EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE MOOLOOGOOL 1:100 000 SHEET

by F. Pirajno, N. G. Adamides, and S. A. Occhipinti

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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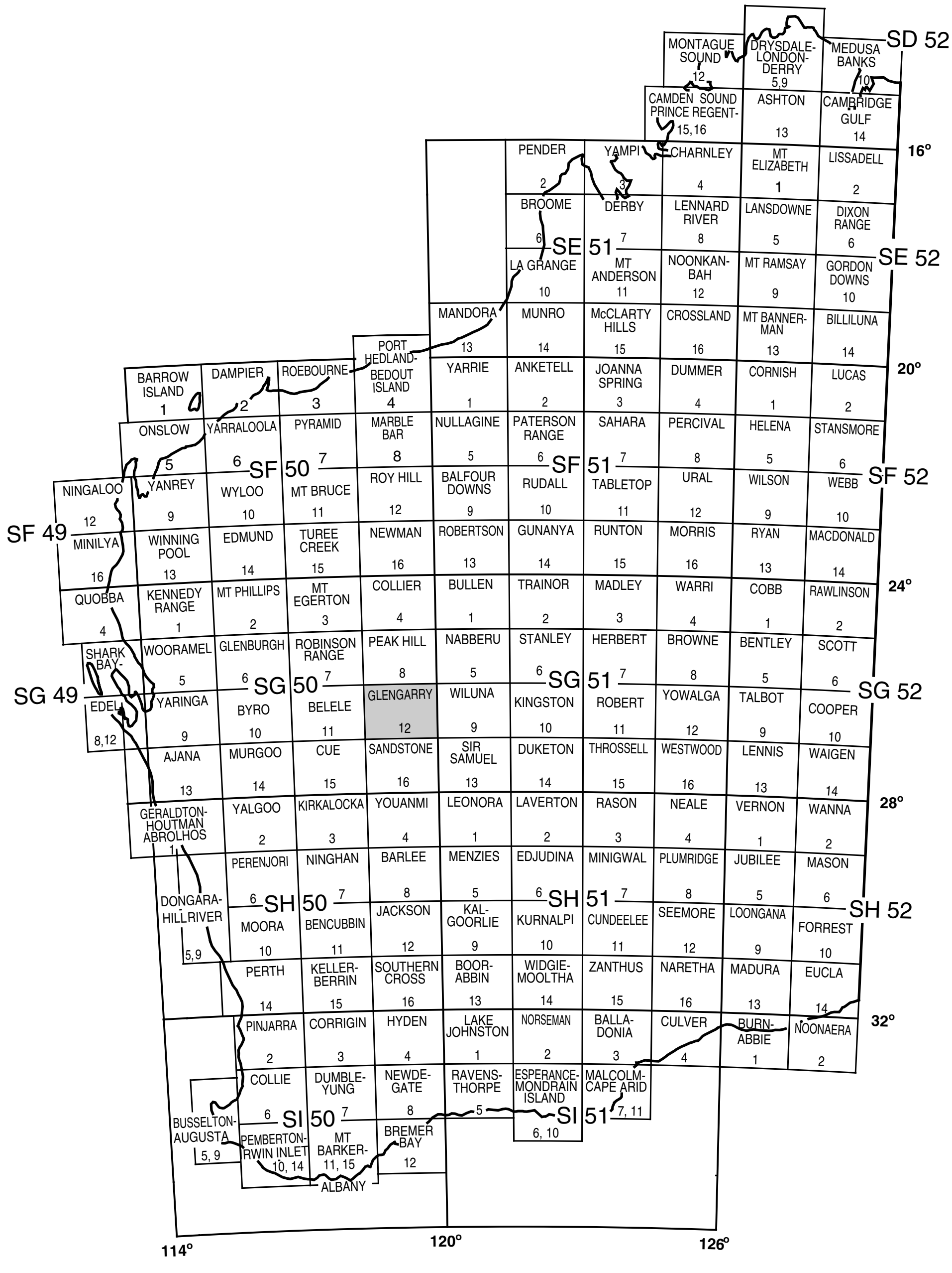

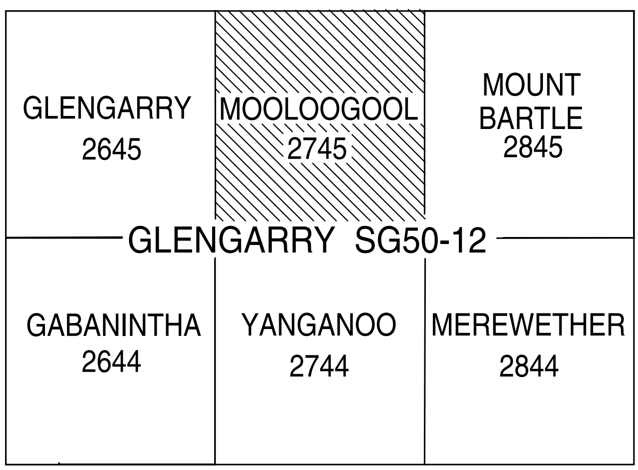

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Cover photograph:
Breakaways of Johnson Cairn Formation, about 3.5 km northeast of Rainlover Well (AMG 130995).

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Geology of the Mooloogool 1:100 000 sheet

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F. Pirajno, N. G. Adamides, and S. A. Occhipinti

Abstract

The Mooloogool 1:100 000 map sheet occupies part of the Capricorn orogen, which resulted from the collision of the Yilgarn and Pilbara Cratons about 2 billion years ago.

The sheet area contains rocks assigned to the Yerrida Group, which rest unconformably on Archaean basement. This basement is partly represented by the Goodin Inlier in the northern part of the sheet area, although other outcrops are present in the southern parts of the Mooloogool. The rocks of the Yerrida Group consist of quartz arenite and shale of the Juderina and Johnson Cairn Formations (Windplain Subgroup), representing a sag-basin facies. The Windplain Subgroup is overlain by the turbidites of the Thaduna and Doolgunna Formations (Mooloogool Subgroup), interpreted as a rift-fill facies. The Maraloou Formation is dominantly composed of black sulfidic shales that were deposited in the southern part of the sheet area and interpreted as a deep-water facies. Mafic rocks of the Killara Formation are present as sills and flows which overlie and locally intrude the older members of the Yerrida Group. The contact between the Killara and Maraloou Formations is transitional. The area underwent two deformation episodes relating to the Capricorn Orogeny that deformed Proterozoic rocks around the Goodin Inlier.

The area holds good potential for stratabound base- and precious-metal mineralization, indicated by the presence of gossans within the sulfidic black shales and siltstones of the Maraloou and Juderina Formations. These gossans contain pseudomorphs of pyrite and chalcopyrite, and anomalous concentrations of barium, platinum, palladium, copper, and zinc.

KEYWORDS: Yerrida Basin, mafic extrusive and intrusive rocks, stratabound gossan, sulfidic shale, geochemistry, Capricorn Orogeny

Introduction

The Mooloogool* 1:100 000 map sheet (SG50-12-2745) occupies the north-central part of the Glengarry (1:250 000) map sheet, covering an area bounded by 26°00'S and 26°30'S latitude and 119°00'E and 119°30'E longitude (Fig. 1). The geology of Mooloogool has previously been described in the Glengarry (1:250 000) Explanatory Notes (Elias et al., 1982). Sofoulis and Mabbut (1963), Hall and Goode (1978), and Gee (1979) also describe the general geology of Mooloogool and surrounding areas.

The Yerrida Basin, formerly Glengarry Basin of Gee (1990) and Gee and Grey (1993), who suggested that the Glengarry Basin contained the Glengarry and Padbury Groups, contains rocks of the Yerrida Group. However, detailed geological mapping, integrated with aeromagnetic and Landsat data, indicates that the Glengarry Basin is a more complex tectonic and depositional structure than previously recognized. Pirajno et al. (1996) divided the previously defined stratigraphy of the Glengarry Basin into three groups: the Bryah and Padbury Groups in the west, and the Yerrida Group in the east and southeast (Fig. 1). The rocks of the Bryah, Padbury, and Yerrida Groups have distinctive stratigraphic, structural, and metamorphic characteristics, and consequently each has been assigned to a different basin, namely: Bryah, Padbury, and Yerrida Basins (Pirajno et al., 1996). These basins were developed on the rifted northern margin of the Yilgarn Craton. The

* Capitalized names refer to standard map sheets. Where 1:100 000 and 1:250 000 sheets have the same name, the 1:100 000 sheet is implied unless otherwise indicated.

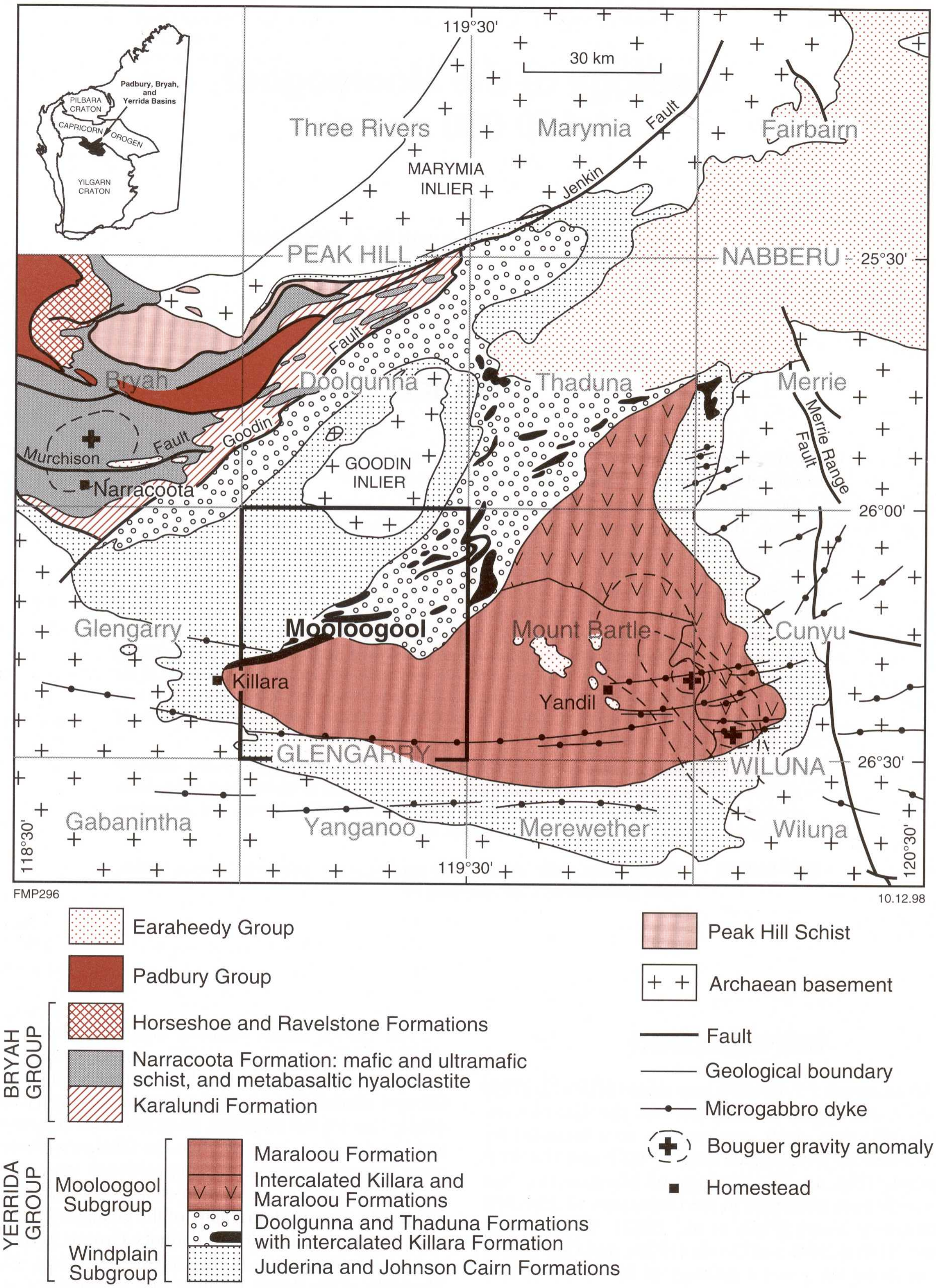

Figure 1. Simplified geological map of the Bryah, Padbury, and Yerrida Basins, and location of MOOLOOGOOL

Bryah and Yerrida Groups were deposited unconformably on the granite–greenstones of the Yilgarn Craton. Contacts between the Bryah and Padbury Groups are typically tectonic, although some depositional (unconformable) contacts have also been reported (Martin 1994; Occhipinti et al., 1997). The contact between the Bryah and Yerrida Groups is tectonic, marked by the northeast-trending Goodin Fault (Fig. 1). In addition, the Padbury Group is now considered to have developed in a peripheral foreland basin (Padbury Basin) on top of the Bryah Group (Martin, 1994; Occhipinti et al., 1996; Pirajno et al., 1996; Pirajno and Occhipinti, 1998). The tectonic and structural evolution of the Bryah, Padbury, and Yerrida Basins is discussed in Pirajno et al. (in press) and Occhipinti et al. (in press).

Climate and vegetation

MOOLOOGOOL has an arid climate, with mean annual rainfall of approximately 230 mm. Rainfall typically occurs between November and April with rain from cyclones and thunderstorms. December, January, and February are the hottest months, when the temperature often exceeds 40ºC. The coolest months are June and July, when the average daily maximum temperature ranges between 18 and 20ºC.

MOOLOOGOOL is within the Eremaean botanical province, bordering the Helms botanical district to the east (Beard, 1969). Vegetation is diverse and depends on the condition of the pastoral land, proximity to drainage systems and, in places, rock type. Red grevillea (*Grevillea deflexa*), ghost gums, river red gums, and mulga (*Acacia aneura*), are locally abundant along drainage systems. Various types of acacia, such as *Acacia acuminata* are also abundant in the area. Spinifex is abundant over the eolian sandplains on north and south-central MOOLOOGOOL. A dwarf annual herb, *Helipterum sterilescens* (Cranfield, R. J., 1995, pers. comm.; quoting from Elliott and Jones, 1990), grows in profusion on calcium-rich soils, and commonly overlies calcrete or calcareous rocks. As such, *Helipterum sterilescens* is useful in outlining areas underlain by dolomite, limestone, and marls.

Access and physiography

The nearest town to MOOLOOGOOL is Meekatharra*, located approximately 54 km west-southwest of the southwestern margin of the sheet area, along the Meekatharra–Wiluna road (unsealed). The town of Wiluna is approximately 79 km east of the southeastern margin of MOOLOOGOOL. Access to southern MOOLOOGOOL is provided by the Meekathara–Wiluna road. Station tracks provide good to reasonable access from the main road. Mooloogool is the only pastoral homestead in the map area, with Killara and Diamond Well very close to the southwestern and northeastern map boundaries, respectively.

The main physiographic features of MOOLOOGOOL are shown in Figure 2. Drainage on MOOLOOGOOL is poor, except for the Yalgar River, which flows westwards through eastern MOOLOOGOOL. Glengarry Creek also drains westward in the west-central part of MOOLOOGOOL, north of an east-northeast-trending range of hills composed of mafic rocks of the Killara Formation.

The greater part of MOOLOOGOOL is flat or gently undulating, covered in alluvium, colluvium, or eolian sand. The physiography of MOOLOOGOOL largely reflects the geology. The most prominent physiographic features are the Glengarry Range (c. 600 m above sea level), and the range of hills referred to above.

Regional geological setting and stratigraphy

Two tectonic units are present on MOOLOOGOOL:

- The Archaean Goodin Inlier in the north that consists of granitoid rocks, considered to be part of the Yilgarn Craton.
- The Palaeoproterozoic volcano-sedimentary Yerrida Group (Occhipinti et al., 1996; Pirajno et al., 1996; Pirajno et al., in press), which was deposited in the Yerrida Basin.

Granitoid rocks of the Goodin Inlier are unconformably overlain by, and locally tectonically interleaved with, the Palaeoproterozoic Juderina Formation of the Yerrida Group. The Yerrida Basin, containing the Yerrida Group, lies in the southern part of the Capricorn Orogen — a major zone of deformed, low- to high-grade metamorphic rocks and granitoid intrusions that developed during continental collision between the Pilbara and Yilgarn Cratons about 2000–1700 Ma (Tyler and Thorne, 1990; Myers, 1993; Myers et al. 1996).

