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A REVIEW OF DATA PERTAINING TO THE HYDROCARBON PROSPECTIVITY OF THE SAVORY SUB-BASIN, OFFICER BASIN WESTERN AUSTRALIA

by M. K. Stevens and G. M. Carlsen

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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A review of data pertaining to the hydrocarbon prospectivity of the Savory Sub-basin, Officer Basin, Western Australia

by

M. K. Stevens and G. M. Carlsen

Abstract

The Savory Sub-basin of the Officer Basin in central Western Australia is part of a large Neoproterozoic episutural basin and is a frontier for hydrocarbon exploration. It contains up to 8 km of clastic, carbonate and rare evaporite sedimentary rocks with minor volcanic dykes, sills, and flows. No petroleum exploration activity had been undertaken in this sub-basin prior to 1995 and hydrocarbon prospectivity is assessed from mineral and recent petroleum exploration drilling. No seismic data have been acquired. An interpretation of available data suggests that source-rock quality is the major exploration risk, but that further investigation of the sub-basin is warranted.

Minor oil shows (fluorescence with solvent cut) recorded in Spearhole Formation sandstones in the northwest of the sub-basin suggest oil has been generated and migrated into potential reservoirs in the sub-basin.

Each of the five depositional sequences recognized in the sub-basin contain potential reservoir rocks which are seen in outcrop as friable sandstones. The Durba Sandstone is interpreted as the best-quality reservoir. Indications of evaporitic environments from the Mundadjini, Skates Hills and Boondawari Formations suggest that seals may be provided by evaporites and mudstones. Neoproterozoic to Cambrian rocks may provide structural closures, including both fold and fault traps for migrating hydrocarbons. Salt diapirs are interpreted from the gravity data. A large semi-detailed gravity survey in the eastern part of the sub-basin revealed major folds, faults and halokinetic structures.

Potential source rocks include marine mudstones of the Skates Hills and Mundadjini Formations, which are associated with stromatolitic dolomites and evaporites. Rare outcrops of black mudstones from other units such as the Boondawari Formation also suggest source potential.

The Geological Survey of Western Australia has drilled one stratigraphic hole (Trainor 1) in the sub-basin to assess the source potential of Neoproterozoic sedimentary rocks. Five of the six samples analysed for Total Organic Carbon in the Cornelia Formation from this well exceeded 0.5% but have a high level of maturation with, at best, dry gas-generating potential. The age of the Cornelia Formation is uncertain but at least part of it is interpreted to be Neoproterozoic and hence part of the Savory succession.

Maturity data, which are very sparse due to limited drilling, are inferred from the Thermal Alteration Index of organic matter to be at about the base of the oil window and the top of the gas window in two waterbores in the southeast of the sub-basin and a mineral drillhole in the north of the region. Rock cuttings from a waterbore in the southwest of the sub-basin are overmature for hydrocarbon generation, but this bore intersected mafic intrusives and hence may not be representative of maturity for the region.

KEYWORDS: hydrocarbon prospectivity, oil shows, Neoproterozoic, Savory Sub-basin, Officer Basin, source rocks, diamond drilling.

Introduction

Recognition in the late 1980s of a thick sequence of generally weakly deformed Neoproterozoic sedimentary rocks of relatively low thermal maturity, previously included within the Mesoproterozoic Bangemall Basin (defined as the Savory Basin by Williams, 1992), revealed a hydrocarbon exploration frontier. The Savory Sub-basin (Fig. 1), now recognized as part of the Officer Basin, is located west of outcrops of Phanerozoic cover rocks of that larger basin. The Officer Basin, a large episutural basin which contains clastic, carbonate and minor evaporite and volcanic rocks, is considered to be part of the Neoproterozoic Centralian Superbasin (Walter and Gorter, 1994). The age of the Officer Basin successions is not well constrained, but in the Savory Sub-basin it is largely Neoproterozoic with possible Palaeozoic strata present in parts.

The boundaries defined by Williams (1992) for the sub-basin have been largely used in this record, but data from sedimentary rocks, previously assigned to older basins that are now recognised or inferred to be of early Neoproterozoic age (Supersequence 1), have been used to assess the hydrocarbon potential of the northwestern part of the Officer Basin.

The southern part of the sub-basin unconformably overlies the Mesoproterozoic Bangemall Basin. The western boundary of the sub-basin is faulted against the Bangemall Basin. The eastern boundary of the Savory Basin, as defined by Williams (1992), was placed along the western edge of Phanerozoic outcrops of the Officer Basin, at approximately 123°E longitude. Recent studies (Perincek, 1996a,b), however, have indicated there is little difference in the Neoproterozoic geology of the two regions. The northeastern boundary of the sub-basin was defined as a reverse- and thrust-faulted contact with the Yeneena and Karara Basins of the Paterson Orogen (Williams, 1992). However, Bagas et al. (1995) subdivided strata from the Yeneena Basin into three new groups, the Throssell, Lamil, and Tarcunyah Groups. The older and more deformed Throssell and Lamil Groups remain part of the Yeneena Basin and the Paterson Orogen. The younger and less-deformed sedimentary rocks of the Yeneena and Karara Basins were considered to be of Supersequence 1 age and were reassigned to the Tarcunyah Group. The Tarcunyah Group was considered to be coeval with the older strata of the Savory Sub-basin. The Tarcunyah Group, Savory Sub-basin and Officer Basin were grouped into a single tectonic unit which was informally referred to as the greater Officer Basin (Bagas et al., 1995).

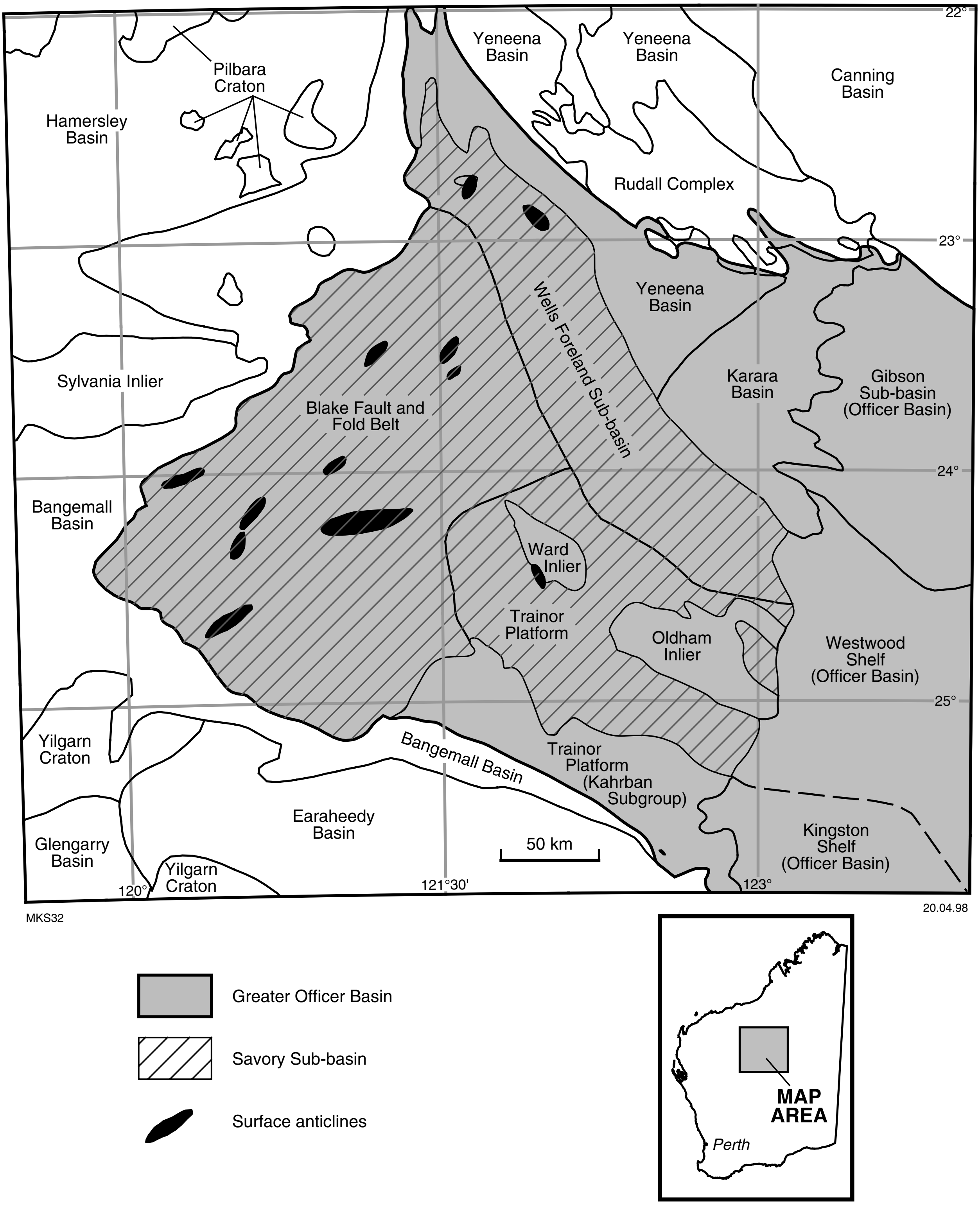

Figure 1. Structural subdivisions of the Savory Sub-basin and surface anticlines

During 1994, in consultation with the Petroleum Industry, the Department of Minerals and Energy received State Government funding for a Petroleum Exploration Initiative, to be undertaken by the Geological Survey of Western Australia (GSWA), with a view to identifying prospective onshore areas for oil and gas, thus increasing the level of onshore exploration in Western Australia. This initiative was originally funded for the first three years of a five-year work program. Two teams of specialists were formed to investigate the prospectivity of both the western margin and interior onshore sedimentary basins.

The Petroleum Exploration Initiative teams seek to enhance the prospectivity of onshore basins by reducing, through focused investigations, the risks perceived by industry to be factors limiting exploration activity. Comprehensive petroleum system reports of the onshore Western Australian basins are to be completed as a result of the projects undertaken during the five-year Initiative. The objective of the Initiative will be achieved through both the analysis of open-file exploration data and the acquisition of new data. New data will include, but not be limited to, geophysical surveys and stratigraphic drilling. Project results are to be reported to the industry through GSWA publications, external publications, conference reports and oral presentations.

This Record is the third in a series of comprehensive reviews by the GSWA of the hydrocarbon prospectivity of some of Western Australia's interior onshore sedimentary basins. The first Record of this series covered the Canning Basin (Apak and Carlsen, 1997). The second Record reviewed the Western Australian Officer Basin (Perincek, 1998), but excluded the Savory Sub-basin.

This study assesses the potential for hydrocarbon exploration within the Savory Sub-basin based on available geological and geophysical data, and defines the scope for future studies. Publications relevant to this investigation, but which are not specifically referred to, are listed in Appendix 1.

Access and climate

The Savory Sub-basin lies east and southeast of the mining town of Newman in the Pilbara region (Fig. 2). The area is largely uninhabited, the only settlement being an outcamp at Poondawari on the GUNANYA* 1:250 000 map sheet. The outcamp is linked by a graded track to the Jigalong Community, 90 km to the west, just outside the northwest margin of the sub-basin. A few pastoral leases lie along the margins of the sub-basin but the majority of the region is Vacant Crown Land.

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* Capitalized names refer to standard map sheets.

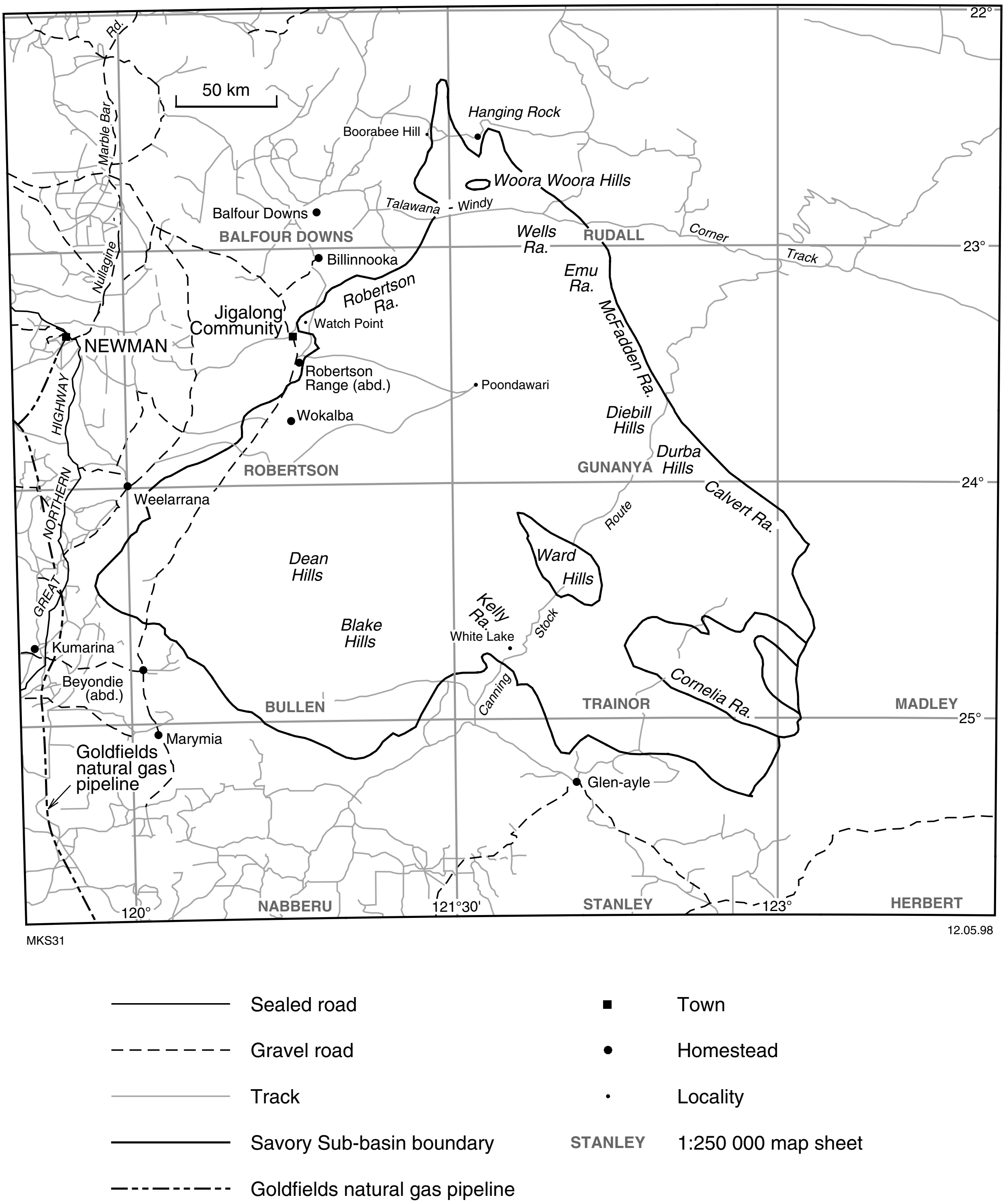

Figure 2. Localities and access routes of the Savory Sub-basin

The sealed Great Northern Highway lies west of the Savory Sub-basin and links Meekatharra to Newman. The Talawana–Windy Corner graded track crosses the northern part of the sub-basin, and graded pastoral station tracks on Balfour Downs, Weelarrana, Kumarina, Marymia and Glen-Ayle give access to the western and southern margins. The Canning Stock Route traverses the sub-basin from north to south and is a well travelled four-wheel-drive track allowing access to the eastern half of the sub-basin. Additional minor tracks also provide access to other parts of the area (Williams, 1992). Recently flown monochrome aerial photography at 1:50 000 and Landsat TM imagery covering the sub-basin is available from the Department of Land Administration.

Cross-country access is similar to that in the Canning Basin, with the average height of sand dunes being lower in the Savory Sub-basin. Potable water has been found in water bores in the south of the sub-basin and is inferred to be present throughout the region. Fuel and supplies are available at Wiluna, Meekatharra, and Newman. A good working relationship with the Western Desert Community, who hold native title claims over most of the sub-basin, has been established by GSWA.

There are no meteorological stations within the Savory Sub-basin, but estimates based on data from nearby Bureau of Meteorology Stations indicate that the area is arid and has its maximum rainfall in summer from monsoonal rains. The sub-basin has reasonable access and a tolerable working climate for all exploration activities. Meteorological data for the town of Wiluna, which lies about 180 km to the south of the sub-basin, are included as Appendix 2.

Regional geology

Stratigraphy

Thirteen formations were recognized by Williams (1992) in the Savory Sub-basin and these are summarized in Table 1. Although unconformities were recognized between some of the formations, and they reflect a wide range of depositional environments, provenance, and climatic conditions, these formations were defined by Williams (1992) as constituting the Savory Group. Five depositional sequences that are generally unconformity-bounded were recognized by Williams (1992) (Fig. 3). The correlation of significant formations within the sub-basin with other parts of the Centralian Superbasin is shown in Figure 4 with the four Neoproterozoic Supersequences having been defined by Walter et al. (1995).

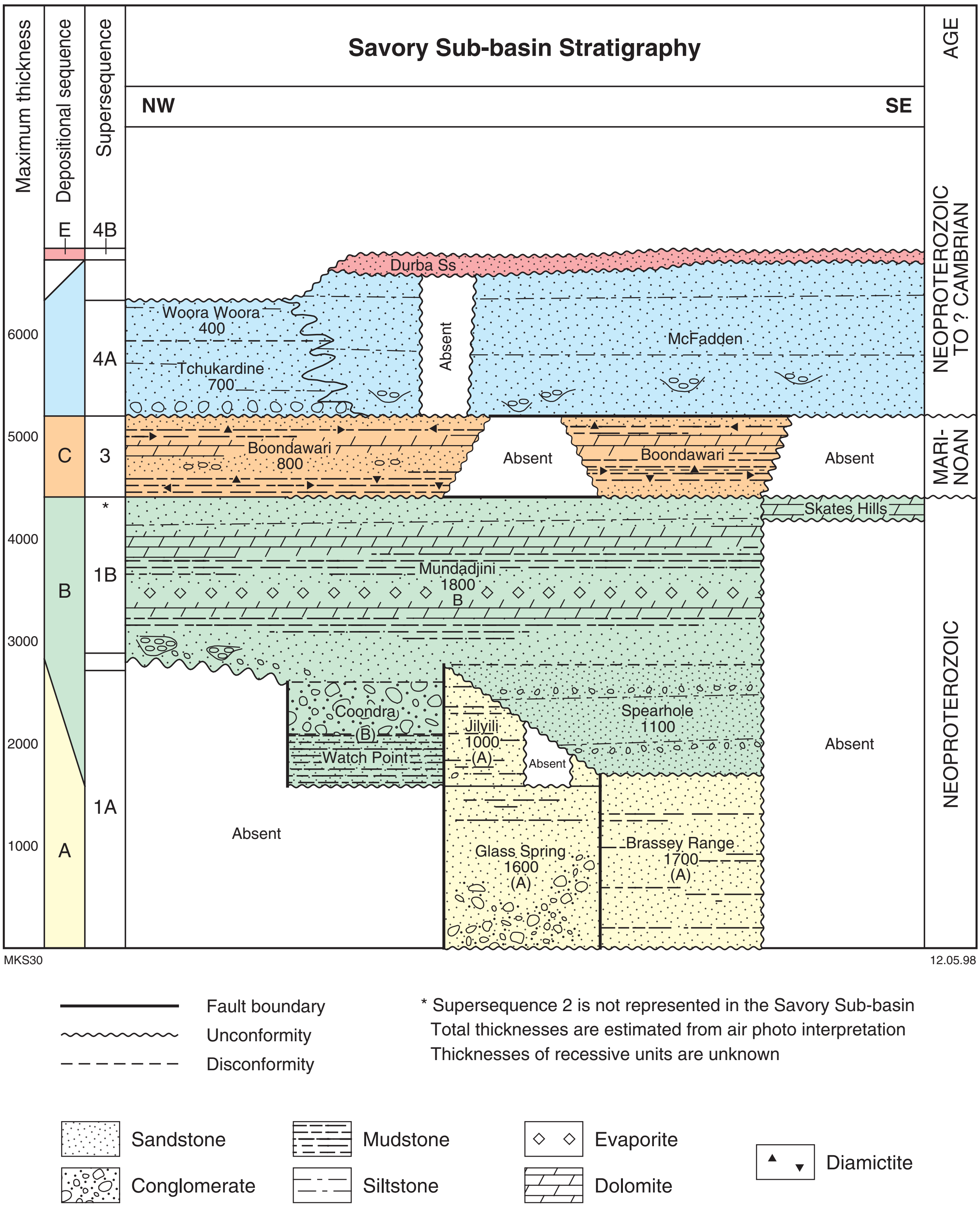

Figure 3. Formations, lithology, and depositional sequences A–E of the Savory Sub-basin

