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1999/9

GOVERNMENT OF
WESTERN AUSTRALIA

GRAVITY DATA — WYLOO 1:250 000 SHEET WESTERN AUSTRALIA

by R. P. Iasky and S. Shevchenko

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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Perth 1999

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REFERENCE
The recommended reference for this publication is:
IASKY, R. P., and SHEVCHENKO, S.,1999, Gravity data — Wyloo 1:250 000 sheet, Western Australia: Western Australia Geological Survey, Record 1999/9, 22p.

National Library of Australia Card Number and ISBN 0 7309 6647 X

Printed by Expo Document Copy Centre (WA) Pty Ltd, Perth, Western Australia

Copies available from:

Information Centre
Department of Minerals and Energy
100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
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by

R. P. Iasky and S. Shevchenko

Abstract

The gravity field of the WYLOO 1:250 000 map sheet was measured over an irregular 4 km grid, and proved to be a successful adjunct to the Geological Survey of Western Australia's helicopter-assisted regional regolith and geochemical mapping program. The density of stations collected in this program was about four times greater than the previously collected gravity data by the Bureau of Mineral Resources (now the Australian Geological Survey Organisation), and the resulting Bouguer values are accurate to ±1 μm/s^2 compared to ±10 μm/s^2 for the previous dataset. The improved accuracy is attributed to more accurate positioning using Global Positioning System methods. Because of the more densely spaced grid and improved accuracy, the structural elements on WYLOO are resolved better than they were from the older dataset.

Gravity lineaments in the Hamersley Basin are interpreted as basement faults initiated during the Fortescue Group rifting and re-activated during the Capricorn Orogeny. Northeasterly trending lineaments are interpreted as much younger (?Early Cretaceous) sinistral transcurrent faults.

KEYWORDS: gravity data, aeromagnetic surveys, gravity anomalies, magnetic anomalies, Hamersley Basin, Ashburton Basin, Bangemall Basin, Capricorn Orogen, Global Positioning System data

Introduction

In 1998, the Geological Survey of Western Australian (GSWA) initiated the systematic recording of gravity data over 1:250 000 map sheet areas as an adjunct to the regional regolith and geochemical mapping program. The Australian Geological Survey Organization (AGSO; previously the Bureau of Mineral Resources — BMR) assisted this new initiative by providing five gravity meters and four Ashtech Z12 differential Global Positioning System (GPS) receivers. The combined geochemical and geophysical mapping program was assisted by helicopters, and incorporates the collection of soil samples, a description of the regolith, and the recording of gravity data over an irregular 4 km grid.

The first 1:250 000 map sheet to be completed by the combined geochemical and geophysical program was WYLOO* (SF 50-10). The WYLOO sheet lies within latitudes 22°00' and 23°00'S and longitudes 115°30' and 117°00'E, and is about 100 km southeast of Onslow and about 120 km east of the Exmouth Gulf in Western Australia (Fig. 1). There has been considerable mineral exploration in the area, resulting in the production of lead, copper, gold, amethyst, and iron from the Ashburton and west Pilbara mineral fields (Pye et al., 1999; MacLeod, 1966; Blockley, 1971; Marston, 1979; Blight, 1985; Seymour et al., 1988; Cooper et al., 1998; Witt et al., 1998).

The available geophysical data on WYLOO include regional gravity collected by AGSO and aeromagnetic surveys conducted by BHP Petroleum. Most of the AGSO gravity data were collected in 1969 along an 11 km grid, and in 1977 two additional short traverses collected with stations spaced about 5 km apart. The aeromagnetic data were recorded during a 1973 survey, flown with a line spacing of 500–1000 m, and a 1983 survey with a line spacing of 1500 m. To delineate local structural features, mineral exploration companies have also carried out numerous, small, detailed potential-field surveys, but these data are not readily available.

The new gravity data collected in 1998 (Plate) resolve the structural features on WYLOO better than the previous data.

Geological setting

The rocks on WYLOO range from Archaean to Mesoproterozoic in age, with a few small outcrops of Cretaceous age in northwestern WYLOO, and a veneer of Cainozoic sediments over most of the sheet (Seymour et al., 1988). Rocks of the Capricorn Orogen (Myers, 1990) outcrop in the southwestern part of the sheet, with rocks of the Hamersley Basin forming part of the Pilbara Craton (Trendall, 1990) in the northeast (Fig. 2). The Capricorn Orogen can be subdivided into the Gascoyne Complex and the Ashburton Basin. The Bangemall Basin overlies the Capricorn Orogen in the western part of the sheet. The following summary of the tectonic evolution of the area has been extracted from the detailed studies by Blight (1985), Seymour et al. (1988), Thorne (1990a,b), Tyler (1990), Tyler and Thorne (1990), Thorne and Seymour (1991), and Thorne and Hickman (1998).

The oldest rocks on WYLOO are Archaean (>2750 Ma) granite–greenstones (Fig. 2) exposed in the core of the Wyloo Dome — an anticlinal structure in the central part of the sheet. In the northeast, Hamersley Basin rocks (Mount Bruce Supergroup; Fig. 3) overlie the Pilbara Craton. These rocks consist of basalts (Fortescue Group) deposited in the initial rift, which are overlain by banded iron-formation, carbonate, fine-grained siliciclastic rock, and acidic volcanics (Hamersley Group), deposited in a stable shelf or platform environment open to the deep ocean. Finally, fine-

* Capitalized names refer to standard 1:250 000 map sheets.

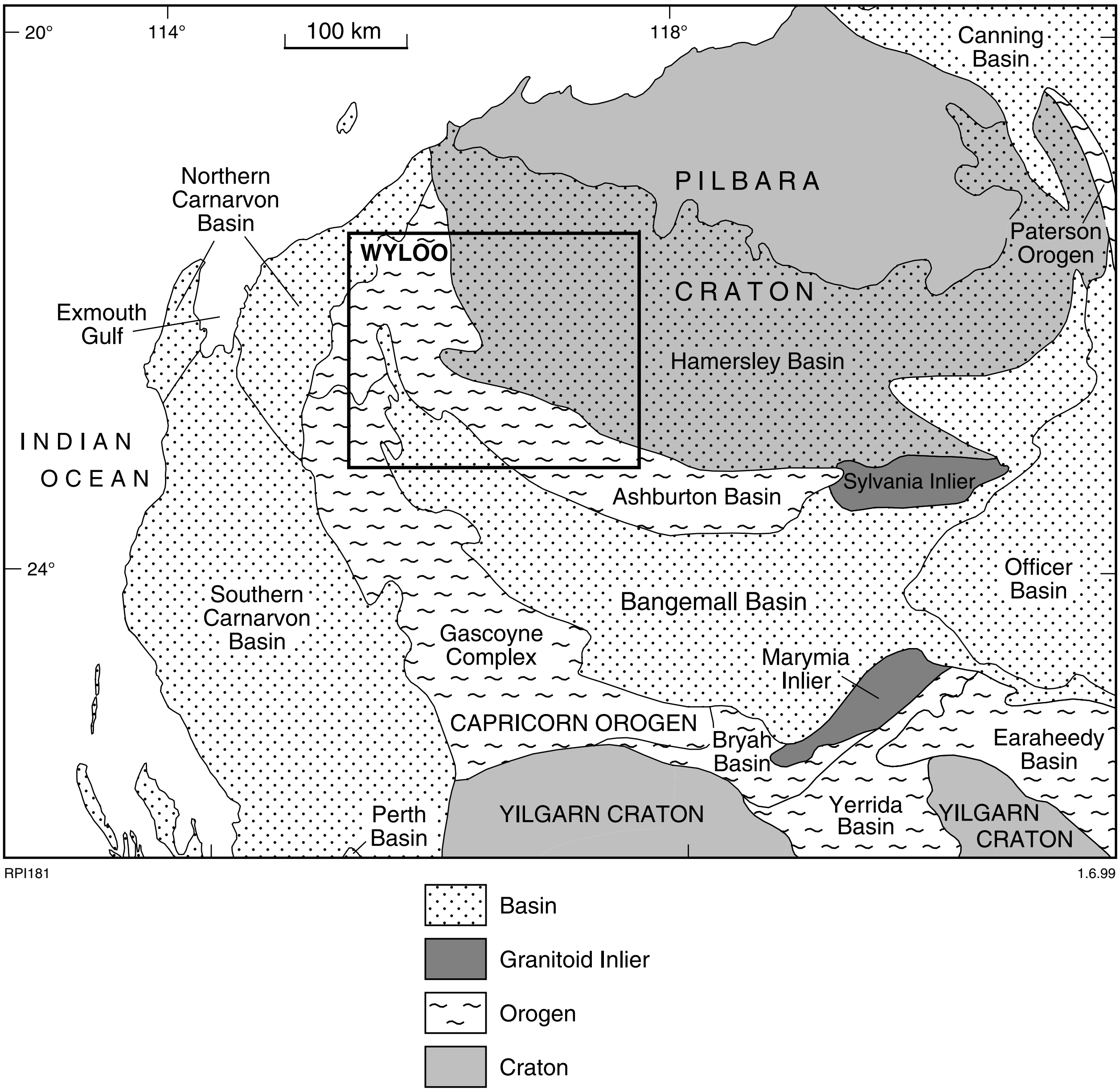

Figure 1. Location of the Wyloo 1:250 000 sheet, showing major tectonic elements

to coarse-grained siliciclastic rocks (Turee Creek Group) were deposited in a shallow-water environment (Tyler and Thorne, 1990). Folding of the Hamersley Basin rocks was followed by deposition of sandstone, conglomerate, and basalt of the lower Wyloo Group in the Ashburton Basin after 2200 Ma (Martin et al., 1998).