The Yerrida Group is divided into the Windplain and Mooloogool Subgroups (Occhipinti et al., 1997). The Windplain Subgroup contains predominantly clastic sedimentary rocks and is divided into the Juderina and Johnson Cairn Formations. In addition, the Juderina Formation includes stromatolitic carbonate and chert (Bubble Well Member) and the Johnson Cairn Formation contains minor dolomitic siltstone and intercalated basalts. The overlying Mooloogool Subgroup is divided into four formations: the Thaduna, Doolgunna, Killara, and Maraloou Formations. The Mooloogool Subgroup has a complex stratigraphy, due to interdigitating of the Doolgunna, Thaduna, and Killara Formations (Fig. 3). The Doolgunna Formation consists of a succession of arkosic clastic rocks and minor pebble conglomerate. The Thaduna Formation is predominantly composed of volcanogenic lithic wacke, siltstone, and shale. The sedimentary rocks of the Thaduna and Doolgunna Formations (conglomerates and turbidites) were deposited in a high-energy environment indicating an abrupt change from the shallow and mature environment of the Windplain Subgroup. The Killara Formation includes mainly tholeiitic basalt, and dolerite sills and dykes. The Maraloou Formation represents a marked change in environmental conditions (deepening of the basin). The contact between the Killara and Maraloou formations is transitional over a stratigraphic thickness of

* Coordinates of localities mentioned in text are presented in the Appendix.

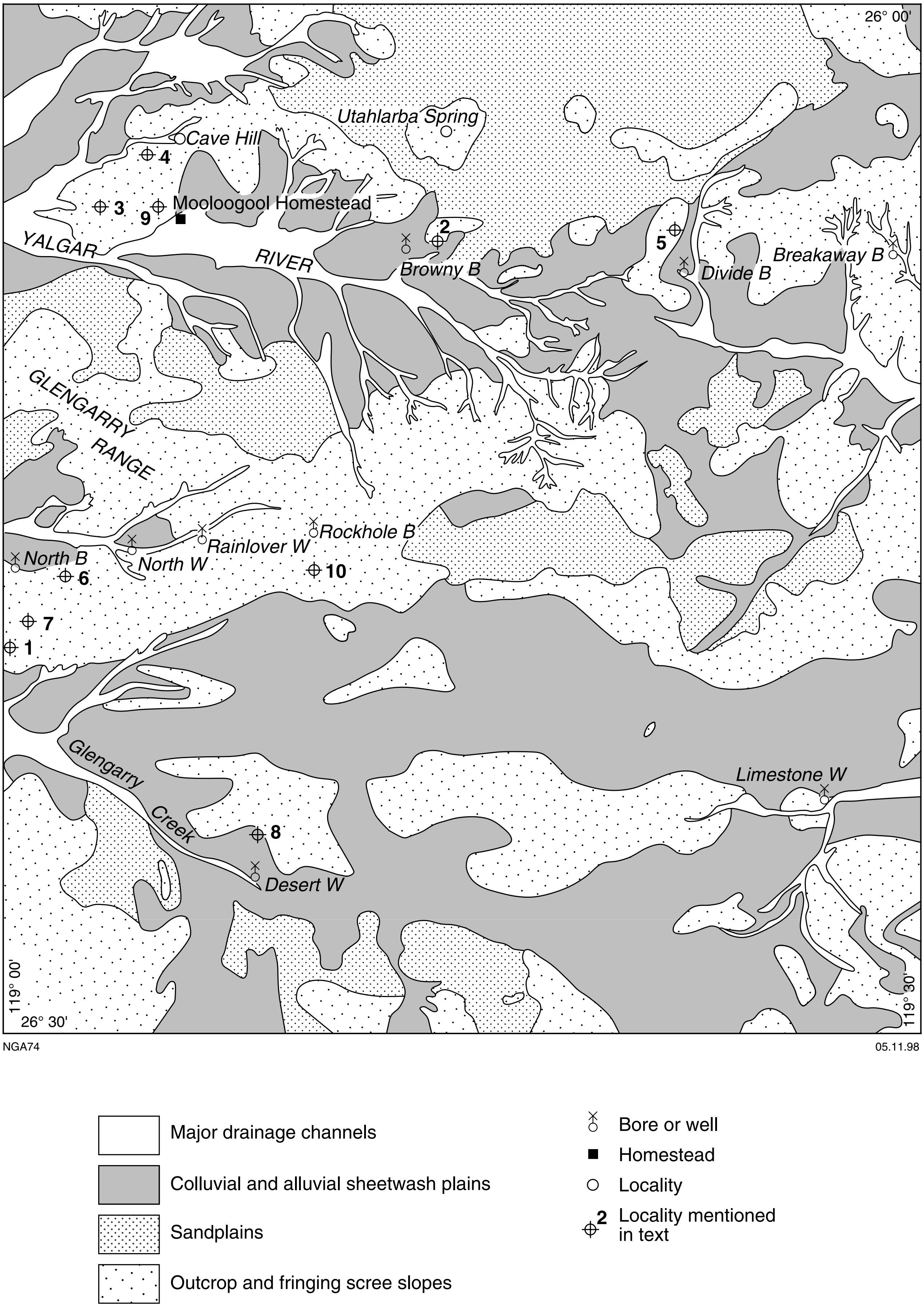

Figure 2. Major physiographic units on Mooloogool and localities mentioned in text

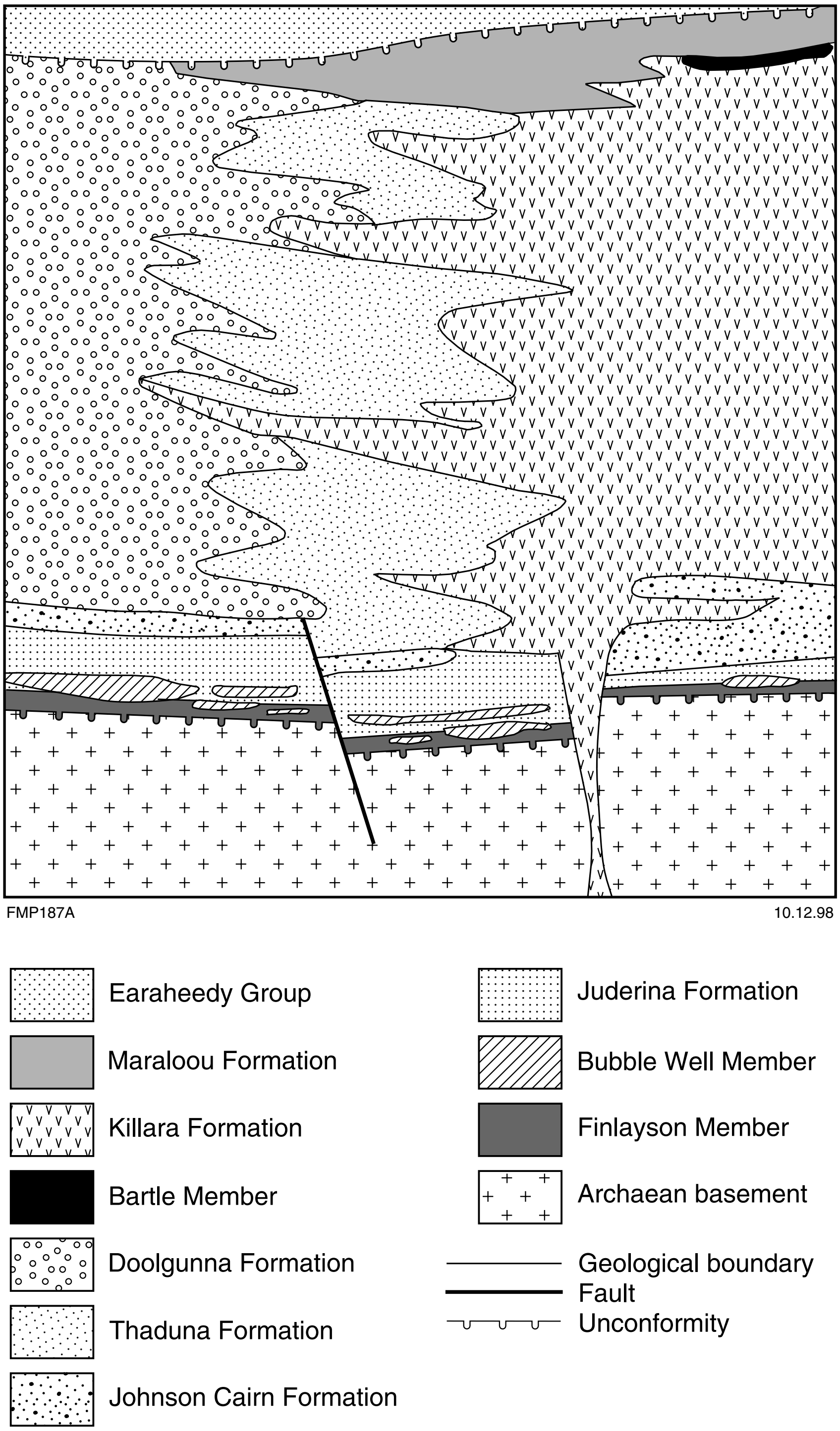

Figure 3. Schematic relationships of stratigraphic units on Mooloogool

Table 1. Stratigraphy of the Yerrida Group (after Pirajno et al., 1996)

Basin / Group / Subgroup	*Formation*	*Rock type*
~ ~ ~ ~ ~ ~ ~ *Unconformity* ~ ~ ~ ~ ~ ~ ~		
YERRIDA BASIN		
Yerrida Group		
Mooloogool Subgroup (rift succession)	Maraloou Formation	Black shale, siltstone, and carbonate
	Killara Formation	Mafic extrusive and intrusive rocks
	Bartle Member	Laminated chert
	Doolgunna Formation	Mixite and other clastic rocks
	Thaduna Formation	Lithic wacke, siltstone, shale, and minor arkose
Windplain Subgroup (sag-basin succession)	Johnson Cairn Formation	Siltstone, shale, carbonate, minor lithic wacke
	Juderina Formation	Arenite, and minor conglomerate and carbonate
	Bubble Well Member	Silicified stromatolitic carbonate, evaporites, and chert breccia
	Finlayson Member	Arenite (ripple marked)
~ ~ ~ ~ ~ ~ ~ *Unconformity* ~ ~ ~ ~ ~ ~ ~		

SOURCE: Modified from Pirajno et al. (1996)

approximately 150 m, with volcanic rock content consistently decreasing with stratigraphic height (see below and Fig. 9).

A generalized stratigraphy for the Yerrida Group is presented in Table 1 and schematic relationships between the various formations are shown in Figure 3.

Geochronology

The age of the Yerrida Group is poorly constrained; however, it is younger than the underlying 2.65 Ga Yilgarn Craton and 2.62 Ga Goodin Inlier (Myers, 1990; Nelson, 1997; Adamides, 1998). The only absolute dating of the Yerrida Group is provided by two Pb–Pb isochrons, 2258 ± 180 Ma (Russell et al., 1994) and 2173 ± 64 Ma (Woodhead and Hergt, 1997), obtained from stromatolitic carbonate rocks of the Bubble Well Member of the Juderina Formation near the base of the Yerrida Group. An age of 1785 ± 11 Ma was obtained by SHRIMP U–Pb dating of zircons from the overlying Earaheedy Group, giving a minimum age for the Yerrida Group (Nelson, 1996, 1997).

Archaean geology

Granitoid rocks (*Age, Ag*)

Archaean units on MOOLOOGOOL include granitoid rocks of the Goodin Inlier (*Age*) in the north and small outcrops of other granitoid rocks (*Ag*) in the south and southwest area.

The southern contact of the Goodin Inlier with rocks of the Yerrida Group is exposed on northern MOOLOOGOOL. The inlier, measuring 35 km across, is a reactivated basement high which influenced Proterozoic sedimentation, and may have contributed detritus for the infilling of the Yerrida Basin (e.g. Doolgunna Formation). Granitoid outcrops of the Goodin Inlier are typically weathered, featuring shallow breakaways with kaolinitized material on the walls, and less weathered granitoid rock on the floors. On MOOLOOGOOL the best granitoid outcrops (*Age*) are centred around Utahlarba Spring, with minor isolated lateritized outcrops farther northwest. Granitoid rocks (*Age*) are equigranular, medium-grained (around 4 mm), with aplitic and pegmatitic phases, and porphyritic (feldspars exceeding 8 mm in size) locally. These granitoid rocks can be defined as a monzogranite, based on equal proportions of K-feldspar and plagioclase (Le Maitre, 1989). Muscovite and green biotite are present as small euhedral crystals, or fine aggregates associated with granular quartz, and are locally enclosed within larger crystals of plagioclase.

Where thermally metamorphosed as a result of intrusion of mafic dykes (see below), the granitoid is characterized by sericitized feldspar. Feldspars are also commonly surrounded by micrographic reaction rims.

On southwestern and southern parts of MOOLOOGOOL, granitoid rock (*Ag*) is exposed through Proterozoic sedimentary cover (Yerrida Group). It is locally weathered, coarse-grained, and consists of microcline, K-feldspar, plagioclase, and biotite, with minor amounts of epidote and sericite as alteration products.

Proterozoic geology

Yerrida Group

Windplain Subgroup

The Windplain Subgroup contains the clastic-dominated Juderina and Johnson Cairn Formations. Their sedimentological characteristics indicate they were deposited

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Figure 4. Unconformity between granitoid rocks and quartz arenite of the Juderina Formation (AMG 226115)

in mature continental fluvial and shallow marine environments within a sag basin or pre-rift depression (Pirajno et al., 1995a, 1996, in press).

Juderina Formation (ⱣYj, ⱣYjf, ⱣYja, ⱣYjb)

Outcrops of Juderina Formation (*ⱣYj*) are present on southern MOOLOOGOOL and on the southwest and southeast margins of the Goodin Inlier. Near Utahlarba Spring, rocks of the Juderina Formation form linear belts dipping at moderate angles to the southwest.

The basal unit of the formation is the Finlayson Member (*ⱣYjf*). It consists predominantly of quartz arenite (commonly ripple marked) and lies unconformably on Archaean granitic rocks (Fig. 4). Good exposures of the Finlayson Member are present on southwestern MOOLOOGOOL. Here, the arenite rocks are part of a broad, approximately easterly trending, arcuate band of shelf-facies rocks that lie unconformably on granite–greenstone rocks (Fig. 1). On MOOLOOGOOL, the quartz arenite dips between 5 and 20° to the north, and contains well-preserved ripple marks and laminae of clay platelets. A limited number of measurements taken on asymmetrical ripples suggest palaeocurrent directions from the northeast and the southwest. Intercalated with the quartz arenite are mappable bands of hematite-rich arenite (e.g. at AMG 007760) less than 10 m thick. This rock consists of round quartz grains, with authigenic overgrowths of silica. Hematite is present as fine dustings or coatings around the quartz grains. Detrital tourmaline crystals (probably schorl) are also present. This rock type resembles typical arenites of Proterozoic continental redbed sequences. Redbeds become significant from about 2000 Ma and form in hot climates under continental oxidizing conditions at latitudes of 30° or less (Keary and Vine, 1996). Continental redbeds are known to be associated with evaporites, as are rocks of the Finlayson Member, which are intercalated with evaporites of the Bubble Well Member (Fig. 3).

Around Utahlarba Spring, the Finlayson Member (*ⱣYjf*) typically consists of cream-coloured, silica-cemented quartz arenite. The base of the Member consists of parallel-laminated arenite, overlain by cross-laminated quartz arenite. Thin bands of quartz siltstone are interbedded between the arenite bands (Fig. 5). Typically rare ripple-marks are poorly preserved and the arenites are characterized by abundant vugs after the dissolution of mudstone clasts. Bed thickness varies from 0.1–1 m.

Quartz arenite of the Juderina Formation is commonly fine- to medium-grained and moderately sorted. Ferruginous varieties contain white mica within the clay matrix and are associated with platelets of hematite. Siltstone interbeds are millimetre thick and consists of angular quartz averaging 0.1 mm in diameter enclosed in a hematitic matrix. The argillaceous laminae contain fine disseminations of iron hydroxides.

Thick-bedded quartz arenites (*ⱣYja*) are found southeast of the Glengarry Range (Fig. 6) and form positive topographic features in a typically subdued environment occupied by siltstones and shales. The quartz

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Figure 5. Thin-bedded siltstone and quartz arenite of the Juderina Formation (AMG 009043)

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Figure 6. Thick-bedded quartz arenite of the Juderina Formation in the Glengarry Range (AMG 060040)

arenite is medium-grained, with angular grains, intraclast moulds, and abundant mudclasts. The rock is silica-cemented and poorly sorted, and forms beds commonly exceeding 1 m in thickness. Thicker beds are massive at their base with laminations in their upper parts, whereas thinner quartz arenite units interbedded with the siltstones have parallel laminations. The quartz arenite contains local kaolinitized feldspars and sparse lithic clasts. Laminated siltstone contains sparse feldspar and weathered muscovite with minor detrital tourmaline in a matrix of quartz and kaolinitic clays. The nature of the Juderina Formation (*ⱣYja*) in the Glengarry Range area suggests the presence of a proximal quartz-rich source associated with an active sedimentary environment.

Bubble Well Member (ⱣYjb)

A small outcrop of stratified chert is present about 4 km south of North Bore, near the western edge of the map sheet (Locality 1, AMG 990875*). The chert is characterized by microbial-like laminae and fragmented laminate-textures with spherulitic or stellate pseudomorphs. The rock contains microcrystalline and cryptocrystalline quartz, minor sericite, euhedral barite crystals, albite, apatite, and isolated K-feldspar crystals. Spherulitic pseudomorphs are up to 10 mm in diameter and consist of radiating aggregates of microcrystalline and polycrystalline quartz, interpreted to be pseudomorphs after anhydrite. Unidentified radiating acicular or blade-like crystals could be pseudomorphed gypsum. Field and petrographic evidence suggest that the precursor lithology was stromatolitic carbonate interbedded with evaporitic sediments. This unit is common in the Yerrida Basin (Pirajno et al., in press; Adamides et al., in prep.; MEREWETHER, Ferdinando and Pirajno, unpublished data) and is assigned member status within the Juderina Formation (Occhipinti et al., 1997).