Table 1. Summary of formations in the Savory Sub-basin

Formation	*Super Seq*[(a)]	*Depo Seq*[(b)]	*Lithology*	*Thickness (m)*	*Depositional environment*	*Savoy Group*[(c)]	*Comments*
Durba Sandstone	?4	E	Quartz sandstone, with minor basal conglomerate lenses	100	Fluvial, lacustrine	Y	Excellent reservoir
Woora Woora Formation	4	D	Medium-grained ferruginous sandstone lithic sandstone quartz wacke, siltstone	400	Shallow marine, deltaic	Y	
McFadden Formation .	4	D	Laminated, fine- to coarse-grained quartz sandstone, feldspathic sandstone, quartz wacke, minor conglomerate, siltstone	1 500	Shallow marine, deltaic	Y	Possible reservoir
Tchukardine Formation	4	D	Medium- to coarse-grained sandstone, lithic sandstone, quartz wacke, conglomerate lenses, siltstone, minor shale	700	Shallow marine	Y	
Boondawari Formation	3	C	Glacigene diamictite, sandstone, siltstone, shale, conglomerate, minor dolomite (some stromatolitic and oolitic), rhythmite	800	Glacial shallow marine	Y	Possible source rock
Skates Hills Formation	1	B	Thin-bedded dolomite (some stromatolitic), chert, evaporites, fine- to medium-grained sandstone, siltstone, shale, patchy basal conglomerate	200	Shallow marine, sabkha	Y	Possible source rock
Mundadjini Formation	1	B	Fine- to coarse-grained sandstone, conglomerate, siltstone, minor shale, mudstone, dolomite (some stromatolitic), and evaporites	1 800	Deltaic, sabkha, shallow marine	Y	Possible source rock
Coondra Formation	1	B	Coarse- to medium-grained sandstone, poorly sorted conglomerate, pebbly sandstone	1 000	Fan delta	Y	Possible reservoir
Spearhole Formation	1	B	Coarse- to medium-grained sandstone, pebbly sandstone, siltstone and conglomerate lenses	1 100	Braided fluvial, deltaic	Y	Possible reservoir, oil shows in Mundadjini 1, Boondawari 1

Watch Point Formation	1	B	Shale, siltstone, fine- to medium-grained sandstone, glauconitic sandstone	400	Shallow marine, deltaic	Y	
Jilyili Formation	1	A	Fine-grained sandstone, siltstone; minor shale, mudstone, conglomerate lenses	1 000	Deltaic	Y	
Brassey Range Formation	1	A	Fine- to medium-grained sandstone, siltstone, shale, minor mudstone	1 700	Fluvial, deltaic	Y	
Glass Spring Formation	1	A	Medium- to coarse-grained sandstone, minor conglomerate and siltstone	1 600	Shallow marine, fluvial	Y	
Tarcunyah Group	1	A&B	Quartz sandstone, feldspathic sandstone, quartz wacke, shale, siltstone, conglomerate, evaporites, dolomite	?	Shallow marine, sabkha, fluvial, lacustrine	N	Bitumen in LDDH1
Cornelia Formation	1	A	Sandstone, siltstone, shale, mudstone, minor glauconitic sandstone	?	Shallow marine ? deep marine	N	Overmature source rocks in Trainor 1
Kahrban Subgroup	?1	?A	Sandstone, siltstone, shale	1 700	Shallow marine, deltaic	N	

NOTES: (a) Supersequences of Walter et al. (1995)
(b) Depositional sequences of Williams (1992)
(c) Y= assigned to Savory Group in Williams (1992), N= previously considered to be older than the Savory Group but now included in the greater Officer Basin

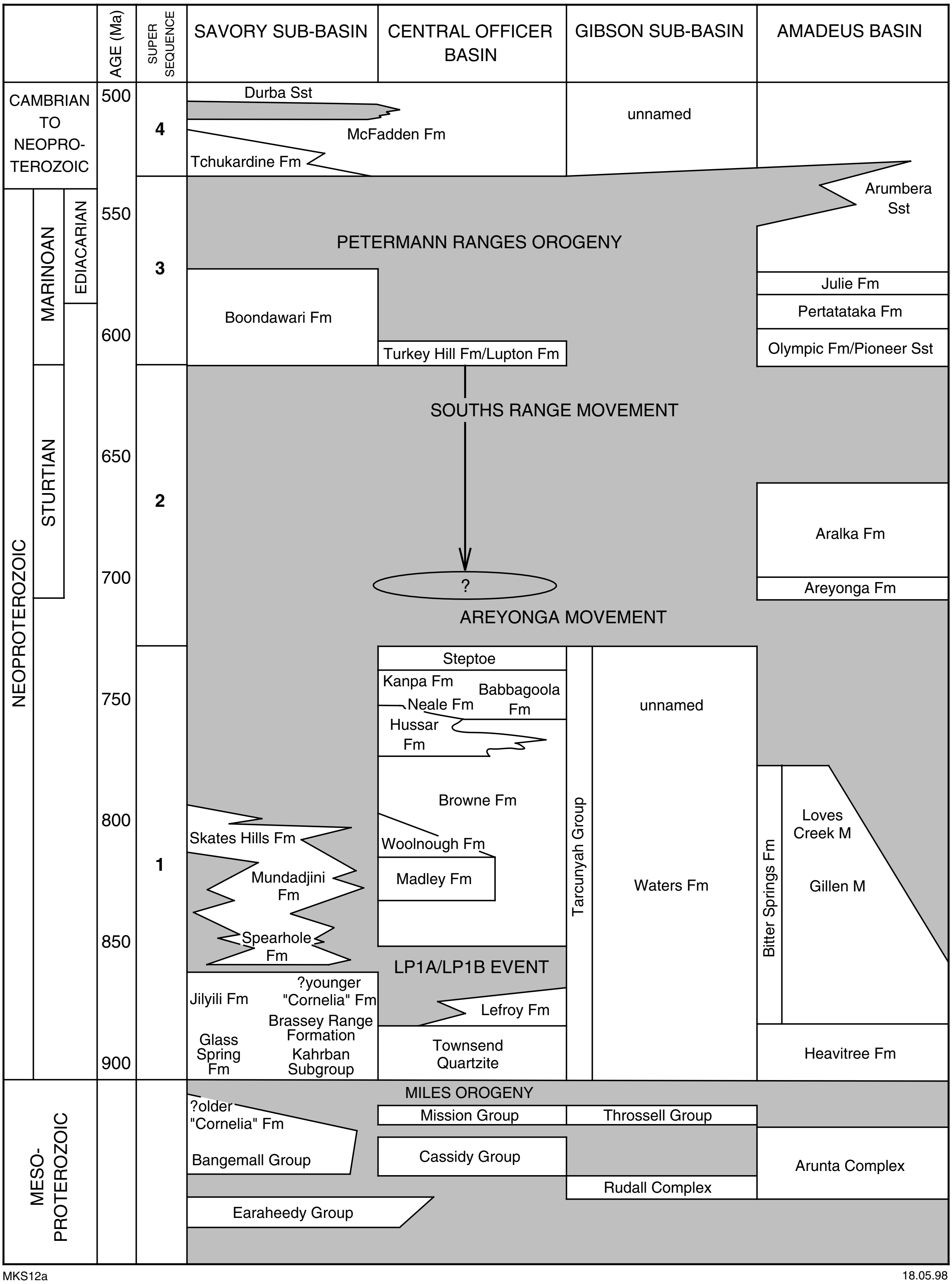

Figure 4. Correlation of Savory Sub-basin formations with the western Officer and Amadeus Basins Fm = Formation; Sst = Sandstone; M = Member

The depositional sequences recognized in the sub-basin are an order of magnitude thicker than those described from Phanerozoic passive-margin settings (Payton, 1977; Posamentier et al., 1988) and are broadly comparable in scale to the second-order cycles of Vail et al. (1977) and to the megasequences of Hubbard et al. (1985). The main subsurface data available to reveal the unweathered nature of these rocks are Trainor-1 and the three-well diamond coring program in Petroleum Permit EP 380 (Akubra 1, Boondawari 1, Mundadjini 1) completed in late 1997 in the central west of the sub-basin (Figs 5 and 6).

The ages of all formations in the Savory Sub-basin are poorly constrained. The only fossils known are stromatolites and palynomorphs (acid-insoluble microfossils). Palynology from available wells is summarized in Appendix 3 from Grey and Stevens (1997) and Grey and Cotter (1996), and correlations using stromatolite biostratigraphy (Stevens and Grey, 1997; Grey, 1995f; Walter et al., 1994, 1995) are consistent with a Neoproterozoic age for the formations for which data are available.

A dolerite within the Boondawari Formation gave a poorly constrained Rb–Sr age of about 640 Ma (Williams, 1992). SHRIMP U–Pb dating of sedimentary zircons from the McFadden and Cornelia Formations in stratigraphic drillhole Trainor 1 are discussed in Stevens and Adamides (in prep.) and Nelson (1997). The youngest ages from these analyses indicate that the maximum age of the Cornelia Formation is Early Cambrian or Sturtian, but these ages are inconsistent with previous tectonic interpretations (Williams, 1992) and current stratigraphic correlations which suggest the Cornelia Formation is of Supersequence 1 age or older (Fig. 4).

Depositional Sequence A, Supersequence 1

Depositional Sequence A includes the Glass Spring, Jilyili, and Brassey Range Formations (Fig. 3). All of these units are predominantly quartzose sandstones, some of which are friable and have significant visible porosity in outcrop. Conglomerates are present in the Glass Spring and Jilyili Formations.

Depositional Sequence B, Supersequence 1

Depositional Sequence B consists of the Watch Point, Coondra, Mundadjini, Spearhole, and Skates Hills Formations (Fig. 3). All of these formations contain beds of quartzose sandstone and some also contain conglomerates. The porosity of dolomites in the Skates Hills Formation appears poor in surface exposures but its subsurface characteristics are unknown.

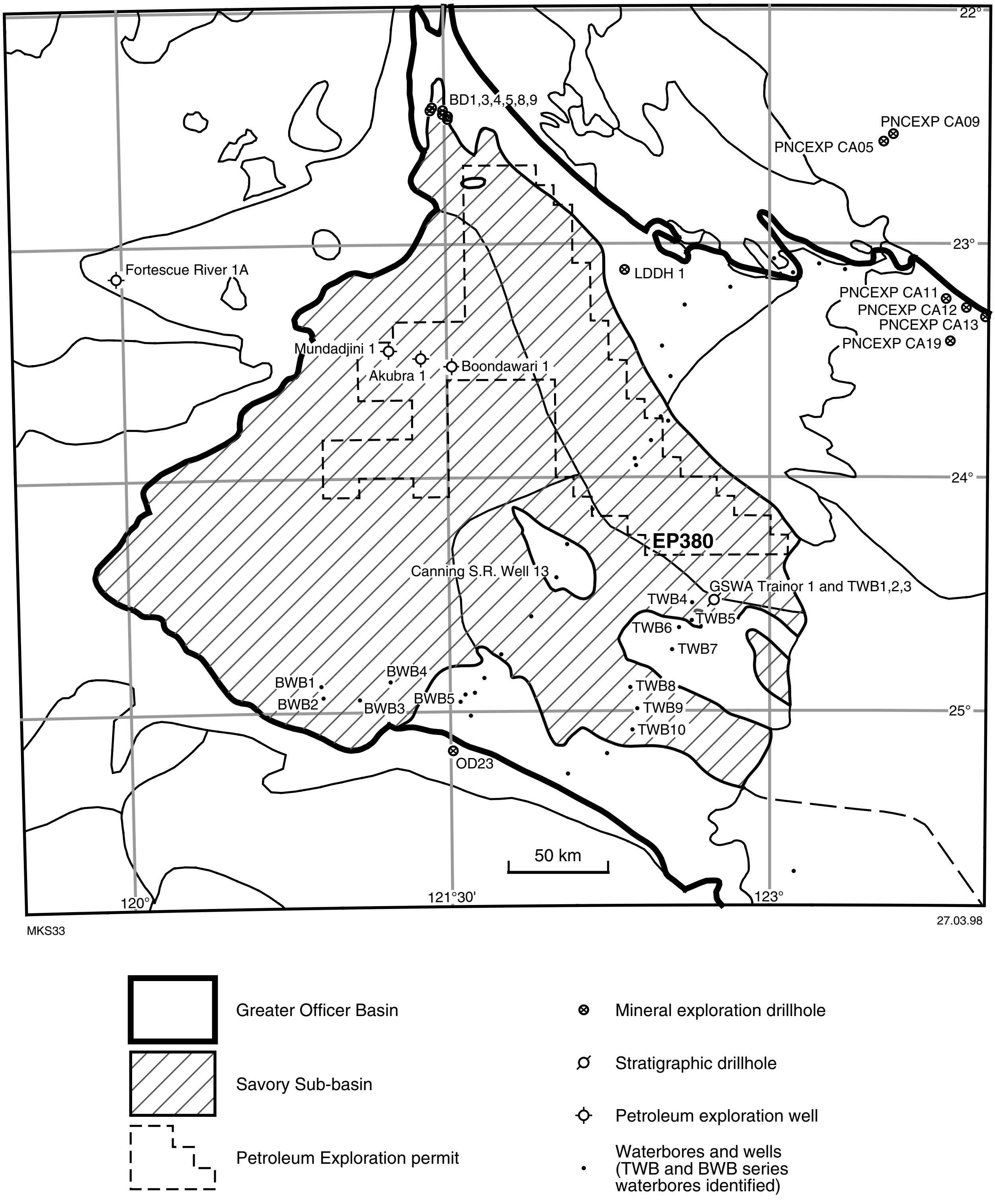

Figure 5. Locations of petroleum exploration wells, mineral exploration and stratigraphic drillholes, water bores and wells, and petroleum exploration permit EP380 in the Savory Sub-basin

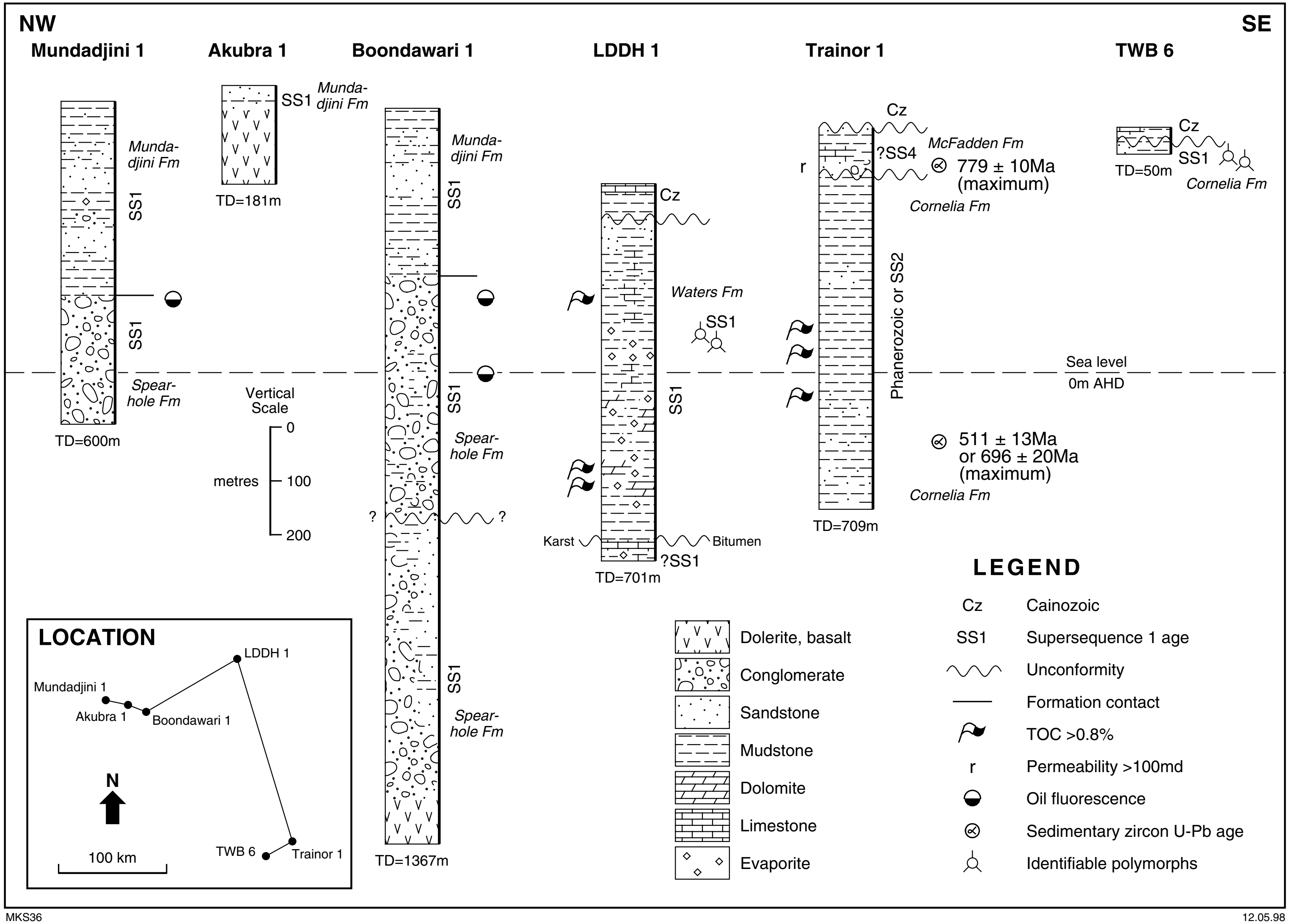

Figure 6. Geological cross section through significant drillholes in the Savory Sub-basin

Depositional Sequence C, Supersequence 3

Depositional Sequence C consists of the Boondawari Formation (Fig. 3) and, although it contains sandstone, conglomerate and dolomite, the sandstones contain significant amounts of feldspar and clay and hence are likely to be poorer reservoirs than older sandstones.

Depositional Sequence D, Supersequence 4

Depositional Sequence D includes the McFadden, Tchukardine, and Woora Woora Formations (Fig. 3). The McFadden Formation is poorly sorted and sandstones contain significant amounts of feldspathic clasts in the north of the basin, but are significantly coarser and cleaner in the northeast of the sub-basin (Williams, 1992).

Sandstones of the Tchukardine and Woora Woora Formations are generally cleaner than those of the McFadden Formation and are expected to have fair to good porosity, although the Tchukardine Formation has a higher clay content in parts.

Depositional Sequence E, Supersequence 4

Depositional Sequence E consists of the Durba Sandstone (Fig. 3), a coarse sandstone with minor conglomerate, which has good to excellent visible porosity in surface exposures.

Other depositional sequences and regional correlations

Sedimentary rocks which were not included in the Savory Group by Williams (1992) but which are likely to be of Neoproterozoic age, and hence part of the greater Officer Basin, include the Tarcunyah Group, the Cornelia Formation, and the Kahrban Subgroup.

As discussed in the **Introduction**, all of the strata in the Karara Basin and the younger strata of the Yeneena Basin were redefined to form the Tarcunyah Group of the greater Officer Basin (Bagas et al., 1995) (Fig. 7). In outcrop, the Tarcunyah Group consists predominantly of quartzose, feldspathic, and arkosic sandstone, shale which is carbonaceous in parts, and carbonate which includes stromatolitic dolomite. Mineral hole LDDH1 drilled on GUNANYA intersected the

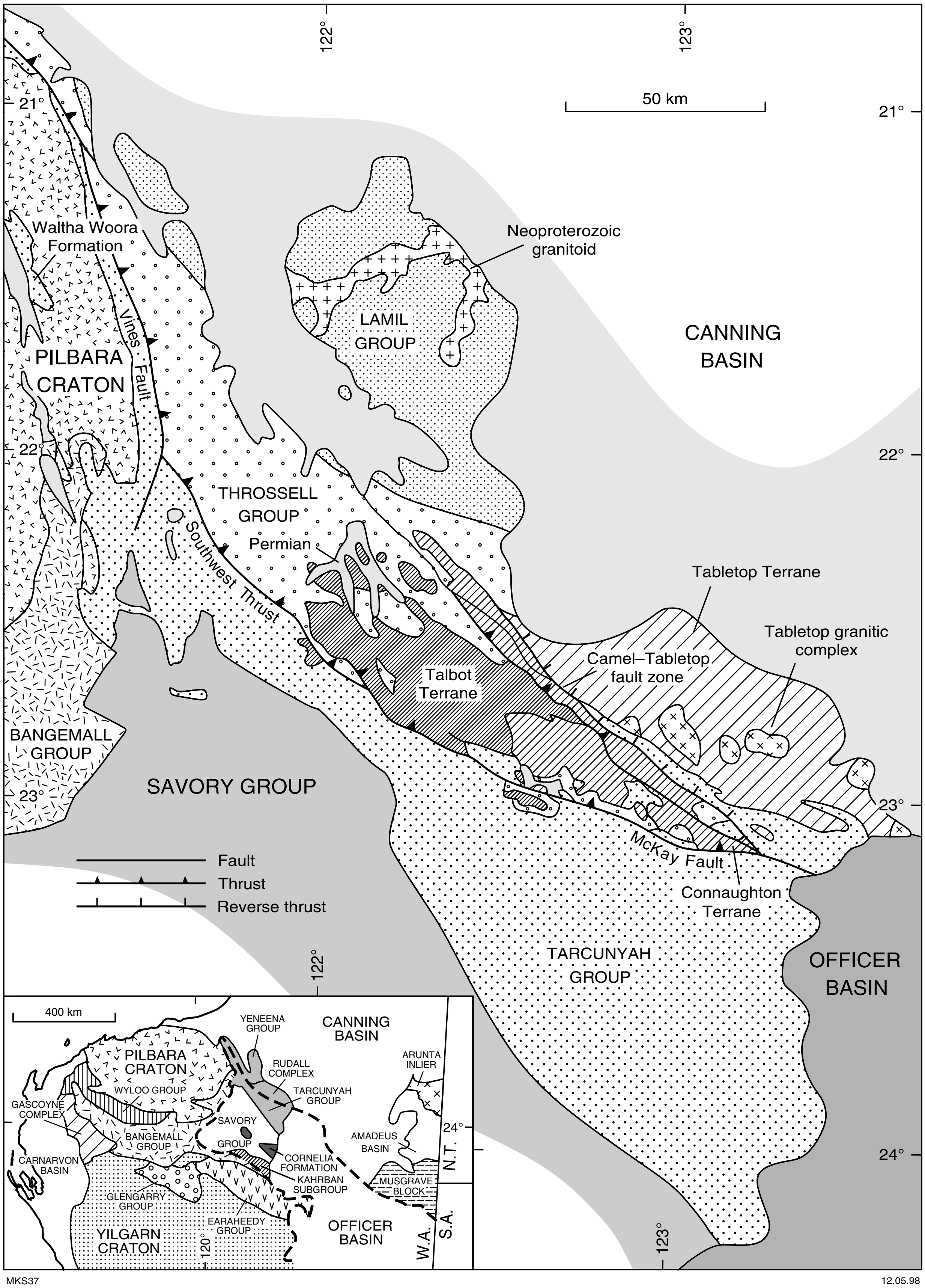

Figure 7. Regional geological setting of the Savory Group and western Officer Basin. The dashed line on the inset map marks the interpreted margin of the greater Officer Basin

Tarcunyah Group and consists predominantly of mudstone with minor sandstone, limestone, dolomite, and anhydrite (Fig. 6).

