REPORT 46

GOVERNMENT OF WESTERN AUSTRALIA

STRATIGRAPHY AND STRUCTURE OF THE ONSHORE NORTHERN PERTH BASIN WESTERN AUSTRALIA

by A. J. Mory and R. P. Iasky

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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Cover:
Vibroseis acquisition in the Dongara area.

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Plates (in wallet)*

* Digital data for appendices and plates are available on request from the Department of Minerals and Energy.

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'The Perth Basin — a featureless sandplain underlain by a maze of geophysics.'
(attributed to an unknown WAPET geologist in the late 1950s)

Stratigraphy and structure of the onshore northern Perth Basin, Western Australia

by

A. J. Mory and R. P. Iasky

Abstract

The onshore northern Perth Basin is interpreted as an extensional basin of Early Permian to Holocene age on the western edge of the Australian Craton.

Data from numerous deep wells, outcrop, and extensive geophysical coverage show that the main sedimentary succession is Permian to Early Cretaceous in age and up to 12 000 m thick. This succession consists of: (a) largely argillaceous Lower Permian glaciomarine to deltaic rocks, (b) Upper Permian nonmarine and shoreline siliciclastics to shelf carbonates, and (c) Triassic to Lower Cretaceous nonmarine to shallow marine siliciclastics deposited in a predominantly regressive phase. Overall, the Triassic and Lower Jurassic succession thickens to the south along the axis of the basin suggesting a period of trough infill. In the northern part of the basin the Northampton Complex was a positive feature during the Middle Triassic to Early Jurassic. Substantial thickening of the Upper Jurassic to Lower Cretaceous succession into the Dandaragan Trough suggests the onset of rifting at this time.

Analysis of structural trends indicates the basin has a complex tectonic history. Pre-existing basement fabric largely determined the pattern of faulting during the Phanerozoic phases of tectonism. Two major phases are recognized:

1. Permian extension in a southwesterly direction;
2. Early Cretaceous transtension to the northwest during the break-up of Greater India from Australia. Sinistral and dextral movement, respectively, is inferred along the Darling Fault during these phases.

The onshore northern Perth Basin contains six commercial hydrocarbon fields of which Dongara is by far the largest. Total proven reserves discovered to date are ~ 17×10^9 m^3 of gas, 500 000 kL of oil and 100 000 kL of condensate. Geohistory modelling of wells in the northern part of the basin shows that the Triassic and Permian units are now within the oil-maturation window. Maturation increases towards the southeast and in the southern Dandaragan Trough these units lie within the gas-maturation window. Modelling also suggests that source rocks within the northern Perth Basin reached the oil-maturation window during the period of rapid subsidence immediately before breakup in the earliest Cretaceous. All the known fields and smaller hydrocarbon accumulations are within wrench anticlines that formed in the Early Neocomian at a time that coincided with the peak period of hydrocarbon expulsion.

KEYWORDS: Permian, Triassic and Jurassic stratigraphy, geophysics, seismic, gravity, aeromagnetics, geohistory modelling, regional geology, petroleum potential, north Perth Basin, Western Australia.

Introduction

The Perth Basin is a north–south elongate trough in the southwest of Western Australia containing a Silurian to Pleistocene sedimentary succession (Fig. 1). About one half of the basin is located onshore and extends from the south coast to near the Murchison River, a distance of approximately 750 km. The eastern boundary is the Darling Fault and the basin extends offshore to the continental–oceanic boundary.

The area of investigation is the northern, onshore portion of the Perth Basin between 29° and 31°S, bounded by the Yilgarn Craton to the east and the coast to the west, and covering an area approximately 220 km long and 90 km wide. Within this area are the Dandaragan Trough, Beagle Ridge, Dongara Terrace and a number of small, newly recognized sub-basins. Information from outcrop on the adjoining Irwin Terrace is also included in this Report. The area covers DONGARA* (SH 50-5), HILL RIVER (SH 50-9), and the western parts of MOORA (SH 50-10) and PERENJORI (SH 50-6) 1:250 000 sheets.

* Capitalized names refer to standard map sheets.

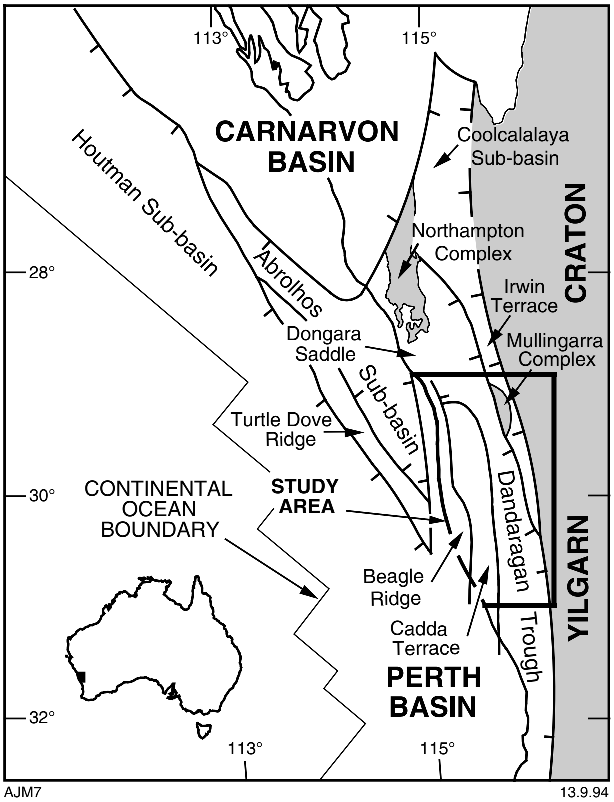

Figure 1. Location map and major tectonic elements, onshore northern Perth Basin

Most of the sedimentary section in the onshore northern Perth Basin is Permian to Early Cretaceous in age (Fig. 2) and pre-dates the separation of Western Australia and greater India during the breakup of Gondwana. A thin veneer of post-breakup Cretaceous sediment is present in the southernmost part of the study area. Pre-Permian sediments are present in the Perth Basin north of the study area and are restricted to a few small outcrops of the Silurian Tumblagooda Sandstone next to the Northampton Complex, and in the Coolcalalaya Sub-basin. The only other evidence for pre-Permian sediments in the Perth Basin is from reworked Devonian spores (Ingram, 1967, Backhouse, 1993d) but no Devonian strata have been identified to date.

The Perth Basin has been described for many years as an intensely faulted half-graben (e.g. Playford et al., 1976). Understanding of the structural evolution of the basin has changed dramatically over the last five years with the recognition of a number of events, in particular trans-tensional faulting, by Stein et al. (1989), Marshall et al. (1989), Middleton (1990), Iasky et al. (1991), Byrne and Harris (1992), Marshall et al. (1993), Iasky and Mory (1994), Mory and Iasky (1994), Harris (1994), and Etheridge and O'Brien (1995).

The analysis here of fault trends and tectonic history of the onshore northern Perth Basin between latitudes 29° and 31° S (Fig. 1) is based largely on subsurface structure maps of the Middle Jurassic (top of Cattamarra Coal Measures), top Permian, and basement levels. The information for these maps was derived from a regional seismic grid totalling 11 800 line kilometres, and 155 petroleum exploration, development and stratigraphic wells. Aeromagnetic and gravity images were also used to establish the orientation of faults and provide additional insight into the structural fabric of the basin.

The discovery of several oil and gas fields onshore, and numerous hydrocarbon shows both onshore and offshore, confirms the petroleum potential of the basin. The early 1990s has been a period of exploration revival, with a large part of the northern half of the study area being under permit to companies with committed active exploration programs. This commitment, together with improvements in seismic processing, led to the discovery of the Beharra Springs gas field in 1990 (Hall and Kneale, 1992). The petroleum potential of the area is discussed only briefly: more detailed accounts are presented by Cadman et al. (1994) and in the report of a concurrent Geological Survey of Western Australia (GSWA) project by Crostella (1995).

Previous investigations

The earliest systematic work on the onshore northern Perth Basin was surface mapping carried out by the GSWA (Campbell, 1907, 1910). Further work by the GSWA in the 1950s concentrated on coal in the northern part of the area (Johnson et al., 1954), and in the 1960s and 1970s on regional outcrop mapping (Playford et al., 1970; Lowry, 1974; Carter and Lipple, 1982; Baxter and Lipple, 1985). These outcrop studies were incorporated into a larger study by Playford et al. (1976) that included much of the well data available at the time. Similarly, surface mapping of the study area west of 115°30'E (Mory, 1994a,b, 1995a,b) and a coal report on the Irwin Terrace (Le Blanc Smith and Mory, 1995) have been utilized in this study. GSWA reviews, such as Playford et al. (1975) and Cockbain (1990), are based largely on the work of Playford et al. (1976). The only seismic structure map of the area published by the GSWA is a top Lower Jurassic horizon map compiled by Luck (1989).

A great deal of the early work on the northern Perth Basin was conducted by staff and students at the University of Western Australia, but this concentrated on outcrop on the Irwin Terrace (Clarke et al., 1951; Playford, G., 1959) or near the Northampton Complex (Playford, P., 1959). A summary of this work was presented in McWhae et al. (1958). It was not until the late 1980s that university workers published on the main part of the onshore northern Perth Basin (Bergmark and Evans, 1987; Rasmussen et al., 1989; Harris, 1994).

History of petroleum exploration

Early views on the petroleum potential of the Perth Basin were not entirely pessimistic: Clapp (1926, p. 423) wrote that the Perth Basin was 'the least unfavourable of any Westralian basin'. Forman (1935) noted a surface anticlinal feature of 'some promise in the search for oil' that, although later questioned by Teichert (1947), ironically was near the non-economic Walyering gas accumulation

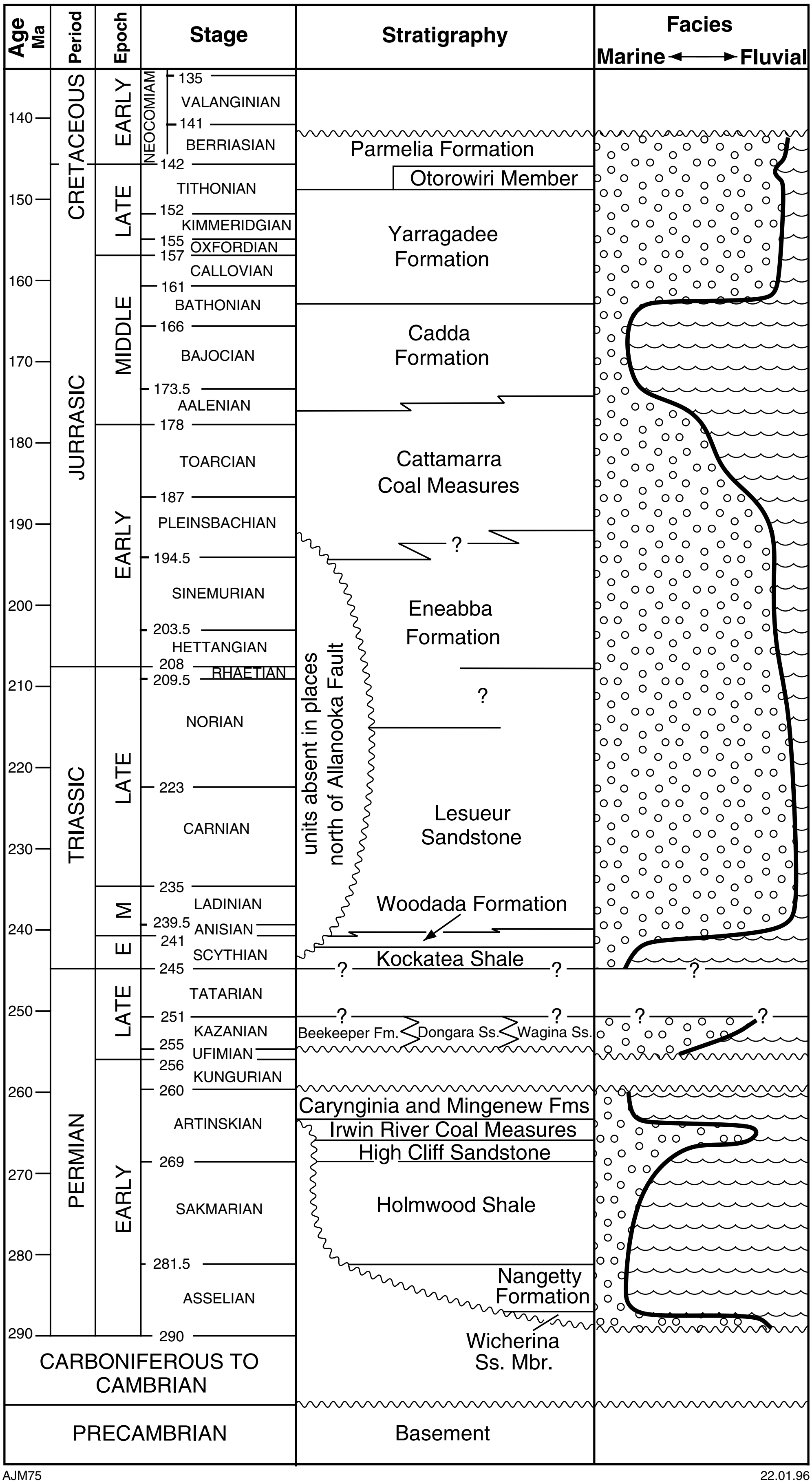

Figure 2. Stratigraphy of the northern Perth Basin

discovered by WAPET in 1971. Fairbridge (1948) suggested that the basin was 'not unfavourable for the initial formation of petroleum' and further suggested the possibility of anticlinal structures in the Permian below Mesozoic cover. Reeves (1951, table 1) listed the basin amongst those with 'moderate oil prospects'.

The search for hydrocarbons in the northern part of the Perth Basin did not commence until the Ampol and Richfield Oil companies commissioned an outcrop study that concentrated on the Mesozoic units in the Gairdner Range (Conrad and Maynard, 1948), and an evaluation of the results of early drilling for water (Fairbridge, 1948). This work was followed by Bureau of Mineral Resources (BMR) gravity surveys in 1949 and 1951–52 (Thyer and Everingham, 1956). When West Australian Petroleum Pty Ltd (WAPET) gained control of the exploration permit that covered the Perth Basin (PE 27H), they carried out further outcrop studies (Kempin and Elliott, 1953; Parry and Hoelscher, 1955; Willmott, 1960) and commenced geophysical reconnaissance in the Hill River area in 1955. This work confirmed the presence of a thick sedimentary section. Oil shows from Lower Permian sandstones in BMR 10 and 10A drilled on a gravity high (the Beagle Ridge) by the BMR in 1959–60 stimulated further drilling by WAPET commencing with Eneabba 1, drilled in 1961.

WAPET dominated early activity in the onshore northern Perth Basin with the discovery of the Yardarino field in 1964, the Dongara and Mount Horner fields in 1965, and the Mondarra field in 1968. Relatively little activity followed these discoveries until smaller companies became active in the 1980s. The most successful of these companies were Hughes and Hughes, with the discovery in 1980 of the Woodada field, and Discovery Petroleum (previously called Barrack Petroleum) with the discovery of the Beharra Springs field in 1990. Of these fields Dongara is the most significant, containing total gas reserves of approximately 12.5×10^9 m^3, 95% of which has been produced, followed by Woodada (1.9×10^9 m^3, 50% produced) and Beharra Springs (1.7×10^9 m^3, 20% produced). Production and remaining reserves for fields and small accumulations in the onshore northern Perth Basin is summarized in Table 2.

Most of the work by petroleum exploration companies on the onshore northern Perth Basin remains unpublished, but many of the reports with non-confidential data are available through the Department of Minerals and Energy in Perth, Western Australia. Some of this work has been published as a number of short papers (Johnstone and Willmott, 1966; Hosemann, 1971; Jones and Pearson, 1972; Jones, 1976; Thomas, 1979; Kantsler and Cook, 1979; Nolin, 1981; Lane and Watson, 1985b; Warris, 1988, 1993; Hall, P. B., 1989; Hall and Kneale, 1992).

Present study

Scope and objectives

The aim of the present study was to produce an integrated regional structural and stratigraphic picture of the onshore northern Perth Basin using selected seismic and well data. For this reason the area between 29° and 31°S was selected as it has both reasonable seismic coverage and the greatest concentration of wells in the northern Perth Basin. In addition, information from GSWA hydrogeological drilling (Barnett, 1969; Harley, 1975; Commander, 1978; Briese, 1979; Moncrieff, 1989; Kern, 1993, 1994; Nidagal, 1995) and recent 1:100 000 outcrop mapping (Mory, 1994a,b, 1995a,b; Le Blanc Smith and Mory, 1995) has been incorporated into the study. A pre-Cainozoic geology map was prepared using all available data to aid the seismic interpretation (Plate 10).

During the project aeromagnetic images of parts of the area became available and as these images provided complementary information to the seismic and well data they have been incorporated into the study. Similarly, gravity data collected over a number of seismic surveys in 1993–1994 (Dongara 3-D, Strawberry Hill 2-D, Mingenew, and Logue seismic surveys) have been used to produce images to complement the available dataset, as well as providing information in areas where there are no seismic data or deep wells; e.g. Arrowsmith borefield.

Well data

The stratigraphy of 82 of the 155 petroleum exploration, development and stratigraphic wells in the area (Fig. 3, Plate 1, Appendix 3) was examined in detail to produce a consistent set of formation tops (Appendix 5) and isopach maps. Four east–west and two north–south well correlation plates were constructed from this data set (Plates 12 to 17).

Seismic data

A regional seismic grid totalling 11 800 line kilometres was selected from the reflection surveys available in 1992 (totalling approximately 17 000 line kilometres — Fig. 4, Plates 2 and 3, Appendix 1). Three horizons were mapped from the seismic data: Top basement (*E*), Top Permian (*P*), and Top Cattamarra Coal Measures (*Jc*). These are shown in Plates 4, 6, and 8 and converted to depths in Plates 5, 7, and 9. A montage of some of the better quality east–west oriented seismic sections, illustrating the overall structure of the onshore northern Perth Basin, is shown in Plate 18.

Physiography

The northern Perth Basin has been divided into a number of physiographic units that reflect distinct topography, drainage, and geology (Lowry, 1974; Playford et al., 1976). The physiographic divisions of Finkl and Churchward (1973), based on the development of etchplains (planar landscapes produced by alternating phases of deep chemical weathering and erosion), are not used here as their divisions cannot be easily reconciled with those of Lowry (1974) and Playford et al. (1976). In addition, Wyrwoll (1988) considers that the development of etchplains in the region is not significant.

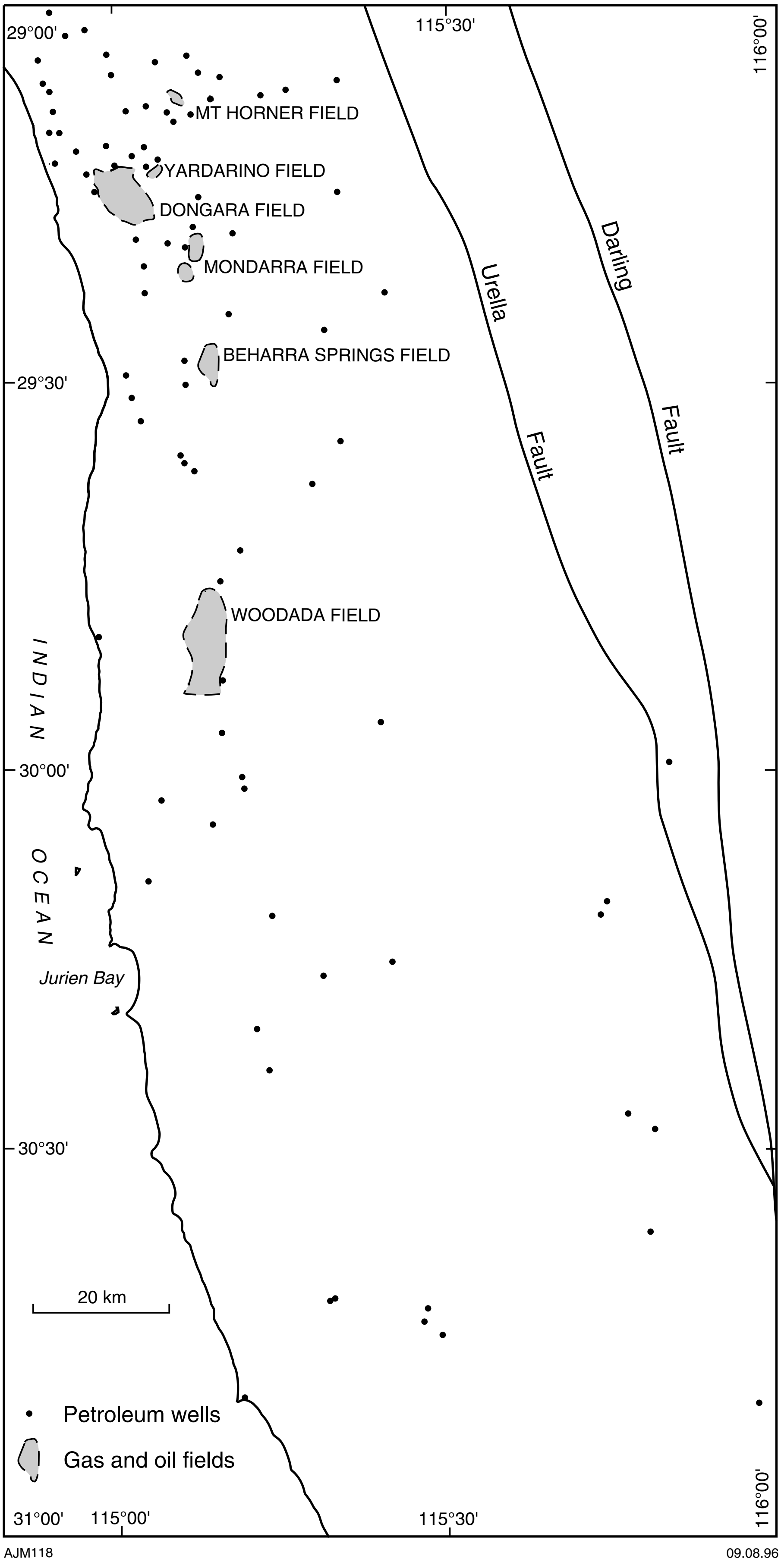

Figure 3. Distribution of petroleum wells in the onshore northern Perth Basin

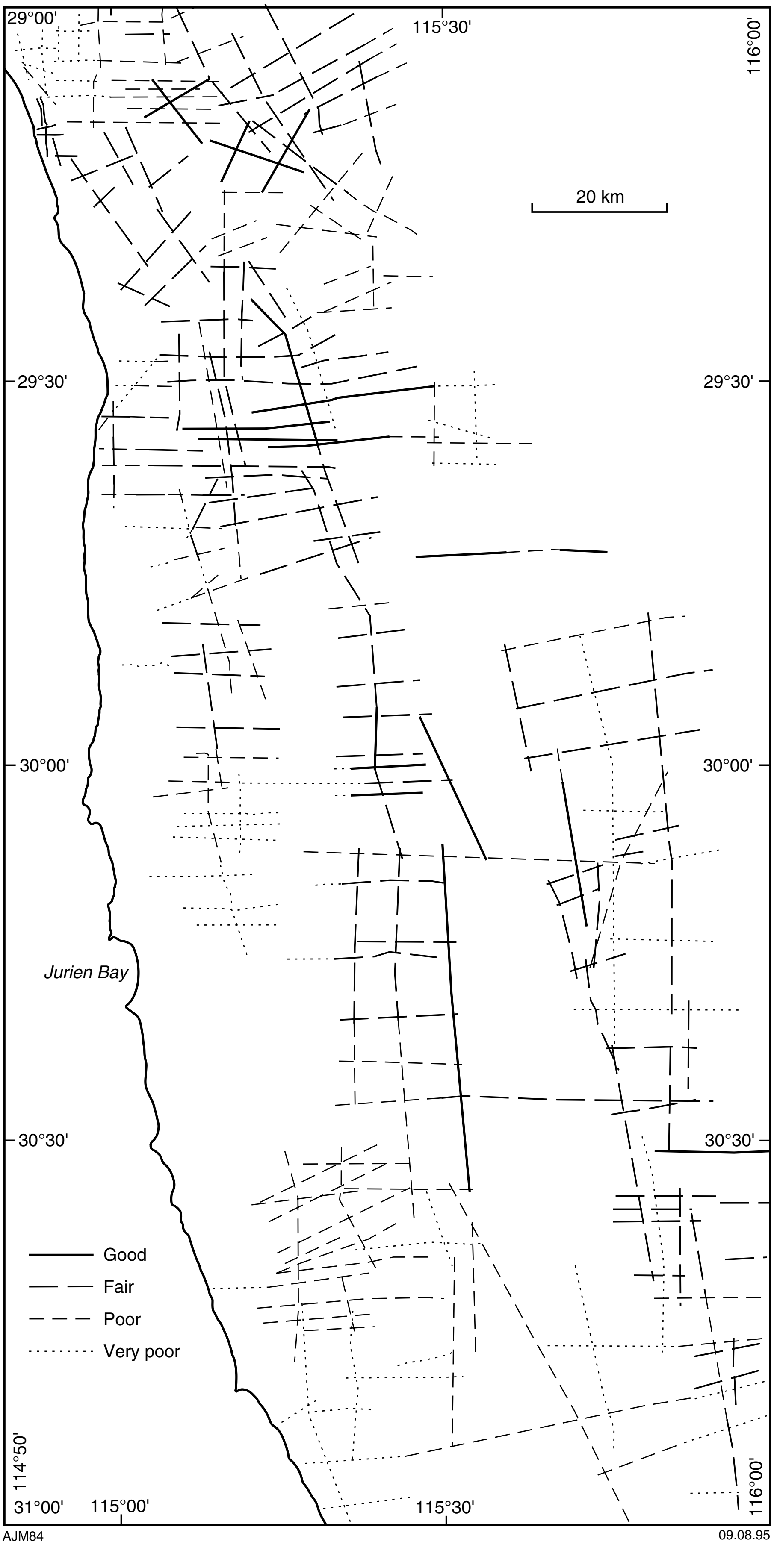

Figure 4. Distribution and quality of seismic lines used for this report

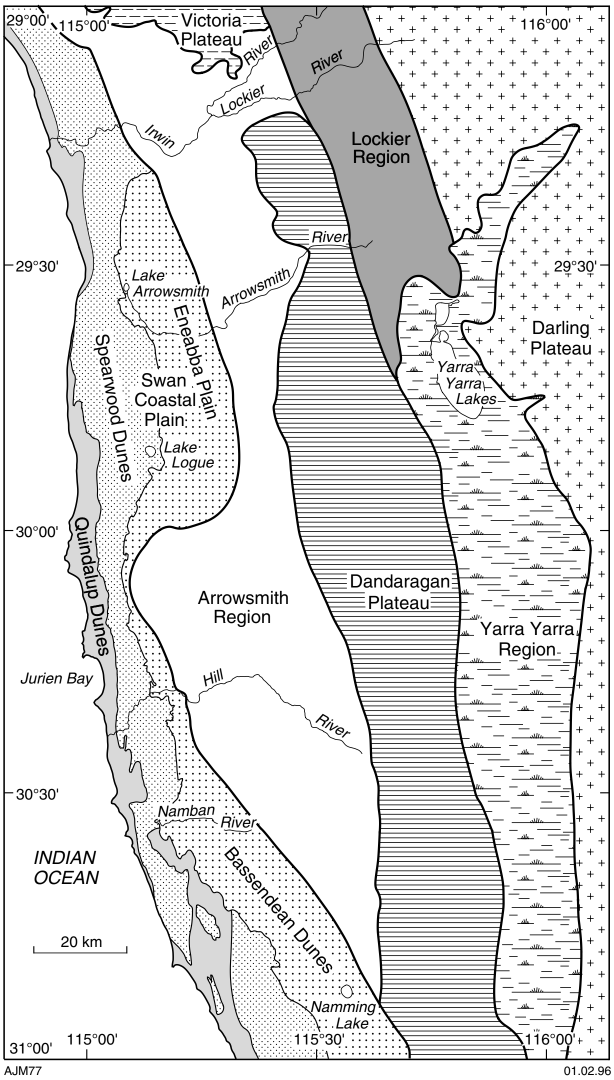

Figure 5. Physiography and major drainage, onshore northern Perth Basin

Six broad physiographic units are present in the northern Perth Basin: the Swan Coastal Plain; the Arrowsmith, Lockier and Yarra Yarra Regions; and the Dandaragan and Victoria Plateaus (Fig. 5).

Swan Coastal Plain

The Swan Coastal Plain (Saint-Smith, 1912) is a low-lying area covered by Quaternary coastal sediments and alluvium at the foot of the Gingin Scarp. In the northern Perth Basin the Swan Coastal Plain may be divided into four north–south oriented areas: the Quindalup Dune System, Spearwood Dune System, Bassendean Dunes, and Eneabba Plain.

The *Quindalup Dune System* (McArthur and Bettenay, 1960; Semeniuk et al., 1989) is the narrow coastal dune zone of Holocene age that extends from Dunsborough in the south to Geraldton in the north. This dune system extends up to 14 km inland south of Cervantes but is virtually absent near Knobby Head, and north of Dongara.

The *Spearwood Dune System* (McArthur and Bettenay, 1960) probably formed during the middle to late Pleistocene in a glacial period (Teichert, 1967) when the sea level was lower than today. Limestone of the Spearwood Dune System (Tamala Limestone) is exposed in cliffs along rivers and creeks, but typically it forms low hills following the old dunal topography that has been greatly lowered by rainwater solution. This dune system extends inland 4 to 21 km. The presence of karst topography, internal irregular cemented zones, and cavernous porosity makes this dune system one of the most difficult areas over which to obtain good quality seismic data. Moreover, in the Dongara area, magnetic minerals have been locally concentrated in the surficial cemented zone thereby obscuring the magnetic signature of the underlying rocks.

The *Bassendean Dunes* (McArthur and Bettenay, 1960; Playford et al., 1976) occupy a low-lying area between the Spearwood Dune System and the Gingin Scarp south of Cockleshell Gully. The unit is similar to the Eneabba Plain to the north but is possibly somewhat younger, and is separated from the Eneabba Plain by the Spearwood Dune System abutting the Gingin Scarp north of Cockleshell Gully. The Bassendean Dunes represent a belt of coastal dunes and associated shoreline deposits with local concentrations of heavy-mineral sands (HMS) that are probably early to middle Pleistocene in age. As the Bassendean Dunes (and the Eneabba Plain to the north) have been modified by Holocene alluvial, lacustrine and eolian processes, the identification of the HMS deposits from surface features is virtually impossible.

The *Eneabba Plain* (Playford et al., 1976) is a low-lying area between the Spearwood Dune System and the Gingin Scarp. The plain consists of a series of shoreline, lagoon and dune deposits, of early Pleistocene to possibly late Tertiary age, which locally have high concentrations of heavy minerals. The Eneabba Plain is restricted to the area north of Cockleshell Gully.

Arrowsmith Region

The Arrowsmith Region (Playford et al., 1976) is an undulating area between the Gingin Scarp to the west, and the Dandaragan and Victoria Plateaus and the Lockier Region to the east. The area contains hills of Jurassic strata commonly capped by laterite discordant with bedding. On those hills that are not flat topped, the laterite surface slopes towards the present drainage system. The area is drained by a small number of watercourses of which only the Irwin and Hill Rivers and their tributaries reach the coast; the rest debouch into swamps and lakes on the Swan Coastal Plain.

Dandaragan Plateau

The Dandaragan Plateau (Gentilli and Fairbridge, 1951; McArthur and Bettenay, 1960) is a laterite- and sand-capped plateau that overlies Cretaceous sediments at an elevation of some 180 to 300 m AHD. The plateau is a flat to gently undulating surface (mostly undissected) bounded by the Arrowsmith Region to the west and north, and the Lockier Region to the east. The edge of the Dandaragan Plateau is coincident with subcrop of the Otorowiri Member of the Parmelia Formation. South of the Arrowsmith River this boundary lies at the base of the Dandaragan Scarp, which is up to 30 m high. In places low dips make the feature less prominent but it is commonly marked by a line of springs discharging over the subcropping shales of the Otorowiri Member.

Victoria Plateau

The Victoria Plateau (Johnson et al., 1951) is a sand- and laterite-capped plateau with an elevation of approximately 250 to 280 m AHD north of the Irwin River. The surface of the plateau is flat to gently undulating and is largely undissected except along its margins.

Lockier Region

The Lockier Region (Playford et al., 1976) is a relatively low region of typically clayey soils overlying Permian sediments east of the Urella Fault. The region lies east of the Victoria and Dandaragan Plateaus and is drained by the Lockier River and the upper part of the Irwin River.

Yarra Yarra Region

The Yarra Yarra Region (Playford et al., 1976) is an area of essentially internal drainage between the Dandaragan Region to the west and the Darling Fault to the east. Numerous swamps and salt lakes, the largest of which are the Yarra Yarra Lakes, characterize this area.

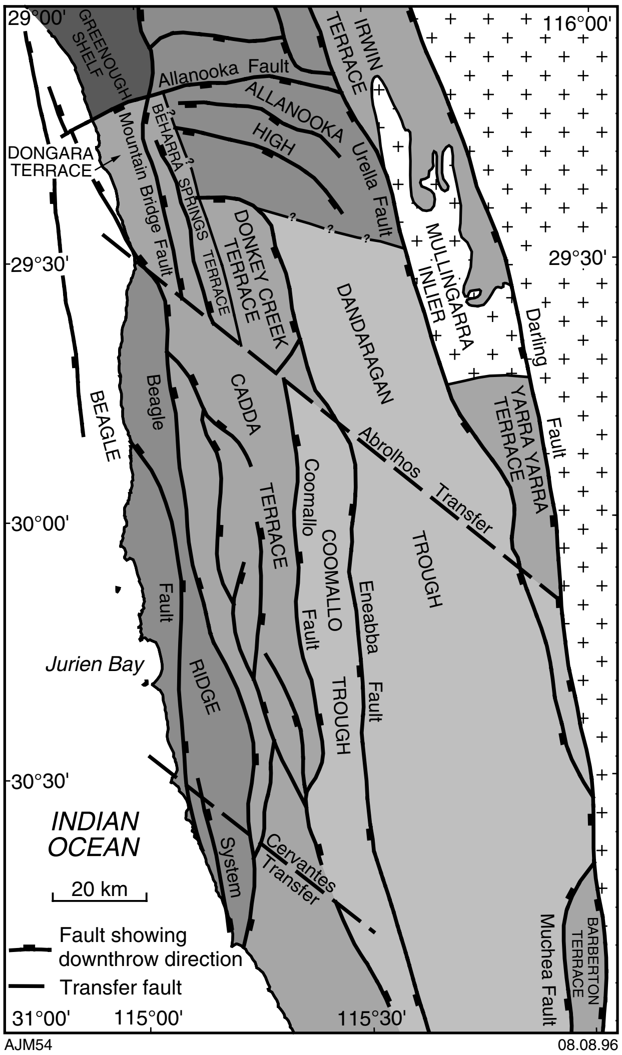

Figure 6. Tectonic elements, onshore northern Perth Basin

Basin subdivisions

The onshore northern Perth Basin is divided into 13 structural units: the Dandaragan and Coomallo Troughs, Beagle Ridge, Allanooka High, Greenough Shelf and the Barberton, Beharra Springs, Cadda, Dongara, Donkey Creek, Irwin and Yarra Yarra Terraces (Fig. 6). Also included in the basin is the Coolcalalaya Sub-basin which lies north of the study area. The southern part of the Northampton Complex extends beneath the Greenough Shelf. These basin subdivisions are defined using criteria outlined by Hocking (1994).

Dandaragan Trough

The Dandaragan Trough (Thyer and Everingham, 1956) is the major depocentre of the onshore Perth Basin and forms a large syncline in the southern part of the area. Maximum width of the trough is 45 km and it contains up to 12 000 m of Permian and Mesozoic sediments. The sub-basin is approximately 500 km long and extends south of Perth to the Harvey Ridge. In the original definition, the sub-basin extended from the Urella–Darling Fault to the east, to the Beagle or Mountain Bridge Faults to the west and so constituted the major part of the onshore northern Perth Basin. Crostella (1995) restricts the sub-basin to the area east of the Eneabba Fault and south of the Allanooka High. The boundaries of the Dandaragan Trough are represented to the east by the Urella Fault and to the west by the Eneabba Fault System. To the south, the trough (although shallowing) extends beyond the area of investigation. The northern boundary is tentatively taken at the latitude of the western trending section of the Eneabba Fault. In the south the Mesozoic sedimentary section thickens rapidly into the trough. The shallowing of the Dandaragan Trough to the north corresponds to thinning of the Triassic and Jurassic units, and post-Jurassic erosion. The geothermal gradient in the trough is uniformly low (2°–2.5°C/100 m).

Coomallo Trough

The Coomallo Trough (Crostella, 1995) lies west of the Dandaragan Trough and south of the Abrolhos Transfer. It is bounded by the Eneabba Fault to the east and the Coomallo Fault to the west. The southern limit is not well defined within the study area. The Coomallo Trough has characteristics intermediate between those of the Cadda

Terrace and those of the Dandaragan Trough: wrench anticlines similar to those in the Cadda Terrace are present, but the thickness of sediments and the low geothermal gradient (2–2.5°C/100 m) are comparable with the Dandaragan Trough. The throw of the Eneabba Fault decreases to the south, suggesting the gradual disappearance of the feature and its merging with the Dandaragan Trough.

Beagle Ridge

The Beagle Ridge (Playford and Willmott, 1958; Dickens et al., 1961; McTavish, 1965) is a mid-basin ridge between the Cadda Terrace to the east and the Abrolhos Sub-basin and Turtle Dove Ridge to the west. The ridge has 1000 to 3000 m of Permian to mid-Jurassic sedimentary cover and the geothermal gradient is 3.5° to 5.5°C/100 m. The Permian and at least part of the Mesozoic sections thin onto the ridge. The eastern boundary is the Beagle Fault System that consists of a series of en echelon north-northwest oriented faults downthrown to the east. The western boundary appears to lie along a southerly extension of the Geraldton Fault which, south of Dongara, coincides with a hinge-zone over which the Mesozoic thickens dramatically to the west.

Allanooka High

The Allanooka High (Crostella, 1995) lies north of the Dandaragan Trough, between the Irwin Terrace to the east, and the Greenough Shelf and Beharra Springs Terrace to the west. On the Allanooka High, basement shallows to the north from approximately 5500 to 2000 m. The boundary with the Dandaragan Trough is somewhat arbitrarily drawn to correspond to the western trending section of the Eneabba Fault. The Allanooka High is distinguished from the Dandaragan Trough by the change in structural style from northerly striking faults in the latter to east-northeasterly and easterly striking faults in the former, and the northerly rise in geothermal gradient from 2.5° to 4°C/100 m. To the west the boundary between the Allanooka High and the Greenough Shelf is marked by the Mountain Bridge Fault. The northern boundary lies to the north of the study area. The eastern boundary is represented by the Urella Fault, while to the south there is a gradual transition to the Dandaragan Trough. The boundary between the Allanooka High and the Beharra Springs Terrace to the west corresponds to the easternmost fault of the Beharra Springs–Mondarra–Yardarino trend. Within the Allanooka High the Mesozoic succession progressively thickens to the south, in contrast to the Permian succession which thins in that direction.

Coolcalalaya Sub-basin

The Coolcalalaya Sub-basin (Condon, 1965) lies north of the study area between the Darling Fault to the east and the Northampton Complex or the Ajana Ridge to the west, and contains Permian, and in the west, Silurian and possibly Devonian rocks. To the north the Coolcalalaya Sub-basin is bounded by a right-lateral strike-slip fault that divides it from the Byro and Merlinleigh Sub-basins. In the southwest, a line of northwest-trending normal faults divides the basin from the Allanooka High. To the south, the boundary with the Irwin Terrace is based on southerly thinning of the pre-Permian succession and thickening of the Permian succession. The lack of subsurface data in this area precludes accurate positioning of this boundary as well as estimates of the thickness of sediment and geothermal gradient.

Greenough Shelf

The Greenough Shelf (new name) is the area of shallow basement between the Dongara Terrace to the south, the Allanooka High to the west, and the Northampton Complex that outcrops to the north. The Abrolhos Sub-basin lies to the west but there may be a small sliver of the Beagle Ridge between the two. The southern and eastern boundaries correspond to the Allanooka and Mountain Bridge Faults, respectively. The shelf contains up to 1500 m of Mesozoic and Permian sediment overlying granite and gneissic metasediments with a granitic composition. The geothermal gradient reaches 5°C/100 m.

Barberton Terrace

The Barberton Terrace (new name) is an area of shallower basement than that in the adjacent Dandaragan Trough between the Darling and Muchea Faults. Depth to basement is approximately 6000–7000 m compared with 10 000–12 000 m west of the Muchea Fault. Approximately half of the throw of the Darling Fault north of the Barberton Terrace has been relayed to the Muchea Fault and most of the Jurassic section on the terrace has been removed by erosion at breakup in the Early Cretaceous. The geothermal gradient is comparable with that in the Dandaragan Trough.

Cadda Terrace

The Cadda Terrace (Cadda Shelf *of* Thomas, 1979) is a structural terrace on the eastern margin of the Beagle Ridge, south of the Abrolhos Transfer. The eastern margin of the terrace adjoins the Coomallo Trough along the Coomallo Fault. The southern boundary is poorly defined as it is covered by post-breakup Cretaceous rocks in an area of poor seismic resolution. The terrace is characterized by an intricate pattern of en echelon faults that progressively step down from the Beagle Ridge with the depth to basement increasing to the east from 2000 to 8000 m. The geothermal gradient is comparable with that of the Dongara Terrace and ranges from 3° to 4°C/100 m. This sub-basin contains north- to north-northwest-oriented folds.

Beharra Springs Terrace

The Beharra Springs Terrace (Crostella, 1995) is an area structurally intermediate between the Dongara Terrace to the west and the Donkey Creek Terrace to the east. The terrace is bounded to the west by the Mountain Bridge Fault and to the east by the easternmost fault of the prominent Beharra Springs–Mondarra–Yardarino trend. The northern boundary is the Allanooka Fault and the southern is the Abrolhos Transfer. The geothermal gradient averages 3.5°C/100 m, and the depth to basement is 3000 to 5000 m.

Dongara Terrace

The Dongara Terrace (‘Dongara Saddle’ *of* Jones and Pearson, 1972) is structurally intermediate between the Beagle Ridge to the south and west, and the Beharra Springs Terrace to the east. The term ‘saddle’ is deemed inappropriate as depth to basement contours over the ‘Dongara Saddle’ (Plate 5) show that basement gradually deepens to the south, towards the Cadda Terrace, rather than revealing a relative low between the Northampton Complex and Beagle Ridge. The Dongara Terrace is bounded to the north by the Allanooka Fault, to the east by the Mountain Bridge Fault, to the south by the Abrolhos Transfer Fault, and to the west by the Beagle Fault. The geothermal gradient is high, typically ranging from 3° to 3.5°C/100 m, but locally up to 4°C/100 m. Depth to basement is in the order of 2000 m.

Donkey Creek Terrace

The Donkey Creek Terrace (Crostella, 1995) is structurally between the higher Beharra Springs Terrace to the west and the lower Dandaragan Trough to the east. The terrace is bounded to the north and east by the Eneabba Fault, to the west by the easternmost fault of the Beharra Springs–Mondarra–Yardarino trend, and to the south by the Abrolhos Transfer. The small terrace is characterized by small westerly downthrown north-trending faults that interrupt the regional dips to the east and, in contrast to surrounding structural units, by a lack of wrench anticlines. The depth to basement is 5000 to 6000 m. The Donkey Creek Terrace covers an area where northerly trending faults disappear and into which easterly trending faults of the adjacent Allanooka High do not extend. Crostella (1995) considers that no (or limited) strike-slip movement occurred in the region, which in some way is a junction of divergent faults, acting like a pivot.

Irwin Terrace

The Irwin Terrace (Irwin Sub-basin *of* Clarke et al., 1951) is an eastward-deepening faulted and folded sub-basin containing Permian sediments between the Darling Fault and Yilgarn Craton to the east, and the Urella Fault or Mullingarra Inlier to the west. The northern end of the sub-basin, where the transition into the Coolcalalaya Sub-basin is ill-defined, contains almost 2000 m of Permian rocks. The Coolcalalaya Sub-basin to the north includes Silurian or Devonian units not present in the Irwin Terrace. The southern boundary of the terrace is marked by the outcropping sedimentary rocks of the Proterozoic Yandanooka Group and underlying gneisses of the Mullingarra Complex (together referred to as the Mullingarra Inlier).

Yarra Yarra Terrace

The Yarra Yarra Terrace (new name) is a small faulted terrace containing up to 3000 m of Mesozoic, and possibly Permian, sediments between the Urella and Darling Faults north of the Abrolhos Transfer. The terrace was previously included within the ‘Irwin Sub-basin’ by Playford et al. (1976) but is separated from the Permian Irwin Terrace by outcrop of the Precambrian Mullingarra Inlier. In addition the Yarra Yarra Terrace contains few folds compared with the Irwin Terrace.

Stratigraphy

Silurian to Carboniferous

The oldest known unit in the Perth Basin, the Tumblagooda Sandstone (Hocking, 1991), is present only north of the study area and on the eastern side of the Northampton Complex. The main exposures are in the southern Carnarvon Basin, west of the Northampton Complex, where it consists of red-bed sandstone, with locally abundant trace fossils, that has been interpreted as braided fluvial, high-energy tidal and interdistributary deposits (Hocking, 1991) or mixed fluvial and eolian sandsheet deposits (Trewin, 1993). The age of the unit has variously been regarded as Silurian (Hocking, 1991) based on conodonts from the overlying Dirk Hartog Formation, Cambro-Ordovician (Gorter et al, 1994, Warris, 1994) based on limited conodont faunas and, most recently, early Devonian to late Silurian (Trewin and McNamara, 1995) based on the ichnofauna. The only body fossils known from the unit are the arthropod *Kalbarria* (McNamara and Trewin, 1993) and a possible eurypterid impression.

Hocking (1991, p. 76, fig. 5) tentatively assigned a Devonian age to a number of outcrops east of the Northampton Complex. His assignment of this age was based on differences (in grain size, sorting, rounding, palaeocurrent directions and probable evironmental setting) from outcrops that can be clearly referred to the Tumblagooda Sandstone. On the published geological map of the area (Playford et al., 1970) these outcrops are shown as Tumblagooda Sandstone. The only evidence of Devonian ages in the Perth Basin is indirect, coming from reworked microfloras in the Upper Cretaceous Otorowiri Member (Ingram, 1967), and the Lower Permian Nangetty Formation (Backhouse, 1993d). In the latter case a sparse microflora lacking younger forms was recovered from the basal core in Wicherina 1. Backhouse (1993d) suggests that, although the microflora is sparse, the lack of younger forms tends to favour a Late Devonian age. Although the basal 173 m of Wicherina 1 does appear to be slightly coarser grained than the overlying sandstone, this lithological difference is subtle and is here considered to represent a minor lithological variation within the Nangetty Formation, in which the reworked Devonian microfloras have been deposited.

The only record of Carboniferous sediments in the Perth Basin is in an unpublished company report on shallow drilling in the Coolcalalaya Sub-basin (North Broken Hill Ltd, 1981). In this report a palynoflora of probable Visean or Namurian (Early Carboniferous) age is listed from a monotonous claystone with gypsum and minor ?nodules in an area with little outcrop. The extent of this unit is unclear at present but it is probably restricted to the Coolcalalaya Sub-basin.

Permian

The first studies on the Permian of the Perth Basin were based on outcrop on the Irwin Terrace, Coolcalalaya Sub-basin and Allanooka High (e.g. Campbell, 1910; Woolnough and Somerville, 1924; Clarke et al., 1951; Johnson et al., 1954). The main exposures are on the Irwin Terrace: elsewhere outcrop is poor, particularly on the Allanooka High where limited exposures occur only north of the study area along the Greenough River. The presence of Permian sediments in the subsurface was not confirmed until BMR 10 and 10A were drilled in 1959–60. Permian sediments are thought to be present in the subsurface over most of the onshore northern Perth Basin. Only in the northern part of the Greenough Shelf is the Permian clearly missing (*see* Condor 1 and Connolly 1, Plate 16). It is unclear whether Permian strata are present in the Dandaragan and Coomallo Troughs as the only well in this area to penetrate below the Jurassic (Eneabba 1) terminated in the Triassic. The Permian, if present in these sub-basins, would be deeper than 4000 m. In addition, owing to the poor quality of seismic data below 2.5 seconds in these areas, the level depicted as top Permian (and basement) is commonly only a phantom horizon (see Plate 18). The possibility that the Permian is missing over at least part of the Dandaragan and Coomallo Troughs is suggested by southerly thinning of this interval on the Allanooka High from 1850 m to approximately 1000 m (Fig. 7, seismic section 89–04, Plate 18). However, isopach maps drawn from well data imply some thickening into the trough of the post-Holmwood Shale formations. The isopach maps suggest that the Permian reaches a total thickness of about 1000 m in the Dandaragan and Coomallo Troughs, a thickness that was followed in phantoming the top Permian seismic horizon in these sub-basins.

Nangetty Formation (*Pn*)

The Nangetty Formation (Clarke et al., 1951) is a glacigene unit of earliest Permian age, or possibly latest Carboniferous. The type area is the Nangetty Hills (29°00'00"S, 115°26'30"E) on the Irwin Terrace, but in this area exposure is poor and discontinuous and a specific type section has not been designated. Playford et al. (1976) reported that there is no outcrop section thicker than 130 m in this area. On the Irwin Terrace the maximum thickness has been calculated from gravity modelling to be over 1000 m (Le Blanc Smith and Mory, 1995). The unit thins to the west and south over the Allanooka High towards the Dongara Terrace and Greenough Shelf (Fig. 7). Futhermore, the unit is absent over the Beagle Ridge and at least the western part of the Cadda Terrace. The eastward thickening of the unit towards the Darling Fault suggests some growth on that fault during deposition of the Nangetty Formation although there is no evidence of the unit east of the fault.

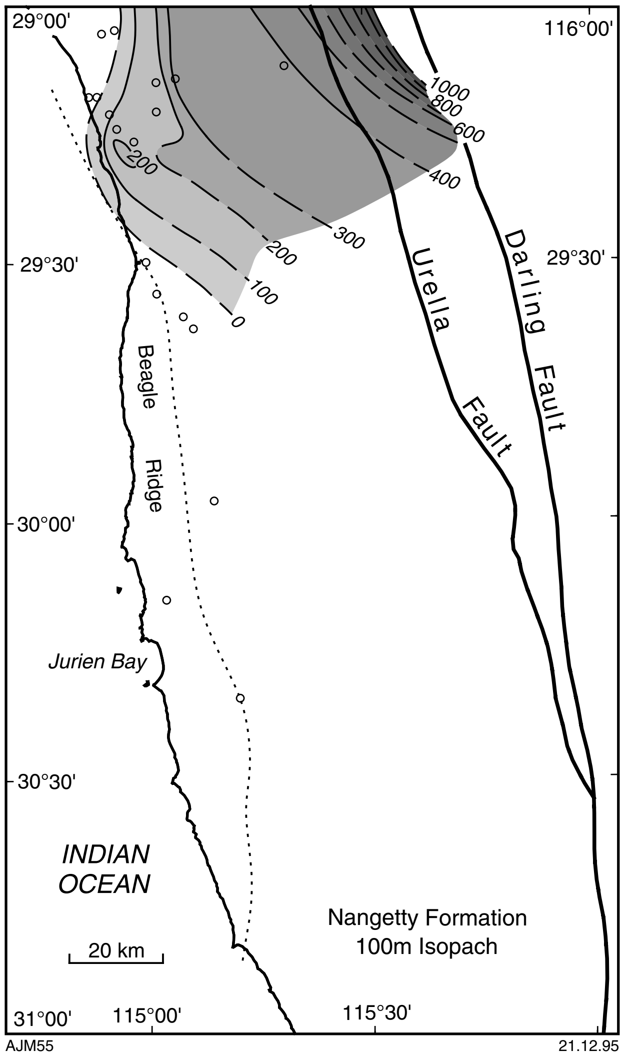

Figure 7. Isopach map, Nangetty Formation (Early Permian)

Basal white sandstone and conglomerate, which has been referred to informally as the Wicherina Beds (McKellar, 1972), is here accorded member status as the Wicherina Member. In the subsurface the member is best seen in Wicherina 1, from 1308 to 1686 m (TD); this interval is designated the type section. The depositional environment of the member is most clearly illustrated by outcrop along the Wooderarrung River north of Mullewa, especially at the confluence with Badgedong Creek. In the study area the member has been intersected only at the base of Dongara 1 and Denison 1 immediately below the Holmwood Shale. The unit is also interpreted from seismic sections along the western side of the Dongara field where it appears to be up to 250 m thick.

Lithology: In outcrop the Nangetty Formation contains predominantly pale greenish-grey laminated sandy siltstone, with subordinate erratics and occasional 'cannonball' limestone concretions, and minor sandstone, pebbly sandstone and conglomerate. The conglomeratic component constitutes only about 0.5% of the whole. Many of the concentrations of boulders on the surface are the result of recent erosive processes removing the fine-grained matrix. Although there are few occurrences of glacial diamictite that are unmistakably outcrop, the glacial origin of many of the so-called boulder beds is indicated by the presence of erratic boulders up to 10 m across. Some of the erratics show faceting and striated surfaces indicative of glacial processes. Erratics in the Nangetty Formation include many pre-Permian rock types, notably various metamorphic and granitic Archaean rocks, as well as various types of Proterozoic sediments. The basal Wicherina Member is a white sandstone with minor conglomerate-filled channels and carbonaceous stringers. In Denison 1 and Dongara 1 the unit consists predominantly of white, fine to coarse, quartz sandstone.