The Capricorn Orogen was produced by the collision of the Yilgarn and Pilbara Cratons between 1840 and 1800 Ma (Tyler et al., 1998), when folding and thrusting occurred and a foreland basin developed along the margin of the Pilbara Craton (upper Wyloo Group of the Ashburton Basin). In the foreland basin, siliciclastic sediments were deposited initially in delta and coastal

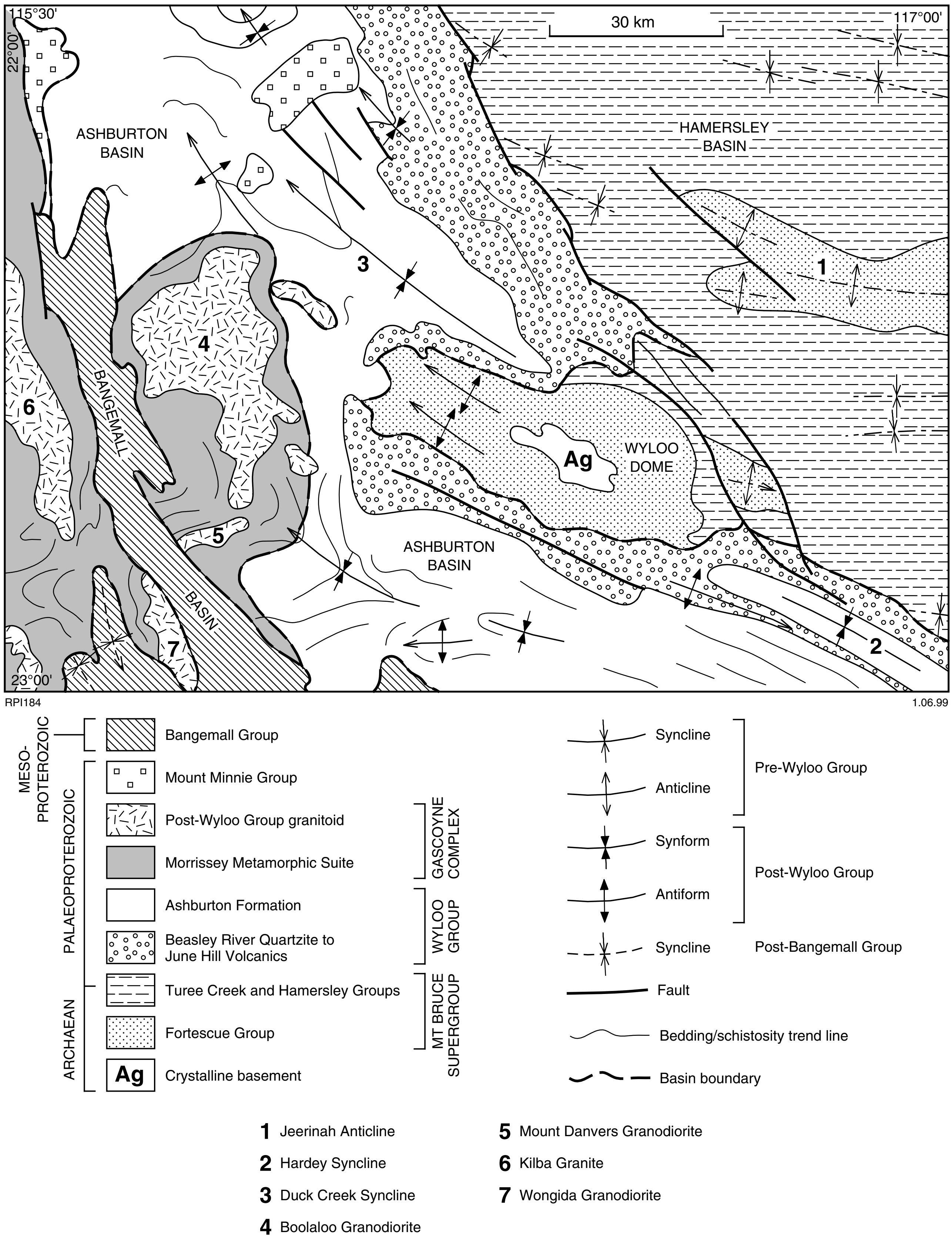

Figure 2. Simplified geology of the WYLOO 1:250 000 sheet

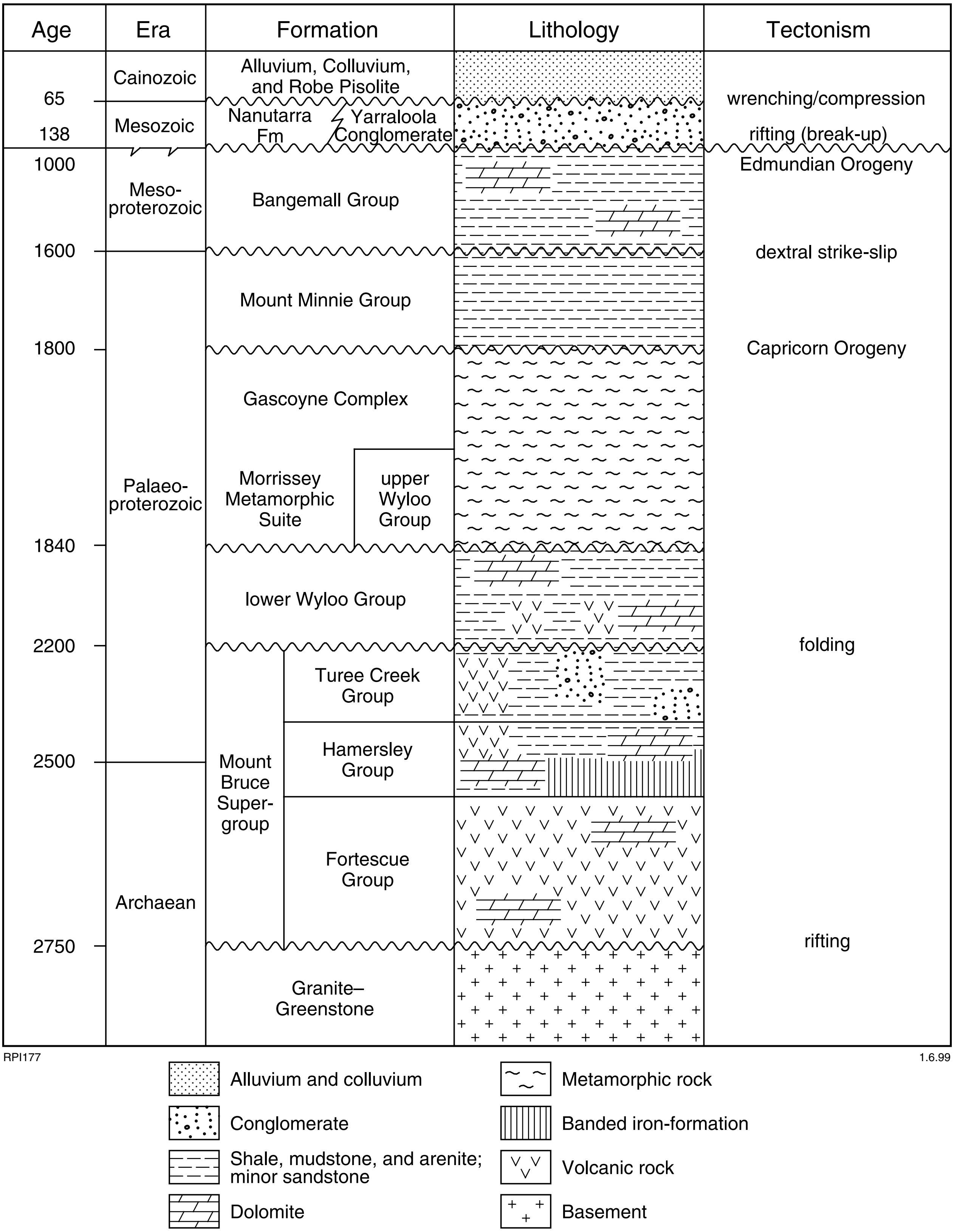

Figure 3. Simplified stratigraphy of the WYLOO 1:250 000 sheet

environments, and later, carbonate rocks and basalt, followed by turbiditic sandstone and siltstone, were deposited in a shallow-marine to deep-water environment. These rocks amount to a thickness of about 12 km, and were weakly to strongly deformed to form low-grade metasedimentary and metavolcanic rocks. The rocks become progressively more deformed to the southwest, and were metamorphosed to medium to high grade (Morrissey Metamorphic Suite; Fig. 3). Both the Morrissey Metamorphic Suite and the Wyloo Group were intruded by granitic rocks at c. 1800 Ma (Krapez and McNaughton, 1999).