The southwest margin of the Goodin Inlier

On the southwest margin of the Goodin Inlier, around Utahlarba Spring, a series of shear zones trend west-northwesterly with moderate dips (45–50°) to the north or south. Quartz veins are present and are oblique to the shearing. Associated with these shear zones are thin outliers (e.g. AMG 226154) of cream-coloured, silica-cemented, laminated, and locally ripple marked, quartz arenite. The contact with the underlying granite is unconformable, starting with a basal unit of parallel-laminated arenite followed by cream-coloured, locally cross-bedded arenite. The rock is cut by longitudinal, steeply dipping to vertical joints. This jointing becomes progressively more closely spaced in a southerly direction across the outlier and is associated with silicification and quartz veining, suggesting the presence of a faulted contact.

Vesicular mafic rocks (probably volcanic) are present in a number of outcrops, from about 2 km east of Browny Bore (Locality 2, AMG 230098) and extending in a northwestward direction. The presence of these rocks signifies magmatic activity contemporaneous with the earliest sedimentation of the Yerrida Basin in this area. This vulcanicity may be correlated with the Killara Formation (see below), which includes similar mafic rocks exposed at higher levels in the Yerrida Group succession within the Johnson Cairn Formation, northwest of Mooloogool Homestead and on central MOOLOOGOOL. The presence of these mafic volcanic rocks in the lower units of the Yerrida Group, coupled with their absence from the same basal units elsewhere, suggests tectonic activity and early development of magma-tapping fractures, along the southern margin of the Goodin Inlier.

* 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.

Johnson Cairn Formation (ⱣYc, ⱣYck, ⱣYcw)

The Johnson Cairn Formation contains predominantly fine-grained terrigenous sedimentary rocks that lie above the basal quartz-arenite of the Juderina Formation. The type locality is at Johnson Cairn Hill 13 km northeast of Thaduna on PEAK HILL, where it is represented by varicoloured shale with minor carbonate beds (Gee, 1987). On MOOLOOGOOL, the most extensive outcrops form a broad east-northeasterly trending belt in the central part of the sheet area where it is interbedded with mafic rocks of the Killara Formation. Outcrops of the Johnson Cairn Formation are also present in the area around the Mooloogool homestead on the northwestern part of MOOLOOGOOL.

The Johnson Cairn Formation includes thinly bedded (up to 0.3 m thick), laminated argillaceous siltstones with local thin dolomite beds and minor lithic and quartzose wacke (*ⱣYc*). The siltstone consists of variable mixtures of kaolinite and illite, commonly associated with iron hydroxides.

Four kilometres west of Mooloogool homestead, (Locality 3, AMG 047116) a moderately sorted quartz wacke (*ⱣYcw*) is composed of rounded quartz grains in a kaolinitic matrix and is locally interbedded with hematitic shale. The quartz wacke consists of subangular to subrounded polycrystalline quartz in a matrix of illite and kaolinite. The matrix also contains weathered white mica and rarer tourmaline and zircon. Arenite units spatially associated with the siltstone consist of subangular, stained quartz, and minor chert in a ferruginous clay matrix.

Tuffaceous units, present 2 km west-southwest of Cave Hill (Locality 4, AMG 062144) exhibit a dark green-grey colour and have a fine vesicular texture. The vesicles are filled with opaline or chalcedonic quartz. The matrix consists of glassy material with abundant illite. The fine spherulitic appearance is probably the result of devitrification of the glass. The matrix is locally replaced by carbonate.

A small outcrop of silica-cemented arenite, locally brecciated and interbedded with kaolinitic sandstone and laminated siltstone (AMG 039111), has replaced a matrix of fine acicular tourmaline, with minor platelets of iron-poor chlorite. The tourmaline also replaces quartz grains locally. This outcrop probably marks the site of a fault, as suggested by the presence of an aeromagnetic lineament, which traverses the outcrop in a northeasterly direction.

Dolomitic siltstone (*ᵽYck*) consists of fine-grained micritic carbonate enclosing detrital quartz grains. The carbonate displays fine lamination on millimetre-scale. Outcrops south of North Bore have oolith-like structures, 1.1 to 1.4 mm in diameter, composed of fine dolomite and opaque minerals.

Mooloogool Subgroup

The Mooloogool Subgroup conformably overlies the Windplain Subgroup. The Mooloogool Subgroup heralds the onset of a high-energy environment dominated by rift-fill facies and is divided into four formations: Thaduna, Doolgunna, Killara, and Maraloou Formations. The dominantly turbiditic facies of this Subgroup suggest it was deposited in a rift-basin setting (Pirajno et al., 1995a, 1996).

Thaduna Formation (ᵽYt, ᵽYts, ᵽYta)

Rocks of the Thaduna Formation (*ᵽYt*) include lithic wacke with minor shale units. Sedimentation mainly took place in two sub-basins, one on the northeastern side of the Goodin Fault (Fig. 1), the other on the southeastern side of the Goodin Inlier, the western portion of which is on MOOLOOGOOL (Occhipinti et al., 1997). The Thaduna Formation conformably overlies, or interdigitates with, the Johnson Cairn Formation and with the Doolgunna and Killara Formations (see below and Fig. 4). The Thaduna Formation is the result of high-energy terrigenous sedimentation after erosion of uplifted basement blocks and overlying mafic volcanic rocks.

Approximately 3.5 km north of Divide Bore (Locality 5, AMG 360115) is a well-exposed succession of turbiditic quartz-wacke, siltstone, laminated volcaniclastic mudstone, and thin beds of grey volcanic ash (*ᵽYts*). These units exhibit dewatering structures, grading, low-angle cross-stratification, and evidence of substrate erosion and loading. The volcaniclastic rock contains quartz, biotite, sericite, chalcedonic quartz, kaolinitic clays replacing crystal fragments (possibly feldspar), and lithic fragments of basaltic scoria (Fig. 7). Grey volcanic ash is composed of quartz, feldspar microlites, sericite, and prehnite sheafs set in vitric textures with recrystallized quartz lenticles, probably after glass shards. Clay-replaced particles may be after original pyroclasts or crystals. The succession is possibly a combination of water-settled fall out and re-sedimented mass-flow deposits, deposited in a deep-water basin or trough, formed by local rapid uplift and subsidence during volcano-tectonic processes.

Quartz wacke and litharenite (*ᵽYta*) outcrop on east-central MOOLOOGOOL, where they form a easterly trending belt and interdigitate with rocks of the Doolgunna and Killara Formations.

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Figure 7. Block of volcanic scoria in turbiditic rocks of the Thaduna Formation (AMG 111361)

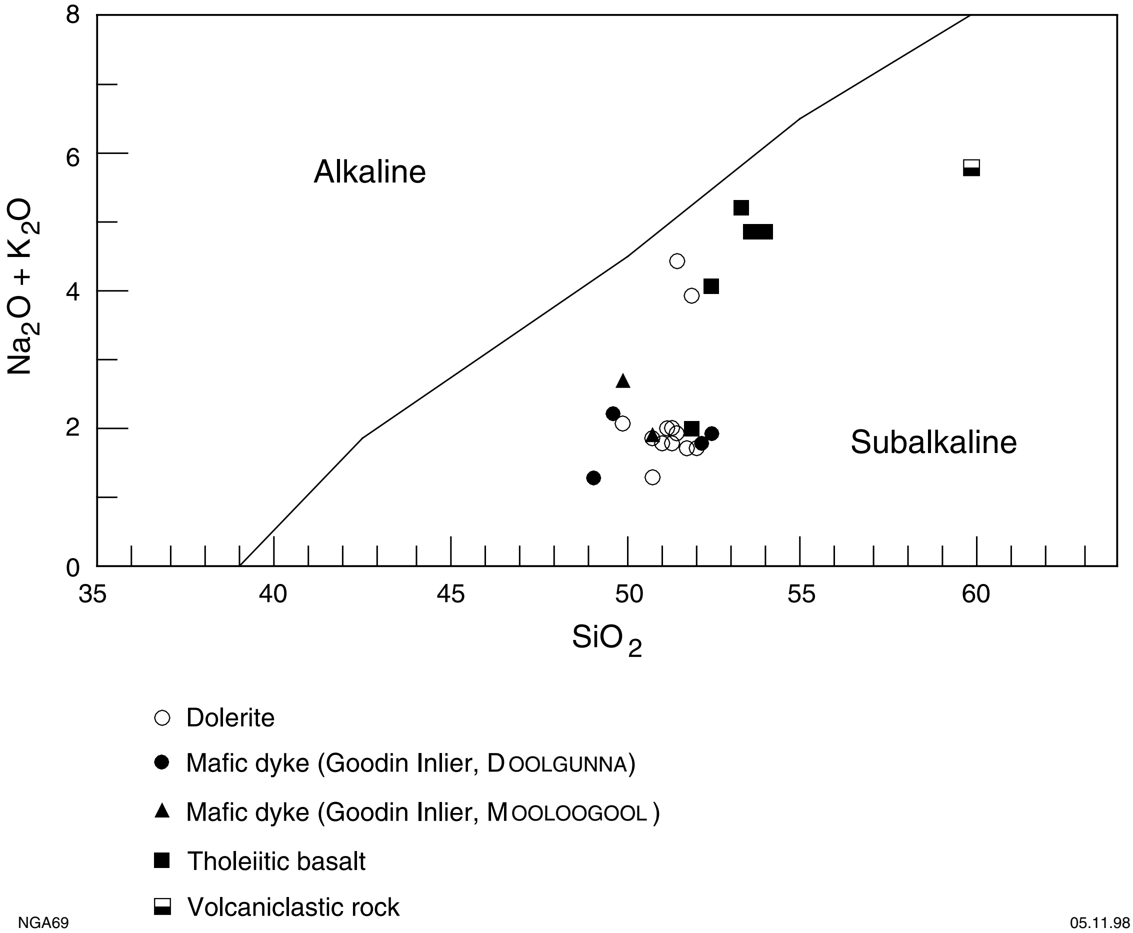

Figure 8. Total-alkali versus silica plot (after Irvine and Baragar, 1971) showing the subalkaline nature of Killara Formation mafic rocks

Doolgunna Formation (ⱣYd, ⱣYds, ⱣYda)

The Doolgunna Formation (*ⱣYd*) is represented by a succession of conglomerates, turbidite-facies rocks, and diamictite units, the latter resulting from mass-wasting sourced from rocks overlying and including the Goodin Inlier. These sediments were accumulated in a north-easterly trending graben — the Doolgunna graben (Pirajno, 1996; Pirajno et al., in press) — on the east side of the Goodin Fault (Fig. 1). On Mooloogool, the Doolgunna Formation is conformable with the Johnson Cairn Formation and consists mainly of arkosic sandstone, arkosic wacke, and kaolinitic quartz-wacke with minor pebble-beds (*ⱣYda*). It is confined to an east-northeasterly trending belt, extending for about 20 km eastward from Rainlover Well. At the eastern end of this belt the Formation includes quartz sandstone with minor pebble-beds (*ⱣYds*) and arkosic wacke (*ⱣYda*), which are intercalated with dolerite sills (Killara Formation, *ⱣYk*) and are in contact with rocks of the Thaduna Formation. The rocks of this east-northeasterly trending belt are locally folded and sheared along northeasterly trending faults (see **Structure and metamorphism**).

Thick beds of wacke commonly display Bouma cycles (Bouma, 1962). Beds average 60 cm in thickness, but may reach up to 2 m (AMG 152944). The wacke contains quartz clasts, which average 5 mm in size (but in places may be up to several centimetres), set in a kaolinitic matrix. Greenish-grey siltstones separate wacke beds and these commonly have scoured tops. The wacke beds are crudely graded at the base, and have parallel-stratified tops (a–b members of the Bouma sequence).

Killara Formation (ⱣYk, ⱣYkx, ⱣYkh, ⱣYkb, ⱣYkc, ⱣYkd)

On Mooloogool, rocks included in the Killara Formation (*ⱣYk*) were originally part of the Dolerite Sill of Elias et al. (1982). The Killara Formation has since been redefined (Occhipinti et al., 1997) and consists of subalkaline intrusive and extrusive rocks (Fig. 8), which were emplaced during a rifting event in the south, east, and southeast of the Yerrida Basin (Yerrida Group; Fig. 1). The thickness of the Killara Formation is uncertain, but is estimated to be in the order of 1000 m (Pirajno et al., 1995a). The mafic rocks are typically unmetamorphosed, flat-lying or shallow dipping, have tholeiitic to calc-alkaline basaltic and basaltic–andesite compositions, and were emplaced as subaerial and subaqueous lava flows, intrusive sheets, sills, and dykes (Pirajno et al., in press). An important component of the Killara Formation is the Bartle Member (*ⱣYkc*), consisting of chertified microbial laminites with barite and anhydrite nodules, massive chert, and chert breccia. These units are stratigraphically at the top of the Killara Formation and represent the end-phase of volcanic activity. Relict textures in the Bartle Member cherts suggest that precursor rock types included volcaniclastic rocks, hot spring-related chemical sedimentary rocks, and evaporites (Pirajno and Grey, 1997; Dawes and Pirajno, 1998). The Bartle Member is not present on MOOLOOGOOL, but is shown in the legend for the sake of completeness.

On MOOLOOGOOL, rocks of the Killara Formation outcrop in a broad, east-northeasterly trending, and southerly dipping belt spatially associated or intercalated with sedimentary rocks of the Johnson Cairn, Doolgunna, and Maraloou Formations (Fig. 3). Dolerite sills (*ᵽYkd*) intrude the Johnson Cairn and Doolgunna Formations to the north and northeast of this belt. Minor sills intruding the Johnson Cairn Formation rocks are present west of the Mooloogool Homestead. Examination of drillcore (see below) from an area 3 km east of North Bore (Locality 6, AMG 029913), resulted in the identification of 15 individual lava flows in a 90 m-thick section — indicating a high rate of eruption. Volcaniclastic deposits are uncommon; however, a possible volcanic centre, approximately 3 km south of North Bore (Locality 7, AMG 001889), is characterized by widespread volcanic breccia (*ᵽYkx*) (possibly a vent breccia), surrounded by pods of laminated silicified material (*ᵽYkh*). The laminae of this rock are composed of quartz grains, microcrystalline quartz, disseminated actinolite needles, and crystal fragments, which are tentatively identified as axinite (a boron-bearing alumino-silicate). Spherulites and shard-like shapes are also present. Similar rock types were also encountered in drillholes 3.5 km northeast of the volcanic centre mentioned above. The association of this rock (*ᵽYkh*) with a volcanic breccia and its textural features, suggest that the precursor lithology may have been either a pyroclastic surge deposit, or a chemical precipitate at the site of hydrothermal discharge

Two kilometres north of Desert Well (Locality 8, AMG 126772), a diamond drillhole (KDD1; Bromley and Cull, 1985) intersected an undisturbed, flat-lying succession of tholeiitic basalt pillow-lavas and dolerite sills, from about 320 m below the surface to the final depth of 503 m (Fig. 9). They underlie a succession of siltstone and pyritic black shales of the Maraloou Formation (see below). Between the siltstone – black shale succession and the pillow lavas, a transition zone, approximately 108 m thick, is characterized by intercalated thin beds of shale, doleritic sills and amygdaloidal lavas. Peperite margins in the contact zones between the igneous material and the sedimentary rocks (Fig. 9) suggest that the mafic melts intruded, or were erupted onto, wet and poorly consolidated sediments (Pirajno et al., 1995b).