Stratigraphic relationships: The Nangetty Formation unconformably overlies a variety of Precambrian crystalline rocks and, on the Irwin Terrace, sedimentary rocks of the Yandanooka Group. The upper contact with the Holmwood Shale is conformable and appears gradational, and may be difficult to determine precisely. However, the principal discriminators are an upward change from pale greenish-grey sandy siltstone to blue-black shale, a decrease in the frequency of erratics, and the prevalence of mica in the overlying unit. Wireline logs show that the Nangetty Formation is more sandy than the overlying Holmwood Shale.

Fossils and age: The only fossils recorded from the Nangetty Formation are plant microfossils (Segroves, 1969, 1970, 1971; Backhouse, 1992a, 1993a). Foraminifers referred to the unit by Crespin (1958) are here considered to come from the overlying unit. Backhouse (1992a, 1993a) identified palynomorphs, from both the Nangetty Formation and the overlying Holmwood Shale, which are equivalent to the eastern Australian Stage 2 assemblage (Kemp et al., 1977) and suggest an Asselian (Early Permian) age. This places the Nangetty Formation near the Carboniferous–Permian boundary.

Depositional environment: Most of the Nangetty Formation was deposited below wave base in a glacial to proglacial marine-shelf setting associated with melting of the Gondwana ice sheet. The basal Wicherina Member is interpreted as fluvioglacial outwash in a proglacial setting.

Holmwood Shale (*Ph*)

The Holmwood Shale (Clarke et al. 1951) is the dark shale overlying the Nangetty Formation and underlying the High Cliff Sandstone. The main exposures are in the valleys of the Irwin and Lockier Rivers on the Irwin Terrace, but the unit has been penetrated in the subsurface in the northern part of the study area. The formation contains three limestone members (Beckett, Woolaga, and Fossil Cliff Limestone Members) but they are restricted to outcrop on the Irwin Terrace although McTavish (1965) tentatively identified the Fossil Cliff Member in BMR 10. A thickness of 566 m has been measured in the type section (Becketts Gully) but the unit is faulted and poorly exposed in that section (Playford and Willmott *in* McWhae et al., 1958; Playford et al., 1976). No other sections are suitable to measure in the Irwin Terrace being much more poorly exposed than the type section. Le Blanc Smith and Mory (1995) estimated that thickness of the unit ranges from 400

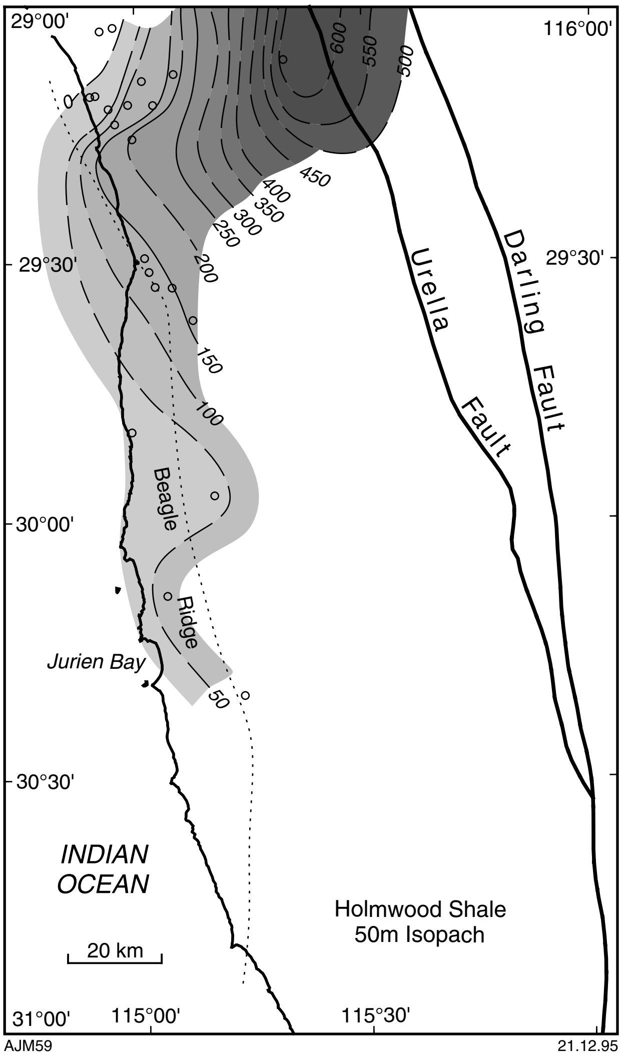

Figure 8. Isopach map, Holmwood Shale (Early Permian)

to 700 m in this sub-basin. In the main part of the basin, the Holmwood Shale thins across the Allanooka High in a similar way to the underlying Nangetty Formation, but extends further south, onto the Beagle Ridge (Fig. 8). As with the underlying Nangetty Formation, the eastward thickening of the Holmwood Shale towards the Darling Fault implies some growth on that fault.

Lithology: In outcrop the lower part of the Holmwood Shale is made up of grey-green shale with thin beds of clayey limestone that show cone-in-cone structures. The Beckett Member, which lies within this lower part of the formation and consists of alternating beds of shale and brown limestone, includes a thin conspicuous horizon of yellow-brown phosphatic limestone concretions containing the goniatite *Juresanites jacksoni* (Playford et al., 1976). Rare glacial erratics occur in the Holmwood Shale, especially near the gradational base of the formation.

The upper part of the Holmwood Shale is dominated by grey to black, micaceous, jarositic and gypsiferous, well-bedded clayey siltstone. The jarosite is probably a weathering product of pyrite. The uppermost part of the unit contains thin fossiliferous limestone beds and lenses especially at the top where they characterize the Fossil Cliff Member.

The Fossil Cliff Member (Woolnough and Somerville, 1924) consists of interbedded dark siltstone, sandy siltstone, shale, and richly fossiliferous limestone. The beds of limestone, which characterize the member, are thin and markedly lenticular. They are mainly bioclastic calcarenites. The siltstone is commonly calcareous and sparsely fossiliferous. The member has been tentatively identified in the subsurface only in BMR 10 (McTavish, 1965).

In the subsurface the Holwood Shale consists of a monotonous section of siltstone, sandy siltstone and mudstone with minor limestone. Two unnamed sandstone units are present high in the unit north of the study area (Johnstone and Willmott, 1966) in Abbarwardoo 1 (279–333 m and 387–429 m) but only the upper one extends south and is present in Wicherina 1 (953–1003 m) and Depot Hill 1 (1885–1920 m).

Stratigraphic relationships: In the central part of the basin the Holmwood Shale rests conformably on the Nangetty Formation, but to the west lies unconformably on basement rocks on the Beagle Ridge and Greenough Shelf. The unit is overlain with apparent conformity by the High Cliff Sandstone, commonly with an extremely sharp contact.

Fossils and age: Plant microfossils (Segroves, 1969, 1970, 1971) and foraminifera (Crespin, 1958) have been recorded from the shales of the formation, but macrofossils are largely confined to the carbonate members (Playford et al., 1976). Backhouse (1992a) has identified palynomorphs from Stage 2 near the base of the Holmwood Shale, placing the lower limit of the unit just within the Asselian. Most of the unit lies within the *Pseudoreticulatispora confluens* Zone of Foster and Waterhouse (1988) but the Fossil Cliff Member at the top of the formation belongs in the *P. pseudoreticulata* Zone (Foster et al., 1985), indicating a general Sakmarian age for the unit.

Depositional environment: Rare glacial erratics in the formation indicate that the Holmwood Shale was deposited in a proglacial marine-shelf setting associated with the melting Gondwana ice sheet. This depositional model is similar to that outlined by Le Blanc Smith (1993) for the Moorhead Formation in the Collie Basin.

High Cliff Sandstone (*Pg*)

The High Cliff Sandstone (Clarke et al., 1951) comprises interbedded sandstone, conglomerate and minor siltstone transitional between the Holmwood Shale and the Irwin River Coal Measures. The type section lies at High Cliff, on the south bank of the North Branch of the Irwin River (28°56'40"S, 115°32'45"E) and is 26 m thick (Le Blanc Smith and Mory, 1995). The main exposures lie in the drainage area of the Irwin and Lockier Rivers. The formation has also been intersected in exploration drillholes west of the Urella Fault where the Permian is covered by Mesozoic units.

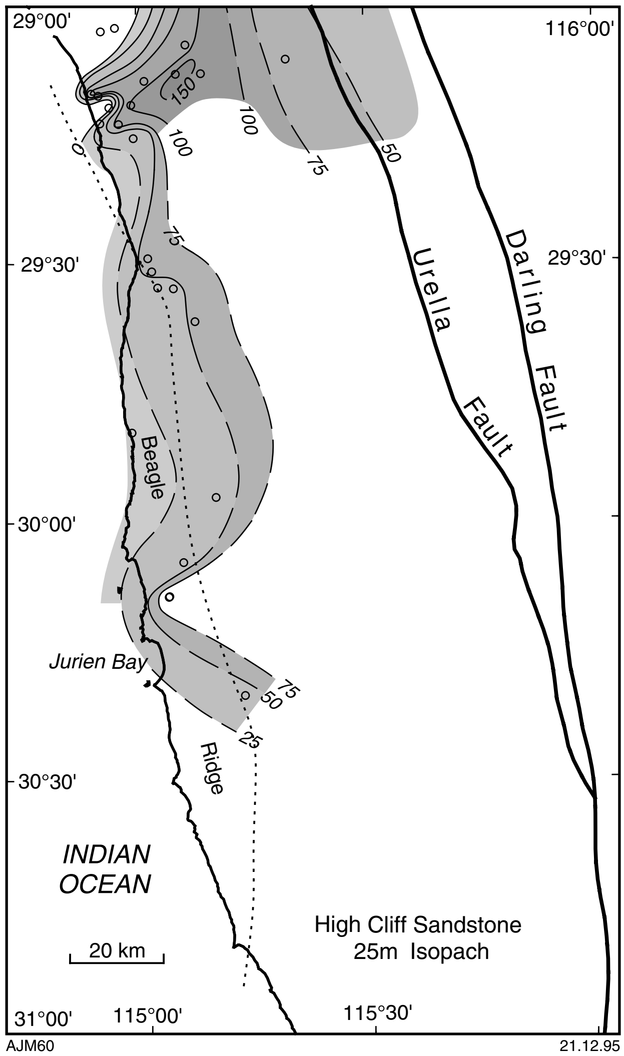

Figure 9. Isopach map, High Cliff Sandstone (Early Permian)

In outcrop on the Irwin Terrace the unit thickens to the south, reaching 42 m at Woolaga Creek (Playford et al., 1976). In the subsurface the unit is thickest in the central part of the Allanooka High (150 m in Mount Horner 1) and thins both to the west, onto the Greenough Shelf and Dongara Terrace, and to the east. Similar thinning to the west on the Beagle Ridge (Fig. 9) suggests a broad trough between the Yilgarn Craton and Beagle Ridge.

There is a case for reducing the rank of the High Cliff Sandstone to member status within the Irwin River Coal Measures as the two are often difficult to distinguish, especially where the unit is thin and contains a similar proportion of siltstone to the overlying Irwin Coal Measures (e.g. Arrowsmith 1, Peron 1, and Cadda 1; Plate 17). In the wells due east of the Irwin Terrace (Plate 12) the unit is much cleaner than the overlying Irwin River Coal Measures, and is readily distinguished from that unit. On the Beagle Ridge and Cadda Terrace, by comparison, the High Cliff Sandstone appears to be more silty and not so easily distinguishable from the overlying unit. In this area the upper boundary of the unit is placed below the first thick sandy carbonaceous siltstone of the

Irwin River Coal Measures (Plate 16, Beharra 1 to Jurien 1; Plate 17, Peron 1 and Cadda 1). This definition follows that of Clarke et al. (1951, p. 58) for outcrop on the Irwin Terrace although in their figure 14 they placed the top of the High Cliff Sandstone some 10 m higher in the section.

Lithology: In outcrop the High Cliff Sandstone consists of a broadly upward-coarsening section of highly bioturbated, rippled, silty sandstone. The predominantly carbonaceous and highly bioturbated sandstone beds contain large angular to sub-angular granite, quartzite, and chert erratics up to 60 cm across. Thin beds of boulder and pebble conglomerate are present and conglomeratic coarse-grained sandstones display rippled siltstone drapes on reactivation surfaces that truncate the crossbed foresets.

Stratigraphic relationships: The High Cliff Sandstone overlies the Holmwood Shale with a sharp but conformable contact, and is conformably overlain by the Irwin River Coal Measures.

Fossils and age: Outcrop of the High Cliff Sandstone generally lacks body fossils although burrows abound and include vertical suspension feeder forms from high-energy environments (*Skolithos* type) and low-energy grazing burrows (*Planolites* and *Rosselia* types). A marine fauna including bivalves, gastropods and brachiopods has been recorded from Woolaga Creek, 27 km south of the type section (Playford, G., 1959). This faunal assemblage indicates an Artinskian (Early Permian) age (Playford et al., 1976; Archbold, in press). Although palynofloras have not been found in the unit, probably because the predominance of sandstone hinders their preservation, Backhouse (1993a) indicates that the unit probably lies within the Artinskian *Striatopodocarpites fusus* zone.

Depositional environment: The invertebrate faunas, trace-fossil assemblages, local hummocky cross-stratification, wave ripples, and sporadic conglomeratic lenses suggest deposition occurred in a suite of shallow marine, beach ridge, and lower deltaic environments (McLoughlin, 1991). This interpretation is supported by the diverse palaeocurrent directions collected from the unit (Fig. 10). Rippled siltstone drapes on crossbed reactivation surfaces in sandstone indicate tidal influence, and large erratics suggest a proglacial setting.

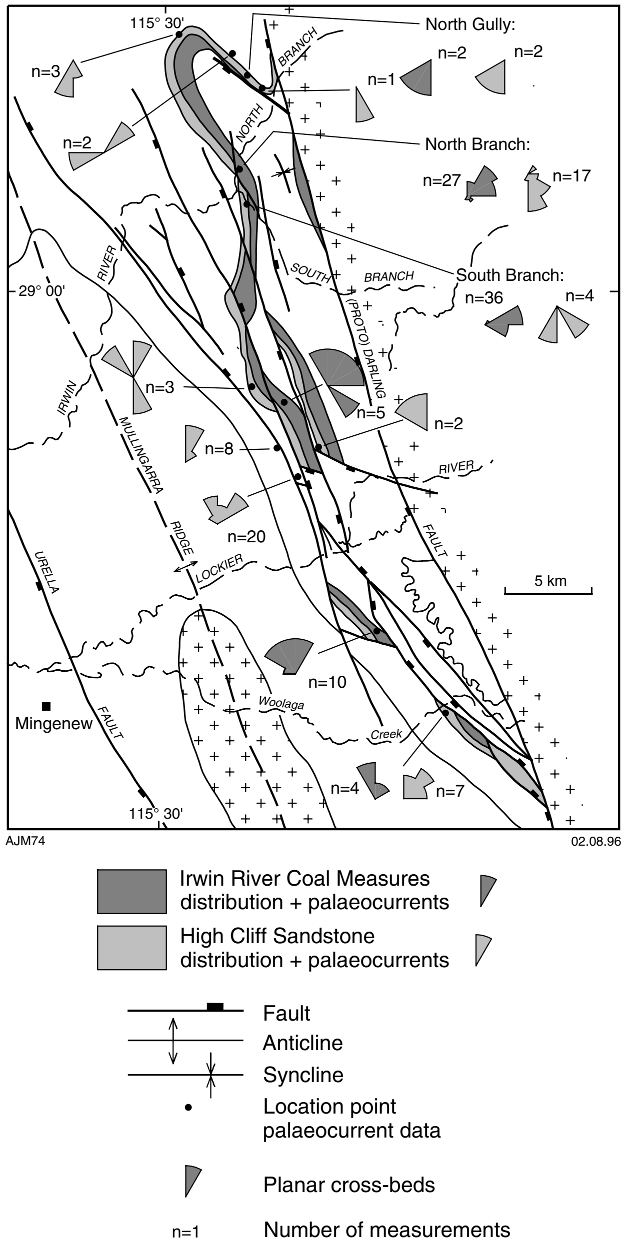

Figure 10. Palaeocurrent data from outcrop of the High Cliff Sandstone and Irwin River Coal Measures (Early Permian)

Irwin River Coal Measures (*Pi*)

The name Irwin River Coal Measures was introduced by Clarke et al. (1951) for the coal-bearing unit lying above the High Cliff Sandstone and below siltstone of the Carynginia Formation. The type section extends north along the North Branch of the Irwin River, commencing approximately 500 m upstream from High Cliff (28°56'40"S, 115°32'45"E) and is 55 m thick. To the west of the Irwin Terrace the unit thickens across the Allanooka High, reaching 288 m in Narlingue 1. Thinning of the Irwin River Coal Measures on the Greenough Shelf is not depositional as it is the result of mid-Permian erosion (Plate 12). The unit reaches a maximum thickness of 307 m in Arrowsmith 1, and the isopach map suggests the unit was deposited across a broad north–south oriented sag (Fig. 11) similar to that indicated for the High Cliff Sandstone.

Lithology: The Irwin River Coal Measures contains alternating sandstone, siltstone, carbonaceous shale, lensoid coal, and scarce conglomerate. The lower contact is at the first appearance of sandy carbonaceous siltstone above coarse- to medium-grained sandstone with minor conglomerate of the underlying High Cliff Sandstone. The sandstones in the Irwin River Coal Measures range from pebbly and very coarse grained to very fine grained. Conglomeratic lenses occur in places. Petrographic analyses have been conducted by McIntosh (1980) and coal microlithotype studies by Santoso (1990). Sedimentary structures include abundant crossbedding,

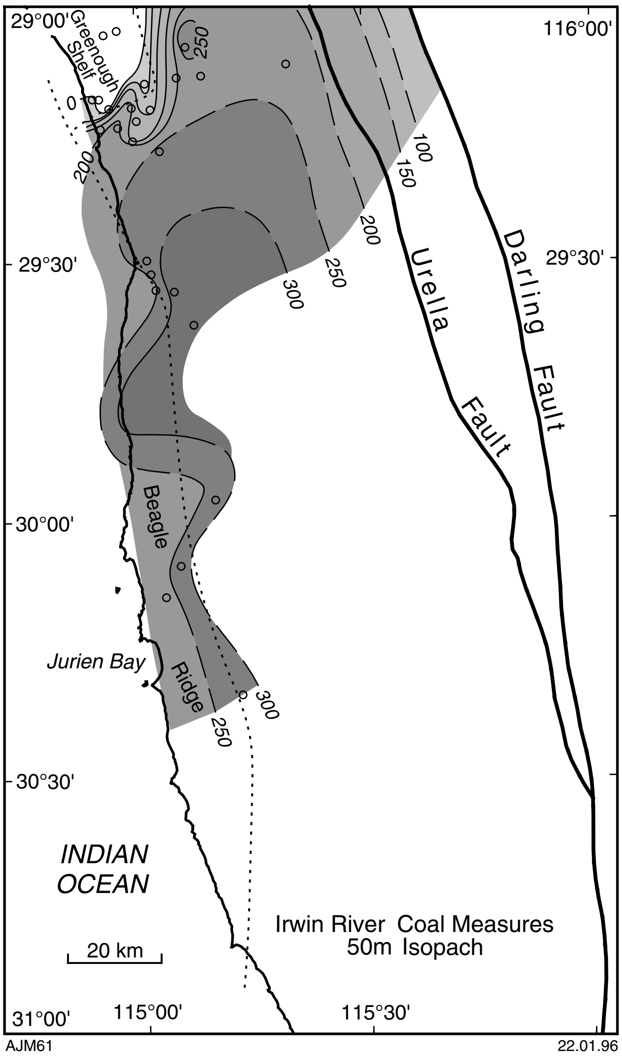

Figure 11. Isopach map, Irwin River Coal Measures (Early Permian)

symmetric (wave) and asymmetric (current) ripple cross-lamination, wavy and flat lamination, scour and fills, slumps, intraformational shale rip-up clasts, coalified plant remains, rootlets, and bioturbation.

Stratigraphic relationships: The Irwin River Coal Measures rests conformably on the High Cliff Sandstone, and is overlain conformably by the Carynginia Formation. In each case the contact is transitional. The upper boundary is placed at the base of the jarositic micaceous siltstone, which characterizes much of the Carynginia Formation (Playford et al., 1976). This definition is not as clear in the subsurface where the Carynginia Formation may contain numerous sandstone horizons.

Fossils and age: The Irwin River Coal Measures contains a *Glossopteris* flora first described by Rigby (1966). McLoughlin (1991) points out that this flora is low in diversity and typical of Early Permian Gondwana assemblages. The formation also yields abundant spores and pollen (Segroves, 1969, 1970, 1971). Backhouse (1993a) reported palynomorphs from the *S. fusus* and *Microbaculispora trisina* zones in the formation indicating an Artinskian (Early Permian) age and a correlation with the Ewington Coal Measures of the Collie Basin (Le Blanc Smith, 1993).

Depositional environment: The depositional setting envisaged is a series of coalesced coarse-grained alluvial deltas prograding into a proglacial cold-temperate marine embayment at high latitude. Deposition in a deltaic environment is supported by palaeocurrent data from outcrop on the Irwin Terrace that show a radiating pattern from the east (Fig. 10). The palaeoenvironmental depositional model is similar to that outlined by Le Blanc Smith (1993) for the Ewington Coal Measures in the Collie Basin, but with greater storm, wave, and tidal influence.

The floras of the Irwin River Coal Measures contain a high proportion of herbaceous plants that are considered characteristic of a lower deltaic setting rather than upper deltaic to fluvial plain settings (McLoughlin, 1991).

Carynginia Formation (*Pc*)

The Carynginia Formation (Clarke et al., 1951; Playford and Willmott *in* McWhae et al., 1958, p. 78) consists predominantly of interbedded siltstone and sandstone with minor shale above the Irwin River Coal Measures. The type locality of the formation is in Carynginia Gully, where Clarke et al. (1951) estimated that the unit is 240 m thick. A detailed section has not been measured there as the exposures are very discontinuous. Playford and Willmott (*in* McWhae et al., 1958) designated the main reference section as that exposed along Woolaga Creek (29°11’20"S, 115°39’30"E), with a measured thickness of 236 m as reinterpreted by Le Blanc Smith and Mory (1995). In the subsurface the unit thickens to the south, reaching 328 m in Cadda 1 (Fig. 12).

Lithology: The Carynginia Formation consists predominantly of dark jarositic, micaceous and carbonaceous siltstone, and fine- to coarse-grained quartz sandstone, with thin beds of fine conglomerate. In outcrop the proportion of sandstone in the unit appears greatest to the south. The sandstones and conglomerates are lenticular, typically showing internal cross-laminae, and have commonly been reworked by wave and storm action into symmetrical ripples and hummocky cross-stratification. Granule to small pebble-sized material commonly coats larger ripples, suggesting that finer material has been removed by storm activity.

Erratic boulders up to 1.5 m in diameter found in the lower part of the Carynginia Formation are attributed to proglacial ice-rafting processes. The boulders consist mainly of granitoids, gneiss, and quartzite.

Stratigraphic relationships: The Carynginia Formation rests conformably on Irwin River Coal Measures. The upper contact with the Wagina and Dongara Sandstones, and the Beekeeper Formation, is an angular unconformity; Backhouse (1993a) shows a lacuna with several palynomorph zones missing between the youngest dated Carynginia Formation and the overlying units.

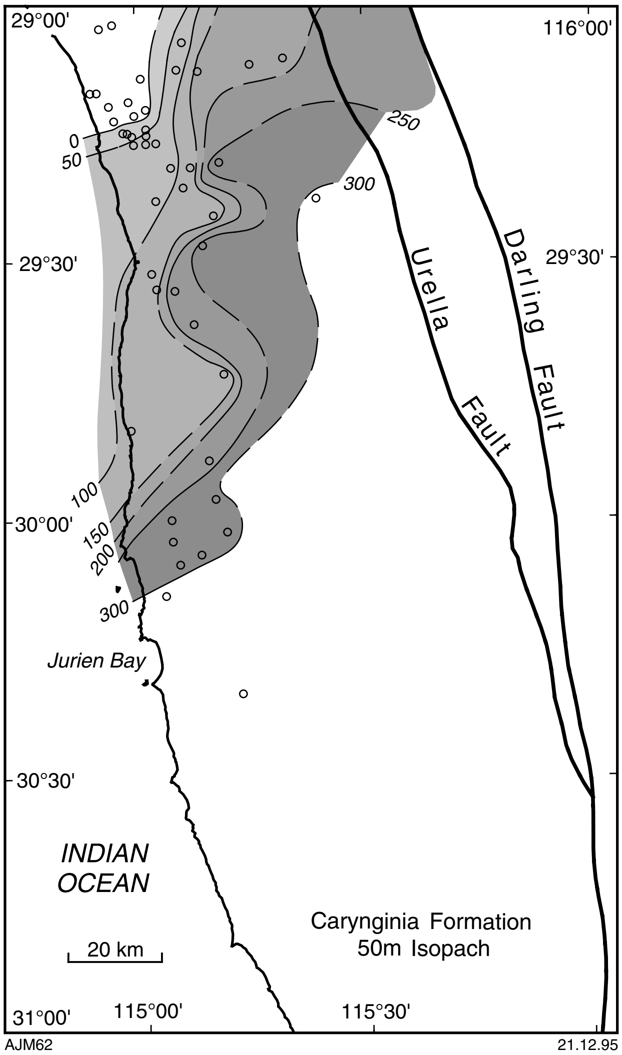

Figure 12. Isopach map, Caryngini Formation (Early Permian)

The Caryngini Formation is correlated with the Mingenew Formation (Playford et al., 1976; Archbold, 1988) which is confined to fault blocks along the Urella Fault System.

Fossils and age: Spores and pollen are common in the Caryngini Formation (Segroves, 1969, 1970, 1971). Backhouse (1993a, 1994) found Artinskian (Early Permian) palynofloras in the unit from the *Praecolpatites sinuosus* and *Microbaculispora villosa* zones. In BMR 10 spinose acritarchs, mainly *Micrhystridium* and *Veryhachium*, are common in the upper part of the Caryngini Formation, but rare in the lower part (Backhouse, 1993a). The formation also contains foraminifers (Crespin, 1958).

Depositional environment: The trace-fossil assemblages, local hummocky cross-stratification, wave ripples, and sporadic conglomeratic lenses suggest deposition in shallow marine environments under proglacial conditions in a setting similar to the Holmwood Shale. Examination of samples from CRA-IRCH-1 core by Dr V. Palmieri (1992, pers. comm.) identified forams typical of a cold, marginal marine environment. The increase in spinose acritarchs upwards through the formation is an indication that more open marine conditions prevailed in the later phase of deposition (Backhouse, 1993a). Sporadic glacial erratics in the formation testify to occasional melting icebergs that dropped material onto the sea floor in a proglacial marine setting associated with the melting Gondwana ice sheet.

Mingenew Formation (*Pm*)

The Mingenew Formation (Mingenew Beds *of* Maitland, 1919; Playford and Willmott *in* McWhae et al., 1958) appears to be a local sandy variation of the Caryngini Formation confined to fault blocks along the Urella Fault System. The type locality at Simpson Knolls, 2 km east of Mingenew, is faulted and so Playford and Willmott (1958) proposed a reference section at Enanty Hill, 2 km north-northeast of Mingenew, where the unit is approximately 90 m thick.

Lithology: The Mingenew Formation consists of ferruginous, fossiliferous, fine to coarse sandstone and siltstone.

Stratigraphic relationships: The unit is known only from fault-bounded sections along the Urella Fault; its stratigraphic limits and maximum thickness are unknown.

Fossils and age: Brachiopods from the unit are similar to those in the Madeline and Coyrie Formations in the Carnarvon Basin, suggesting that the Mingenew Formation is coeval with the Caryngini Formation (Playford et al., 1976; Archbold, 1988).

Depositional environment: The Mingenew Formation is a shallow-marine deposit.

Wagina Sandstone (*Pw*)

The Wagina Sandstone (Clarke et al., 1951) is an Upper Permian unit in the northern part of the basin. Although the name has also been applied to bioturbated sandstone (in the Dongara field and other wells west of the Urella Fault) that lies below the Kockatea Shale, that sandstone is here excluded from the Wagina Sandstone and identified as the Dongara Sandstone. The inclusion of the Dongara Sandstone in the Wagina Sandstone was based largely on the presence of a similar Late Permian microflora in both units, and overlooked lithological differences. The name Wagina Sandstone is here restricted to outcrop along the eastern part of the Irwin Terrace and to the northern part of the Allanooka High (the Eradu area) north of the study area. By comparison, Tupper et al. (1994) suggested that the 'Wagina Formation' include lithologies here included in the Dongara Sandstone and Beekeeper Formation. The type section is near Wagina Well along the South Branch of the Irwin River (28°59'30"S, 115°35'00"E) but exposures are poor. The main reference section for the unit is near Woolaga Creek, commencing at Red Hill (29°11'01"S, 115°40'00"E) and continuing east to the axis of the syncline adjoining the Darling Fault (Playford and Willmott *in* McWhae et al., 1958). The Wagina Sandstone is up to 250 m thick on the Irwin Terrace (Fig. 13).

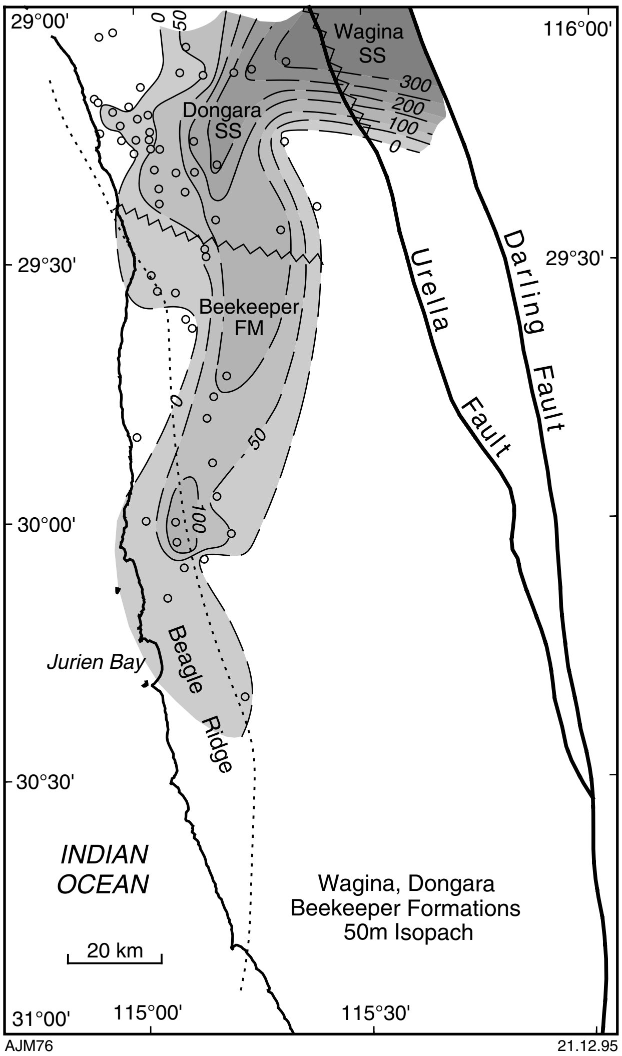

Figure 13. Isopach map, Wagina Sandstone plus Beekeeper Formation (Late Permian)

Lithology: The Wagina Sandstone consists chiefly of fine- to medium-grained crossbedded clayey sandstone and pebbly sandstone with minor conglomerate, carbonaceous siltstone, and rare sapropelic coal.

Stratigraphic relationships: In the Irwin Terrace, the Wagina Sandstone rests with an abrupt low-angle unconformable contact on the Carynginia Formation and displays a truncated upper surface overlain by a veneer of Cainozoic deposits (Playford, 1976; Le Blanc Smith and Mory, 1995). Palynological data show that the *Microbaculispora villosa* to *Camptotriletes warchianus* zones (approximately Kungurian to Ufimian — late Early to early Late Permian) are missing in the northern Perth Basin (Backhouse, 1993a) confirming the unconformable relationship between the Wagina Sandstone and the underlying Carynginia Formation. A disconformable relationship with the overlying Lower Triassic Kockatea Shale in the vicinity of the Greenough River is indicated as the Tatarian Stage (Late Permian) is missing in the few shallow wells drilled in the area (e.g. WMC Ltd, 1982, 1983). The Late Permian palynoflora of the Wagina Sandstone suggests that the unit is coeval, at least in part, with the Dongara Sandstone to the east and the Beekeeper Formation to the southeast.

Fossils and age: The presence of palynofloras that include *Dulhuntyispora parvithola*, *Camptotriletes warchianus*, *Microreticulatisporites bitriangulatus*, *Verrucosisporites* sp. cf. *V. trisecatus* and *Triadispora* sp. cf. *T. epigona* suggests a correlation with the upper part of the Permian in the southern Perth Basin, i.e. a possibly Early Tatarian (Late Permian) age (Backhouse, 1993a). Acritarchs are also present in the palynofloras. Plant macrofossils are also present but the only systematic descriptions are those of Rigby (1966).

Depositional environment: The lithology indicates an accumulation of proximal fan to coarse-grained deltaic deposits. Bergmark and Evans (1987, fig. 9) interpret the depositional setting as a humid alluvial fan delta centred at the Darling Fault east of Dongara. They suggest that coarse-grained siliciclastics were deposited by sheet flows and braided streams, with siltstones and coals forming on adjactent floodplains and in semi permanent bodies of standing water. In the Irwin Terrace coal-forming swamps developed on the flanks of the main fan, although only a single thin sapropelic coal has been located (Le Blanc Smith and Mory, 1995).

Dongara Sandstone (*Po*)

The Dongara Sandstone (Playford et al., 1976; amended herein) is the clean and bioturbated silty sandstone below the Kockatea Shale. The unit was originally referred to as the 'Basal Triassic Sandstone' by Hosemann (1971). That terminology was abandoned when Late Permian ages were obtained from the lower part of this unit (Playford et al., 1976). These authors used the name Dongara Sandstone Member (of the Kockatea Shale) for the upper, apparently Triassic, part of the sandstone unit, and referred the clearly Upper Permian sandstone in the area to the Wagina Sandstone of Clarke et al. (1951). The name Wagina Sandstone is considered inappropriate as east of the Urella Fault that unit is a pebbly sandstone of fluvial origin, whereas the Upper Permian west of the Urella Fault is largely a bioturbated marine sandstone. Tupper et al. (1994) included the Dongara Sandstone, as defined herein, along with the Beekeeper Formation within their Wagina Formation.

Based on wireline log correlations from well-dated sections, the type section of the Dongara Sandstone (Dongara 11, 1682–1701 m) as defined by Playford et al. (1976) appears to include some Upper Permian section. Secondly, the name has not been widely used for the clean, coarse-grained sandstone that lies directly below shale of the Kockatea Shale. Instead the term 'basal Triassic sandstone' was retained by some authors (e.g. Hall, P. B., 1989; Quaife et al., 1994). This usage is misleading as there is no evidence as to its age. Based on the wireline logs the entire unit consists of a series of upward-coarsening cycles with the 'basal Triassic sandstone' representing the upper part of the youngest cycle. For this reason the entire sandstone section is best regarded as one unit, the Dongara Sandstone, which is possibly all latest

Permian in age. The base of the type section in Dongara 11 is extended from 1701 to 1713 m, so as to include the remainder of the Upper Permian succession. Correlation with other wells in the field suggests that this section may be incomplete, due either to thinning of the unit or to the presence of a small fault. To overcome this difficulty, the fully cored section in Dongara 12 between 1625 and 1663 m (Fig. 14) is designated as a reference section.

The Dongara Sandstone increases in thickness to the east from less than 60 m in the Dongara field to 336 m in Depot Hill 1 adjacent to the Urella Fault. The isopach map shows a fan-like distribution for the unit centered near that well. The distinctive 'upper sandstone member' (the Yardarino Sandstone *of* Playford and Low, 1972) of the Dongara Sandstone is up to 60 m thick and extends further west than the remainder of the Dongara Sandstone. On the present data it is not clear whether the anomalous thicknesses in the Dongara field (*see* Appendix 5) are due to the presence of small faults or to the infilling of some pre-existing topography.

Lithology: The Dongara Sandstone consists predominantly of bioturbated medium to coarse sandstone with minor thin pebble bands, carbonaceous streaks and carbonaceous siltstone. The uppermost part of the unit contains a significant proportion of monazite (Rasmussen et al., 1989) and is noticeably cleaner and coarser grained with less carbonaceous material and little evidence of biotubation (Fig. 14). Two wells (Mount Adams 1 and Warradong 1) contain thin limestone beds interbedded with sandstone at the base of the Dongara Sandstone.

Stratigraphic relationships: From log correlations the Dongara Sandstone rests with a disconformable contact on the Carynginia Formation (Plate 12) but this break cannot be seen in seismic sections from the onshore part of the basin. Offshore a distinctly angular relationship is evident from seismic data between the Carynginia Formation and the Kockatea Shale and has been attributed to Late Permian tectonism (Smith and Cowley, 1987). It is not made clear by these authors exactly how this break relates to the onshore succession. Nevertheless, in Edel 1 it is tempting to correlate the predominantly sandy interval between approximately 945 and 1850 m with the Dongara Sandstone and, consequently, correlate the offshore seismic break between the Permian and Triassic with the base, rather than the top, of the unit. Palynological data show that the *Microbaculispora villosa* to *Camptotriletes warchianus* zones (approximately Kungurian to Ufimian — late Early to early Late Permian) are missing in the onshore north Perth Basin (Backhouse, 1993a) supporting the disconformable relationship between the Dongara Sandstone and the underlying Carynginia Formation, at least in this part of the basin. The relationship with the overlying Lower Triassic Kockatea Shale is uncertain as the Tatarian Stage (Late Permian) has not yet been documented either because it is missing or this time interval is represented by an as yet unsampled condensed sequence (Tupper et al., 1994). A similar difficulty exists with the upper contact of the coeval Beekeeper Formation to the south. An angular relationship has not been observed at the upper contact of the Dongara Sandstone in the onshore seismic data.

At the southwestern limit of its distribution the Dongara Sandstone contains thin limestone beds suggesting that the unit interfingers with the Beekeeper Formation to the south. The two units contain Late Permian palynofloras suggesting they are coeval, at least in part.

The Dongara Sandstone is coeval with the Wagina Sandstone to the east and north. The two units may interfinger but the lack of core in the most northeasterly wells (especially Heaton 1, East Heaton 1, and Depot Hill 1) makes it difficult to demonstrate such a relationship.

Fossils and age: As with the Wagina Sandstone the Dongara Sandstone contains palynofloras from the *Dulhuntyispora parvithola, D. dulhuntyi* and *D. ericians* zones indicating a late Kungurian to Kazanian (late Early to early Late Permian age (Backhouse, 1992c, 1994). Acritarchs are also present in the palynofloras.

The 'upper sandstone member' has been correlated with the Wittecarra Sandstone directly below the Kockatea Shale near Kalbarri (Hocking et al., 1987). While neither sandstone unit contains direct evidence for an Early Triassic age, the time transgressive nature of the Kockatea Shale implies that the Wittecarra Sandstone is significantly younger and raises the possibility that the 'upper sandstone member' may be significantly time transgressive.

Depositional environment: The lithology indicates an accumulation of proximal fan to coarse-grained deltaic deposits. Bergmark and Evans (1987, fig. 9) interpret the depositional setting as a humid alluvial fan delta centred at the Darling Fault to the east of Depot Hill, but the presence of acritarchs in the unit, and coeval marine sediments to the south suggest a marine influence. Deposition of sandstone and conglomerate in the coeval Wagina Sandstone on the Irwin Terrace was by sheet flow and braided streams. Tupper et al. (1994) identify fluvial, beach and shoreface environments in the east with a transition to shelf environments to the south where the Dongara Sandstone appears to interfinger with marginal marine to shallow marine environment of the Beekeeper Formation. This transition suggests deposition in a fan-delta complex for the terrigenous sediments. By comparison Rasmussen (1986) interprets the Dongara Sandstone as a beach and shallow-marine unit. The location of the 'upper sandstone member' depocentres suggests that a significant proportion of this unit was reworked from the crest of the Late Permian fan.

Beekeeper Formation (*Pb*)

The Beekeeper Formation (Hall and Kneale, 1992) is a mixed clastic and carbonate unit which is south of, and in part coeval with, the Dongara Sandstone. The reservoir for the Woodada gasfield is either fractured limestone or thin sandstone interbeds within the unit and was previously recognized by Lane and Watson (1985b) as the informal 'Carynginia Limestone'. Tupper et al. (1994) included this unit within their 'Wagina Formation'. The type section of the Beekeeper Formation is in Woodada 1, between 2239 and 2353 m (Hall and Kneale, 1992). The unit is restricted to the subsurface and has its most northern occurrence in

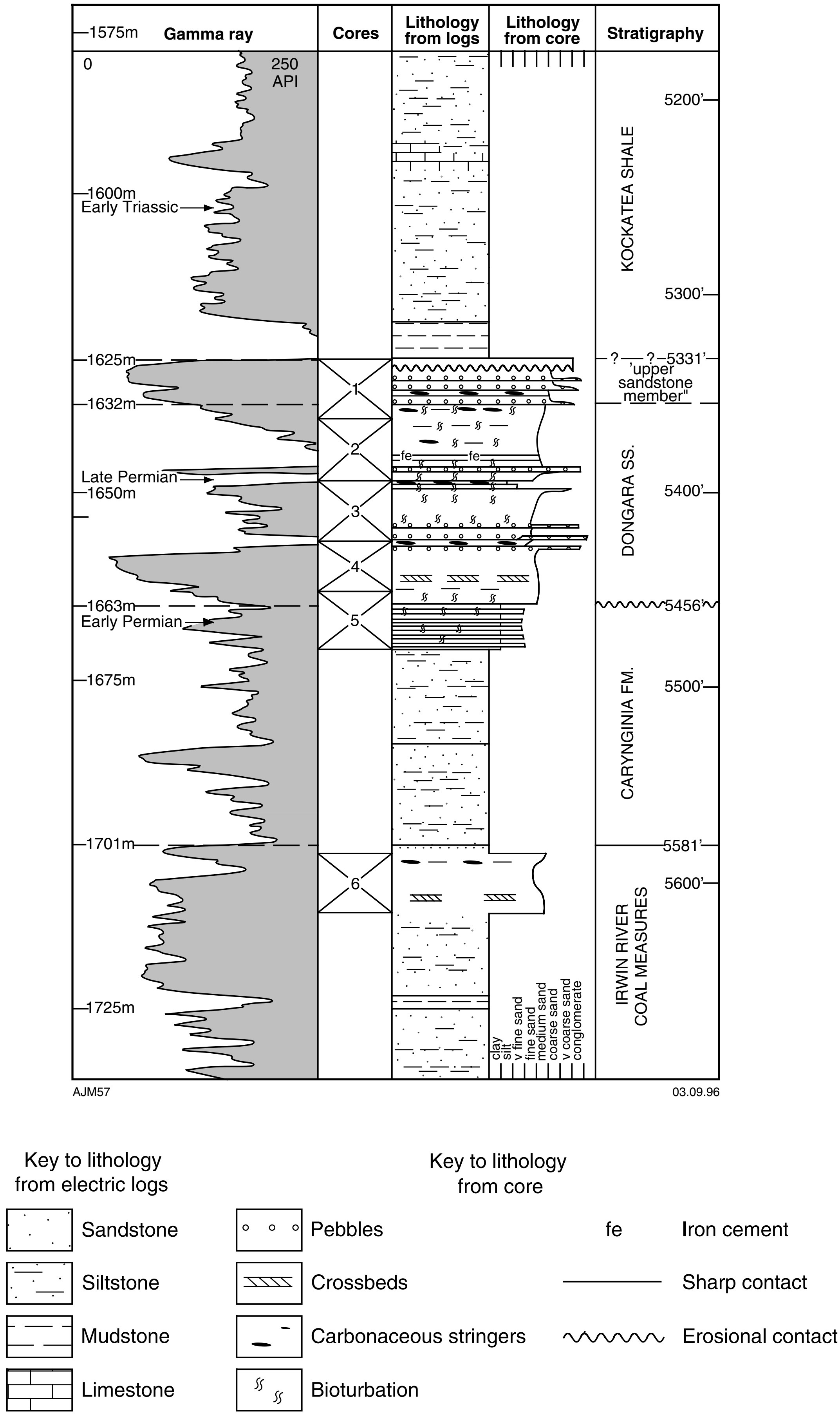

Figure 14. Reference section for the Dongara Sandstone in Dongara 12

the Beharra Springs field. The unit is up to 134 m thick in Point Louise 1 (Fig. 13). South of Mountain Bridge 1 recognition of the unit is entirely dependant on log correlations as there are no palynologic data to corroborate identification of the unit.

Lithology: The Beekeeper Formation (Hall and Kneale, 1992) is a mixed unit consisting of medium- to coarse-grained sandstone, limestone and shale. In the north the unit consists mainly of sandstone with minor shale and limestone, whereas to the south limestone is dominant. The limestone in the Woodada gasfield consists of skeletal packstone and grainstone, quartz sandstone, intraformational skeletal breccia and dolostone. Post-depositional diagenesis has destroyed the primary porosity in these limestones, but subsequent tensional stress and dolomitization have created a secondary porosity.

Stratigraphic relationships: The Beekeeper Formation lies disconformably above the Lower Permian Carynginia Formation based on the palynological correlation of the unit with the Dongara Sandstone. The amount of erosion at this level appears to be minor based on the results of geohistory modelling (this Report), and the lack of an angular relationship at this level in onshore seismic data. The relationship with the overlying Lower Triassic Kockatea Shale is uncertain as there is the possibility that the Tatarian Stage (Late Permian) is missing or that this time interval is represented by a condensed sequence that is unsampled (Tupper et al., 1994). In Mountain Bridge 1 a *Didectriletes ericanus* zone microflora of probable late Kungurian to Ufimian (Early to Late Permian) age (Purcell, 1993; Backhouse, 1994) lies approximately 25 m below a definite Early Triassic palynoflora. The unsampled interval between represents approximately 10 million years. In Beharra Springs 3 a late Kazanian (early Late Permian) palynoflora lies less than 15 m from the top of the unit and 25 m below a definite Early Triassic palynoflora, with a ‘gap’ of 6 million years. On this evidence a disconform-able relationship with the overlying Kockatea Shale seems more likely than a condensed sequence, although the latter possibility has not been disproved.

Fossils and age: The presence of a *Dulhuntyspora* microflora assemblage in Robb 1, and Beharra Springs 2 and 3 suggests a Kazanian (Late Permian) age (Backhouse, 1994) but the unit may also extend down into the Kungurian (latest Early Permian) in Mountain Bridge 1 as discussed above. South of these wells this formation is overmature and no identifiable microfloras have been recovered. The abundant macrofauna in the limestone includes bryozoans, crinoids, brachiopods, bivalves and serpulids. Only the brachiopods have been identified and they indicate an Ufimian (early Late Permian) age (Archbold, 1995).

Depositional environment: The high proportion of fossiliferous carbonate with interbedded calcareous sandstone and shale together with abundant acritarchs indicates an open marine environment. Lane and Watson (1985b) suggest that this unit was deposited in an inner-shelf environment.

Triassic

The Triassic of the northern Perth Basin is represented by three formations (in ascending order, Kockatea Shale, Woodada Formation and Lesueur Sandstone) having a total maximum thickness probably in excess of 4000 m. The Lower Triassic Kockatea Shale was first identified by WAPET geologists, working on outcrop along the Greenough River and bores in the Geraldton–Tenindewa area (Playford and Willmott *in* McWhae et al., 1958). In that area the Kockatea Shale is disconformably overlain by Jurassic sediments. A complete Triassic section was not found until the BMR 10 and 10A bores were drilled in 1959–1960 (McTavish, 1965). Subsequently the Upper Triassic Lesueur Sandstone was identified in outcrop in the Gairdner Range near Jurien (Willmott, 1964). The Triassic is widespread in the subsurface of the Perth Basin.

Kockatea Shale (*R̶k*)

The Lower Triassic Kockatea Shale (Playford and Willmott *in* McWhae et al., 1958, p. 83; Playford et al., 1976) is considered to be the major oil source-rock and seal in the basin (Thomas, 1979). The part of the unit with the most source potential is a basal shale, rich in sapropel, with an average TOC of 2.0%, compared with an overall average for the unit of 0.8% (Hall, P. B., 1989). Outcrop of the unit lies north of the study area on GERALDTON. The type section is near the junction of the Greenough River and Kockatea Creek (28°33'10"S, 115°10'10"E) and is less than 12 m thick. The best well that could be considered to make up a reference section is BMR 10 as this well contains the most regular core samples from the unit in the basin. In this well 16 cores (#20–35) were cut, at approximately 30 m intervals, and a total of 30 m of core was recovered from the 382 m-thick unit. Unfortunately, relatively little of this core has been preserved. The largest amount of core in the formation is from Dongara 24 and 25 with a total of 92 m of core, without stratigraphic overlap between the two wells. In these wells the Kockatea Shale is approximately 270 m thick and the core comes from the Arranoo Member and just above that member respectively.

In petroleum exploration wells the Kockatea Shale is up to 1060 m thick (in Woolmulla 1). The thickness of the unit generally increases to the south, but the presence of a local depocentre near the Beharra Springs field, taken with reduced thicknesses on the Dongara Terrace and on the northern part of the Beagle Ridge, suggests Early Triassic activity along the Mountain Bridge and Beagle Faults (Fig. 15).

Two sandy members are recognized in the Kockatea Shale. They are the Bookara Sandstone Member of Playford et al. (1976), and the Arranoo Member. The Dongara Sandstone that Playford et al. (1976) placed at the base of the Kockatea Shale (also known as the ‘basal Triassic sandstone’, e.g. Hall, P. B., 1989) is here excluded from the formation.

The ‘Bookara Sandstone Member’ is restricted to the Greenough Shelf. In wells such as Conder 1, Bonniefield 1

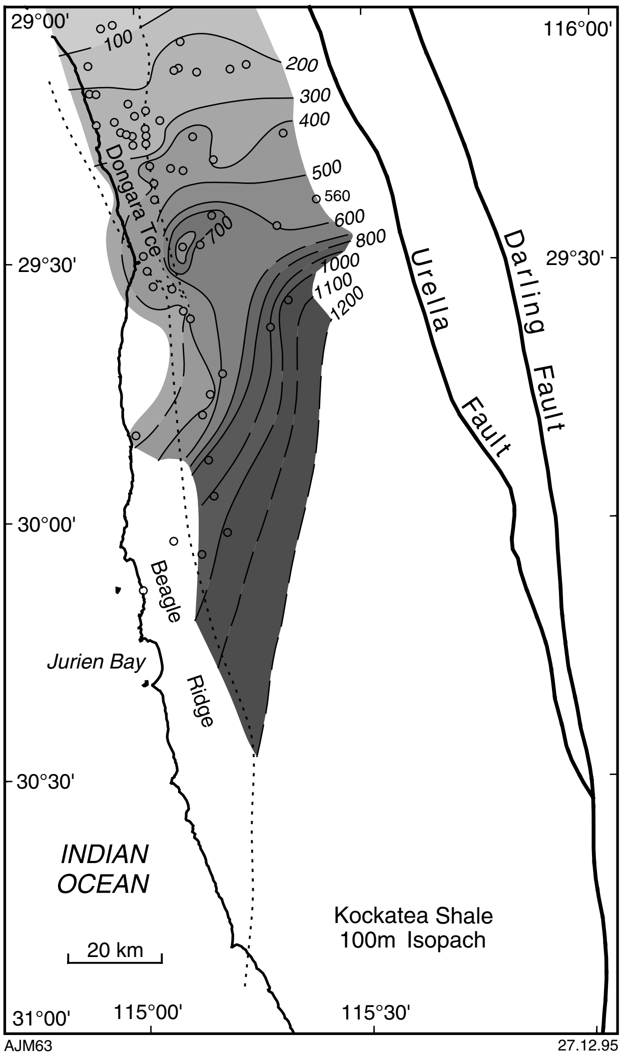

Figure 15. Isopach map, Kockatea Shale (Early Triassic)

and Rakrani 1, the Bookara Sandstone Member clearly lies within the Lower Triassic Kockatea Shale (Fig. 16). In the type section (Dongara 5, 1497–1508 m) the presence of Lower Triassic palynomorphs from sidewall core immediately below the member has been questioned by J. Backhouse (1994, pers. comm.) as possibly due to downhole contamination. This suggestion raises the possibility that in this well the member disconformably overlies shale of the Carynginia Formation, rather than clearly lying within the Kockatea Shale. In addition, the lower contact of the shale with the Irwin River Coal Measures appears to be faulted, raising the possibility that this section may be complicated by other, smaller faults. The type section of the Bookara Sandstone is also problematical as the log response is somewhat similar to the 'upper sandstone member' of the Dongara Sandstone. Such a correlation is also suggested by the presence of a small embayment illustrated in the Bookara Sandstone Member isopach map (Fig. 17b) that corresponds to a lobe in the 'upper sandstone member' of the Dongara Sandstone isopach map (Fig. 17a). Although this correlation is shown in Figure 16 it cannot be confirmed given the lack of palynological data from the 'upper sandstone member' of the Dongara Sandstone. While the combined isopach map for the two members (Fig. 17c) eliminates most of the 'Bookara embayment' and 'upper sandstone lobe', the absence of both members in Denison 1 suggests an irregular distribution no matter which correlation is accepted.

The thinly bedded sandstone, siltstone, mudstone, and minor limestone in the upper part of the Kockatea Shale in the Dongara–Mount Horner area has been informally referred to as the Arranoo Member in WAPET reports and Arranoo Sandstone Member by Warris (1988) and Hall, P. B. (1989). The type section is here nominated as the interval 1451–1529 m in Dongara 24 (*after* Gilchrist and Holloway, 1983) as this well contains the longest cored interval in the member (69.8 m). There is limited production in the Dongara field from the Arranoo Member, and the first oil produced from the Mount Horner field was from this unit. The informal 'Rabbit Ears Sandstone' of Bergmark and Evans (1987), recognized largely from the spontaneous potential logs of wells in the Mount Horner–Dongara area, is here considered to lie above the Arranoo Member.