Following the Capricorn Orogeny, sands and silts derived from high ground north and east of the Ashburton Basin were deposited within fan-deltas (Mount Minnie Group) in the northwestern part of WYLOO. At the beginning of the Mesoproterozoic (c. 1600 Ma), after an episode of dextral strike-slip movements on major faults, siliciclastic rocks with minor carbonate beds (Bangemall Group) were deposited in a terrestrial to open-marine shelf environment. Folding of the Bangemall Group occurred during the c. 1000 Ma Edmundian Orogeny.

A large gap in the geological history of WYLOO exists until the deposition of the Cretaceous Nannutarra and Yarraloola Conglomerates. During this time, some tectonism occurred within the area when Australia separated from Greater India.

After the break up of Australia from Greater India, thin fluvial to shallow-marine siliciclastic sediments (Nannutarra Formation and Yarraloola Conglomerate) were deposited in the northwesternmost part of WYLOO (Hocking et al., 1987). These Cretaceous strata are relatively undeformed. Finally, a thin layer of colluvial and alluvial sediments were deposited over the central and western part of WYLOO, during the Tertiary and Quaternary.

Gravity data

Previous data

Between 1969 and 1972, as part of a systematic nationwide program to measure the gravity field, BMR carried out regional gravity surveys over an 11 km grid across parts of Western Australia and South Australia (Fraser and Pettifer, 1980). WYLOO was covered in 1969. In 1977, BMR carried out crustal studies over selected sites in the Pilbara area by collecting seismic refraction, gravity, and magnetic data (Drummond, 1979). As part of the project, gravity data were collected along two perpendicular gravity traverses, at an average station spacing of 5 km, across the Wyloo Dome.

The BMR surveys were conducted using La Coste – Romberg model G meters to measure gravity. Barometers were used for height control and stations were located using topographic maps. The accuracy of the resultant Bouguer gravity is ± 10 $\mu m/s^2$, which is entirely dependent on the accuracy of the barometric height (about ± 1.8 m; Darby, 1970). This resolution provides only a regional picture of the gravity field (Fig. 4).

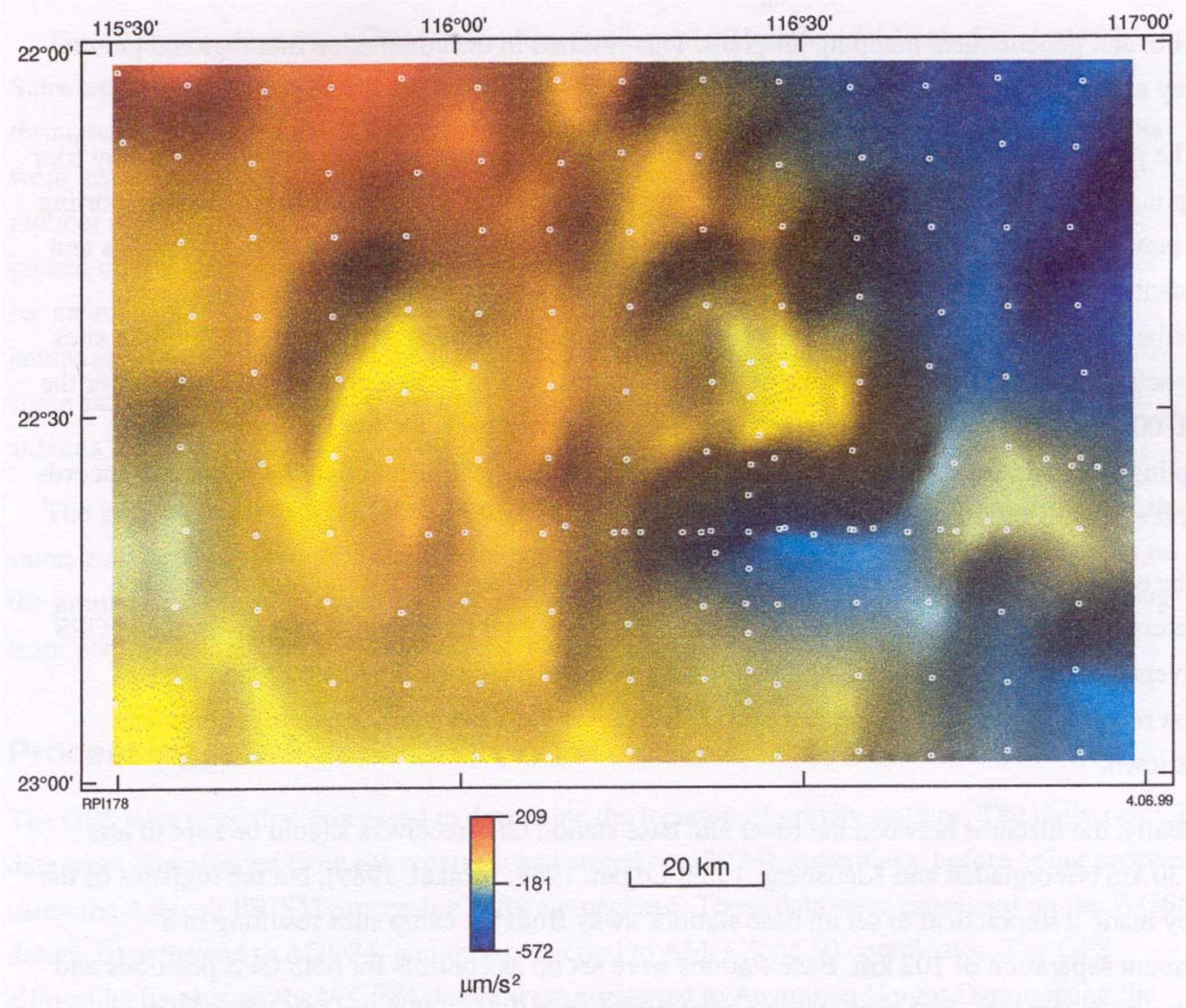

Figure 4. Bouguer gravity using the 11 km-grid data from the AGSO database

New data acquisition

The helicopter-supported acquisition of the new gravity data on WYLOO began on 19 May 1998 and was completed on 8 June 1998. A total of 1254 stations were recorded along an irregular 4 km grid. Included in the 1254 stations are 120 stations that were recorded along main roads using four-wheel drive vehicles. To fill in gaps and check dubious measurements, an additional 144 gravity stations were obtained between 12 and 16 August 1998. Appendix 1 is a summary of operations and processing. Digital and hard copies of the data are available through the publications section of AGSO.

The GSWA regional regolith and geochemical mapping program has been supported by helicopters since 1997, and its logistics are such that gravity data could be collected without affecting the geochemical sampling or substantially increasing helicopter flying time. Procedures were developed to carry out both tasks efficiently with minimum inconvenience to the regional regolith and geochemical mapping program. This resulted in the completion of a regional gravity survey at low marginal cost.

The previous geochemical sampling and regolith description at each site was carried out by four sampling teams, each consisting of a geologist and an assistant. Two helicopters, each transporting two sampling teams, leap-frogged each team between the designated sample sites. Geologists and assistants had about 10–12 minutes at each site to take a sample, find the GPS position, and describe the regolith before the helicopter returned to transport them to the next site. Sample sites were selected to coincide with creeks or drainage points, and to form a grid of about 4 km over the 1:250 000 map sheet. The additional gravity measurement at each site has required that each sampling team carries a gravity meter and that a differential GPS installed in the helicopter records the three-dimensional location of the site.

The equipment used to carry out the survey consisted of four La Coste – Romberg model G meters (G20, G101, G132, and G252) to record gravity, and three dual-frequency Ashtech GPS receivers to locate gravity stations — two rover receivers, one in each helicopter, and a base station receiver. A spare gravity meter and GPS receiver were available in case of equipment breakdown.