Mafic intrusive rocks (ᵽYkd)

An east-northeasterly trending dolerite – tholeiitic-basalt complex, about 23 km long and 200 to 300 m thick, lies on central-western MOOLOOGOOL. The dolerites are locally intercalated with thin units of amygdaloidal tholeiitic basalt. Dolerite is generally well jointed, has a characteristic spheroidal weathering, and consists of clinopyroxene and labradorite (An_{54-65}) crystals set in a cryptocrystalline

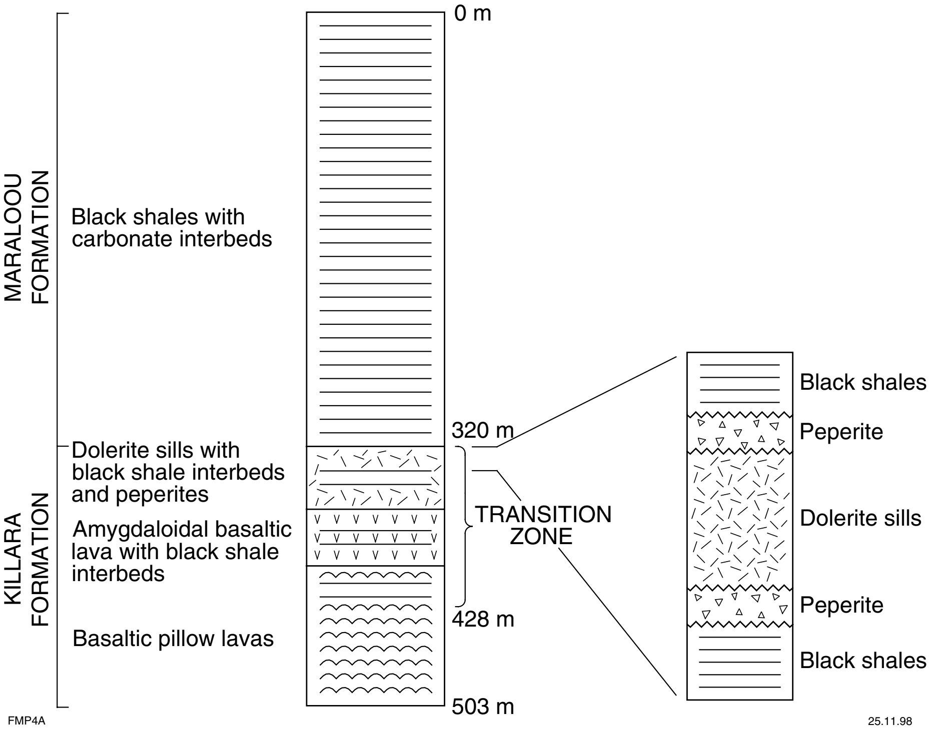

Figure 9. Idealized stratigraphy of Killara and Maraloou Formations in drillhole KDD1; see text for details

to holocrystalline groundmass, which also contains disseminated titanite, in part altered to leucoxene, and minor chlorite and carbonate. Dolerite rocks are quartz, albite, diopside, and hypersthene normative (Table 2).

On central MOOLOOGOOL, a series of dolerite sills are intercalated with argillaceous siltstone of the Johnson Cairn Formation in the higher part of this unit up to the contact with the Doolgunna Formation. Textures of the dolerite vary from fine- to medium-grained holocrystalline to ophitic. Hornblende, clinopyroxene, and plagioclase are the dominant minerals. Clinopyroxene is locally replaced by amphibole. A granophyric texture is well developed locally. Chlorite, clinozoisite, epidote, and titanite are present as alteration minerals. The chlorite–clinozoisite assemblage replaces plagioclase along fractures, in the form of microgranular aggregates. Amphibole encloses euhedral epidote.

The dolerite 1.5 km west-northwest of Mooloogool Homestead (Locality 9, AMG 079116) is well jointed with a characteristic spheroidal weathering creating spheres up to 30 cm in diameter or subrounded masses up to 1 m in diameter. Differential weathering results in a rough dark surface with the more resistant mafic minerals in positive relief. Some degree of differentiation is evident in places, and is characterized by plagioclase-rich facies. On north-eastern (e.g. around Breakaway Bore) and eastern MOOLOOGOOL, dolerite and tholeiitic rocks are associated with the Thaduna and Maraloou Formations respectively.

To the west, halfway between North Bore and North Well (Locality 6, AMG 029913), three diamond drillholes — GD-1, -2, and -3 (AMG 073901; Guj and McIntosh, 1984) — intersected a gabbroic sill approximately 80–90 m thick and dipping about 60° to the south. The sill intruded between layers of pyritic black shale of the Johnson Cairn Formation (Fig.10). Along the footwall of the sill is a well-developed zone of hydrothermal alteration associated with weak sulfide disseminations. This zone of alteration and mineralization correlates with a surface gossan (Guj and McIntosh, 1984), which is further discussed in **Mineralization**. A fourth diamond drillhole (GD-4; Guj and McIntosh, 1984) collared in dolerite about 4.5 km east-southeast of the first three intersected a succession of 15 aphyric, vesicular, tholeiitic-basalt lava flows with minor interflow cherty sedimentary material between 72 and 162 m. Thus, from outcrop data and the four diamond drillholes, the entire succession consists of (from top to bottom) dolerite, tholeiitic basalt lava flows, black shale, a gabbroic sill with associated hydrothermal alteration, a black shale with intercalated thin tholeiitic lava, shale, and another gabbroic sill.

Mafic extrusive rocks (ƐYkb)

On MOOLOOGOOL, outcrops of tholeiitic basalt (*ƐYkb*) are associated with the east-northeasterly trending dolerite sill, described above. Other outcrops of tholeiitic basalt are associated with argillaceous rocks of the Maraloou Formation on eastern MOOLOOGOOL. In addition to the lavas intersected in drillhole GD-4 mentioned above, a series of rotary air-blast (RAB) drillholes near the eastern margin of the map sheet (AMG 460928) penetrated black shale to a depth of 21 m, and vesicular tholeiite to 30 m.

The tholeiitic basalts are characterized by a brown-black weathering colour, with much of the outcrop having a hummocky appearance, locally resembling pillow forms (Fig. 11). The rocks are generally aphyric, or less commonly microporphyritic or glomeroporphyritic, and contain normative albite, diopside, hypersthene, minor quartz, and olivine (Table 2). Aphyric varieties have a fine-grained, variolitic, or intersertal to hyalopilitic texture with plagioclase microlites, augite grains, and minor amounts of quartz, with alteration phases such as chlorite, epidote, prehnite, calcite, and chlorite. In places, plagioclase also forms curious shard-like or sinuous veinlet-like shapes (?quenched melts). The groundmass is a brown, greenish to dark-grey glass with abundant disseminated rutile granules. Amygdales are usually filled with calcite, chlorite, epidote, quartz, and in places, feldspar or granophyric quartz and feldspar. Elsewhere, vesicles contain (from rim to core) calcite, chlorite, zeolite (?stilbite), or chlorite only.

The microporphyritic and glomeroporphyritic varieties are characterized by microphenocrysts of plagioclase, clinopyroxene, or amphibole in a variolitic matrix composed of randomly oriented plagioclase and feathery clinopyroxene crystals, with disseminated rutile granules. Plagioclase laths are about 0.6 mm in length and are associated with amphibole. The laths form clusters set in a fine groundmass dominated by actinolitic amphibole and plagioclase (about 2 mm in length). The laths are either partly albitized, or show a fine pervasive alteration to chlorite and epidote. Vesicles are rounded (about 1 mm in diameter) and completely filled by quartz, clinozoisite, and minor biotite. Vein minerals include quartz and clinozoisite.

Geochemistry of Killara Formation mafic rocks

Twenty-one samples were collected from various mafic rocks on MOOLOOGOOL and analyzed for major, trace, and rare-earth elements (Tables 2 and 3). Most samples were collected from the east-northeasterly trending dolerite – tholeiitic-basalt complex. The analyzed samples also include one from the mafic dykes which cut the granite in the area of Utahlarba Spring, a basaltic rock interbedded with the basal arenite in the Browny Bore area, and two cherty volcaniclastic rocks.

The results of these analyses indicate that mafic rocks of the Killara Formation on MOOLOOGOOL have an SiO_2 content of 49.95–54.00 wt% (mean: 51.60 wt%), an MgO content of 4.17–8.91 wt% (mean: 7.16 wt%), and an FeO content of 6.45–11.30 wt% (mean: 8.88 wt%). The analyses also gave averages for some key elements: 249 ppm for Ba (range: 41–911 ppm), 17 ppm for Y (range: 12–26 ppm), 64 ppm for Zr (range: 37–108 ppm), 4.4 ppm for Nb (range: 0.9–8 ppm), 87 ppm for Ni (range: 50–147 ppm), and 10 ppm for Au (range: 9–13 ppm).

Based on the total-alkali vs silica diagram (Le Maitre, 1989), mafic rocks of the Killara Formation on MOOLOOGOOL range from basalt (dolerite sills) to basaltic andesite. The mafic dykes that intrude the Goodin Inlier (4 samples

Table 2. Major and trace element analyses of Killara Formation rocks, and mafic dykes in the Goodin Inlier

GSWA sample.	*104311*[a]	*104312*[b]	*104313*[b]	*112798*[a]	*112800*[a]	*120392*[b]	*120394*[b]	*120396*[c]	*136738*[c]	*130918*[d]	*130921*[e]
Easting	*698823*	*699823*	*699655*	*717478*	*706299*	*707300*	*707300*	*707300*	*712614*	*722060*	*722967*
Northing	*7088627*	*7089076*	*7088614*	*7097500*	*7110396*	*7090900*	*7090900*	*7090900*	*7091692*	*7114962*	*7113100*
						Percentage					
SiO_2	51.40	54.00	53.30	52.00	51.80	53.50	52.50	59.80	51.82	50.76	49.98
TiO_2	0.68	0.93	0.98	0.80	0.80	0.84	1.17	0.66	0.82	1.04	1.19
Al_2O_3	14.20	12.50	13.40	13.50	13.70	14.60	13.80	15.20	13.41	13.94	14.42
Fe_2O_3	2.03	1.39	1.83	1.86	2.37	1.04	1.54	1.64	1.44	2.38	1.41
FeO	8.05	8.88	8.70	9.50	8.89	9.50	11.30	6.32	9.27	8.48	9.98
MnO	0.18	0.20	0.17	0.20	0.20	0.19	0.18	0.18	0.20	0.19	0.21
MgO	7.31	8.15	5.91	7.15	7.12	4.94	4.17	2.36	6.78	7.22	6.59
CaO	9.59	6.87	8.35	11.20	11.40	5.89	7.28	3.09	11.24	11.57	11.47
Na_2O	3.31	4.73	4.74	1.67	1.63	4.40	2.45	1.39	1.45	1.67	2.51
K_2O	1.14	0.14	0.48	0.07	0.08	0.49	1.64	4.39	0.59	0.25	0.20
P_2O_5	0.06	0.08	0.08	0.06	0.06	0.08	0.11	0.04	0.07	0.08	0.10
H_2O^+	3.07	3.43	3.08	2.57	2.85	2.81	2.34	3.32	–	1.38	1.47
H_2O^-	–	–	–	–	–	–	–	–	–	0.13	0.08
CO_2	–	–	–	–	–	–	–	–	–	0.06	0.05
Total	**101.02**	**101.30**	**101.02**	**100.58**	**100.90**	**98.28**	**98.48**	**98.39**	**97.09**	**99.37**	**99.82**
						CIPW Norms					
Q	–	–	–	6.32	6.70	1.33	5.18	20.38	6.14	4.99	–
C	–	–	–	–	–	–	–	2.53	–	–	–
or	6.76	0.83	2.84	0.41	0.47	2.90	9.52	25.99	3.49	1.48	1.18
ab	28.01	40.02	40.10	14.13	13.79	37.23	20.73	11.76	12.27	14.13	21.26
an	20.53	12.47	13.89	29.14	29.84	18.66	21.85	15.49	28.36	29.83	27.50
di	21.93	17.28	22.45	21.46	21.64	8.45	11.67	–	23.38	22.27	23.84
hy	7.25	16.49	6.31	22.21	20.53	23.65	22.40	15.38	20.73	19.35	18.61
ol	9.17	6.83	7.72	–	–	–	–	–	–	–	1.20
mg	2.94	2.02	2.65	2.70	3.44	1.51	2.23	2.38	2.09	3.45	2.04
il	1.29	1.77	1.86	1.52	1.52	1.60	2.22	1.25	1.56	1.98	2.26
ap	0.14	0.19	0.19	0.14	0.14	0.19	0.26	0.10	0.17	0.19	0.24
Total	**98.03**	**97.90**	**98.01**	**98.05**	**98.08**	**95.51**	**96.27**	**95.25**	**97.18**	**97.65**	**98.10**
						Parts per million					
Sc	–	–	–	–	–	–	–	–	–	52	52
V	217	318	335	280	284	253	291	90	232	275	275
Cr	78	76	70	98	106	133	51	130	79	237	75
Mn	–	–	–	–	–	–	–	–	1 480	1 450	1 550
Co	–	–	–	–	–	41	45	24	61	55	62
Ni	87	58	61	94	69	87	50	85	67	92	71
Cu	146	117	110	148	140	131	121	19	160	50	49
Zn	70	89	80	99	83	95	108	118	85	96	96
Ga	14	12	14	14	15	0.5	2.2	2.1	15	15.0	15.0
As	4	4	4	4	4	0.8	0.5	0.5	0.5	1.0	1.0
Rb	47	4	17	2	2	15	58	119	20	12.5	1.5
Sr	292	61	284	125	123	58	140	112	158	167	212
Y	17	17	20	18	17	17	26	20	16	21	19
Zr	71	86	91	65	65	80	108	117	59	80	88
Nb	7.0	127.0	5.3	3.3	0.9	1.6	2.8	8.0	4.0	8.0	8.0
Sn	4.0	4.0	4.0	4.0	4.0	0.9	1.5	1.0	4.0	4.0	4.0
Ba	303	96	396	41	85	239	911	1 404	574	420	100
La	–	–	–	–	–	–	–	–	–	12	7
Ce	–	–	–	–	–	–	–	–	–	20	22
Pb	5	5	4	4	4	13	4	19	4	7	2
Th	3	5	6	2	3	4	3	14.8	2	1.5	1.5
U	2.0	1.5	2.0	0.4	0.3	1.0	1.3	2.4	0.05	0.05	0.5

Table 2. (continued)

GSWA sample	*130930(a)*	*130939(a)*	*130945(a)*	*130956(a)*	*130957(a)*	*130977(a)*	*130979(a)*	*130985(a)*	*130989(a)*	*130992(a)*
Easting	*706748*	*705479*	*709687*	*720460*	*722675*	*711181*	*709229*	*717056*	*720586*	*723215*
Northing	*7112220*	*7109882*	*7097757*	*7100465*	*7099070*	*7093797*	*7094150*	*7096393*	*7097340*	*7097594*
					Percentage					
SiO_2	50.73	50.99	50.76	49.95	51.46	51.36	51.85	49.89	51.30	51.20
TiO_2	0.56	0.61	0.68	0.77	0.71	0.82	0.75	0.70	0.68	0.65
Al_2O_3	13.91	14.34	14.28	14.50	13.34	13.25	13.48	13.74	13.66	13.84
Fe_2O_3	1.91	1.46	1.60	1.49	1.52	1.35	2.10	1.53	1.67	1.31
FeO	6.45	7.07	8.13	8.39	9.06	9.70	9.18	8.39	9.33	9.23
MnO	0.17	0.17	0.18	0.17	0.20	0.21	0.25	0.18	0.20	0.20
MgO	8.91	8.57	7.83	8.00	7.69	7.45	7.53	8.74	7.15	7.30
CaO	13.14	12.26	12.07	11.58	11.48	11.35	7.83	12.22	11.00	11.31
Na_2O	1.12	1.51	1.68	1.92	1.67	1.46	3.78	1.29	1.68	1.66
K_2O	0.20	0.32	0.20	0.16	0.26	0.34	0.18	0.46	0.35	0.33
P_2O_5	0.04	0.05	0.05	0.07	0.05	0.07	0.05	0.05	0.05	0.05
H_2O^+	2.54	2.39	2.07	2.52	2.48	2.32	2.92	2.50	2.43	2.43
H_2O^-	0.03	0.03	0.08	0.11	0.10	0.09	0.25	0.10	0.07	0.13
CO_2	0.05	0.04	0.06	0.05	0.06	0.15	0.08	0.09	0.08	0.12
Total	**100.00**	**100.03**	**99.86**	**99.86**	**100.29**	**100.10**	**100.39**	**100.11**	**99.85**	**99.95**
					CIPW Norms					
Q	4.75	3.29	3.17	1.30	4.31	5.02	–	2.08	4.74	4.08
C	–	–	–	–	–	–	–	–	–	–
or	1.18	1.90	1.18	0.95	1.54	2.01	1.07	2.72	2.07	1.95
ab	9.48	12.78	14.21	16.24	14.13	12.35	31.98	10.91	14.21	14.05
an	32.35	31.41	30.84	30.49	28.14	28.61	19.30	30.35	28.72	29.35
di	26.34	23.63	23.50	21.74	23.43	22.50	15.85	23.93	21.15	21.82
hy	19.14	20.97	20.86	22.54	22.26	23.23	21.25	23.42	22.42	22.63
ol	–	–	–	–	–	–	2.99	–	–	–
mg	2.77	2.12	2.32	2.16	2.20	1.96	3.04	2.22	2.42	1.90
il	1.06	1.16	1.29	1.46	1.35	1.56	1.42	1.33	1.29	1.23
ap	0.09	0.12	0.12	0.17	0.12	0.17	0.12	0.12	0.12	0.12
Total	**97.17**	**97.37**	**97.50**	**97.05**	**97.48**	**97.41**	**96.99**	**97.28**	**97.15**	**97.12**
					Parts per million					
Sc	54	52	49	46	56	51	60	49	53	53
V	203	211	221	206	238	241	267	215	239	232
Cr	391	364	159	255	119	67	123	247	89	99
Mn	1 350	1 310	1 390	1 300	1 520	1 580	1 850	1 370	1 540	1 520
Co	60	57	61	61	65	68	65	67	64	64
Ni	147	134	96	132	85	78	74	130	78	78
Cu	137	122	95	69	142	113	66	86	153	133
Zn	64	69	78	79	83	89	92	79	87	83
Ga	12.5	13.0	13.5	15.5	14.0	14.0	12.5	13.0	13.5	13.5
Rb	6.0	11.0	5.5	2.5	12.5	12.0	4.5	21.0	13.5	10.5
Sr	119	110	126	181	134	109	120	124	135	126
Y	12	13	13	16	15	15	17	14	15	14
Zr	37	42	45	66	48	53	47	44	42	42
Nb	2	2	3	4	3	4	2	3	3	3
Sn	2	2	2	4	4	4	4	4	2	4
Ba	68	66	66	122	80	118	146	114	385	124
La	4	4	5	8	5	6	4	4	4	3
Ce	8	10	10	18	12	12	10	8	10	10
Pb	2	1	2	3	2	1	2	1	1	2
Th	1.0	1.0	0.05	1.5	1.0	1.5	1.0	1.0	0.5	2.0
U	0.05	0.05	0.05	0.05	0.05	0.5	0.05	0.05	0.05	0.05