Lithology: The unit consists of dark shale, micaceous siltstone, and minor sandstone and limestone. In outcrop the unit consists of thin, red, purple, brown or buff-coloured ferruginous siltstone or fine-grained sandstone commonly exposed as loose scree; beds are typically less than 10 cm thick. Cross-bedding, large undulose asym-metric ripples, tool marks and trails are present.

Stratigraphic relationships: The unit overlies the Permian Carynginia Formation or, in the northern part of the area, the Dongara Sandstone. The former contact is unconformable while the latter has not yet been clearly determined. The Kockatea Shale is conformably overlain by the Woodada Formation except in the north of the study area where it is disconformably overlain by either the Cattamarra Coal Measures, Eneabba Formation or Lesueur Sandstone. Immediately west of Mount Hill the unit unconformably overlies Precambrian basement (*see* Connolly 1, Plate 16).

Fossils and age: A varied flora and fauna have been recorded in the unit and include Smithian ammonoids, bivalves, and nautiloids (Skwarko and Kummel, 1974), vertebrate remains from BMR 10 (Dickins and McTavish, 1963; Cosgriff, 1965), ostracods (Jones, 1970) and conodonts (McTavish, 1973). The rich palynomorph assemblages in the unit range from the *Kraeuselisporites saeptatus* Zone of Dolby and Balme (1976) up to the *Triplexisporites playfordii* Zone of Helby et al. (1987) indicating a Scythian (Early Triassic) age (Backhouse, 1992c). Playford et al. (1976) demonstrated that the unit onlaps the Northampton Complex.

Depositional environment: The formation represents a period of shallow-marine deposition. Sandstone bodies in the middle and lower part of the formation have been ascribed to strandlines and offshore bars (Playford et al., 1976, Rasmussen, 1986).

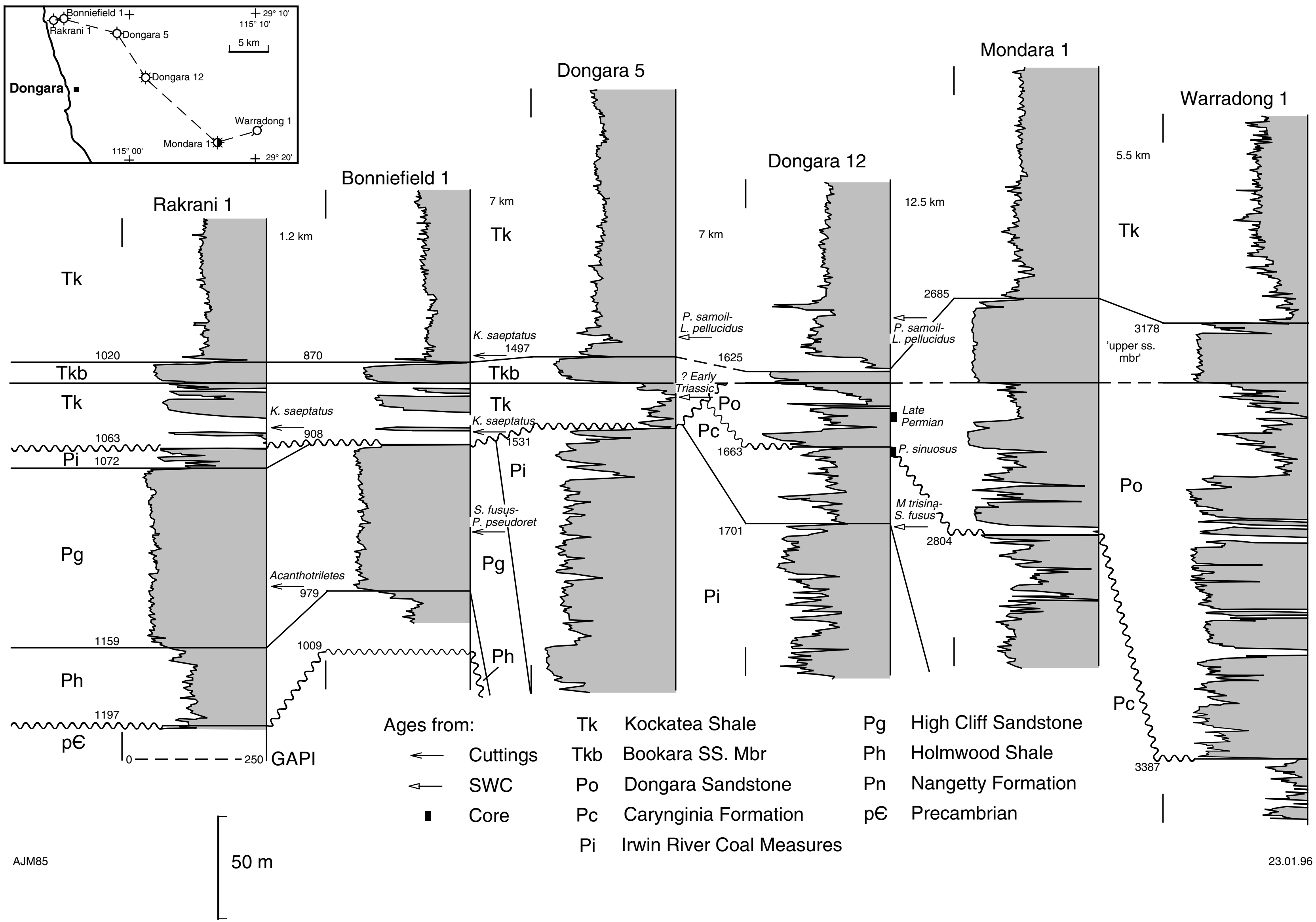

Figure 16. Correlation of the Bookara Sandstone Member of the Kockatea Shale in Rakrani 1, Bonniefield 1, and Dongara 5 with the 'upper sandstone member' of the Dongara Sandstone in Dongara 12, Mondarra 1 and Warradong 1. Datum is base of the two members

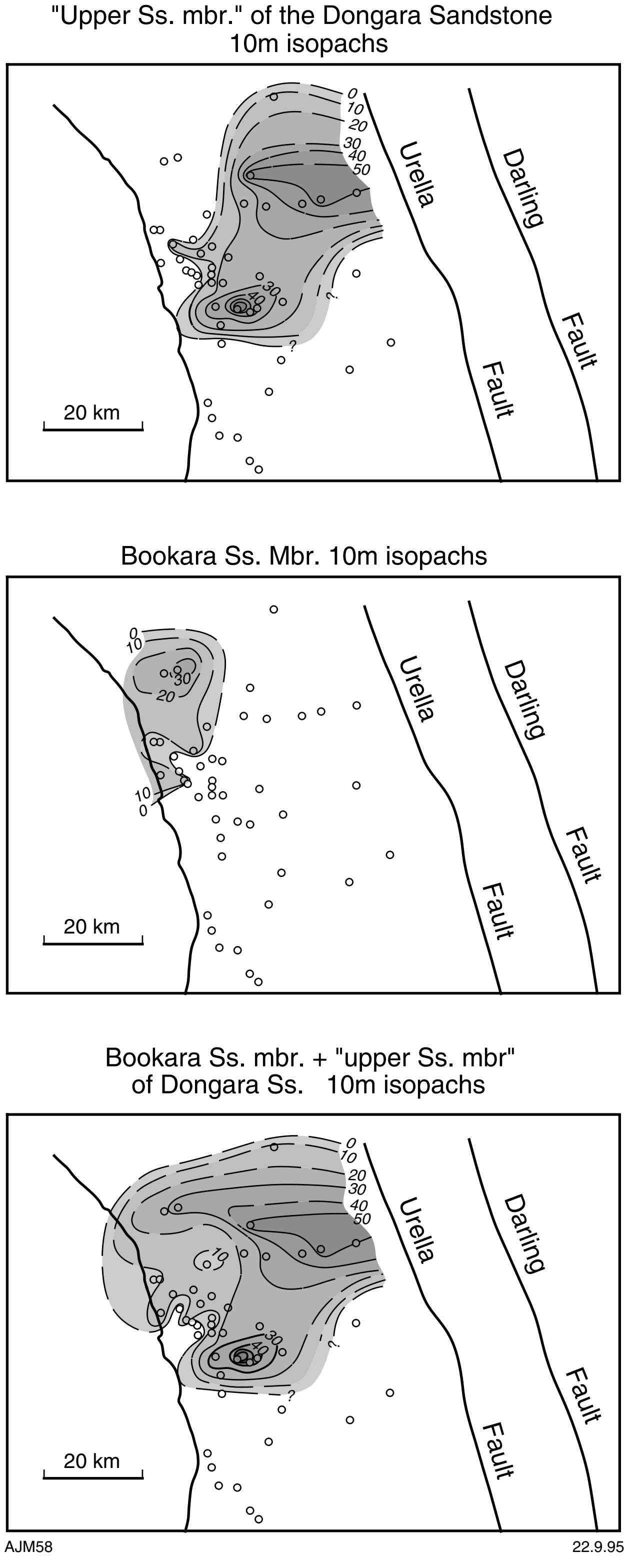

Figure 17. Isopach maps for Upper Permian–Lower Triassic sandstone members: (a) 'upper sandstone member' of the Dongara Sandstone (Late Permian), (b) Bookara Sandstone Member of the Kockatea Shale (Early Triassic), and (c) combined 'upper sandstone member' and Bookara Member

Woodada Formation (TRw)

The Woodada Formation (Willmott and McTavish, *in* Willmott, 1964, p. 15) has been identified only in the subsurface. The unit gradually thickens to the south and reaches a maximum known thickness of approximately 230 m in the Woodada field. However, subtle thinning to the west (Fig. 18) suggests the Beagle Ridge remained a relatively positive feature during deposition of the Woodada Formation.

Lithology: The Woodada Formation consists of interbedded fine-grained sandstone and carbonaceous siltstone. On wireline logs the unit shows a character intermediate between the underlying fine grained Kockatea Shale and overlying coarser material of the Lesueur Sandstone.

Stratigraphic relationships: The unit normally lies conformably between the underlying Kockatea Shale and overlying Lesueur Sandstone. North of the Allanooka Fault, however, the unit is either disconformably overlain by the Eneabba Formation or Cattamarra Coal Measures, or is absent.

Fossils and age: Backhouse (1992b,c) recorded palynofloras from the *Triplexisporites playfordii* Zone indicating a late Scythian to early Anisian (late Early to early Middle Triassic) age and supporting the earlier age determination of Balme (1969).

Depositional environment: The unit represents the commencement of a regressive phase of deposition, probably in a deltaic environment, following that of the marine Kockatea Shale.

Lesueur Sandstone (TRl)

The Lesueur Sandstone was named for the coarse-grained unit of Middle to Late Triassic age (Willmott, Johnstone and Burdett *in* Willmott, 1964, p. 14) that had previously been included in the Cockleshell Gully Formation by Playford, Willmott and McKellar (*in* McWhae et al., 1958, p. 99). The type section, as proposed by those authors in Woolmulla 1 between 429 and 1012 m, is here modified to 264 to 1008 m based on the blocky character of the gamma ray log. The unit thickens dramatically to the southeast reaching almost 3000 m in Barberton 1, compared with about 200 m in the Woodada field and 100 m near Dongara (Fig. 19).

Lithology: The Lesueur Sandstone consists of coarse to very coarse feldspathic and pebbly sandstone with minor siltstone and conglomerate. Large angular feldspar grains up to 2 cm long are present in fresh exposures of the unit whereas quartz clasts are usually subangular to well rounded. Sandstone predominates through the unit as indicated by the blocky character of the gamma-ray log, especially in wells in the southern part of the study area. The proportion of fine-grained lithologies increases to up to 20% of the unit in wells north of Eneabba.

Stratigraphic relationships: The unit lies conformably between the underlying Woodada Formation and the

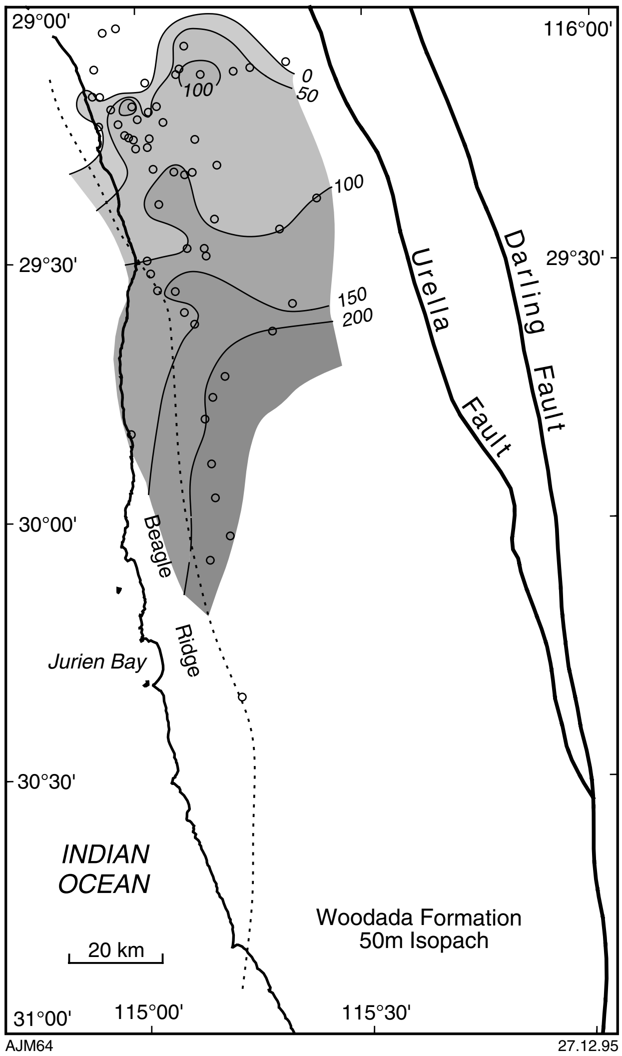

Figure 18. Isopach map, Woodada Formation (Early Triassic)

overlying Eneabba Formation except near West White Point 1, where it apparently disconformably overlies the Kockatea Shale. A similar disconformable relationship is also seen offshore where it is described as a mid-Triassic sequence boundary (Quaife et al., 1994).

Near the northern limit of the unit in the study area, especially north of Eneabba, microfloras from the Lesueur Sandstone are dominated by the spore *Falcisporites australis* indicating a general Late Triassic age. Consequently, in these wells it is not clear that the unit is conformable with the enclosing units, or if deposition was continuous through the Middle and Late Triassic. Dongara 7 and North Erregulla 1, however, respectively contain palynomorphs of the *Triplexisporites playfordii* Zone (Early to Middle Triassic) within 80 and 40 m of the top of the unit. In these wells the Lesueur Sandstone is relatively thin (<160 m) and the Upper Triassic may be absent. If the apparent absence of the Upper Triassic is not due to faulting, or even a condensed sequence, then it is possible that in this part of the basin there is either a significant disconformity, due to a period of non-deposition at the top of the Lesueur Sandstone, or the overlying Eneabba is much more diachronous and extends further into the Triassic than depicted in Figure 2.

Fossils and age: Spores and pollen from the *Triplexisporites playfordii, Staurosaccites quadrifidus*, *Samaropollenites speciosus* and *Minutosaccus crenulatus–Ashmoripollis reducta* Zones of Helby et al. (1987) have been found in this unit (Backhouse, 1992b) and suggest an Anisian to ?Hettangian (Middle Triassic to possible earliest Jurassic) age. The only macrofossil present is fossil wood.

Depositional environment: The lack of marine fossils indicates a general fluvial environment of deposition. In the southern part of its distribution the dominance of coarse-grained lithologies suggests that deposition in an alluvial-fan setting is possible. Palaeocurrent directions from planar crossbeds are largely to the northwest (Fig. 20) and, together with the high proportion of feldspar in

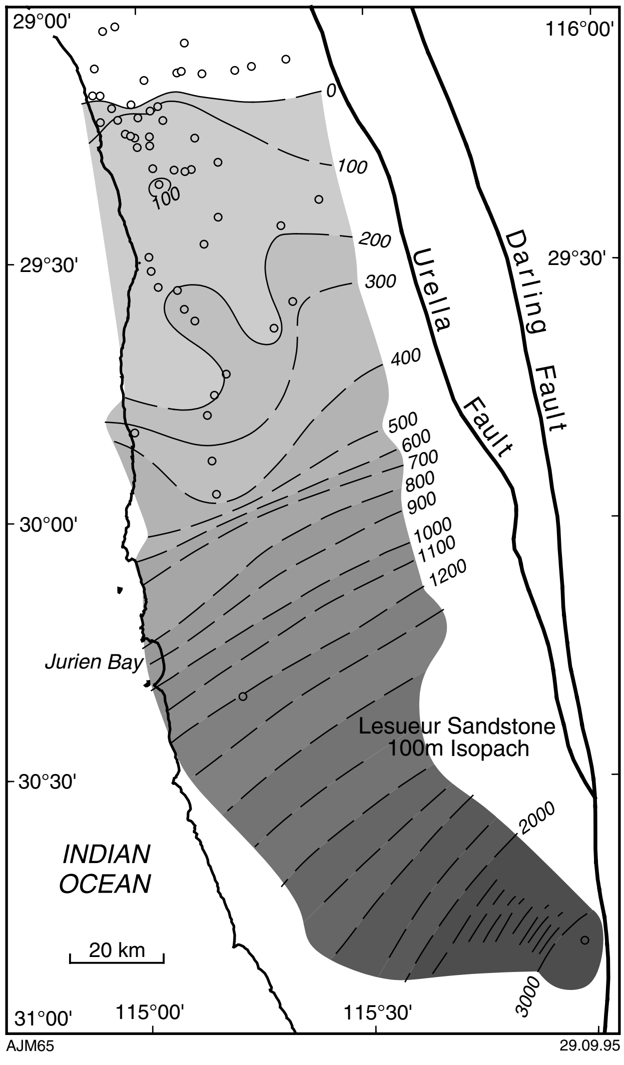

Figure 19. Isopach map, Lesueur Sandstone (Middle to Late Triassic)

the unit, suggest a provenance from a granitic source, probably from immediately east of the Dandaragan Trough. These directions contrast with the northeasterly directions obtained from a dipmeter study of Dongara 17 (Bird et al., 1971) here considered to be of dubious reliability. In Barberton 1 the dipmeter logs indicate a large number of directions to the southeast that are also considered dubious based on the likely southeasterly provenance of the unit.

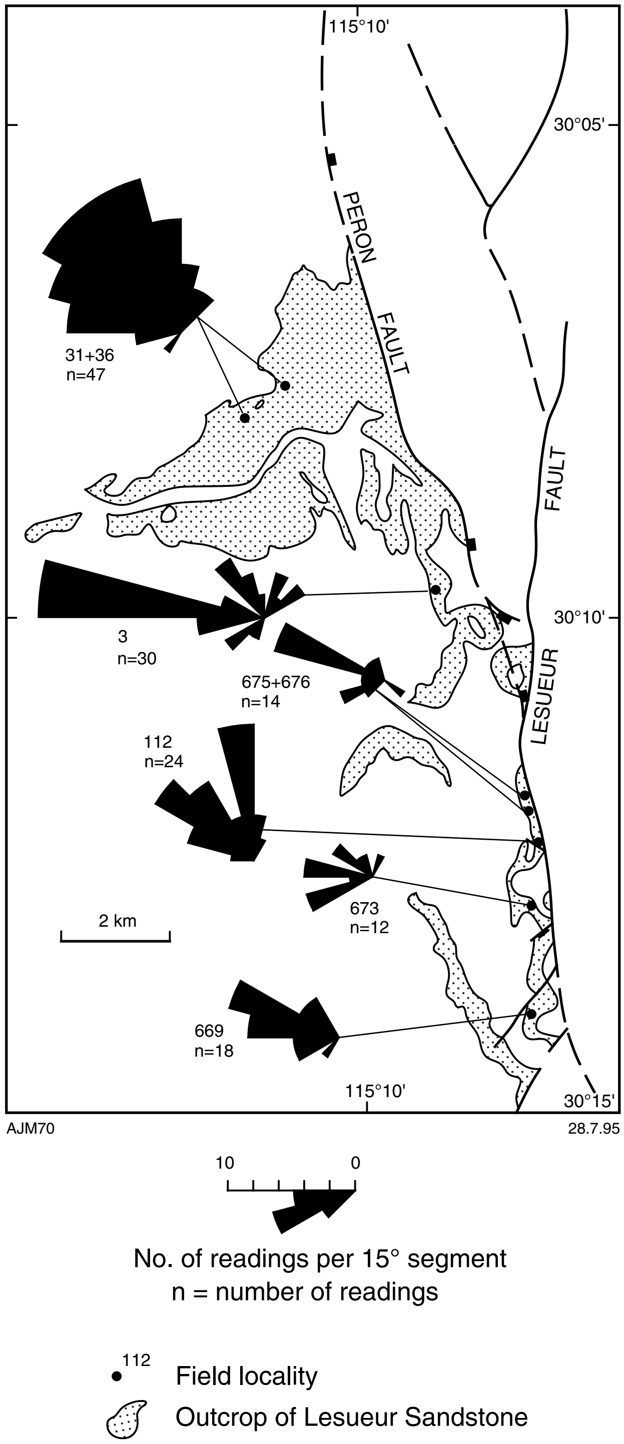

Figure 20. Palaeocurrent data from outcrop of the Lesueur Sandstone (Middle to Late Triassic)

Jurassic

Jurassic sediments are widespread in the northern Perth Basin. They comprise essentially continental strata with a thin predominantly Bajocian (Middle Jurassic) marine incursion (Cadda Formation).

The main outcrop areas are in the Gairdner Range near Jurien, and north of the study area in the mesas surrounding Geraldton. The latter exposures are atypical of the Jurassic as the sections are incomplete and condensed being less than 200 m thick compared with over 6000 m in the subsurface at the southern end of the study area.

Early collections of marine fossils from the Geraldton area found their way to Europe in the middle of last century and the first published descriptions by Moore (1870), Clarke (1867), Neumayr (1885), and Crick (1894) recognized their Jurassic age. Since that time a considerable amount of work has been done on these faunas (e.g. Etheridge, 1910, Arkell and Playford, 1954, Hall, R. L., 1989). By comparison, the Jurassic age for units in the Gairdner Range area was not established until Conrad and Maynard (1948) found a Bajocian limestone similar to the one near Geraldton, in what is now known as the Cadda Formation.

Eneabba Formation (*Je*)

The Eneabba Formation (Eneabba Member of the Cockleshell Gully Formation — Playford and Low, 1973; Playford et al., 1976) is an Lower Jurassic terrigenous redbed unit that was originally referred to as the 'multicoloured member' in unpublished WAPET reports. The unit is considered sufficiently distinctive to be given formation status and the name 'Cockleshell Gully Formation' has been abandoned (Mory, 1994a,b). The type section is in Eneabba 1 over the interval 2320 to 2978 m, modified slightly from Playford and Low (1973). The Eneabba Formation thickens to the south and reaches a maximum known thickness of 854 m in Donkey Creek 1. Owing to the great depth of the unit or to erosion, there are no known complete sections south of that well . In the Woodada field a dramatic thinning of the unit occurs between Woodada 3 and 1 (from 847 to 483 m). It is not clear if this thinning is entirely the result of a fault in the latter well. Nevertheless, thinning to the west, although less dramatic, is also evident farther north (Fig. 21) suggesting that some growth took place across faults downthrown to the east, such as the Mountain Bridge and Beharra Springs Faults.

Lithology: The Eneabba Formation consists of fine- to coarse-grained sandstone interbedded with multicoloured siltstone and claystone. Minor grey carbonaceous shale and thin coal are also present.

Stratigraphic relationships: In the south the unit lies apparently conformably between the Lesueur Sandstone

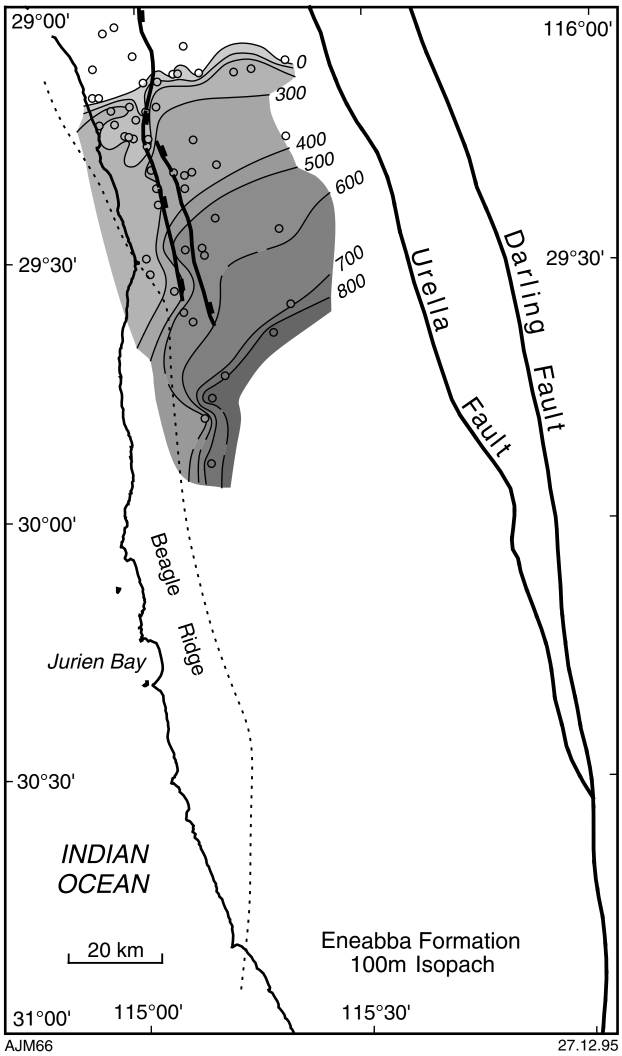

Figure 21. Isopach map, Eneabba Formation (Early Jurassic)

and Cattamarra Coal Measures. To the north the unit is absent or sits disconformably on the Kockatea Shale. It is not clear whether the unit has been removed by erosion, or there was a period of non-deposition in the Early Jurassic.

Fossils and age: The Eneabba Formation is mostly Early Jurassic in age, based on the presence of palynomorphs of the *Corollina torosa* zone of Helby et al. (1987) in petroleum and coal exploration wells (Backhouse, 1992b, 1993c). South of the Woodada field the youngest zone in the underlying Lesueur Sandstone is either the *Corollina torosa* or *Minutosaccus crenulatus–Ashmoripollis reducta* zone suggesting that the lower contact of the Eneabba Formation is diachronous across the Triassic–Jurassic boundary. In one mineral exploration bore, approximately 8 km northwest of Woolmulla 1, the base of the Eneabba Formation is virtually coincident with the base of the *Corollina torosa* zone (Backhouse, 1993c). In this bore the abrupt change in microfloras at the base of the Eneabba Formation suggests the presence of a local disconformity. The only macrofossils present are bivalves and rare fossil wood.

Depositional environment: The multicoloured lithologies (including redbeds) present in the unit suggest oxidizing conditions in a continental environment; this may explain the lack of microfloras in so many wells. Palaeocurrent data from outcrop of the unit (Fig. 22) are mostly from planar crossbeds, up to 1 m thick, in thick lenticular sandstone bodies. The dominant direction is north to northwest although a number of localities show south-easterly directions. The thick sandstone bodies

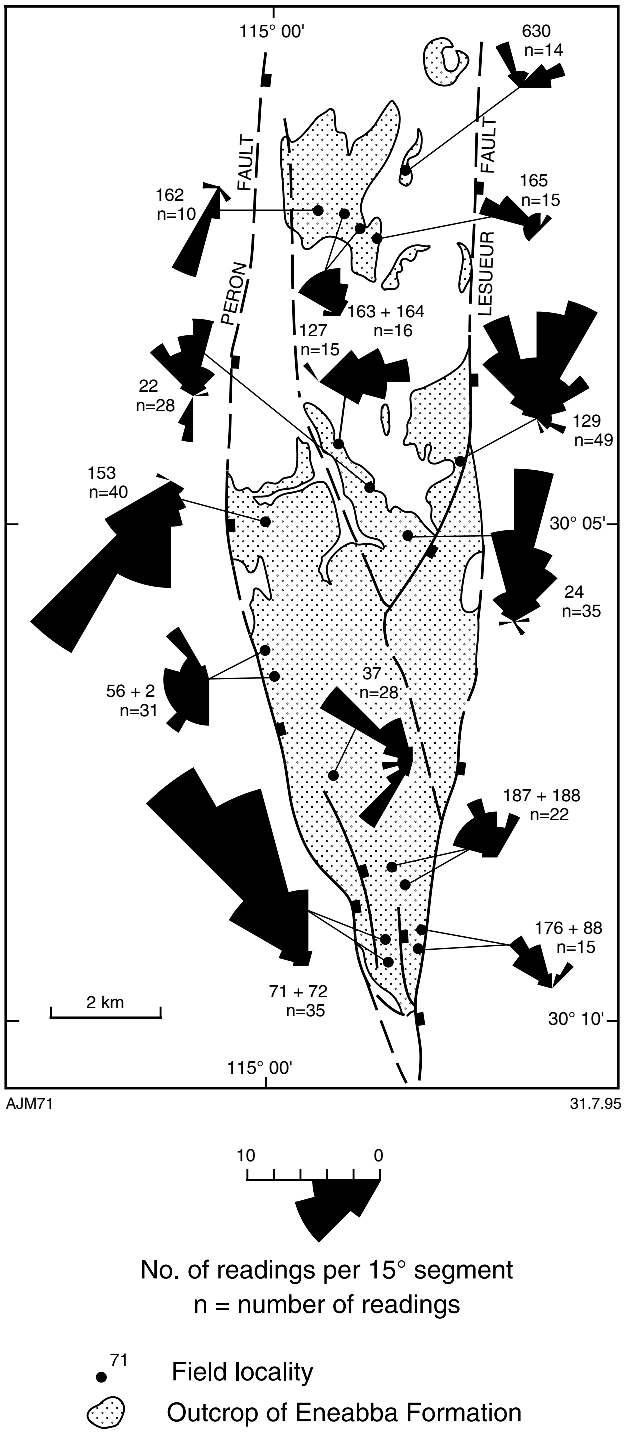

Figure 22. Palaeocurrent data from outcrop of the Eneabba Formation (Early Jurassic)

are interpreted as channel-fill deposits in an alluvial setting.

Cattamarra Coal Measures (*Jc*)

The Cattamarra Coal Measures was originally named the Cattamarra Coal Member by Willmott (1964) for the coal-bearing unit within the Lower Jurassic Cockleshell Gully Formation of Playford, Willmott and McKellar (*in* McWhae et al., 1958). Subsequently, the name was changed, first to Cattamarra Coal Measures Member (Playford and Low, 1973) and then to Cattamarra Member (Cockbain and Hocking, 1989). The name 'Cockleshell Gully Formation' has been abandoned (Mory, 1994a,b).

The type section in Eneabba 1, originally defined as the interval from 1790 to 2302 m (Willmott, 1964), is here modified to 1554 to 2320 m largely to incorporate changes to the definition of the overlying Cadda Formation. The Cattamarra Coal Measures generally becomes thicker to the south reaching almost 1500 m in Cataby 1 (Fig. 23). In addition some thickening to the east is evident, e.g. between Beharra 1 and Mountain Bridge 1 the unit increases from 525 to 663 m over a distance of 9 km. This thickening, although not as clear as for the underlying Eneabba Formation (Fig. 21), suggests either continued growth across easterly downthrown faults such as the Mountain Bridge and Beharra Springs Faults or is the result of delta-lobe switching. The unit appears to continue thickening to the east. The only evidence to the contrary is from Enanty Hill next to the Urella Fault where the unit is approximately 20 m thick (in UWA10 — Coleman and Skwarko, 1967). However, it is possible that the unit is faulted at that locality.

Lithology: The formation consists of fine- to coarse-grained sandstone interbedded with dark carbonaceous siltstone and claystone, and seams of coal up to 11 m thick. The unit is distinguished from the underlying Eneabba Formation by the presence of thick carbonaceous siltstone and mudstone and by the higher gamma-ray response in sandstone beds, possibly due to the presence of glauconite which is a common accessory mineral. The most northern outcrop is at Mount Hill, where the unit consists of crossbedded ferruginous sandstone with locally abundant plant fossils.

Stratigraphic relationships: The unit lies conformably between the overlying Cadda Formation and the underlying Eneabba Formation, except in the north of the area where it disconformably overlies the Kockatea Shale or Woodada Formation. In a coal-exploration bore at Mount Hill the Cattamarra Coal Measures unconformably overlies Precambrian basement.

Fossils and age: Palynomorphs of the upper *Corollina torosa* and lower *Callialasporites turbatus* zone of Helby et al. (1987) suggest a Pliensbachian to Aalenian (Early to Middle Jurassic) age for this unit. In the most northern wells, where the unit rests disconformably on the Kockatea Shale, only spores of the upper *C. turbatus* Zone are present (Backhouse, 1992b). Macrofossils in the unit include common fossil wood and leaves, and rare bivalves, branchiopods, and insects.

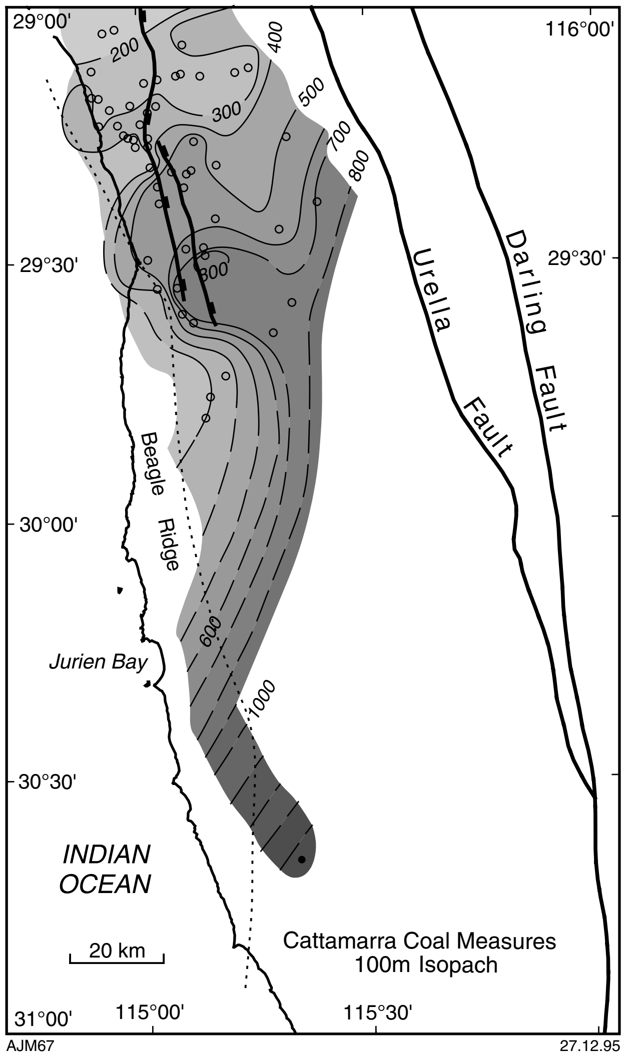

Figure 23. Isopach map, Cattamarra Coal Measures (Early Jurassic)

Depositional environment: The depositional setting of the Cattamarra Coal Measures is interpreted as deltaic, with fine-grained carbonaceous lithologies and the coal seams representing interdistributary bay environments. Thicker sandstone beds, especially those which overlie the coal seams, are probably fluvial and suggest an upper delta plain. Palaeocurrent directions collected from trough and planar crossbeds in this unit are variable (Fig. 24), although overall transport to the northwest is indicated. The variations in directions determined in the Hill River area probably reflect the variety of nearshore to fluvial environments present in a deltaic setting.

Cadda Formation (*Jd*)

The Cadda Formation (Playford, Willmott and McKellar, *in* McWhae et al., 1958, p. 99) was first recognized, but not named, by Conrad and Maynard (1948) as a Bajocian (Middle Jurassic) unit composed of clastics and fossiliferous limestone.

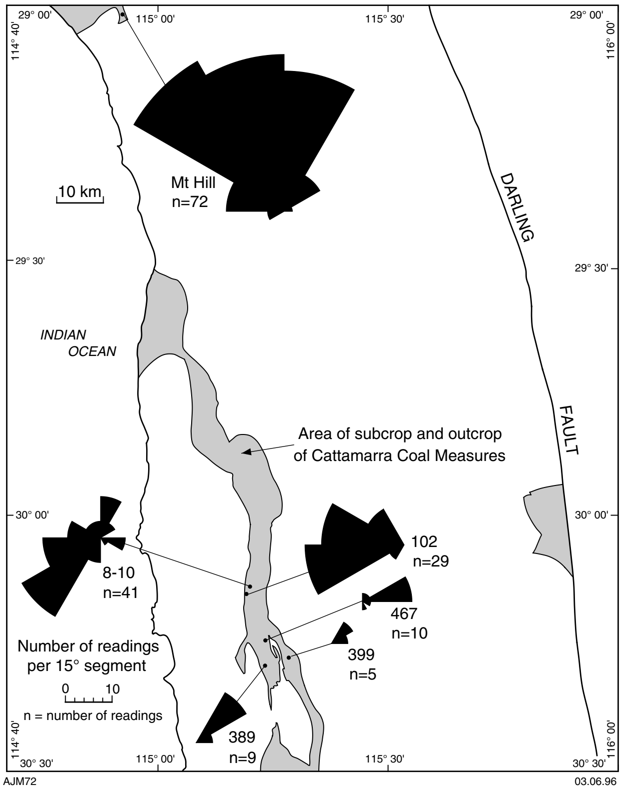

Figure 24. Palaeocurrent data from outcrop of the Cattamarra Coal Measures (Early Jurassic)

The definition used here of the Cadda Formation in the subsurface follows that of Pearson (1965) and Williams (1966) in that it excludes underlying sandstone. By comparison, many workers (mostly in unpublished well-completion reports) have included an underlying sandstone in the same manner that the Champion Bay Group has a basal fossiliferous marine sandstone unit, the Colalura Sandstone (Playford et al., 1976). In outcrop the Colalura Sandstone is typically 0.5 m thick, and the thickest section that has been measured is 8.5 m (Playford et al., 1976). The inclusion of sandstone at the base of the Cadda Formation is unsatisfactory as far as the subsurface data are concerned as the sandstone immediately below the shales of the Cadda Formation is indistinguishable on the wireline logs from those lower in the Cattamarra Coal Measures. The only core through the sandstone in question is from Eneabba 1 (core 11: 1739–1744 m) and consists of medium- to very coarse-grained, cross-bedded pebbly sandstone with carbonaceous stringers. The absence of evidence of marine conditions, such as shell material or glauconite, excludes this sandstone from the Cadda Formation.

The Cadda Formation reaches a maximum known thickness of 290 m in Mullering 1, and 288 m in Ocean Hill 1. On the isopach map of the unit (Fig. 25) the depocentre is in the central part of the study area, south of Eneabba. Unfortunately, the location of this depocentre is based on only six petroleum wells and the Gillingarra 8 hydrogeological exploration bore, so its position must be considered approximate. In the north of the study area, where well control is better, the unit thins to less than 50 m north of Dongara. In the vicinity of the Dongara field some of the thicknesses appear anomalously low (e.g. 21 m in Dongara 27, and 29 m in Yardarino 1 compared with approximately 60 m for most of the field). The numerous small faults that cut this field may explain such low values.

Lithology: The Cadda Formation consists of shale, siltstone and medium to very coarse sandstone, grading in places into sandy shelly limestone. In outcrop the limestone beds are generally ferruginized and leached of carbonate, with moulds of small molluscs. Fossiliferous beds, previously assigned to the Newmarracarra Limestone of the Champion Bay Group, are present in outcrop at Mount Hill (Arkell and Playford, 1954) and Enanty Hill (Coleman and Skwarko, 1967). Similar limestone is also recorded within the Cadda Formation in the Mount Horner field. In the subsurface, the unit may be distinguished by its higher gamma-ray log response compared with that of shales in the underlying Cattamarra Coal Measures.

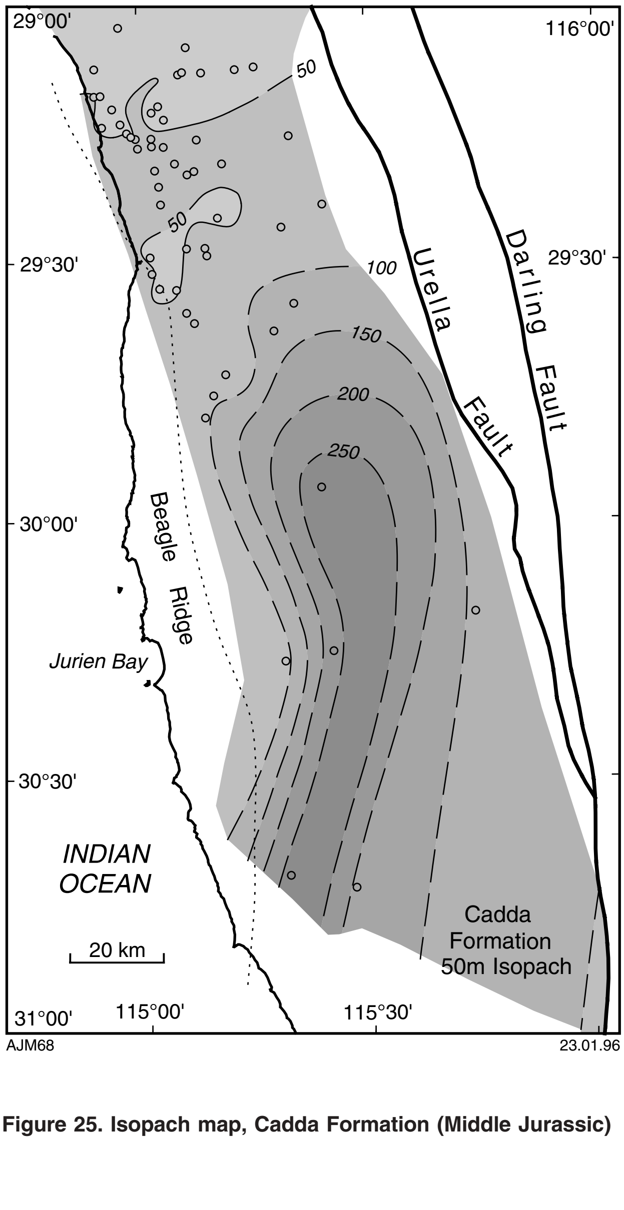

Figure 25. Isopach map, Cadda Formation (Middle Jurassic)

Stratigraphic relationships: The Cadda Formation lies conformably between the underlying Cattamarra Coal Measures and the overlying Yarragadee Formation. By comparison, the basal contact of the coeval Champion Bay Group to the north of the study area has been interpreted by Peter Arditto (1994, BHP Petroleum, pers. comm.) as a significant disconformity or sequence boundary. Similarly, he interprets the contact between the Newmarracarra Limestone and Kojarena Sandstone as a downlap surface.

Fossils and age: Dinoflagellates of the *Dissiliodinium caddaense* Zone and spores and pollen of the *Dictyotosporites complex* and upper *Callialasporites turbatus* Zones of Helby et al. (1987) suggest an Aalenian to Bajocian (Middle Jurassic) age for this unit (Backhouse, 1992b). The main outcrops in the Hill River area are dominated by a small fauna of molluscs (Playford et al., 1976). Bajocian marine macrofossils are also present in outcrop at Mount Hill and Enanty Hill and are described in Arkell and Playford (1954) and Coleman and Skwarko (1967) respectively.

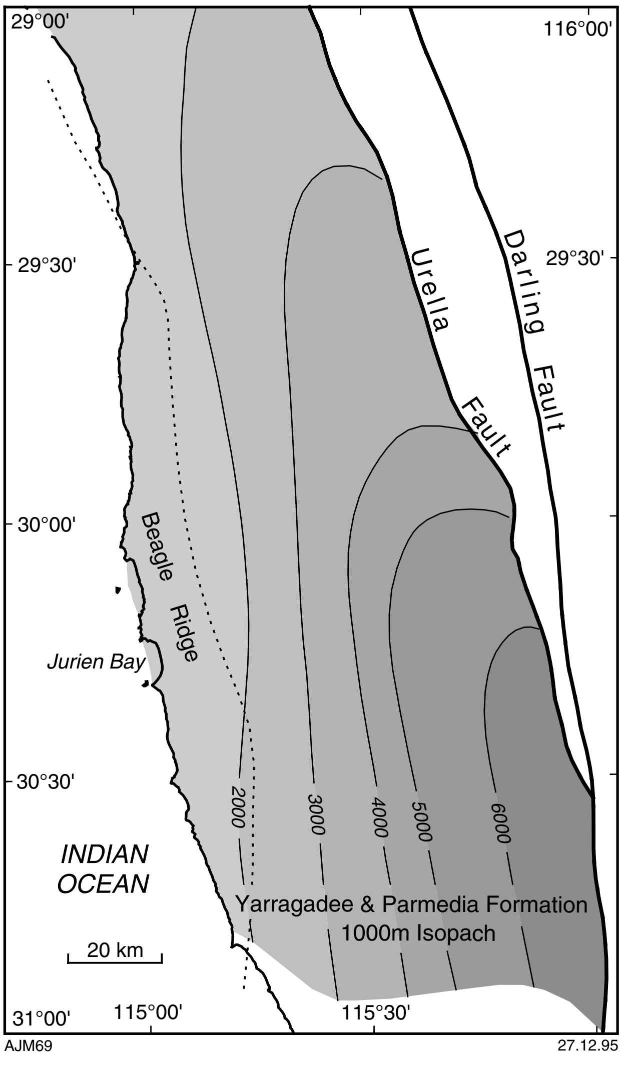

Figure 26. Isopach map, pre-breakup thickness of Yarragadee plus Parmelia Formations (Late Jurassic to Early Cretaceous)

Depositional environment: The unit is regarded as a shallow marine to paralic deposit (Playford et al., 1976). The unit, and the coeval Champion Bay Group to the north, represent a short-lived Middle Jurassic transgression by a shallow sea. A depositional environment is envisaged similar to that of Champion Bay Group in which the basal Colalura Sandstone and Bringo Shale represent an early transgressive phase, the overlying Newmarracarra Limestone marks the maximum extent of the transgression, and the Kojarena Sandstone at the top of the group represents a progradational highstand cycle.

Yarragadee Formation (*Jy*)

The Yarragadee Formation (Fairbridge, 1953; *amended* Playford, Willmott, and McKellar *in* McWhae et al., 1958, p. 98; *amended* Backhouse, 1984) is a predominantly sandy unit of Late Jurassic age and outcrops east of the Gingin Scarp in small weathered exposures beneath laterite breakaways. The best exposures of the unit are near Depot Hill on the banks of the Irwin River and in the type section 2.5 km south-southeast of Yarragadee homestead, although fewer than 25 m are exposed in each of these sections and the type section abuts the Urella Fault. Playford, Willmott, and McKellar (*in* McWhae et al., 1958, p. 98) proposed two reference sections: Bringo cutting near Geraldton, and 1.6 km north of Cantabilling Springs homestead east of Jurien, neither of which is substantially thicker than the type section. Playford et al. (1976) proposed Gingin 1 (188–3315 m) as a subsurface reference section. The upper limit was later modified to 356 m by Backhouse (1984) to accommodate the inclusion of the Otorowiri Member and overlying section in the Parmelia Formation. While the unit is almost 3000 m thick in the Gingin wells and Coomallo 1, the top of the unit has been removed by erosion in the latter. In the study area, the unit is estimated from cross sections (Plate 11) to be 2000 to 4000 m thick with the greatest thickness in the south. The isopach map for the Yarragadee plus Parmelia Formations (Fig. 26) is based on both the cross sections (Plate 11) and estimates, from geothermal modelling of wells with vitrinite reflectance data, of the amount of section removed at breakup. The modelling suggests that the Yarragadee Formation (plus the overlying Parmelia Formation) originally thinned considerably to the west onto the Beagle Ridge, and north towards the Allanooka High prior to erosion associated with the Early Cretaceous breakup.

Lithology: The Yarragadee Formation consists of interbedded fine to coarse feldspathic sandstone, siltstone, and claystone with minor conglomerate and coal. Beds are typically discontinuous and the correlation of units within the formation is difficult, even over short distances.

Stratigraphic relationships: The unit lies conformably between the underlying Cadda Formation and the overlying Parmelia Formation.

Fossils and age: The Yarragadee Formation has been reliably dated by palynomorphs as Bathonian to Tithonian (Middle to Late Jurassic — Backhouse, 1984, 1988). The only macrofossils are plant impressions and fossil wood.

Depositional environment: The unit is essentially a fluvial deposit in which shaly sections may represent a lacustrine or overbank environment. Palaeocurrent data from outcrop indicate transport largely to the northwest and north-northwest (Fig. 27). Variations from the main trend in palaeocurrent directions are either from localities in which smaller bedforms were measured, or may represent local variations in channel orientations. In outcrop in the Irwin River northwest of Depot Hill, for example, cross-beds are less than 25 cm thick in a fine-grained silty sandstone and show a bipolar east–west distribution (Fig. 27, locality 317). This locality is interpreted as the last phase of a channel infill with the palaeocurrents showing the effect of small rises and falls in the waterlevel. Other variations, such as the southwesterly directions near the Irwin River, are not systematic and are considered to represent local channel meanders.

Cretaceous

Cretaceous sedimentary rocks are widespread over much of the Perth Basin and onshore are up to 3100 m thick (Playford et al., 1976). In the study area the Cretaceous is confined to the east and south (Plate 10). Within Cretaceous sedimentary rocks of the Perth Basin are two unconformities that correspond to the Neocomian breakup of Gondwana, and possibly the onset of rifting along Australia's southern margin. Only the pre-breakup Cretaceous succession is discussed in any detail as post-breakup deposits in the study area are thin and incomplete.

Parmelia Formation (*Kp*)

The Parmelia Formation was formally named by Backhouse (1984). Previously the unit had been included within the Yarragadee Formation and informally identified as 'upper Yarragadee' in well-completion reports from the offshore part of the basin. The type section is the interval 1625 to 3551 m in Peel 1 in the Vlaming Sub-basin (Backhouse, 1984). It is now recognized that this section is heavily faulted suggesting the unit is well over 2000 m thick in that well. The formation has been intersected in numerous waterbores in the eastern part of the study area, south of Mingenew. In the few petroleum wells in this area the formation is less than 200 m thick and, being near surface, is deeply weathered. The unit is estimated to be up to 500 m thick in the study area.

Two members are identified within the unit: the basal Otorowiri Member (Otorowiri Siltstone Member *of* Ingram, 1967) and the Carnac Member (Backhouse, 1984). The type sections are in Arrowsmith 25 waterbore between 253 and 277 m (29°33'25"S, 115°32'00"N), and in Peel 1 between 2408 and 3064 m respectively. A near-surface section of clay, approximately 50 m thick, in the Erregulla and North Erregulla petroleum exploration wells possibly represents weathered Otorowiri Member.

Lithology: In the study area the Parmelia Formation consists of feldspathic sandstone, with minor siltstone and claystone, and is lithologically very similar to the underlying Yarragadee Formation. Small pebbles of red, black and white jasper near at the base of the formation in outcrop south of the Arrowsmith River were probably derived from the Proterozoic Noondine Chert to the northeast. The basal Otorowiri Member consists predominantly of siltstone with minor, thin, fine-grained sandstone interbeds.

Stratigraphic relationships: The unit conformably overlies the Yarragadee Formation and is disconformably overlain by the Warnbro or Coolyena Groups.

Fossils and age: Palynomorphs from the Parmelia Formation indicate a Tithonian to Berriasian (latest Jurassic to Early Cretaceous) age for the unit (Backhouse, 1984, 1988). In addition, reworked Devonian, Permian and Triassic palynomorphs have been recorded from the Otorowiri Member by Ingram (1967) in some of the Arrowsmith waterbores. Reworked Early Permian and Early Triassic palynomorphs are common through the remainder of the unit, but Late Permian and Late Triassic to Early Jurassic forms are rare (Backhouse, 1984).

Depositional environment: The environment of deposition of the unit is fluvial, similar to that of the underlying Yarragadee Formation. The Otorowiri Member is believed to be a lacustrine deposit. Palaeocurrent data from outcrop are bimodal to the northwest and southwest (Fig. 27). The latter direction implies some uplift in the Early Cretaceous prior to breakup, presumably along the Urella–Darling Fault system. In addition the palaeocurrent data, though limited, suggest that reworked Permian to Triassic palynomorphs were derived from the Irwin Terrace or perhaps from east of the Darling Fault.

Warnbro Group (*Kw*)

The Warnbro Group (Cockbain and Playford, 1973) comprises fluvial to shallow marine sediments, of late Neocomian to Aptian (Early Cretaceous) age, that unconformably overlie the Parmelia Formation or older units. The group has been divided into three units: Gage Formation, South Perth Shale, and Leederville Formation (in ascending order). The Dandaragan Sandstone, which was previously included in the group by Cockbain and Playford (1973), has since been assigned to the overlying Coolyena Group (Moncrieff, 1989; Davidson, 1995). Of these units only the Leederville Formation is present in the southern part of the study area and has been intersected in shallow waterbores, none of which penetrated the unit by more than 20 m (Kern, 1993). By comparison, in the Gillingarra line of bores, just south of the study area, Moncrieff (1989) showed that the unit is up 649 m thick and overlies thin South Perth Shale (up to 88 m) and Gage Formation (up to 88 m). Offshore, the group is over 1000 m thick. Spring and Newell (1993), working on the group in the offshore Vlaming Sub-basin, found this subdivision inadequate to describe the evident stratigraphic complexities, and the group was described instead in terms of a sequence stratigraphic model.