Ideally, the distance between the rover and base station GPS receivers should be kept to less than 30 km (Georgiadau and Kleusberg, 1988; Logan, 1988; Minkel, 1989), but the logistics of the survey made it impractical to set up base stations away from the camp sites resulting in a maximum separation of 102 km. Base stations were set up as controls for both GPS positions and gravity measurements. Two base stations were established (9861-7001 and 9861-7002), one in each of the two base camps set up in the map sheet area. Each base station consisted of a star picket extending about 1.5 m above ground, with a metal rod, flush with the ground, about 0.3 m from the star picket. The base stations were surveyed for location using first and second order Department of Land and Administration (DOLA) Bench Marks (Appendix 2). An indication of the accuracy in Australian Height Datum (AHD) height of the base stations is provided by the differences in the coordinates of Bench Marks observed by GPS against those provided by DOLA (1–15 cm; Appendix 2). Distances between base station and rover GPS receivers (gravity stations) ranged from a few kilometres to a maximum of 102 km, and the height accuracy achieved for all gravity stations is better than 1 m.

The two base stations were tied to the Isogal gravity station at Onslow (6792-0225) by first recording gravity at the base stations then at the Isogal station and again at the base stations, in one round trip. To increase the accuracy of the gravity measurement of the base stations, four independent measurements were taken, with two operators reading two gravity meters each. The gravity values of the two base stations are shown in Appendix 2 and were measured to an accuracy of 0.3 $\mu m/s^2$. All survey gravity stations collected by helicopter and four-wheel drive vehicles were tied to the two base stations.

The GPS recording was carried out in Kinematic mode (Hofmann-Wellenhof et al., 1993; Schwartz, 1990), with both the rover and base station GPS receivers recording continuously throughout the day. To easily identify the landing sites at the processing stage, helicopter pilots were instructed to enter the site number in the GPS receiver upon landing, and to remove that number on take-off. All sites were visited twice en route, when the helicopter dropped off and picked up the sampling team. At each site the helicopter was stationary and recorded GPS data for an average of 0.5–1 minute each time it landed. This period proved satisfactory if the antennae on the helicopter did not lose lock on satellites while travelling. Occasionally, lock on some satellites would be lost if the helicopter banked sharply when turning, thereby tilting the antenna from the horizontal and causing it to lose connection with a number of satellites.

The gravity readings were taken from the gravity meters that were placed on the ground at the same level as the helicopter's skids, whereas readings by four-wheel drive vehicle were taken on the ground at the level of the tyres. The average rate of acquisition was 20 stations per sampling team per day, amounting to 80 stations per day.

Processing

The GPS data were first processed to determine the location of gravity stations. The daily raw GPS data were downloaded from the receivers and stored on 120 Mb superdisks, before being processed using the Ashtech PRISM processing software package. These data were processed on the WGS84 datum, transformed to AGD84, and then converted to AMG Zone 50 coordinates. The GPS ellipsoidal heights on the WGS84 datum were converted to Australian Height Datum using the Australian National Geoid model.

Because two independent GPS recordings were taken at each station, the average position was calculated unless one of the recordings showed a high standard deviation (>1.0 m), in which case the worse of the two was discarded. The statistics for the measured stations generated by the PRISM software in a summary file include the standard deviation, post-fit carrier phase residual, Chi square, and position dilution of precision (PDOP). The standard deviation is the primary indicator used in evaluating the accuracy of the GPS measurement, although the other statistics may help identify specific problems in the measurement.

The daily gravity records from the four meters were entered in separate digital files and the following processing sequence was applied using in-house software:

1. correction for instrument drift (Telford et al., 1976);
2. tidal correction (Longman, 1959);
3. reduction to International Gravity Standardization Net 1971 (IGSN71) gravity datum (Wellman et al., 1985);

4. free air, latitude, and Bouguer corrections using a background density of 2.67 g/cm^3 (Telford et al., 1976).

Terrain corrections were not applied as the major part of the area is characterized by slightly undulating and open terrain. In the northeastern part of the sheet, terrain correction should probably be applied over the rugged Hamersley Range. Gravity measurements, however, were commonly taken in areas of low local relative relief and the effect of the terrain is assumed to be small.

When the data were reduced and Bouguer values calculated, they were gridded with a 1000 m grid cell using Intrepid software and imaged using ER Mapper software (Fig. 5 and Plate 1). The older, less accurate AGSO data were not included with the new data.

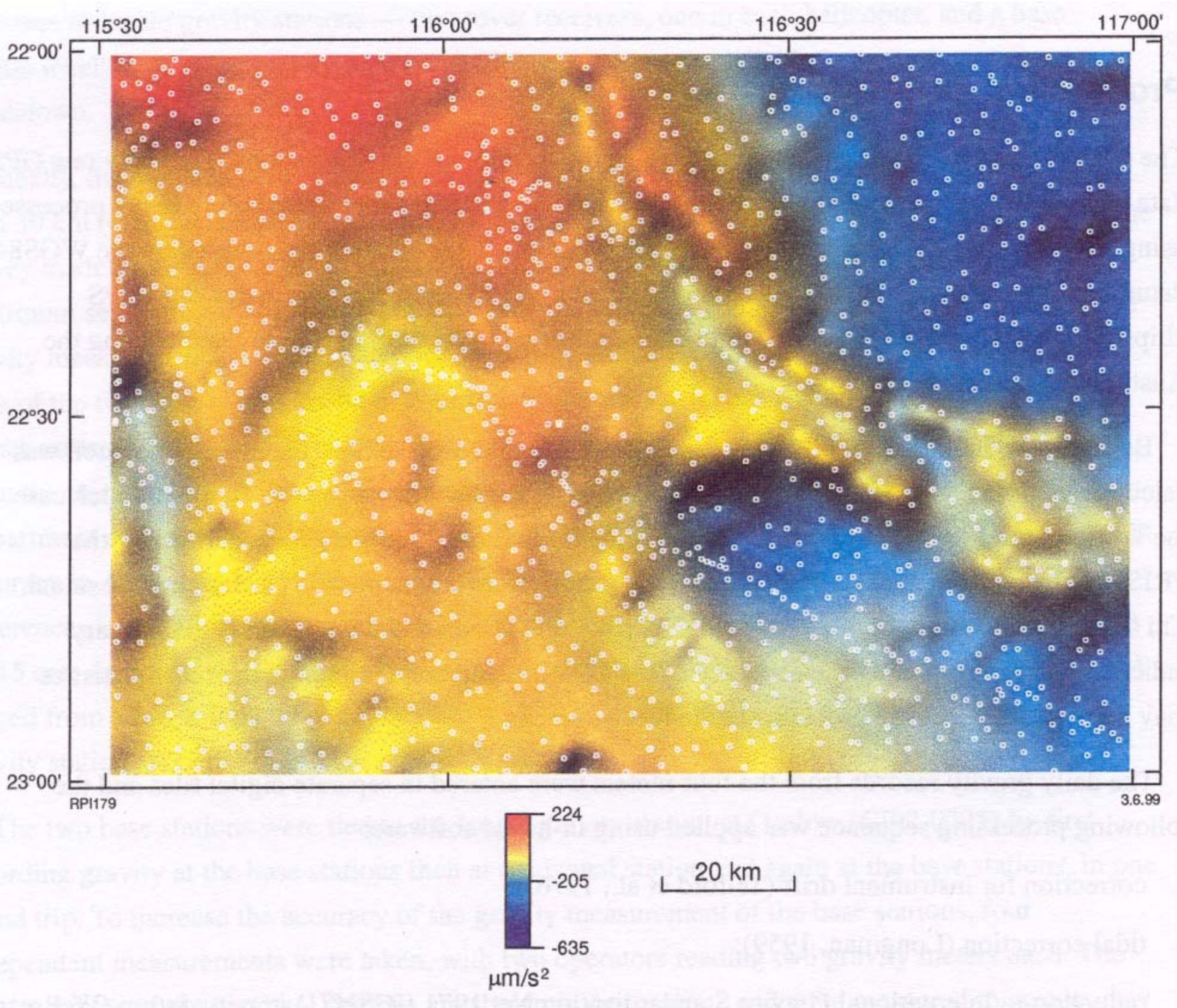

Figure 5. Bouguer gravity from the new data collected at an irregular grid of 4 km. Circles show locations of sites