NOTES: (a) dolerite
(b) tholeiitic basalt
(c) volcaniclastic rock
(d) mafic dayke (Goodin Inlier)
(e) tholeiitic basalt (Goodin Inlier)

Analyses were performed at the Chemistry Centre of the Department of Minerals and Energy, by XRF for major elements, following incorporation of sample into a borate glass disk, or a pressed powder. Co, Cr, Cu, Ni, V, and Zn were determined by ICP-AES following a mixed acid solution; all other analyte concentrations (e.g. REE) were quantified using ICP-MS after a mixed acid solution

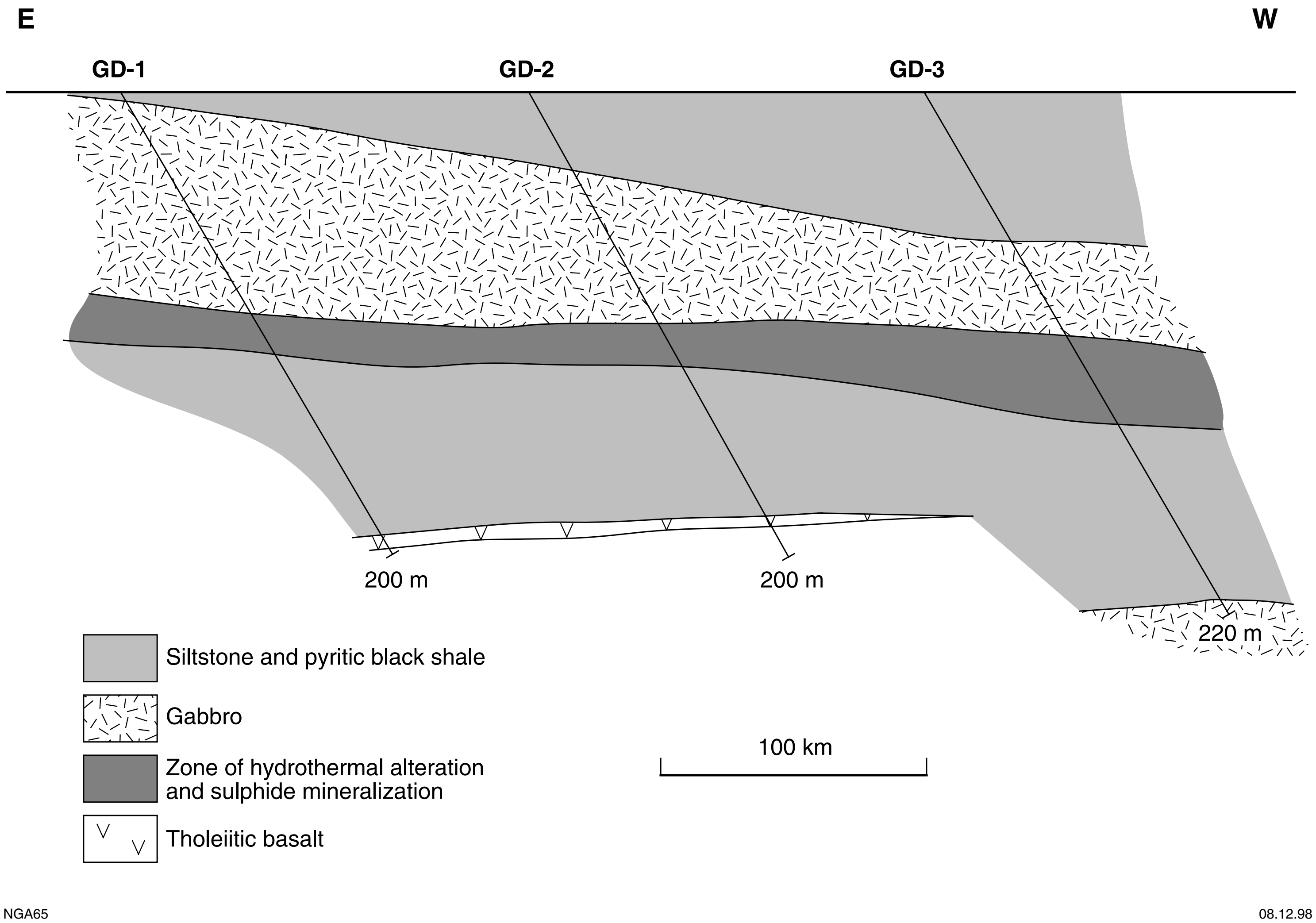

Figure 10. Idealized section through drillholes GD-1, -2, and –3 (data from Guj and McIntosh, 1984)

NGA63 08.09.98

Figure 11. Typical hummocky appearance of tholeiitic volcanic rocks of the Killara Formation (AMG 230096)

of which are from Doolgunna; Adamides, 1998) cluster together with most dolerites (Fig. 12). The subalkaline nature of the Killara Formation rocks (Fig. 8) supports a tholeiitic composition.

A trend of iron enrichment in mafic rocks is shown in Figure 13, with tholeiitic basalt rocks tending to be enriched in total alkalis — a characteristic of the tholeiitic fractionation series. The mafic dykes that intrude the Goodin Inlier are enriched in Fe relative to dolerite and tholeiitic basalt. The tholeiitic trend of Mg depletion from dolerite sills to tholeiitic basalt rocks is also suggested by the Jensen cationic plot (Fig. 14). The above features are consistent with a comagmatic origin for all of these mafic rocks.

The more fractionated nature of the tholeiites relative to the dolerites can be further gauged by using data relating to the highly incompatible elements such as Y and Zr, which are least affected by phenomena linked with metasomatism and hydrothermal alteration. The tholeiitic basalts generally display higher Y/Zr ratios than the dolerite and other mafic dykes (Fig. 15).

The multielement plots, shown in Figures 16 and 17, indicate that the mafic rocks of the Killara Formation are enriched in the more incompatible elements, 10 to 100 times relative to N-type MORB, but only between 1 and 5 times when normalized to continental crust, the nearly flat pattern of the latter suggestive of contamination with crustal material. Chondrite-normalized rare-earth element (REE) patterns show a slight enrichement in the light REE (LREE: La, Ce, Pr, Nd, and Sm), which is again suggestive of crustal contamination, or an enriched mantle source (Fig. 18). Dolerites have REE abundances approximately 10 to 20 times chondritic values, whereas the basaltic rocks have approximately between 15 and 35 times the chondritic values. One sample of volcaniclastic material is LREE enriched (up to 80 times chondrite) and slightly heavy REE depleted. A weak positive Eu anomaly indicates lack of plagioclase fractionation. The similar patterns for basalt and dolerite confirm that they are cogenetic.

Maraloou Formation (ⱣYm, ⱣYms, ⱣYmk)

On Mooloogool, the Maraloou Formation covers most of the southern half of the map area, where it forms a series of sparse, low-lying outcrops, surrounded by sheetwash deposits (*Cza*). The thickness of the formation is estimated to be around 1000 m (Occhipinti et al., 1997). The Maraloou Formation consists of thin-bedded siltstone, carbonaceous shale, and quartz wacke with intercalated basalt and dolerite near the top. An east-northeasterly trending belt of fine-grained dolomitic rocks and calcareous siltstone (*ⱣYmk*) overlies and flanks basalt and dolerite of the Killara Formation on central-west Mooloogool. The dolomitic units (*ⱣYmk*) consist of packed aggregates of fine-grained zoned, dolomite rhombohedra. Zoning of the dolomite rhombs is characterized by a dark, Fe-rich core surrounded by clear dolomite. The dolomitic rocks are commonly silicified or chertified to varying degrees. On southestern Mooloogool, around

Table 3. Rare-earth element analyses of dolerite and tholeiitic basalt of the Killara Formation

Sample[a]	*104312*[b]	*112798*[c]	*112800*[c]	*120392*[b]	*120394*[b]	*136735*[c]	*120396*[d]	*136738*[d]	*130918*[c]	*130921*[b]	*130930*[c]	*130939*[c]	*130945*[c]	*130956*[c]	*130957*[c]	*130977*[c]	*130979*[c]	*130989*[c]	*130992*[c]
Easting	*699823*	*717478*	*706299*	*707300*	*707300*	*710445*	*707300*	*712614*	*722060*	*722967*	*706748*	*705479*	*709687*	*720460*	*722675*	*711181*	*709229*	*720586*	*723215*
Northing	*7089076*	*7097500*	*7110396*	*7090900*	*7090900*	*7090729*	*7090900*	*7091692*	*7114962*	*7113100*	*7112220*	*7109882*	*7097757*	*7100465*	*7099070*	*7093797*	*7094150*	*7097340*	*7097594*
										Parts per million									
La	13.00	6.80	6.60	5.26	10.85	–	28.76	–	13.48	7.52	5.51	5.28	5.83	11.52	6.25	7.63	5.59	5.98	5.54
Ce	29.70	15.50	13.90	13.94	26.63	–	58.91	–	23.62	26.67	12.85	14.02	13.65	24.43	14.59	17.83	13.77	13.78	12.74
Pr	3.60	2.10	1.20	2.20	3.57	2.16	7.30	4.17	3.23	2.42	1.68	1.58	1.80	2.92	1.88	2.25	1.82	1.75	1.65
Nd	13.80	8.40	8.10	8.75	14.28	9.22	23.66	15.34	12.83	9.71	6.97	6.70	7.74	11.27	7.64	9.34	7.98	7.67	6.93
Sm	3.10	2.00	1.70	2.46	3.88	0.97	1.72	1.45	3.12	2.68	1.81	1.84	2.10	2.75	2.05	2.44	2.27	2.00	1.93
Eu	1.10	0.80	1.30	1.15	2.01	1.72	4.26	3.00	1.13	0.86	0.66	0.64	0.78	0.98	0.71	0.87	0.85	0.93	0.73
Gd	3.70	2.80	3.00	3.22	4.03	2.59	4.26	3.00	3.23	2.97	2.06	2.06	2.33	2.90	2.31	2.65	2.60	2.30	2.15
Tb	0.60	0.50	0.40	0.60	0.75	0.45	0.60	0.40	0.51	0.51	0.37	0.36	0.42	0.45	0.41	0.45	0.51	0.43	0.38
Dy	3.60	2.90	2.30	3.49	4.12	2.70	3.11	2.25	2.95	3.03	2.25	2.19	2.55	2.59	2.49	2.79	3.01	2.63	2.42
Ho	0.70	0.60	0.50	0.81	1.09	0.56	0.65	0.41	0.61	0.63	0.48	0.46	0.54	0.53	0.53	0.59	0.64	0.56	0.52
Er	2.20	1.90	1.30	2.22	2.92	1.72	1.86	1.29	1.81	1.88	1.45	1.43	1.65	1.60	1.60	1.78	1.99	1.75	1.56
Tm	0.30	0.30	0.20	0.42	0.14	0.25	0.33	0.18	0.26	0.26	0.21	0.21	0.25	0.22	0.23	0.25	0.28	0.25	0.23
Yb	1.90	1.70	1.00	2.31	2.62	1.78	1.62	1.26	1.81	1.82	1.56	1.47	1.74	1.54	1.69	1.88	2.01	1.85	1.70
Lu	0.30	0.30	0.20	0.50	0.59	0.26	0.44	0.18	0.28	0.25	0.23	0.22	0.27	0.23	0.25	0.28	0.27	0.28	0.26

NOTES: For analytical details see Table 2 footnotes
(a) GSWA sample number
(b) dolerite
(c) tholeiitic basalt

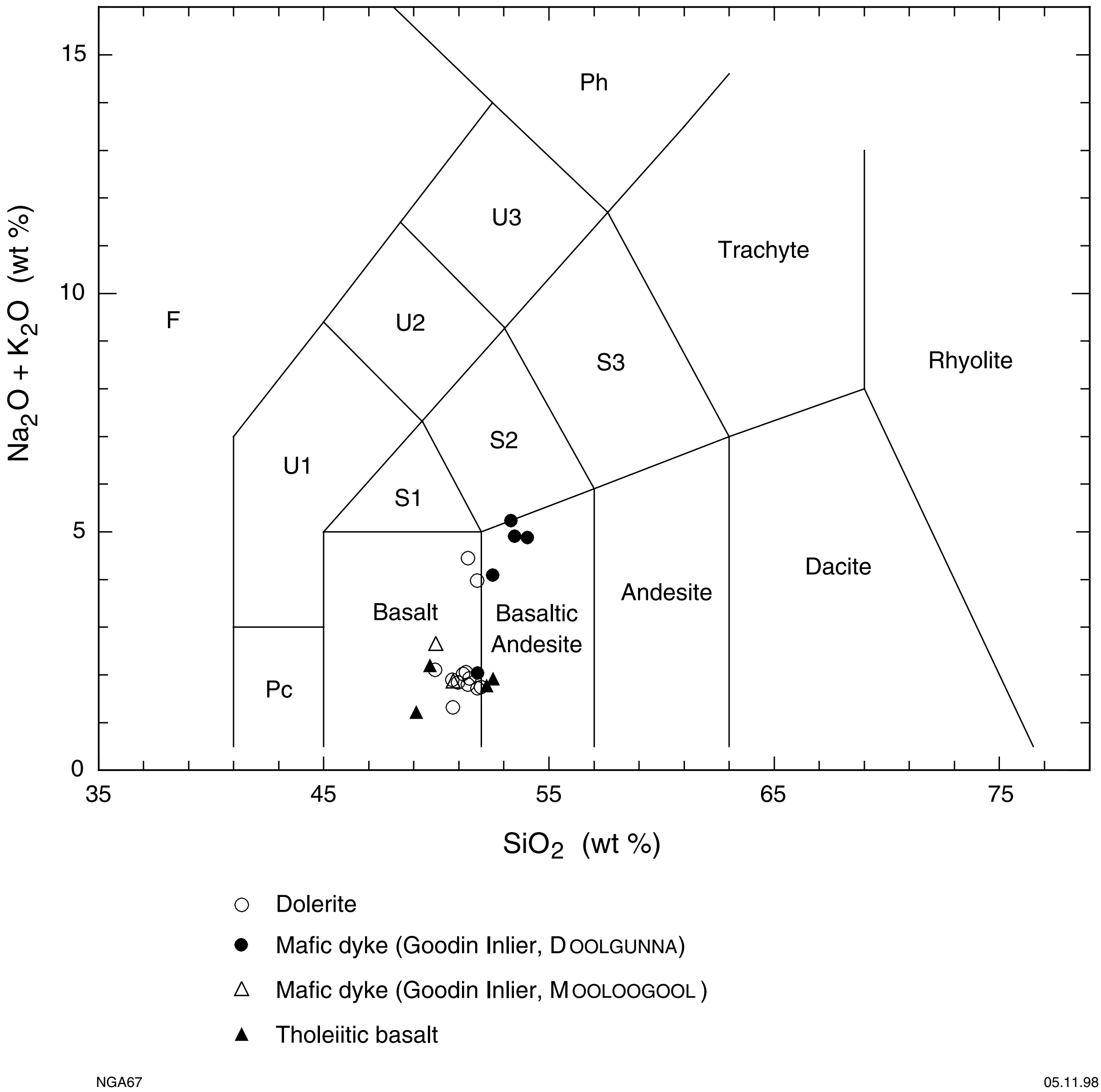

Figure 12. Total-alkali versus silica plot (after Le Maitre, 1989) showing composition of Killara Formation rocks; mafic dykes intruding the Goodin Inlier are included for comparison

and west of Limestone Well (AMG 395817), the dolomitic rocks are characterized by oolitic textures.