Coolyena Group (*Kc*)

The Coolyena Group (Cockbain and Playford, 1973) is an Albian to Maastrichtian (latest Early to Late Cretaceous)

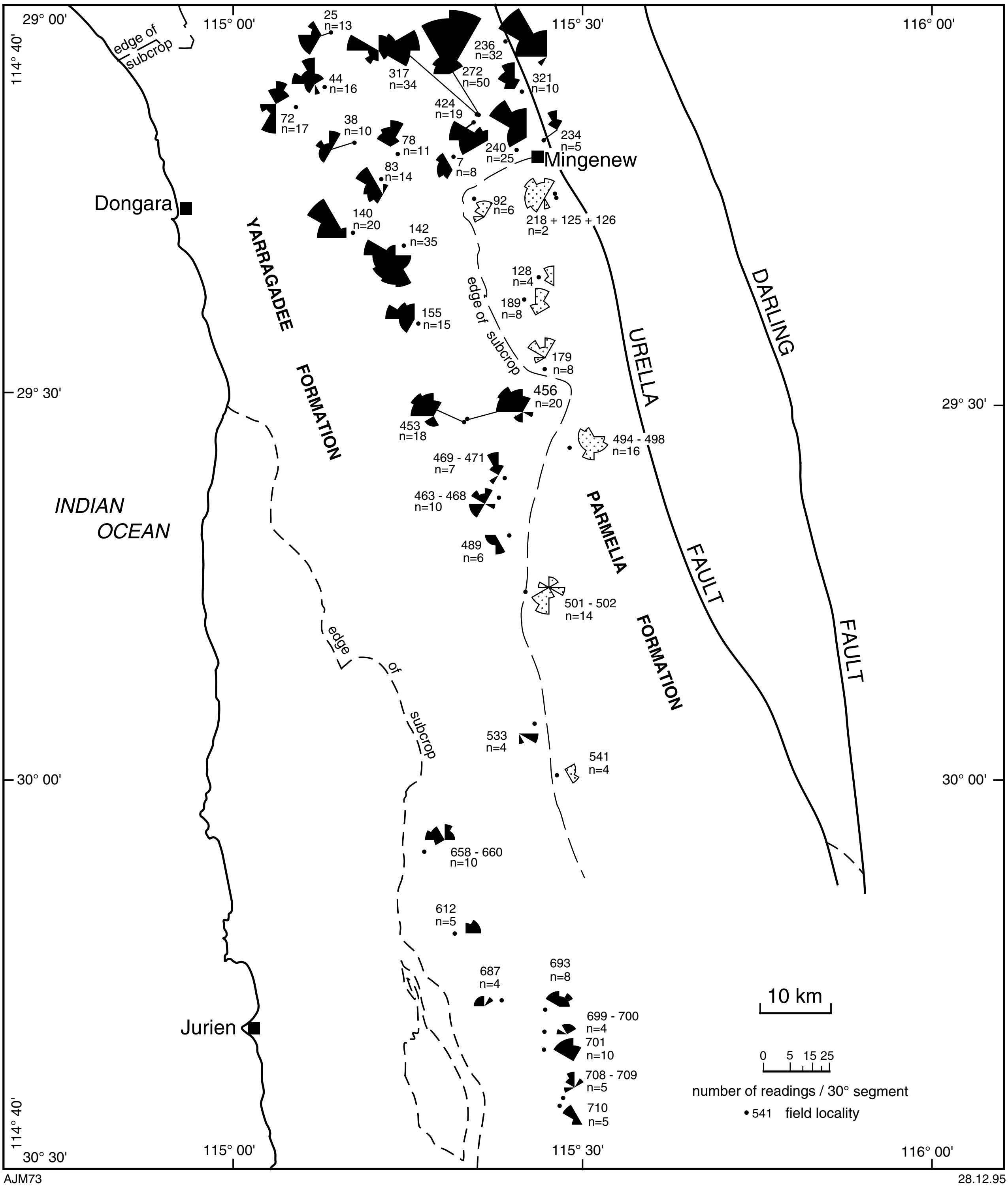

Figure 27. Palaeocurrent data from outcrop of the Yarragadee and Parmelia Formations (Late Jurassic to Early Cretaceous)

marine unit unconformably overlying the Warnbro Group. The group comprises the Osborne Formation, Molecap Greensand, Gingin Chalk and Poison Hill Greensand (in ascending order) and is contiguous with the Lancelin Formation near the coast, recently included in the group by Davidson (1995). The Dandaragan Sandstone is correlated with the Henley Sandstone Member, at the base of the Osborne Formation in the Perth Metropolitan area (Davidson, 1995). The group is restricted to the south of the study area where it outcrops poorly east of the Dandaragan Scarp (Carter and Lipple, 1982) and is less than 150 m thick (Moncrieff, 1989, fig. 4). By comparison the group is over 500 m thick in the offshore Vlaming Sub-basin. It is likely that several disconformities or lacunae are present in the group in the onshore sections.

Structure

Gravity, aeromagnetic and seismic datasets were analysed along with some data from outcrop mapping to provide an insight into the structure of the onshore northern Perth Basin. Differences in resolution, and the areas covered by these datasets, limited the possibility of producing an entirely integrated structural interpretation from the geophysical data. For example aeromagnetic and gravity lineaments could not be directly correlated with faults identified from the seismic data.

Gravity and magnetic data have been used in the petroleum industry to analyse subsurface geological structures since the 1920s, but the seismic reflection method has predominated throughout the history of exploration because the resultant reflections can be correlated directly with geological strata (Nettleton, 1971). In the 1990s, there has been a revival in the use of aeromagnetic methods in petroleum exploration because technological advances in computing, satellite navigation and instrumentation have improved the resolution of small anomalies. The new technology has facilitated the identification of anomalies relating to structures within the sedimentary strata, whereas in the past, potential field data were mainly used for identification of broad, basement-related features. Mapping the gravity field, especially onshore, has had a delayed resurgence because ground surveying is logistically difficult and therefore expensive to conduct, and airborne gravity surveying can only define broad features. Because gravity data are relatively more expensive to collect than aeromagnetic data, for example, most gravity surveys have a wide spacing between stations, resulting in poor resolution of anomalies within the sedimentary succession.

In the last decade, potential field data have been displayed as images similar to those used by Landsat, thus providing improved structural interpretation through the easier visualization of trends and lineaments.

Gravity data

Gravity anomalies are produced when there are horizontal and vertical density differences in sedimentary and basement lithologies. Unlike magnetic anomalies, gravity anomalies are not affected by surface cultural effects and surficial magnetic sediments or rocks. Basement structures dominate images because of the large density contrast between sediments and crystalline rock. However, smaller anomalies within the sedimentary strata can also be identified, given adequate data resolution. The processed gravity images show lineaments caused by faulting, intra-basement structural and lithological changes and, possibly, by intra-sedimentary variations in density. Gravity surveys represent a low-cost method of addressing local and regional structural problems. Depending on the amount of coverage, gravity can provide a powerful complementary dataset to seismic and magnetic data with which to analyse subsurface structural geological features. The improper use of densities to calculate Bouguer corrected values may result in anomalies that mirror the topography rather than depicting subsurface structure (Iasky, 1994, fig. 3). A fortuitous example of the improper use of densities is illustrated by the discovery of the Dongara field: Dongara 1 was located on a Bouguer gravity anomaly for which too high a density value was used. Recalculation of Bouguer anomalies in the area using a density of 2.0 g/cm^3 rather than 2.67 g/cm^3, as originally used by WAPET, shows that there is no significant anomaly over the field.

An opportunity to improve the gravity coverage in the study area, with minimum logistical problems, arose in late 1993 and early 1994, when five seismic surveys were to be recorded back to back in the northern Perth Basin. WAPET recorded a two-dimensional (2D) and 3D seismic survey over the Strawberry Hill structure and the Dongara field respectively. The 3D survey was an ideal place to record gravity data along a regular grid and allowed a station spacing that is close to that obtained in aeromagnetic surveys. These surveys were followed by 2D surveys by Discovery Petroleum NL over the Mount Horner field, by Victoria Petroleum NL to delineate a small structure northwest of Mount Horner, and by Consolidated Gas Pty Ltd over the Woodada field. The GSWA, in cooperation with these companies, proceeded to collect gravity measurements along seismic lines as well as a number of roads (Fig. 28).

A total of 3299 new and 4269 existing gravity stations were combined in the onshore northern Perth Basin between latitudes 29°00' and 31°00'S, and longitudes 114°55' and 116°00'E, to produce gravity images of the basin. The northern quarter of the area between latitudes 29°00' and 29°30'S is the most densely populated with a good to average coverage containing 4643 stations (61% of all stations). The remaining stations are spread over the southern three-quarters of the study area, with the southern half containing only regional coverage at a station spacing of 10–12 km. The resolution of the data, and therefore the amount of information obtained, was found to be directly proportional to station coverage.

The total datasets include data from the AGSO national database as well as the recent surveys conducted during November 1993 to April 1994. The recent data consist of measurements along seismic lines at a station spacing of 300 to 500 m, and additional regional traverses collected along main roads and tracks at 500 m spacing. By comparison, the AGSO data consist of a compilation of WAPET 1960s vintage data at 800 m (half-mile) spacing, BMR regional data collected at 10–12 km spacing, and a number of smaller mineral exploration surveys at the eastern boundary of the basin, spaced at 500 to 1000 m. The area of investigation has good coverage over the Dongara and Mount Horner fields, medium coverage over the Woodada field and the Darling Fault, and poor coverage in the rest of the area. An account of the acquisition and processing of these data is in Iasky (1994, in prep.).

Structural trends and lineaments were identified using images of the Bouguer gravity and the first and second derivatives illuminated from different directions. The most useful of these images were the Bouguer gravity and first vertical derivative, illuminated from the northwest (Figs 29

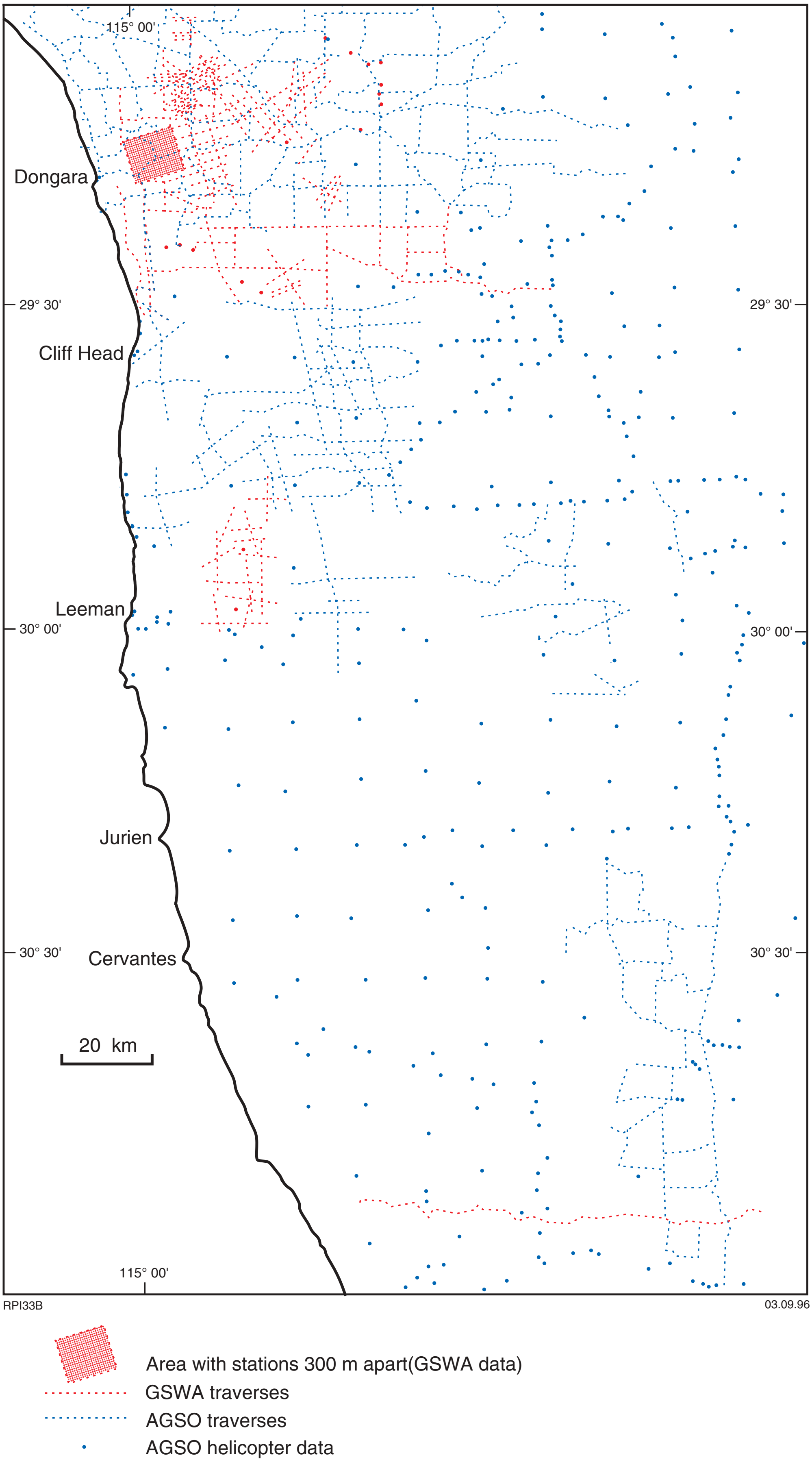

Figure 28. Distribution of gravity stations in the study area

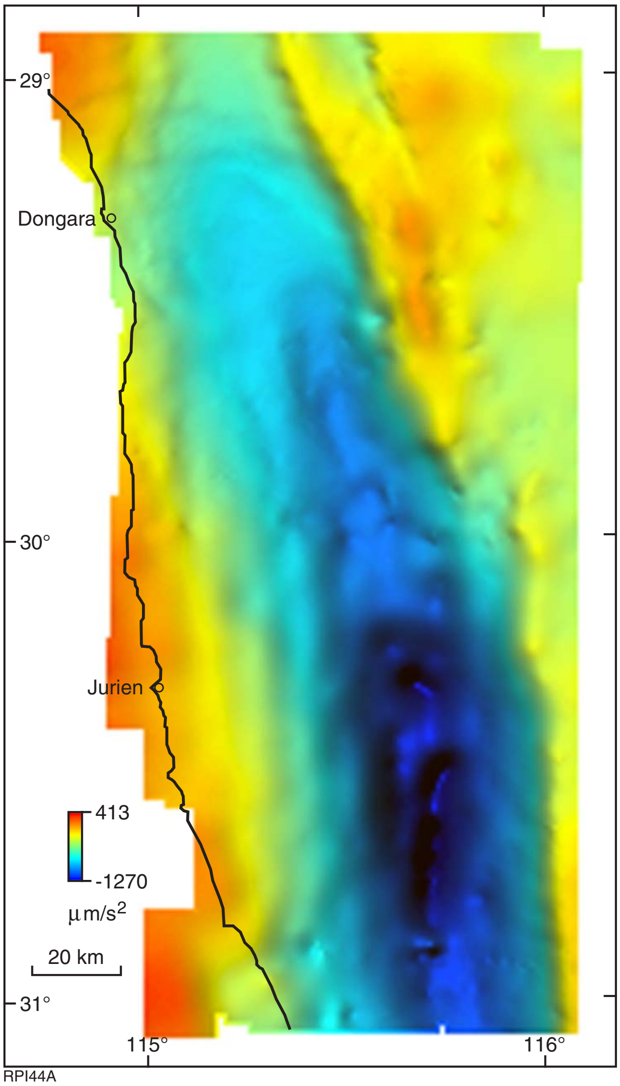

Figure 29. Bouguer gravity image for the northern Perth Basin. Sun illumination 60 degrees from the northwest

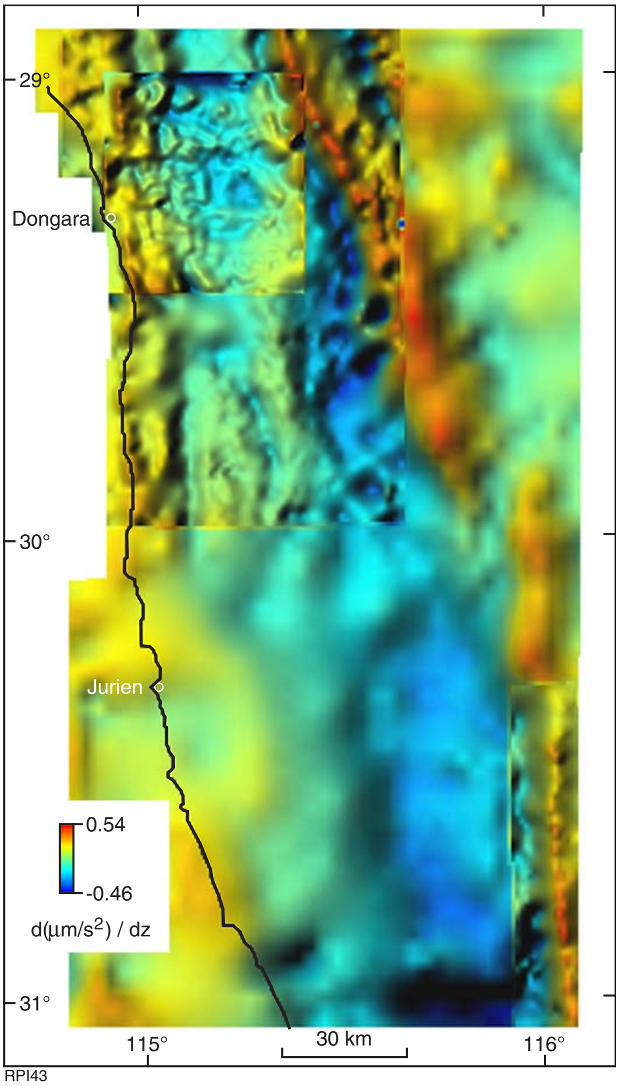

Figure 30. Gravity image of first vertical derivative for the northern Perth Basin. Sun illumination 80 degrees from the northwest. Note that the data is aliased in the southwest of the image

and 30). The northern part of the study area has a more detailed interpretation because of the higher resolution resulting from better coverage (Fig. 31). The positions of the lineaments (Figs 32, 33), when compared with those of faults mapped on seismic horizons (Plates 5, 7, 9) suggest that the majority can be attributed to basement structures.

Modelling

Two Bouguer gravity profiles (Fig. 34) across the onshore northern Perth Basin have been modelled to obtain additional structural information in areas where seismic data are absent or very poor. The northern profile was chosen to test for the existence of shallow basement west of the Urella Fault. This possibility became apparent when Permian palynomorphs were found near surface in the Arrowsmith water bores (Backhouse, 1993b), in an area where surface sediments had been interpreted as Cretaceous. The implication was that there are either uplifted fault blocks adjacent to the Urella Fault, or that the palynomorphs were reworked. The southern profile was chosen to verify the interpolated depth to basement at the southern edge of the study area and, in particular, in the deeper Dandaragan Trough. This traverse is a western extension of the New Norcia seismic survey that is confined largely to the Yilgarn Craton (Middleton et al., 1994; Dentith et al., 1994).

Both traverses, each 80 km in length, are oriented east–west across the basin. Both begin at the coastline with the northern traverse extending approximately 20 km east of the Urella Fault and the southern traverse some 16 km east of the Darling Fault.

A forward two-dimensional modelling computer program was used to derive a geological model for the two profiles. Forward modelling is a process whereby the gravity effect of a model is calculated for stations along a

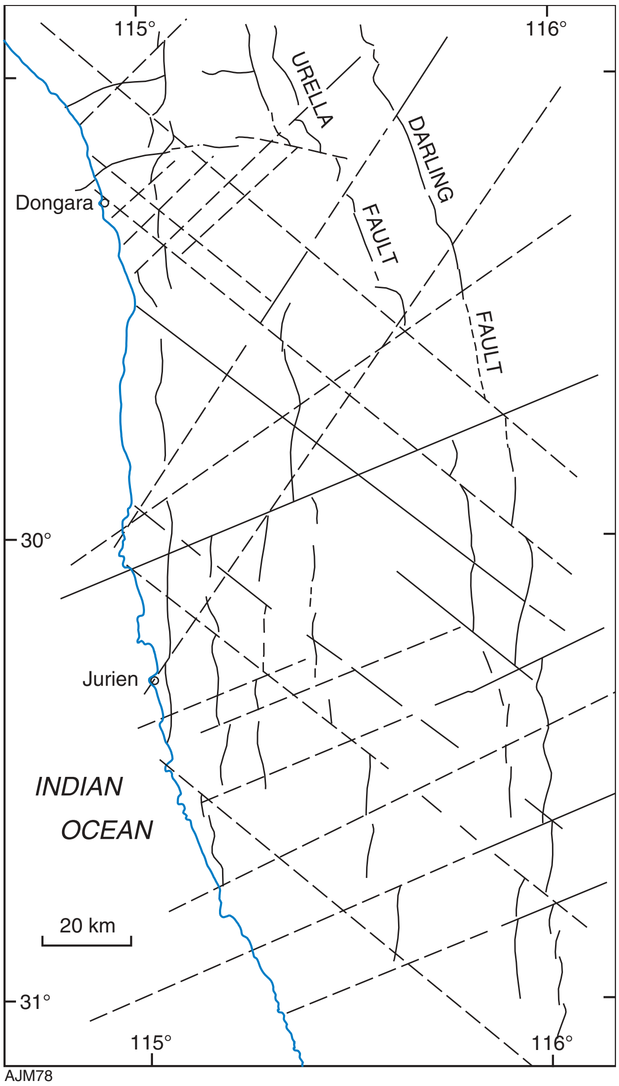

Figure 31. Gravity lineaments in the northern Perth Basin

traverse and compared with observed data. The model is adjusted until calculated gravity matches observed data of the profile.

In both models, the sedimentary basin was stratified into layers of increasing density with depth, in accordance with density logs from petroleum wells (Iasky, R. P. *in* Le Blanc Smith and Mory, 1995). The thickness of the layers and the densities used in each were varied to provide a geologically feasible model that would match the observed data. Initially, the layers were assigned a thickness of 2 km that was later varied where appropriate. Density values were calculated using Gardner et al.'s (1974) density versus velocity curves. The density of crystalline basement used in the models (2.7 g/cm^3) was estimated from laboratory measurements of outcrop samples (Iasky, R. P. *in* Le Blanc Smith and Mory, 1995).

Seismic mapping of depth to basement provided an important constraint to the thickness of sediment and the densities used in the models. Consequently, to fit the calculated gravity effect of a model to observed data, layer thicknesses and densities were adjusted rather than the total thickness of sediment in the basin. This principle has been applied to obtain the final model for the northern traverse (Fig. 35). In the west of the model, a density layer of 2.35 g/cm^3 is juxtaposed against a layer of density 2.3 g/cm^3 immediately to the east. This horizontal density variation is interpreted as a fault contact upthrown to the west. This fault boundary on the model corresponds to the Mountain Bridge–Beharra Springs Faults on the seismic map, and the regional easterly dip of approximately 10° immediately east of the fault closely agrees with the dips measured from seismic mapping across the Donkey Terrace.

The northern model shows that the Urella Fault is listric with an average dip of approximately 55°, in good agreement with seismic mapping. The model also shows a large uninterrupted throw on the Urella Fault downthrown directly to the deepest part of the profile. The model suggests that Permian sediments should be found at considerable depth and implies that the Permian palynomorphs near surface in the Arrowsmith waterbores are reworked.

Gneisses of the Mullingarra Inlier (2.75 g/cm^3 in model) and Proterozoic sediments of the Yandanooka Group (2.6 g/cm^3 in model) outcrop east of the Urella Fault as shown in the northern profile. A large positive anomaly in this region can only be accounted for in the model by a higher density body (2.85 g/cm^3), such as a mafic dyke, below the Yandanooka Group.

The final model for the southern traverse (Fig. 36) shows that, given the assumed density stratification, the depth to basement of the Dandaragan Trough corresponds to that interpolated using well velocity data. In the western part of the profile, a positive anomaly has been modelled as a basement high. This basement feature has not been mapped with seismic data, and it is possible that it is a basement feature such as a higher density dyke similar to that modelled in the northern profile. Unfortunately, seismic data in this part of the basin are very poor and neither support nor disprove the gravity model. The western part of the model depicts basement dipping gently east, and supports the presence of low-dipping faults as interpreted from seismic data (Plate 11, section FF'; Plate 18, southernmost composite traverse). The eastern part of the model corresponds to the seismic mapping in that the presence of the Barberton Terrace is confirmed. The horizontal density variation between the Barberton Terrace and Dandaragan Trough indicates uplift along the Muchea Fault, similar to uplift along the Urella Fault indicated in the northern traverse.

On the eastern part of the model a high-density body of 2.8 g/cm^3 east of the Darling Fault is interpreted as the shear zone of the proto-Darling Fault (Blight et al., 1981). This body corresponds to the zone without a seismic response immediately east of the Darling Fault on the New Norcia seismic traverse, interpreted as a zone of severe structural deformation (Middleton et al. 1994).

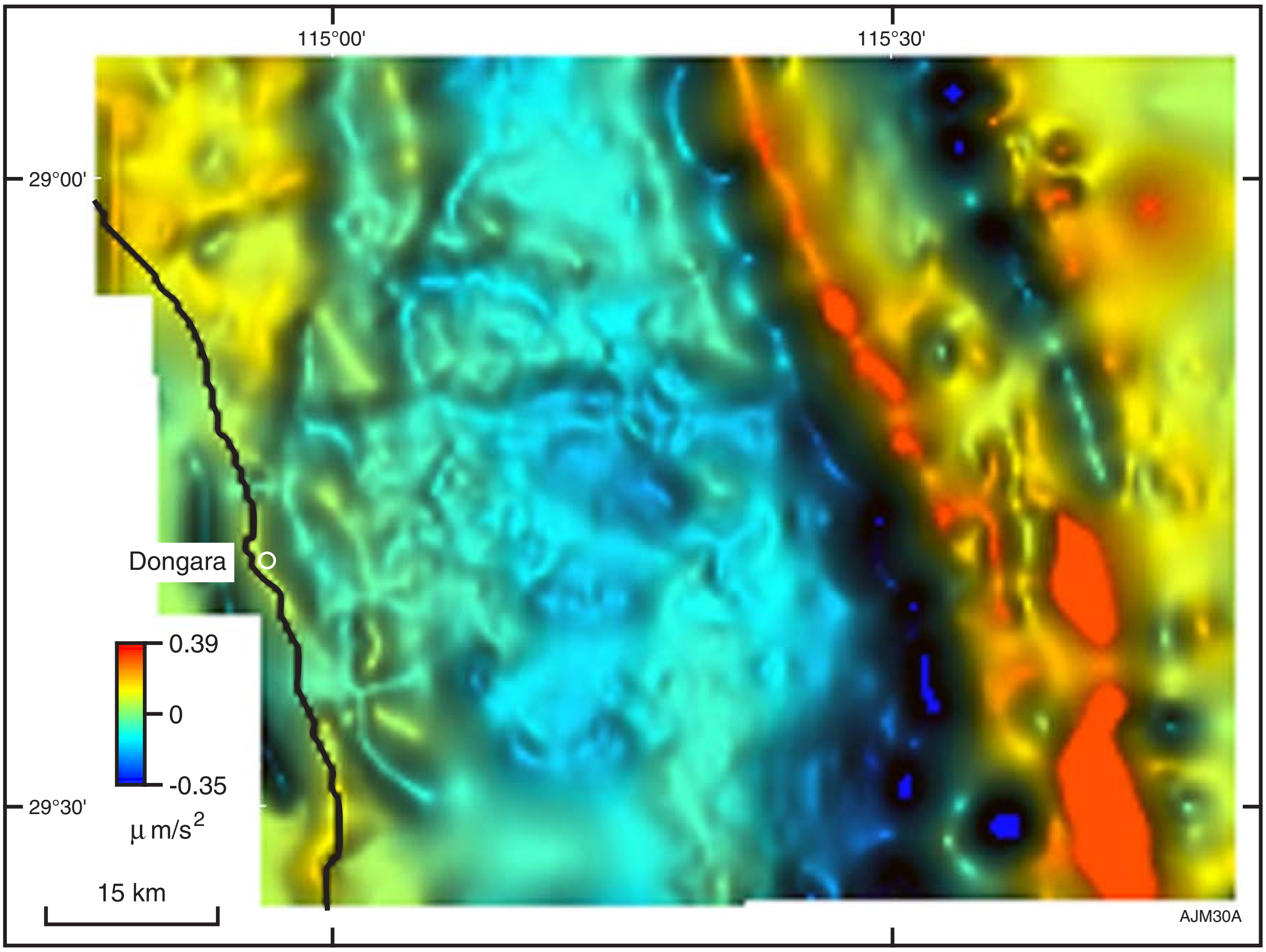

Figure 32. First vertical derivative gravity image for the Dongara–Mount Horner area. Sun illumination 60 degrees from the northwest

Lineaments striking north to northwest

The Darling Fault is a major north to north-northwest trending feature on the southeastern part of the images, but it has a considerably reduced amplitude in the north. The throw on the Darling Fault decreases significantly as the throw on the Urella Fault increases between latitudes 29°40' and 30°05'S. This type of fault geometry and kinematics has been described as a relay ramp (Peacock and Sanderson, 1994). Northeast-trending lineaments displace the Darling Fault sinistrally in several places along its length. The most dominant of these is seen at approximately 29°40'S where the throw of the Darling Fault is relayed to the Urella Fault (Figs 30, 32). These faults appear to continue to the north and south respectively, but their gravity anomaly is considerably smaller. Where the Yilgarn Craton juxtaposes the Mullingarra Complex, the Darling Fault cannot be identified clearly because of the minimal density contrast. At this point the anomaly representing the Urella Fault increases in width because of the effect of the near-surface rocks of the Mullingarra Complex.

The Urella Fault is the major north-northwesterly trending feature in the northeastern part of the image, with the Darling Fault remaining parallel to it on its eastern side. A major splay of the Urella Fault, which strikes west at approximately 29°10'S, is interpreted as the intersection with the Allanooka Fault. North of the Allanooka Fault the gravity data show that the throw of the Urella Fault diminishes and that two smaller splays striking west are present. The high-amplitude lineament parallel to, and west of, the Urella Fault in that area is interpreted as the Wicherina Fault (Figs 30, 32).

The Beagle Fault System is identified by the higher amplitude anomalies on the western part of the images, bordering the coast. There are several broken lineaments striking north to northwest that probably represent several en echelon faults as mapped with seismic data (Plate 5). Unfortunately, the data coverage near the coast is poor and the resolution of these lineaments is low.

The Mountain Bridge Fault is represented by a set of northerly striking lineaments identified north of approximately 29°30'S, immediately east of the Beagle Fault System (Figs 30, 32). Another set of near-parallel lineaments, immediately to the east, the Beharra Springs Fault as mapped with seismic data. The lineaments coincident with these two faults are discontinuous, indicating that parts may not penetrate basement even

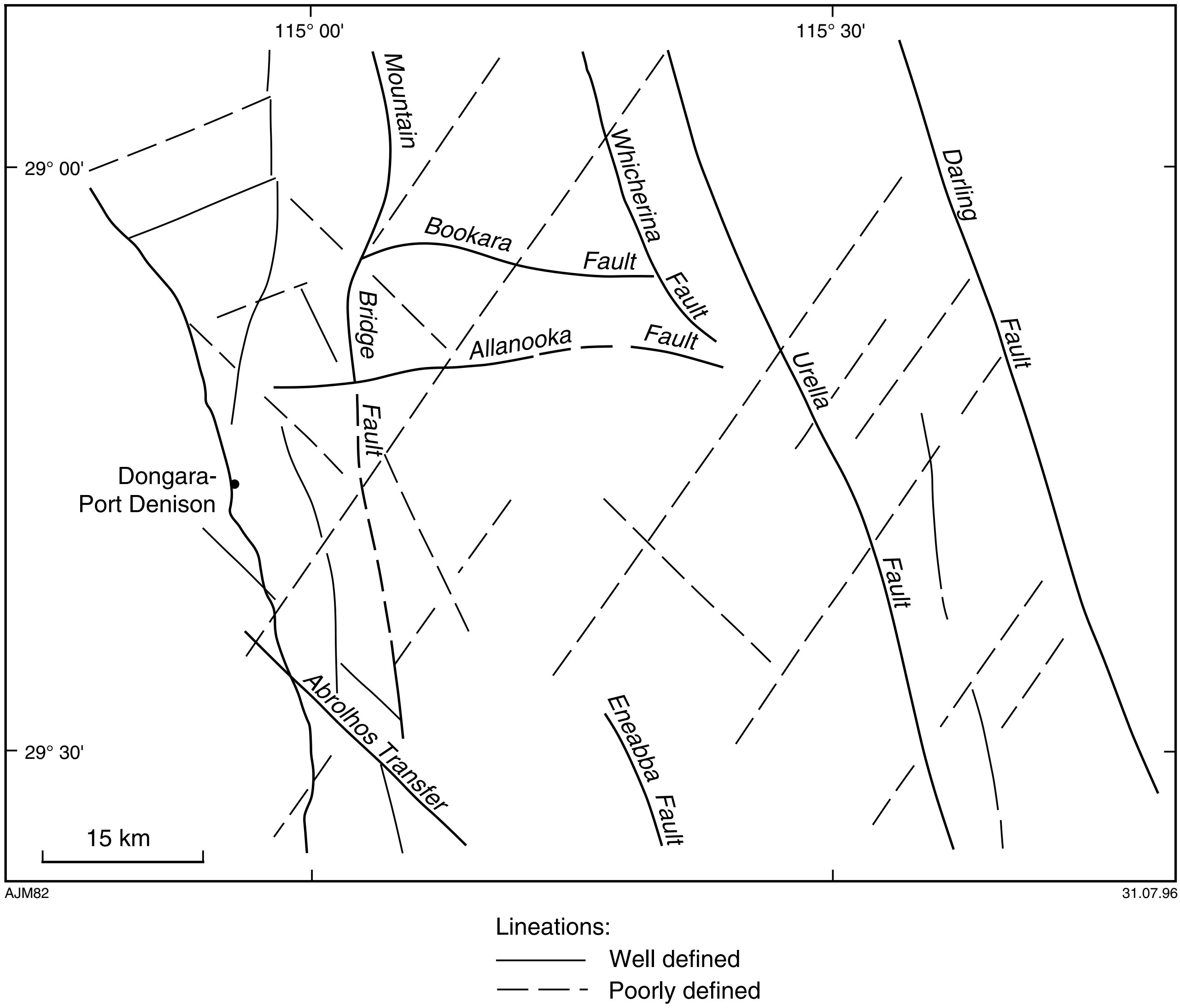

Figure 33. Gravity lineaments in the Dongara–Mount Horner area

though they may be present within the sediments. North of the Allanooka Fault, other larger amplitude, north-northeasterly striking lineaments appear to be unrelated to the these two faults. Both the Mountain Bridge and Beharra Springs Faults appear to be dissected by northeasterly striking lineaments.

The Eneabba Fault system can be identified in the central part of the image as northerly striking lineaments that divide the deeper Dandaragan Trough in the east from the shallower Coomallo Trough to the west. This lineament extends throughout the length of the image, south of the Allanooka Fault.

Lineaments striking east

The Allanooka Fault is well defined on both its western and eastern margins approximately at 29°10'S. In the west, it is a linear feature that strikes east-northeast: it diminishes in amplitude towards the east. The high-amplitude broad anomaly seen to the northwest of the Allanooka Fault represents the southern extension of the Northampton Complex, and the Allanooka Fault is seen as the southern edge of this high basement block. The fault appears to comprise a series of east-northeasterly striking lineaments that are not necessarily continuous at basement level.

The Bookara Fault is identified as an easterly striking lineament on the northwest part of the image at approximately 29°00'S. The amplitude of this lineament is high in the west where basement is shallower, diminishes to the east as sediment thickens, and continues through to the Wicherina Fault. Two other easterly striking lineaments are displayed north of the mapped position of the fault, indicating further east–west faulting to the north.

It is important to note that easterly trending lineaments characterize only the northern part of the study area, adjacent to the southern extension of the Northampton Complex. Mory and Iasky (1994) suggested that the easterly striking faults are a direct result of a northerly

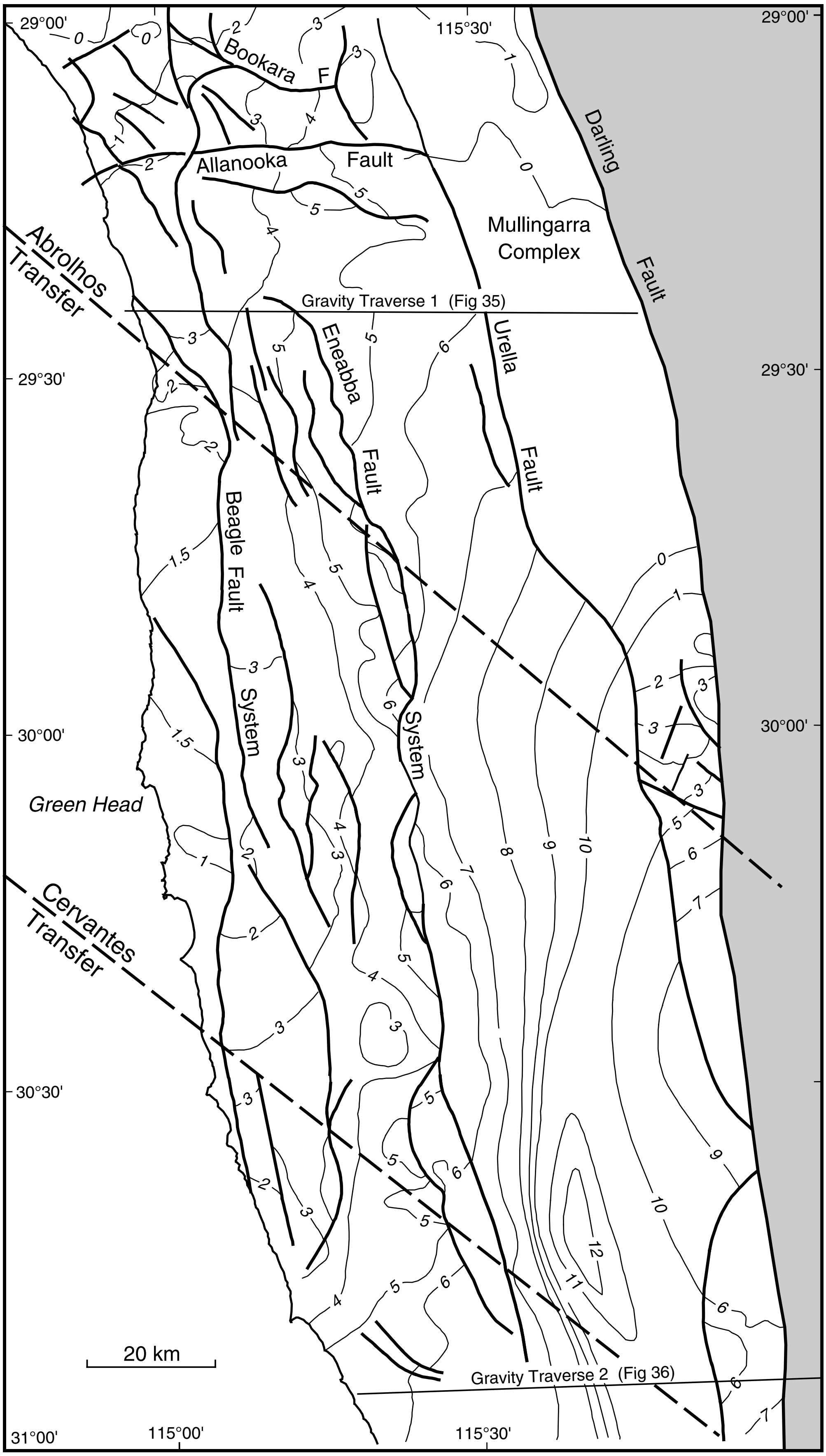

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Figure 34. Diagram showing the location of gravity profiles superimposed on the depth to basement of the onshore northern Perth Basin

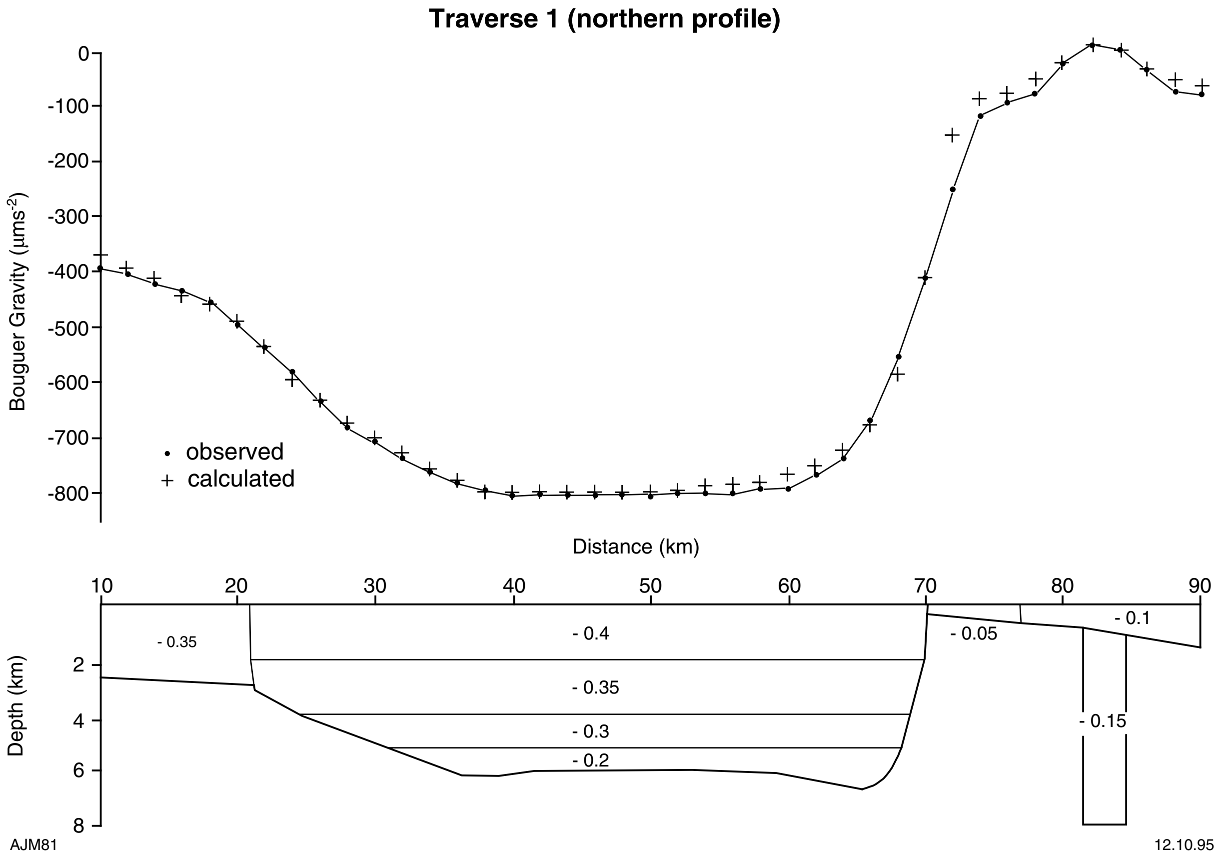

Figure 35. Gravity model for traverse 1 in the northern part of the study area. Calculated and observed Bouguer gravity are in mm/sec² and density is shown in g/cm³. Distance along traverse and depth of body are in kilometres

extension phase in the Permian. However, Harris et al. (1994) could not reproduce these faults in analogue modelling experiments, which suggests that the lineaments are a consequence of pre-existing structures within basement. The density of east–west lineaments west of a northerly trending lineament at 115°10'E suggests that this latter lineament is a basement terrane boundary and may be that between the Northampton Complex and the Mullingarra Gneiss, a suggestion not easily verified. Nevertheless, it seems likely that the east–west faults in the Phanerozoic cover were propagated from the east–west fabric of the western basement terrane (?Northampton Complex).

Lineaments striking northeast to east-northeast

There are numerous northeasterly striking lineaments between 045 and 065° throughout the images (Figs 29 to 31). These appear to displace horizontally intersecting lineaments in a left-lateral sense, and examples of this displacement are seen on the Allanooka, Darling and Urella Fault systems. One of the east-northeast lineaments at the southern edge of the image was identified from seismic mapping and named the Vlaming Transfer by Hall and Kneale (1992). The northeast lineaments were also identified in the aeromagnetic images, and correspond to antithetic strike-slip faults to the northwestern extension phase of tectonism that occurred at breakup (Harris, 1994). They are also recognized by Harris et al. (1994) in an analogue modelling experiment. The direction of these lineaments correlates with the direction of dolerite dykes found in the Northampton Complex, and it is possible that they represent re-activated basement fractures.

Lineaments striking northwest

Northwest-striking lineaments (~300°) correspond to fractures associated with the transfer faulting initiated at breakup, such as the Abrolhos Transfer Fault (Hall and Kneale, 1992; Mory and Iasky, 1994), and appear to have a sinistral horizontal displacement on the images and on seismic sections (Plate 9). These lineaments are more easily identified when the gravity image is illuminated from the southwestern direction and therefore are not delineated clearly in Figure 30. Although only a few of these lineaments have been identified in gravity images, in aeromagnetic images they are numerous and identified at intervals of 3–6 km. The analogue modelling performed by Harris et al. (1994) shows that pre-existing north-northwest faults acted as transfer faults during the northwest–southeast extension at break up. This modelling indicates the influence that older modes of deformation have on the pattern of faulting in subsequent tectonism.

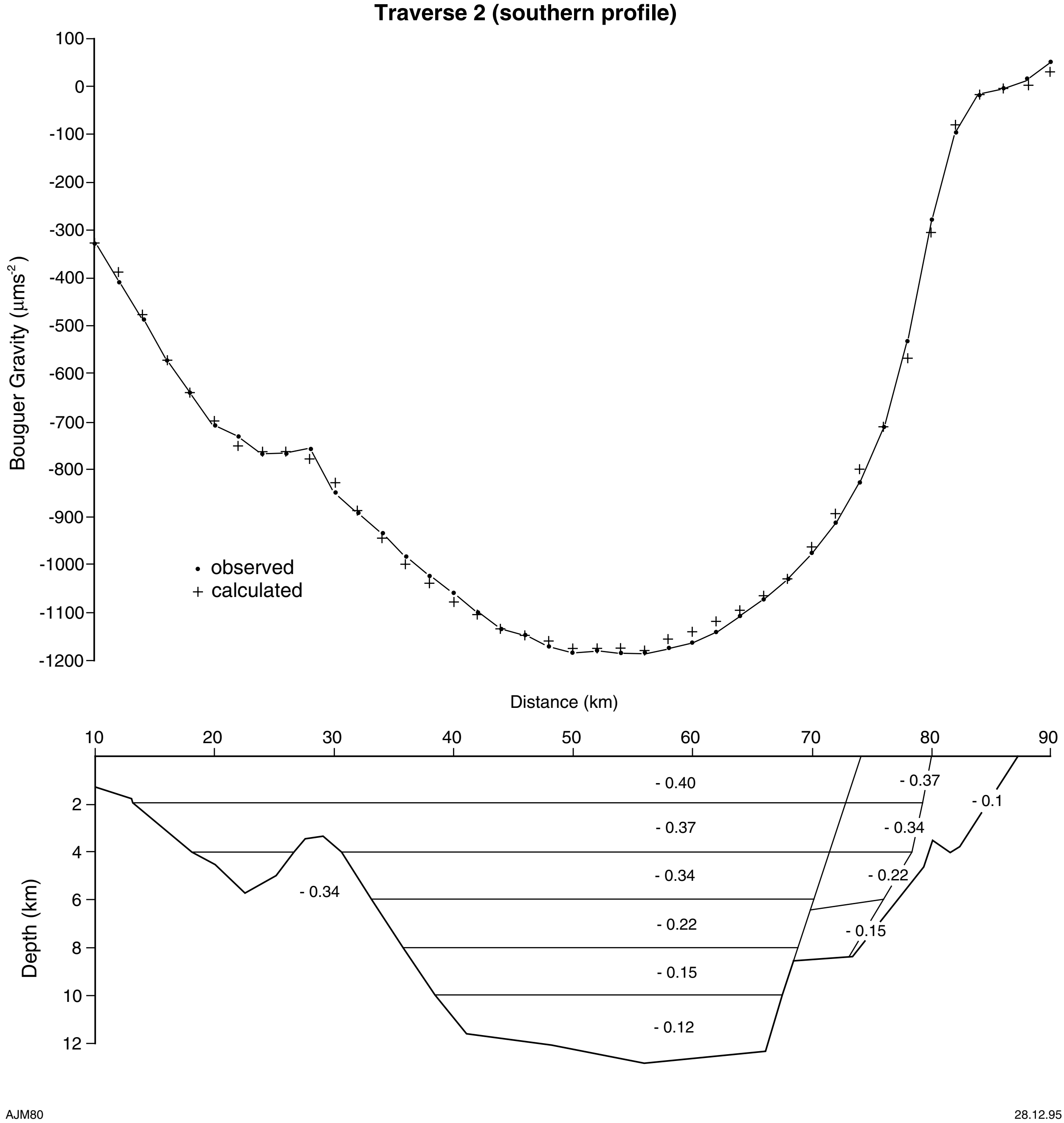

Figure 36. Gravity model for traverse 2 in the southern part of the study area. Calculated and observed Bouguer gravity are in mm/sec^2 and density values are shown in g/cm^3. Distance along traverse and depth of body are in kilometres

Aeromagnetic data

The first studies of aeromagnetics in the Perth Basin were those of the BMR (Newman, 1959; Quilty, 1963) and show only the broad structure of the basin. Three large anomalies identified on the Beagle Ridge are probably due to a deep batholith (Heath et al., 1994). The BMR dataset flown in 1957 is still the only regional coverage available in the onshore part of the basin.

Three detailed aeromagnetic surveys completed in the study area in 1992–93 (Fig. 37) show structural features that are not obvious in the seismic or well data. The surveys were flown by World Geoscience over production licences L1 and L2 for WAPET and the surrounding area for Enterprise (Fig. 38) and WA-228-P for Woodside Petroleum (Fig. 40). The Woodside survey was extended onshore only a short distance between Jurien and Wedge Island in order to see part of the Beagle Ridge. The surveys were all flown at a height of approximately 80 m. The Woodside and Enterprise surveys have a line spacing of 1000 m with tie lines at 3000 m; the WAPET survey was flown with a 333 m line spacing. The first two surveys were flown east–west, while the third was flown along 068°. Images of total magnetic intensity (TMI), first and second vertical derivatives, and depth slices were

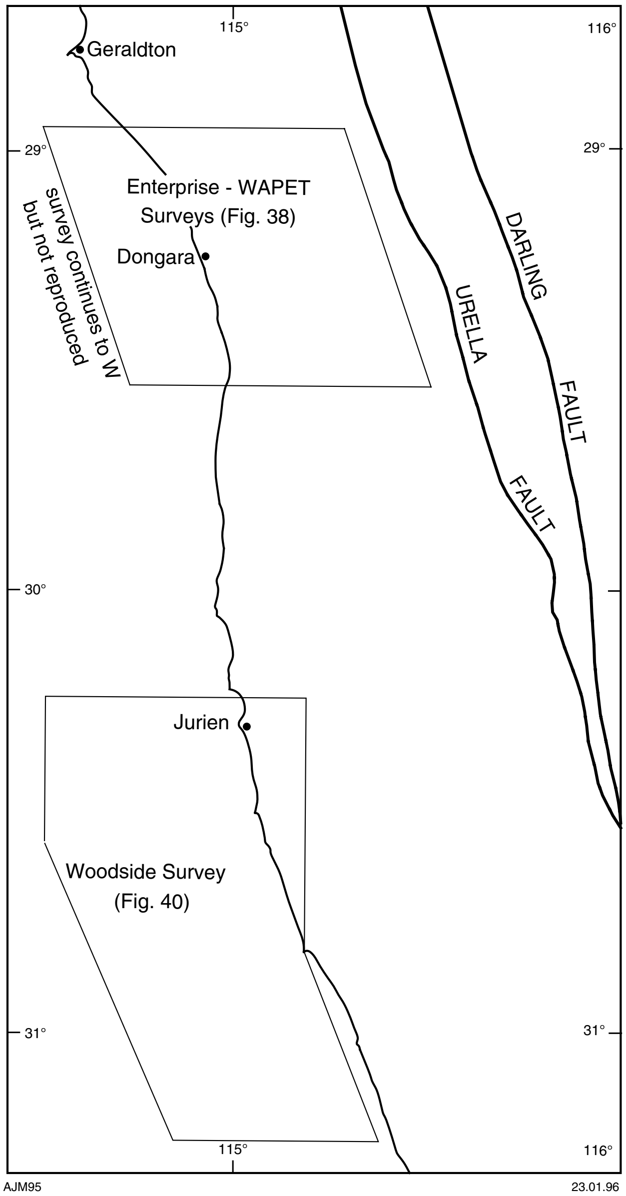

Figure 37. Location of aeromagnetic surveys over the onshore northern Perth Basin

generated by World Geoscience for the three areas. An interpretation of the Woodside survey has been published by Heath et al. (1994).

Anomalies identified are due to both shallow and deep magnetic features. The former are either cultural, such as towns, or surficial Cainozoic magnetic features. Deeper structural features are related either to basin fill or basement lithologies and may be difficult to separate.

Cultural features

Cultural features with an obvious magnetic response include the settlements such as Dongara, Port Denison, Jurien, Cervantes and Grey, many of the well heads in the Dongara field, and the gas-collecting facilities for the Dongara field. Features with a less clear magnetic response include the gas pipelines and railway lines near Dongara. Three prominent cultural anomalies are present near Dongara. These anomalies correspond to magnetic Pleistocene limestone used as ballast on the rail line 14 km south of Dongara (Figs 38, 39 — anomaly #1), a northerly oriented power cable supplying cathodic protection to a gas pipeline from the Dongara 9 and 10 wells (#2), and a market garden that utilizes a large amount of copper wire to control its irrigation system next to the Yardarino field (#3).