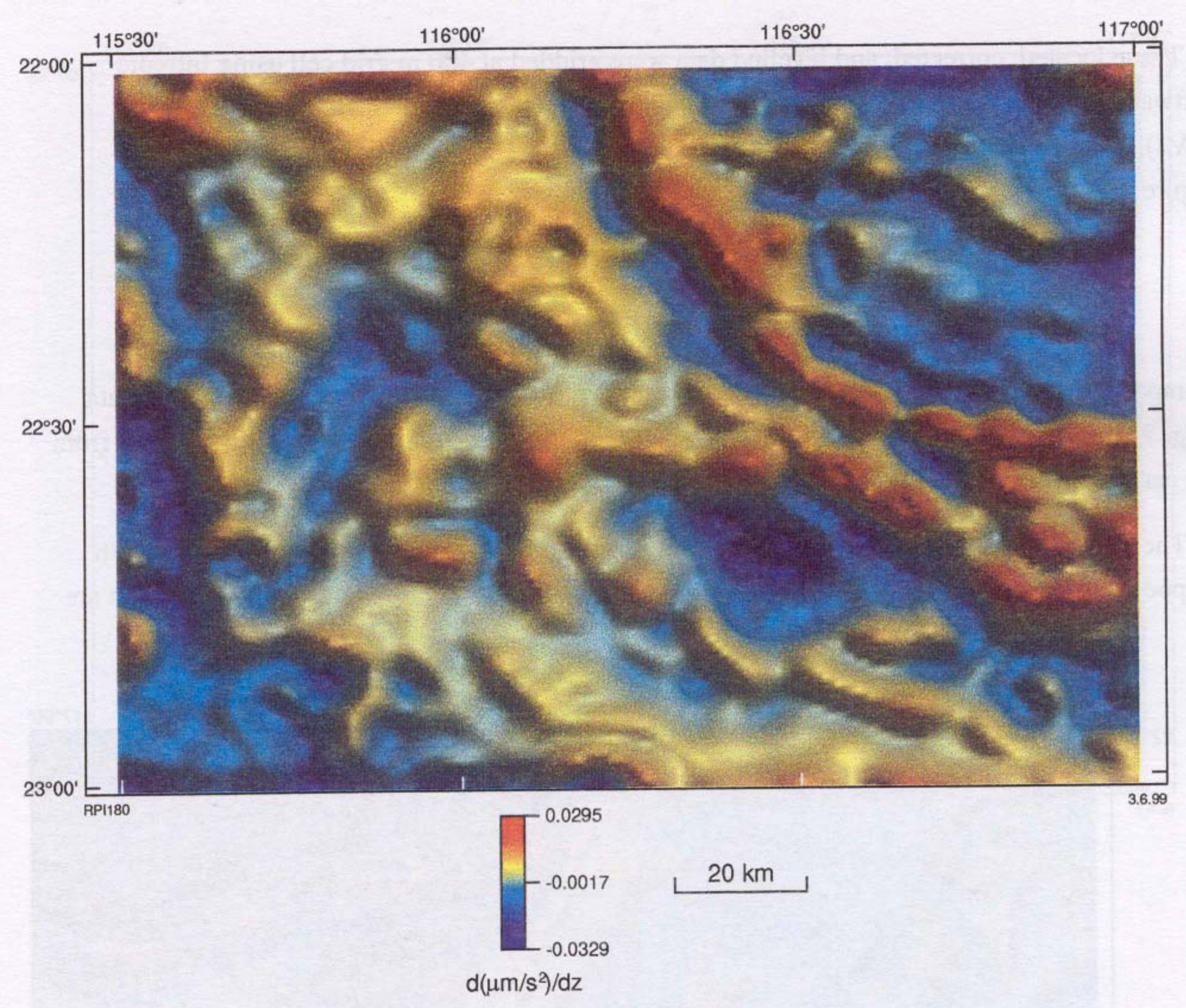

Figure 6. First vertical derivative Bouguer gravity from new data

To accentuate the higher frequency anomalies, a first vertical derivative calculation was applied to the gridded data. Aliasing effects created by the gridding process were removed by applying a low-pass filter with a cut-off frequency of 0.0002 cycles/m to eliminate wavelengths of less than 5 km (Fig. 6).

Magnetic data

Two aeromagnetic surveys flown by BHP Petroleum in 1973 and 1983 covered all of WYLOO. The 1973 survey was flown over the western part of the sheet, 130 m above ground, with a line spacing of 500–1000 m and a 13 m sample interval. The 1983 survey was flown over the eastern part of the sheet, 100 m above ground, with a line spacing of 1500 m and a 60 m sample interval.

These located, corrected, and levelled data were gridded at 400 m grid cell using Intrepid software and imaged using ER Mapper software. An image of the total magnetic intensity (TMI), after the removal of the International Geomagnetic Reference Field, is shown in Figure 7.

Interpretation of lineaments

Comparison of the new improved-resolution gravity data (Figs 5 and 6) with the magnetic data (Fig. 7) and regional geology (Fig. 2) shows major structural features that were not apparent from the earlier gravity data (Fig. 4).

The lineaments drawn on the first vertical derivative (Fig. 6) show a strong correlation with mapped features (Seymour et al., 1988), and indicate some subsurface structural features that are