The age of the Tarcunyah Group is uncertain although limited palynological and stromatolite evidence suggests that it is probably coeval with Supersequence 1 of the Centralian Superbasin. Drillhole LDDH1 contains palynomorphs equivalent to assemblages in the Browne and Bitter Springs Formations of the Officer and Amadeus Basins respectively, and from the Cornelia Formation in TWB 6 (Grey and Stevens, 1997) (Figs 4 and 6). Stromatolite specimens tentatively assigned to *Acaciella australica* (Howchin 1914) Walter 1972 occur in the lower Tarcunyah Group (Bagas et al., 1995). The stromatolite *Baicalia burra* Preiss 1972, and a conical stromatolite, were reported from the upper part of the Tarcunyah Group (Stevens and Grey, 1997).

The recognition of two stromatolite assemblages interpreted to have age significance in Supersequence 1 sedimentary rocks of the Centralian Superbasin has permitted biostratigraphic correlations between outcrop and well data. The ***Acaciella australica*** **assemblage** appears to be slightly older than 800 Ma and is restricted to the middle part of Supersequence 1. The ***Baicalia burra*** **assemblage** is considered to be slightly younger than 800 Ma and occurs in the upper part of Supersequence 1 (Grey, 1996b; Stevens and Grey, 1997). The older ***A. australica*** **assemblage** is recognized in the Skates Hills Formation in the Savory Sub-basin and the stromatolite *A. australica* itself has been tentatively identified in the lower Tarcunyah Group. The occurrence of the ***A. australica*** **assemblage** in the Woolnough, Madley, and Browne Formations of the Officer Basin and in the Loves Creek Member of the Bitter Springs Formation of the Amadeus Basin allows correlations throughout the Centralian Superbasin (Fig. 4).

The younger ***B. burra*** **assemblage** has not been recognized in sedimentary rocks of the Savory Group as defined by Williams (1992), but it occurs in the upper parts of the Tarcunyah Group and allows correlation of this group with outcrops of the Neale Formation and with the Kanpa Formation in petroleum exploration well Hussar 1, both located in the central Officer Basin of Western Australia (Fig. 4), (Grey, 1996b; Stevens and Grey, 1997). The occurrence of the ***B. burra*** **assemblage** in these units permits their correlation with the Burra Group in the Adelaide Geosyncline of South Australia (K. Grey, unpublished data).

The Cornelia Formation and Kahrban Subgroup outcrop in the southeast of the sub-basin and were considered by Williams (1992) to be part of the Mesoproterozoic Bangemall Basin. Limited evidence suggests that all or parts of these two units are of Neoproterozoic age. The Ward and Oldham Inliers consist of outcrops of the Cornelia Formation. Waterbore TWB 6, which was drilled on TRAINOR in the Cornelia Formation, contains palynomorphs consistent with a Supersequence 1 age (Grey and Stevens, 1997) (Figs 5 and 6). In outcrop, the Cornelia Formation consists predominantly of sandstone and quartzite with lesser siltstone, shale, mudstone, and chert. In Trainor 1, this formation consists predominantly of indurated mudstone with minor sandstone, chert, and dolomite. A major erosional unconformity separates the Cornelia Formation from overlying formations and parts of the Cornelia Formation have been folded with dips exceeding 70°. In contrast the majority of the Savory Sub-basin sedimentary rocks have dips of less than 30°, except where they are adjacent to faults. The Cornelia Formation apparently consists of an older unit of steeply dipping quartzites, cherts, and well-indurated mudstones, and a younger unit of shallower dipping sandstones which are sub-friable in parts. However, caution should be used in interpreting the age of units based on their structural deformation and additional mapping and age dating of this formation is required.

It is proposed here that the Kahrban Subgroup is likely to be of early Neoproterozoic age and hence should be considered as part of the greater Officer Basin. This proposal is based largely on the relatively low dip of the strata (generally less than 20°) and their west-northwest strike, which is parallel with strikes in the overlying Brassey Range Formation of the Savory Group. The lower contact of the Kahrban Subgroup is obscured but is thought to be an unconfirmity on the Earaheedy Basin on the southeast of STANLEY (Muhling and Brakel, 1985)

Structural setting

The Savory Sub-basin forms the most northwesterly sub-basin of the Neoproterozoic to Phanerozoic Officer Basin. The western boundary of the sub-basin with the Mesoproterozoic Bangemall Basin consists of steep-reverse and strike-slip faults. The northeastern boundary of the Savory Sub-basin was mapped where Supersequence 4 formations of the Savory Group unconformably overlie sedimentary rocks of the Karara and Yeneena Basins, with the two older units considered to be part of the Paterson Orogen (Williams, 1992). This contact was defined as a series of steeply dipping reverse faults in the northernmost parts of the sub-basin on BALFOUR DOWNS and RUDALL, and was extrapolated as an inferred reverse fault farther along strike to the southeast on GUNANYA and MADLEY where the contact is obscured by Cainozoic sediments. It is now recognized that all the sedimentary rocks in the Karara Basin and younger sedimentary rocks of the Yeneena Basin are from the Supersequence 1 Tarcunyah Group and part of the greater Officer Basin (Bagas et al., 1995). The northern boundary of the Tarcunyah Group and the greater Officer Basin is in thrust-and reverse-faulted contact with the Rudall Complex and other parts of the Paterson Orogen (Fig. 7).

To the south the sub-basin unconformably overlies the Bangemall Basin. The eastern boundary of the sub-basin used in this study is where Permian and younger strata of the Officer Basin unconformably overlie Neoproterozoic strata, although there are no significant structural or stratigraphic differences between the Neoproterozoic units.

The sub-basin is subdivided into three principal structural areas (Fig. 1): Trainor Platform, Blake Fault and Fold Belt, and Wells Foreland Sub-basin (Williams, 1992). A major review of these boundaries is beyond the scope of this report but the processing of regional aeromagnetic data (Appendix 4) and acquisition of a semi-detailed gravity survey by the GSWA in the east of the sub-basin has enabled these tectonic units to be reassessed, and some modifications are proposed.

The Wells Foreland Sub-basin (originally termed the Wells Foreland Basin in Williams, 1992) and sedimentary rocks of the Tarcunyah Group are both considered to be the northwest continuation of the Gibson Sub-basin of the Officer Basin. Aeromagnetic, gravity, and outcrop data suggest that the Blake Fault and Fold Belt is significantly faulted and folded in the west, but is less deformed in the east where the thickest sedimentary section in is located on BULLEN (Appendix 4). The Trainor Platform is reinterpreted to represent an area of the sub-basin that has undergone major compression during the Petermann Ranges Orogeny, resulting in folding and faulting with a northwest strike. This interpretation contrasts with that proposed by Williams (1992) who envisaged that only a thin section of the Savory Group was present on the platform.

Perincek (1998) has recognized nine periods of tectonic activity in the Officer Basin, from the beginning of the Neoproterozoic to the end of the Cretaceous. Three major tectonic episodes are recognized in the Centralian Superbasin. The oldest event is the Areyonga Movement which is pre-Sturtian and forms the boundary between Supersequences 1 and 2 (Fig. 4). The Souths Range Movement occurred at the end of the Sturtian at the boundary between Supersequences 2 and 3. The youngest major event is the Petermann Ranges Orogeny which occured at the end of the Marinoan and forms the boundary between Supersequences 3 and 4.

One minor and two major tectonic episodes are recognized in the Savory Sub-basin: the LP1A/LP1B structural event, and the Areyonga Movement and the Petermann Ranges Orogeny respectively. The LP1A/LP1B structural event is revealed where the Spearhole Formations rests disconformably, and locally unconformably, on the Brassey Range, Jilyili, and Glass Spring Formations. The Neoproterozoic Areyonga Movement (equivalent to the Blake Movement of Williams, 1992) produced folds and faults with a general northeast strike in the western and southern parts of the region. The Souths Range Movement has not been recognized in the sub-basin. This may be due to the fact that no Sturtian glacial rocks have been identified, and hence it is possible that structures attributed to the Areyonga Movement could be the result of the Souths Range Movement or a combination of the two movements.

The major tectonic event recorded in the sub-basin is the latest Neoproterozoic to Cambrian Petermann Ranges Orogeny (equivalent to the Paterson Orogeny), which produced large reverse faults, thrusts, strike-slip faults, and folds with a general northwest strike. The McFadden Formation and other Supersequence 4 strata are considered to be at least partially coeval with this orogeny (Williams, 1992). We also interpret the Durba Sandstone as having been deposited during the later stages of the Petermann Ranges Orogeny as this unit mildly deformed with fold axes parallel to the strike of other structures attributed to the Petermann Ranges Orogeny.

Quantitative aeromagnetic interpretation of the Savory Sub-basin, utilizing the 3D Euler deconvolution method supported by wave-number filtering and image processing, has provided structural trends and depth to magnetic source within the sub-basin (Cowan, 1995). Gravity data are interpreted by Cowan (1995) as changes in both the density of the basement rocks and/or basement topography, depending on local conditions. Part of Cowan's report is reproduced in Appendix 4.

Exploration history

The only petroleum exploration conducted in the sub-basin has been the recent drilling in the western part of three diamond drillholes, of which two have minor oil shows (Table 2). There has been some mineral exploration, the results of which are stored in the GSWA Western Australian Mineral Exploration (WAMEX) database system. Much of the mineral exploration was in the southwest and west, where the sub-basin is in contact with the Bangemall Basin, and along the northern margin of the sub-basin. Many of these mineral exploration programs included aeromagnetic surveys and surface geochemical sampling (Fig. 8).

Hydrocarbon potential

The sub-basin contains a sedimentary succession, up to 8 km thick, which is generally gently folded and faulted, and apparently unmetamorphosed. Limited drilling has shown that thick mudstones are present in the sub-basin with some mudstones in Trainor 1 having high Total Organic Carbon (TOC) values. Outcrops of sub-friable sandstones in many of the formations within the sub-basin suggests widespread reservoir potential. Mudstone, and inferred thick evaporite sequences are likely to form seals. Maturity data suggest that near-surface samples are approximately at the base of the oil window and top of the gas window in parts of the north and southeast of the sub-basin. However, parts of the southwest of the sub-basin and the mudstones in Trainor 1 have very high levels of maturity. Numerous faults and folds have been identified from surface mapping, suggesting good potential for large structural traps. Minor oil shows in

Table 2. Neoproterozoic formations and hydrocarbon shows in diamond drillholes in the Savory Sub-basin

Drillhole	*AMG (AGD84)*	*Core start (m)*	*TD (m)*	*Approx GL (m)*	*Formation*	*Depth (m)*	*Formation*	*Depth (m)*	*Formation*	*Depth (m)*	*Shows*
LDDH 1	431148E 7443826N	112	701	350	Tarcunyah Group	68–701	–	–			bitumen at 662.3 m
Trainor 1	473640E 7287400N	6	709	455	McFadden Fm	9–83	Cornelia Fm	83–709			possible bitumen at 453.7 m
Mundadjini 1	319056E 7404844N	170	600	500	Mundadjini Fm	16–361	Spearhole Fm	361–600			10% fluorescence at 361.02 m
Boondawari 1	348959E 7398174N	299	1 367	490	Mundadjini Fm	15–312	Spearhole Fm	312–1 283	Intrusive	1 283–1 367	40% fluorescence at 353.64 m, 5% fluorescence at 496.3 m
Akubra 1	334249E 7401252N	15	181	530	Mundadjini Fm	15–42	Intrusive	42–181			None

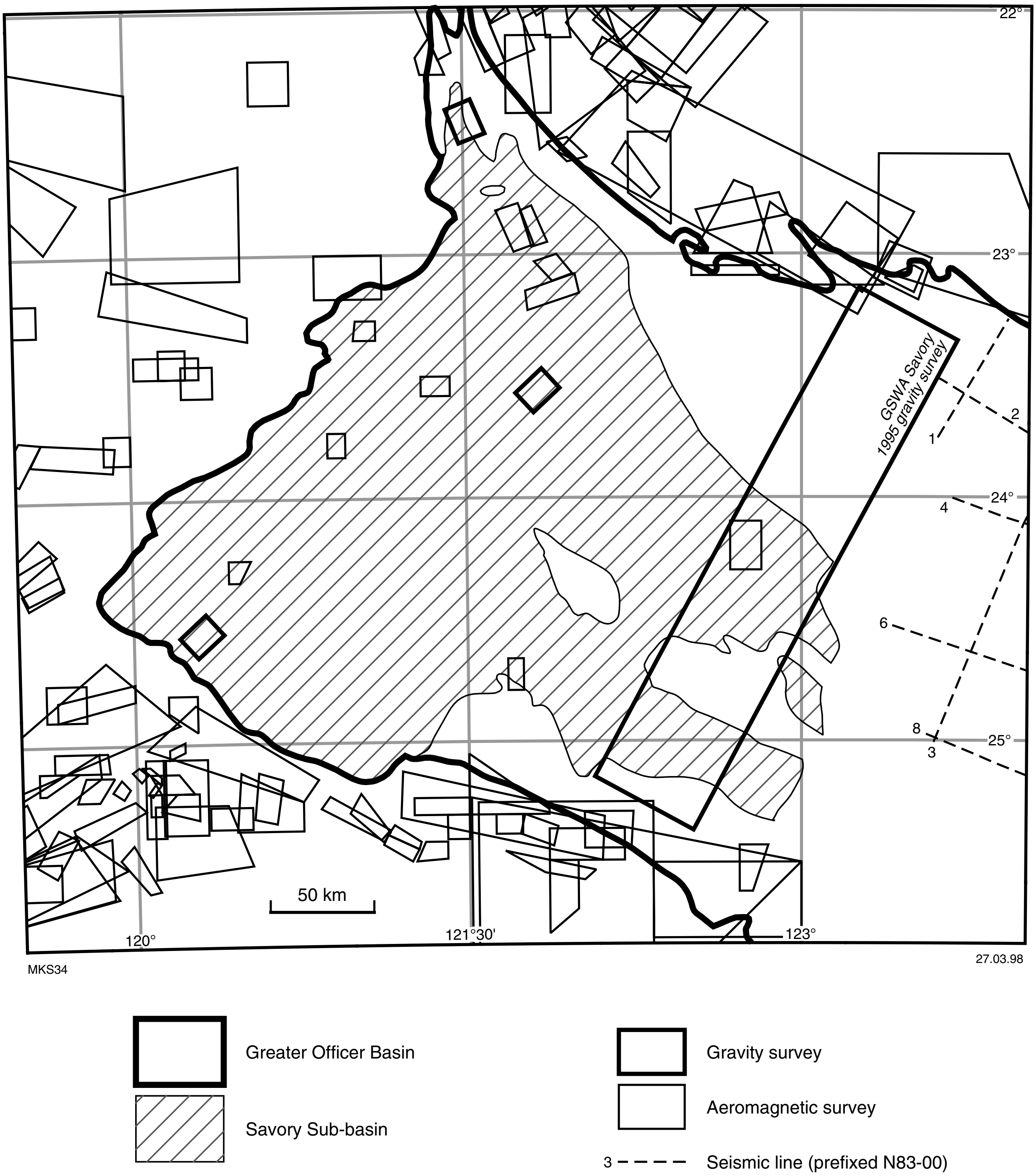

Figure 8. Locations of aeromagnetic and gravity surveys (other than regional BMR/AGSO data)

sandstones in two petroleum wells in the northwest of the sub-basin, and bitumen and oil shows elsewhere in the region, indicate that oil has been generated and migrated through the sub-basin.

Source rocks

Source potential is considered to be the major exploration risk in the Savory Sub-basin although minor oil shows in Mundadjini 1 and Boondawari 1 indicate that at least some oil has been generated and migrated into potential reservoirs within the sub-basin. Sandstone is the predominant lithology observed in outcrop. Outcrops of fine-grained lithologies in the basin are rare because of intense surface weathering and erosion. Only about 8% of the surface area of the sub-basin is exposed bedrock, and recessive lithologies (such as shale, evaporite, and friable sandstone) may be present, although they rarely outcrop.

Outcrops of stromatolitic dolomite with associated cauliflower chert, and cubic pseudomorphs interpreted as being after halite, indicate that evaporitic environments are present within the Mundadjini, Skates Hills and Boondawari Formations. Evaporitic minerals are also present in drillhole LDDH1 in the Tarcunyah Group.

In 1995, GSWA drilled a continuous-core diamond drillhole (Trainor 1) in the sub-basin on TRAINOR to a depth of 709 m to test for source rocks, thus providing the first such data for the sub-basin. The drillhole intersected flat-lying clastics and carbonates of the McFadden Formation (9–83 m) overlying indurated mudstones of the Cornelia Formation (83–709 m total depth) dipping at about 40°. Of the six samples analysed from the Cornelia Formation in this drillhole, the five located between 375 and 603.2 m depth have TOC values exceeding 0.5% (range: 0.66%–3.65%). Rock-Eval pyrolysis of these five samples indicates that they are, at best, in the dry-gas thermal stage and, as a result of their high level of maturation (Stevens and Adamides, in prep.), have poor remaining hydrocarbon-generating potential. Although the Cornelia Formation is overmature at Trainor 1, the high TOC values are encouraging as it is likely that this sequence is less mature elsewhere in the sub-basin.

The Mundadjini Formation contains potential source rocks that comprise marine mudstones with evaporitic minerals present in parts. Thin dark mudstones were intersected in the Mundadjini Formation in Akubra 1. In Mundadjini 1 and Boondawari 1, however, the mudstones appear to be too oxidized to have source potential.

The Boondawari Formation also may be a source rock as it contains black mudstones. The unit is laterally equivalent to the Pertatataka Formation of the Amadeus Basin, and the Ungoolya

Group of the Officer Basin in South Australia, both of which have some source potential (Summons and Powell, 1991; Morton and Drexel, 1997). Samples from the Dey Dey Mudstone of the Ungoolya Group generally have poor TOC values (average 0.11%, range 0.03–0.81%), moderate hydrogen index (HI) values (100–382), and poor to fair genetic potential with a maximum of 2.92 kg hydrocarbon per tonne of source rock (Morton and Drexel, 1997).

Stromatolitic dolomites and mudstones at the top of the Boondawari Formation and within the Skates Hills Formation are potential source rocks. Stromatolitic dolomite and evaporitic rocks deposited in a marginal marine to sabkha environment are considered to have good potential to generate and preserve organic carbon without requiring a deep-water setting (Stevens and Grey, 1997). Such conditions are recognized in the Skates Hills Formation and in the upper parts of the Tarcunyah Group.

Maturity

Knowledge of the maturity of sedimentary rocks within the Savory Sub-basin is still limited. From a review of palynological studies, Grey and Stevens (1997) report that the thermal maturity inferred from the Thermal Alteration Index (TAI) of 3+ from Supersequence 1 age palynomorphs in TWB 6, TWB 9, and LDDH1 is within the hydrocarbon window (Appendix 3). In Phanerozoic spores and pollen, a TAI of 3+ approximately equates to the end of liquid petroleum generation and the start of dry gas generation, and to a vitrinite reflectance of about 1.3% (Traverse, 1988). However, the use of TAI for estimating thermal maturity from Neoproterozoic palynomorphs requires calibration.