Cainozoic features

Only the onshore data in the Dongara area show magnetic surficial features (Fig. 38). The most obvious of these are associated with the alluvial deposits along the Irwin River, outcrop of the Tamala Limestone and, to a lesser degree, the diatomaceous earth deposits at the foot of the Gingin Scarp.

Alluvial deposits along the Irwin River show a marked increase in amplitude especially along the main channel. The somewhat reduced anomalies associated with the northwesterly oriented alluvial flats near 'The Grange' probably reflect a reduced thickness of alluvium on these flats. Magnetic material in the alluvium is probably derived from the Precambrian east of the Darling Fault. Magnetic susceptibility readings from alluvium on the banks of the Irwin River have a range of 40–150 × 10^{-5} SI units and are in marked contrast to readings of -2 to 3 × 10^{-5} from white to yellow sands on the Eneabba Plain 10 km south of the river.

On the western part of the image there is a marked increase in the magnitude of magnetic anomalies east of the coastal Holocene deposits and coincident with outcrop of the Pleistocene Tamala Limestone. This effect is particularly noticeable on the first and second vertical derivative images. The anomalies associated with the Tamala outcrop are clearly near surface because the presence of overlying Holocene sand, which is generally less than 20 m thick, appears to have suppressed the anomalies in the limestone south of Dongara. Magnetic susceptibility readings from two quarries in the limestone near Dongara confirmed that the near-surface cemented cap rock is more magnetic, with readings of 10–25 × 10^{-5} SI units compared with -2–2 × 10^{-5} from the weakly cemented cross-bedded limestone at base of the quarry. In addition, outcrop of the caprock gave a range of readings from 0–100 × 10^{-5}, over distances of less than 100 m. The increase in magnetic response over the Tamala Limestone is probably the result of magnetic alluvial material being incorporated into the surficial cemented caprock.

A tenuous magnetic anomaly north of the Beharra Springs gas facility coincides with claypans associated with the diatomaceous earth deposits at the foot of the Gingin Scarp (Fig. 39 — anomaly #4). Such coincidence is unusual as diatomaceous earth deposits and associated lacustrine clays generally contain little magnetic material. Possible explanations include the concentration of iron minerals by groundwater movement along the claypan margins ('coffee rock'), or by shallow groundwater in the

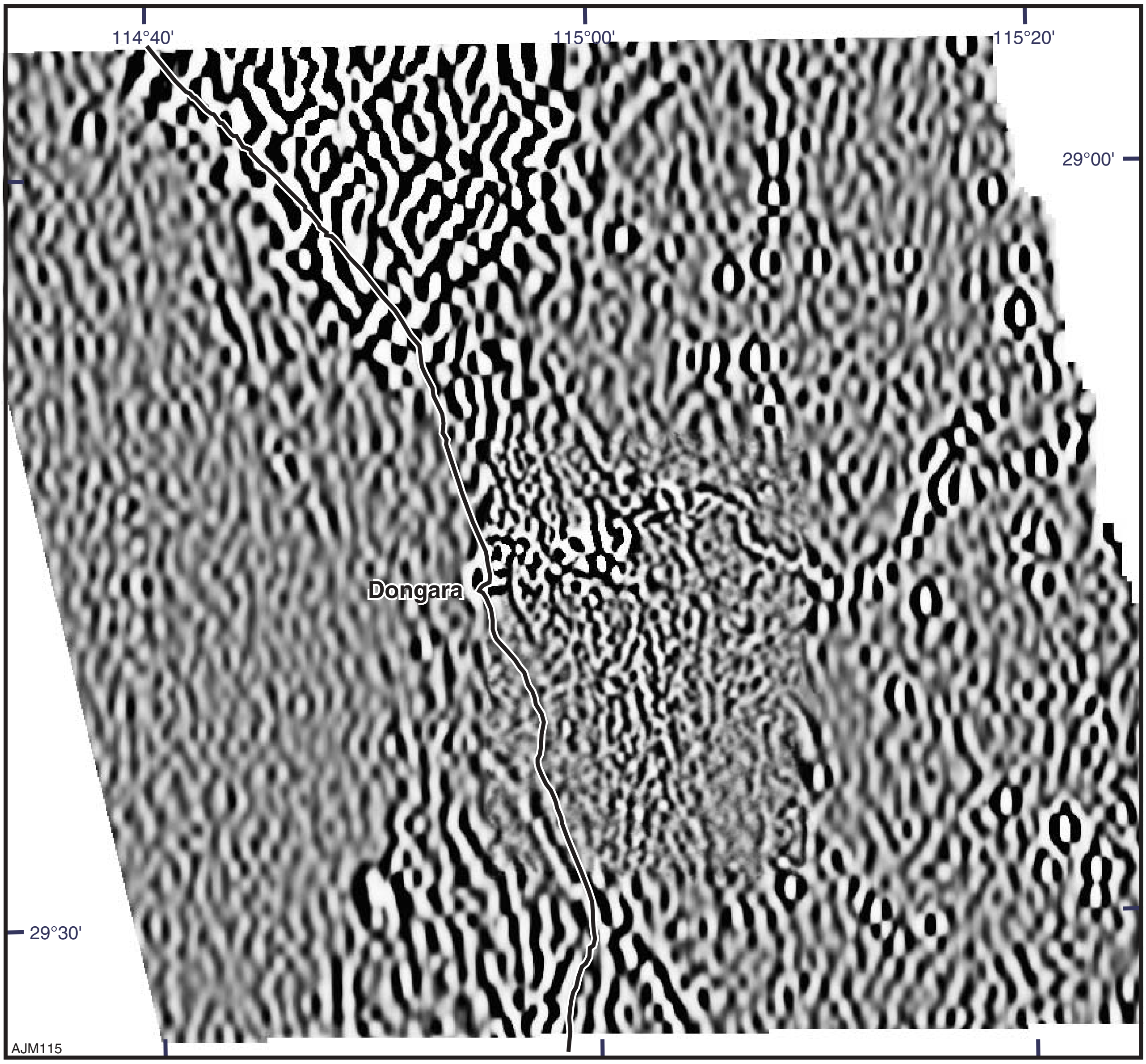

Figure 38. First vertical derivative magnetic image over the Dongara area (flown, compiled and image processed by World Geoscience Corporation and incorporating proprietary data of WAPET and World Geoscience Corporation)

clays creating a weak electric cell in contrast to the surrounding dry sands.

Deep features

Most of the lineaments identified are probably faults and are seen on the images as low-amplitude, low-frequency anomalies. The faults interpreted on the northern image (Fig. 38) show a better correspondence with seismic faults extrapolated to near surface than with their positions mapped at deeper levels. An explanation for such a correlation is that fluid movements have deposited magnetic minerals along the faults at shallow depths. In the Woodside image some of the clearest lineaments are associated with the north–south Beagle Fault, and proximate parts of some of the northwesterly transfer faults that cut the Beagle Fault. This suggests that magnetic minerals have been emplaced along the Beagle Fault but have then managed only to move a short distance into selected transfer faults. The magnetic material probably originated from an igneous body and dyke swarm associated with the Beagle Ridge or southern Turtle Dove Ridge, as indicated by both gravity (Quilty, 1963) and magnetic data (Heath et al., 1994). Fault trends identified from the magnetic images have been incorporated into the 1:100 000 surface geological maps of the area by Mory (1994a, 1995a,b).

In the northern image the main lineaments are oriented northeast and northwest (Fig. 39). In the southwest of this image a prominent high-amplitude north-northwesterly trending anomaly is associated with the Beagle Fault. North–south lineaments associated with the Mountain Bridge and Beharra Springs Faults are partly obscured by the anomalies associated with the Pleistocene Tamala Limestone, as are lineaments associated with the east–west Allanooka Fault. By comparison, in the southern image the

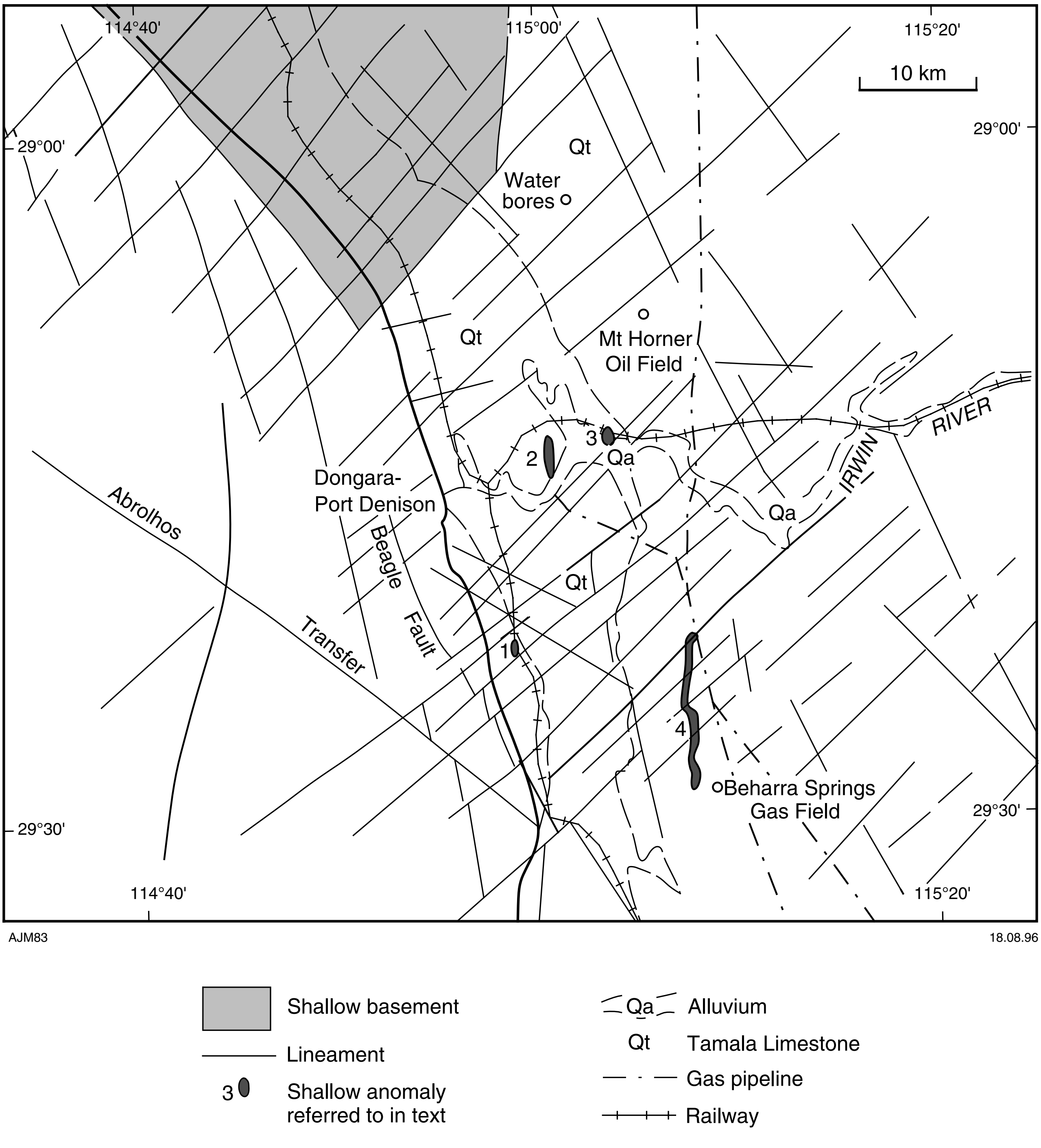

Figure 39. Aeromagnetic lineaments in the Dongara area

dominant lineaments trend northwest and north (Fig. 40). Woodside has correlated the former with faults mapped from seismic data, whereas the latter were not evident in the seismic data.

The trends oriented approximately 045 to 050° run throughout the northern image and sinistrally displace northerly and northeasterly trending lineaments by 500 to 1500 m (Fig. 38). The horizontal displacement appears to be an order of magnitude smaller than that seen with the northwest-trending transfer faults. The orientation of these northeasterly lineaments is consistent with that of strike-slip faults antithetic to northwesterly trending transfer faults, and suggests they are also associated with breakup. The northeasterly faults are oriented in the same direction as dolerite dykes found in the Northampton Complex, and it is possible that these faults were propagated from the basement features. In the southern area a single northwest lineament was identified and was interpreted as a sinistral fault (Jurien Fault *of* Heath et al., 1994, fig. 5).

Lineaments, striking between 280 and 310°, are spaced 3 to 6 km apart in the northern images (Figs 38, 39) compared with 1 to 3 km in the southern image (Figs 40,

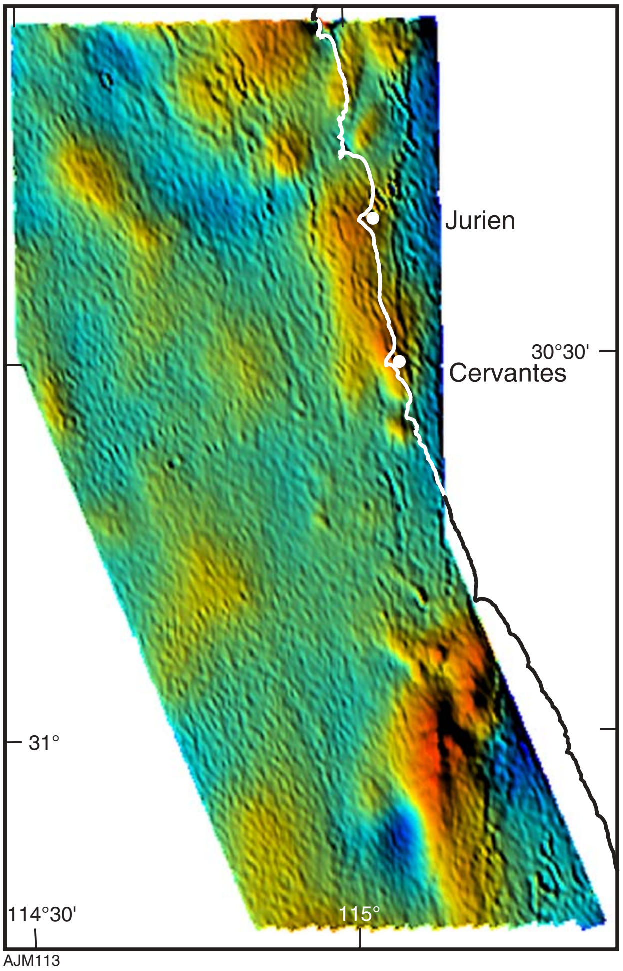

Figure 40. First vertical derivative magnetic image over the Wedge Island–Jurien area (WA-228-P — digital data supplied by Woodside Offshore Petroleum)

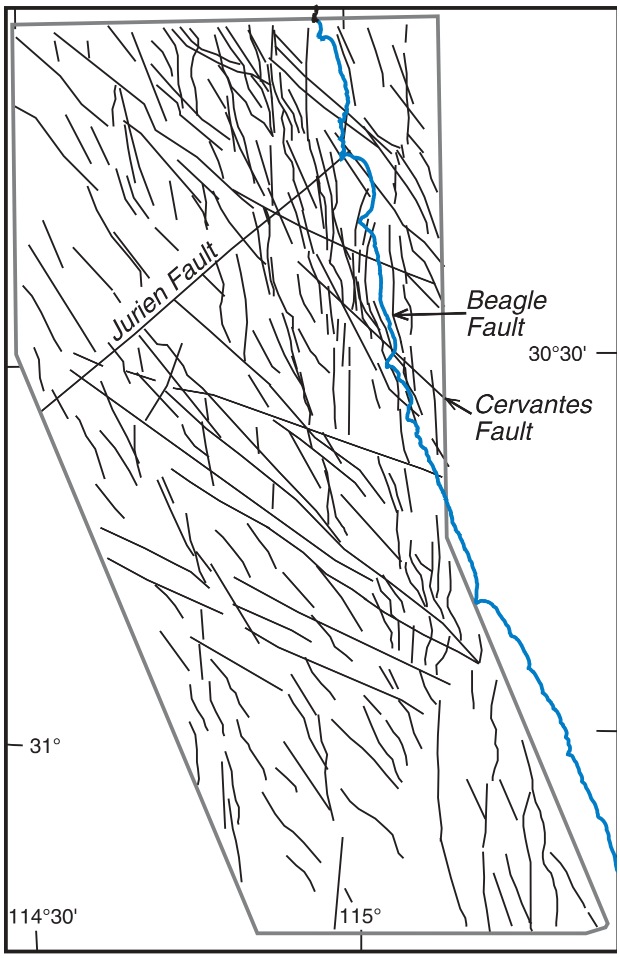

Figure 41. Major aeromagnetic lineaments in the Wedge Island–Jurien area WA-228-P (from Heath et al., 1994 — digital data supplied Woodside Offshore Petroleum)

41). They are interpreted as predominantly right-lateral transtensional faults associated with breakup (Heath et al., 1994). By comparison, the most prominent of the northwesterly faults identified from the onshore seismic data is the sinistral Abrolhos Transfer Fault. The northwesterly trending lineament with the largest displacement in the southern image cuts the Beagle Fault just north of Cervantes (Cervantes Transfer Fault, Plate 10) also with an apparent sinistral displacement.

The Abrolhos Transfer Fault is identifiable on the Enterprise image as a lineament oriented at 305° proceeding from the southern edge of the image. The magnetic signature to the north of the transfer zone shows higher frequency anomalies, indicating the juxtaposition of two different terranes. Basement to the north of the transfer fault is inferred from the higher frequency anomalies to be shallower. The displacements of the broad high-amplitude anomaly, and other lineaments intersecting the transfer fault, confirm that the sense of movement is left lateral.

Elements of the Allanooka Fault are tentatively identified in the northwestern part of the northern image (Fig. 39). These elements consist of a lineament oriented at approximately 060° that appear to lie along strike from another lineament oriented at approximately 090°. The lack of continuity of the lineament to the east suggests that it follows a basement feature similar to those seen in the gravity image of the area (Fig. 31).

In the northern image, lineaments striking approximately 330° are spaced at 3 to 6 km and are interpreted as basement shear zones, similar to those that offset dolerite dykes in outcrop of the Northampton Complex, as described by Byrne and Harris (1992). A triangular zone of high-amplitude, high-frequency anomalies in the northwest of this image, bounded on the southwest by the north-northwest trend and on the southeast by the northeast trend, is clearly the southern extension of the Northampton Complex, with a thin cover of Mesozoic rocks.

Seismic data

The aim of mapping horizons from the seismic data was to obtain a regional structural framework for the onshore northern Perth Basin. Seismic time and depth maps of

Precambrian basement (*Ꞓ*), top Permian (*P*), and Middle Jurassic top Cattamarra Formation (*Jc*) horizons (Plates 4–9) were produced from the interpretation of 11 800 line kilometres of seismic and 127 petroleum well ties. The Middle Jurassic and Permian horizons were chosen because they represent the top of objectives for petroleum exploration and have been mapped previously by exploration companies in permitted areas. Depth to Precambrian basement was mapped to provide information on sediment thickness in the basin. Plate 3 shows the location of seismic lines and wells used in the study area.

Data coverage

Lines from 61 seismic surveys have been selected to provide a regional coverage over the onshore northern Perth Basin. The vintages of the surveys range from 1966 to 1992 and the data quality ranges from very bad to good, depending on the location of the survey and the vintage of acquisition and processing. Appendices 1 and 2 list surveys conducted for petroleum exploration, and selected lines.

Initially, the intention was to create a grid of seismic lines spaced at 10 km. However, this proved difficult given the poor quality of pre-1975 surveys and the lack of data in some areas. Consequently, where possible, a denser grid was adopted in areas of poor data quality, but in some areas a much wider line spacing had to be accepted. The latest seismic surveys have been selected wherever possible, and with older data, the latest processing was chosen. In general, the grid provides good coverage over the Dongara Terrace and Allanooka High, reasonable coverage along the Coomallo Trough and northern half of the Cadda Terrace, and poor coverage over the remaining part of the basin where there has been less exploration activity (Fig. 4). There are two noticeable gaps in the seismic grid cover; the area between Cervantes and Green Head, and the central part of the Dandaragan Trough east of the Eneabba Fault System.

The majority of seismic lines are oriented in an east–west direction, approximately normal to the predominantly north-northwesterly structural grain. A number of strike lines have been chosen as tie lines. The final processed wavelet on all surveys is minimum phase with normal polarity (where the compression pulse is represented as a white trough). Ninety-five percent of the seismic sections used in the interpretation are migrated.

Of the 155 petroleum wells in the study area (Fig. 3), 127 have associated velocity data. This information was used to calibrate the seismic profiles with respect to the depths of the three horizons. Although few of the wells intersected all three of these horizons, most intersected two. The wells in the Dandaragan and Coomallo Trough intersected only the youngest horizon (*Jc*). A list of two-way times, and depths from the sea level datum to the three horizons, is given in Appendix 6 for those wells with velocity data. Additional constraints to the seismic interpretation were provided by outcrop data and several hundred water and mineral exploration bores, and were particularly important in areas with poor seismic coverage or low resolution.

Data quality

Seismic lines have been rated according to the quality of reflection resolution as good, fair, bad, and very bad (Fig. 4). Seismic data are typically of poor quality over the Spearwood Dune System that extends up to 21 km inland from the coast. The poor seismic resolution in these areas is probably due to the dissipation of energy associated with the karstified upper surface, or internal solution features, of the Pleistocene Tamala Limestone (Taylor, 1969).

In the study area, the energy source used for surveys conducted before 1973 was dynamite: since then, explosives have been replaced, almost exclusively, by vibroseis methods. Typically, the older dynamite surveys were designed for regional coverage. They consisted of a series of nine- to sixteen-hole arrays, drilled to 6–10 m, and each loaded with a charge of around 2.5 kg. The older surveys recorded 48 channels from a 36 geophone array split spread, with a shot point interval of 268 m, and a group interval of 67 m. The later vibroseis surveys typically employ a line of 4 vibrators that are vibrated 4 times every 8 seconds, and the recording instruments contain 440 channels. The more recent surveys are usually designed to detail prospective structures, and recording parameters consist of an array of 6 geophones every 25 m, a 30 m source interval, and a 15 m group interval. A large number of older seismic lines have been reprocessed using updated techniques and have produced results comparable to recent surveys in areas of good coupling.

The finite differences wave-equation migration method has been employed on all migrated seismic sections. The amount that the stacking velocities are scaled ranges from 85 to 105%, and the smoothing distance varies with the processing contractor and location of survey. Overall, the migration process for most surveys was successful where sufficient energy had penetrated the strata, and produced excellent fault definitions in areas where good-quality data were obtained. In areas of poor data quality, reflections appear to be chaotic with only a few hints of stratigraphic dips, and the migration process did not significantly improve reflection resolution.

Seismic data are often processed to enhance objective horizons to the detriment of the deeper section, and the mapped horizons do not always produce high-amplitude reflections. In areas where the sedimentary section is less than 6000 m, and there is insignificant near-surface energy absorption, the three mapped horizons are easily recognizable. The top Cattamarra Coal Measures (*Jc*) horizon does not have a good reflector although the first strong reflections are the coal seams that commonly occur within the upper 500 m of the formation. In the deeper Dandaragan Trough, both the Permian (if present) and Precambrian basement horizons are too deep to be recognized, and in some instances are beyond the five seconds display of the seismic sections. The seismic character of the three horizons displays reasonable continuity in areas of good seismic resolution and poor continuity in areas of poor resolution. Inferior resolution is due to poor penetration of energy rather than stratigraphic changes in the sedimentary section.

Character of reflections

The top Precambrian basement (Fig. 42), top Permian (Fig. 43), and top Cattamarra Coal Measures (Fig. 44) horizons were mapped throughout the study area unless absent due to erosion or fault slippage. The horizons were carried as a trough on the seismic trace and Figure 45 shows the typical reflection characteristics generated from each.

Because the lithology of both formations consists of siltstone, mudstone and shale, the contact between the Cattamarra Coal Measures and the overlying Cadda Formation does not everywhere produce a reflection. In places, a sandstone unit underlying the Cadda Formation produces a weak reflection. However, the top Cattamarra Coal Measures horizon may be recognized from the strong reflections generated by the thick sandstone beds overlying the coal seams. The vertical separation of the coal seams from the top of the Cattamarra Coal Measures varies, suggesting that the seams are time transgressive. The beds produce three or four strong closely spaced reflections at a frequency of approximately 40 Hz.

The top Permian horizon is a strong, broad reflector at a frequency of 20 to 25 Hz that is recognizable in most of the study area. In the southeastern part of the area the reflections mark the contact between shale of the Kockatea Shale, and siltstone and sandstone of the underlying Caryngina Formation. In the north and northwestern part of the area the Kockatea Shale overlies the Dongara Sandstone, but to the south the latter unit, which consists predominantly of sandstone, grades laterally into limestone and shale of the Beekeeper Formation.

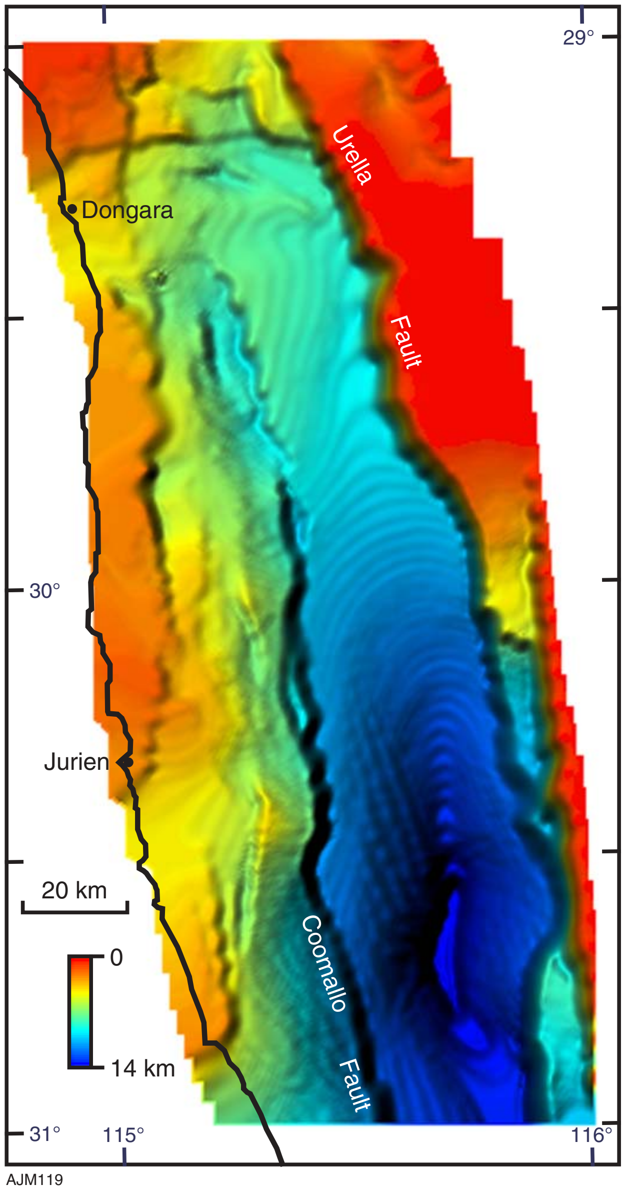

Figure 42. Image of depth to basement

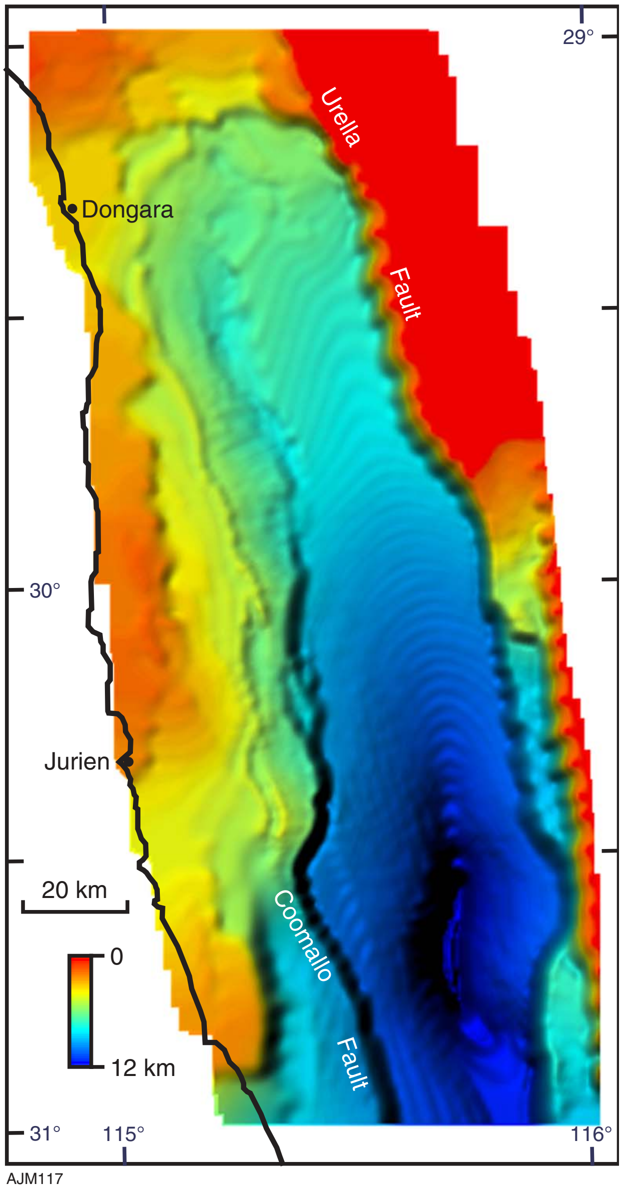

Figure 43. Image of depth to top Permian horizon

In most of the northern part of the study area the sedimentary thickness may reach 6000 m and the basement horizon is recognized as a discontinuous strong reflector at a frequency of 20 to 30 Hz. The reflection is caused by the change in acoustic impedance between crystalline basement and the sandstone, siltstone and occasional tillites of the overlying Nangetty Formation. The basement horizon is difficult to distinguish where the usual reflection is replaced by semi-parallel discontinuous reflections that become chaotic at depth (Fig. 46).

In the northern part of the area the top Cattamarra Coal Measures horizon is mapped with a good degree of confidence, because the underlying coal beds are easily distinguishable, and there are numerous well ties. The degree of confidence with which this horizon can be mapped in the central and southern part of the area diminishes because of inadequate seismic coverage and poor-quality data; the horizon has been phantomed in most of that area.

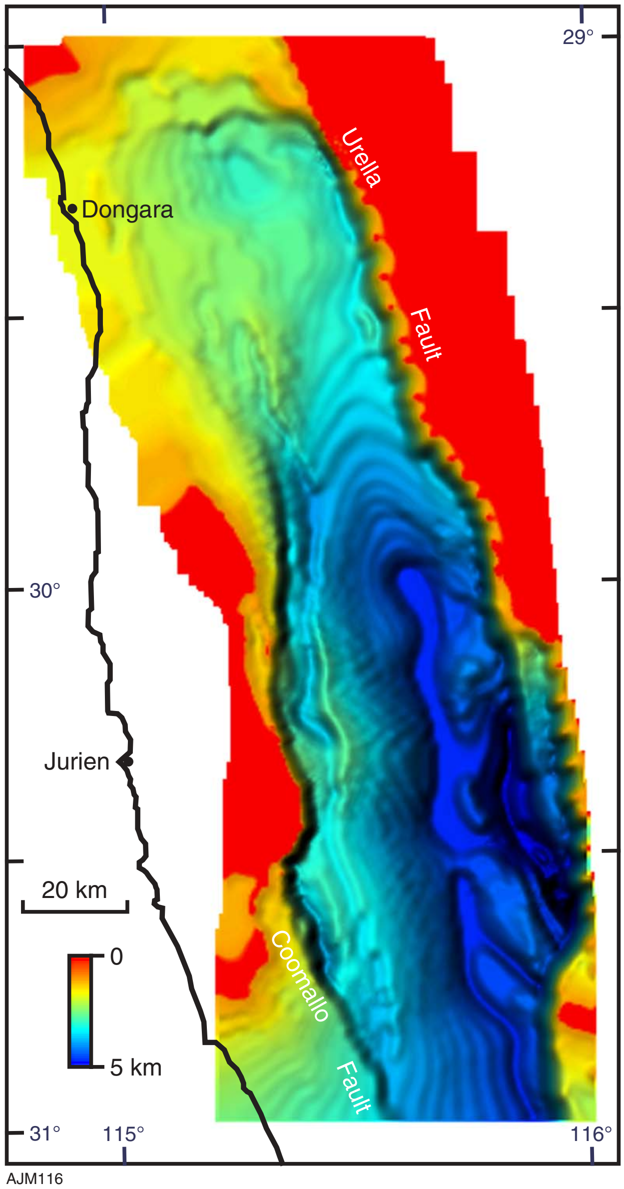

Figure 44. Image of depth to top Cattamarra Coal Measures horizon

The top Permian and Precambrian basement horizons are mapped with less confidence overall than the top Cattamarra Coal Measures horizon, but with relatively greater sureness in the northern half of the map. The confidence with which these horizons can be mapped in the Dandaragan Trough is poor because reflections are indistinguishable and, in the deeper part of the trough, horizons were interpolated from velocity functions. The confidence level of mapping in the southwestern part of the area is also low because of structural complexity and low-quality seismic data.

Faults seen in the younger horizon are commonly not well defined in the lower horizons because seismic resolution decreases with depth. It is not clear whether some faults have fractured through to basement, or detach at a horizon. Furthermore, fault correlation is difficult across transfer faults, where estimates of horizontal slippage are speculative. However, overall there is a reasonably high degree of confidence in the fault correlation for the three maps as fault characteristics are retained across most seismic lines.

Velocity analysis and depth conversion

The three two-way time horizon maps are converted to depth maps with data from 57 well velocity surveys. Most data from these surveys were obtained from wells that intersect only one or two of the mapped horizons, and velocity extrapolations below the total depth of the well are needed to convert the two-way time values of deeper horizons to depths.

Normal moveout velocities were not used for depth conversion because they proved to be too inaccurate. A velocity function is determined for each of the 57 wells by fitting the most appropriate least-squares curve to the well velocity data. As there are insufficient data to draw meaningful velocity contours for each horizon, depth conversion was accomplished by using velocity functions of nearby wells. The study area was arbitrarily subdivided into fault-bounded blocks in which velocity functions of inclusive wells were applied. In general, velocity functions within designated areas were found to be closely related, and average depths are calculated for closely spaced wells with velocity functions. Depth-derived contours were averaged and smoothed in places where the junction between two areas is not clearly defined by a fault.

Power, exponential and hyperbolic functions produced the best fit for the velocity data. The choice of function depended on the closeness of fit, and whether the curve extrapolation below the depth of the well seemed realistic. In general, the greater the extrapolation, the lower the degree of confidence, regardless of closeness of fit to data points. Appendix 7 lists selected wells with velocity functions and coefficients.

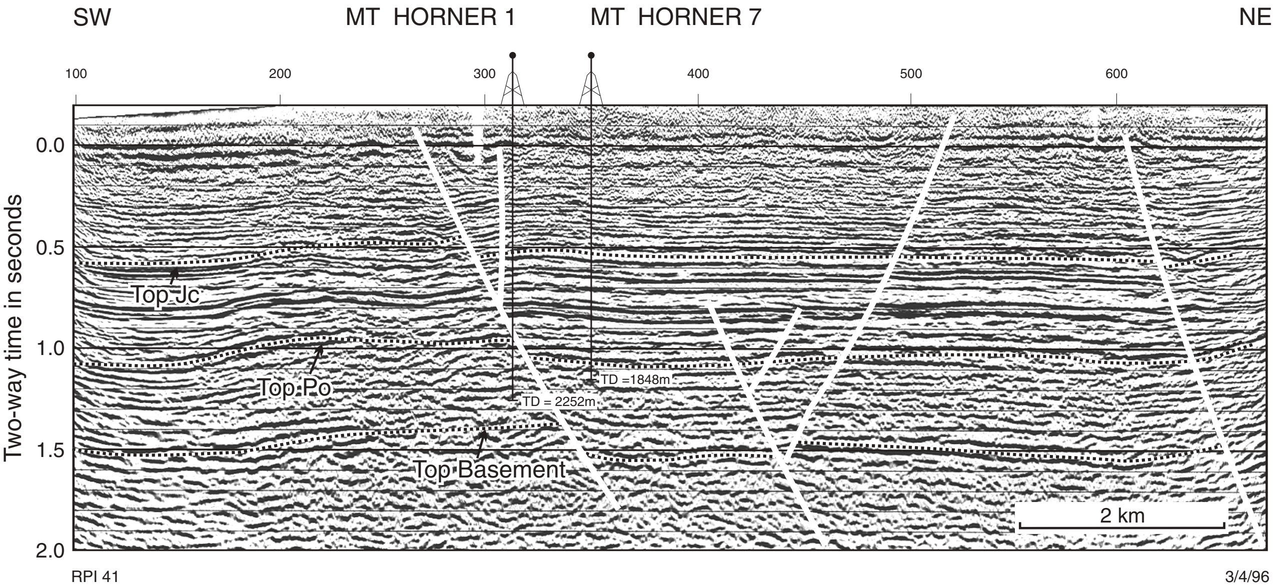

Figure 45. Seismic section (B89-422) showing typical reflection characteristics generated for the top Cattamarra Coal Measures, top Permian, and Precambrian basement horizons

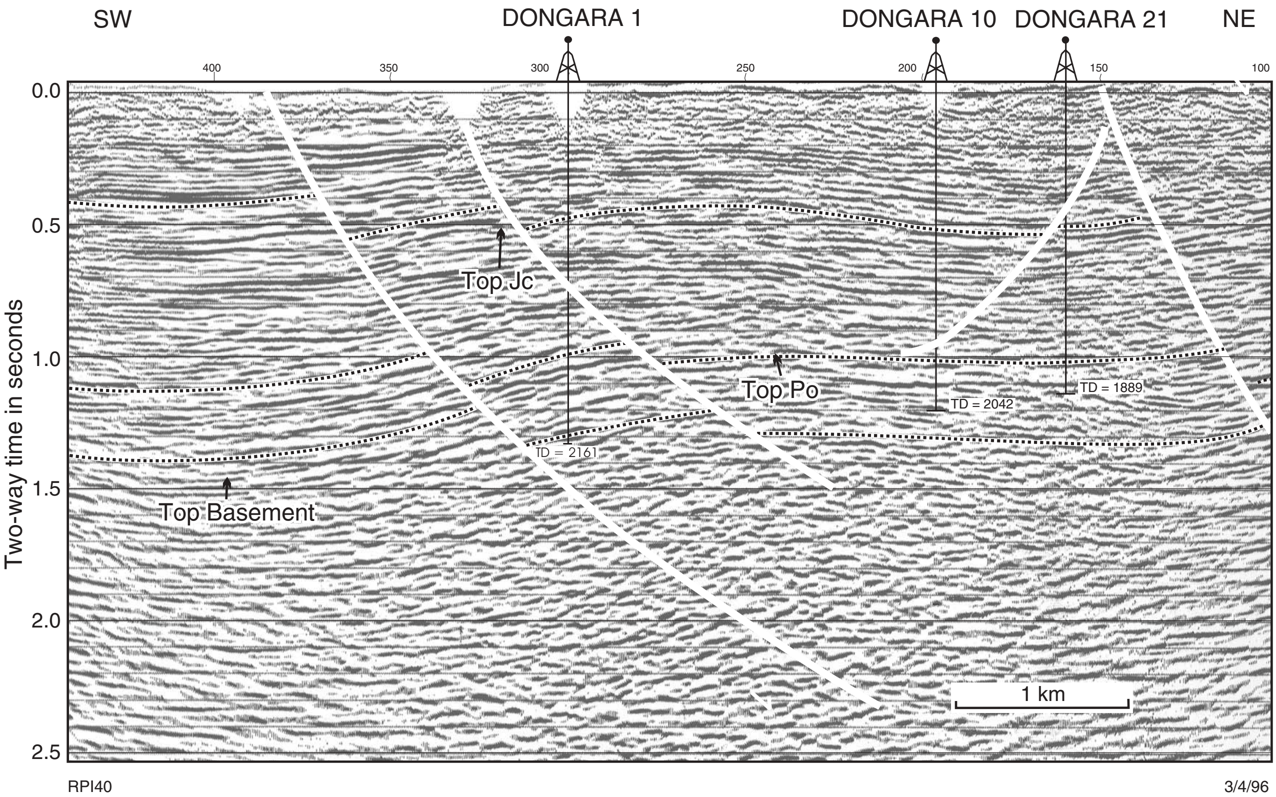

Figure 46. Seismic section (P89-01L) across the Dongara field showing the variable nature of basement-horizon reflection characteristics

The functions used are:

Power	$D = A_0 * (T ** A_1)$
Exponential	$D = A_0 * T * \exp(A_1 * T)$
Hyperbolic	$D = A_0 + (A_1/(A_2 + T))$

where: A_0, A_1 and A_2 are coefficients.
D = depth from sea level datum to horizon (metres).
T = two-way time to horizon (seconds).

Structural interpretation

The seismic mapping, and gravity and magnetic images have prompted a review of the major structural elements of the onshore northern Perth Basin, and led to revised structural subdivisions as discussed in the introductory section of this Report. The perspective diagram of the basin at basement level (Fig. 47) shows that the basin consists of a deep trough in the south that rises gently to the north, onto the Allanooka High, with a regional dip of 2.5°. The trough rises across major faults onto the Beagle Ridge to the west with an average regional dip of 11°. To the east, the deepest part of the Dandaragan Trough upwarps gently against the Darling Fault system that forms the boundary with the Yilgarn Craton (Fig. 48). Because of its asymmetry, the basin has been described as a half-graben by Playford et al. (1976), although the Dandaragan Trough is better described as a syncline (Crostella, 1995). The apparent absence of mapped faults in the central part of the Dandaragan Trough may be due in part to inadequate or insufficient data.

There are three major fault zones in the onshore northern Perth Basin, these are the Darling Fault system that includes the Urella and Muchea Faults, the Eneabba Fault system that includes the Coomallo Fault, and the Beagle Fault system consisting of a number of en echelon faults, including the Mountain Bridge and Beharra Springs Faults. These fault systems trend in a north to northwest direction, and as they are long linear features a component of strike-slip movement can be implied (Lowell, 1985; Middleton, 1990; Crostella, 1995). Because of their arcuate shape, decreasing dip with depth, basinward dips and parallelness to the coastline (Tearpock and Bischke, 1991), these fault systems, are interpreted to be the main growth faults that contributed towards the formation of the basin.

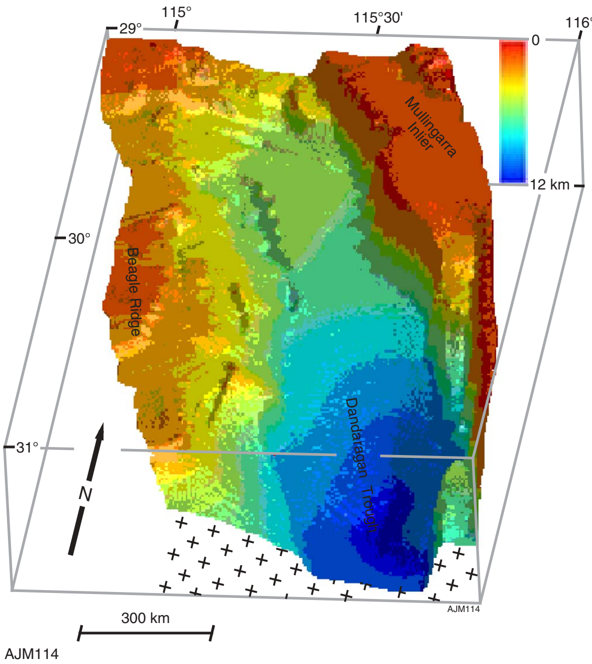

Figure 47. Perspective view (looking north) of the Precambrian basement horizon

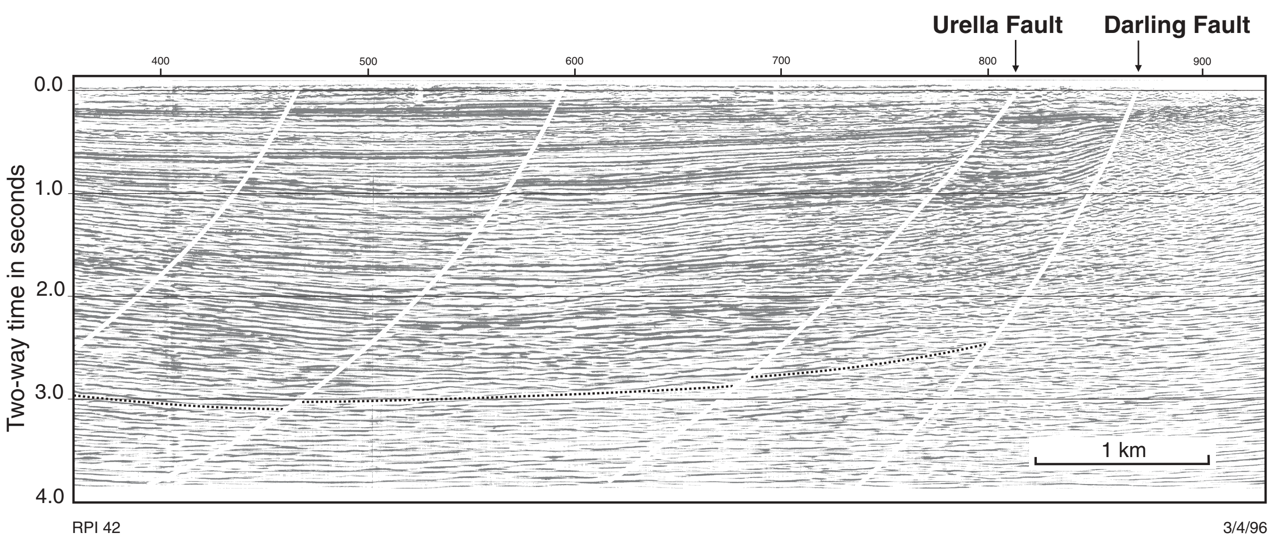

Figure 48. Seismic section (A89-708) showing the character of the Darling Fault

Aeromagnetic images clearly show the Northampton Complex below the thin sedimentary cover north of the major easterly trending Allanooka Fault on the Greenough Shelf. In addition, the images show northeasterly and north-northwesterly oriented lineaments extending from the Northampton Complex across the Dongara Terrace and into the Allanooka High. At basement level, these lineaments may correspond to northeasterly dolerite dykes and north-northwesterly shears within basement, as described by Byrne and Harris (1992; 1993) from outcrop of the Northampton Complex.

The Abrolhos Transfer Fault (Hall and Kneale, 1992) is a major structural feature in the basin because it divides the basin into two regions of significantly different structural character. The fault strikes across the basin at approximately 310° and may also cross the Darling Fault and extend onto the Yilgarn Craton. The presence of this fault is inferred from changes in throw directions on faults, a number of offsets in major faults, the sudden dissipation of the Eneabba Fault north of the transfer, and the presence of an offshore continuation of an onshore aeromagnetic lineament. Seismic data onshore and aeromagnetic lineaments offshore show an apparent sinistral displace-ment on the transfer fault system. The horizontal displacement of this fault has not been determined but, from observation of fault offsets in the seismic mapping, is believed to be in the order of a few kilometres. Across the Abrolhos Transfer Fault, throws on major northerly trending faults appear to be displaced up to 20 km west; for example, from the Coomallo Fault to the Mountain Bridge and Beharra Springs Faults, and the large offset to the west on the Urella Fault. This apparent displacement is interpreted as indicating the size of fault relay systems in the area, rather than a displacement of this magnitude along the Abrolhos Transfer Fault.

The Urella Fault is offset by the Abrolhos Transfer Fault at latitude 30°05'S where previous maps (e.g. Luck, 1989; Hall and Kneale, 1992) showed the bifurcation of the Urella and Darling faults. Current mapping indicates that the Urella Fault continues south of this offset and joins the Darling Fault at latitude 30°30'S. Approximately 10 km south of this point the Darling Fault bifurcates again with the Muchea Fault to the south. These bifurcations are demonstrated most clearly in the first vertical derivative gravity image (Fig. 30).

A second large transfer fault, parallel to and south of the Abrolhos Transfer Fault, crosses the coast near Cervantes (Fig. 6). This fault also shows a sinistral displacement, and has the largest lateral offset of a series of parallel faults identified from offshore aeromagnetic data. This transfer is also visible on the Bouguer gravity image (Fig. 29). On the seismic data there is a marked change in the orientation of small faults, from approximately 010° north of the Cervantes Transfer Fault, to approximately 345° south of the fault.

All faults in the basin have been interpreted on the seismic sections as listric normal faults (Plates 11 and 19). Many detach within the sedimentary section, whereas the steeper dips and significant throw at the base of the sedimentary section indicate that the major growth faults may detach at greater depths within the basement. The characteristics of the major faults in the basin (throw, strike and dip) as determined from seismic sections are summarized in Table 1.

The Allanooka Fault is the major easterly striking fault and one of only a few mapped in this orientation in the northern part of the study area. These faults can be explained as the results of reactivation of older shear zones within basement (Byrne and Harris, 1992). Compared with other major faults in the basin, the Allanooka Fault has the steepest dip (Table 1), which implies a strike-slip component.

The Beharra Springs Fault has a similar strike and dip and is synthetic to the Mountain Bridge Fault; both faults are considered to be listric. The former fault is the boundary between the Dongara and Beharra Springs Terraces. The Dongara Terrace has the shallower basement with northwest-trending faulting and folding (Crostella, 1995) akin to the structural style of the Cadda Terrace. By comparison, the Donkey Terrace to the east of the Beharra Springs Terrace has a thicker sedimentary section, increasing thickness to the east (with a regional dip of 7.5°) and characterized by northerly trending normal faults downthrown to the west.

The Beagle Fault system consists of a number of north-northwesterly oriented en echelon faults that dip to the east more steeply than other major faults farther into the basin. Because of the shallow basement on the Beagle Ridge, the fault can be recognized only in the upper part of the seismic section. Therefore, dip measurements were taken farther up-dip than for most other faults, resulting in the measurement of a steeper dip. The fault continues in basement but is ill defined on the seismic data.

The Eneabba Fault dips to the west with a throw varying from several hundred metres in the north to a few tens of metres in the south (Fig. 34 and Plate 5). The largest displacement on the fault is just south of the Abrolhos Transfer Fault. To the north the displacement appears to be dissipated into a number of faults, downthrown to the west, across the Donkey Creek Terrace. South of the Abrolhos Transfer Fault the Eneabba Fault appears to be a shallow dipping antithetic fault. However, the length of this feature on the map, over 100 km, suggests a strike-slip component (Crostella, 1995). To be consistent with transtension during the Early Cretaceous breakup, dextral strike-slip movement is implied along northerly trending faults (Harris, 1994). Poor seismic resolution obscures the root of the Eneabba Fault.

The Coomallo Fault (Plate 18, BD89-104) dips to the east and begins south of the Abrolhos Transfer Fault where its throw increases rapidly to the south to a maximum of 3000 m. This fault is low-dipping at depth and probably detaches shortly below basement. In the southern part of the study area, the Walyering prospect corresponds to a large rollover structure that is faulted by several westerly antithetic fractures onto the easterly dipping Coomallo Fault (Plate 18, line B89-439, BD89-104). This type of structure is repeated to the west (Plate 11, section 6) and was drilled in the Mullering prospect.

Table 1. Characteristics of major faults in the onshore northern Perth Basin

Fault name	*Approx. throw (metres)*	*Average strike*	*Dip range*	*Seismic line and figure illustrating fault*	
Allanooka	400 – 1 000	265°	60–70°	89–04	(Plate 19)
Mountain Bridge	400 – 1 000	345°	45–60°	B89–306	(Plate 19)
Beharra Springs	200 – 600	347°	50–60°	B89–306	(Plate 19)
Beagle	500 – 1 200	355°	55–70°	HP82–224	(Plate 19)
Eneabba	200 – 1 000	355°	50–70°	B89–413	(Plate 19)
Coomallo	500 – 3 000	355°	30–65°	BD89–104	(Plate 19)
Urella	3 000 – 6 000	345°	30–65°	AW, AF	(Plate 19)
Darling	up to 7 500	345°	55–70°	A89–708	(Fig. 48)

The Urella Fault is the dominant basin-forming fault north of the Abrolhos Transfer Fault. North of the transfer most of the throw on the Darling Fault has been transferred to the Urella Fault in a geometry that can be identified as relay ramp (cf. Peacock and Sanderson, 1994). To the south of the Abrolhos Transfer Fault, the Darling Fault is the dominant growth fault and the Urella Fault becomes synthetic to it with a diminishing throw.

A prominent lineament oriented at approximately 070° in the centre of the gravity image (Fig. 29) has not been observed on the seismic data. The lineament is parallel to the Vlaming Transfer Zone of Hall and Kneale (1992). Although the presence of the latter zone was not confirmed by aeromagnetic images of the adjacent offshore area (Heath et al., 1994), it seems likely that lineaments of this orientation are related to basement features.

The only known record of post-Cretaceous faulting in the study area is found in the Pleistocene Tamala Limestone on the west wall of the Jurien heavy-mineral sand (HMS) mine. At this locality a number of small reverse faults, each with displacements of about 5 to 10 cm, dip at approximately 80° towards 340°. Approximately 200 m to the south of the reverse faults a vertical fault, striking at approximately 290°, juxtaposes two large foresets, each approximately 5 m high, so that both foresets dip towards the plane of the fault. As the vertical displacement of the latter fault is less than 2 m, the main movement must have been strike slip to juxtapose the foresets in this manner. If the two faults occurred in the same stress field, a dextral sense of movement may be implied. Such a stress field indicates compression in a north-northwest–south-southeast direction and may be related to a late movement of the Australian plate along the Banda arc. The dextral strike-slip fault may represent a reactivation of a minor late-stage strike-slip fault, synthetic to the 310° trend, which was previously active at breakup.