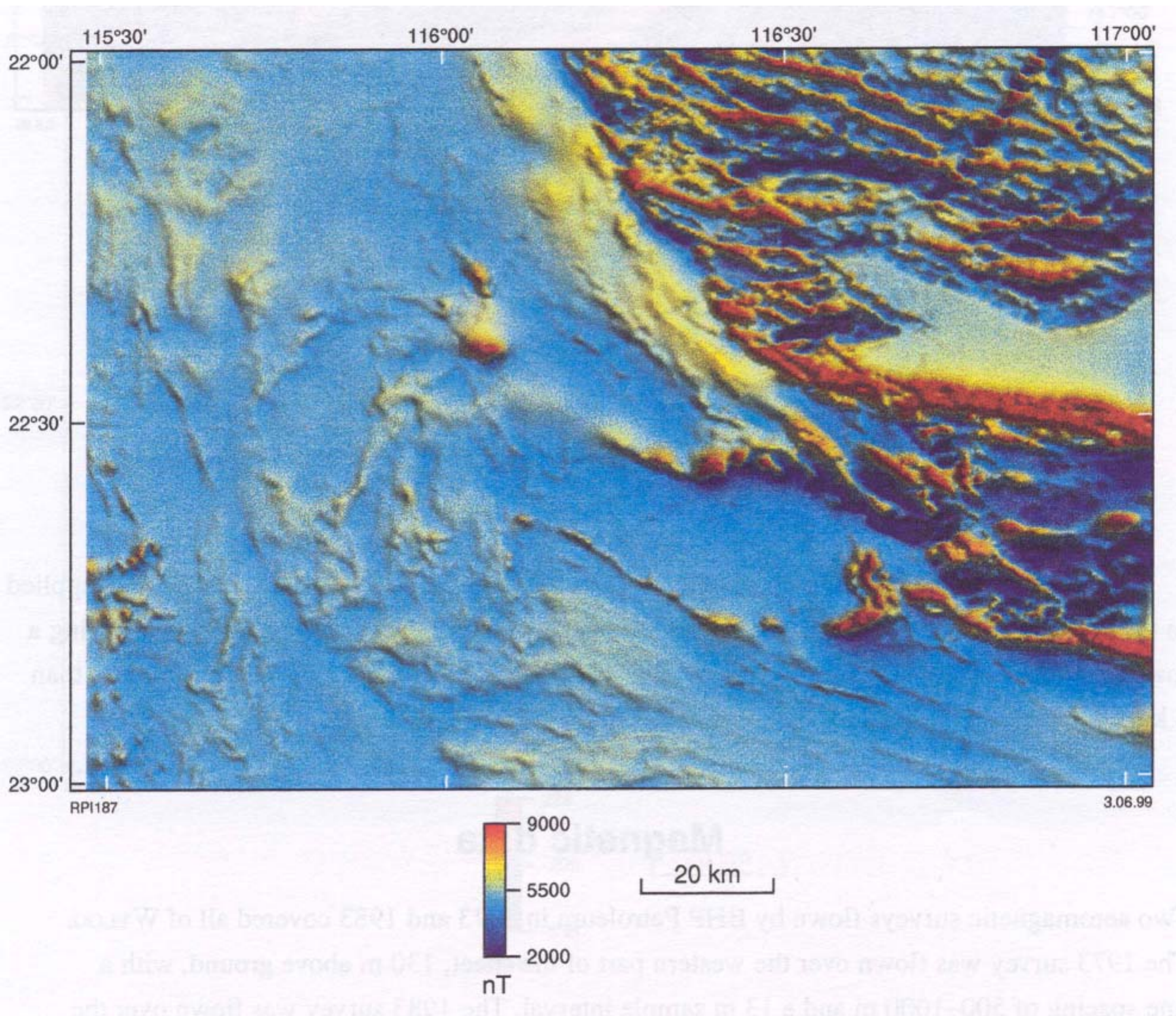

Figure 7. Total magnetic intensity

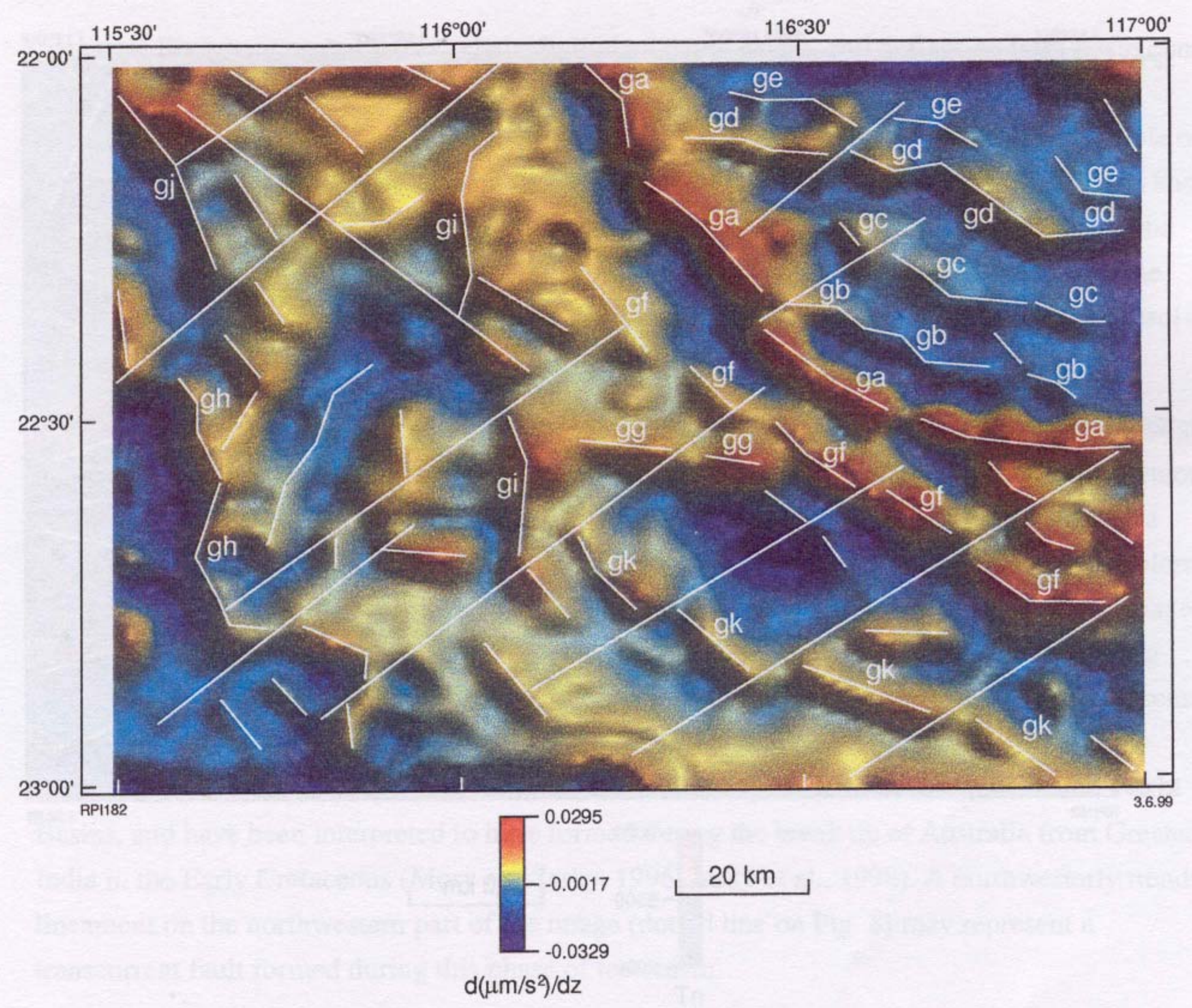

Figure 8. First vertical derivative Bouguer gravity with lineaments

not evident on the surface. Because of the large station spacing, lineaments identified on the gravity image (Fig. 8) show deep structural features. In contrast, lineaments from the magnetic image (Fig. 9) are typically related to near-surface features, such as the high-amplitude anomalies corresponding to banded iron-formations in the Hamersley Ranges, or the low-amplitude anomalies reflecting the concentration of magnetic material along drainage systems.

In the northeastern part of WYLOO, there is a major arcuate structure (ga) extending from 116°15’E on the northern edge of the sheet to 22°30’E on the eastern edge of the sheet (Fig. 8). This feature is also seen on the magnetic image (Fig. 9), and is interpreted to represent a significant fault zone near the southern margin of the Hamersley Basin. The edge of the Hamersley Basin is marked by the gi and gk lineaments that are probably deep-seated faults buried by the Wyloo Group. North of this zone, there are four other lineaments (gb, gc, gd, and ge) that probably represent other deep-seated faults that do not project to the surface. These were basement faults

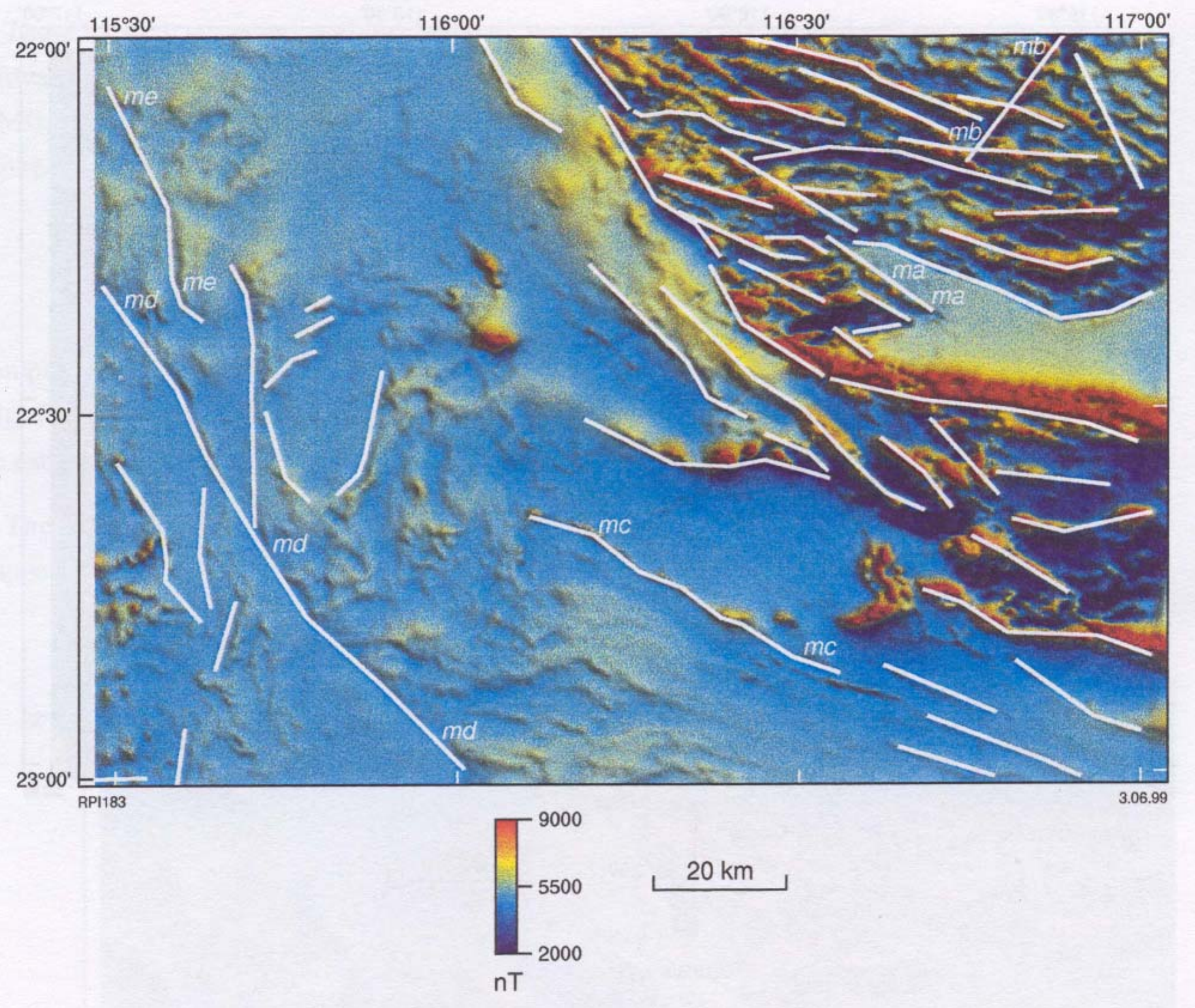

Figure 9. Total magnetic intensity with selected lineaments

initiated during Fortescue Group rifting and were later buried by the Hamersley Group. They were reactivated during the Capricorn Orogeny. The lineaments correlate with flexures in the boundary of the Mount McRae Shale and Mount Sylvia Formation of the Hamersley Group (Seymour et al., 1988). Lineament gd coincides with the position of the Jeerinah–Sylvania fault system postulated by Thorne (1990c) and Tyler and Thorne (1994). This fault system is interpreted as a syn-Fortescue Group normal fault that was reactivated periodically (Tyler and Thorne, 1994) as a thrust and strike-slip fault, and is truncated by the ga fault system. Southwest of lineament ga, other arcuate lineaments (gf and gg on Fig. 8) probably represent basement faults east and north of the Wyloo Dome (Fig. 2). The Wyloo Dome is identified on the gravity image as a large negative anomaly, as the uplifted Archaean granite has a lower density than the surrounding Mount Bruce Supergroup.