In Trainor 1, the Cornelia Formation contains organically rich claystones between 375 and 603.2 m depth. Based on Rock-Eval maturity data (Stevens and Adamides, in prep.) and the dark colour of poorly preserved organic material (Grey, 1995d,e, 1996) with TAI 4- to 5, all samples had a high level of maturation with, at best, dry-gas generating potential remaining. In contrast, drillhole LDDH1 on GUNANYA recorded lower levels of maturity (TAI values of 3+), with two of sixteen samples from the Tarcunyah Group having greater than 1% TOC (Grey, 1995a,b,c; Grey and Cotter, 1996). Organic petrology and Rock-Eval maturity data for samples from LDDH1 indicate that the section above 500 m is within the oil-generative window, whereas below 500 m the rocks are within the gas window (Ghori, in prep., Fig. 9, Appendix 5).

Waterbores TWB 1, 2, 6, and 9, which are located on TRAINOR in the southeast of the sub-basin, all had organic matter with TAI values of 3+ from the McFadden, Skates Hills, Cornelia, and Brassey Range Formations respectively.

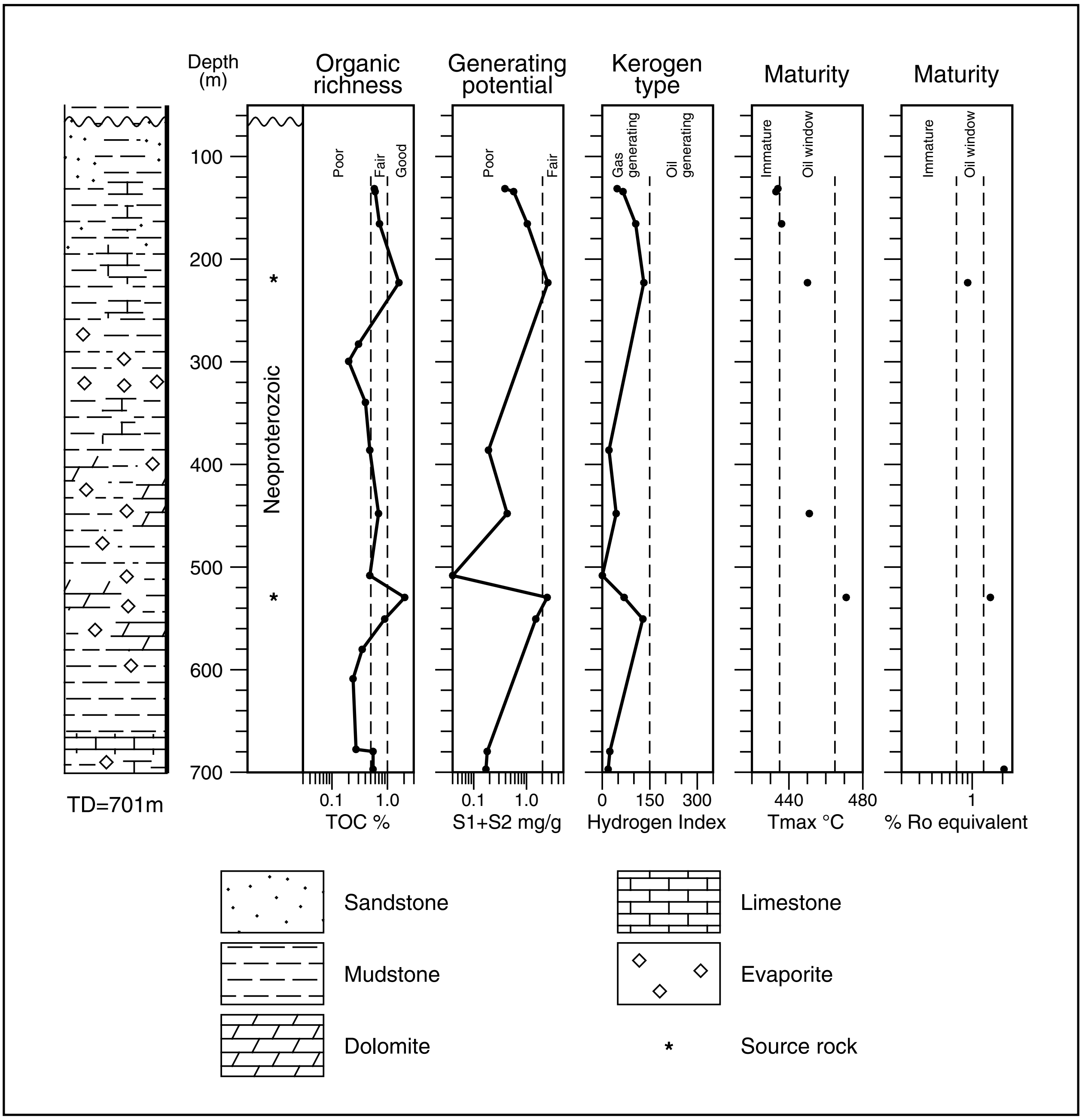

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Figure 9. Petroleum source potential of rocks in Normandy LDDH1

Small amounts of organic matter associated with basalt and dolerite in cuttings from waterbore BWB 1 on BULLEN showed high levels of thermal maturity (Grey, 1995a; Libby, 1995). It is unclear whether all sedimentary rocks on BULLEN are overmature for hydrocarbon generation, or the results from BWB 1 are related to local heating events associated with the volcanic bodies that are common in the Jilyili Formation.

Reservoirs

Each of the five depositional sequences of the Savory Group (Table 1) are inferred to contain significant sandstone reservoirs, with the possible exception of depositional sequence C, as discussed above in **Stratigraphy**. The Spearhole Formation was cored in Mundadjini 1 and Boondawari 1 and visual estimates of porosity vary from generally poor (less than 5%) to fair (approximately 5–15%). The McFadden Formation in Trainor 1 has porosity values of up to 23.2 % and a maximum permeability of 195 md (Stevens and Adamides, in prep.). Sandstones from Neoproterozoic formations form the acquifers in the following waterbores; the McFadden Formation in TWB 1, the Cornelia Formation in TWB 6, and the Brassey Range Formation in TWB 8 and TWB 9 (Appendix 6, Table 6.1).

Based on outcrop observations, the Durba Sandstone is considered to be the best reservoir of the Savory Group. Similarly, some sandstones from the Tarcunyah Group also have good visible porosity in outcrop.

Dolomites occur in several formations in the sub-basin. Reservoir potential may exist, particularly where the dolomites are stromatolitic and oolitic. However, dolomites have not been drilled in the sub-basin and porosity can only be inferred from the preferential silicification of some stromatolite bioherms observed in outcrop (Stevens and Grey, 1997). Elsewhere in the Officer Basin porosities of up to10% have been measured in dolomites. A limestone breccia (karst) is described from 663 to 677 m in drillhole LDDH1 (Fig. 6; Busbridge, 1994)

Seals

Indications of evaporitic environments in the Mundadjini, Skates Hills, and Boondawari Formations are described by Williams (1992). In Mundadjini 1, from 287 to 337 m, anhydrite and chert occurs as nodules, beds, and veins in mudstone of the Mundadjini Formation. Evaporitic minerals (predominantly gypsum) are described in the Tarcunyah Group in LDDH1. The presence of the Woolnough and Madley salt diapirs in the Officer Basin (approximately 110 km east of the sub-basin) and halite beds over 25 m thick in the well Hussar 1 (130 km east of the sub-basin) provide further evidence that evaporite seals may be present in the Savory Sub-basin.

Mudstones and shales form only a small proportion of the limited Neoproterozoic outcrop in the sub-basin but significant thicknesses of mudstone were encountered in the Mundadjini Formation in Mundadjini 1 and Boondawari 1, the Tarcunyah Group in LDDH1, and in the

Cornelia Formation in Trainor 1. These data suggest that mudstones form a significant proportion of strata in the sub-basin, despite their limited outcrop.

Traps

Potential structural closures, including folds and faults, occur at various scales throughout the Savory Sub-basin. However, the region has only been mapped at 1:250 000 scale and independently closed structures, such as domes, have yet to be confirmed. The western margin of the basin contains abundant faults (with a northeast strike) but elsewhere faults are less common. Some anticlines are recognized in outcrop, including one with a strike length of up to 45 km inferred from surface bedding dips in the Mundadjini and Spearhole Formations at approximately 24°15'S, 121°10'E on BULLEN (Fig. 1).

Salt diapirs and other halokinetic structures are recognized in outcrop, well and seismic data in the Officer Basin to the west of the Savory Sub-basin, and it is probable that there are significant thicknesses of evaporitic sedimentary rocks in the sub-basin. The gravity field data suggest there is good potential for salt diapirs and traps related to halokinesis.

Although there is potential for stratigraphic traps to be present in the sub-basin, insufficient data are available to assess them.

Preservation of hydrocarbons

The range of thermal maturities measured to date, and the large periods of time envisaged for deposition of sediments, implies hydrocarbon generation may have occurred a number of times during the evolution of the Savory Sub-basin. Any hydrocarbons that were generated early may have been trapped in palaeostructures, and remigration to younger traps could have taken place later. The Petermann Ranges Orogeny, which has been equated with the Paterson Orogeny (Myers, 1990), is believed to have occurred in the latest Neoproterozoic to early Cambrian. This is the last major tectonic event recognized in the sub-basin, suggesting that it is reasonable to expect that trap integrity will have been preserved.

If the inference of the presence of thick halite beds in the sub-basin is correct, the preservation potential of sub-salt traps should be excellent.

Reported hydrocarbon shows and oil seep

Amadeus Petroleum recorded minor oil shows in cores from Mundadjini 1 and Boondawari 1. In Mundadjini 1 at 361.02 m (top of the Spearhole Formation) a 3 mm thick zone had 10% moderate white fluorescence with slow solvent cut. This show was in a granular sandstone with visually estimated porosity of about 10%. In Boondawari 1 at 353.64 m (within the Spearhole Formation) a broken surface of sandstone had 40% moderate yellow-white fluorescence with slow solvent cut. Visually estimated porosity is about 5%. Because the fluorescing surface was broken during the drilling process, this show could have resulted from contamination. A second show occurs in Boondawari 1 at 496.3 m (within the Spearhole Formation) where a 1 cm-thick zone had 5% dull yellow fluorescence with slow solvent cut in a conglomerate with visually estimated porosity of about 10%. The company intends to further investigate the nature of these occurrences.

Minor bitumen is present at 662.3 m in drillhole LDDH1 on GUNANYA (Figs 5 and 6) as a vein in mudstones of the Tarcunyah Group. A sample was analysed by gas chromatography (Ghori, in prep.) and confirmed that it is natural bitumen (Appendix 5).

Mineral hole OD 23, drilled by Jubilee Gold Mines NL on NABBERU in the Bangemall Basin immediately to the south of the Savory Sub-basin (Fig. 5), encountered bitumen and trace oil in vugs in dolomite (M. Stevens, unpublished data) but no further data are available at present.

In their popular guide to the Canning Stock Route, Gard and Gard (1990, p. 218) refer to an oil seep at Well 13 on TRAINOR (Fig. 5). They reported that between 1977 and 1984 'natural oil' was seen in the well. Although the well is now largely filled with sediment, four auger drill samples were collected by the GSWA in 1995 and all four were analysed for oil shows. One sample from 3.15 m total depth (GSWA sample 135604) yielded just enough extract (51.9 ppm) for saturate gas chromatography analysis. The gas chromatograph (Appendix 5) shows that the extract does contain some hydrocarbons, probably from recent plant material. Because the depth to the oil was not quoted in Gard and Gard (1990), the hand-augered well may not have been deep enough to properly test this reported seep.

Geological and geophysical databases

Geological and geophysical data available for the Savory Sub-basin are limited. The most recently completed geological maps for the sub-basin were published by the GSWA between 1991 and 1995 (Williams and Tyler, 1991; Williams, 1992, 1995a,b).

The cores from the five drillholes listed in Table 2, believed to be all of the core available from the sub-basin, are available for inspection at GSWA. Mineral exploration reports submitted to GSWA may be searched using the WAMEX database and open-file reports are available on microfiche. Geophysical data acquired by the mining industry is not required to be filed with GSWA if acquired over Vacant Crown Land, which is the case for much of the sub-basin. Geophysical survey data submitted in mining tenement reports and which extend into Vacant Crown Land remain confidential to the companies. Original regional aeromagnetic and gravity datasets are available from the Australian Geological Survey Organisation (AGSO).

Data pertinent to oil exploration in the sub-basin, such as structural style and salt diapirism, are presented in a review of the hydrocarbon prospectivity of the Officer Basin (Perincek, 1998).

Drilling

Significant drillholes in the sub-basin are summarized in Table 2.

Petroleum industry data

Amadeus Petroleum drilled three petroleum exploration wells in the central west of the Savory Sub-basin in late 1997. These wells, Mundadjini 1, Boondawari 1, and Akubra 1 were drilled by continuous diamond coring (Figs 5 and 6). All targeted potential reservoirs within the Spearhole Formation, with the Mundadjini Formation as the proposed seal. The wells were located on structures interpreted from Landsat images and limited geological investigations. Both Mundadjini 1 and Boondawari 1 had minor oil shows as discussed above (**Reported hydrocarbon shows**).

Government data

Stratigraphic drillhole Trainor 1 was drilled by GSWA in 1995 (Stevens and Adamides, in prep.) and the main results are discussed above (**Source rocks** and **Maturity**).

Mineral industry data

Normandy Exploration drillhole LDDH1 was cored in the Tarcunyah Group to a total depth of 701 m and provided source-rock and maturity data as discussed above.

Oilmin NL drilled six percussion drillholes (BD 1, 3, 4, 5, 8, and 9) through sandstones and shales in the northern part of the Savory Sub-basin to a maximum depth of 198 m (Fig. 5, WAMEX Microfiche File M 2681/1, I 2610), but only brief geological descriptions are available.

Hydrogeological data

Hydrogeological data within the Savory Sub-basin are limited although a long history of water exploration extends back to the construction of the Canning Stock Route early this century. No detailed geological or wireline logs are available for the older wells along this route. A few station wells have been drilled by various methods on the south and west margins of the basin, but data are unavailable as reports are not required to be filed with the government. Depth to watertable throughout the basin is largely controlled by porosity of the bedrock.

The GSWA drilled fifteen waterbores in the winter of 1995 in the southern part of the sub-basin in preparation for the drilling of Trainor 1 and the proposed Bullen 1. Twelve bores found water and six of these bores have salinities of less than 1000 mg/L (Fig 5; Appendix 6, Table 6.1). One waterbore, TWB 6, has gamma ray and neutron logs run through PVC casing and these are available from the GSWA, with the digital log data included herein.

Seismic data

No geophysical data have been acquired by the petroleum industry in the Savory Sub-basin. Seismic data acquired in the Officer Basin to the east, particularly in the Gibson and Yowalga Sub-basins, is pertinent to structural interpretation in the Savory Sub-basin (Perincek, 1996a, 1998).

Aeromagnetic surveys

Government data

There are over 95 277 line kilometres of aeromagnetic data included in the AGSO dataset. There are three regional aeromagnetic surveys covering the Savory Sub-basin. These were flown by the Bureau of Mineral Resources (BMR, now AGSO) in 1984 at a line spacing of 1500 m with 36 740 and 52 587 line kilometres flown; and by Aerodata in 1984 at a line spacing of 1000m with 5950 line kilometres flown. These data were reprocessed and interpreted for GSWA by Cowan (1995). An edited copy of this report is included as Appendix 4 and the original report is filed in the GSWA Library under S-series reports, item 10331.

Mineral industry data

The approximate locations of non-AGSO aeromagnetic surveys are shown in Figure 8. More detailed information regarding the location of these surveys may be obtained using the GSWA MAGCAT II database. Additional information such as contours of aeromagnetic values may be obtained by inspecting items on file with the GSWA.

Gravity surveys

Government data

The average spacing for gravity data in the Savory Sub-basin is one station per 121 km^2 (11 × 11 km grid). These data were principally collected by BMR in the early 1960s. There are a few additional regional gravity traverses across the sub-basin which are also included in the BMR/AGSO dataset. These data were reprocessed and interpreted for GSWA (Fig. 10) and a report on this work is also included in Appendix 4.

The GSWA completed a large semi-detailed gravity survey in the eastern Savory Sub-basin utilizing helicopter support and Differential Global Positioning Survey (DGPS) techniques (Fig. 8). This gravity survey, completed in August 1995, consists of 2300 gravity stations on a 2 × 3 km grid. All stations were acquired by helicopter, using Scintrex gravimeters, and Ashtek dual frequency DGPS equipment for determining location. This highly efficient system allowed the acquisition of more than 100 gravity stations per day in remote areas. The resolution of this survey is ±30 cm and ±0.5 μms^{-2} (Daishsat, 1995). These data (Fig. 11) represent a significant improvement on the previous regional survey data and are available from GSWA (GSWA, 1996a,b). The results of the interpretation of these data were presented at the 1997 ASEG Convention (Carlsen and Shevchenko, 1997).

Mineral industry data

Three small gravity surveys were conducted by Oilmin NL (Fig. 8) and the relevant WAMEX reports are: M 2681/I 2610, I 2435, I 2567. These three surveys are of limited value because height control was provided by barometers only and the surveys were not tied to the national gravity grid.

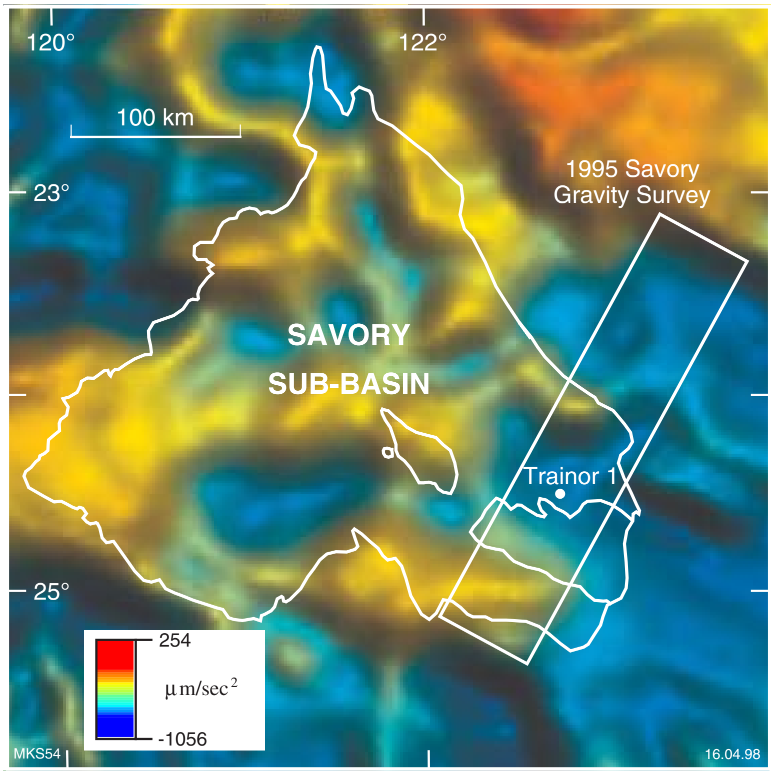

Figure 10. Regional Bouguer gravity map of the Savory Sub-basin

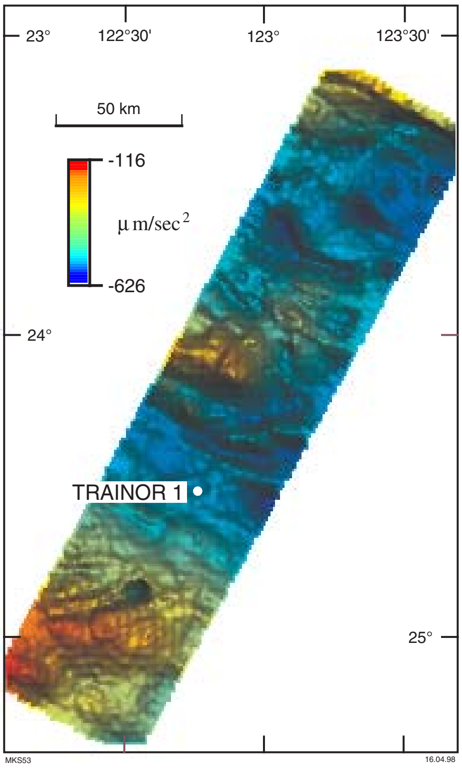

Figure.11 Detailed Bouguer gravity map of the Savory 1995 Gravity Survey from the eastern Savory Sub-basin

Government and academic reports

Chronostratigraphy and geochemistry

The understanding of Neoproterozoic organic chemistry, palynology, and structural evolution is essential to the interpretation of hydrocarbon prospectivity. Pertinent reports are included in the bibliography (Appendix 1). Unpublished palaeontology reports describe the palynology of wells in the Savory Sub-basin (Grey, 1995a–e, 1996a). Grey and Cotter (1996) discussed the potential for Neoproterozoic palynomorphs to provide a biostratigraphic framework and palaeoenvironmental interpretation. Grey and Stevens (1997) reviewed the results of palynological studies of wells drilled in the sub-basin and reported that Supersequence 1 palynomorphs are present in TWB 6, TWB 9, and LDDH1 (Appendix 3). Grey (1996b) reported on the use of stromatolites for correlation in the Neoproterozoic, and Stevens and Grey (1997) discussed the application of stromatolite biostratigraphy in correlating isolated dolomite outcrops in the sub-basin with well and seismic data in the Officer Basin and Centralian Superbasin.

