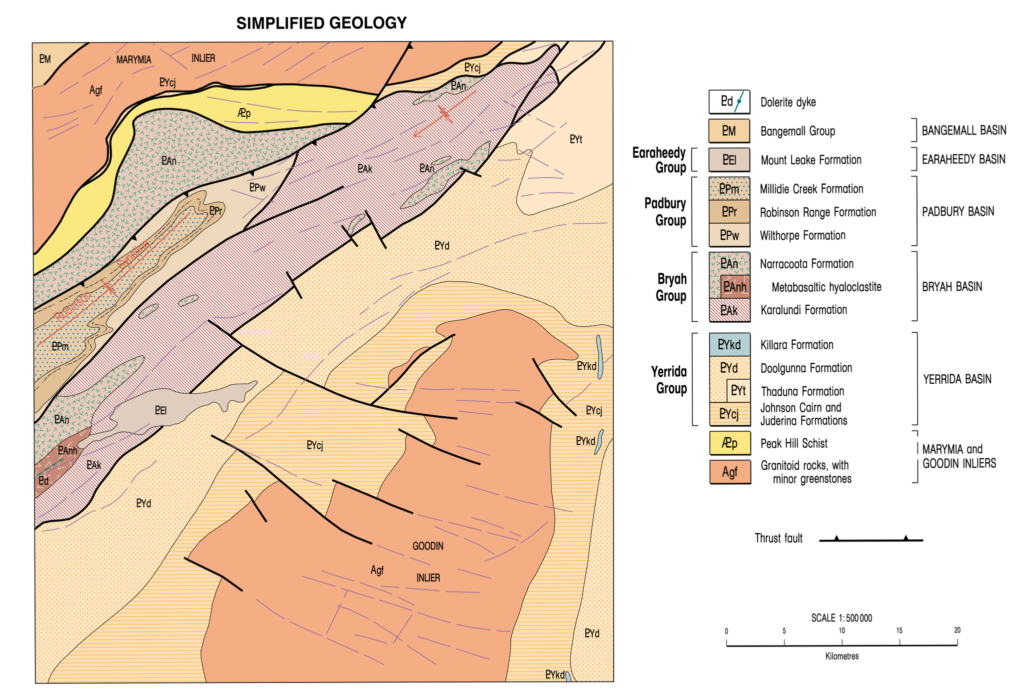
- Æp — **PEAK HILL SCHIST:** quartz sericite schist

ARCHAEAN

c. 2624 ± 8 Ma

- Age — Equigranular to porphyritic granitoid rock, undivided; with aplitic phases
- Agf — Foliated (gneissic), cataclastic, and porphyritic granitoid rock; with aplitic phases and inclusions of calc-silicate rocks
- Aci — Banded iron-formation; metamorphosed
- Aba — Amphibolite; undivided

SIMPLIFIED GEOLOGY



Map symbols

Geological boundary
- exposed
- concealed

Fault, showing dip of fault plane
- exposed
- concealed
- concealed, position uncertain
- slickenside, showing direction and plunge of striation
- mylonite zone

Strongly foliated rock

Fold, showing trend and plunge direction
- anticline, exposed
- syncline, exposed
- syncline, concealed

Small scale fold, showing strike and dip of axial surface, and plunge of fold axis
- anticline, unassigned
- D_2 anticline
- D_2 syncline

Bedding, showing strike and dip
- inclined
- overturned
- trend

Way-up indicators
- sedimentary structure
- upwards fining sequence

Metamorphic foliation, showing strike and dip
- inclined

Cleavage, showing strike and dip
- inclined
- vertical

Intersection lineation, showing trend and plunge direction
- plunging

Fracture or joint, showing strike and dip
- inclined

Stromatolite locality

Airphoto lineament
- foliation trend

Aeromagnetic lineament

Isotopic age determination site with GSWA identification number — 118963

Highway with national route marker — 95

Formed road

Track

Fence, generally with track

Homestead — Doolgunna

Building

Yard — Yd

Horizontal control, major

Breakaway

Sand dune

Contour line, 20 metre interval — 120

Watercourse, ephemeral

Waterhole — WH

Spring — S

Pool — P

Bore — B

Well — W

Windpump

Dam — D

Tank — T

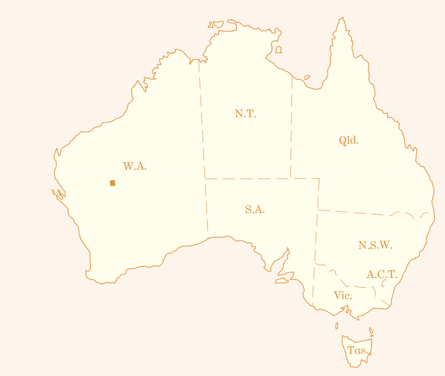
Abandoned — (abd)

Position doubtful — (PD)

Mineral field boundary

Quarry or pit

Mineral occurrence
- Road materials — Rm



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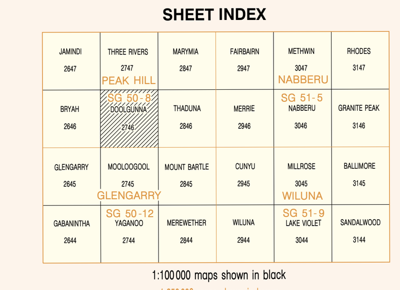
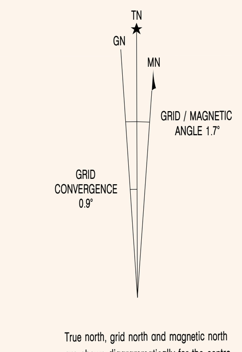


1:100 000 maps shown in black
1:250 000 maps shown in brown



True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1995 and moves easterly by about 0.1° in 6 years.

DEPARTMENT OF MINERALS AND ENERGY
K.R. PERRY, DIRECTOR GENERAL

GOVERNMENT OF WESTERN AUSTRALIA
HON. KEVIN MINSON, M.L.A.
MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PIETRO GUJ, DIRECTOR

SCALE 1:100 000

Metres 1000 0 1 2 3 4 5 6 7 8 9 10 Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 1000 metre interval of the Australian Map Grid Zone 50

Geology by N.G. Adamides 1994
Edited by D. Ferdinando, G. Loan and C. Brien
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DOOLGUNNA

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