A northwesterly trending fault shown on the geology map within the Hamersley Basin (Fig. 2) is not seen on the gravity image, but is apparent on the magnetic image (lineament ma). This magnetic lineament probably has relatively limited depth extent, and defines an intra-basin contact between lithologies with large differences in magnetic susceptibility. A north-northeasterly magnetic lineament in the northern part of the Hamersley Basin (lineament mb) is not visible on the gravity image. This lineament correlates strongly with Quaternary and Tertiary deposits shown on the geological map, and could represent a dolerite dyke as it is of similar orientation to the Channar dyke of the Mundine Well Suite (Tyler, 1990). The absence of this lineament on the gravity image implies that either it is a surface to near-surface feature or that it cannot be resolved because of the large station spacing of the gravity data.

In the southern part of the gravity image (Fig. 8), west-northwesterly trending lineaments (gk) correspond to the southern boundary of the Duck Creek Dolomite of the Wyloo Group (Seymour et al., 1988). A nearby lineament on the magnetic image (mc on Fig. 9) represents the Marra Mamba Iron Formation, rather than the probable fault along the edge of the Duck Creek Dolomite. The mc lineament on the magnetic image coincides with the gk lineament on the gravity image, which represents the buried southern margin of the Hamersley Basin. Northeasterly trending lineaments (dotted lines in Fig. 8) offset the west-northwesterly lineaments in a left lateral sense. These lineaments are present throughout WYLOO, and probably represent a late tectonic transcurrent movement. Lineaments of this orientation are present in the Carnarvon and Perth Basins, and have been interpreted to have formed during the break up of Australia from Greater India in the Early Cretaceous (Mory and Iasky, 1996; Iasky et al., 1998). A northwesterly trending lineament on the northwestern part of the image (dotted line on Fig. 8) may represent a transcurrent fault formed during this phase of tectonism.

In the southwestern part of WYLOO, a magnetic lineament (md on Fig. 9) follows the concentration of iron oxides in the Yilgatherra Member of the Bangemall Group. The continuation of the lineament to the south coincides with the boundary between the ferruginous mudstone of the Ashburton Formation of the Wyloo Group, and the mudstone and shale of the Wannery Member of the Bangemall Group. In contrast, this lineament is not easily identifiable on the gravity image because these rocks have similar densities. However, further to the west, a gravity lineament (gh on Fig. 8), possibly representing a deep-seated shear zone, coincides with the boundary between the Gascoyne Complex and the Ashburton Basin, and also with the outcrop of the Bangemall Basin. This lineament could be related to a lineament in the northwestern part of the sheet (gj on Fig. 8), which coincides with the boundary between the Ashburton Basin and the Mount Minnie Group, and also with a magnetic lineament (me on Fig. 9). Elsewhere in the Ashburton Basin, there are a few low-amplitude anomalies, indicating a low level of magnetization in these rocks.

The gravity lineaments over the Ashburton Basin are more randomly orientated than those in the Hamersley Basin, probably because of the greater degree of deformation, particularly towards the southwest. The c. 1800 Ma Boolaloo Granodiorite, which intrudes the Ashburton Basin (Fig. 2), displays a relative gravity low that corresponds to a low magnetic intensity area (Figs 8 and 9).

Conclusions

Operationally, the collection of gravity data as part of the regional regolith and geochemical mapping program added little to the cost of the program. Inevitably, the accuracy of the Bouguer gravity, measured to an accuracy of 1 μm/s^2, depends on the accuracy of the measured height (AHD) at the station. Better positioning accuracy could be achieved by increasing the number of base stations, which would decrease the distance from base station to rover station; ensuring that continuous lock on satellites is maintained, by minimizing helicopter tilt while in flight; and staying an extra 0.5–1 minute at each station. These measures, however, would increase the cost of the program.

The new gravity data for WYLOO are an improvement on the old 11 km-grid AGSO dataset. Although the acquisition over a 4 km grid must be regarded as regional scale, the new data provide enough detail to identify subsurface structural features not evident in the magnetic or surface geological maps. The boundaries of major tectonic units are represented as lineaments in the gravity image and probably represent buried deep-seated faults. A lineament in the Hamersley Basin corresponds to the Jeerinah–Sylvania fault system and other lineaments coincide with faults shown on the geological map. Gravity lineaments over the Ashburton Basin are randomly orientated, as there is a greater degree of deformation than in the Hamersley Basin and due to the influence of the granodiorite intrusives. Northeasterly gravity lineaments have been identified throughout WYLOO, and are believed to be ?Early Cretaceous sinistral transcurrent faults as they offset lineaments representing older faults.

Modelling the gravity and magnetic data and using the known geological constraints would assist in interpreting thicknesses of the main lithologies, and would provide a better geologic model for the area.

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Appendix 1

Summary of operations and processing for the WYLOO gravity survey

Organization: Geological Survey of Western Australia
Start date: 19 May 1998
Completion: 8 June 1998

	GPS	*Gravity*
Equipment	4 Ashtech Z12 receivers N223, N226, N900, N942	La Coste and Romberg × 5 units G20, G101,G132, G252, G460
Calibration		By AGSO 1998
Surveying transport	Two Jet Ranger helicopters	Two Jet Ranger helicopters
DOLA Bench Marks used	PW3 for position and height control Wyloo 5, Wyloo 37,Wyloo 57 for vertical control	6792-0225 (Onslow)
New base stations	9861-7001, 9861-7002	9861-7001, 9861-7002
Survey method used to establish base stations	Static	4 gravimeters, 2 per helicopter
Survey method for ordinary stations	Kinematic with 100% repeats	1 gravimeter,1 operator, two readings 1254 stations 4 × 4 km irregular grid
Software for reductions and field processing	PRISM	In-house developed programs for reductions Surfer for Windows, for gridding and contouring
Final processing		Intrepid (v.3.2a) for gridding and filtering, and ER Mapper (v. 5.5a) for imaging
Accuracy	$\sigma_{elevation} = \pm 1$ m	$\sigma_{grav} = \pm 0.5^2{}_{stn} + 0.3^2{}_{base}$ µm/s^2
	$\sigma_{x,y} = \pm 5$ m	$\sigma_{stn} = 0.6$ µm/s^2
Total Bouguer accuracy		$\sigma_{bouguer} = 3$ µm/s^2

Appendix 2

Bench mark data

Table 2.1. Coordinates of bench marks used to establish base stations and Isogal station

Name	*DOLA[a] database number*	*Type of Mark*	*Type of grid*	*Latitude (S)/ easting (m)*	*Longitude (E)/ northing (m)*	*AHD[f] height (m)/ AMG84[e] zone*	*Convergence*	*Date surveyed/ Point scale*	*Method*	*Order*	*Horiz.[k] accuracy/ vertical accuracy*	*Gravity value ($\mu m/s^2$)*	*Gravity error ($\mu m/s^2$)*
PW 3[b]	100878	S[c]	AGD84[d]	22°24'32.79165"	116°03'40.84483"	213.324		01/04/1997	GEOD[g]	1st	7.5 ppm	–	–
			AMG84[e]	403388.244	7521579.033	50	-0°21'28.29"	0.99971532	SLEV[h]	3rd	$12\sqrt{K}$ (mm)		
WYLOO 5[b]	114005	S[c]	AGD84[d]	22°32'59.89379"	116°06'57.21855"	187.873		01/10/1993	GEOD[g]	3rd	30 ppm	–	–
			AMG84[e]	409095.005	7506019.371	50	-0°20'20.65"	0.99970209	SLEV[h]	3rd	$12\sqrt{K}$ (mm)		
WYLOO 37[b]	146440	S[c]	AGD84[d]	22°24'27.11682"	115°44'26.91993"	128.636		15/11/1994	GEOD[g]	3rd	30 ppm	–	–
			AMG84[e]	370392.174	7521512.275	50	-0°28'48.22"	0.99980754	SLEV[h]	3rd	$12\sqrt{K}$ (mm)		
WYLOO 57[b]	146460	S[c]	AGD84[d]	22°45'51.11442"	116°29'57.37957"	252.533		01/10/1993	GEOD[g]	3rd	30 ppm	–	–
			AMG84[e]	448595.291	7482487.397	50	-0°11'37.52"	0.99963264	SLEV[h]	3rd	$12\sqrt{K}$ (mm)		
9861-7001	–	–	AGD84[d]	22°47'20.37012"	116°32'22.47242"	259.250	–	20/05/1998	GPS[i]	–	–	9 787 373.9	0.3
			AMG84[e]	452741.459	7479756.225	50			GPS[i]	–	–		
9861-7002	–	–	AGD84[d]	22°21'17.19332"	115°42'53.64130"	140.857	–	20/05/1998	GPS[i]	–	–	9 787 591.2	0.3
			AMG84[e]	367674.986	7527330.447	50			GPS[i]	–	–		
6792-0225[l]	–	–	AGD84[d]	21°39'54"	115°06'42"	3.25	–	1967	MAP[j]	–	–	9 787 596.0	–
(Onslow)			AMG84[e]	304604	7603055	50			SLEV[h]	–	–		