Although geochemical data from the Savory Sub-basin are very limited, results mostly confirm thermal maturities inferred from TAI for LDDH1 and Trainor 1 (Ghori, in prep.; Stevens and Adamides, in prep.). Those parts of the Officer Basin in Western Australia which lie to the east of the Savory Sub-basin are sparsely drilled but Ghori (in prep.) reports that most of the Neoproterozoic succession presently lies within the oil-generative window. However, his study has been unable to identify effective source-rock units and the source for oil shows. Thin source rocks are present in the Neoproterozoic in LDDH1 (Fig. 9) and in three wells which lie to the east and southeast of the Savory Sub-basin, namely NJD 1, Kanpa 1A, and Yowalga 3.

Proposed work program

From the above limited information it is concluded that additional research on the hydrocarbon potential of the sub-basin is justified and proposals are outlined below.

- Additional modelling of gravity and aeromagnetic data from the Savory Sub-basin is required in light of the results from Trainor 1 and Boondawari 1. Trainor 1 showed that what appeared to be a structurally simple area based on outcrop, aeromagnetic, and gravity data was in fact an area of major structuring. Boondawari 1 intersected a dolerite which is in good depth agreement with aeromagnetic depth to source results, showing this technique is useful in detecting the depth to intrusive bodies.

- Additional data from mineral and petroleum exploration bores may become available and analysis of samples from these wells should be undertaken and interpreted in the context of their relevance to the Officer Basin.

- Stratigraphic coring in the Blake Fault and Fold Belt and in the Wells Foreland Sub-basin (Fig. 1) targeting source rocks is considered essential to the continuing evaluation of the hydrocarbon prospectivity of the Savory Sub-basin.

- Correlations using at least outcrop, well, and potential-field data should be prepared to link the sub-basin with the better known parts of the Officer Basin to the east.

- Remapping is required to clarify boundary positions within the Cornelia Formation; this may resolve some of the current problems of the relationship between this unit and the rest of the Savory Sub-basin.

- Further work is required to explain the Early Cambrian or Sturtian ages interpreted for the Cornelia Formation from sedimentary zircon U–Pb dating in drillhole Trainor 1. The determination of the age of the organically rich but overmature claystones in this well is critical to assessing the hydrocarbon potential of the region.

- The thin, dark mudstones intersected by Akubra 1 in the Mundadjini Formation warrant geochemical analysis. Analyses of the oil shows in Mundadjini 1 and Boondawari 1 are currently being undertaken by Amadeus Petroleum.

- Geochemical analysis of hydrocarbons in the Bangemall Basin drillhole OD23 has been performed by Jubilee Gold and the results will be reviewed when they are submitted to GSWA. The possibility of source rocks within the Bangemall Basin charging traps within the Bangemall Basin and the overlying Savory Sub-basin requires further investigation.

Conclusions

The Savory Sub-basin is a frontier region with only three recently drilled petroleum exploration wells and no seismic data. Based on existing geological and geophysical data, it is considered too early to draw conclusions about the hydrocarbon prospectivity of the sub-basin at this stage, and there are several reasons why the area warrants further investigation.

1. Thick accumulations of sedimentary rocks are present (up to 8 km thickness inferred) which may contain source, reservoir, and sealing strata.

2. Minor oil shows occur in Mundadjini 1 and Boondawari 1, and bitumen is present in mineral exploration drillhole LDDH1, suggesting that hydrocarbons have migrated within the Neoproterozoic sequence of the Savory Sub-basin. Oil and bitumen are present in mineral exploration drillhole OD23 in the Bangemall Basin, immediately to the south of the Savory Sub-basin, and it is possible that source rocks from the Bangemall Basin could charge traps in the overlying Savory Sub-basin.

3. The age of sedimentary rocks in the sub-basin is still poorly constrained but some of the Neoproterozoic sedimentary rocks located on GUNANYA and TRAINOR are within the hydrocarbon-generation window. It is possible that a significant thickness of Phanerozoic sedimentary rocks may also be present.

4. Friable sandstones with visible porosity outcrop extensively, suggesting numerous potential reservoirs.

5. Significant, but not intense, faulting and folding has been mapped, implying large structural traps may be present.

6. Evaporitic sedimentary rocks occur in several formations, and may provide good source rocks and excellent seals.

References

APAK, S. N., and CARLSEN, G. M., 1997, A compilation and review of data pertaining to the hydrocarbon prospectivity of the Canning Basin: Western Australia Geological Survey, Record 1996/10, 103p.

BAGAS, L., GREY, K., and WILLIAMS, I. R., 1995, Reappraisal of the Paterson Orogen and Savory Basin: Western Australia Geological Survey, Annual Review 1994–95, p. 55–63.

BUSBRIDGE, M., 1994, Lake Disappointment Exploration Licence 45/1064, Third Annual Report, Lake Disappointment Diamond Drill Hole LDDH1: Normandy Exploration Limited: Western Australia Geological Survey, M-series, Item 7567, A41358 (unpublished).

CARLSEN, G. M., and SHEVCHENKO, S. I., 1997, Petroleum exploration in Proterozoic basins using potential fields data and stratigraphic coring: Australian Society of Exploration Geophysicists, 12th Geophysical Conference Handbook, Sydney, 1997, Preview, no. 66, p. 83 (abstract only).

COWAN, D., 1995, Savory Basin quantitative magnetic interpretation: Western Australia Geological Survey, S-series, S10331 (unpublished).

DAISHSAT PTY LTD, 1995, Operational and processing report, Savory Basin gravity survey: Western Australia Geological Survey, S-series, S10332 (unpublished).

GARD, E., and GARD, R., 1990, Canning Stock Route a traveller's guide for a journey through history: Perth, Western Australia, Western Desert Guides, 448p.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 1996a, Savory Basin first vertical derivative of Bouguer gravity image, 1:250 000: Western Australia Geological Survey.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 1996b, Savory Basin Bouguer gravity image, 1:250 000: Western Australia Geological Survey.

GHORI, K. A. R., in prep., Petroleum source rock potential and thermal history, Officer Basin, Western Australia: Western Australia Geological Survey, Record.

GREY, K., 1995a, Savory Basin drillhole BWB 1 (Bullen waterbore) palynology and thermal maturation. GSWA Palaeontology Report no. 1995/12 (unpublished).

GREY, K., 1995b, Savory Basin drillholes TWB 1, 2, 6, 9 (Trainor waterbores) palynology and thermal maturation. GSWA Palaeontology Report no. 1995/20 (unpublished).

GREY, K., 1995c, Palynology of Normandy-Poseidon Lake Disappointment-1 corehole, Tarcunyah Group, Paterson Orogen: GSWA Palaeontology Report no. 1995/21 (unpublished).

GREY, K., 1995d, Savory Basin drillhole Trainor 1 (Trainor diamond drilling) palynology and thermal maturity: GSWA Palaeontology Report no. 1995/24 (unpublished).

GREY, K., 1995e, Savory Basin drillhole Trainor 1 (Trainor diamond drilling) Additional Preparation of two samples: GSWA Palaeontology Report no. 1995/28 (unpublished).

GREY, K., 1995f, Neoproterozoic stromatolites from the Skates Hills Formation, Savory Basin, Western Australia, and a review of the distribution of *Acaciella australica*: Australian Journal of Earth Sciences, v. 42, p. 123–132.

GREY, K., 1996a, Savory Basin drillhole Trainor 1 (Trainor diamond drilling) Additional samples; palynology and thermal maturation: GSWA Palaeontology Report no. 1996/15 (unpublished).

GREY, K., 1996b, Preliminary stromatolite correlations for the Neoproterozoic of the Officer Basin and a review of Australia-wide correlations: GSWA Palaeontology Report no. 1996/15 (unpublished).

GREY, K. and COTTER, K. L., 1996, Palynology in the search for Proterozoic hydrocarbons: Western Australia Geological Survey, Annual Review for 1995–96, p. 70–80.

GREY, K., and STEVENS, M. K., 1997, Neoproterozoic palynomorphs of the Savory Sub-basin, Western Australia, and their relevance to petroleum exploration: Western Australia Geological Survey, Annual Review for 1996–97, p. 49–54.

HUBBARD, R. J., PAPE, J., and ROBERTS, D. G., 1985, Depositional sequence mapping as a technique to establish tectonic and stratigraphic framework and evaluate hydrocarbon potential on a passive continental margin, *in* Seismic stratigraphy II: an integrated approach *edited by* O. R. BERG and D. G. WOOLVERTON: American Association of Petroleum Geologists, Memoir 39, p. 79–91.

LIBBY, W.G., 1995, A petrological report on six samples of bore cuttings from the Savory Basin, Western Australia: Western Australia Geological Survey, S-series, S31307 (unpublished).

MORTON, J.G.G., and DREXEL, J.F., 1997, The petroleum geology of South Australia. Vol. 3: Officer Basin: South Australia Department of Mines and Energy Resources, Report Book, 97/19.

MUHLING, P. C., and BRAKEL, A. T., 1985, Geology of the Bangemall Group — the evolution of an intracratonic Proterozoic basin: Western Australia Geological Survey, Bulletin 128, 219p.

MYERS, J. S., 1990, Precambrian tectonic evolution of part of Gondwana, southwestern Australia: Geology, v.18, p. 537–540.

NELSON, D. R., 1997, Compilation of SHRIMP U–Pb zircon data: Western Australia Geological Survey, Record 1997/2, 196p.

PAYTON, C. E., 1977, Seismic stratigraphy — applications to hydrocarbon exploration: American Association of Petroleum Geologists, Memoir 26, 516p.

PERINCEK, D., 1996a, The age of Neoproterozoic–Palaeozoic sediments within the Officer Basin of the Centralian Super-basin can be constrained by major sequence-bounding unconformities: APPEA Journal, v. 36, pt 1, p. 350–368.

PERINCEK, D., 1996b, The stratigraphic and structural development of the Officer Basin, Western Australia: a review: Western Australia Geological Survey, Annual Review 1995–1996, p. 135–148.

PERINCEK, D., 1998, A compilation and review of data pertaining to the hydrocarbon prospectivity of the Officer Basin, Western Australia Geological Survey, Record 1997/6.

POSAMENTIER, H. W., JERSEY, M. T., and VAIL., P. R., 1988, Eustatic controls on clastic deposition 1 — Conceptual framework, *in* Sea-level changes: an integrated approach *edited by* C. K. WILGUS, B. S. HASTINGS, C. G. St C KENDALL, H. W. POSAMENTIER,

C. A. ROSS, and J. C. VAN WAGONER: Society of Economic Paleontologists and Mineralogists, Special Publication no. 42.

STEVENS, M. K., and ADAMIDES, N. G., in prep., GSWA Trainor 1 well completion report; Savory Sub-basin, Officer Basin, Western Australia, with notes on petroleum and mineral potential. Western Australia Geological Survey, Record 1996/12.

STEVENS, M. K., and GREY, K., 1997, Skates Hills Formation and Tarcunyah Group, Officer Basin — carbonate cycles, stratigraphic position, and hydrocarbon prospectivity: Western Australia Geological Survey, Annual Review for 1996–97, p. 55–60.

SUMMONS, R.E., and POWELL, C. McA, 1991, Petroleum source rocks of the Amadeus Basin, *in* Geological and geophysical studies in the Amadeus Basin, central Australia *edited by* R. J. KORSCH and J.M. KENNARD: Australia BMR Geology and Geophysics, Bulletin 236.

TRAVERSE, A., 1988, Palaeopalynology: Boston, Unwin Hyman, 600p.

VAIL, P. R., MITCHUM, R. M., Jr., TODD, R. G., WIDMIER, J. M., THOMPSON, S. III, SANGREE, J. B., BUBB, J. N., and HATLELID, W. G., 1977, Seismic stratigraphy and global changes of sea level, *in* Seismic stratigraphy — applications to hydrocarbon exploration *edited by* C. E. PAYTON.: American Association of Petroleum Geologists, Memoir 26, 516p.

WALTER, M. R., and GORTER, J., 1994, The Neoproterozoic Centralian Superbasin in Western Australia: the Savory and Officer Basins, *in* The sedimentary basins of Western Australia *edited by* P. G. PURCELL, and R. R. PURCELL: Petroleum Exploration Society of Australia Symposium, Perth, W.A., 1994, Proceedings, p.851–864.

WALTER, M. R., GREY, K., WILLIAMS, I. R., and CALVER, C. R., 1994, Stratigraphy of the Neoproterozoic to early Palaeozoic Savory Basin and correlation with the Amadeus and Officer Basins: Australian Journal of Earth Sciences, v. 41, p. 533–546.

WALTER, M. R., VEEVERS, J. J., CALVER, C. R., and GREY, K., 1995, Neoproterozoic stratigraphy of the Centralian Superbasin, Australia. Precambrian Research, v. 73, p. 173–195.

WILLIAMS, I. R., 1992, Geology of the Savory Basin, Western Australia. Western Australia Geological Survey, Bulletin 141, 115p.

WILLIAMS, I. R., 1995a, Bullen, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 23p.

WILLIAMS, I. R., 1995b, Trainor, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 31p.

WILLIAMS, I. R., and TYLER, I. M., 1991, Robertson, W.A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 36p.

Appendix 1

Bibliography

Reports which are relevant to this investigation but which are not specifically cited are listed below.

BAILLIE, P. W., POWELL, C. McA., LI, Z. X., and RYALL, A. M., 1994, The tectonic framework of Western Australia's Neoproterozoic to recent sedimentary basins, *in* The sedimentary basins of Western Australia *edited by* P. G. PURCELL, and R. R. PURCELL: Petroleum Exploration Society of Australia Symposium, Perth, W.A., 1994, Proceedings, p. 45–62.

BRADSHAW, M. T., BRADSHAW, J., MURRAY, A. P., NEEDHAM, D. J., SPENCER, L., SUMMONS, R. E., WILMOT, J., and WINN, S., 1994, Petroleum systems in West Australian basins, *in* The sedimentary basins of Western Australia *edited by* P. G. PURCELL, and R. R. PURCELL: Petroleum Exploration Society of Australia Symposium, Perth, W.A., 1994, Proceedings, p. 93–118.

CLARKE, G. L., 1991, Proterozoic tectonic reworking in the Rudall Complex, Western Australia: Australian Journal of Earth Science, v.38, p. 31–44.

COCKBAIN, A. E., and HOCKING, R. M., 1990, Phanerozoic, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 750–755.

ETHERIDGE, M., and WALL, V., 1994, Tectonic and structural evolution of the Australian Proterozoic: 12th Australian Geological Convention, Geological Society of Australia, Abstracts no. 37, p. 102–103.

GOODE, A. D. T., 1981, Proterozoic geology of Western Australia, *in* Precambrian of the Southern Hemisphere. Developments in Precambrian geology 2 *edited by* I. R HUNTER: Amsterdam, Elsevier, p. 105–203

GREY, K., and JACKSON, M. J., 1983, A re-assessment of stromatolite evidence for the correlation of the Late Proterozoic Neale and Ilma Beds, Officer Basin, Western Australia: Australia BMR, Journal of Australian Geology and Geophysics, v. 8, p. 359.

HICKMAN, A. H., WILLIAMS, I. R., and BAGAS, L., 1994, Proterozoic geology and mineralization of the Telfer–Rudall region, Paterson Orogen: Geological Society of Australia (WA Division), Excursion Guidebook no. 5, 56p.

HOCKING, R. M., MORY, A. J., and WILLIAMS, I. R., 1994, An atlas of Neoproterozoic and Phanerozoic basins of Western Australia**,** *in* The sedimentary basins of Western Australia *edited by* P. G. PURCELL, and R. R. PURCELL: Petroleum Exploration Society of Australia Symposium, Perth, W.A., 1994, Proceedings, p. 21– 44.

JACKSON, P. R., 1966, Geology and review of exploration, Officer Basin, Western Australia, Hunt Oil Company: Western Australia Geological Survey, S-series, S26 (unpublished).

JACKSON, M. J., 1971, Notes on a geological reconnaissance of the Officer Basin, Western Australia: Australia BMR, Geology and Geophysics, Record 1971/5, 30p.

JACKSON, M. J., and van de GRAAFF, W. J. E., 1981, Geology of the Officer Basin, Western Australia: Australia BMR, Geology and Geophysics, Bulletin 206, 102 p.

LOWRY, D. C., JACKSON, M. J., van de GRAAFF, W. J. E., and KENNEWELL, P. J., 1971, Preliminary result of geological mapping in the Officer Basin, Western Australia: Western Australia Geological Survey, Annual Report for 1971, p. 50–56.

MYERS, J. S., 1990, Precambrian, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 737–750.

MYERS, J. S., SHAW, R. D., and TYLER, I. M., 1994, Proterozoic tectonic evolution of Australia: 12th Australian Geological Convention, Geological Society of Australia, Abstracts no. 37, p. 312.

NEDIN, C., and JENKINS, R. J. F., 1991, Re-evaluation of unconformities separating the ‘Ediacaran’ and Cambrian systems, South Australia: Palaios, v. 6, p. 102–108.

PHILLIPS, B. J., JAMES, A. W., and PHILIP, G. M., 1985, The geology and hydrocarbon potential of the north-western Officer Basin: APEA Journal 25 (1), p. 52–61.

POWELL, C. McA., LI, Z. X., McELHINNY, M. W., MEERT, J. G., and PARK, J. K., 1993, Paleomagnetic constraints on timing of the Neoproterozoic breakup of Rodinia and Cambrian formation of Gondwana: Geology, v. 21, p. 889–892.

POWELL, C. McA., PREISS, W. V., GATEHOUSE, C. G., KRAPEZ, B., and LI, Z. X., 1994, South Australian record of a Rodinian epicontinental basin and its mid-Neoproterozoic breakup to form the Palaeo-Pacific Ocean: Tectonophysics, v. 237, no. 3–4, p. 113–140.

PREISS, W. V., 1976, Proterozoic stromatolites from the Nabberu and Officer Basins, Western Australia, and their biostratigraphic significance: South Australia Geological Survey, Report of Investigations, no. 47, p. 1–51.

TOWNSON, W. G., 1985, The subsurface geology of the western Officer Basin — results of Shell's 1980–1984 petroleum exploration campaign: APEA Journal, v. 25 (1), p. 34–51.

WATTS, K. J., 1982, The geology of the Townsend Quartzite; Upper Proterozoic shallow water deposit of the Northern Officer Basin, Western Australia: Perth, University of Western Australia, BSc honours thesis (unpublished).

WELLS, A. T., and KENNEWELL, P. J., 1974, Evaporite exploration in the Officer Basin, Western Australia, at the Madley Diapirs: Australia BMR, Record, 1974/194 (unpublished).

WILLIAMS, I. R., and MYERS, J. S., 1990, Paterson Orogen, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 274–286.

WILLIAMS, I. R., 1990, Savory Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 329–334.

WILLIAMS, I. R., 1994, The Neoproterozoic Savory Basin, Western Australia, *in* The sedimentary basins of Western Australia *edited by* P. G. PURCELL, and R. R. PURCELL: Petroleum Exploration Society of Australia Symposium, Perth, W.A., 1994, Proceedings, p. 841–850.

WILSON, R. B., 1967, Woolnough Hills and Madley diapiric structures, Gibson Desert, W.A.: APEA Journal, v. 7, p. 94–102.