Other possible indications of late Quaternary tectonism are a northerly trending topographic low on the Eneabba Plain along the Beharra Springs Fault, the topographic high over the Dongara field, and weak northwesterly lineaments across the Arrowsmith Region. The topographic low on the Eneabba Plain is filled by surficial lacustrine sediments including diatomaceous earth deposits, and suggests a small amount of sag along the Beharra Springs Fault between the Mondarra and Beharra Springs fields. The topographic high over the Dongara field is notable only because of its coincidence with that field; otherwise, the feature could be explained as a local variation in the thickness of the Tamala Limestone. It is much more difficult to suggest a tectonic origin for other topographic features, especially those east of the Gingin Scarp as this region has been actively eroded in the Quaternary. Nevertheless, northwesterly lineaments in the Arrowsmith Region, which mainly follow the drainage pattern, appear to post-date the laterite cover over this region. Inasmuch as the laterite has been dated as Late Oligocene to Early Miocene from palaeomagnetic data (Schmidt and Embleton, 1976), the presence of these lineaments suggests post-Miocene movements on minor faults associated with the Abrolhos Transfer Fault. As with the faults in the Jurien HMS mine, these Cainozoic events are thought to be related to north–south compression from a late movement of the Australian plate along the Banda arc.

Fault-azimuth analysis

The area of investigation has been divided into four sections, each spanning 30 minutes of latitude, and fault-azimuth analyses for the top Cattamarra Coal Measures horizon in each section are shown in Figure 49a–d. The major fault trends seen in the top Cattamarra Coal Measures map are also present in the basement and Permian maps.

The top Cattamarra Coal Measures map was used for the fault-azimuth analysis because the seismic quality, and the detail to which it can be interpreted, diminishes below this level. Where the Jurassic section is absent, the fault pattern from the top Permian or basement horizon map was incorporated into a composite map for the fault-azimuth analysis. Although the faulting pattern at the top Cattamarra Coal Measures is the result of several periods of deformation, with the youngest period being dominant, it was felt that the fault pattern from earlier periods would be adequately represented because of the reactivation of the older faults. This obviously excludes the analysis of faults that do not intersect the Cattamarra Coal Measures level. Only normal faults have been identified in the mapping, complicating the reconstruction of structural stresses in the study area.

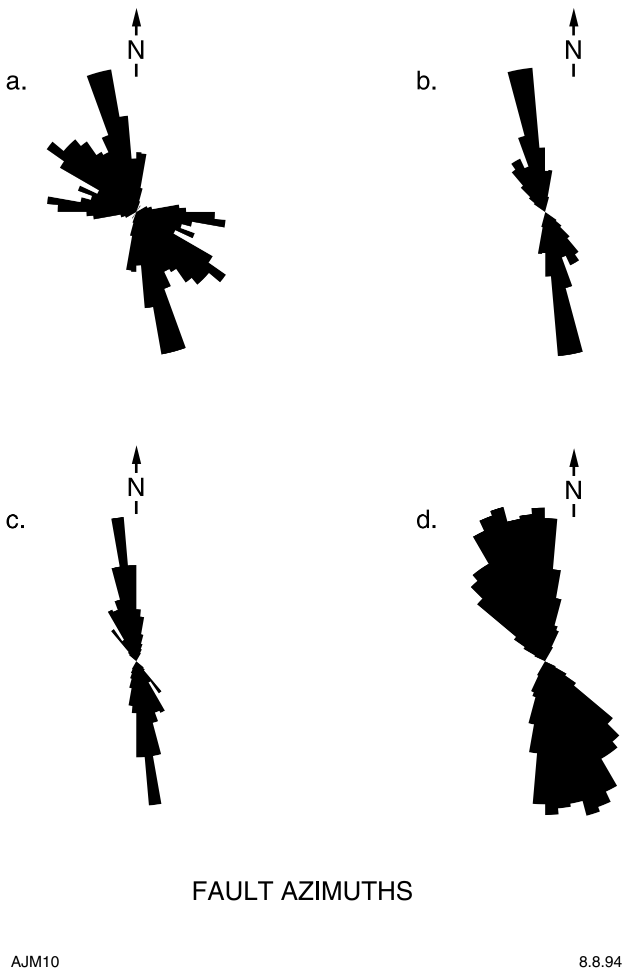

Figure 49. Rose diagrams of fault azimuths for the areas shown in Figure 1
(a) azimuths from area bounded by latitudes 29°00' to 29°30'S; (b) azimuths from area bounded by latitudes 29°30' to 30°00'S; (c) azimuths from area bounded by latitudes 30°00' to 30°30'S; (d) azimuths from area bounded by latitudes 30°30' to 31°00'S

Fault trends were established by sampling azimuths at a one kilometre interval along interpreted faults. The frequencies of azimuths were grouped in intervals of 5° and plotted as rose diagrams. The resulting diagrams show two main trends, at azimuths 275° (Fig. 49a) and 345 to 350° (Fig. 49a,b,c), and a minor trend at 305° (Fig. 49a).

Permian movements on north-northwesterly striking normal faults, which probably correspond to the Beagle Fault system, are inferred from the thick Permian succession preserved along the Cadda Terrace. These faults probably developed during the Permian and imply a northeasterly extension, confirmed by stress-tensor analysis (Beeson, 1992) and dyke orientations on the Yilgarn Craton. Byrne and Harris (1992) analysed the fault patterns in the Perth Basin and suggested a sinistral transtensional regime consistent with a northeasterly extension (Fig. 50). Further evidence of this stress field is found adjacent to the Darling Fault on the Irwin Terrace, where a small fold axis strikes at about 020° and a normal fault strikes at about 280° (Le Blanc Smith and Mory, 1995). Any existing northerly trending fractures, such as the Darling Fault, would have been reactivated with a significant sinistral strike-slip component.

The fault-azimuth analysis shows normal faults orientated at 275° (Fig. 49). These correspond to easterly striking faults such as the Allanooka and Bookara Faults, which show some growth in the Permian sediments, implying contemporaneous activity. The sinistral transtensional stress field (Fig. 50) in the Permian implies that easterly striking faults should have a dextral component (Harris, 1994, fig. 4a). The higher dips observed on the Allanooka Fault, when compared with dips of other faults in the basin, are consistent with a strike-slip component along the fault.

Faulting probably persisted from the Late Permian into the Early Triassic. Between Mondarra 1 and 4 wells, the Triassic section increases in thickness on the upthrown side of an apparently normal fault, striking at about 010°. This suggests either reverse movement in the Triassic (Iasky and Mory, 1994), or a later component of strike-slip movement. If this is a minor reverse fault, then it is consistent with the stress field for the Permian shown in Figure 50. In addition, a local depocentre in the Kockatea Shale is evident near North Yardanogo 1 (Fig. 15), implying normal fault activity on the margin of the Dongara Terrace and Beagle Ridge in the Early Triassic.

Sinistral strike-slip faulting, such as the Abrolhos and Cervantes Transfer Faults, is inferred from seismic mapping (Plates 4–9) as well as gravity and aeromagnetic imagery. The aeromagnetic image over the most northern section (Fig. 38) shows lineaments oriented at approximately 45 to 50°, offsetting northwest-trending normal faults in a sinistral sense (Fig. 39). The orientation of the latter lineaments and the size of the horizontal displacement suggests that these are strike-slip faults antithetic to a dextral transtensional regime (Fig. 50). The similarity of the orientation of these strike-slip faults to that of dykes in the Northampton Complex suggests that the faults represent reactivated basement fractures.

The predominant azimuth direction of normal faulting is north–south (Fig. 49a,b,c), which also corresponds to the direction of the major growth faults in the basin (Table 1). This direction of normal faulting implies an east–west extension that is postulated by Harris (1994) to have occurred in the Late Triassic to Early Jurassic. A dextral transtensional stress field oriented in this direction (Fig. 50) is also consistent with transfer faults striking in a northwesterly direction. In the Hill River area the pattern of faulting (especially between the Lesueur and Warradarge Faults) indicates a component of dextral movement along the northerly to north-northwesterly trending faults, although they appear as normal faults on seismic sections. The sinistral displacement along the Abrolhos and Cervantes transfer faults contrasts with the dextral movement inferred on apparently normal faults oriented at 345 to 350° in the three northern areas (Fig. 49a,b,c), and the dextral strike slip seen in the Vlaming Sub-basin (Heath et al., 1994). This difference reflects local relative movement between fault blocks.

The northwesterly orientation of transform faults, such as the Wallaby Transform, implies that the direction of extension at breakup is northwest, and also implies a transtensional stress regime as depicted in Figure 50. Breakup of Australia from Greater India is confidently dated to be Early Cretaceous (Falvey and Mutter, 1981) from the angular unconformity of this age evident in offshore seismic data. Northeasterly striking normal faults would form under this stress field; however, these are not observed on onshore seismic data and it is apparent that northerly striking faults were reactivated with a significant dextral strike-slip component.

A minor normal fault trend of 305° is present only in the northernmost section (Fig. 49a). This trend is probably due to the interaction of pre-existing fractures within the new stress fields.

In the most southern section (Fig. 49d) normal faults show a large scatter from 310 to 015°, with the major trends appearing at 345 and 360°. The faults oriented at 345° are associated with breakup as seen in the north of the study area. The large scatter in the direction of normal faulting, and the other predominant direction at 360°, may derive from the more-detailed mapping conducted in an area intersected by the Cervantes Transfer Fault. The large scatter is typical of an extensional regime of faulting (Middleton, 1990).

Analogue modelling conducted by Harris et al. (1994) shows that Precambrian terrane boundaries and pre-existing basement fractures determine the pattern of faulting created in the Phanerozoic phases of tectonism. They have shown that the structural evolution of the Perth Basin can be explained by the activation of two main events; a southwesterly extensional regime in the Permian followed by a northwesterly extension in the Early Cretaceous. Structures emanating from their analogue modelling are consistent with the fault pattern from seismic data and the distribution of sediments in the onshore northern Perth Basin.

Geohistory analysis

Geothermal modelling

Geohistory analysis is a term used to describe a twofold modelling process to determine the maturation history of sedimentary strata. Firstly, burial history (time versus depth) plots are constructed by backstripping successive stratigraphic layers while allowing for palaeobathymetry,

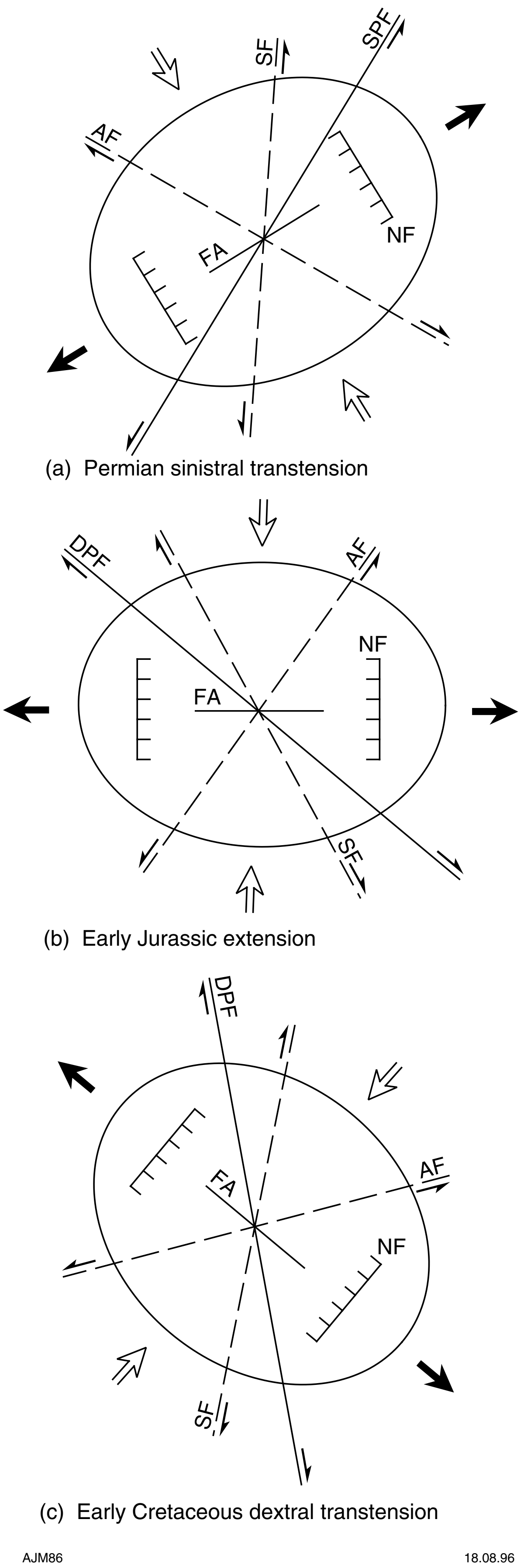

Figure 50. Stress ellipsoids showing stress fields when: (a) Permian: normal faults are oriented at 275° and the principal fracture is left-lateral; (b) Early Jurassic normal faults are oriented at 000° and the principal fracture is right lateral; and (c) Early Cretaceous: normal faults are oriented at 345° and the principal fracture is right-lateral. NF, direction of normal faults; FD, fold direction; SPF, sinistral principal fracture; DPF, dextral principal fracture; ASF, antithetic sinistral fault

compaction, and erosional episodes. Secondly, vitrinite reflectance is modelled to determine the palaeogeothermal history and the timing and magnitude of erosional episodes. Intrusive or extrusive magma can produce short-lived high geothermal gradients in local areas that can overprint the maturation history of earlier tectonism, and therefore make the analysis less effective. The geohistory analysis was performed with a non-commercial computer program (Iasky, 1990, 1993) in which vitrinite reflectance is calculated by using the time–temperature integral defined by Middleton (1982).

Present-day geothermal gradients were calculated for all petroleum wells and waterbores in the study area (Appendix 9) and a contour map produced (Fig. 51). Calculations were made by using bottom-hole temperatures that were corrected for time lapsed from circulation (Facer, 1991) and for present-day surface temperature. Depending on when the well was drilled, one of three surface temperatures was used: 25° in summer, 20° in winter and 22°C in autumn and spring. However, this seasonal change has little effect on the geothermal-gradient of deeper wells. Overall, the resultant temperature gradients agree with calculations made by Bestow (1982), and the geothermal gradient map produced by Thomas (1984). The geothermal-gradient map of the onshore northern Perth Basin (Fig. 51) shows a cool Dandaragan Trough, and a hot Beagle Ridge and Northampton Complex. Thomas (1984) suggested that although the high geothermal gradients coincide with basement highs, the presence of thick shale units, with lower than average thermal conductivities, may also have contributed to the elevated geothermal gradients.

Well geothermal modelling

Of 155 petroleum wells in the study area, vitrinite samples from 31 were examined for reflectance (Appendix 8). Geohistory analysis was performed on all wells with vitrinite reflectance but only results of the more typical ones are shown in this report (Figs 52–55). Wells that have only one or two vitrinite reflectance measurements, such as Arrowsmith 1, Cadda 1, Jurien 1, Mondarra 1, and Rakrani 1, cannot be modelled adequately though these measurements may support models from wells with more data.

The geohistory analyses were carried out assuming a constant palaeotemperature gradient before breakup. At breakup a geothermal pulse was introduced to allow for higher gradients near spreading ridges, and thereafter it was assumed that temperature gradients would quickly drop to no lower than present gradients. In Middleton's (1982) time–temperature integral method, the important factors in modelling vitrinite reflectance are the potential increase in temperature gradient at the commencement of rifting, and the amount of uplift that occurred. A model with a rise in temperature gradient and a respectively smaller uplift would generate vitrinite reflectance values similar to a model with a larger uplift but a lower temperature gradient. Therefore, a knowledge of the stratigraphy becomes essential in determining a balance between these two factors.

Commercial modelling packages that have recently become available, such as WINBURY and BASINMOD, use heat flow and thermal conductivities of rocks, instead of temperature gradients to model the palaeoheat of a basin. This approach is more sophisticated and provides more accurate results, but a trial of the WINBURY package showed little difference in the maturation history, between the two methods of modelling.

Vitrinite reflectance modelling of petroleum wells in the onshore northern Perth Basin shows one major heating event in the Late Jurassic to Early Cretaceous. This event coincides with rifting followed by the breakup of Australia from Greater India. No other heating events can be identified because of the large scatter in vitrinite reflectance values from pre-Jurassic units.

Vitrinite reflectance values throughout all wells in the basin display a large scatter (e.g. Fig. 52) and it has been recognized by Kanstler and Cook (1979) that it is possible that the variation of vitrinite type and the presence of subertinite and bitumen may depress reflectance measurements. Studies by Wilkins et al. (1992) of vitrinite reflectance data from wells in the Carnarvon Basin have related suppression of reflectance to the high hydrogen content sourced from liptinite in dispersed organic matter. Permian coals on the Irwin Terrace show a component of liptinite as high as 29% (Le Blanc Smith and Mory, 1995) and if such coals are present throughout the basin, suppression of vitrinite reflectance should occur. Two wells that show suppression are West White Point 2 and Allanooka 2 (Fig. 53), where the calculated vitrinite reflectance values may be fitted to those measured only by assuming no tectonic activity, heating events or erosional episodes.

Because of the obviously suppressed vitrinite reflectance readings, models were established by fitting the calculated vitrinite reflectance to the higher, less suppressed measurements. Using this procedure, an uplift of 1300 to 1500 m may be estimated for wells on the Beagle Ridge, assuming a heating pulse that increased the geothermal gradient to 6°C/100 m (Fig. 54). Similarly, uplifts of 2000 m and 1500 m (Figs 54, 55) may be suggested for wells on the Allanooka High and the northern part of the Dandaragan Trough respectively. Modelling of wells on the Cadda Terrace indicates an approximate uplift of 2000 m, although a relatively high geothermal gradient has to be applied at breakup to match the high vitrinite reflectance values (Fig. 55).

Vitrinite reflectance at Woolmulla 1 is unusually high with respect to other measurements in the basin, and modelling shows that the Kockatea shale is within the gas generative window while the full Permian section is overmature for hydrocarbons (Fig. 55). Anomalously high vitrinite reflectance values were also recorded in Cadda 1, on the Cadda Terrace, and may represent a thermal event caused by igneous intrusion associated with uplift prior to breakup (Thomas, 1984).

Modelling of wells in the Allanooka High, Dongara Terrace and Greenough Shelf shows that in the northern

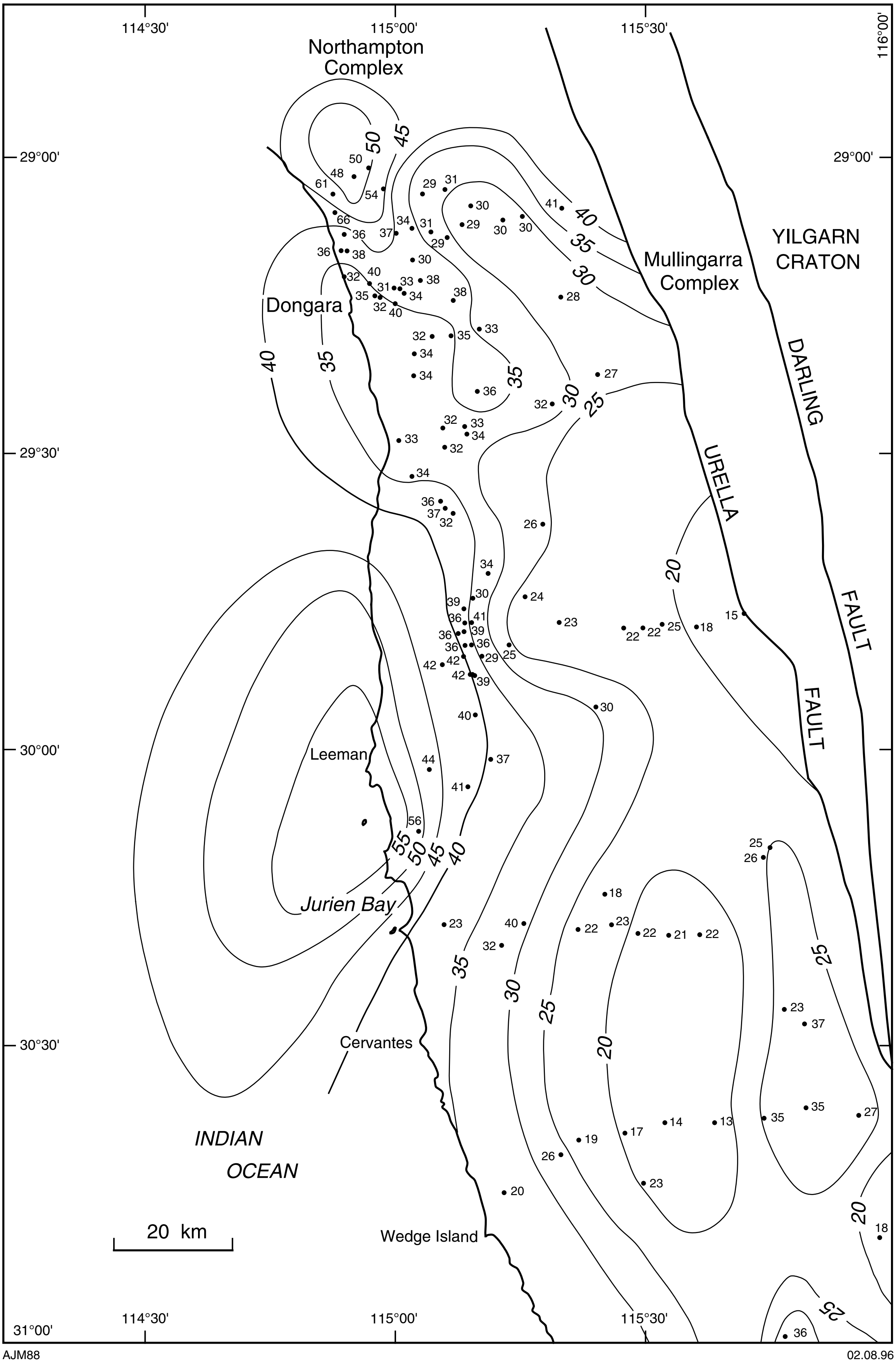

Figure 51. Geothermal gradient (°C/100 m) contour map of the onshore northern Perth Basin

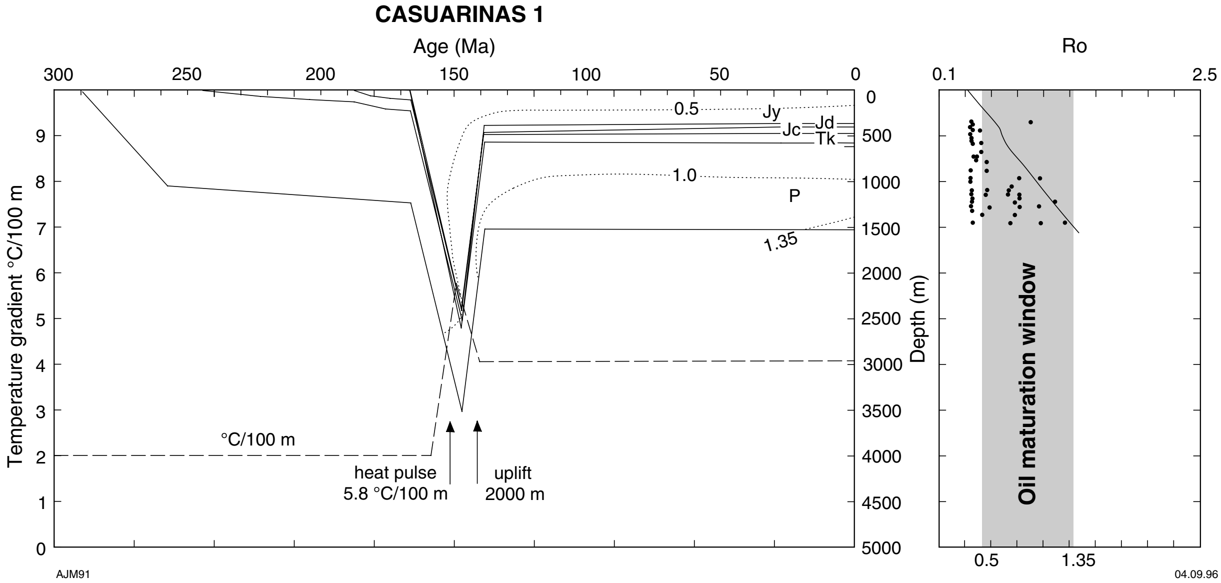

Figure 52. Vitrinite reflectance versus depth for Casuarinas 1, showing the large scatter of values. Modelled curve and burial history (time versus depth) plot are also shown. Calculated vitrinite reflectance is the continuous line, and measured samples are represented as dots. Shaded area represents oil window

part of the basin, the Triassic and Permian section is within the oil-maturation window (Figs 56, 57). Maturation increases towards the southeast where the Triassic lies within the oil window and where the Permian section is within the gas-generative window. Further south, in the Dandaragan Trough, the Triassic Kockatea Shale and Permian units lie within the gas-maturation window (Figs 56, 57).

Burial history of regional profile

A burial history reconstruction for a profile across the northern part of the study area (Fig. 58) shows the effect of backstripping stratigraphic layers. The accuracy of the resultant model relies on determining the correct ages for episodes of erosion and uplift, and can provide an understanding of the structural and depositional history of the basin. The amount of uplift was estimated initially by comparing thicknesses of units at well sites, and later refined from modelling the vitrinite reflectance data.

The onshore northern Perth Basin is interpreted as an extensional basin of Early Permian to Holocene age that formed on the western side of the Australian Craton. Sedimentary rock of possible Silurian age in the northern Perth Basin is sparsely d]istributed and poorly understood, and not considered in the burial history scenarios shown in Figure 58.

The burial history reconstructions along an east–west traverse (Fig. 58 — based on section BB' in Plate 11) show that during the Permian a moderately uniform thickness of sediments blanketed the basin while it subsided (Fig. 58a). The southern extension of the Northampton Complex to the west, and the eastern margin of the basin may have been topographic highs before deposition commenced. The onset of rifting with a northerly extension in the Late Permian (Marshall et al., 1989; Quaife et al., 1994) initiated a period of faulting in the basin which probably continued into the Early Triassic (Fig. 58b). Several reactivations may have occurred during this time, but only one significant event is recognized prior to deposition of the Dongara Sandstone. Relatively little faulting appears to have occurred from Late Triassic to Early Jurassic, a period of subsidence and trough infill in the Dandaragan Trough (Fig. 58c–e). Early Jurassic erosion in the northern part of the study area is interpreted as local uplift of the Northampton Complex. Mantle upwelling in the Middle Jurassic initiated the onset of rifting, with the extension axis shifting to a northwesterly direction in a dextral transtensional regime by the Early Cretaceous (Fig. 58f). The Darling and Urella Faults are believed to have been most active at this time. Post-breakup Cainozoic deposition is minor, with little faulting or uplift of the dissected laterite deposits east of the Gingin Scarp (Mory, 1994a,b, 1995a,b).

Basin evolution

Although sediments of Silurian to Pleistocene age are present within the Perth Basin, only the Permian to Lower Cretaceous section is discussed here. The presence of older Phanerozoic sediments in the study area is questionable, and younger sediments are not well represented.

The main Permian depocentre (Fig. 3) appears to be on the northeastern margin of the Dandaragan Trough, near Depot Hill 1. The Permian section thins to the south into the Dandaragan Trough suggesting a limited sediment supply, and west towards the Beagle Ridge–Dongara Terrace suggesting that the basement high was already in existence in the Early Permian. Sustained subsidence and

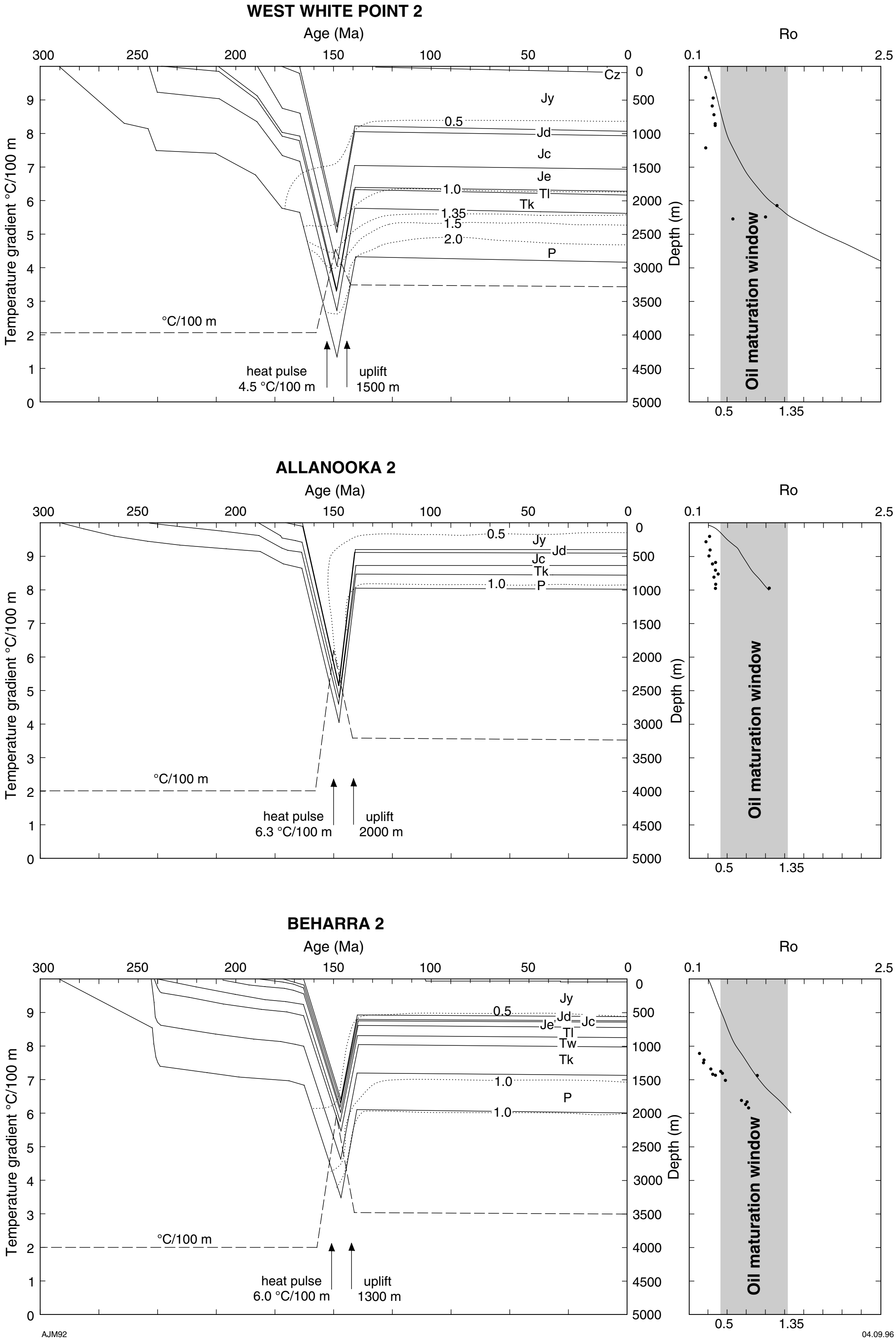

Figure 53. Vitrinite reflectance versus depth for West White Point 2, Allanooka 2, and Beharra 2, including burial history (time versus depth) plot. Calculated vitrinite reflectance is the continuous line, and measured samples are represented as dots. Shaded area represents oil window

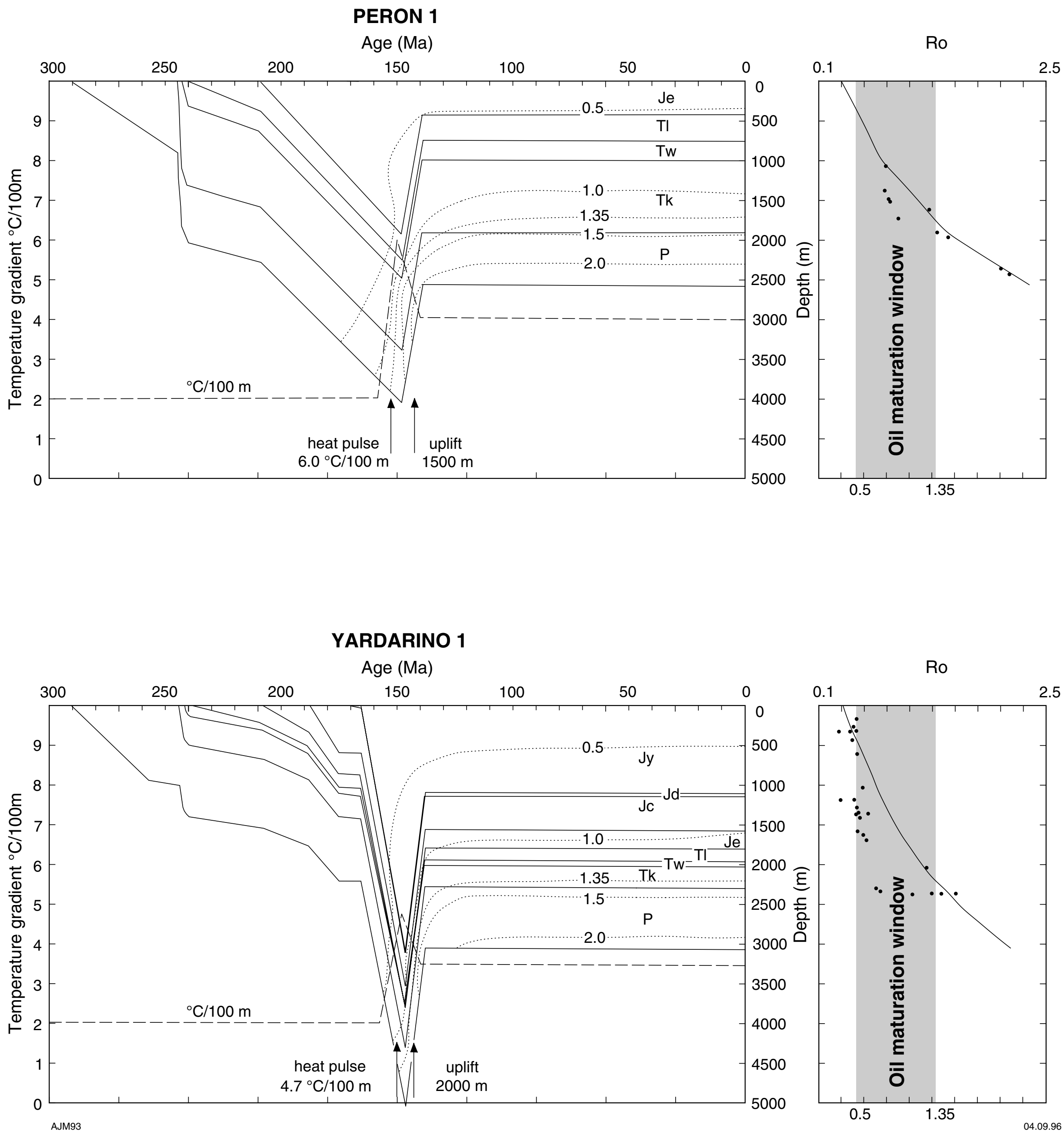

Figure 54. Vitrinite reflectance versus depth for Peron 1 and Yardarino 1, including burial history (time versus depth) plot. Calculated vitrinite reflectance is the continuous line, and measured samples are represented as dots. Shaded area represents oil window

the formation of abundant accommodation space in the Early Permian are indicated by the predominance of argillaceous marine sediments, particularly higher in the section (Carynginia Formation), with a brief regressive pulse associated with the coal seams. Permian deposition commenced in fluvioglacial to glacial to proglacial marine-shelf settings, associated with the melting of the Gondwana ice sheet (Nangetty Formation), in a depocentre over the central and eastern part of the basin (Fig. 7). The marine transgression continued with deposition in a proglacial marine-shelf environment (Holmwood Shale) encroaching farther to the southwest onto the Beagle Ridge (Fig. 8). A minor regression followed with the deposition of sand and conglomerate in shallow marine, beach ridge, and lower deltaic proglacial environments (High Cliff Sandstone; Fig. 9) and a series of coalesced coarse-grained alluvial deltas prograding into a proglacial cold temperate marine embayment at high latitude (Irwin River Coal Measures; Fig. 11). This regression was followed by a return to a proglacial marine-shelf setting (Carynginia Formation; Fig. 12) near the end of the Early Permian. Indirect evidence of growth on the Darling Fault,

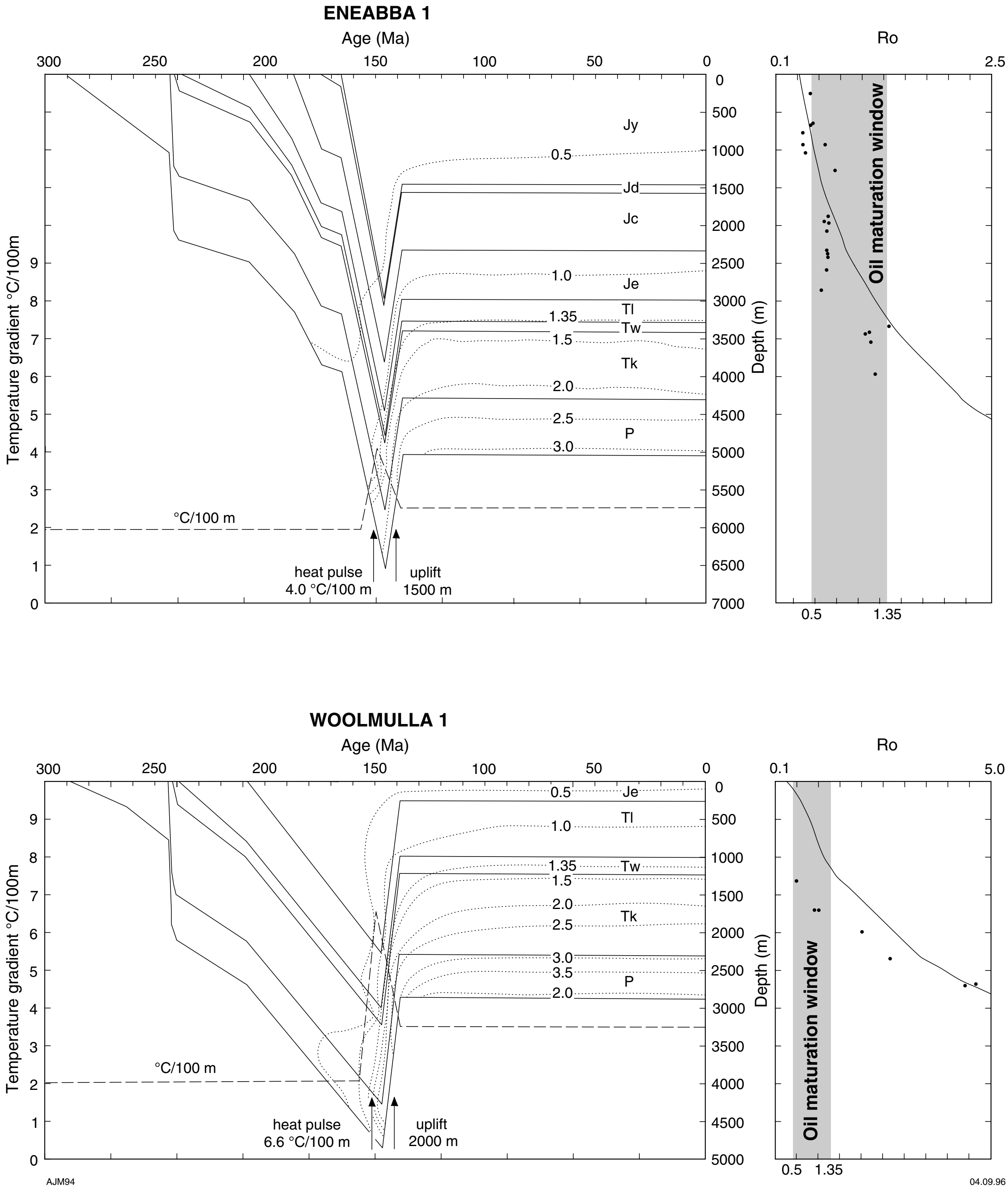

Figure 55. Vitrinite reflectance versus depth for Eneabba 1 and Woolmulla 1, including burial history (time versus depth) plot. Calculated vitrinite reflectance is the continuous line, and measured samples are represented as dots. Shaded area represents oil window

from isopachs of the earliest Permian units, suggests that the Permian represents a period of rifting followed by trough infill.

A period of uplift and erosion in the Late Permian in the northern half of the area was interrupted by the deposition of a series of coalesced, coarse-grained alluvial deltas, prograding west into a proglacial marine embayment at high latitude (Wagina and Dongara Sandstones, Beekeeper Formation; Fig. 13). This uplift is probably related to the onset of rifting in the offshore part of the basin (Marshall et al., 1989, Quaife et al., 1994) and has been interpreted by Harris (1994) as a period of east-northeasterly extension.

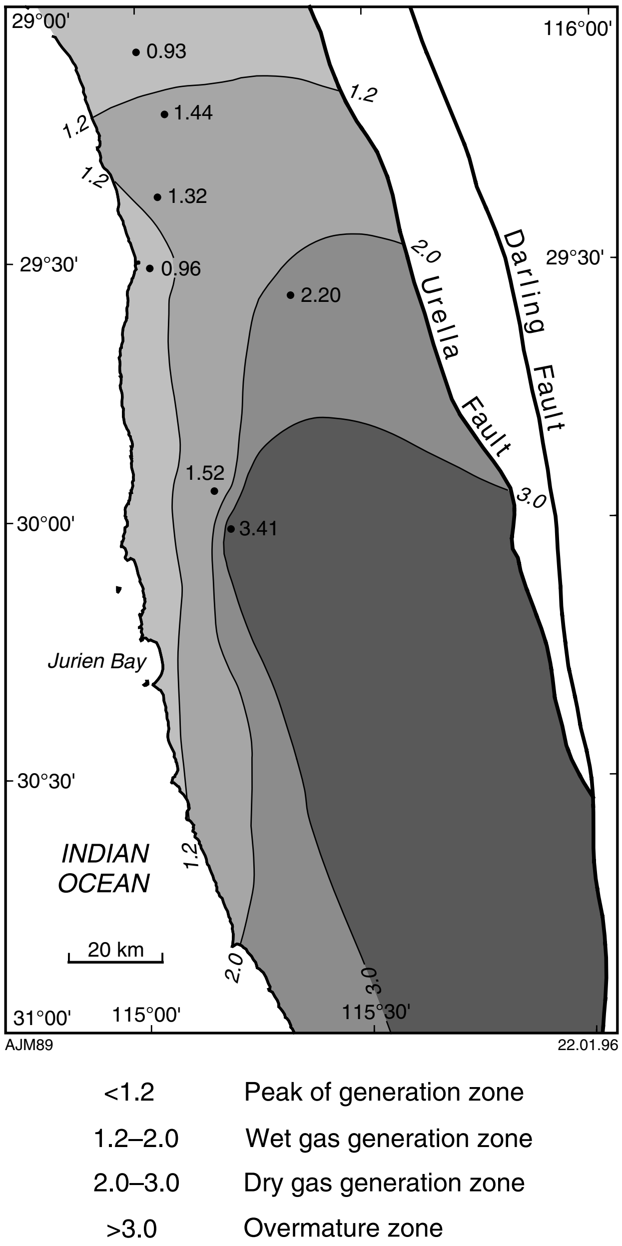

Figure 56. Maturity map of the top Permian in the onshore northern Perth Basin

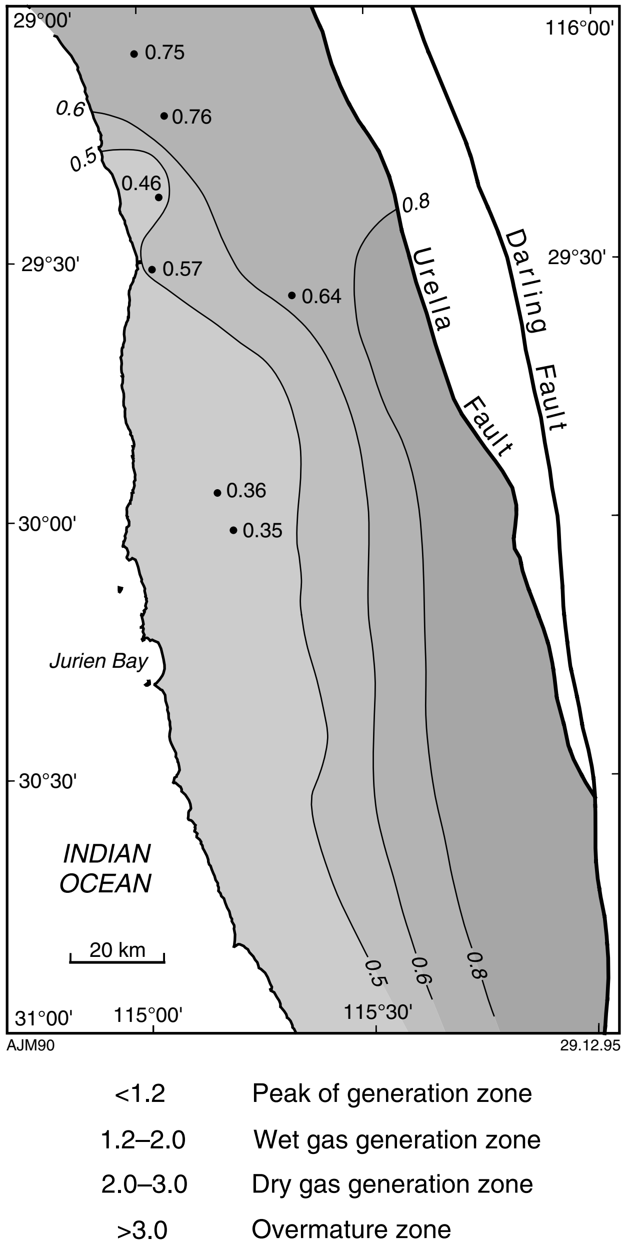

Figure 57. Maturity map of the Jurassic (top Cattamarra Coal Measures) in the onshore northern Perth Basin

Following Late Permian tectonic activity, an Early Triassic marine transgression across the northern Perth Basin resulted in the deposition of the Kockatea Shale. Thinning of the Kockatea Shale to the north indicates Early Jurassic erosion or non-deposition near the Northampton Complex, or the location of the edge of the basin at that time. Thinning onto the northern part of the Beagle Ridge and Dongara Saddle suggests some Early Triassic growth along that ridge (Fig. 15). Following deposition of the Kockatea Shale a long-lasting regressive phase of fluvial deposition persisted until the Early Jurassic. The overlying paralic Woodada Formation represents a thin transitional unit between the underlying marine Kockatea Shale and the predominantly alluvial-fan–fluvial deposition of the overlying Upper Triassic Lesueur Sandstone. There is some evidence that the Beagle Ridge continued as a relatively positive feature during deposition of the Woodada Formation (Fig. 18), but this feature appears to have been inactive during deposition of the Lesueur Sandstone. Dramatic thickening to the southeast of the latter unit (from approximately 400 m in the Woodada Gasfield to probably over 3000 m at Barberton 1; Fig. 19) suggests significant movement on the Darling Fault in the Late Triassic. The Lower Jurassic Eneabba Formation, which is fluvial in origin and probably was deposited by meandering streams, shows significant thinning onto the Beagle Ridge and Dongara Terrace (Fig. 21). This ridge continues to be active towards the end of the Early

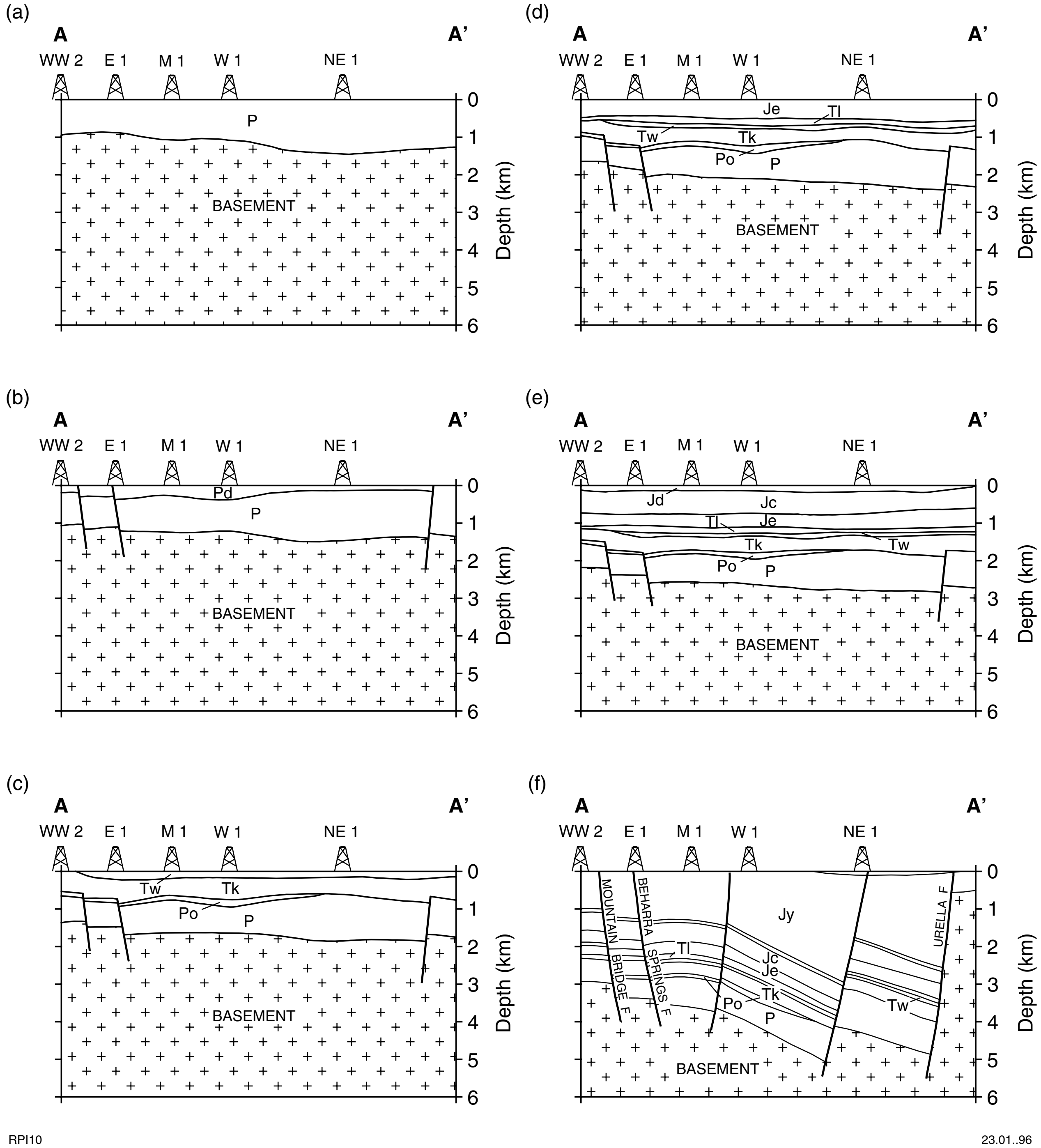

Figure 58. Burial history reconstruction of east–west traverse A–A' (location shown in Fig. 34) through a number of petroleum wells and ending east of the Urella Fault. The stratigraphic symbols are defined in Appendix 5, and the times of the various episodes are: (a) 260 Ma — Early Permian; (b) 250 Ma — Late Permian; (c) 241 Ma — Middle Triassic; (d) 188 Ma — Early Jurassic; (e) 166 Ma — Middle Jurassic; (f) Present. Wells shown on the traverse are E 1 (Ejarno 1); M 1 (Mondarra 1); NE 1 (North Erregulla 1); W 1 (Warradong 1); WW 2 (West White Point 2). Note that the vertical exaggeration is approximately 4.6 and horizontal distances between wells are approximate

Jurassic, during deposition of the marginal marine Cattamarra Coal Measures (Fig. 23). The peak of the Jurassic marine transgression was reached in the Middle Jurassic, with deposition of the Cadda Formation into a shallow depression centred over the Dandaragan Trough (Fig. 25). The sudden change in sedimentation (back to fluvial conditions) in the Middle Jurassic, and the great thickness of the Middle Jurassic to Lower Cretaceous succession (over 6000 m of Yarragadee and Parmelia Formations; Fig. 26), is interpreted as the onset of rifting prior to the separation of Australia and Greater India in the Neocomian (Scott, 1991).

Local thickening in Triassic to Middle Jurassic units east of the Mountain Bridge and Beagle Fault System suggests growth along the Beagle Ridge. Overall, the Triassic and Lower Jurassic thickens to the south along the axis of the Dandaragan Trough, suggesting a period of trough infill. Early Jurassic erosion or non-deposition in the northern part of the area indicates that the Northampton Complex was a positive feature at that time.

The predominant fault trend throughout the study area is from 345 to 350° and coincides with the separation of Australia from Greater India in the Early Cretaceous during a phase of northwesterly transtension. Vitrinite reflectance modelling shows one major heating event in the Late Jurassic to Early Cretaceous which coincides with rifting followed by the breakup of Australia from Greater India. No other heating events can be identified because of the large scatter in vitrinite reflectance values from pre-Jurassic units (Iasky and Mory, 1994). Burial history modelling shows that geothermal gradients increased in the Late Jurassic to Early Cretaceous. This increase was probably caused by crustal thinning and mantle upwelling before breakup (Middleton, 1982; Iasky and Mory, 1994). The major vertical movements on most faults are normal and occurred at this time, effectively masking pre-Cretaceous movements, although many faults appear to have reactivated in zones of crustal weakness developed at earlier times (Byrne and Harris, 1992).

A transtensional tectonic regime in the Perth Basin has been proposed by Marshall et al. (1989), Middleton (1990), Byrne and Harris (1992), and Marshall et al. (1993). Fault-azimuth analysis and aeromagnetic lineaments confirms such a regime. An azimuth of 345–350° for the predominant normal fault trend is a consequence of this stress regime.