The dolomitic rocks are locally intercalated with thin amygdaloidal basalts near the contact with the Killara Formation. Along strike and east of the above-mentioned belt of dolomitic rocks are outcrops of thinly bedded siltstone and black sulfidic shale (*EYms*). These rocks are exposed along easterly trending breakaways. Siltstone and black sulfidic shale were intersected in a series of RAB holes at the eastern end of these breakaways (AMG 480928). The colour of these rocks varies with depth, due to decreased weathering, from pale-grey to black. The same black shale unit is also intersected by drillhole KDD1 (see Fig. 9). The black sulfidic shale consists of fine laminae or lenticles of silt-size, quartz grains, sericite, chlorite, kaolinite, Fe oxides, and carbonaceous matter. Pyrite and minor chalcopyrite are the main sulfides and are commonly replaced by secondary Fe oxides and oxyhydroxides. Gossanous horizons are present 2.5 km south of Rockhole Bore (Locality 10, AMG 165907; see **Mineralization**).

Dykes (*Ed*)

Mafic dykes (*Ed*) intrude the Goodin Inlier typically in an east-southeasterly direction. They are of uncertain age, but are assumed to have been emplaced during the Palaeoproterozoic on the basis of geochemical and structural trends. They are associated with a series of shear zones which also control the distribution of narrow slices of quartz arenite of the Juderina Formation. The dykes weather brownish-black, and give rise to poorly exposed

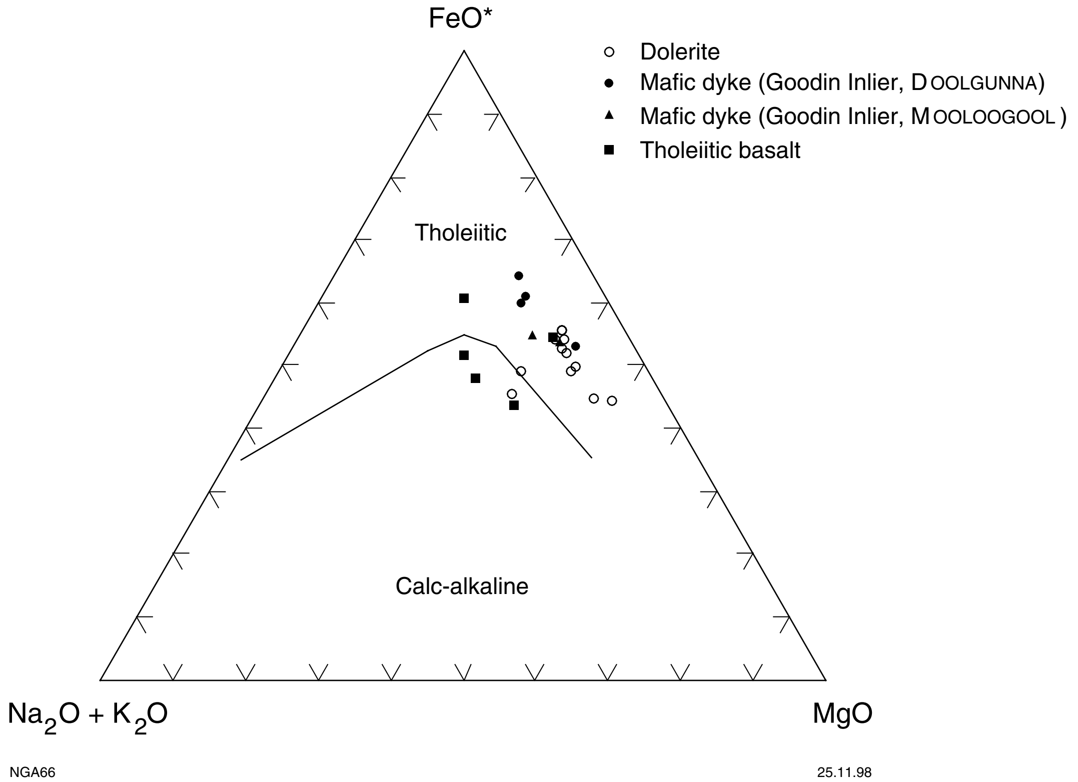

Figure 13. FeO*, total-alkali, and magnesia triangular plot (after Irvine and Baragar, 1971) showing the predominantly tholeiitic trend of Killara Formation rocks (dolerite and tholeiitic basalt) and mafic dykes intruding the Goodin Inlier

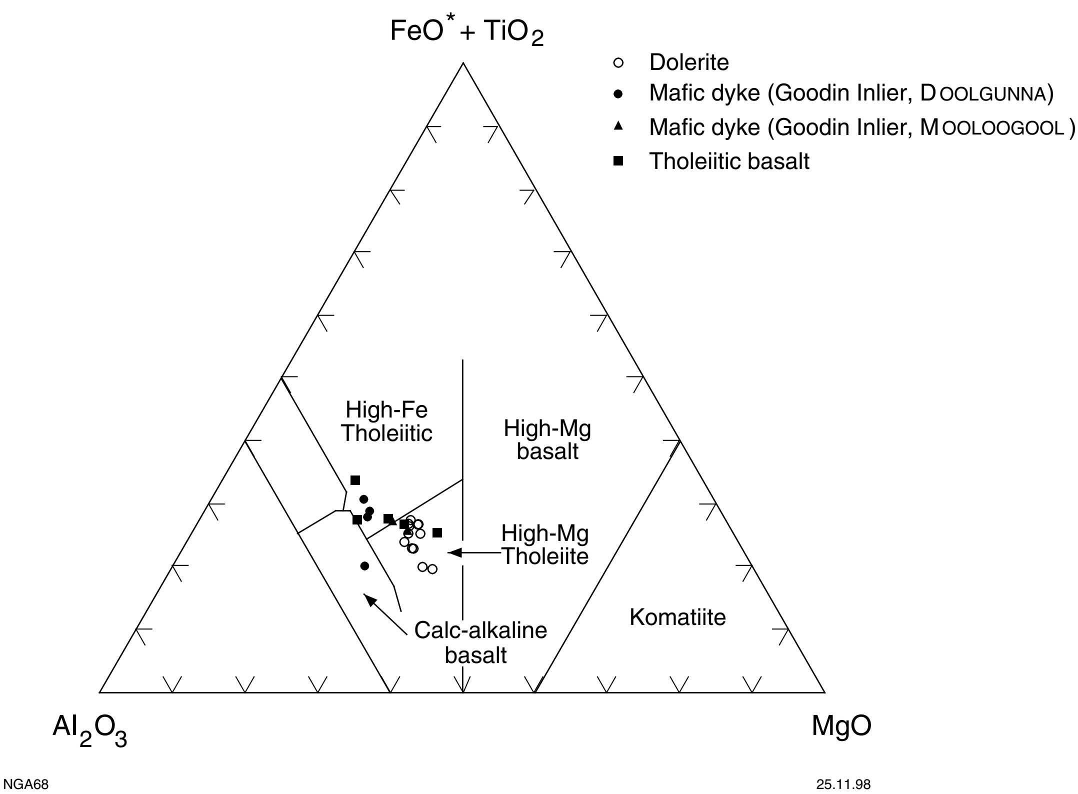

Figure 14. Jensen cationic plot (modified from Jensen, 1976) for Killara Formation and mafic dykes intruding the Goodin Inlier. Tholeiitic basalts and mafic dykes plot astride the high-Fe and high-Mg tholeiite fields (HFT and HMT, respectively). Dolerite plots in the high-Mg tholeiite field

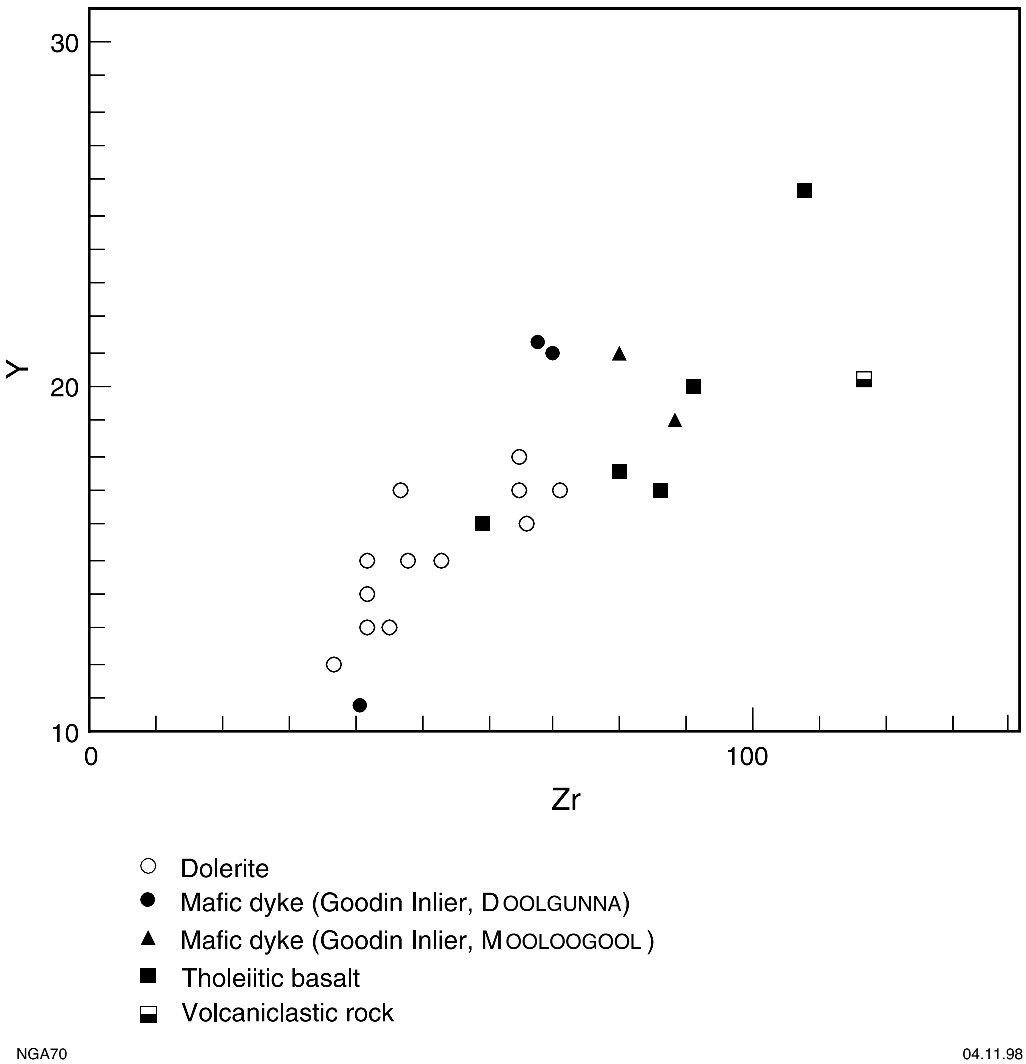

Figure 15. Binary plot of yttrium versus zirconium, showing a differentiation trend between dolerite and tholeiitic basalt of the Killara Formation

rubbly outcrop of angular to spheroidal blocks. Contacts are rarely observed. The dykes are well-defined on aerial photographs, due to a photogeological contrast with the granitoid rocks, and locally bifurcate (e.g. AMG 220115). Mafic dykes that intrude the granitoid rocks are characterized by a holocrystalline doleritic texture with interlocking andesine to labradorite (An_{50}) plagioclase laths and abundant strongly pleochroic hornblende. Grain size ranges from 0.8–1 mm. The plagioclase is fresh, locally zoned, and may enclose fine-grained amphibole needles. Interstitial hornblende constitutes up to 70% of the rock and comprises strongly pleochroic (yellow-green to deep blue-green) — probably sodic — hornblende. Opaque minerals, predominantly titanite, locally form euhedral crystals 0.04 mm in size. One sample collected from a mafic dyke near Utahlarba Spring, also contains minor amounts of brown biotite in addition to strongly pleochroic hornblende.

A poorly exposed dolerite dyke is present in the area around AMG 096169. This dyke coincides with a northwesterly trending aeromagnetic lineament and is located at the contact between the Johnson Cairn and Juderina Formations. The dyke consists of pleochroic brown hornblende in various stages of pseudomorphous replacement of diopsidic clinopyroxene, with well-developed micrographic intergrowth of quartz and feldspar enclosing the hornblende. Plagioclase is altered to clinozoisite and iron-poor chlorite along fractures. Chlorite is associated with relict resorbed quartz and idiomorphic clinozoisite, and as crystalline chlorite with anomalous brown and purple birefringence. Titanite is the principal opaque mineral. These minerals are associated with granophyric intergrowths, which may be due to late magmatic, or autometamorphic alteration processes.

Easterly trending, linear, aeromagnetic anomalies that traverse the southern part of MOOLOOGOOL are interpreted to be mafic dykes of Proterozoic age as they cut through rocks of the Maraloou Formation (e.g. Limestone Well, AMG 440789). They are part of a

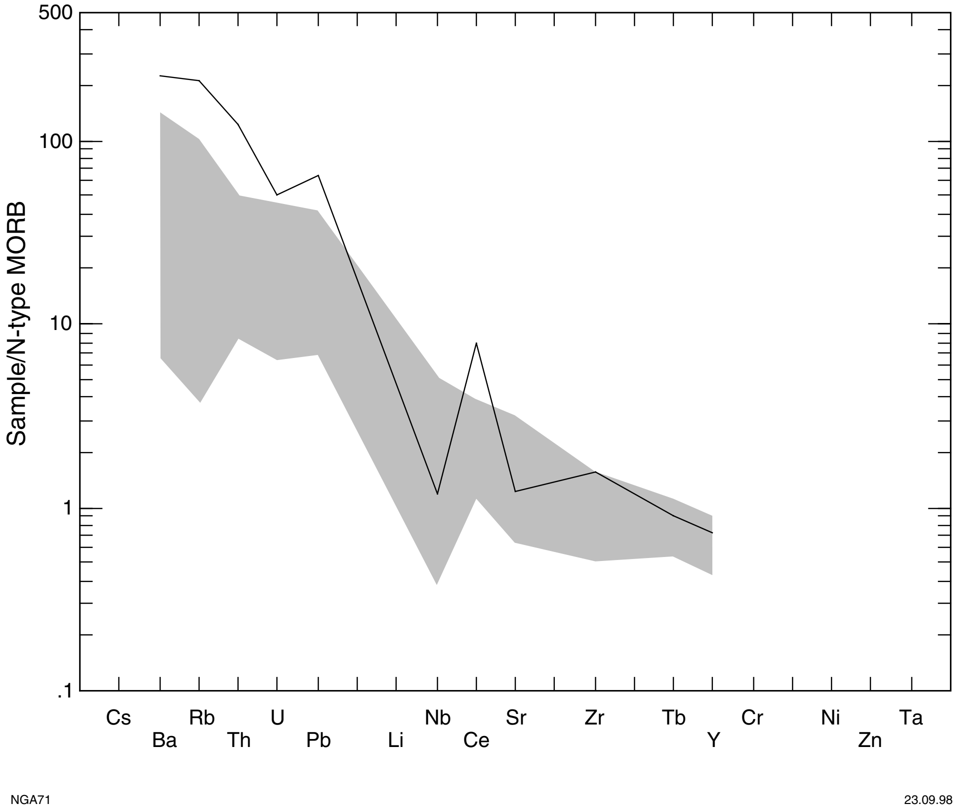

Figure 16. Multi-element diagram of Killara Formation rocks, dolerite, and tholeiitic basalt (shaded), and volcaniclastic rock (line) normalized to N-type MORB. Normalization factors after Sun and McDonough (1989)

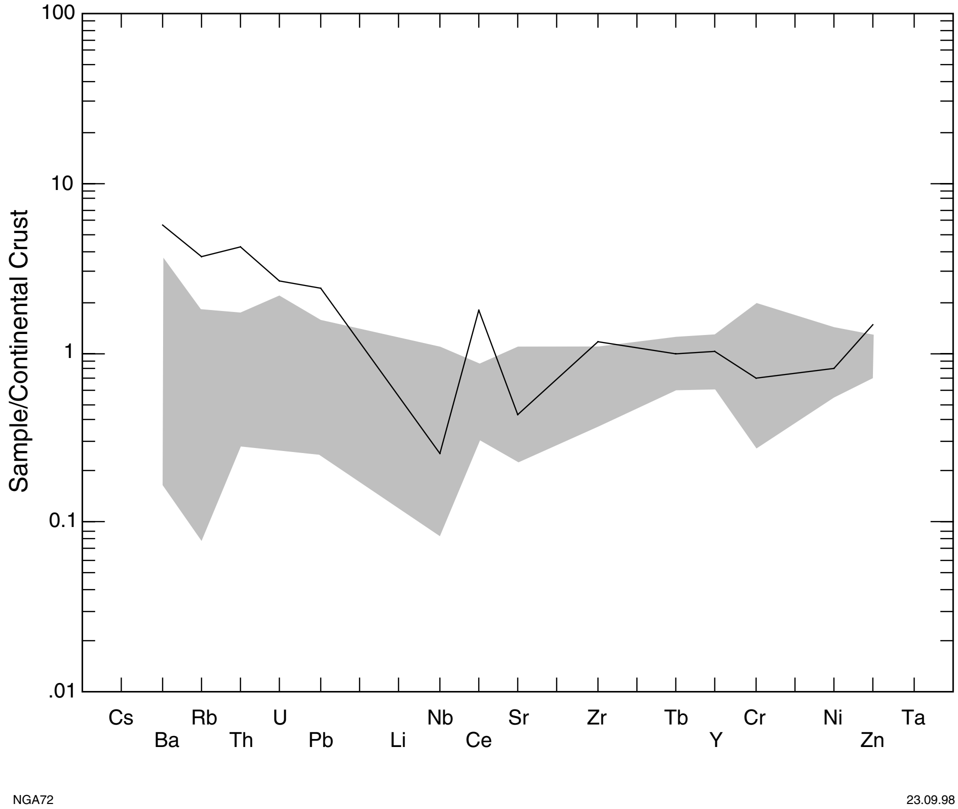

Figure 17. Multi-element diagram of Killara Formation rocks, dolerite, and tholeiitic basalt (shaded), and volcaniclastic rock (line) normalized to continental crust. Normalization factors after Taylor and McLennan (1985)