Appendix 2

Meteorological data

(from Bureau of Meteorology, Perth, 1994)

Table 2.1. Wiluna rainfall (mm)

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1975	0	45	44.6	30.9	30.6	5.9	27.6	4	3.4	88.6	63.8	16.4
1976	16	15.4	12	13.8	5.3	1.6	3.4	6.2	1.2	23.8	0	2
1977	4.4	0	6.6	7.4	6.8	9.5	2.4	36.3	1	5.8	1.2	72.7
1978	23.4	52.2	9.4	16	0	9.6	36.7	24	1.6	35.3	18.5	4.5
1979	19	17.3	12.2	8.8	9.1	4	0	24.6	5.8	0	16.9	11.4
1980	14.8	76.4	6.8	108.1	25.9	62.6	62.9	0.6	5.6	0.2	17.4	0
1981	12.3	47.6	19.2	3.2	19.6	11.8	4.4	7.4	1.4	0	2.8	31.2
1982	37.4	70.5	20.6	24.4	107.9	9.2	0.2	14.3	36.8	52.6	36.8	11.8
1983	1	11.2	92.8	24.8	0	21.2	5.6	3.2	5	1	42	49.6
1984	14.9	7	34.2	8.4	83.6	0	34.8	13.2	22.4	0.4	1.6	17.2
1985	59.6	48.3	0	16.6	55.6	0	51.4	5.6	0	0	4	0
1986	0	15.4	3.5	0	0	108.5	23	0.1	23.9	13.7	0	0.4
1987	120.4	119	1.9	8.9	17	57.5	15.4	12.6	0.7	1	0	39.8
1988	4.6	20.2	16.4	13	38.8	0	20.2	10.4	0	0	22.4	130.9
1989	20.7	23.4	2.6	70.3	27.8	53.6	5.7	0	0.1	0	14.4	0.2
1990	103.5	23	28.1	4.6	12.6	5.3	9.4	21.8	4.4	9	4.2	0
1991	4.8	0	4.1	4.5	0	47.2	29.7	1.2	0	1	0	7
1992	11.2	9.6	102.5	122.7	32.3	65	0.4	17.4	0	13.2	4.8	4
1993	0	69.7	0	20.2	44.5	0	1.2	30.6	1.8	0.5	1.4	3.3
Mean	**25**	**35**	**22**	**27**	**27**	**25**	**18**	**12**	**6**	**13**	**13**	**21**

Mean monthly rainfall in Wiluna

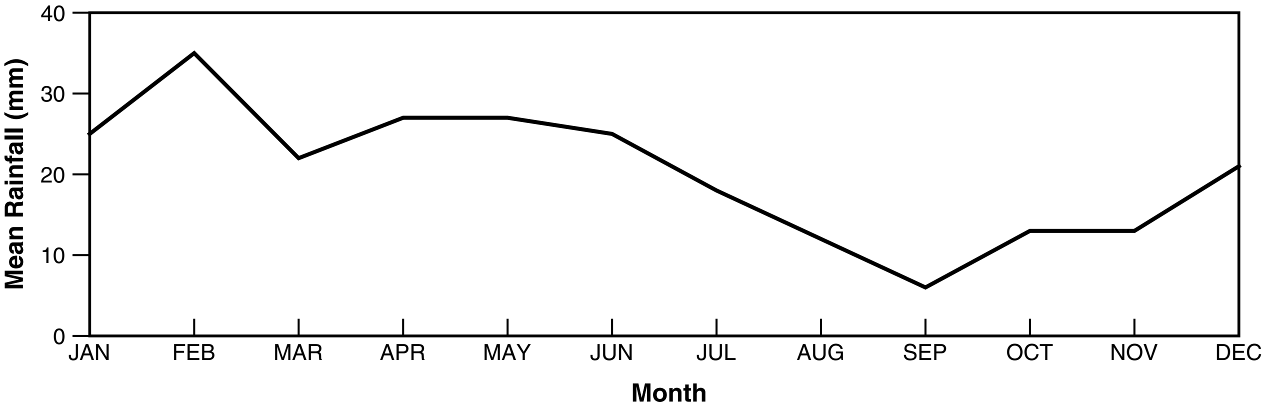

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Table 2.2. Wiluna minimum temperature (°C)

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1975	–	23	20.3	15	9.4	6.3	7.1	6.2	10.3	12.4	16.9	20.5
1976	24.2	22.9	19.4	15	10	6.3	5.9	7.3	9.5	14.3	16	22.8
1977	24.3	25	19.7	14.8	9.6	9.5	5.6	8.6	10.2	–	18.8	23
1978	24.1	23.2	20.3	18	10.2	6.4	7.6	8	9	15.2	19	20.5
1979	25.5	22.6	21.6	16.7	8.3	6	5.9	7.9	9.7	14.5	19.8	22.3
1980	25.5	22.6	23.1	15.5	13.4	8.3	6.8	7.5	12.1	10.8	19.3	22.3
1981	24.5	21.6	19	18.2	11.9	6	5.4	7.8	13.8	15.9	16.3	21.8
1982	23.2	22.4	17.7	16	–	–	3.7	11.1	11.2	16.4	20.9	22.5
1983	23.5	24	19.7	14.7	11.2	8.8	3.9	8.8	12.1	16.2	18.9	21.9
1984	24.1	24.3	19.1	15.6	–	7.2	6.6	7	9.5	16.1	18.2	21.1
1985	24.4	23.1	–	15.9	9.8	6.5	7.1	7.3	11.7	14.7	20.5	–
1986	–	22.9	22.6	15.5	9.3	9.6	4.3	4.9	10	12.2	–	21.9
1987	–	21.7	18.3	17.5	8.5	7.7	6.8	6.8	11.2	–	–	22.1
1988	23.8	21.4	20.9	17.8	11.1	–	–	8.6	10.4	15.7	17.1	19.5
1989	–	23.7	19.9	16.5	10.7	6.7	4.4	6.1	10.7	13.1	18.7	–
1990	23.2	–	21.1	15.5	11.8	6.2	5.7	8.7	10.2	14.9	19.5	22
1991	26	25.6	21.7	16.8	12.2	10.1	7.8	–	11.3	18	16.8	21.9
1992	22.7	22.7	21.4	16.9	10.2	9.8	5.9	6.9	–	12.5	15.9	19.6
1993	24.1	21.8	19.6	17.1	10.3	–	4.9	6.8	8.8	12.8	19.2	21.1
Mean	**24**	**23**	**20**	**16**	**10**	**8**	**6**	**8**	**11**	**14**	**18**	**21**

NOTE: Dashes indicate data unavailable

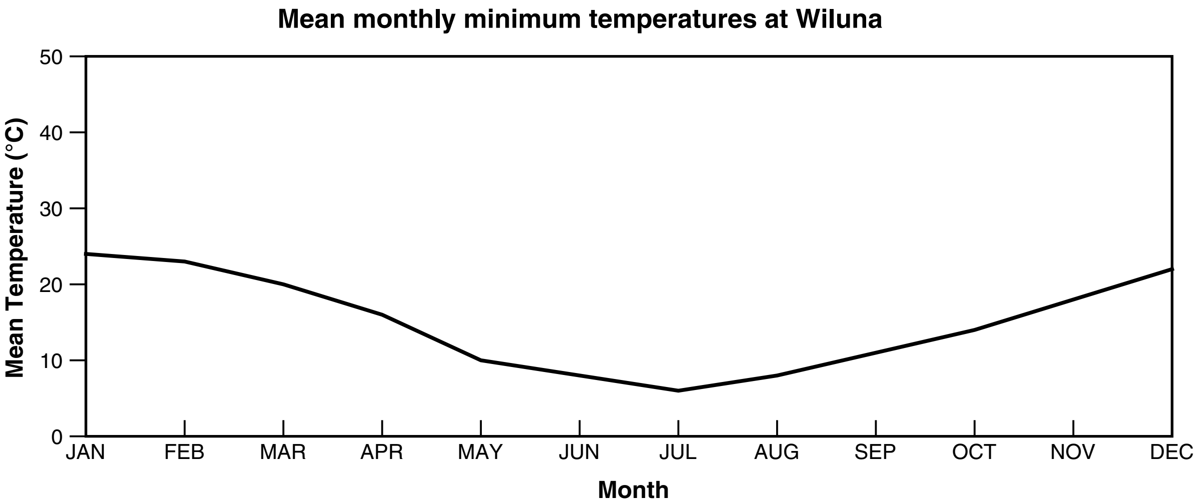

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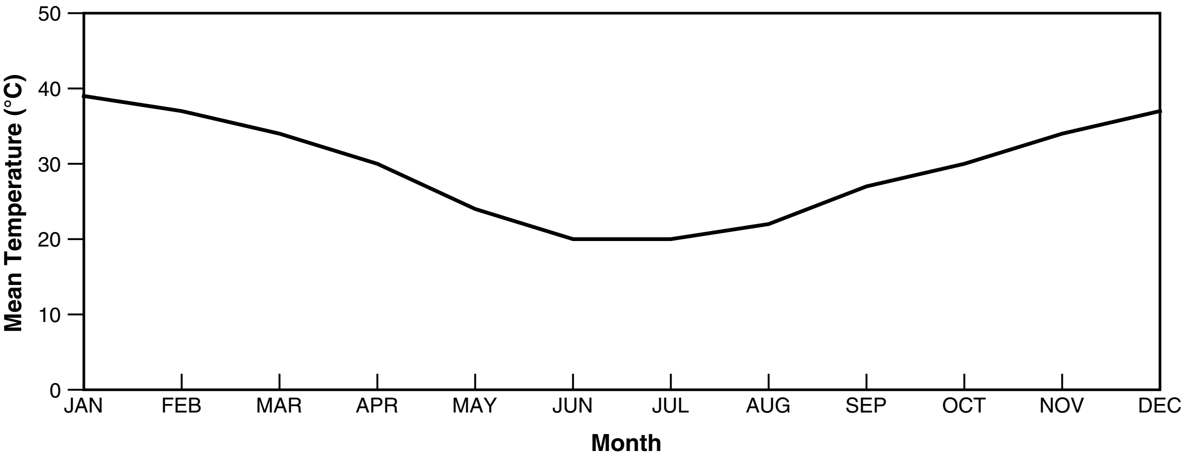
Table 2.3 Wiluna maximum temperature (°C)

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1975	–	34.9	32.6	28.1	24.7	20.1	19.7	21.2	25.6	24.8	31	34.4
1976	37.4	36.9	34.6	29.7	24.8	20.6	20.8	22.5	26.5	28.7	31.3	38.8
1977	39.7	39.2	35.2	29.6	23.4	21.2	22.2	24.4	–	30.8	33.7	38.3
1978	37.8	34.5	34.6	31.6	24.2	19.5	17.6	20.5	23.1	29.5	33.4	35.6
1979	40.3	36	36.4	29.5	–	–	–	19.3	24.2	31.8	35.9	37.3
1980	39.2	34.2	37.7	27.5	24	17.6	17.9	23.3	29.2	28.8	34.9	39.1
1981	38.5	34.6	33.7	34.2	24.2	17.8	20.1	22.4	30	32.6	32.6	36.9
1982	37.2	35.9	31.5	30.7	–	–	19.6	25.3	25.2	30.5	35.3	37.9
1983	38.1	38.9	32.7	27.2	26.3	22.2	18.7	24.8	28.7	32.1	33.6	36.6
1984	37.8	39.3	32.2	29.9	22.6	21.5	17.8	21.4	23.4	–	33.6	36.4
1985	40	36.6	–	29.4	22.4	21.6	20.5	21.2	28.4	30.7	35.5	–
1986	–	38.3	37.2	30.7	–	19.3	16.6	19.6	26.1	27.7	–	38.2
1987	–	33.9	32.8	30.5	21	20.2	21.4	21.8	27.5	–	–	37.4
1988	38.8	36.5	35.3	30.1	23	–	–	22.8	28.3	33.4	31	33
1989	–	37.5	33.9	28.5	23.8	17.9	18.1	21.9	27.5	29.8	33.6	–
1990	36.8	–	36	30.9	26.8	19	18.8	20.5	27.4	30.9	37.3	39.3
1991	41.4	41.6	36.3	31.5	26.8	20.6	21	–	27.9	33.8	33.2	36.8
1992	36.3	38.3	33.6	26.3	21.3	17.8	21.3	19.7	–	28.5	31.3	35.9
1993	39.6	35.7	34.4	30.1	22.1	–	19.7	21.5	25.3	29.4	34.7	36.2
Mean	**39**	**37**	**34**	**30**	**24**	**20**	**20**	**22**	**27**	**30**	**34**	**37**

NOTE: Dashes indicate data unavailable

Mean monthly maximum temperatures at Wiluna



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Appendix 3

Table 3.1. Summary of palynological results

Drillhole	*Depth (m)*	*F no.*[(a)]	*GSWA no.*	*Lithology*	*Formation*	*Assemblage*	*TAI**[(b)]
BWB 1	74–75	F49668	135741	dark-grey siltstone, basalt	Jilyilli	?	>5
BWB 1	98–100	F49669	135742	dark-grey siltstone, basalt	Jilyilli	?	>5
BWB 1	121–122	F49670	135743	dark-grey siltstone, basalt	Jilyilli	?	>5
TWB 1	86–87	F49671	135631	dark-grey siltstone	McFadden	?	3+
TWB 1	104–105	F49672	135632	dark-grey siltstone	Cornelia	?	3+
TWB 1	121–122	F49673	135633	dark-grey siltstone	Cornelia	?	4
TWB 2	14–15	F49674	135634	dark-grey siltstone	Skates Hills	?	3+
TWB 6	49–50	F49675	135675	dark-grey siltstone	?Cornelia	1	3+
TWB 9	49–51	F49676	135704	dark-grey siltstone	Brassey Range	1	3+
Trainor 1	374.97-375.09	F49733	138939	black mudstone with light-grey siltstone	Cornelia	?	5
Trainor 1	380.9	F49734	138940	dark-grey and black laminated mudstone	Cornelia	?	4-
Trainor 1	417.0	F49735	138941	black unlaminated mudstone	Cornelia	?	4-
Trainor 1	495.0	F49851	139501	dark-grey indurated siltstone	Cornelia	?	5
Trainor 1	603.2	F49852	139502	dark- and light-grey indurated siltstone	Cornelia	?	5
Trainor 1	643.4	F49853	139503	greenish indurated finely laminated siltstone	Cornelia	?	5
LDDH 1	270	F49678	138934	dark-grey siltstone interbeds in ?enterolithic evaporite	Waters Tarcunyah Gp	1	3+
LDDH 1	277	F49679	138935	dark-grey siltstone in cavity in ?enterolithic evaporite	Waters Tarcunyah Gp	1	3+

NOTES: (a) GSWA Fossil Catalogue number
(b) TAI = Thermal Alteration Index of Traverse (1988, plate 1)

Appendix 4

Savory Sub-basin quantitative magnetic and gravity interpretation

(extracted from Cowan, 1995)

Summary

A program of quantitative aeromagnetic interpretation has been completed on BMR/AGSO data from the Savory Sub-basin, Western Australia. Quantitative aeromagnetic interpretation utilized the 3D Euler deconvolution method, supported by wavenumber filtering and image processing. The results have provided useful information on structural trends and depth to magnetic sources in a structurally complex area. Depth to magnetic source analysis has provided information on 'intra-sedimentary' magnetic sources as well as basement rocks.

The results of the interpretation support previously identified depocentres. However, the presence of magnetic sources at several levels makes it very difficult to produce a reliable magnetic basement depth contour map. It is considered more productive to work with the 3D Euler colour circle plots and images rather than trying to contour the results. It would be necessary to carry out a full-scale interpretation of the BMR/AGSO profile data to improve on the 3D Euler results. The regional gravity was found to be useful in interpreting the regional setting of the area, although the very wide data spacing limits quantitative use of the data. The gravity data show quite a complex picture with limited consistent correlation between gravity features and basin structures. This suggests that gravity anomalies reflect changes in density of the basement rocks rather than basement topography, especially in the northern part of the basin.

It is recommended that the GSWA investigate access to company confidential high-resolution aeromagnetic data prior to planning further aeromagnetic surveys. Private companies have flown large parts of the northern half of the area as part of their diamond exploration program. Additional gravity coverage of the area may be more cost effective than magnetic surveys as the gravity data provides more information on changes within the sedimentary section.

Introduction

The main use of aeromagnetic data in petroleum exploration has been the determination of 'magnetic' basement topography, although there has been increasing interest in analysis of intra-sedimentary magnetic anomalies, intrabasement and suprabasement magnetic anomalies. These anomalies are used to determine depth to magnetic basement rocks and hence determine the thickness of the sedimentary sequence. Unfortunately, interpretation of the intrabasement and suprabasement magnetic anomalies is non-unique in terms of position and size of causative sources because of the inherent ambiguity of potential-field methods. However, this ambiguity can be reduced by placing constraints on source geometry and magnetization, and by using geological and other geophysical data to constrain the solution.

Before 1970, most depth-determination techniques involved graphical determination of slopes of selected magnetic anomalies and application of various empirical factors to convert the slopes into depth estimates. Geological Society of America Memoir 47, 'Interpretation of Aeromagnetic Maps' by Vacquier et al. (1951) was a landmark for this type of interpretation.

Automated interpretation procedures have played an increasingly important role in depth interpretation and a wide range of techniques have been developed. Many of these techniques are designed for application to located data profiles and assume a two-dimensional geometry. However, there has been renewed interest in techniques applicable to gridded data.

Two distinct types of method can be recognized. In the first case, often described as 'discrete methods', individual isolated magnetic anomalies are interpreted and the results used to produce a map of basement relief. In the second case, often described as 'continuous methods', areas of data containing a number of anomalies are interpreted statistically to produce direct output of basement depths.

The ***discrete methods*** usually involve a semiautomatic initial phase which generates a large number of possible depth solutions, and an interactive second phase to screen and select acceptable solutions. The advantage of this approach is that the interpreter can select features that are relatively free from interference from adjacent anomalies and consider all aspects of a particular magnetic anomaly. The disadvantage is that interpretation can be very time consuming as a wide range of depths are usually possible depending on the initial model chosen and a significant amount of effort is needed to select the correct model. In the case of the Savory Sub-basin dataset, we encountered problems in separating basement related effects from the effects of shallower 'intrasedimentary' magnetic sources. Because of these problems, we have concentrated on displaying the Euler results, accompanied by separation filter images of the data to show the shallower effects and deeper effects rather than trying to refine a 3D Euler deconvolution depth-to-crystalline-basement contour.

The ***continuous methods*** are very direct provided that the rather restrictive assumption can be made that all anomalies are due to lateral magnetization changes due to basement topography. This means that shallow effects and large intrabasement anomalies must be removed from the data. This involves judgement and skill as it is necessary to distinguish between the lower amplitude suprabasement anomalies due to basement topography, and the larger intrabasement anomalies reflecting magnetization changes within the basement. These methods were not considered suitable for the Savory Sub-basin magnetic dataset but were used to invert the gravity data.

Limitations of magnetic and gravity interpretation

Interpretation of the area is limited by a shortage of information on the nature and physical properties of the deeper sedimentary sequence and the underlying basement rocks. However, using techniques such as cross-correlation of gravity and pseudo-gravity data, it is possible to try to differentiate between anomalies relating to basement and those related to the sedimentary sequence.

Gravity anomalies reflect changes within the sedimentary sequence as well as basement condition. These changes in density of sedimentary rocks produce gravity anomalies without a corresponding magnetic anomaly, hence the complementary nature of gravity and magnetic surveys. The main use of **magnetics** is to determine depth to magnetic basement and any intra-sedimentary volcanic rocks or intrusives, whereas **gravity** provides much more general information on the sedimentary sequence.

Unfortunately interpretation of gravity anomalies is complicated since they can be due to a number of geological features including :

- major basement faults
- basement highs
- igneous intrusions within the basement
- sedimentary basins which may or may not be isostatically compensated
- intra-sedimentary volcanics and associated plutonic centres

Two major problems affect the interpretation of both magnetic and gravity data.

1. The inherent ambiguity of potential-field data. There is no unique solution to any measured gravity or magnetic anomaly and theoretically there will be an infinite number of source geometry and magnetization/density combinations which will fit the observed data. This means that any a priori information which helps to select a suitable model is very useful.

2. Measured anomalies are the summation of effects from different depths. For example, an observed gravity profile may contain contributions from shallow sources (density variations within the sedimentary basin), intermediate depth sources (density variations due to large igneous intrusions within the basement) and deep sources (crustal thinning producing a mantle anomaly). Separation of these component responses is the regional/residual problem which we solve using spectral analysis and differential upward continuation-based separation filtering.

Regional setting and interpretation overview

The area studied includes parts of BALFOUR DOWNS (SF51-9), RUDALL (SF51-10), ROBERTSON (SF51-13), GUNANYA (SF51-14), COLLIER (SG50-4), BULLEN (SG51-1), TRAINOR (SG51-2), MADLEY (SG51-3), NABBERU (SG50-5), STANLEY (SG51-6) and HERBERT (SG51-7) 1:250 000 sheets. Broadly, the area lies between latitudes 22°00'–25°30'S and longitudes 119°30'–123°30'E.

Regional gravity

The AGSO regional gravity data (at nominal 11 km spacing) was gridded at a 4 km mesh spacing using a minimum-curvature algorithm. Bouguer gravity values in the area are negative, reflecting mass deficiency at depth and range from -84 mgals to -25 mgals.

A Bouguer gravity colour image is shown as Figure 4.1. A residual grid was produced by removing a fifth-order orthogonal polynomial from the Bouguer data but did not add to the interpretation.