A sinistral strike-slip fault trend at 310° is inferred from seismic structure mapping, and aeromagnetic and gravity lineaments along the Abrolhos and Cervantes transfer faults. The sinistral displacement reflects different rates of movement between fault blocks during Early Cretaceous transtension and implies that the blocks to the north are underpinned by cratonic basement.

Petroleum potential

The onshore northern Perth Basin is a proven petroleum province with six known fields, of which one is depleted, and several minor occurrences of gas (Fig. 59, Table 2). Current proven reserves are some 17×10^9 m^3 of gas, 500 000 kL of oil and 100 000 kL of condensate. The controlling factors for hydrocarbon accumulations in this area are discussed in detail by Crostella (1995) from which the following account is extracted. The stratigraphic distribution of source rocks, reservoirs and seals in the area is summarized in Table 3.

Source rocks

The most informative discussions of the source-rock potential of the northern Perth Basin are by Thomas (1979, 1982, 1984), Thomas and Brown (1983) and Summers et al. (1995). They indicate that source rocks rich in land plants are widely distributed in the Perth Basin through the Permian, Triassic and Jurassic with the most notable being the condensed sequence at the base of the Triassic Kockatea Shale. An evaluation of the large amount of TOC, Rock-Eval and Pyrolysis GC data presently available for wells in the onshore Perth Basin was beyond the scope of this study.

The Permian source rocks appear to be mature for gas generation in large tracts of the northern Perth Basin, either because of a relatively high geothermal gradient or because of their depth of burial. Crostella (1995) implied that, as the gas in the Dongara field is dry and not in equilibrium with the oil, the gas was generated largely from the Permian Irwin River Coal Measures, and the oil was sourced from the Lower Triassic Kockatea Shale. The mixed origin of hydrocarbons in the field reflects differences in maturity of source rocks in the two units.

Where source rocks are not mature, lateral migration may still lead to a hydrocarbon accumulation. A possible exception is the northernmost part of the Allanooka High, which is considered too far from the hydrocarbon generation area for significant hydrocarbon accumulations. Most of the Greenough Shelf also appears to require relatively long migration paths to yield hydrocarbon accumulations.

The geothermal gradient ranges from low values in the Coomallo and Dandaragan Troughs, to medium values in most of the Cadda and Beharra Springs Terraces, to high values in part of the Cadda Terrace, Dongara Terrace and Allanooka High. The presence of thick sandy sections with a high thermal conductivity in the younger units plays a significant role in lowering the geothermal gradient in the Coomallo and Dandaragan Troughs. There is little evidence of volcanic activity except near the southernmost part of the Beagle Ridge (Heath et al., 1994).

Maturity maps for the main source-rock intervals (Thomas and Brown, 1983) show the distribution of mature source rocks is mostly in the central part of the basin. The oil-prone Lower Triassic Kockatea Shale has reached maturity for hydrocarbon generation over most of the basin. Locally, as in the Allanooka High and the Dongara Terrace, maturity levels are only marginal. Conversely, where the formation is deeply buried, the Kockatea source beds may be below the oil window and the unit may generate only gas. Owing to their shallow depth the Jurassic source rocks are largely immature, but in the Dandaragan and Coomallo Troughs the Cattamarra Coal Measures are mature. The lower parts of the Yarragadee Formation are marginally mature.

Hydrocarbons are still being generated in those units with source potential that have reached maturity. In the northern Perth Basin, maximum bottom-hole temperatures up to 150°C have been calculated, but such temperatures have been reached only locally (Mount Adams 1 and Warradong 1). Thomas (1979) estimated that thermal destruction becomes advanced at temperature exceeding 200°C. Stein et al. (1989) reproduced vitrinite reflectance data from 22 wells of the Perth Basin, and found that only

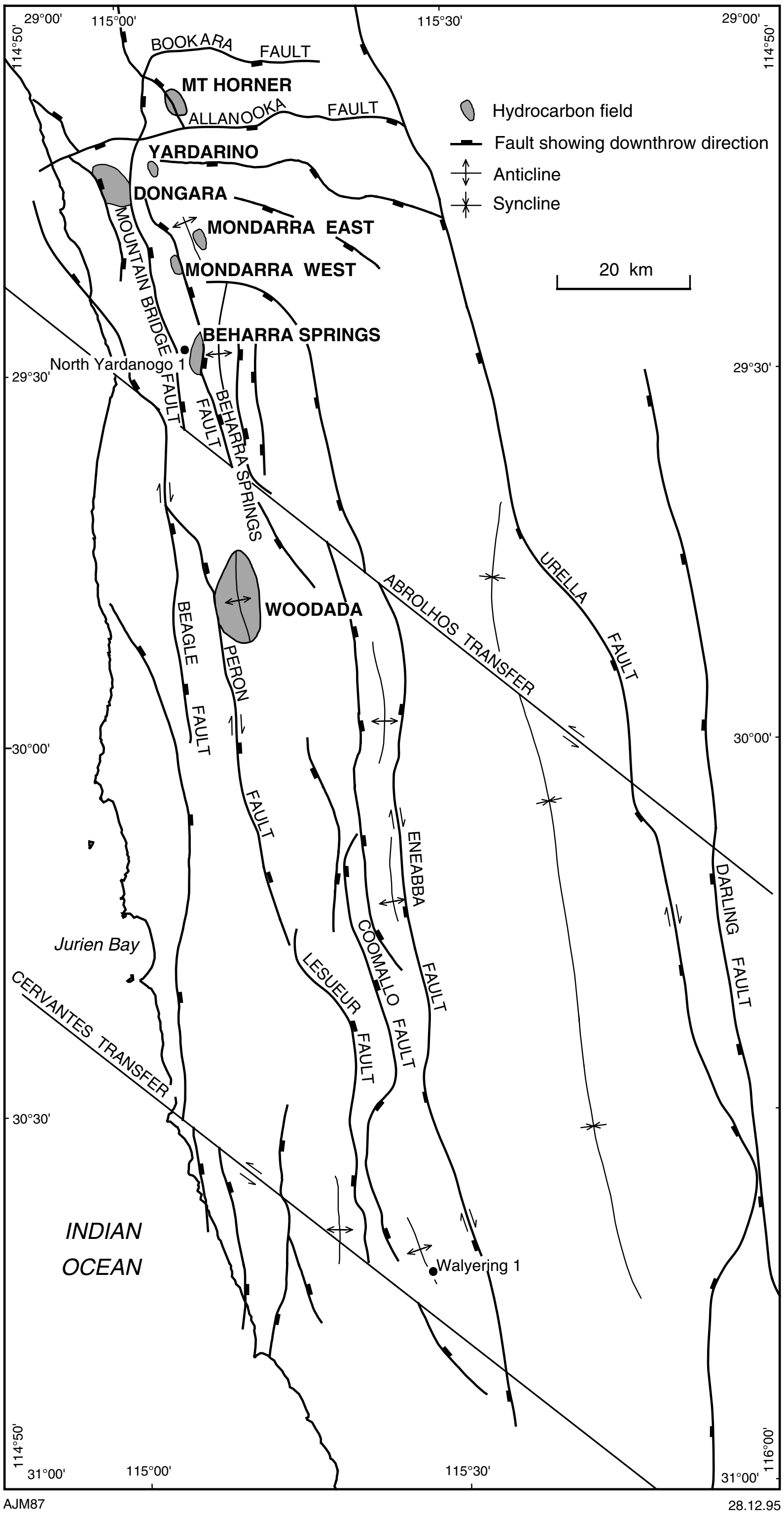

Figure 59 Location of oil and gas fields as well as important minor hydrocarbon occurrences in the onshore northern Perth Basin

Table 2. Summary of production and remaining proven reserves in the onshore northern Perth Basin as at 31 December 1993

Field	*Oil (10^6kl)*		*Gas ($10^9 m^3$)*		*Condensate (10^6kl)*	
	Produced	*Remaining reserves*	*Produced*	*Remaining reserves*	*Produced*	*Remaining reserves*
Beharra Springs	0	0	0.595	1.122	0.009	0.018
Dongara	0.219	0.027	11.983	0.399	0.045	?
Mondarra	0.009	0	0.722	0.019	0.009	0.001
Mt Horner	0.197	0.043	0	0	0	0
Woodada	0	0	0.999	0.886	0.008	0.006
Yardarino	0.002	0	0.134	0	0.001	0
Small accumulations						
Gingin	0	0	0.049	?	0.003	?
North Yardanogo	0.0003	?	0	0	0	0
Walyering	0	0	0.007	?	0.0002	?
Totals	**0.427**	**0.070**	**14.489**	**2.426**	**0.075**	**0.024**

Woolmulla 1 reached the gas-generation threshold in the Permian section. The only other well with similar vitrinite reflectance values is Cadda 1 (Thomas, 1979).

Reservoirs

Lithostratigraphic units with reservoir potential are widespread throughout the entire sedimentary succession. The Lower Permian sandstone of the Irwin River Coal Measures show low permeability, but still produced gas of economic significance in the Dongara field although their contribution to the total production of the field has been modest. The best reservoir potential is offered by the Upper Permian Dongara Sandstone and Beekeeper Formation. These reservoirs contain most of the hydrocarbons discovered in the basin. There are minor accumulations in the Lower Triassic Arranoo Member sandstones (Dongara and Mount Horner) and several thin sandstone horizons of the Lower to Middle Jurassic Cattamarra Coal Measures (Mount Horner).

In spite of high porosities and permeabilities, the reservoir potential of the sand-dominated Woodada Formation, Lesueur Sandstone, Eneabba Formation and Yarragadee Formation has not been realized to date, owing to the lack of effective traps at those levels.

Tight (partially silicified) reservoirs have been encountered in several wells, such as the Erregulla wells (Eneabba Formation), the Gingin, Bootine and Walyering wells (Cattamarra Coal Measures) and the Warro wells (Yarragadee Formation). Hydrocarbons produced from these wells seem consistently to be contained in permeability traps. The petrophysical features of the diagenesis are strikingly similar for all the formations, possibly reflecting the similar provenance of all sands in the northern Perth Basin. The relationship between diagenesis and reservoir quality of the Upper Permian section is discussed in detail by Tupper et al. (1994), who show that the main factors reducing porosity and permeability are silicification in the case of quartz sandstones, carbonate cementation in the case of carbonate sediments, and that the development of clay minerals does not necessarily destroy excellent reservoirs. It is likely that their conclusions are valid for other intervals, and also that clay minerals are deposited from solutions that were able to move freely throughout reservoir rocks. The Dongara Formation of the Mondarra field, for example, presents gas-bearing sands with good reservoir characteristics, whereas water-bearing sands are tight.

Seals

Seals of regional distribution are represented by the Cadda Formation and by some intervals within the Cattamarra Coal Measures, but mainly by the thick and laterally extensive Kockatea Shale. Some anticlines breached at the shallower and sandier levels by minor faults may provide effective traps at depth if the throw of the faults is less than the thickness of the Kockatea Shale. Locally, shales in the Carynginia Formation may provide a seal to the Irwin River Coal Measures. In undisturbed four-way dip closures intraformational seals can be effective, such as in the minor oil pools at Mount Horner and Dongara.

Prospectivity

Geohistory modelling (Figs 52–55) shows that the main source rocks within the northern Perth Basin reached the oil-generation window during the period of rapid subsidence immediately prior to breakup in the earliest Cretaceous. All the known fields and smaller hydrocarbon accumulations lie within wrench anticlines that formed in the Early Neocomian (Early Cretaceous), the peak period of hydrocarbon expulsion. While an unfaulted anticline would provide the best chance of success, the presence of

Table 3. Summary of petroleum potential of stratigraphic units in the onshore northern Perth Basin

Unit	*Source*	*Maturation*	*Seal*	*Reservoir*
Parmelia Formation	possible	probably immature	intraformational	high ϕ and k
Yarragadee Formation	gas and oil, from coals	marginally mature in troughs	no	high ϕ and k
Cadda Formation	?		regional	no
Cattamarra Coal Measures	gas and oil, from coals	marginally mature in troughs	intraformational shales and coal	high ϕ and k
Eneabba Formation	no		unlikely	high ϕ and k
Lesueur Sandstone	no		no	high ϕ and k
Woodada Formation	no		unlikely	moderate ϕ and k
Kockatea Shale	oil, in basal section	generally mature	regional	Arranoo Member low ϕ and k
Dongara Sandstone	no		no	high ϕ and k
Beekeeper Formation	?		possible	fractured limestone and thin sands
Carynginia Formation	gas	mature for gas	intraformational	minor sands
Irwin River Coal Measures	gas	mature for gas	intraformational	low ϕ and k
High Cliff Sandstone	no		no	low ϕ and k
Holmwood Shale	?	?mature for gas	possible	minor sands
Nangetty Formation	?		?	?Wicherina Member

the Lower Triassic Kockatea Shale at the depth of the main objective could provide an effective seal to a faulted structure. The best potential for a stratigraphic trap is offered by the Dongara Sandstone where this unit thins out below the Kockatea Shale.

The Dongara Terrace, which is characterized by several elongated faults with subordinate folds, has proven production of both oil and gas. Further discoveries are considered likely, although their size is expected to be smaller than that of the Dongara field.

Three gas fields have been discovered in the Beharra Springs Terrace within sandstones of the Dongara Sandstone or interbedded limestone and sandstone of the Beekeeper Formation. Good migration paths exist from the more deeply buried source rocks to the east and to the south, and the discovery of additional oil- and gasfields seems likely.

The Allanooka High is characterized by easterly trending faults and related anticlines, offering a wide spectrum of trapping mechanisms. The only discovery in this sub-basin is the Mount Horner oilfield. In the highly faulted and fairly thin section north of the Allanooka Fault the high percentage of coarse clastics possibly reduces the potential for traps. To the south, faulting is less intense and the stratigraphic section thickens, increasing the trapping potential of the area. The Allanooka High offers, perhaps, the best chances for additional discoveries in the basin, especially in the southern part, where migration of hydrocarbon from the Dandaragan depocentre has occurred. Maturity of source rocks and lateral migration offer potential for both oil and gas accumulations.

Within the large and only sparsely explored Cadda Terrace the Woodada field is the only known hydrocarbon accumulation. Many structural features have been recognized, providing interesting targets, but a limiting factor is related to the high vitrinite reflectance values that are presented by the Cadda 1 and Woolmulla 1 wells (Thomas, 1979). These values eliminate the possibility that the Lower Permian source rocks generated hydrocarbons in the area after the formation of the traps. However, there is good potential for generating oil and gas from younger source rocks.

The low exploration activity on the Beagle Ridge reflects a view that its potential is low. This is in spite of minor shows in the BMR 10 wells and the Green Head 1 coal bore, none of which were located on a seismically defined structure. The main difficulties with plays in this sub-basin are the low porosities and permeabilities encountered in the five wells drilled to date on the Beagle Ridge (BMR 10 and 10A, Cadda 1, Jurien 1, Point Louise 1). In other respects, the shallow depth of the Permian section (less than 2000 m) would be perceived as a positive feature of the area. Similarly, the relatively shallow depths to the Permian section on the Yarra Yarra Terrace (less than 3000 m) suggest this area may be worthy of further investigation, although the strata dip fairly consistently to the south with few folds. In the case of the Barberton Terrace, the depth to Permian is greater than 6000 m and Barberton 1 encountered a thick sandstone section with no seals. However, the shallow presence of the Cadda Formation (583 m in the Gillingarra 8 hydrogeological exploration bore — Moncrieff, 1989) suggests potential for plays in the Cattamarra Coal Measures immediately south of the study area.

The prospectivity of the Donkey Creek Terrace, Dandaragan Trough and Coomallo Trough is considered poor. The first two sub-basins have had relatively little structural development, and in the Coomallo Trough the more attractive objectives are very deep.

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Appendix 1

Surveys conducted for petroleum exploration in the onshore northern Perth Basin

Survey name	*Year*	*Company*	*Tenement*	*Type*	*Kms*	*S-number*	*Microform*
Aeromag. S. of the Perth Basin	1957	BMR	PE-27-H	Mag.	36 520.0	S152	
Alpha 1 geochem. S.	1978	Exp. Geophys	EP100	Geoc.	0.0	S1430	PES1430
Arrowsmith airborne spectrometer S.	1985	Metramar	EP96 (R1)	R	0.0	S3175	PES3175
Arrowsmith detail S.S.	1970	WAPET	EP21				
			EP100 (R2)	Refl.	31.0	S1169	39
Arrowsmith geochem. S.	1986	Barrack	EP320	Geoc.	0.0	S3065	PES3065
Athamo S.S. & grav. S.	1966	French	PE-228-H	Refl.	578.0	S270	
Augusta–Moora grav. S.	1963	WAPET	PE-27-H	Grav.	0.0	S54V1	10
Barberton S.S.	1972	WAPET	EP24	Refl.	59.0	S810	
Barragoon S. reconn. S.	1971	WAPET	EP21				
			EP23				
			EP24				
			EP25	Refl.	687.2	S622	
Beagle S. refr. S.	1960	WAPET	PE-27-H	Refr.	172.3	S635V1	
Beagle S.S.	1993	Sagasco	EP100 (R3)				
			EP320				
			L4	Refl.	108.1	S10146	
Beharra Springs S.S.	1987	Barrack	EP100 (R1)				
			EP320	Refl.	177.0	S3122	
Bonniefield detail S.S.	1966	WAPET	PE-27-H	Refl.	83.0	S282	
Bonniefield grav. S.	1984	Lassoc	EP201	Grav.	0.0	S2615	PES2615
Bonniefield S. reconn. S.	1965	WAPET	LP111-H				
			LP126-H				
			PE-27-H	Refl.	10.0	S16V1	607, 625
Bookara aeromag. S.	1984	Lassoc	EP201	Mag.	800.0	S2735	PES2735
Bookara detail S.S.	1965	WAPET	LP111-H				
			LP126-H				
			PE-27-H	Refl.	41.0	S217	
Bookara Shelf S.S.	1982	Mesa	EP232	Refl.	279.0	S2007	PES2007
Brand S.S.	1979	XLX	EP96	Refl.	63.0	S1573	PES1573
Burma S.S.	1982	Pancon	EP111	Refl.	168.0	S1948	PES1948
Cadda detail S.S.	1962	WAPET	PE-27-H	Refl.	292.0	S74V1	
Cattamarra S.S.	1962	WAPET	PE-27-H	Refl.	292.0	S74V2	
Central Perth Basin grav. S.	1963	WAPET	PE-27-H	Grav.	2 534.0	S54V2	10
Cockleshell S.S.	1960	WAPET	PE-27-H	Refl.	31.0	S635V2	
Conder geochem. S.	1988	Doral	EP111 (R1)				
			EP201 (R1)	Geoc.	0.0	S3265	
Conder S87 S.S.	1987	Strata Oil NL	EP111 (R1)				
			EP201 (R1)	Refl.	11.4	S3145	
Coolcalalaya grav. & mag. S.	1973	Sunningdale Oils Pty Ltd	EP48				
			EP69	Grav.	2 027.0	S819	
Coomallo detail S.S.	1990	Barrack	EP320	Refl.	118.4	S3987	
Coomallo Hill S.S.	1989	Barrack	EP100 (R2)				
			EP320	Refl.	76.1	S10001	
Coomallo II S.S.	1973	WAPET	EP21	Refl.	35.0	S835	
Coomallo S.S.	1972	WAPET	EP21				
			EP24	Refl.	146.0	S690	
Coorow 1982 S.S.	1982	Hudbay	EP100	Refl.	292.0	S2078	PES2078
Correy S.S.	1989	Barrack	EP320	Refl.	80.0	S3849	
Cypress Hill S.S.	1988	Ampolex	EP100 (R1)				
			EP321	Refl.	274.0	S3324	
Cypress Hill test S.S.	1989	Ampolex	EP321	Refl.	10.0	S3499	
Dalaroo S.S.	1993	Ampolex	EP3211	Refl.	56.0	S10148	
Dalaroo West grav. & mag. S.	1989	Agnew	EP278 (R1)				
			EP321	Grav.	50.9	S3286	
Dandaragan area mag. S.	1966	WAPET	PE-27-H	Mag.	26.0	S321	
Dandaragan East Flank Detail S.S.	1972	WAPET	EP23				
			EP24				
			EP100 (R2)	Refl.	372.0	S684	
Dandaragan S.S.	1966	WAPET	PE-27-H	Refl.	287.0	S276	

Appendix 1 (*continued*)

Survey name	Year	Company	Tenement	Type	Kms	S-number	Microform
Dandaragan S.S. 1981	1981	Mesa	EP242				
			EP100	Refl.	117.0	S1867	PES1867
Dandaragan West S.S.	1970	WAPET	EP24	Refl.	48.0	S542	
Dempster S.S.	1989	Barrack	EP100 (R2)				
			EP320	Refl.	85.0	S3485	
Depot Hill detail S.S.	1963	WAPET	PE-27-H	Refl.	285.0	S52V1	10, 40
Depot Hill S.S.	1967	WAPET	PE-27-H	Refl.	116.0	S284V1	
Depot S.S.	1966	WAPET	PE-27-H	Refl.	69.0	S284V2	39
Dongara detail S.S.	1963	WAPET	PE-27-H	Refl.	285.0	S52V2	10, 40
Dongara experimental S.S.	1988	WAPET	L1				
			L2	Refl.	22.0	S3306	PES3306
Dongara experimental 2 S.S.	1989	WAPET	L2	Refl.	6.9	S3500	PES3500
Dongara North 3D (483) S.S.	1994	WAPET	L1 (R1)				
			L2 (R1)	3D	469.8	S10201	
Dongara regional S. reconn. S.	1963	WAPET	PE-27-H	Refl.	64.7	S53	10
Dongara S. reconn. S. 1963	1963	WAPET	PE-27-H	Refl.	285.0	S52V3	10, 40
Dongara South West S. reconn. S.	1970	WAPET	EP21				
			EP23	Refl.	122.0	S645V2	39
Dongara 2 S.S.	1978	WAPET	L1				
			L2	Refl.	48.0	S1471	PES1471
Dongara 3 S.S.	1989	WAPET	L1				
			L2	Refl.	171.8	S3540	PES3540
Dongara–Mullewa grav. S.	1962	WAPET	PE-27-H	Grav.	0.0	S59	10
Duggan S.S.	1989	Barrack	EP100 (R2)				
			EP323	Refl.	145.6	S3507	
Eganu grav. S.	1962	WAPET	PE-27-H	Grav.	16.0	S73	14
Eganu S.S.	1964	WAPET	PE-27-H	Refl.	210.0	S159	13
Ejarno detail S.S.	1965	WAPET	LP111-H				
			LP126-H				
			PE-27-H	Refl.	90.0	S216V1	39
Ejarno S. reconn. S.	1965	WAPET	LP111-H				
			LP126-H				
			PE-27-H	Refl.	348.0	S216V2	39
Eneabba S.S.	1960	WAPET	EP21	Refl.	241.0	S676	
Eneabba 1984 S.S.	1984	Strata Oil NL	EP1001				
			EP174	Refl.	180.0	S2441	PES2441
EP111 geochem. S.	1985	Strata	EP96 (R1)				
			EP111 (R1)				
			EP201	GEOC	0.0	S2835	PES2835
EP 23 exp. 1986 S.S.	1986	WMC	EP233	Refl.	20.0	S2928	PES2928
Erangy Spring S.S.	1984	WMC	EP232	Refl.	94.0	S2550	PES2550
Eridon S. reconn. S.	1962	WAPET	PE-27-H	Refl.	282.0	S58	10
Erregulla ext 1 S.S.	1966	WAPET	PE-27-H	Refl.	66.0	S291V1	86
Erregulla S.S. 1966	1966	WAPET	PE-27-H	Refl.	60.0	S291V2	39
Erregulla S.S. 1967	1967	WAPET	PE-27-H	Refl.	27.4	S284V3	PES284
Erregulla West S.S.	1989	Barrack	EP233				
			EP320	Refl.	51.0	S3910	
Erregulla 2 detail S.S.	1970	WAPET	EP23	Refl.	50.0	S1345	86
Erregulla 3 S.S.	1974	WAPET	EP21				
			EP23	Refl.	92.0	S980V1	PES980V1
Erregulla 4 uphole vel. S.	1978	WAPET	EP231	VEL	0.0	S1479	PES1479
Eurangoa S.S.	1990	Barrack	L7	Refl.	34.3	S10002	
Gairdner airborne geochem. S.	1988	Barrack	EP1002	GEOC	800.0	S3334	
Georgina experimental S.S.	1989	Barrack	L7	Refl.	11.5	S3971	
Georgina S.S.	1989	Barrack	EP233				
			L2				
			L7	Refl.	67.2	S3893	
Gingin detail S.S.	1964	WAPET	PE-27-H	Refl.	319.0	S83V1	42, 14
Gingin S. reconn. S.	1956	WAPET	PE-27-H	Refl.	84.0	S83V2	14
Gingin S. refl.. S.	1955	BMR	PE-27-H	Refl.	0.0	S3008	–
Gingin S.S.	1955	WAPET	PE-27-H	Refl.	84.0	S457V2	
Goondaring S.S.	1988	WMC	EP233	Refl.	59.6	S3289	
Goonderoo airborne geochem. S.	1984	Agnew	EP278	GEOC	0.0	S2664	PES2664
Goonderoo geochem. S.	1983	Agnew	EP278	GEOC	0.0	S2318	PES2318
Goonderoo S.S.	1985	Agnew	EP278	Refl.	17.0	S2603	PES2603
Goonderoo West ground mag. S.	1983	Agnew	EP278	Mag.	0.0	S2295	PES2295
Goonderoo 1986 grav. S.	1986	Agnew	EP278				
			EP321	Grav.	0.0	S2962	

Appendix 1 (*continued*)

Survey name	Year	Company	Tenement	Type	Kms	S-number	Microform
Goonderoo 1989 grav. S.	1989	Ampolex	EP100 (R2)				
			EP321	Grav.	23.0	S3545	
Goonderoo 1989 S.S.	1989	Ampol Exploration Ltd	EP100 (R2)				
			EP321	Refl.	201.8	S3466	
Grange S.S.	1970	WAPET	EP23	Refl.	122.0	S645V1	39
Green Head S. refr. S.	1962	WAPET	PE-27-H	REFR	174.0	S57	
Grey S.S.	1979	Hughes and Hughes	EP100	Refl.	152.0	S1496	625
Heaton exp. S.S.	1981	MESA	EP232	Refl.	12.0	S1759	PES1759
Heaton S.S.	1968	WAPET	PE-27-H	Refl.	29.0	S1416V1	
Heelans S.S.	1990	Victoria	EP233				
			EP111 (R2)				
			L7	Refl.	56.4	S3967	
Hill River aeromag. S.	1955	WAPET	PE-27-H	Mag.	0.0	S712V1	39
Hill River detail S.S.	1962	WAPET	PE-27-H	Refl.	249.0	S60	10
Hill River S. & grav. S.	1955	WAPET	PE-27-H	Refl.	26.0	S712V2	39
Hunt Gully detail S.S.	1965	WAPET	LP-111-H				
			LP-126-H				
			PE-27-H	Refl.	35.0	S179	628
Hunt Gully S. reconn. S.	1965	WAPET	LP-111-H				
			LP-126-H				
			PE-27-H	Refl.	348.0	S216V3	39
Irwin Detail S.S.	1964	WAPET	PE-27-H	Refl.	43.0	S155	12
Irwin River airborne geochem. S.	1988	WMC	EP233	GEOC	0.0	S3335	
Irwin River S.S.	1981	Mesa	EP105				
			L1	Refl.	100.0	S1833	607
Karinga geochem. S.	1987	Barrack	EP100 (R1)				
			EP323	GEOC	0.0	S3228	PES3228
Koojan West S.S.	1986	Agnew	EP321	Refl.	12.0	S2995	
Lake Indoon S.S.	1981	Hughes	EP100	Refl.	157.0	S1735	PES1735
Lancelin exp. S.S.	1970	WAPET	PE-27-H	Refl.	39.0	S579	
Lancelin S.S.	1967	WAPET	PE-27-H	Refl.	24.0	S376	PES376
Lancelin 3 S.S.	1973	WAPET	EP24	Refl.	122.0	S841V1	
Logue 1994 S.S.	1994	Congas	EP100 (R3)				
			L4				
			L5	Refl.	136.0	S10210	
Lovegrove S.S.	1993	Sagasco	EP100 (R3)				
			EP320 (R1)	Refl.	109.6	S10145	
Mondarra S.S.	1968	WAPET	PE-27-H	Refl.	145.0	S1416V2	
Mondarra 2 S.S.	1974	WAPET	L1	Refl.	12.0	S980V2	
Mondarra 3 S.S.	1982	WAPET	L1	Refl.	12.0	S2011	PES2011
Mooladarra land S.S. & grav. S.	1975	WAPET	EP 21				
			EP23	Refl.	112.0	S1113	86
Mooladarra 2 land S.S.	1976	WAPET	EP211				
			EP231	Refl.	23.0	S1181	86
Mooratara S.S.	1993	Carnarvon	EP201 (R2)				
			L2	Refl.	14.6	S10167	
Mooriary (Phase 2) S.S.	1987	WMC	EP233	Refl.	42.0	S3138	PES3138
Mooriary S.S.	1987	WMC	EP233	Refl.	66.0	S3114	PES3114
Mount Adam detail S.S.	1980	Layton	EP105	Refl.	59.0	S1474	607
Mount Adams S.S.	1966	WAPET	PE-27-H	Refl.	121.0	S263V1	39
Mount Hill S.S. 1985	1986	Strata	EP111 (R1)	Refl.	75.0	S2768	PES2768
Mount Hill S.S. 1986	1986	Lassoc	EP111 (R1)				
			EP201 (R1)	Refl.	52.0	S2925	PES2925
Mount Hill 80 S.S.	1980	Pancon	EP23				
			EP111	Refl.	12.0	S1713	PES1713
Mount Horner airborne spectrometer survey	1985	Metramar	EP96 (R1)	R	0.0	S2889	PES2889
Mount Horner ground geochem. S.	1985	Metramar	EP96 (R1)	GEOC	0.0	S2911	PES2911
Mullering S.S.	1973	WAPET	EP24	Refl.	74.0	S841V2	
Mullering 2 S.S.	1975	WAPET	EP24	Refl.	38.0	S983	PES983
Mungarra detail S.S.	1963	WAPET	PE-27-H	Refl.	285.0	S52V4	10, 40
Mungarra 1980 S.S.	1981	Pancon	EP232				
			EP111	Refl.	384.0	S1738	PES1738
Namban (Lancelin) S.S.	1969	WAPET	PE-27-H	Refl.	69.0	S478	
Nhargo S.S.	1984	Lassoc Pty Ltd	EP96 (R1)				
			EP201	Refl.	30.0	S2706	PES2706

Appendix 1 (*continued*)

Survey name	Year	Company	Tenement	Type	Kms	S-number	Microform
Nine Mile exp. S.S.	1984	Lassoc Pty Ltd	EP201	Refl.	5.0	S2573	
Nine Mile S.S.	1984	Lassoc Pty Ltd	EP201	Refl.	31.0	S2602	PES2602
North Perth A.L.F.	1989	BP	SI1/1988-89	S	6 593.0	S3862V2	PES3862
North Perth Basin detail grav. S.	1965	WAPET	PE-27-H				
			PE-228-H	Grav.	0.0	S286	39
Northampton grav. S.	1955	WAPET	PE-27-H	Grav.	0.0	S931	CVS931
Northern Perth Basin digital refl.. S.	1965	WAPET	LP-111-H				
			LP-126-H				
			PE-27-H	Refl.	87.0	S16V2	607, 625
Ocean Hill S.S.	1988	Barrack	EP320	Refl.	90.6	S3444	
Pacific S.S.	1981	Pacific	EP96	Refl.	140.0	S1845	PES1845
Peron S.S.	1961	WAPET	PE-27-H	Refl.	11.0	S651	
Perth Basin grav. S.	1952	BMR	PE-27-H	Grav.	0.0	S3001	-
Perth Basin grav. S.	1956	WAPET	PE-27-H	Grav.	0.0	S416	39
Poodooloo S.S.	1965	French	PE-228-H	Refl.	75.0	S222	
P81 S.S.	1981	Aquitaine	EP100				
			EP174	Refl.	272.0	S740	624
Rakrani S.S.	1989	Lassoc	EP201 (R1)	Refl.	40.2	S3530	
Sangaree grav. S.	1990	Ampolex	EP100				
			EP321	Grav.	20.0	S10013	
Skipper S.S.	1990	Barrack	EP233				
			EP320	Refl.	78.0	S10005	
Strawberry Bridge 1988 geochem.S.	1988	WMC	EP233				
			EP320	GEOC	132.0	S3415	
Tabletop S.S.	1989	Barrack	L2				
			L7	Refl.	51.1	S3326	PES3326
Tabletop 1994 S.S. & ext. S.	1994	Victoria	EP111 (R2)	Refl.	24.5	S10209	
Terling grav. S. & ext. S.	1982	CRA	EP181				
			EP278	Grav.	150.0	S2204V1	PES 2204
Terling grav. S. & extension S.	1983	CRA	EP181	Grav.	50.0	S2204V2	PES 2204
Tomkins S.S.	1989	Barrack	EP320				
			L1	Refl.	77.5	S3790	
Wakeford S.S.	1987	Lassoc	EP96 (R2)				
			EP111 (R1)				
			EP201 (R1)	Refl.	77.0	S3124	
Walcott S.S.	1989	WMC	EP233				
			EP320				
			L2	Refl.	130.0	S3523	
Walyering detail S.S.	1970	WAPET	EP 24	Refl.	35.0	S595	
Walyering S.S.	1967	WAPET	PE-27-H	Refl.	134.0	S340	BMR
Walyering West detail S.S.	1971	WAPET	EP24	Refl.	130.0	S661	
Warradong S. reconn. S.	1962	WAPET	PE-27-H	Refl.	55.0	S61	
Warradong S.S.	1966	WAPET	PE-27-H	Refl.	71.0	S263V3	39
			EP23				
			L1	Refl.	47.0	S845	
Warramia S.S.	1991	Ampolex	EP100 (R2)				
			EP321				
			EP351	Refl.	89.0	S10053	
Wedge Island S. reconn. S.	1966	WAPET	PE-27-H	Refl.	198.0	S290	
White Point detail S.S.	1968	WAPET	PE-27-H	Refl.	25.0	S344V3	86
White Point East S.S.	1972	WAPET	L1	Refl.	24.0	S777	625
Wicherina detail S.S.	1963	WAPET	PE-27-H	Refl.	235.0	S52V5	10, 40
Winchester land S.S. & grav. S.	1975	WAPET	EP24	Refl.	42.0	S1114	PES1114
Winchester 2 S.S.	1976	WAPET	EP241	Refl.	42.0	S1180	PES1180
Wondado Spring airborne spectrometer S.	1985	Balmoral	EP201	R	0.0	S2893	PES2893
Woodada S. reconn. S. & grav. S. spectrometer S.	1965	French	PE-228-H	Refl.	211.0	S171	13, 86
Woolka S.S.	1990	Barrack	EP100 (R2)				
			EP323	Refl.	224.8	S10000	
Woolmulla Detail S.S.	1962	WAPET	PE-27-H	Refl.	72.0	S48	10
Woolmulla South detail S.S.	1962	WAPET	PE-27-H	Refl.	163.0	S74V3	
Woolmulla South S.S.	1989	Barrack	EP100 (R2)	Refl.	85.9	S3524	
Wye Springs S.S.	1987	Barrack	EP96 (R2)				
			L7	Refl.	20.0	S3123	PES3123
Yallalie aeromag. S.	1989	Ampol Exploration Ltd	EP100 (R2)				
			EP321	Mag.	220.0	S3464	

Appendix 1 (*continued*)

Survey name	*Year*	*Company*	*Tenement*	*Type*	*Kms*	*S-number*	*Microform*
Yandanooka S.S.	1992	Sagasco	EP100 (R1)				
			EP320				
			L1	Refl.	262.7	S10091	
Yardanogo North S.S.	1990	Barrack	EP100				
			EP320	Refl.	44.0	S10006	
Yardanogo S.S.	1989	Barrack	EP233				
			EP100 (R2)				
			EP320	Refl.	212.0	S3456	
Yardarino detail S.S.	1963	WAPET	PE-27-H	Refl.	285.0	S52V6	40
Yardarino 2 S.S.	1975	WAPET	EP23				
			L2	Refl.	16.0	S980V3	

Note: S.S. = seismic survey

Appendix 2

Seismic lines used in this report

Survey name	Line number	Shotpoint range	Year of processing
Barragoon S reconn. S.	Arrowsmith–Carnamah AE	1 – 61	1989
	Arrowsmith–Carnamah AF	1 – 111	
	Arrowsmith–Gingin–Hl–Moora AZ	1 – 90	
	Arrowsmith–Gingin–Hl–Moora AZ	1 – 244	
	Gingin–Hill River–Warro–Moora BA	1 – 191	
	Hill River–Namban AS	1 – 139	
	Hill River–Warro AT	1 – 115	
	Hill River–Warro AW	1 – 202	
	Hill River–Warro AX	1 – 120	
	Moora–Namban AH	1 – 73	
	Moora–Namban AJ	1 – 204	
	Warro U	1 – 64	
	Warro–Carnamah T	1 – 225	
Beharra Springs S.S.	B87-004	80 – 750	1982
	B87-007	100 – 432	
	B87-011	100 – 1 350	
	B87-013	100 – 476	
	B87-014	86 – 642	
	B87-017	100 – 540	
	B87-018	38 – 586	
Bookara Shelf S.S.	BS82-003	3 695 – 103	1982
	BS82-004	1 500 – 3 875	
	BS82-005	3 550 – 131	
	BS82-006	101 – 2 001	
	BS82-007	101 – 1 783	
	BS82-009	1 921 – 101	
	BS82-011	101 – 2 943	
	BS82-014	137 – 3 550	
Brand S.S.	79-002	101 – 287	1980
	79-003	101 – 227	
Coomallo detail S.S.	B89-450	100.5 – 684.5	1990
	B89-451	162.5 – 726.5	
	B89-452	116.5 – 726.5	
	B89-455	96.5 – 700.5	
Coomallo Hill S.S.	B89-413	252.5 – 1 198.5	1990
	B89-414	112.5 – 1 200.5	
	B89-415	100.5 – 1 050.5	
Coomallo S.S.	P72-041L	1 – 60	1989
	P72-042L	1 – 90	
	P72-043L	1 – 181	
	P72-045L	1 – 76	
	P72-046L	1 – 83	
	P72-047L	1 – 88	
Coorow 1982 S.S.	HP82-201	122 – 260	1984
	HP82-202	102 – 250	
	HP82-210	102 – 384	
	HP82-214	100 – 286	
	HP82-215	100 – 413	
	HP82-216	100 – 386	
	HP82-217	100 – 414	
	HP82-219	34 – 369	
	HP82-221	102 – 423	
	HP82-224	102 – 385	
	HP82-225	100 – 380	
Correy S.S.	B89-407	102.5 – 700.5	1990
	B89-408	102.5 – 550.5	
	B89-409	100.5 – 1 500.5	
	B89-410	100.5 – 600.5	
	B89-411	100.5 – 1 150.5	
Cypress Hill S.S.	A88-100	100 – 400	1988
	A88-108	100 – 400	
	A88-112	138 – 500	
	A88-124	100 – 400	

Appendix 2 (*continued*)

Survey name	Line number	Shotpoint range	Year of processing
Cypress Hill S.S. (cont.)	A88-126	100 – 598	
	A88-127	100 – 926	
	A88-132	100 – 870	
	A88-140	100 – 784	
Cypress Hill test S.S.	A89-132	267 – 764	1989
Dandaragan East Flank detail S.S.	P72-025L	1 – 103	1989
	P72-026L	1 – 111	
	P72-027L	1 – 102	
	P72-028L	1 – 70	
	P72-029L	1 – 100	
	P72-030L	1 – 49	
	P72-031L	1 – 220	
	P72-032L	1 – 96	
	P72-033L	1 – 60	
	P72-034L	1 – 69	
	P72-035L	1 – 69	
	P72-036L	1 – 107	
	P72-037L	1 – 138	
	P72-039L	1 – 47	
Dandaragan S.S.	Moora C	500 – 594	1966
	Warro H	500 – 695	
	Warro M	504 – 582	
	Warro–Moora J	511 – 794	
Dandaragan S.S. 1981	D81-008A	601 – 709	1982
	D81-010	120 – 410	
Dandaragan West S.S.	Moora AC	1 – 134	1970
	Moora AE	1 – 215	
Dempster S.S.	B89-301	100 – 1 650	1989
	B89-302	100 – 1 100	
	B89-306	100 – 1 600	
	B89-307	100 – 1 500	
	B89-308	100 – 1 500	
Depot Hill S.S.	Dongara DK	511.5 – 751.5	1987
	Dongara DW	910 – 990	
	Dongara DW	980.5 – 1 182.5	
Dongara experimental 2 S.S.	P89-011	100 – 444	1989
Dongara 3 S.S.	P89-003L	102 – 1 084	1989
	P89-004L	100 – 549	
	P89-005L	98 – 724	
	P89-006L	68 – 458	
	P89-007L	50 – 723	
	P89-009L	100 – 628	
	P89-011L	548 – 912	
	P89-013L	128 – 731	
	P89-014L	62 – 827	
	P89-015L	103 – 760	
Duggan S.S.	BD89-101	180.5 – 1 266.5	1989
	BD89-102	188.5 – 1 300.5	
	BD89-103	178.5 – 750.5	
	BD89-104	100.5 – 1 512.5	
	BD89-105	100.5 – 940.5	
	BD89-106	100.5 – 600.5	
	BD89-107	100.5 – 500.5	
Eneabba 1984 S.S.	S84-002	4000 – 5380	1984
	S84-013	16 400 – 18 090	
EP23 exp. 1986 S.S.	X86-001	544 – 1 660	1986
Erangy Spring S.S.	ES84-003	100 – 1 212	1984
	ES84-006	100 – 2 942	
	ES84-013	100 – 600	
	ES84-014	100 – 1 202	
Erregulla 3 S.S.	P74-001L	1 – 157	1974
Georgina experim. S.S.	B89-422	99.5 – 675.5	1990
Georgina S.S.	B89-419	100.5 – 827.5	1990
Goondaring S.S.	88-007	103 – 473	1988
Goonderoo 1989 S.S.	A89-700	100 – 620	1989
	A89-702	120 – 650	
	A89-703	100 – 644	

Appendix 2 (*continued*)

Survey name	*Line number*	*Shotpoint range*	*Year of processing*
Goonderoo 1989 S.S. (cont.)	A89-705	114 – 1 150	
	A89-706	100 – 936	
	A89-708	100 – 936	
	A89-709	100 – 950	
	A89-710	148 – 1 012	
	A89-711	100 – 776	
	A89-712	188 – 746	
Grey S.S.	G79-002 Winooka	104 – 248	1979
	G79-016 Woodada	100 – 224	
Heelans S.S.	V90-001	153.5 – 794.5	1990
	V90-007	100.5 – 520.5	
Irwin River S.S.	81-R-003	100 – 259	1989
	81-R-009	100 – 248	
Lake Indoon S.S.	81-064A	18 – 156	1981
	81-067	15 – 589	
	81-068	15 – 246	
	81-069	15 – 96	
	81-074	15 – 204	
	81-117	67 – 235	
	81-118	15 – 415	
	81-119	27 – 100	
Lancelin 3 S.S.	P73-007L	251 – 601	1989
	P73-008L	3 – 357	
	P73-009L	1 – 269	
	P73-010L	5 – 130	
	P73-011L	1 – 92	
	P73-016L	1 – 182	
Mondarra S.S.	FB	750 – 990	1968
Mooladarra land S.S.	P75-012L	1 – 103	1975
& grav. S.	P75-013L	1 – 110	
	P75-014L	1 – 110	
	P75-016L	93 – 168	
	P75-020L	1 – 150	
Mooladarra 2 land S.S.	P76-005L	2 – 114	1976
	P76-006L	1 – 145	
Mooriary S.S.	87-003	676 – 2 116	1987
	87-004	188 – 548	
Mount Adam detail S.S.	A80-002	128 – 228	1980
	A80-006	130 – 258	
Mount Hill S.S. (1985)	S86-001	1 100 – 1 370	1988
	S86-005	100 – 636	
	S86-007	3 506 – 3 790	
	S86-009	4 400 – 4 750	
Mullering S.S.	P73-014L	1 – 63	1989
	P73-015L	1 – 64	
Mungarra 1980 S.S.	P80-100	125 – 388	1992
	P80-104	300 – 592	
	P80-107	440 – 790	
Nine Mile S.S.	84-01E	454 – 1 448	1984
	84-02	100 – 1 450	
	84-02E	100 – 1 450	
	84-03E	90 – 1 000	
	84-04E	100 – 515	
	84-05E	100 – 456	
Ocean Hill S.S.	B88-319	118 – 638	1989
	B88-320	100 – 580	
	B88-323	100 – 1 340	
Pacific S.S.	81-002	126 – 504	1981
	81-003	276 – 505	
P81 S.S.	P81-101	116 – 680	1981
	P81-106	100 – 310	
	P81-107	108 – 320	
	P81-110	100 – 321	
P81 S.S.	P81-112	115 – 404	
	P81-204	100 – 249	

Appendix 2 (*continued*)

Survey name	*Line number*	*Shotpoint range*	*Year of processing*
Rakrani S.S.	LP89-001	100 – 400	1989
	LP89-002	100 – 386	
	LP89-005	100 – 346	
	LP89-008	106 – 270	
Skipper S.S.	B90-469	100.5 – 700.5	1990
	B90-470	100.5 – 700.5	
	B90-471	100.5 – 2 200.5	
Tabletop S.S.	BD89-107	100.5 – 900.5	1989
Wakeford S.S.	87-024	99 – 1 350	1987
	87-028	1 – 652	
	87-030	100 – 700	
	87-032	100 – 799	
Walcott S.S.	89-001	100 – 594	1989
	89-004	92 – 1 130	
	89-008	100 – 826	
	89-010	100 – 650	
Walyering S.S.	AB	988.5 – 722.5	1990
	Z	988.5 – 712.5	
Walyering West detail S.S.	AK	1 – 51	1990
	AN	1 – 82	
	AQ	1 – 116	
Warradong 2 S.S.	P73-020l	1 – 90	1973
Warramia S.S.	A91-001	80 – 568	1991
	A91-002	114 – 555	
	A91-004	100 – 620	
	A91-006	100 – 570	
	A91-007	100 – 858	
	A91-008	100 – 910	
Winchester land S.S. & grav. S.	P75-004L	1 – 190	1990
	P75-021L	1 – 156	
Winchester 2 S.S.	P76-002L	1 – 165	1989
	P76-003L	1 – 134	
Woolka S.S.	B89-435	86.5 – 1 132.5	1990
	B89-436	100.5 – 1 100.5	
	B89-437	94.5 – 1 192.5	
	B89-439	103.5 – 1 200.5	
	B89-445	100.5 – 1 100.5	
	B89-447	102.5 – 1 650.5	
Woolmulla South S.S.	B89-301	103 – 1 600	1989
	B89-302	100 – 1 750	
	B89-303	100 – 1 550	
	B89-304	100 – 1 350	
	B89-305	100 – 1 290	
	B89-306	104 – 1 650	
Wye Springs S.S.	B87-023	102 – 902	1987
Yardanogo S.S.	B88-007X	100 – 280	1989
	B88-301	100 – 499	
	B88-303	100 – 500	
	B88-305	100 – 600	
	B88-306	100 – 1 060	
	B88-308	100 – 751	
	B88-309	100 – 900	
	B88-313	100 – 660	
	B88-314	100 – 860	
Yandanooka S.S.	S92-01N	1 136 – 1 550	1992
	S92-01	100 – 874	
	S92-02	110 – 2 234	
	S92-06	100 – 714	
	S92-07	100 – 1 034	
	S92-18	104 – 1 316	
	S92-18	106 – 1 048	
	S92-20	100 – 1 034	

Note: S.S. = seismic survey

Appendix 3

Wells drilled for petroleum exploration in the onshore northern Perth Basin

Well name	*S-no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Operator*	*Status 1*	*Status 2*	*Gas show*	*Oil show*
Allanooka 1	188	NFW	29°08'37"	115°00'47"	51	1 187	L. Permian	1965	WAPET	Dry	P&A	Nil	Nil
Allanooka 2	191	NFW	29°06'04"	114°59'42"	70	1 006	Precambrian	1965	WAPET	Dry	P&A	Nil	Nil
Arramall 1	3442	NFW	29°35'28"	115°05'45"	37	2 250	Precambrian	1989	Barrack	Dry	P&A	Poor	Poor
Arranoo 1	20206	NFW	29°08'24"	115°04'38"	161	1 750	L.Permian	1994	Discovery	Dry	P&A	Nil	Good
Arranoo South 1	20274	NFW	29°09'24"	115°05'01"	150	1 782	L. Permian	1994	Discovery	Dry	P&A	Poor	Poor
Arrowsmith 1	203	NFW	29°36'42"	115°06'55"	56	3 446	Precambrian	1965	French	Gas	P&A	Excl	Nil
Barberton 1	20030	NFW	30°49'09"	115°58'20"	237	3 414	L. Triassic	1990	Ampolex	Dry	P&A	Nil	Nil
Beekeeper 1	1964	NFW	29°42'52"	115°11'07"	51	3 012	L. Permian	1982	Aquitaine	Dry	P&A	Nil	Nil
Beharra Springs 1	20009	NFW	29°27'55"	115°08'23"	49	3 700	L. Permian	1990	Arrow	Gas	Well	Prod	Poor
Beharra Springs 2	20061	EXT	29°28'45"	115°08'37"	57	3 493	L. Permian	1991	Arrow	Gas	Well	Prod	Poor
Beharra Springs 3	20092	EXT	29°27'05"	115°08'21"	51	3 505	L. Permian	1992	Sagasco	Gas	Well	Prod	Nil
Beharra 1	333	NFW	29°29'14"	115°00'52"	27	2 056	Precamb	1966	French	Dry	P&A	Nil	Nil
Beharra 2	336	NFW	29°30'59"	115°01'22"	33	1 924	L. Permian	1967	French	Dry	P&A	Nil	Nil
BMR 10	3048 A1	STR	29°49'38"	114°58'30"	6	1 192	L. Permian	1959	BMR	Dry	P&A	Nil	Nil
BMR 10A	3048 A2	STR	29°49'36"	114°58'30"	8	1 482	Precamb	1960	BMR	Dry	P&A	Nil	Nil
Bonniefield 1	2689	NFW	29°10'17"	114°54'47"	21	1 012	Precambrian	1985	Balmoral	Dry	P&A	Poor	Nil
Bookara 2	384	STR	29°10'03"	114°54'36"	11	762	L. Triassic	1967	WAPET	Dry	P&A	Nil	Nil
Bookara 3	385	STR	29°06'31"	114°53'20"	33	538	Precambrian	1967	WAPET	Dry	P&A	Nil	Nil
Cadda 1	226	NFW	30°20'15"	115°12'48"	82	2 795	Precambrian	1965	French	Dry	P&A	Poor	Nil
Cataby 1	20220	NFW	30°41'15"	115°19'56"	65	2 298	L. Jurassic	1994	Discovery	Dry	P&A	Fair	Good
Conder 1	3351	NFW	29°02'43"	114°55'22"	29	253	Precambrian	1988	Doral	Dry	P&A	Nil	Poor
Connolly 1	3355	NFW	29°02'16"	114°57'06"	112	478	Precambrian	1988	Doral	Dry	P&A	Nil	Poor
Coomalloo 1	953	NFW	30°14'56"	115°24'57"	258	3 520	L. Jurassic	1974	WAPET	Dry	P&A	Nil	Nil
Cypress Hill 1	3361	NFW	30°27'51"	115°48'42"	215	990	U. Jurassic	1988	Ampolex	Water	Well	Nil	Nil
Dandaragan 1	20307	NFW	30°35'52"	115°48'27"	270	1 103	U. Jurassic	1995	Discovery	Dry	Susp	Poor	Good
Denison 1	1307	NFW	29°13'32"	114°57'17"	35	2 300	L. Permian	1977	WAPET	Dry	P&A	Nil	Nil
Depot Hill 1	2346	NFW	29°06'30"	115°19'32"	270	2 473	L. Permian	1983	Mesa	Dry	P&A	Nil	Nil
Dongara 1	303	NFW	29°15'12"	114°59'21"	49	2 161	L. Permian	1966	WAPET	Gas & oil	Well	Prod	Prod
Dongara 2	307	EXT	29°14'58"	114°58'36"	27	1 745	L. Permian	1966	WAPET	Gas	Shut in	Prod	Nil
Dongara 3	319	EXT	29°15'32"	115°00'04"	32	1 775	L. Permian	1966	WAPET	Gas	Well	Prod	Nil
Dongara 4	347	EXT	29°13'50"	114°58'56"	65	1 818	L. Permian	1967	WAPET	Gas	Shut in	Prod	Nil
Dongara 5	386	EXT	29°11'19"	114°59'01"	32	1 808	L. Permian	1967	WAPET	Dry	P&A	Nil	Nil
Dongara 6	395	EXT	29°11'45"	114°56'22"	25	1 559	Precambrian	1967	WAPET	Dry	P&A	Nil	Nil
Dongara 7	401	EXT	29°18'37"	115°01'42"	47	2 164	L. Permian	1968	WAPET	Dry	P&A	Nil	Nil
Dongara 8	465	EXT	29°15'09"	115°01'21"	54	1 899	L. Permian	1969	WAPET	Oil & gas	Shut in	Prod	Prod
Dongara 9	466	EXT	29°13'31"	115°00'08"	87	1 910	L. Permian	1969	WAPET	Gas	Well	Prod	Nil
Dongara 10	468	EXT	29°14'24"	115°00'15"	72	2 042	L. Permian	1969	WAPET	Gas & oil	Well	Prod	Good
Dongara 11	490	EXT	29°16'04"	115°00'32"	67	1 835	L. Permian	1969	WAPET	Gas	Well	Prod	Nil
Dongara 12	496	EXT	29°14'21"	115°01'17"	29	2 013	L. Permian	1969	WAPET	Gas	Well	Prod	Fair
Dongara 13	499	EXT	29°12'50"	114°59'47"	88	2 033	L. Permian	1969	WAPET	Dry	P&A	Nil	Poor
Dongara 14	506	EXT	29°13'32"	115°01'03"	77	1 918	L. Permian	1969	WAPET	Oil	Shut in	Nil	Prod
Dongara 15	501	EXT	29°16'32"	115°01'02"	66	1 939	L. Permian	1969	WAPET	Gas	Shut in	Prod	Nil