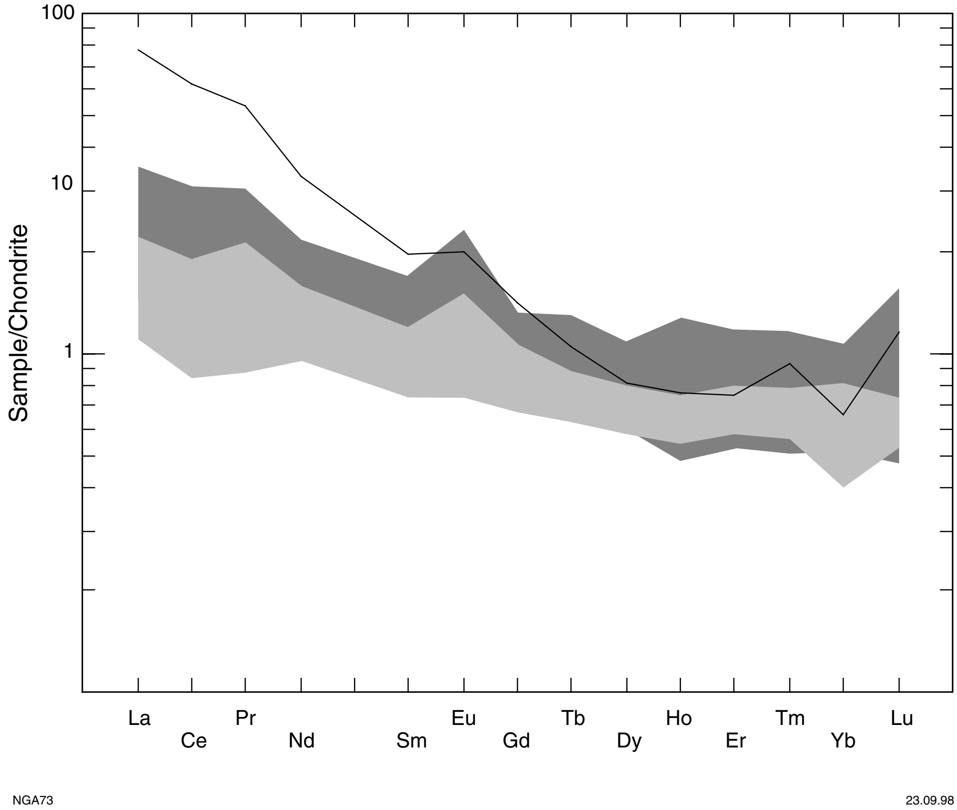

Figure 18. Chondrite-normalized rare-earth element (REE) plot for dolerite (dark grey shading), tholeiitic basalt (light grey shading), and volcaniclastic rock (line). Normalization factors after Sun and McDonough (1989)

regional swarm that can be traced for several hundred kilometres from the western margins of the Yilgarn Craton, northeastward to east-northeastward, towards the northern margin of the Craton, and through the Yerrida and Earaheedy Basins (Parker et al., 1987). On MOOLOOGOOL, linear magnetic anomalies are interpreted as mafic dykes located between 50 and 200 m below ground (Tucker and Boyd, 1987).

Cainozoic geology

The regolith deposits on MOOLOOGOOL are dominated by sheetwash plains, eolian sands, lateritic soils, and colluvium. Active river and stream beds contain unconsolidated alluvial material (sand, silt, and clay; *Qa*), locally grading into floodplains (*Cza*). In the south, claypans (*Qac*) are present.

Sheetwash fans comprise colluvial sand, silt, and ferruginous clay (*Cza*). Colluvium (*Czc*) on scree slopes is particularly well developed at the foot of hills on central MOOLOOGOOL. Calcrete (*Czk*) is well developed around outcrops of the Maraloou Formation in the southwest. Sandplain deposits (*Czs*) overlie much of the Goodin Inlier (on northern MOOLOOGOOL), areas around the contact between rocks of the Juderina and Maraloou Formations in the south, and over Killara and Maraloou Formations in central MOOLOOGOOL. Outcrops of calcrete (*Czk*) are present mostly in the southwest along a northwest-draining stream channel. Silcrete (*Czz*) is locally developed over silica-rich rocks. A coarse quartzofeldspathic sand (*Czg*) commonly overlies granitoid rocks. Lateritic and other ferruginous materials include massive ironstone (*Czi*) and related debris (*Czf*).

An idealized weathering profile for MOOLOOGOOL, as deduced from outcrop sections, is shown in Figure 20. The profile is particularly relevant to outcrops of the Maraloou Formation on eastern MOOLOOGOOL.

THE MOOLOOGOOL sheet area was sampled as part of a program of regional regolith geochemical sampling which covered the whole of GLENGARRY (1:250 000). Crawford et al. (1996) provides a detailed account of the results of this sampling, including multi-element assays, accompanying element plots, and regolith geology.

Structure and metamorphism

The siliciclastic, carbonate, and mafic volcanic rocks of the Yerrida Group represent a sag- and (overlying) rift-basin succession (Pirajno et al., 1995c). Following initial transtension, the sag-basin evolved into a horst and graben style rift-basin, in which the Goodin Inlier was uplifted as a 'horst' block. The Windplain Subgroup, which was initially deposited on Archaean basement, was eroded from the top of the uplifted Goodin Inlier and

Figure 19. Interference anticlinal mesofolds in quartz arenite of the Juderina Formation (AMG 056993)

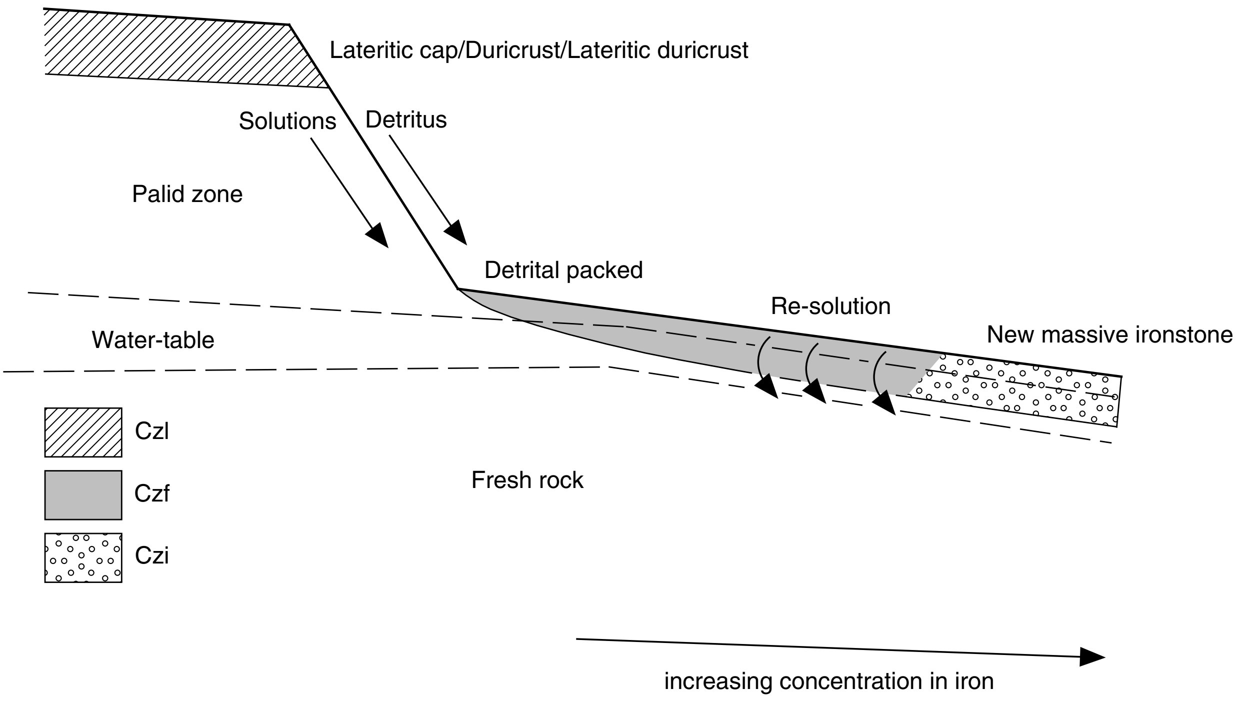

Figure 20. Schematic representation of weathering profile and weathering processes (after Goudie, 1973)

re-sedimented in sub-basins as part of the Mooloogool Subgroup. This is supported by sedimentological evidence in Adamides (1998), where diamictite beds of the Doolgunna Formation contain exotic blocks of the Bubble Well Member (Doolgunna graben of Pirajno, 1996; Adamides, 1998). However, the faulted thin outlier of quartz arenite (*ⲢYjf;* see **Juderina Formation**) is the only evidence of the Windplain Subgroup initially overlying the Goodin Inlier. These rocks were deformed along the northern margin of the Archaean Yilgarn Craton, during the c. 1.8 Ga Capricorn Orogeny (Tyler and Thorne, 1990), which records oblique convergence and collision of the Yilgarn and the Pilbara Cratons.

On MOOLOOGOOL, Proterozoic sedimentary and igneous rocks are commonly unmetamorphosed, or metamorphosed to low grades. Lower greenschist-facies metamorphism affects the Archaean granitoid rocks of the Goodin Inlier and the sedimentary rocks of the Juderina Formation around its southern margin. Albite, sericite, epidote, and chlorite are the most common mineral phases. Mafic rocks of the Killara Formation contain minor amounts of quartz, actinolite, chlorite, prehnite, calcite, epidote, and possibly stilbite as metamorphic minerals. This low-grade metamorphic assemblage straddles the sub-greenschist to greenschist facies boundary and is consistent with temperatures between 100 and 250°C and pressures of approximately 2 to 6 kbar (Bucher and Frey, 1994).

Deformation

On MOOLOOGOOL, faults and folds dominantly trend northwest and east-northeast. The intensity of deformation decreases from the edge of the Goodin Inlier in the north, to the margin of the Yilgarn craton in the south. At least two deformation events are recognized on MOOLOOGOOL.

The dominant structural fabric on MOOLOOGOOL is attributed to D_1, which developed during the Capricorn Orogeny. During this time, the Goodin Inlier acted as a stable buttress about which rocks were variably deformed. The only evidence of internal deformation of the Goodin Inlier on MOOLOOGOOL, is localized northwest-trending D_1 fractures and faults, along which mafic dykes were emplaced. The southwest contact of the Goodin Inlier, is defined by a series of high-angle shear zones, probably with an accompanying reverse movement, resulting in the tectonic slicing of the unconformable contact between the granitoid rocks and the Juderina Formation. Anticlinal mesofolds are present in rocks of the Juderina Formation (Fig. 19).

On west-central MOOLOOGOOL, open to closed, shallow to steep, east plunging folds (F_1) are present. An east-northeasterly trending fault zone, dipping 40° to the southeast locally, extends through the areas around North Bore and Rainlover Well and is associated with dykes, quartz veins, and aeromagnetic lineaments. In the vicinity of Rainlover Well, dolerite sills of the Killara Formation that intrude the Doolgunna Formation are dextrally sheared along the fault zone. West-northwesterly and northwesterly trending faults dominate west-central MOOLOOGOOL, and cut through the Killara, Doolgunna, and Johnson Cairn Formations. On northern MOOLOOGOOL, the sedimentary and volcanic rocks are moderately to steeply dipping, with local open folds. On southern MOOLOOGOOL, by contrast, beds of the Maraloou Formation gently dip to the south, north, or northeast. The change in dip direction on southern MOOLOOGOOL could be due to gentle folding.

The second deformation event (D_2) involved localized late, northerly to northeasterly trending brittle faulting. In the southwest, some of these faults juxtapose the Juderina Formation against the Maraloou Formation. On northwest MOOLOOGOOL, D_2 northerly trending faults displace D_1 west-northwesterly trending faults.

Mineralization

On MOOLOOGOOL, mineralized localities outcrop as stratabound gossans and fault-associated gossanous quartz veins. Rock grab samples from some of these localities were analyzed for trace elements, and results are presented in Table 4.

Stratabound gossans, derived from the oxidation of sulfides, are present in the siltstone – black-shale succession of the Maraloou Formation, and thinly bedded arenaceous units of the Juderina Formation. Black-shale hosted gossans form small, sparse outcrops, distributed along a strike length of approximately 6 km, 2.5 km south of Rockhole Bore (Locality 10, AMG 165907). These gossans are situated parallel to, or along, the contact between the Maraloou and Killara Formations. They consist of hematite, goethite, and limonite forming well-defined boxworks after sulfides, in places cut by veins of goethite and limonite. Relict sulfides are locally recognizable and consist of pyrite and chalcopyrite. The black-shale hosted gossans have anomalous Ba, Pt, Pd, Cu, and Zn (Table 4).

Approximately 3 km east of North Bore (Locality 6), the previously mentioned stratabound zone of sulfide mineralization was intersected by drillholes GD-1, -2, and -3, at depths between 90 and 100 m (Guj and McIntosh, 1984). This is a zone of hydrothermal alteration and disseminated sulfides, hosted in a gabbroic sill, which intruded pyritic black-shales of the Johnson Cairn Formation (Fig. 10). The zone is at the base of the sill, and is parallel to the contact with underlying black shale units. Hydrothermal mineral phases in the gabbroic rock include epidote, biotite, hornblende, chlorite, sericite, and aggregates of microcrystalline montmorillonite clays. Granophyric intergrowths are associated with this alteration. Sulfides are represented by pyrite, chalcopyrite, pyrrhotite, and lesser arsenopyrite. Assays of core from three drillholes revealed anomalous Au (20 to 33 ppb), Zn (1360 to 2230 ppm), and Cu (650 ppm) in core lengths less than 3 m (Guj and McIntosh, 1984).

Gossans hosted in the thinly bedded arenaceous units of the Juderina Formation on northwestern MOOLOOGOOL, near the contacts with the Goodin Inlier, contain anomalous Pt, Pd, V, and Cu (Table 4).

(d) volcaniclastic rock

Table 4. Trace element analyses of gossans

GSWA sample	*137743A*[(a)]	*119423*[(a)]	*119424*[(a)]	*119425*[(a)]	*P173143*[(b)]	*P173146*[(b)]	*P173147*[(b)]	*P173148*[(b)]	*P173160*[(b)]	*130916*[(c)]	*130940*[(d)]	*130943*[(e)]	*130944*[(f)]	*130948*[(e)]
Easting	*715625*	*718400*	*714000*	*709500*	*709400*	*709400*	*709400*	*709400*	*709400*	*721251*	*712232*	*710208*	*710005*	*705488*
Northing	*7090692*	*7091500*	*7091300*	*7087300*	*7120000*	*7120000*	*7120000*	*7120000*	*7120000*	*7112427*	*7114223*	*7098337*	*7098087*	*7099400*
						Parts per billion								
Au	3	–	–	–	33	6	81	19	3	1	–	–	–	–
Pt	23	5	5	5	22	26	21	3	6	–	–	–	–	41
Pd	6	8	1	1	8	5	3	24	3	1	–	–	–	16
						Parts per million								
Cr	43	26	66	32	16	37	5	60	109	6	6	22	54	97
Co	2	18	11	138	38	10	74	75	12	11	8	19	282	23
Cu	251	260	27	447	2770	2000	12400	2180	100	683	170	499	205	1778
Ni	44	57	91	463	164	20	132	89	81	23	33	39	275	178
Sc	31.0	24.0	5.2	5.4	–	–	–	–	–	52.0	8.4	29.0	23.0	76.0
V	41	140	15	23	101	54	30	143	58	45	24	68	140	284
Y	6	19	15	85	–	–	–	–	–	23	10	26	104	14
Zn	362	258	197	1855	403	70	70	77	210	349	111	158	462	156
Zr	5	6	5	23	56	31	22	52	37	–	–	–	–	135
Sb	–	–	–	–	5.0	5.0	25.0	5.0	5.0	–	–	0.5	–	–
As	108.0	19.0	0.7	217.0	197.0	49.0	761.0	59.0	40.0	–	6.3	16.0	–	43.0
Cd	0.1	0.1	0.1	5.6	7.0	5.0	7.0	5.0	5.0	–	0.1	0.3	0.9	0.6
Ce	204.0	12.0	4.0	29.0	–	–	–	–	–	23.0	5.3	42.0	76.0	23.0
Ga	8.20	11.00	8.60	20.00	–	–	–	–	–	2.20	0.84	4.50	2.90	9.70
La	127.0	6.0	22.0	14.0	–	–	–	–	–	7.0	3.3	23.0	52.0	11.0
Pb	181.0	12.0	4.0	15.0	25.0	49.0	82.0	67.0	12.0	4.8	56.0	11.0	4.5	33.0
Mo	1.8	5.4	1.1	23.0	13.0	5.0	79.0	8.0	5.0	1.1	0.6	0.5	0.5	2.5
Nb	1.2	0.6	0.5	1.8	–	–	–	–	–	5.9	0.5	6.2	4.0	3.9
Rb	3.70	3.50	1.00	17.00	–	–	–	–	–	1.23	0.38	1.20	1.30	5.50
Se	–	–	–	–	–	–	–	–	–	2.9	1.0	3.3	3.2	7.4
Ag	0.09	–	–	–	<1	<1	<1	<1	–	0.22	–	0.18	–	0.17
Sr	37.0	6.6	3.5	9.4	–	–	–	–	–	2.0	4.3	60.0	9.3	13.0
Th	5.30	1.40	0.60	2.40	–	–	–	–	–	1.15	0.58	0.80	0.62	34.00
Sn	0.5	0.4	0.4	0.4	–	–	–	–	–	1.6	2.2	9.7	2.6	3.5
W	3.5	1.4	1.0	1.0	9.0	5.0	9.0	5.0	9.0	2.9	0.1	1.2	1.5	0.4
U	5.90	1.00	0.11	16.00	–	–	–	–	–	2.00	1.03	1.25	0.26	1.95
S	2200.00	700.00	100.00	900.00	1400.00	1030.00	344.00	172.00	1590.00	0.01	0.20	0.47	0.05	0.06
Ba	4477	156	132	373	1190	2430	197	575	6050	28	31	83	42	199

NOTES: (a) Gossan in black shale
(b) Gossan
(c) Ferruginous quartz
(d) Ferruginous quartz vein
(e) Gossanous siltstone
(f) Ironstone

Analyses performed at AMDEL, using ICP and ICP-MS after a mixed acid solution. Analyses of sample numbers P173143 to P173160 were kindly provided by Morning Star Resources. These analyses were performed at Australian Laboratory Services, using XRF spectrometry.