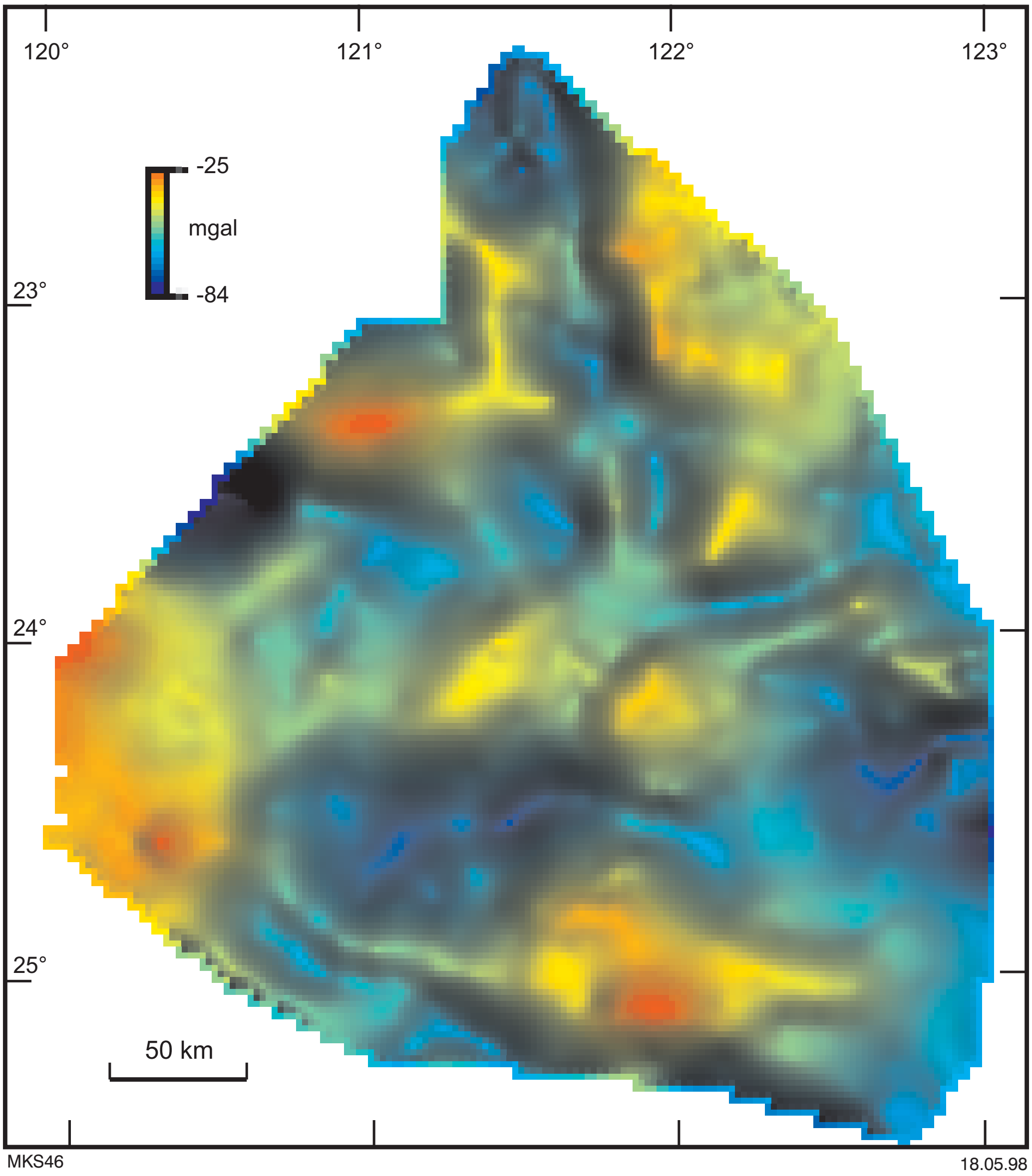


Figure 4.1. Regional Bouguer gravity (BMR/AGSO data) gridded at 4 km

The data show a complex pattern of positive and negative anomalies with no clearly defined trends. Correlations with aeromagnetic data and known basin structures are poor. A vague north-northwest linear trend appears to coincide with the Marloo Fault (Figure 4.2). A prominent negative anomaly appears to coincide with the Blake Fold and Fault Belt depocentre and continues as a narrower negative anomaly to the east until it widens out again near the edge of the basin. Elsewhere, the gravity data show little correlation with known basin structures and it is likely that, especially in the north of the area, gravity anomalies are due to density changes in the basement rather than changes in basement topography.

Production of wavelength-filtered residual gravity plots and vertical gradient plots showed very patchy, aliased data reflecting poor sampling in much of the area.

Regional magnetics

The AGSO regional aeromagnetic data were gridded at a 400 m mesh spacing using a minimum-curvature algorithm (Figure 4.3). Most of the data has a line spacing of 1600 m with small areas of 1 km spacing. The quality of the data is acceptable for regional interpretation but is not adequate for detailed analysis. The accuracy of the flight path is rather variable, reflecting the vintage of the data, and the noise envelope of the data is poor by modern standards. Problems were also encountered in joining different map sheets.

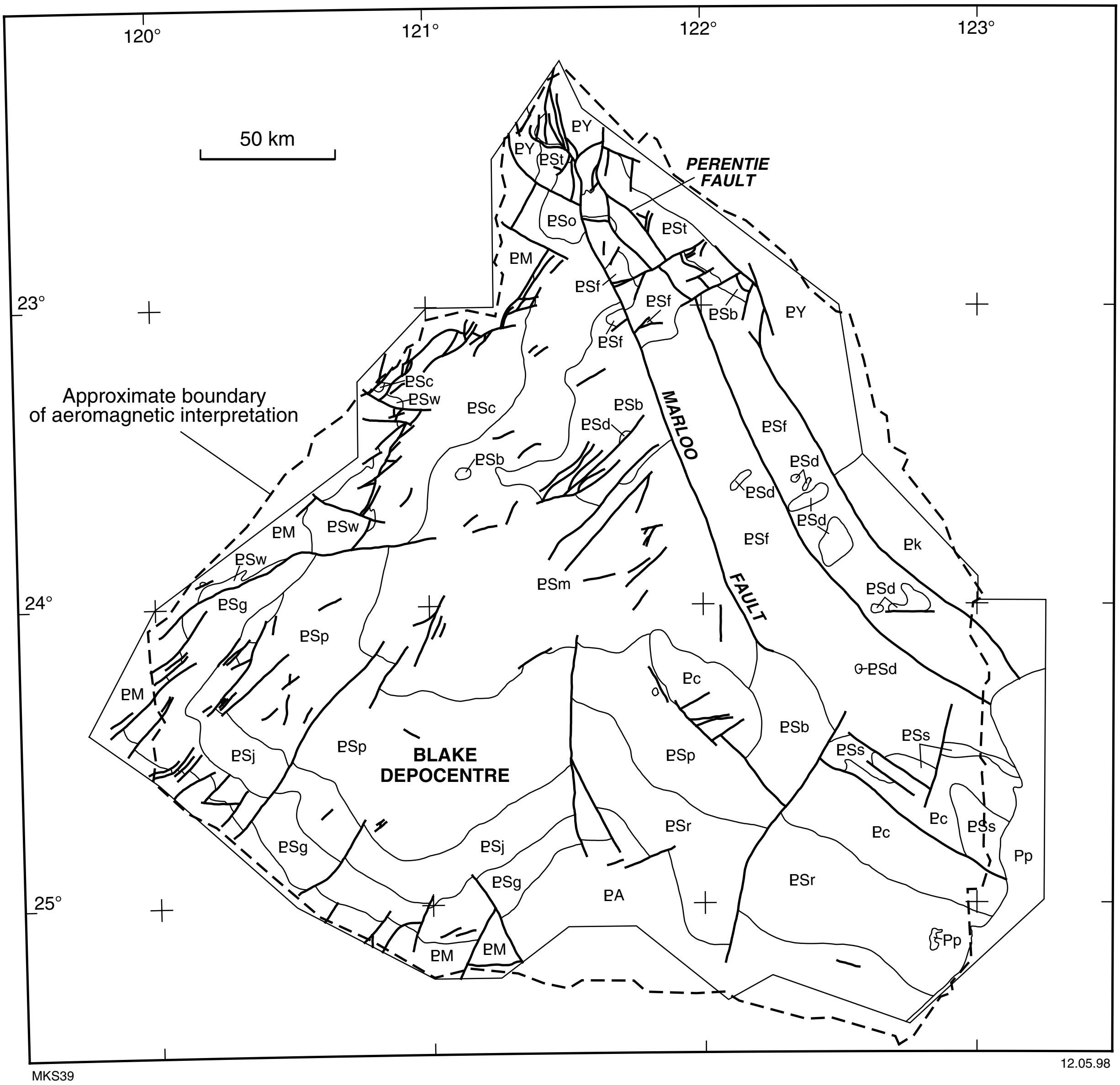
The magnetic anomaly pattern over the south and west part of the area shows a strong high frequency signature, reflecting the presence of widespread basic sills and dykes. Some of the major north-northeasterly trending dykes can be traced over considerable distances.

Discontinuous high-frequency anomalies extend as a northwest-trending zone through the centre of the area and this zone includes a conspicuous circular magnetic anomaly which is probably a ring complex.

The northern and eastern parts of the area are characterized by long-wavelength, deep-seated basement magnetic anomalies with 120° and 150° trends dominant. The Marloo and Perentie Faults (Figure 4.2) appear as distinct linear zones and offsets. A prominent easterly trending negative anomaly in the northwest of the area appears to swing round to the southeast and may separate different basement blocks. One possible interpretation is that this very deep seated anomaly separates areas of Archaean and Proterozoic basement.

Regional geology

The regional geology is described in Williams (1992). The GSWA provided a digitized version of Plate 2 from this Bulletin, the structural interpretation map, to use as an overlay (Figure 4.2).



Savory Group

ⱣSd	Durba Sandstone
ⱣSo	Woora Woora Formation
ⱣSf	McFadden Formation
ⱣSt	Tchukardine Formation
ⱣSb	Boondawari Formation
ⱣSs	Skates Hills Formation
ⱣSm	Mundadjini Formation
ⱣSc	Coondra Formation
ⱣSp	Spearhole Formation
ⱣSw	Watch Point Formation
ⱣSj	Jilyili Formation
ⱣSr	Brassey Range Formation
ⱣSg	Glass Spring Formation

Other Units

Pp	Paterson Formation
ⱣY	Yeneena Group
Ᵽk	Karara Formation
Ᵽc	Cornelia Formation
ⱣA	Kahrban Subgroup
ⱣM	Bangemall Group

Fault

Formation boundary

Figure 4.2. Regional geology and structure map (after Williams, 1992)

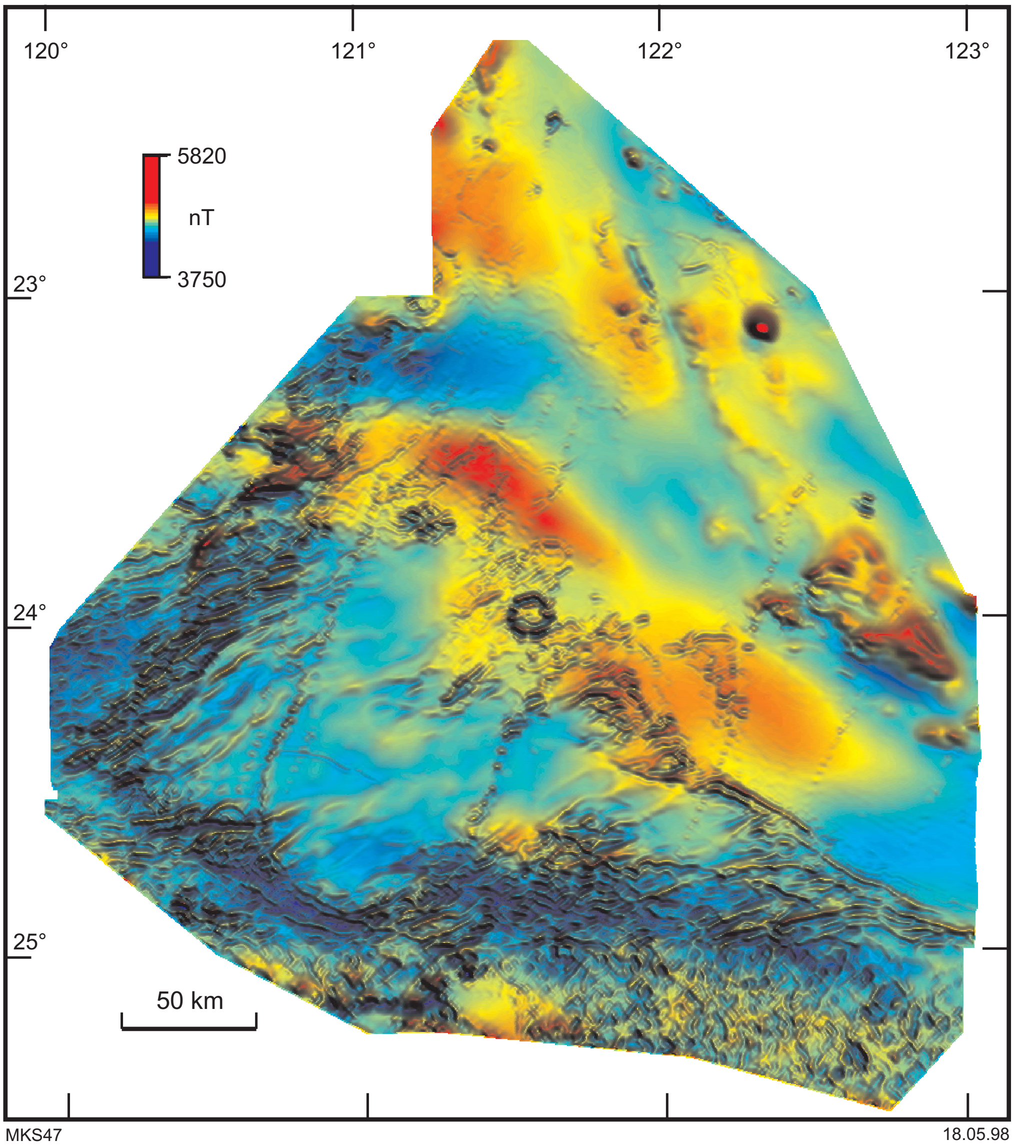


Figure 4.3. Regional aeromagnetic data, total magnetic intensity (BMR/AGSO data), gridded at 400 m

Analysis

3D analysis

3D Euler deconvolution was used as the primary depth-determination method. The advantage of this approach is that consistent solutions can be obtained over the entire area with minimal assumptions about source geometries. Euler deconvolution of gridded data is used for positional information and estimation of depth to top of source. Euler deconvolution yields a large number of depth solutions which have to be screened to reject spurious solutions. Results are plotted as circles in eight depth ranges with radius proportional to depth and colour coded.

The 400 m total magnetic intensity grid was used for the analysis. Horizontal gradients in x and y and the vertical gradient were calculated. 3D Euler deconvolution was tested on the 400 m gridded data using windows of 9 × 9 and 11 × 11 and 16 × 16 data points and structural indices 0.5 (fault) and 1.0 (sill or dyke). It was concluded that the 16 × 16 window produced the best results overall and final plots were produced for the 16 × 16 window and structural index 0.5 (Fig 4.4). Results were very good over the northern and central parts of the area showing magnetic sources

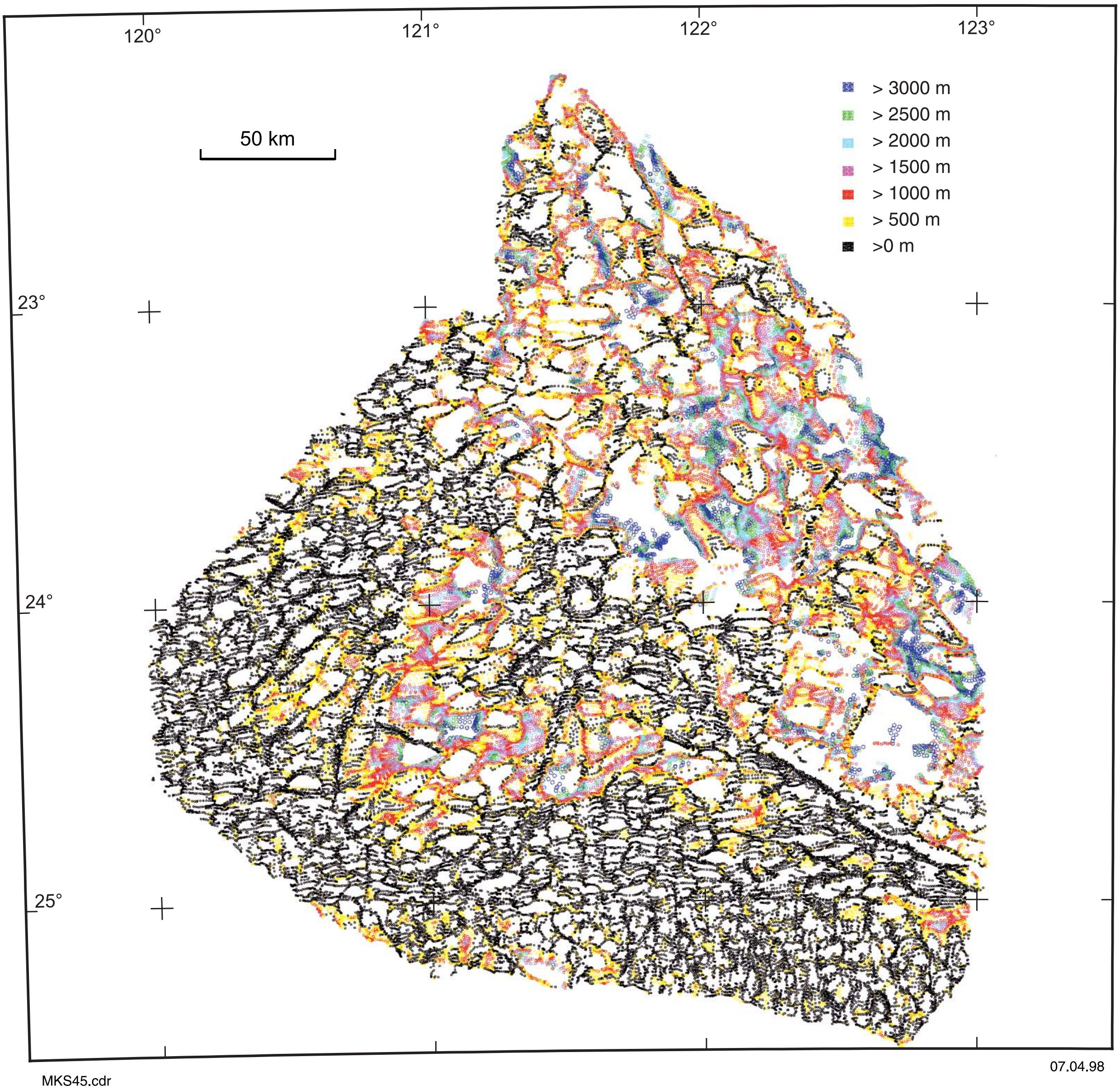


Figure 4.4. Depth to magnetic source, 3D Euler deconvolution, 16 × 16 window of 400 m gridded data, structural index 0.5

at several different levels. Unfortunately, in the extreme south of the area, shallow intrasedimentary magnetic sources (sills and dykes) dominated the inversion and the results contained few basement solutions.

In order to reduce these problems, the 400 m gridded data were filtered using a separation filter based on interpretation of the log-energy spectrum. The 3D Euler method was run on the filtered data in order to generate more basement-depth solutions. Results for the deep-separation filter data were gridded and presented as a colour image in Cowan (1995). Attempts to grid the Euler output were unsatisfactory and it is considered safer to interpret the 3D Euler depth plots. The 3D Euler depth results from the separation-filter run should be analysed with care as perfect separation of the basement can never be achieved and there will always be some contamination from sources at different levels.

The results of original total magnetic intensity 3D Euler depth estimation for structural index 0.5 using a 16 point window have been plotted at 1:500 000 scale (not included in this publication, but available in Cowan (1995) from the GSWA Library as S10331) and as reduced A4 colour circle plots (Figure 4.4).

The results of deep-basement 3D Euler depth estimation for structural index 0.5 using a 16 point window have been plotted as a colour image at 1:500 000 scale and as an A4 image (not included in this publication).

2D analysis

Two equispaced profiles were interpolated with a 50 m station interval from the AGSO-located data profiles for the BULLEN 1:250 000 sheet. The interpolated profiles were analysed using 2D Euler deconvolution and Werner deconvolution. Results are included in Cowan (1995) and show the use of these methods for more detailed analysis.

Filtered data

In order to reconcile 3D Euler results from shallow basement and intrasedimentary magnetic sources, we produced several separation-filtered maps and images. We found the shallow-layer double-separation filter (Figure 4.5) to be very effective for shallow sources and the deep-layer standard-separation filter (Figure 4.6) for the 'basement' layer.

Gravity and magnetic data correlation

Both ‘reduced to the pole’ (RTP) magnetics (Figure 4.7) and pseudo-gravity data (Figure 4.8) were produced as part of the reconciliation of gravity and magnetic signatures. In both cases the filtering operations assumed magnetization by induction in the present Earth's field. The RTP data are fairly similar to the total magnetic intensity. The pseudo-gravity data are dominated by a northwest-trending strong positive anomaly and there is little correlation with the Bouguer gravity data.

The poor magnetic/gravity correlation is confirmed by cross-correlation of the RTP magnetics and the gravity gradient. The correlation plot in Figure 4.9 shows little coherent response, with numerous zones of positive and negative correlation.