NOTES:
(a) Department of Land Administration
(b) Coordinates from DOLA
(c) Standard survey mark
(d) Australian Geodetic Datum 1984
(e) Australian Map Grid 1984
(f) Australian Height Datum
(g) Geodetic
(h) Spirit level
(i) Global Positioning System
(j) From a map
(k) Horizontal
(l) AGSO Isogal station

Table 2.2. Observed coordinate differences

	DOLA[a]			Observed GPS[b]			Differences		
Bench Mark	*Easting (m)*	*Northing (m)*	*AHD[c] height (m)*	*Easting (m)*	*Northing (m)*	*AHD[c] height (m)*	*d easting (m)*	*d northing (m)*	*d height (m)*
WYLOO 5	409095.005	7506019.371	187.873	409095.079	7506018.074	187.899	+0.074	-1.297	+0.026
WYLOO 37	370392.174	7521512.275	128.636	370392.537	7521513.124	128.627	+0.363	+0.849	-0.009
WYLOO 57	448595.291	7482487.397	252.533	448595.021	7482483.333	252.391	-0.270	-4.064	-0.142

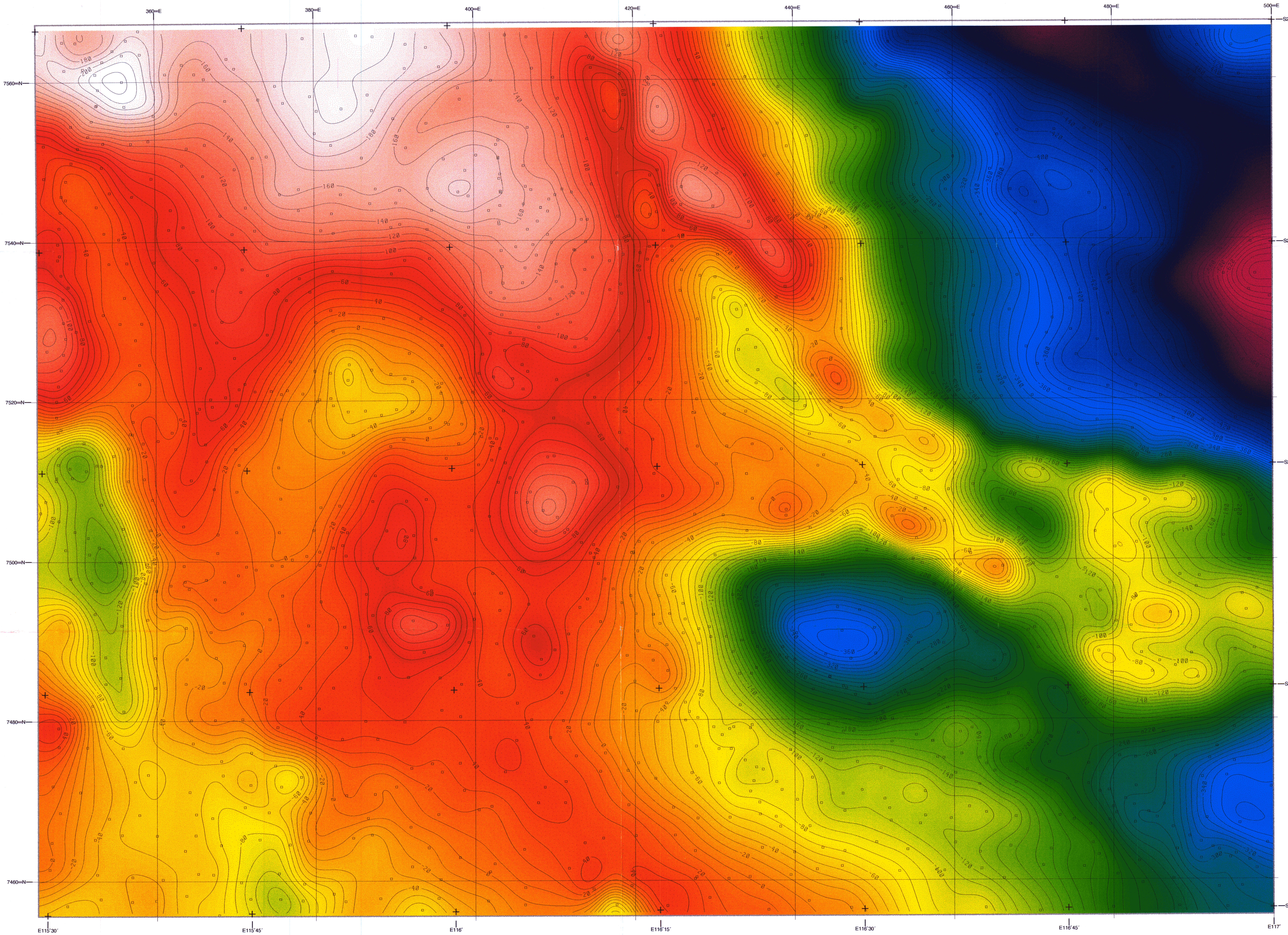
NOTES: (a) Department of Land Administration
(b) Global Positioning System
(c) Australian Height Datum

WYLOO

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

1:250 000 BOUGUER GRAVITY

SHEET SF 50-10

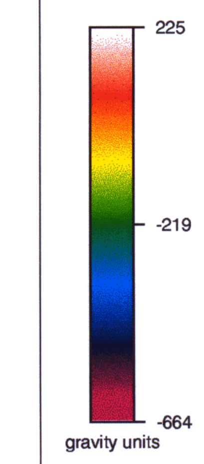


LEGEND

Gravity unit — $1 \mu ms^{-2}$

Contour value — 200

Gravity station — □



SURVEY SPECIFICATIONS

Acquisition date:	May 1998
Acquired by:	Geological Survey of Western Australia
Nominal station spacing:	4 km
Gravity meter:	LaCoste and Romberg G
Gravity survey accuracy:	$3 \mu ms^{-2}$
Positioning:	Ashtech Z-12 dual frequency GPS
Horizontal accuracy:	5 m
Vertical accuracy:	1 m

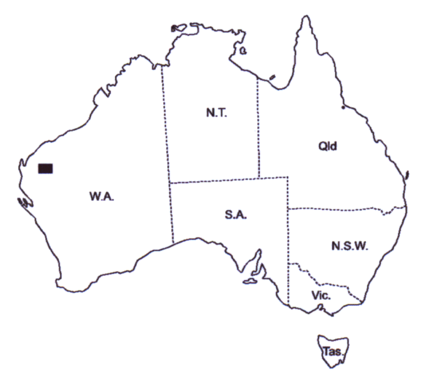
PROCESSING

Data reduction by:	GSWA
Bouguer density:	$2.67 tm^{-3}$
Terrain correction:	Not applied
Geodetic datum:	AGD66
Height datum:	Australian Height Datum (approximated assuming constant geoid-ellipsoid separation over area)
Gridding software:	Intrepid 3.2
Grid cell size:	1000 m
Contour interval	$10 \mu ms^{-2}$
Image processing software:	ER Mapper 5.5
Project geophysicist:	R. Iasky
Processing:	S. Shevchenko
Map compilation:	J. H. Watt

Published by the Geological Survey of Western Australia. Copies available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, WA 6004. Phone (08) 9222 3459, Fax (08) 9222 3444, www.dme.wa.gov.au/insidedme/infocentre.html

These data are also available in digital form from the Geophysical Mapping Section, AGSO GPO Box 378, Canberra, ACT 2601. Phone (02) 6249 9222, Fax (02) 6249 9913, www.agso.gov.au/geophysics/gravimetry

The recommended reference for this map is:
IASKY, R. P., and SHEVCHENKO, S., 1999, Bouguer gravity, Wyloo, Sheet SF 50-10, *in* Gravity data – Wyloo 1:250 000 sheet, Western Australia: Western Australia Geological Survey, Record 1999/9, Plate 1.



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

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

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

Scale 1:250 000

0 5 10 15 20 25

Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1966
Grid lines indicate 20 000 metres interval of the Australian Map Grid Zone 50

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 1999/9 PLATE 1

BOUGUER GRAVITY
WYLOO
SHEET SF 50-10

Algorithm: wyloo_grav99.alg