Ferruginous quartz-veins are associated with northwest-trending faults and are hosted in rocks of the Juderina Formation on northwestern MOOLOOGOOL. They contain slightly elevated values of Cu and Zn (Table 4).

Acknowledgments

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Appendix

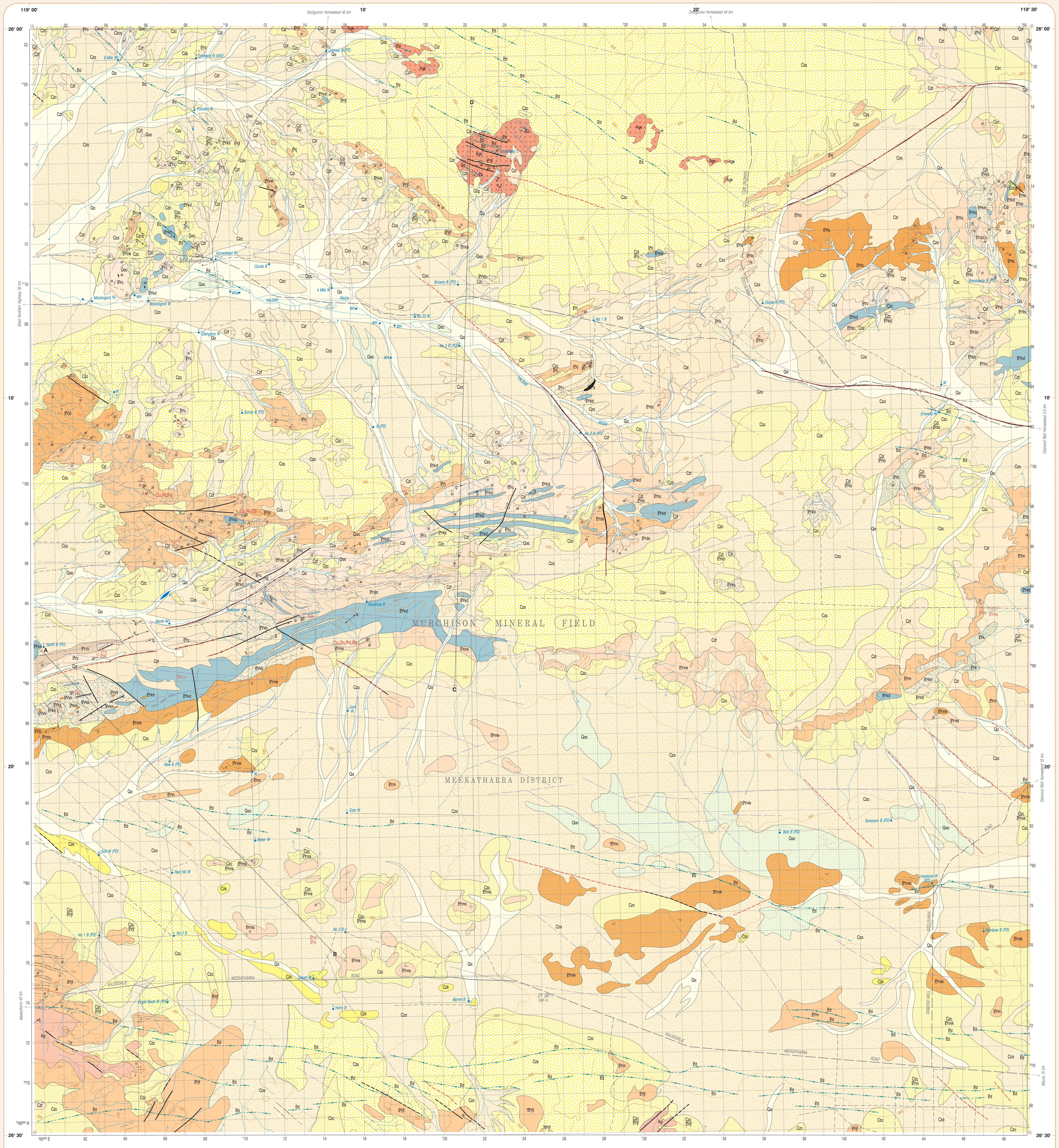
Gazetteer of localities

Locality	*Latitude (S)*	*Longitude (E)*	*AMG coordinates*	
			easting	*northing*
Breakaway Bore	26°06'47"	119°28'55"	748200	7109400
Browny Bore	26°07'36"	119°12'12"	720300	7108400
Cave Hill	26°03'52"	119°05'06"	709000	7115500
Desert Well	26°25'51"	119°08'27"	713500	7074800
Diamond Well Homestead	26°11'17"	119°32'12"	753500	7101000
Divide Bore	26°07'30"	119°21'55"	736500	7108300
Glengarry Creek	26°22'04"	119°01'28"	702000	7082000
Glengarry Range	26°11'14"	119°00'40"	701000	7102000
Killara Homestead	26°21'02"	119°57'25"	695300	7084000
Limestone Well	26°23'17"	119°27'03"	744500	7079000
Meekatharra	26°36'00"	119°30'00"	649400	7057000
Mooloogool Homestead	26°06'18"	119°05'24"	709000	7111000
North Bore	26°16'46"	119°00'18"	700200	7091800
North Well	26°16'10"	119°04'04"	706500	7092800
Rainlover Well	26°15'49"	119°06'24"	710400	7093400
Rockhole Bore	26°15'39"	119°10'00"	706400	7093600
Utahlarba Spring	26°03'27"	119°13'59"	723400	7116000
Wiluna	26°35'00"	119°14'00"	224400	7056700
Yalgar River	26°07'22"	119°06'01"	710000	7109000

NOTE: All AMG coordinates are in zone 50 with the exception of Wiluna, which is in zone 51

MOOLOOGOOL

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



PHANEROZOIC — CAINOZOIC — QUATERNARY

- Qa — Alluvium—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, nodules, 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

PROTEROZOIC

- q — Quartz vein
- go — Gossan; gossanous zone
- Ꝑd — Dolerite dyke; dashed where interpreted from aeromagnetic data

Yerrida Group — YERRIDA BASIN

Mooloogool Subgroup

- ꝐYm — **MARALOOU FORMATION:** thin-bedded siltstone and carbonaceous shale; local quartz wacke, intercalated basalt, and dolerite sills
  - ꝐYms — Thin-bedded siltstone
  - ꝐYmk — Fine-grained dolomitic rocks and calcareous siltstone; local intercalations of thin amygdaloidal basalt
- ꝐYk — **KILLARA FORMATION:** undivided mafic intrusive and extrusive rocks
  - ꝐYkd — Dolerite in dykes and sills
  - ꝐYkb — Aphyric tholeiitic basaltic lava
  - ꝐYkc — **Bartle Member:** chertified microbial laminites with barite and anhydrite nodules
  - ꝐYkh — Chert, and silicified mafic rock
  - ꝐYkx — Basaltic volcanic breccia
- ꝐYd — **DOOLGUNNA FORMATION:** arkosic sandstone; minor granulestone (section only)
  - ꝐYda — Arkosic wacke, and kaolinitic quartz wacke; minor pebble beds
  - ꝐYds — Laminated quartz sandstone; minor pebble beds
- ꝐYt — **THADUNA FORMATION:** lithic wacke; subordinate shale
  - ꝐYta — Quartz wacke and litharenite; minor shale
  - ꝐYts — Siltstone and shale; minor quartz wacke locally containing fragments of basaltic scoria, and thin mafic volcaniclastic lenses

Windplain Subgroup

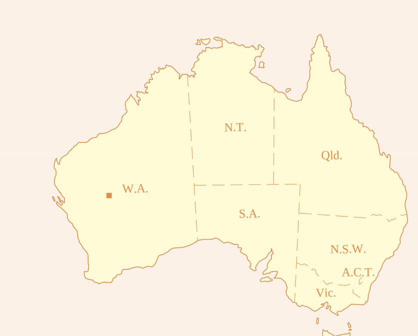
- ꝐYc — **JOHNSON CAIRN FORMATION:** argillaceous siltstone and thin-bedded dolomite; minor wacke and arenite; (brecciated rock)
  - ꝐYcw — Quartz wacke and minor shale
  - ꝐYck — Dolomitic rocks, locally oolitic; locally intercalated with basaltic lava
- ꝐYj — **JUDERINA FORMATION:** quartz sandstone; minor ferruginous quartz arenite; local siltstone, chert breccia, and pebble beds
  - ꝐYjb — **Bubble Well Member:** stromatolitic chert and chert breccia
  - ꝐYja — Thick-bedded arenite with widespread mudstone intraclasts; minor intercalated shales
  - ꝐYjf — **Finlayson Member:** quartz arenite; commonly ripple-marked

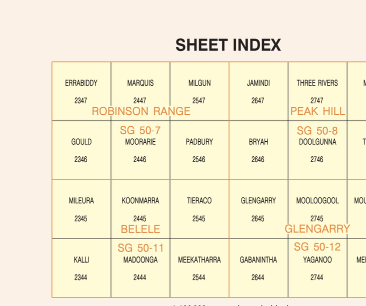
ARCHAEAN

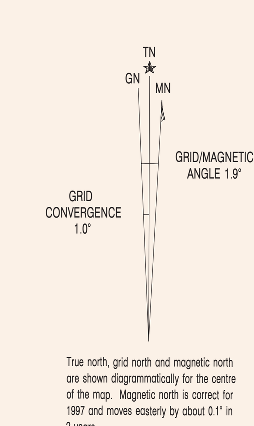
- Age — Equigranular to porphyritic granitoid rock, undivided; with aplitic phases (GOODIN INLIER)
- Ag — Granitoid rock, undivided; locally saprolitic (YILGARN CRATON)

Symbols

- Geological boundary
  - exposed
  - concealed
- Fault
  - exposed
  - concealed
  - concealed, interpreted from aeromagnetic data
  - normal; inclined showing dip
  - relative displacement
- Strongly foliated rock
- Fold, showing trend and plunge direction
  - anticline; exposed
  - syncline; exposed, concealed
  - anticline, small-scale showing orientation of axial surface and direction of plunge
  - minor anticline, showing plunge direction
- Bedding, showing strike and dip
  - inclined
  - horizontal
  - overturned
  - interpreted from aerial photographs
    - 0—15°
    - 15—45°
    - trend
- Cleavage, showing strike and dip
  - inclined
- Fracture or joint, showing strike and dip
  - inclined
- Veins, showing dip
  - inclined
- Airphoto lineament
- Aeromagnetic lineament
- Road, unsealed
- Track
- Fence, generally with track
- Homestead — Mooloogool
- Building
- Horizontal control, minor
- Breakaway
- Sand dune
- Contour line, 20 metre interval
- Watercourse, ephemeral
- Bore, well — B, W
- Windpump
- Tank — T
- Waterhole — WH
- Spring, pool — S, P
- Abandoned — (abd)
- Position doubtful — (PD)
- Mineral exploration drillhole, showing subsurface data — ꝐYms
- Mineral occurrence
  - Barium — Ba
  - Cobalt — Co
  - Copper — Cu
  - Nickel — Ni
  - Paladium — Pd
  - Platinum — Pt
  - Zinc — Zn

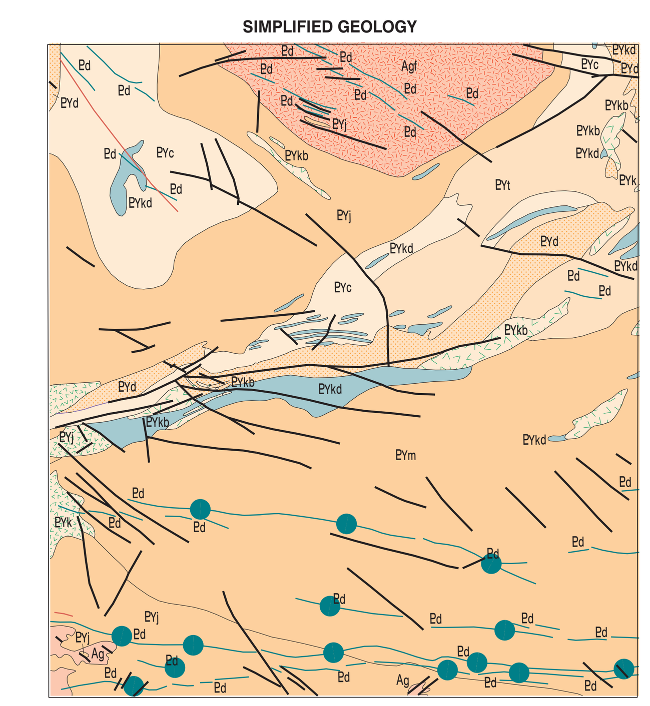






True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1997 and moves easterly by about 0.1° in 2 years

SIMPLIFIED GEOLOGY

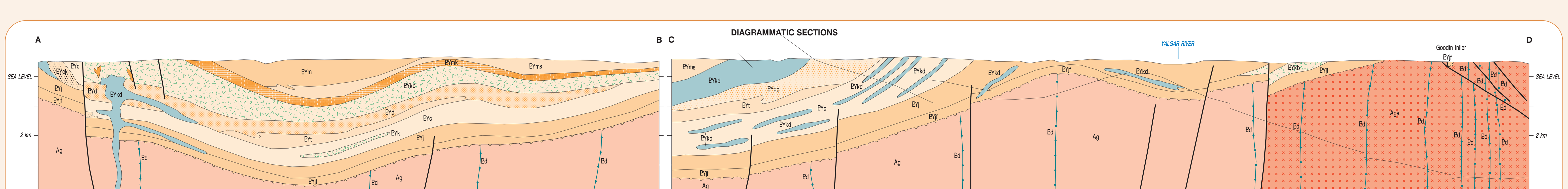


- Ꝑd — Dolerite dyke
- Maraloou Formation
- Killara Formation
  - Basalt
  - Dolerite
- Doolgunna Formation
- Thaduna Formation
- Johnson Cairn Formation
- Juderina Formation

Yerrida Group — YERRIDA BASIN

- Age — Granitoid rock — GOODIN INLIER
- Ag — Granitoid rock — YILGARN CRATON

DIAGRAMMATIC SECTIONS



DEPARTMENT OF MINERALS AND ENERGY
L. C. RANFORD, ACTING DIRECTOR GENERAL

GOVERNMENT OF WESTERN AUSTRALIA
HON. NORMAN MOORE, M.L.C.
MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PIETRO GUJ, DIRECTOR

SCALE 1:100 000

1000 Metres 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

The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions

Reference points to align maps based on the previous datum, AGD84, have been placed near the map corners

Geology by F. Pirajno, N. G. Adamides, and S. A. Occhipinti 1995

Edited by D. Ferdinando and G. Loan

Cartography by P. Taylor

Topography from the Department of Land Administration Sheet SG 50-12, 2745, with modifications from geological field survey

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SHEET 2745 FIRST EDITION 1997