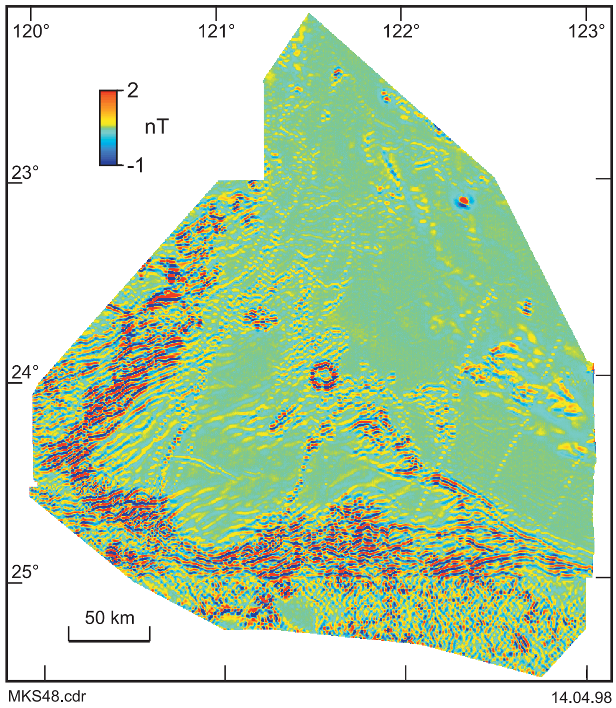


Figure 4.5. Regional aeromagnetic data, shallow layer separation filter (BMR/AGSO data), gridded at 400 m

Results

In the north and east of the area, on the Wells Foreland Sub-basin trend (refer to Figure 1, main text), we see a range of quite deep 3D Euler depths and several trend directions with north-northwesterly dominant. There are relatively few shallow intrasedimentary solutions in this zone.

The second area of deep 3D Euler solutions lies over the Blake depocentre (Figure 4.3) with several trend directions.

Elsewhere the 3D Euler results are dominated by shallow intrasedimentary depth solutions, reflecting mainly the dolerite sills, dykes, and the ring complex. However, where we do see basement-related solutions in the south and west of the area, they appear to be shallower than those noted for the Wells Foreland Sub-basin and the Blake depocentre.

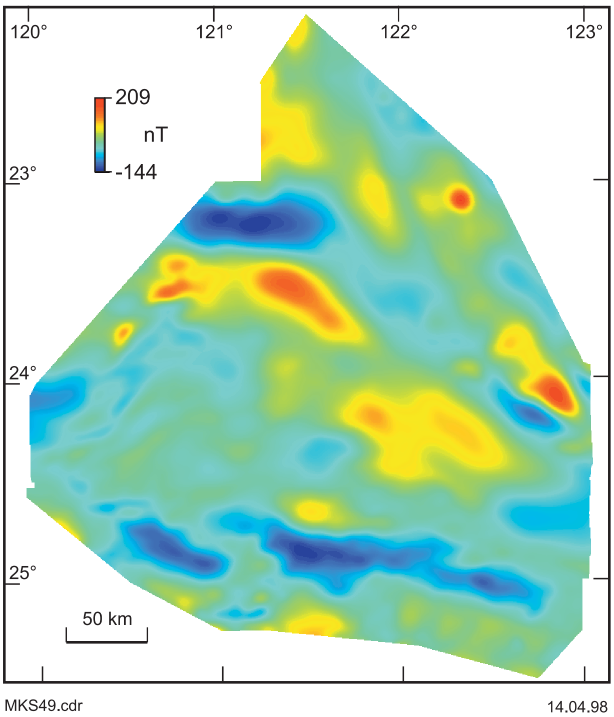


Figure 4.6. Regional aeromagnetic data, deep-layer separation filter (BMR/AGSO data), gridded at 400 m

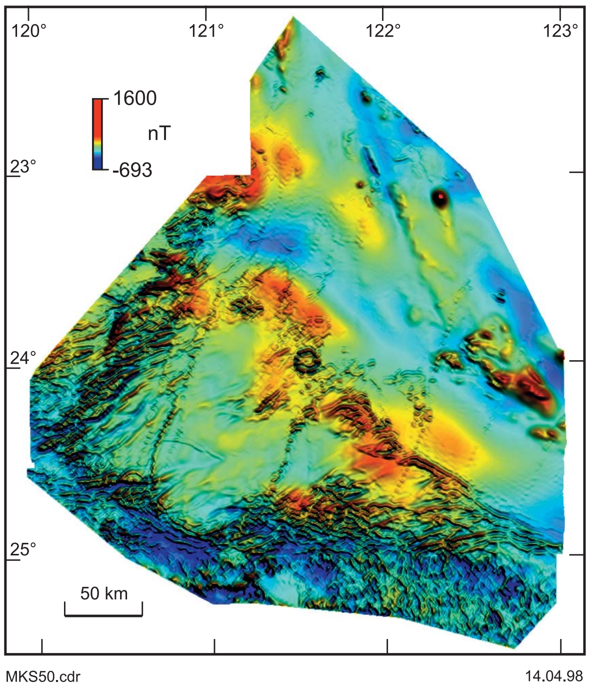


Figure 4.7. Regional aeromagnetic data, reduced-to-pole (BMR/AGSO data), gridded at 400 m

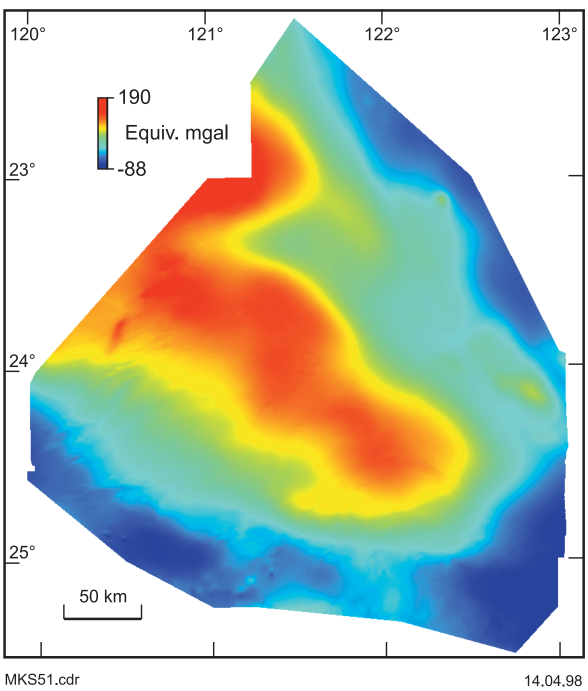


Figure 4.8. Regional aeromagnetic data, pseudo-gravity transform (BMR/AGSO data), gridded at 400 m

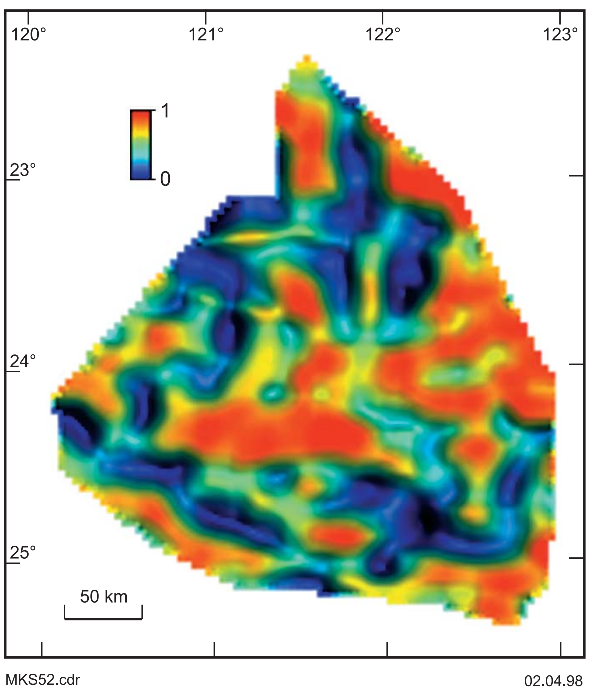


Figure 4.9. Regional aeromagnetic and gravity data, gravity/magnetic correlation using RTP magnetics and gravity gradient (BMR/AGSO data), gridded at 4 km

This subdivision of the area into two zones of deep solutions is consistent with interpreted depocentres. However, the interference between sources at different levels and the complexity of the magnetic response of the basement rocks precludes more refined interpretation at this stage.

The area of deep 3D Euler solutions over the Blake depocentre correlates with the pronounced negative gravity anomaly discussed in the gravity interpretation section. Using a density contrast of -0.15 g/cc, the negative gravity anomaly could indicate up to 6–8 km of low-density sedimentary rocks, depending on assumptions about the regional field.

The area of deep 3D Euler solutions over the Wells Foreland Sub-basin has a complex gravity expression and no clear basin structure emerges from inversion of these data. As noted previously, it is likely that observed gravity anomalies reflect contrasts in basement density rather than basement topography.

Separation filtering applied to the magnetic data helps to enhance the intrasedimentary magnetic signature and to give a better impression of the basement magnetic signature even though separation of the basement response is not perfect.

Conclusions

Quantitative aeromagnetic interpretation using 3D Euler deconvolution, supported by wavenumber filtering and image processing, has been successful in providing structural trend and depth information for the Savory Sub-basin

Quantitative magnetic interpretation has revealed two zones of relatively deep magnetic basement beneath the Wells Foreland Sub-basin and the Blake depocentre.

This analysis of the magnetic data supports interpreted depocentres but the complexity of the basement magnetic signature and interference from sources at different depths precludes further refinement to a map of basement topography.

Regional gravity proved to be very useful in understanding the regional setting of the area and in providing support for aspects of the interpretation. The gravity data support the interpretation of the Blake depocentre, suggesting up to 6–8 km of low-density sedimentary rocks.

The deep structure of the Savory Sub-basin area is obviously complex, with different areas underlain by Archaean and Proterozoic basement and with the Capricorn suture occurring in the centre of the area.

Recommendations

The quantitative magnetic interpretation needs to be reconciled with geological models available for the area.

In particular, the zones tentatively identified as areas with thick sedimentary rocks, the Wells Foreland Sub-basin, and the Blake depocentre need to be investigated.

Cross sections should be prepared across the basin for joint magnetic/gravity modelling, especially for the Blake depocentre. It is important to be able to explain the strong negative gravity anomaly in this area.

In view of the effects of basement density contrasts on the gravity field for the northern part of the area, we think that additional gravity interpretation and acquisition of new gravity data may not be justified as they will not contribute significantly to understanding basin evolution and structure.

It is recommended that GSWA try to get access to company confidential high-resolution aeromagnetic data rather than flying new surveys. The GSWA might offer to fund flying of new infill areas as a bargaining point.

References

The original text of this report by Cowan (1995) and 1:500 000 scale maps are filed in the GSWA Library under S10331.

COWAN, D., 1995, Savory Basin quantitative magnetic interpretation: Western Australia Geological Survey, S-series, S10331 (unpublished).

VACQUIER, V., STEENLAND, N. C., HENDERSON, R. G., and ZIETZ, I., 1951, Interpretation of aeromagnetic maps: The Geological Society of America, Memoir 47, 151p.

WILLIAMS, I. R., 1992, Geology of the Savory Basin, Western Australia: Western Australia Geological Survey, Bulletin 141, 115p.

Appendix 5
Geochemistry

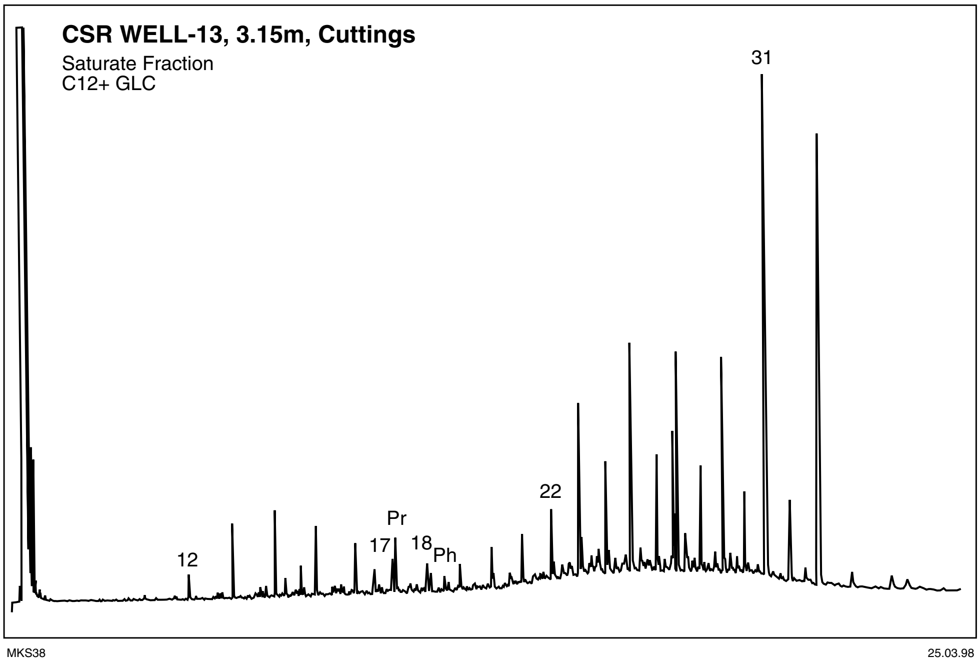


Figure 5.1. Canning Stock Route Well 13 gas chromatograph of extract of auger drill sample

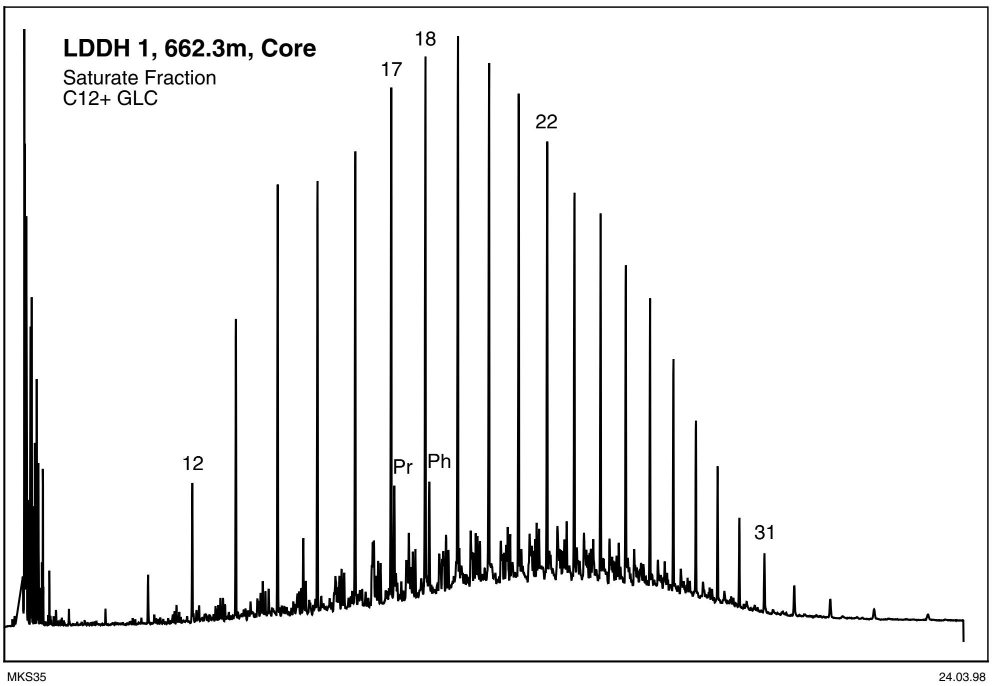


Figure 5.2. Gas chromatograph of extract from core sample at 662.3 m LDDH1

Table 5.1. Canning Stock Route Well 13 auger drill samples

GSWA sample	*Drill depth (m)[(a)]*	*Comments*
135601	1.50	At watertable
135602	2.03	(all samples consist
135603	3.10	of sand, mud and water)
135604	3.15	At total depth

NOTE: (a) Datum for drill depth is the top of sediment fill in the well, which is 1.55 m below ground level (i.e. the total depth of 3.15 m is 4.7 m below ground level).

Table 5.2. Canning Stock Route Well 13 gas chromatography data for 3.15 m depth sediment sample

Parameter	*Value*
Weight of rock extracted (grams)	94.5
Total extract (ppm)	51.9
n-Alkane distribution	
n-C12	0.7
n-C13	2.3
n-C14	2.6
n-C15	2.2
n-C16	1.9
n-C17	1.4
i-C19	2.3
n-C18	1.4
i-C20	0.8
n-C19	1.1
n-C20	1.6
n-C21	2.5
n-C22	2.9
n-C23	7.0
n-C24	4.2
n-C25	9.5
n-C26	4.3
n-C27	8.3
n-C28	3.8
n-C29	8.7
n-C30	3.1
n-C31	27.3
Alkane compositional data	
Pristane / phytane ratio	2.79
Pristane / n-C17 ratio	1.61
Phytane / n-C18 ratio	0.59
CPI (1)[(a)]	2.84
CPI (2)	2.09
(C21 + C22) / (C28 + C29)	0.43

NOTE: (a) CPI= Carbon preference index.

Table 5.3. LDDH1 extract liquid chromatography data for 662.3 m: concentration

Rock extracted (grams)	*Total extract (ppm)*
70.2	31.3

NOTE: ppm= parts per million

Table 5.4. LDDH1 saturate gas chromatography data of core for 662.3 m: alkane composition

Pristane/ Phytane	*Pristane/ n-C17*	*Phytane/ n-C18*	[(a)] *CPI (1)*	*CPI (2)*	*{(C21+C22)/ (C28+C29)}*
1.03	0.26	0.24	1.03	1.02	3.25

NOTE: [(a)]CPI = carbon preference index

Table 5.5. LDDH1 saturate gas chromatography data of core for 662.3 m: n-alkane distributions

Parameter	*Value*
n-C12	1.7
n-C13	3.8
n-C14	5.5
n-C15	6.0
n-C16	6.5
n-C17	7.4
i-C19	1.9
n-C18	7.8
i-C20	1.9
n-C19	8.0
n-C20	7.9
n-C21	7.1
n-C22	6.4
n-C23	5.7
n-C25	4.3
n-C24	3.8
n-C27	3.1
n-C28	2.3
n-C29	1.9
n-C30	1.2
n-C31	1.0

Appendix 6

Table 6.1. Summary of data from Trainor waterbores (TWB) and Bullen waterbores (BWB)

Well	*AMG AGD84 Z51*[(a)]	*Elevation GL (m)*	*TD (m)*	*Status*[(b)]	*Completion details* Interval (m)	*(100 mm PVC)*	*Water struck (m)*	*Salinity mg/l*[(c)] *(mg/l)*[(d)]	*Water level (m)*	*Flow rate (L/Hr)*	*Depth to consolidated lithology, aquifer*[(e)]
TWB 1	473660E 7287404N	453	122	comp	0–75 75–93 93–99	plain slotted plain	63	7 300 (9 260)	24	2 880	12 m McFadden Fm
TWB 2	472 977E 7285877N	475	23	abd			nil				1.5 m Skates Hills Fm, dry
TWB 3	473259E 7285849N	475	50	abd			nil				7 m Skates Hills Fm, dry
TWB 4	463225 E 7286143N	445	50	comp	0–22 22–34 23–60	plain slotted plain	35	7 200 (8 140)	5.5	3 600	0 m Tertiary sand and gravel
TWB 5	463095E 7277721N	445	31	comp	0–19 19–25 25–31	plain slotted plain	13	26 000 (36 700)	6.55	3 600	Tertiary sand and gravel
TWB 6	457013E 7274352N	455	50	comp	0–42 42–48	plain slotted	38	920 (1 030)	11.9	600	0 m Cornelia Fm ss
TWB 7	453739E 7263891N	475	26	susp	0–2	plain	11	9 300 (10 500)	4.8	4 500	0 m Tertiary sand
TWB 8	433893E 7245991N	535	60	susp	0–2	plain	47	8 500 (10 900)	>4.6	1 200	0 m Tertiary sand and Brassey Range Fm ss
TWB 9	437219E 7235905N	505	51	comp	0–47 47–51	plain slotted	45	1 000 (990)	5.8	600	1 m Brassey Range Fm ss
TWB 10	434927E 7225875N	495	32	susp	0–2	plain	23.5	450 (500)	120		0 m Dolerite

BWB 1	287337E	580	122	abd				Nil			1 m
	7245861N										Jilyili Fm, dry
BWB 2	288346E	545	50	comp	0–26	plain	15	630	3	29 000	0 m
	7240423N				26–38	slotted		(730)			Tertiary sand and gravel
					38–50	plain					
BWB 3	305637E	545	50	abd			19	8 800	4.3	7 200	0 m
	7240423N							(10 550)			Tertiary ss
BWB 4	320167E	515	44.5	comp	0–20	plain	9	980	4.45	24 000	0 m
	7248097N				20–32	slotted		(1 190)			Tertiary ss
					32–44	plain					
BWB 5	353393E	545	20	susp	0–2	plain	4.5	(970)			1 m
	7238934N										Basalt

NOTES: (a) GPS accuracy ~ 150 m
(b) Comp = completed; abd = abandoned; susp = suspended
(c) Salinity from conductivity
(d) Analysis, total dissolved solids
(e) Fm = Formation; ss = sandstone