Appendix 3 (*continued*)

Well name	*S-no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Operator*	*Status 1*	*Status 2*	*Gas show*	*Oil show*
Dongara 16	524	EXT	29°16'14"	114°59'34"	29	1 924	L. Permian	1969	WAPET	Gas	P&A	Prod	Nil
Dongara 17	529	EXT	29°17'10"	115°01'39"	82	1 949	L. Permian	1969	WAPET	Oil	Shut in	Nil	Prod
Dongara 18	535	EXT	29°16'33"	115°02'01"	105	1 920	L. Permian	1970	WAPET	Gas & oil	Well	Prod	Prod
Dongara 19	538	EXT	29°16'19"	115°02'43"	114	2 179	L. Permian	1970	WAPET	Gas &oil	Shut in	Prod	Prod
Dongara 20	1005	DEV	29°16'03"	115°01'18"	81	1 939	L. Permian	1974	WAPET	Gas	Well	Prod	Nil
Dongara 21 St1	1591	DEV	29°14'07"	115°00'31"	90	1 889	L. Permian	1980	WAPET	Gas	Shut in	Prod	Nil
Dongara 22	1607	DEV	29°14'57"	114°58'43"	36	1 800	L. Permian	1980	WAPET	Dry	Shut in	Prod	Nil
Dongara 23	1753	DEV	29°15'44"	115°00'20"	27	1 765	L. Permian	1981	WAPET	Gas	Well	Prod	Nil
Dongara 24	1799	DEV	29°14'14"	115°01'01"	30	1 808	L. Permian	1981	WAPET	Gas	Shut in	Prod	Good
Dongara 25	1823	DEV	29°14'35"	115°01'29"	55	1 830	L. Permian	1981	WAPET	Gas	Well	Prod	Fair
Dongara 26	20006	DEV	29°14'50"	114°58'15"	23	1 830	L. Permian	1990	WAPET	Dry	P&A	Nil	Nil
Dongara 27	20007	DEV	29°12'06"	115°01'19"	38	1 730	L. Permian	1990	WAPET	Dry	P&A	Fair	Fair
Donkey Creek 1	320	NFW	29°37'35"	115°17'25"	111	3 853	L. Triassic	1966	French	Dry	P&A	Nil	Nil
East Heaton 1	2736	NFW	29°06'52"	115°14'59"	259	2 520	L. Permian	1985	WMC	Dry	P&A	Nil	Nil
E. Lake Logue 1	2287	NFW	29°50'03"	115°09'12"	54	2 430	L. Permian	1983	Hudbay	Gas	Susp	Prod	Nil
E. Lake Logue 2	20138	DEV	29°49'09"	115°09'17"	46	2 303	L. Permian	1992	Consol	Gas	Well	Prod	Poor
Eganu 1	35	STR	29°59'09"	115°49'42"	237	600	M. Jurassic	1963	WAPET	Dry	P&A	Nil	Nil
Ejarno 1	1803	NFW	29°18'54"	115°04'33"	80	2 868	Permian	1981	WAPET	Dry	P&A	Nil	Nil
Eleven Mile 1	3366	NFW	29°04'39"	114°52'57"	37	322	Precambrian	1988	Lassoc	Dry	P&A	Nil	Nil
Eneabba 1	34	NFW	29°34'14"	115°19'56"	127	4 179	L. Triassic	1961	WAPET	Dry	P&A	Good	Poor
Erregulla 1	293	NFW	29°22'38"	115°23'51"	237	4 244	L. Permian	1966	WAPET	Oil	P&A	Fair	Excl
Erregulla 2	1584	EXT	29°22'31"	115°23'51"	248	3 577	M. Triassic	1980	Mesa	Dry	P&A	Poor	Poor
Eurangoa 1	219	NFW	29°07'38"	115°08'16"	254	2 277	L. Permian	1965	WAPET	Dry	P&A	Nil	Nil
Gairdner 1	20040	NFW	30°04'17"	115°08'45"	182	2 172	Precambrian	1990	Arrow	Dry	P&A	Nil	Poor
Georgina 1	1830	NFW	29°08'41"	115°04'25"	146	1 831	L. Permian	1981	XLX	Dry	P&A	Poor	Poor
Goonderoo Corehole 1	2262V 1	NFW	30°30'45"	116°02'06"	237	28	Precambrian	1982	Agnew Clg	Dry	Susp	Nil	Nil
Goonderoo Corehole 1A	2262V 2	NFW	30°30'45"	116°02'06"	237	25	Precambrian	1982	Agnew Clh	Dry	Susp	Nil	Nil
Green Head 1	M7391	Coal	30°06'00"	115°05'04"	62	685	E. Permian	1974	Amax	Dry	Abd	Poor	Nil
Green Head 2	M7391	Coal	30°08'20"	115°00'00"	2	328	L. Triassic	1974	Amax	Dry	Abd	Nil	Nil
Green Head 3	M7391	Coal	30°00'00"	115°04'02"	54	690	E. Permian	1974	Amax	Dry	Abd	Nil	Nil
Heaton 1	702	NFW	29°07'18"	115°12'45"	190	2 438	E. Permian	1972	Abrolhos	Dry	P&A	Nil	Nil
Hill River 1	15 A1	STR	30°16'04"	115°18'45"	112	579	L. Jurassic	1962	WAPET	Water	Well	Nil	Nil
Hill River 2	15 A2	STR	30°11'00"	115°14'07"	191	494	L. Jurassic	1962	WAPET	Dry	P&I	Nil	Nil
Hill River 2A	15 A5	STR	30°11'16"	115°14'07"	184	116	L. Jurassic	1962	WAPET	Dry	Abd	Nil	Nil
Hill River 3	15 A3	STR	30°00'36"	115°11'20"	126	264	L. Jurassic	1962	WAPET	Dry	P&A	Nil	Nil
Hill River 4	15 A4	STR	30°23'28"	115°13'56"	94	308	L. Triassic	1962	WAPET	Dry	P&A	Nil	Nil
Hill River 4/1	15 A4	STR	30°21'43"	115°12'20"	68	155	L. Jurassic	1962	WAPET	Dry	P&A	Nil	Nil
Hill River 4/2	15 A4	STR	30°21'39"	115°12'41"	72	155	U. Triassic	1962	WAPET	Dry	P&A	Nil	Nil
Hill River 4/3	15 A4	STR	30°22'41"	115°13'10"	74	155	U. Triassic	1962	WAPET	Dry	P&A	Nil	Nil
Hill River 4/4	15 A4	STR	30°22'36"	115°13'41"	87	155	U. Triassic	1962	WAPET	Dry	P&A	Nil	Nil
Horner West 1	3133	NFW	29°08'12"	115°02'34"	98	1 451	U. Permian	1987	Barrack	Dry	P&A	Nil	Nil
Hunt Gully 1	3330	NFW	29°05'54"	115°09'07"	243	1 983	L. Permian	1988	Barrack	Dry	P&A	Nil	Poor
Huntswell 1	20256	NFW	29°07'04"	115°07'47"	250	1 903	L. Permian	1994	Discovery	Dry	P&A	Fair	Fair
Indoon 1	2251	NFW	29°53'01"	115°09'04"	43	2 257	L. Permian	1982	Hudbay	Gas	Well	Prod	Nil
Jay 1	20187	NFW	29°04'44"	115°03'23"	134	1 295	L. Jurassic	1993	Victoria	Dry	P&A	Nil	Poor
Jurien 1	40	NFW	30°08'44"	115°02'54"	12	1 026	Precambrian	1962	WAPET	Dry	P&A	Poor	Nil
Mondarra 1	445	NFW	29°18'06"	115°07'00"	83	3 063	L. Permian	1968	WAPET	Gas	Well	Prod	Poor

Appendix 3 (*continued*)

Well name	*S-no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Operator*	*Status 1*	*Status 2*	*Gas show*	*Oil show*
Mondarra 2	451	EXT	29°21'09"	115°06'12"	31	2 854	L. Permian	1969	WAPET	Gas	Well	Prod	Nil
Mondarra 3	464A4	EXT	29°17'36"	115°06'46"	103	2 987	L. Permian	1969	WAPET	Oil	P&A	Poor	Good
Mondarra 4	491	EXT	29°19'13"	115°06'05"	49	2 895	U. Permian	1969	WAPET	Dry	P&A	Poor	Nil
Mooratara 1	20207	NFW	29°12'51"	114°54'32"	8	1 630	L. Permian	1993	Royal	Dry	P&A	Nil	Nil
Mountain Bridge 1	20156	NFW	29°36'05"	115°06'06"	46	3 416	L. Permian	1993	Sagasco	Dry	P&A	Good	Poor
Mount Adams 1	288	NFW	29°24'25"	115°10'00"	91	3 791	L. Permian	1966	WAPET	Dry	P&A	Fair	Poor
Mount Hill 1	193	STR	29°04'09"	114°59'02"	117	565	L. Triassic	1964	WAPET	Dry	P&A	Poor	Nil
Mount Horner 1	195	NFW	29°07'46"	115°05'06"	200	2 252	L. Permian	1965	WAPET	Oil	Shut in	Nil	Prod
Mount Horner 2	204	EXT	29°08'45"	115°04'40"	155	2 056	L. Permian	1965	WAPET	Dry	P&A	Nil	Poor
Mount Horner 3	1707	EXT	29°07'47"	115°05'06"	198	1 558	L. Permian	1980	XLX	Oil	Susp	Nil	Prod
Mount Horner 4	1730	EXT	29°07'49"	115°05'24"	219	1 816	L. Permian	1981	XLX	Dry	Susp	Poor	Poor
Mount Horner 4A	3272	DEV	29°07'47"	115°05'25"	211	1 265	L. Jurassic	1988	Barrack	Oil	Well	Nil	Prod
Mount Horner 5	1793	EXT	29°07'36"	115°05'17"	216	1 819	L. Permian	1981	XLX	Oil	Well	Poor	Prod
Mount Horner 5A	3279	DEV	29°07'37"	115°05'20"	217	1 280	L. Jurassic	1988	Barrack	Oil	Well	Nil	Prod
Mount Horner 6	2476	DEV	29°08'12"	115°05'25"	205	1 850	Permian	1983	Barrack	Dry	P&A	Nil	Poor
Mount Horner 7	3132	EXT	29°07'28"	115°05'29"	217	1 848	U. Permian	1987	Barrack	Oil	Well	Nil	Prod
Mount Horner 8	3312	DEV	29°08'01"	115°05'30"	201	1 306	L. Jurassic	1988	Barrack	Oil	Well	Nil	Prod
Mount Horner 9	3302	EXT	29°07'41"	115°05'35"	216	1 310	L. Jurassic	1988	Barrack	Oil	Well	Nil	Prod
Mount Horner 10	3377	DEV	29°07'56"	115°05'47"	217	1 451	L. Jurassic	1989	Arrow	Oil	Well	Nil	Prod
Mount Horner 11	3715	DEV	29°08'50"	115°06'32"	181	1 408	L. Jurassic	1989	Arrow	Dry	P&A	Nil	Poor
Mount Horner 12	20134	DEV	29°07'23"	115°04'59"	191	1 805	L. Jurassic	1992	Arrow	Oil	Well	Nil	Prod
Mount Horner 13	20153	DEV	29°07'09"	115°04'49"	179	1 676	L. Permian	1993	Discovery	Oil	Well	Poor	Prod
Mount Horner 14	20194	DEV	29°07'26"	115°05'14"	202	1 803	L. Permian	1993	Discovery	Oil	Well	Fair	Prod
Mullering 1	20119	NFW	30°41'27"	115°19'30"	61	1 666	L. Jurassic	1992	Arrow	Dry	P&A	Nil	Nil
Narkarino 1	2523	NFW	29°07'06"	114°54'00"	29	600	L. Triassic	1984	Balmoral	Dry	P&A	Nil	Nil
Narlingue 1	701	NFW	29°04'14"	115°06'10"	197	2 130	L. Permian	1972	Abrolhos	Dry	P&A	Nil	Nil
North Erregulla 1	383	NFW	29°14'44"	115°19'34"	167	3 444	L. Permian	1967	WAPET	Dry	P&A	Poor	Good
North Yardanogo 1	3995	NFW	29°28'03"	115°06'05"	42	2 387	U. Triassic	1990	Barrack	Oil	Susp	Nil	Excl
North Yardarino 1	1801	NFW	29°11'24"	115°02'24"	63	2 207	Permian	1981	WAPET	Dry	P&A	Nil	Nil
Ocean Hill 1	20066	NFW	29°56'13"	115°23'47"	220	3 840	L. Jurassic	1991	Arrow	Dry	P&A	Good	Fair
Peron 1	2313	NFW	29°57'08"	115°09'34"	58	2 600	L. Permian	1983	Hudbay	Dry	P&A	Nil	Nil
Point Louise 1	1888	NFW	30°02'25"	115°04'08"	43	950	L. Permian	1981	Mesa	Dry	P&A	Nil	Nil
Rakrani 1	3983	NFW	29°10'17"	114°53'59"	15	1 201	Precambrian	1990	Lassoc	Dry	P&A	Nil	Nil
Robb 1	2285	NFW	29°32'48"	115°02'13"	32	1 981	Precamb	1985	Strata	Dry	P&A	Poor	Poor
S. Turtle Dove 1A	1104 A2	NFW	30°07'46"	114°38'11"	30	330	L. Permian	1975	WAPET	Dry	P&A	Nil	Nil
S. Turtle Dove 1B	1104 A3	NFW	30°07'46"	114°38'11"	30	1 830	L. Permian	1975	WAPET	Dry	P&A	Nil	Nil
South Yardanogo 1	20055	NFW	29°29'57"	115°06'11"	52	2 350	U. Triassic	1990	Barrack	Dry	P&A	Nil	Nil
Strawberry Hill 1	480	NFW	29°15'17"	115°07'16"	63	2 903	L. Permian	1969	WAPET	Dry	P&A	Nil	Nil
Tabletop 1	20264	NFW	29°05'33"	115°07'12"	224	1 825	L. Permian	1994	Discovery	Dry	P&A	Nil	Poor
Wakeford 1	3370	NFW	29°01'49"	114°53'58"	16	27	Precambrian	1988	Lassoc	Dry	P&A	Nil	Nil
Walyering 1	627	NFW	30°42'57"	115°27'55"	99	3 643	L. Jurassic	1971	WAPET	Gas	P&A	Excl	Nil
Walyering 2	643	EXT	30°42'12"	115°28'26"	99	4 115	L. Jurassic	1971	WAPET	Dry	P&A	Excl	Nil
Walyering 3	673	EXT	30°44'05"	115°29'39"	99	4 187	L. Jurassic	1972	WAPET	Dry	P&A	Good	Nil
Warradong 1	1700	NFW	29°18'05"	115°10'17"	103	3 717	L. Jurassic	1981	Mesa	Dry	P&A	Good	Nil
Warramia 1	20121	NFW	30°11'08"	115°43'41"	308	1 498	U. Jurassic	1992	Ampolex	Dry	P&A	Poor	Nil
Warro 1	1331	NFW	30°10'06"	115°44'11"	299	4 385	M. Jurassic	1977	WAPET	Dry	P&A	Fair	Nil

Appendix 3 (*continued*)

Well name	*S-no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Operator*	*Status 1*	*Status 2*	*Gas show*	*Oil show*
Warro 2	1370	NFW	30°10'05"	115°44'03"	299	4 854	L. Jurassic	1978	WAPET	Dry	P&A	Good	Nil
Wattle Grove 1	2752	NFW	29°08'39"	114°54'18"	37	822	Precambrian	1985	Balmoral	Dry	P&A	Nil	Nil
Wedge Island 1A	606	STR	30°49'14"	115°11'32"	6	485	U. Triassic	1970	WAPET	Dry	P&A	Nil	Nil
West Erregulla 1	20020	NFW	29°25'37"	115°18'32"	227	4 065	U. Permian	1990	Barrack	Dry	P&A	Excl	Poor
West White Point 1	628	NFW	29°20'46"	115°02'23"	79	2 248	U. Permian	1971	WAPET	Dry	P&A	Poor	Nil
West White Point 2	631	NFW	29°22'48"	115°02'30"	36	2 355	L. Permian	1971	WAPET	Dry	P&A	Nil	Nil
Woodada 1	1624	NFW	29°47'45"	115°08'21"	40	2 546	L. Permian	1980	Hughes	Gas	Susp	Prod	Nil
Woodada 2	1667	EXT	29°47'42"	115°09'07"	42	2 460	L. Permian	1980	Hughes	Gas	Susp	Prod	Nil
Woodada 3	1742	EXT	29°45'17"	115°09'21"	47	2 540	L. Permian	1981	Hughes	Gas	P&A	Good	Fair
Woodada 4	1778	EXT	29°50'06"	115°08'33"	45	2 271	L. Permian	1981	Hughes	Gas	Susp	Prod	Nil
Woodada 5	2028	EXT	29°46'22"	115°08'23"	57	2 808	L. Permian	1982	Hudbay	Gas	Susp	Poor	Fair
Woodada 6	2091	EXT	29°48'43"	115°08'26"	45	2 708	L. Permian	1982	Hudbay	Gas	Well	Prod	Nil
Woodada 8	2456	EXT	29°51'47"	115°08'43"	43	2 271	L. Permian	1983	Strata	Gas	Well	Prod	Nil
Woodada 9	2535	DEV	29°53'02"	115°09'36"	46	2 350	Permian	1984	Strata	Dry	P&A	Poor	Nil
Woodada 10	2547	DEV	29°49'00"	115°07'45"	39	2 340	Permian	1984	Strata	Gas	Well	Prod	Nil
Woodada 11	20076	DEV	29°49'47"	115°08'32"	44	2 191	L. Permian	1991	Consol	Gas	Well	Prod	Nil
Woodada 12	20090	DEV	29°50'11"	115°07'42"	38	2 300	L. Permian	1991	Consol	Gas	Well	Prod	Poor
Woodada 14	20245	DEV	29°50'09"	115°08'22"	42	2 265	Permian	1994	Consol	Gas	Susp	Excl	Nil
Woolmulla 1	49	NFW	30°01'28"	115°11'34"	120	2 811	Precambrian	1963	WAPET	Dry	P&A	Fair	Nil
Yallallie 1	20029	NFW	30°20'40"	115°46'16"	222	3 321	U. Jurassic	1990	Ampolex	Dry	P&A	Nil	Nil
Yardarino 1	154	NFW	29°13'19"	115°03'18"	47	2 377	L. Permian	1964	WAPET	Oil & Gas	Shut in	Prod	Excl
Yardarino 2	163	EXT	29°12'22"	115°03'38"	92	3 075	L. Permian	1964	WAPET	Dry	P&A	Poor	Poor
Yardarino 3	169	EXT	29°13'32"	115°03'18"	45	2 700	L. Permian	1964	WAPET	Oil & Gas	Shut in	Good	Excl
Yardarino 4	183	EXT	29°13'03"	115°02'39"	44	2 490	L. Permian	1964	WAPET	Gas	P&A	Good	Poor

Notes: abd = abandoned; DEV = development; P&A = plugged and abandoned; EXT = extension; prod = producing; NFW = new field wildcat; susp = suspended; STR = stratigraphic

Appendix 4

Deep waterbores drilled by the Geological Survey of Western Australia, and selected deep mineral-exploration bores in the onshore northern Perth Basin

Well name	*Latitude (S)*	*Longitude (E)*	*AHD (m)*	*TD (m)*	*Bottomed in*	*Reference*	*Comments*
AR 1	28°41'10"	115°14'50"	220	391	Ph	WMC Ltd, 1983	
Arrowsmith 23	29°31'40"	115°30'00"	306	256	Jy	Barnett, 1969	Gas flow, mainly N_2
Arrowsmith 25	29°33'15"	115°32'00"	311	552	Jy	"	Deepest of 54 bores
BC 1	29°06'35"	114°53'30"	40	261	Jc	Agg, 1982	Bookara coal deposit
BC 2	29°05'20"	114°53'20"	32	213	Jc	"	
BC 3B	29°04'30"	114°52'25"	56	294	Jc	"	
BC 4	29°01'10"	114°55'05"	45	45	granite	"	
BC 5	29°01'10"	114°54'20"	15	26	granite	"	
BC 6	29°03'05"	114°54'30"	25	30	Jy	"	
BF 8/1	28°37'00"	115°08'00"	230	203	?Ph	WMC Ltd., 1982	
Dathagnoorara	29°48'07"	115°42'15"	276	305	Kpo	Commander, 1978	
Dathagnoorara 1/86	29°48'00"	115°42'50"	277	211	Ŧk	Water Authority well (abd)	Bore lies east of Urella Fault
Eneabba Line 1	29°48'00"	115°39'40"	257	751	Jy	Commander, 1978	
Eneabba Line 2	29°48'00"	115°35'30"	264	762	Jy	"	
Eneabba Line 3	29°48'00"	115°31'30"	295	762	Jy	"	
Eneabba Line 4	29°48'10"	115°27'10"	254	627	Jy	"	
Eneabba Line 5	29°48'17"	115°23'09"	201	718	Jy	"	
Eneabba Line 6	29°47'45"	115°19'30"	138	763	Jy	"	
Eneabba Line 7	29°45'08"	115°15'45"	95	765	Jy	"	
Eneabba Line 8	29°50'10"	115°13'40"	69	730	Je	"	
Eneabba Line 9	29°51'10"	115°10'30"	51	797	Je	"	
Eneabba Line 10	29°52'	115°03'	11	159	Je	"	
Eneabba Line 11	29°06'	115°06'	66	102	Ŧk	"	
Gillingarra Line 1	31°02'26"	115°20'32"	4	1 002	Jy	Moncrieff, 1989	
Gillingarra Line 2	31°01'38"	115°25'54"	130	1 004	Jy	"	
Gillingarra Line 3	31°00'54"	115°31'11"	59	1 007	Jy	"	
Gillingarra Line 4	31°01'36"	115°37'07"	77	1 200	Jy	"	
Gillingarra Line 5	31°00'14"	115°42'32"	85	1 200	Jy	"	
Gillingarra Line 6	30°59'13"	115°46'55"	128	974	Jy	"	
Gillingarra Line 7	31°00'41"	115°53'36"	145	1 201	Kpo	"	
Gillingarra Line 8	31°02'09"	116°00'16"	172	1 169	Jc	"	
Green Head 1	30°06'00"	115°05'04"	50	685	Ph	Romanoff and Shepherd, 1974	Small gas show, CH_4+N_2
Green Head 2	30°08'20"	115°00'00"	2	328	Ŧk	"	
Green Head 3	30°00'00"	115°04'02"	54	690	Pc	"	
Lake Eganu 1	30°00'10"	115°50'50"		165	Jc	Ashburton Oil, 1971a	
Lake Eganu 2	30°06'10"	115°51'40"	230	291	Jc	"	
Lake Eganu 3	30°06'45"	115°55'30"		43	schist	"	Jc on Darling Fault at 37 m

Appendix 4 (*continued*)

Well name	*Latitude (S)*	*Longitude (E)*	*AHD (m)*	*TD (m)*	*Bottomed in*	*Reference*	*Comments*
Lake Eganu 4	30°06'50"	115°53'30"	230	305	Jy	“	
Moora Line 1	30°37'04"	115°55'21"	213	756	Kpo	Briese, 1979; Moncrieff, 1989	
Moora Line 2	30°36'19"	115°49'22"	206	464	Kpo	“	
Moora Line 3	30°37'22"	115°44'15"	193	762	Jy	“	
Moora Line 4	30°37'55"	115°38'18"	285	731	Jy	“	
Moora Line 5	30°37'55"	115°32'22"	204	772	Jy	“	
Moora Line 6	30°38'48"	115°27'43"	115	772	Jy	“	
Moora Line 7	30°39'36"	115°22'24"	69	801	Jy	“	
Moora Line 8	30°34'14"	115°13'35"	39	770	Ŧk	“	
Moora Line 9	30°39'28"	115°08'08"	9	25	Ŧk	“	
Per 6	29°47'45"	115°51'45"	243	72	Ŧk	Ellis, 1982	
UWA 10	29°10'20"	115°27'10"	145	25	Ŧk	Coleman and Skwarko, 1967	
Watheroo Line 1	30°19'20"	115°55'02"	234	552	?Jy	Harley, 1975	
Watheroo Line 2	30°19'34"	115°49'58"	261	165	?Kpo	“	
Watheroo Line 3	30°19'01"	115°43'59"	314	604	Jy	“	
Watheroo Line 4	30°19'11"	115°39'22"	335	574	Jy	“	
Watheroo Line 5	30°19'02"	115°35'38"	286	765	Jy	“	
Watheroo Line 6	30°19'07"	115°32'27"	217	762	Jy	“	
Watheroo Line 7	30°19'08"	115°28'46"	187	758	Jy	“	
Watheroo Line 8	30°18'04"	115°25'36"	149	755	Jy	“	
Watheroo Line 9	30°19'00"	115°42'07"	324	319	Kpo	“	
Watheroo Line 10	30°18'43"	115°21'24"	141	765	Jy	“	
Watheroo Line 11	30°18'02"	115°15'29"	79	762	Jc	“	
Watheroo Line 12	30°18'08"	115°06'15"	50	762	Ŧk	“	
Woodada No. 1	29°37'54"	115°01'36"	29	276	?Je	Ashburton Oil, 1971b	

Notes: Kpo = Otorowiri Member (Parmelia Formation); Jy = Yarragadee Formation; Jc = Cattamarra Coal Measures; Je = Eneabba Formation; Ŧk = Kockatea Shale, Pc = Carynginia Formation; Ph = Holmwood Shale

Appendix 5

Formation tops and thicknesses of selected wells in the onshore northern Perth Basin

Well name	*Abbarwardoo 1*	*Allanooka 1*	*AR 1 Coal Bore*	*Arramall 1*	*Arrowsmith 1*	*Barberton 1*	*Beekeeper 1*	*Beharra 1*	*Beharra 2*	*Beharra Springs 1*	*Beharra Springs 2*	*BMR 10A*	*Bonniefield 1*	*Cadda 1*	*Casuarinas 1*	*Conder 1*	*Connolly 1*	*Coomallo 1*
Eastings	320168	306708	328800	315573	317502	401692	324471	307500	308363	319610	320000	304333	297043	328252	323423	297743	300542	347593
Northings	6836535	6774447	6825650	6725010	6722749	6589966	6711454	6736379	6733160	6739001	6737470	6698689	6771198	6642452	6577049	6785206	6786087	6652578
GL (m AHD)	219	47	220	34	51	215	47	22	28	42	49	5	18	69	240	26	108	253
KB (m AHD)	221	51	–	37	56	237	51	27	33	49	57	8	21	82		29	112	258
Jy	2	47	0	0	5	NP	0	6	34	0	0	NP	48	NP	4	NP	10	5
Jd	–	420	–	534	569	NP	980	598	566	1 307	1 308	NP	349	NP	389	NP	188	2 972
Jd (*Th.*)	0	47	0	59	60		59	47	58	76	78		43		45		42	230
Jc	–	467	–	593	629	NP	1 039	645	624	1 383	1 386	NP	392	NP	434	24	230	3 202
Jc (*Th.*)	0	239	0	590	670		323	525	?500	645	807		285		48	143	145	>318
Je	–	–	–	(f)1 133	1 299	?346	1 362	1 170	(f)657	?2 028	2 193	32	–	4	–	–	–	NP
Je (*Th.*)	0	0	0	530	531		710	237	?230	527	562	>68	0	>168		0	0	
Ʀl	–	–	–	1 512	1 830	620	(f)1 682	1 407	734	?2 555	2 755	100	–	172	–	–	–	NP
Ʀl (*Th.*)	0	0	0	168	205	>2 794	200	164	148	131	?130	391	0	1 202		0	0	
Ʀw	–	–	–	1 680	2 035	NP	1 874	1 571	882	2 686	(f)2 814	491	–	1 374	–	–	–	NP
Ʀw (*Th.*)	0	0	0	108	148		209	100	137	130	131	121	0	223		0	0	
Ʀk	?23	706	175	1 788	2 183	NP	2 083	1 671	1 019	(f)2 764	2 945	612	677	(f)1 597	489	167	375	NP
Ʀk (*Th.*)	33	178	50	?500	524		661	420	423	650	>357	382	231	1 150	95	62	75	
Ʀkb	–	861	–	–	–	NP	–	–	–	–	NP	–	870	–	–	200	411	NP
Ʀkb (*Th.*)	0	6	0	0	0		0	0	0	0		0	9	0	0	29	39	
Pou	–	–	–	–	–	NP	–	–	–	–	NP	–	–	–	584	–	–	NP
Pou (*Th.*)	0	0		0	0		0	0	0	0		0	0	0	14	0	0	
Po	–	–	–	–	–	NP	–	–	–	–	–	–	–	–	584	–	–	NP
Po (*Th.*)	0	0	0	0	0		0	?	0	0	0	0	0	0	62	0	0	
Pw	–	–	225	–	–	NP	–	–	–	–	–	–	–	–	–	–	–	NP
Pw (*Th.*)	0	0	57	0	0		0	0	0	0	0	0	0	0	0	0	0	
Pb	–	–	–	–	–	NP	2 744	–	?1 442	3 283	3 302	–	–	?2 034	–	–	–	NP
Pb (*Th.*)	0	0	0	0	0		112	0	23	46	86	0	0	26		0	0	
Pc	–	–	?282	–	2 707	NP	2 856	–	?1 465	3 329	3 388	994	–	2 060	646	–	–	NP
Pc (*Th.*)	0	0	24	?	216		128	?	129	263	>105	107	0	328	42	0	0	
Pi	56	884	306	(f)2 221	2 923	NP	2 984	(f)1 751	1 594	3 592	NP	1 101	–	2 388	688	–	–	NP
Pi (*Th.*)	105	40	31	>4	307		>28	265	265	>108		300	0	262	181	0	0	
Pg	161	924	337	–	3 230	NP	NP	1 866	1 859	NP	NP	1 401	908	2 650	869	–	–	NP
Pg (*Th.*)	37	92	(i)6	?	58			55	63			23	71	42	116	0	0	
Ph	198	1 016	353	–	3 288	NP	NP	1 921	1 922	NP	NP	1 424	979	2 692	985	–	–	NP
Ph (*Th.*)	>402	137	>38	?	158			135	120			37	30	53	395	0	0	
Pn	NP	1 153	NP	–	–	NP	NP	–	NP	NP	NP	–	–	–	1 380	–	–	NP
Pn (*Th.*)		>34		?	0			0				0	0	0	>98	0	0	
p∈	NP	NP	NP	2 225	3 420	NP	NP	2 041	NP	NP	NP	1 461	1 009	2 745	NP	229	450	NP
TD (m)	600	1 187	391	2 250	3 446	3 414	3 012	2 056	1 924	3 700	3 493	1 482	1 012	2 795	1 478	253	478	3 520

Note: Formation tops are relative to KB. In some cases where a formation is faulted or not fully penetrated, the thickness given is based on seismic data
Jy = Yarragadee Formation; Jd = Cadda Formation; Jc = Cattamarra Coal Measures; Je = Eneabba Formation; Ʀl = Lesueur Sandstone; Ʀw = Woodada Formation; Ʀk = Kockatea Shale; Ʀkb = Bookara Sandstone Member; Pou = 'upper sandstone member' of the Dongara Sandstone; Po = Dongara Sandstone; Pw = Wagina Sandstone; Pb = Beekeeper Formation; Pc = Carynginia Formation; Pi = Irwin River Coal Measures; Pg = High Cliff Sandstone; Ph = Holmwood Shale; Pn = Nangetty Formation; p∈ = Precambrian basement;
NP = not penetrated; (*Th.*) = thickness of unit; (f) = faulted contact

Appendix 5 (*continued*)

Well name	*Denison 1*	*Depot Hill 1*	*Dongara 1*	*Dongara 2*	*Dongara 5*	*Dongara 6*	*Dongara 7*	*Dongara 8*	*Dongara 12*	*Dongara 13*	*Dongara 16*	*Dongara 19*	*Dongara 20*	*Dongara 22*	*Dongara 26*	*Dongara 27*	*Donkey Creek 1*	*East Heaton 1*	*Eganu 1*
Eastings	301200	337002	304603	303380	303939	299658	308516	307841	307708	305230	304989	310093	307788	303569	302806	307687	334474	329697	386975
Northings	6765280	6779580	6762260	6762670	6769423	6768548	6756013	6762407	6763883	6766643	6760352	6760294	6760743	6762700	6762908	6768036	6721380	6778058	6782195
GL (m AHD)	27	263	45	23	28	25	43	49	26	84	25	110	76	32	18	34	107	252	235
KB (m AHD)	35	270	49	27	32	29	47	54	29	88	29	114	81	36	23	38	111	259	237
Jy	0	40	61	78	0	0	69	5	3	4	0	123	5	0	0	0	5	0	2
Jd	757	–	826	732	587	639	790	731	803	770	775	1 195	707	702	777	688	1 640	1 375	–
Jd (*Th.*)	36		31	60	60	39	72	54	50	69	69	55	61	62	48	21	119	44	0
Jc	793	(f)656	857	792	647	678	862	785	853	839	844	1 250	768	764	825	709	1 759	1 419	98
Jc (*Th.*)	333	>473	209	314	279	265	260	331	241	322	>256	>411	321	314	374	323	749	278	>502
Je	1 126	–	1 066	1 106	926	943	1 122	1 116	(f)1 094	1 161	(f)1 100	–	1 089	1 078	1 199	1 032	2 508	(f)1 650	NP
Je (*Th.*)	161	0	196	>190	200	236	332	118	?260	189	>95	?	154	153	105	?>78	854	250	
TRl	1 287	–	1 262	(f)1 296	–	1 179	1 454	1 234	1 197	1 350	1 195	–	1 243	1 231	1 304	1 110	3 362	–	NP
TRl (*Th.*)	160	0	85	>45	0	101	158	122	100	128	123	?	127	117	84	65	177	0	
TRw	1 447	–	1 347	1 341	1 126	1 280	1 612	1 356	1 297	1 478	1 318	–	1 370	1 348	1 388	1 175	3 539	1 767	NP
TRw (*Th.*)	66	0	61	73	123	50	59	89	44	63	66	?	66	91	86	?>40	203	54	
TRk	1 513	785	1 408	1 414	1 249	(f)1 323	1 671	1 445	1 341	1 541	1 384	(f)1 661	1 436	1 439	1 474	1 215	3 742	1 821	NP
TRk (*Th.*)	260	177	263	268	282	>125	423	264	284	255	268	>112	273	262	212	271	900	220	
TRkb	–	–	–	–	1 497	–	–	–	–	–	–	–	–	–	1 674	–	NP	–	NP
TRkb (*Th.*)	0	0	0	0	12	0	0	0	0	0	0	0	0	0	12	0		0	
Pou	–	962	–	–	–	1 448	2 094	1 709	1 625	1 796	–	1 773	1 709	–	–	1 482	NP	2 041	NP
Pou (*Th.*)	0	50	0	0	0	12	38	5	7	12	0	22	13	0	0	11		55	
Po	1 773	962	–	–	–	1 448	2 094	1 709	1 625	1 796	–	1 773	1 709	1 701	–	1 482	NP	2 041	NP
Po (*Th.*)	14	336	0	0	0	>12	62	38	38	12	0	56	47	9	0	43		258	
Pw	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	NP	–	NP
Pw (*Th.*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Pb	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	NP	–	NP
Pb (*Th.*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Pc	–	1 298	1 671	1 682	–	–	2 156	1 747	1 663	–	1 652	1 829	1 756	1 710	?1 686	–	NP	2 299	NP
Pc (*Th.*)	0	198	42	22	0	0	>8	60	37	0	52	82	64	28	8	0		194	
Pi	1 787	1 496	1 713	1 704	(f)1 531	–	NP	1 807	1 701	1 808	1 704	1 911	1 820	1 738	1 694	1 525	NP	2 493	NP
Pi (*Th.*)	224	229	139	>41	>130	0		>92	253	141	>220	>268	>119	>62	>136	169		>27	
Pg	2 011	1 725	1 852	NP	1 661	–	NP	NP	1 954	1 949	NP	NP	NP	NP	NP	?1 694	NP	NP	NP
Pg (*Th.*)	89	69	28		107	0			>69	>84						>36			
Ph	2 100	1 794	1 880	NP	1 768	(f)1 460	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Ph (*Th.*)	119	625	210		>40	14													
Pn	2 219	2 419	2 090	NP	NP	1 474	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Pn (*Th.*)	174	393	190			66													
p∈	NP	NP	NP	NP	NP	1 540	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
TD (m)	2 300	2 473	2 161	1 745	1 808	1 559	2 164	1 899	2 013	2 033	1 924	2 179	1 939	1 800	1 830	1 730	3 853	2 520	600

Note: Formation tops are relative to KB. In some cases where a formation is faulted or not fully penetrated, the thickness given is based on seismic data
Jy = Yarragadee Formation; Jd = Cadda Formation; Jc = Cattamarra Coal Measures; Je = Eneabba Formation; TRl = Lesueur Sandstone; TRw = Woodada Formation; TRk = Kockatea Shale; TRkb = Bookara Sandstone Member; Pou = 'upper sandstone member' of the Dongara Sandstone; Po = Dongara Sandstone; Pw = Wagina Sandstone; Pb = Beekeeper Formation; Pc = Carynginia Formation; Pi = Irwin River Coal Measures; Pg = High Cliff Sandstone; Ph = Holmwood Shale; Pn = Nangetty Formation; p∈ = Precambrian basement;
NP = not penetrated; (*Th.*) = thickness of unit; (f) = faulted contact

Appendix 5 (*continued*)

Well name	*Ejarno 1*	*Eneabba 1*	*Erregulla 1*	*Erregulla 2*	*Eurangoa 1*	*Gairdner 1*	*Gillingarra Line 8*	*Gingin 1*	*Greenough 1*	*Green Head 1*	*Green Head 2*	*Green Head 3*	*Heaton 1*	*Hill River 1*	*Hill River 2*	*Hill River 2A*	*Hill River 3*	*Hill River 4*	*Horner West 1*
Eastings	313144	338446	344475	344472	318825	321273	404990	388203	271246	315417	307354	313570	326086	337671	329909	330104	325325	330160	309604
Northings	6755558	6727627	6749142	6749358	6776475	6671849	6565990	6553940	6805920	6668574	6664124	6679631	6777203	6650325	6659569	6659079	6678714	6636538	6775285
GL (m AHD)	73	123	233	241	250	175	172	198	10	5066	2	54	186	111	189	183	124	93	95
KB (m AHD)	80	127	237	248	254	182	172	203	12	?	?	?	190	112	191	184	126	94	98
Jy	200	12	5	7	4	NP	323	356	NP	NP	NP	NP	50	0	NP	NP	NP	NP	0
Jd	1 222	1 442	2 019	2 029	1 077	NP	583	3 315	NP	NP	NP	NP	1 274	67	NP	NP	NP	NP	789
Jd (*Th.*)	59	112	65	61	36		86	189					37	84					50
Jc	1 281	1 554	2 084	2 090	1 113	NP	679	3 504	48	NP	NP	NP	1 311	151	2	1	NP	NP	839
Jc (*Th.*)	520	766	720	704	195		>662	>1 040	258				289	>428	>492	>117			274
Je	1 801	2 320	2 804	2 794	–	NP	NP	NP	–	NP	NP	NP	1 600	NP	NP	NP	2	NP	1 113
Je (*Th.*)	254	658	600	597	0				0				259				>262		176
₮l	2 055	2 978	–	3 391	–	0	NP	NP	–	NP	NP	NP	–	NP	NP	NP	NP	1	–
₮l (*Th.*)	170	292	140	141	0	>599			0				0					>234	?
₮w	2 225	3 270	–	3 532	1 308	599	NP	NP	–	NP	NP	NP	1 859	NP	NP	NP	NP	235	–
₮w (*Th.*)	109	132	100	>45	145	215			0				60					>73	?
₮k	2 334	3 402	(f)3 362	NP	1 453	814	NP	NP	306	?14	28	NP	1 919	NP	NP	NP	NP	NP	–
₮k (*Th.*)	393	1 152	560		243	926			138	>146	>300		211						?
₮kb	–	NP	–	NP	–	–	NP	NP	–	–	NP	NP	–	NP	NP	NP	NP	NP	–
₮kb (*Th.*)	0		0		0	0			0	0			0						?
Pou	2 727	NP	–	NP	1 696	–	NP	NP	–	–	NP	NP	2 130	NP	NP	NP	NP	NP	–
Pou (*Th.*)	63		0		33	0			0	0			46						?
Po	2 727	NP	–	NP	1 696	–	NP	NP	–	–	NP	NP	2 130	NP	NP	NP	NP	NP	–
Po (*Th.*)	88		0		33	0			0	0			196						?
Pw	–	NP	–	NP	–	–	NP	NP	–	–	NP	NP	–	NP	NP	NP	NP	NP	–
Pw (*Th.*)	0		0		0	0			0	0			0						?
Pb	–	NP	–	NP	–	–	NP	NP	–	?160	NP	?51	–	NP	NP	NP	NP	NP	–
Pb (*Th.*)	0		0		0	0			0	10		114	0						0
Pc	2 815	NP	3 905	NP	1 729	1 740	NP	NP	–	?170	NP	?165	2 326	NP	NP	NP	NP	NP	–
Pc (*Th.*)	>53		337		181	294			0	?240		298	>112						?
Pi	NP	NP	4 242	NP	1 910	2 034	NP	NP	–	310	NP	463	NP	NP	NP	NP	NP	NP	–
Pi (*Th.*)			>2		225	>138			0	293		>227							?
Pg	NP	NP	NP	NP	2 135	NP	NP	NP	–	607	NP	NP	NP	NP	NP	NP	NP	NP	–
Pg (*Th.*)					108				0	36									?
Ph	NP	NP	NP	NP	2 243	NP	NP	NP	–	643	NP	NP	NP	NP	NP	NP	NP	NP	(f)1 253
Ph (*Th.*)					>34				0	>42									>109
Pn	NP	NP	NP	NP	NP	NP	NP	NP	–	NP	NP	NP	NP	NP	NP	NP	NP	NP	1 362
Pn (*Th.*)									0										170
p∈	NP	NP	NP	NP	NP	NP	NP	NP	444	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
TD (m)	2 868	4 179	4 244	3 577	2 277	2 172	1 169	4544	445	685	328	690	2 438	579	494	116	264	308	1 451

Note: Formation tops are relative to KB. In some cases where a formation is faulted or not fully penetrated, the thickness given is based on seismic data
Jy = Yarragadee Formation; Jd = Cadda Formation; Jc = Cattamarra Coal Measures; Je = Eneabba Formation; ₮l = Lesueur Sandstone; ₮w = Woodada Formation; ₮k = Kockatea Shale; ₮kb = Bookara Sandstone Member; Pou = ‘upper sandstone member’ of the Dongara Sandstone; Po = Dongara Sandstone; Pw = Wagina Sandstone; Pb = Beekeeper Formation; Pc = Carynginia Formation; Pi = Irwin River Coal Measures; Pg = High Cliff Sandstone; Ph = Holmwood Shale; Pn = Nangetty Formation; p∈ = Precambrian basement;
NP = not penetrated; (*Th.*) = thickness of unit; (f) = faulted contact

Appendix 5 (*continued*)

Well name	*Indoon 1*	*Jay 1*	*Jurien 1*	*Mondarra 1*	*Mondarra 2*	*Mondarra 4*	*Moora Line 8*	*Mooratara 1*	*Mount Adams 1*	*Mount Bridge 1*	*Mount Horner 1*	*Mount Horner 7*	*Mullering 1*	*Narkarino 1*	*Narlingue 1*	*North Erregulla 1*	*North Yardanogo 1*	*North Yardarino 1*	*Ocean Hill 1*
Eastings	321465	310818	312023	317080	315877	315630	329910	296716	322121	316166	313693	314307	339559	295656	315318	337337	315885	309430	345227
Northings	6692663	6781691	6663466	6757112	6751454	6755022	6616640	6766473	6745519	6723872	6776146	6776715	6603467	6777083	6782700	6763636	6738699	6769368	6687116
GL (m AHD)	37	130	9	77	27	45	39	4	86	39	195	213	57	27	193	162	35	56	213
KB (m AHD)	43	134	12	83	31	49	39	8	91	46	200	217	61	29	197	167	42	63	220
Jy	NP	4	NP	402	?	176	NP	74	5	?7	29	0	14	59	375	68	7	0	0
Jd	NP	917	NP	1 278	1 190	1 172	NP	351	1 421	577	1 078	1 066	284	214	950	1 820	1 092	991	2 959
Jd (*Th.*)		63		69	32	51		44	42	47	39	34	290	41	41	57	50	27	288
Jc	5	980	NP	1 347	1 222	1 223	NP	395	1 463	624	1 117	1 100	574	255	991	1 877	1 142	1 018	3 248
Jc (*Th.*)	>48	>281		522	605	517		292	579	776	>211	266	>1092	232	317	510	633	431	>592
Je	53	NP	NP	1 869	1 827	1 740	5	?787	2 042	?1 410	(f)	1 366	NP	–	–	2 387	1 775	1 449	NP
Je (*Th.*)	747			311	379	313	>145	223	539	353		112		0	0	399	579	248	
Ꞧl	800	NP	NP	2 180	2 306	2 053	150	1 000	2 581	1 763	(f)	–	NP	–	–	2 786	2 354	1 697	NP
Ꞧl (*Th.*)	309			135	>169	191	>659	95	141	221		0		0	0	>16	?100	115	
Ꞧw	1 109	NP	NP	2 315	–	2 244	NP	–	2 722	1 984	(f)1 328	1478	NP	–	1 308	–	NP	1 812	NP
Ꞧw (*Th.*)	221			63		119		0	75	176	>59	96		0	73	?	?100	>73	
Ꞧk	1 330	NP	27	(f)2 384	(f)2 474	2 363	NP	1 095	2 797	2 160	1 387	1 574	NP	487	1 381	(f)2 802	NP	–	NP
Ꞧk (*Th.*)	827		>247	>301	>252	438		213	731	487	190	213		>113	209	>419	?900	?	
Ꞧkb (*Th.*)	–	NP	–	–	–	–	NP	1 296	–	–	–	–	NP	NP	–	–	NP	–	NP
Ꞧkb (*Th.*)	0		0	0	?	0		12	0	0	0	0			0	0		–	NP
Pou	–	NP	–	2 685	–	2 801	NP	–	–	–	1 577	1 787	NP	NP	1 590	–	NP	–	NP
Pou (*Th.*)	0		0	41	?	55		0	0	0	23	26			52	0		?	
Po	–	NP	–	2 685	2 726	2 801	NP	–	3 528	–	1 577	1 787	NP	NP	1 590	–	NP	–	NP
Po (*Th.*)	0		0	119	36	>93		0	128		23	26			52	0		?	
Pw	–	NP	–	–	–	–	NP	–	–	–	–	–	NP	NP	–	–	NP	–	NP
Pw (*Th.*)	0		0	0	0	0		0	0	0	0	0			0	0		?	
Pb	2 157	NP	?274	–	–	–	NP	–	–	2 647	–	–	NP	NP	–	–	NP	–	NP
Pb (*Th.*)	57		24	0	0	0		0	0	23	0	0			0	0		0	
Pc	2 214	NP	298	2 804	2 762	NP	NP	–	3 656	2 679	1 600	1 813	NP	NP	1 642	–	NP	–	NP
Pc (*Th.*)	>43		306	122	>128			?	125	207	73	>35			79	?		?	
Pi	NP	NP	604	2 926	NP	NP	NP	(f)1 380	3 781	2 886	1 673	NP	NP	NP	1 721	3 221	NP	–	NP
Pi (*Th.*)			237	>137				>151	>10	332	178				288	>223		?	
Pg	NP	NP	841	NP	NP	NP	NP	1 459	NP	3 218	1 851	NP	NP	NP	2 009	NP	NP	(f) 1 885	NP
Pg (*Th.*)			79					46		30	150				89			>43	
Ph	NP	NP	920	NP	NP	NP	NP	?1 505	NP	3 248	2 001	NP	NP	NP	2 098	NP	NP	1 928	NP
Ph (*Th.*)			56							137	165				>32			140	
Pn	NP	NP	–	NP	NP	NP	NP	NP	NP	–	2 166	NP	NP	NP	NP	NP	NP	2 068	NP
Pn (*Th.*)			0							0	334							131	
p∈	NP	NP	976	NP	NP	NP	NP	NP	NP	3 385	NP	NP	NP	NP	NP	NP	NP	2 199	NP
TD	2 257	1 295	1 026	3 063	2 854	2 895	770	1 630	3 791	3 416	2 252	1 848	1 666	600	2 130	3 444	2 387	2 207	3 840

Note: Formation tops are relative to KB. In some cases where a formation is faulted or not fully penetrated, the thickness given is based on seismic data
Jy = Yarragadee Formation; Jd = Cadda Formation; Jc = Cattamarra Coal Measures; Je = Eneabba Formation; Ꞧl = Lesueur Sandstone; Ꞧw = Woodada Formation; Ꞧk = Kockatea Shale; Ꞧkb = Bookara Sandstone Member; Pou = ‘upper sandstone member’ of the Dongara Sandstone; Po = Dongara Sandstone; Pw = Wagina Sandstone; Pb = Beekeeper Formation; Pc = Carynginia Formation; Pi = Irwin River Coal Measures; Pg = High Cliff Sandstone; Ph = Holmwood Shale; Pn = Nangetty Formation; p∈ = Precambrian basement;
NP = not penetrated; (*Th.*) = thickness of unit; (f) = faulted contact

Appendix 5 (*continued*)

Well name	*Peron 1*	*Point Louise 1*	*Rakrani 1*	*Robb 1*	*Strawberry Hill 1*	*Wakeford 1*	*Walyering 1*	*Walyering 2*	*Warradong 1*	*Warro 2*	*Wedge Island 1*	*West Erregulla 1*	*West White Point 1*	*West White Point 2*	*Wicherina 1*	*Woodada 1*	*Woodada 3*	*Woolmulla 1*	*Yardarino 1*
Eastings	322368	313807	295749	309788	317428	295440	353044	353850	322389	378109	327082	335959	309689	309940	328340	320147	321674	325725	310943
Northings	6685060	6675166	6771183	6729840	6762321	6786829	6600873	6602270	6757211	6661902	6588875	6743499	6752060	6748307	6809290	6702378	6706972	6677119	6765846
GL (m AHD)	53	39	12	25	59	13	94	100	96	291	5	220	75	32	263	34	41	116	43
KB (m AHD)	58	43	15	32	63	16	99	104	103	299	6	227	79	36	266	40	47	120	47
Jy	NP	NP	83	NP	427	NP	5	5	0	8	NP	0	88	34	18	10	20	NP	12
Jd	NP	NP	368	NP	1 339	NP	2 685	2 647	1 728	4 327	NP	1 913	957	824	280	377	325	NP	1 076
Jd (*Th.*)			52	–	57		180	217	58	145		71	76	63	17	89	89		29
Jc	NP	NP	420	80	1 396	NP	2 865	2 864	1 786	4 472	NP	1 984	1 033	887	297	466	414	NP	1 105
Jc (*Th.*)			329	>368	517		>778	>1251	467	>382		513	569	569	74	299	298		355
Je	5	NP	–	?448	1 913	NP	NP	NP	2 253	NP	NP	2 497	1 602	(f)1 356	–	765	712	4	1 460
Je (*Th.*)	>427		0	?232	334				316			576	245	243	0	483	847	>260	333
Ʀl	432	NP	–	680	2 247	NP	NP	NP	2 569	NP	30	3 073	1 847	1 489	–	1 248	1 559	264	1 793
Ʀl (*Th.*)	328		0	163	197				158		>456	195	50	139	0	207	192	744	147
Ʀw	760	NP	749	843	2 444	NP	NP	NP	2 727	NP	NP	3 268	–	1 628	–	1 455	1 751	1 008	1 940
Ʀw (*Th.*)	227		31	143	65				58			96	?	122	0	192	229	224	69
Ʀk	987	43	780	986	(f)2 502	NP	NP	NP	2 785	NP	NP	3 364	(f)1 897	1 750	371	1 647	1 980	1 232	2 009
Ʀk (*Th.*)	922	>439	283	430	450				393			599	400	481	78	558	426	1 060	279
Ʀkb	–	–	1020	–	–	NP	NP	NP	–	NP	NP	–	–	–	–	–	–	–	–
Ʀkb (*Th.*)	0	0	9	0	0				0			0	0	0	0	0	0	0	0
Pou	–	–	–	–	2 735	NP	NP	NP	3 178	NP	NP	3 963	2 177	–	–	–	–	–	2 288
Pou (*Th.*)	0	0	0	0	24				27			57	22	0	0	0	0	0	19
Po	–	–	–	–	2 735	NP	NP	NP	3 178	NP	NP	3 963	2 177	2 231	–	–	–	–	2 288
Po (*Th.*)	0	0	0	0	>168				209			>101.5	>71	52	0	0	0	0	71
Pw	–	–	–	–	–	NP	NP	NP	–	NP	NP	–	–	–	449	–	–	–	–
Pw (*Th.*)	0	0	0	0	0				0			0	0	0	96	0	0	0	0
Pb	1 909	482	–	1 416	–	NP	NP	NP	–	NP	NP		–	–	–	2 205	2 406	?2 292	–
Pb (*Th.*)	44	134	0	36	0				0				0	0	0		91	51	0
Pc	1 953	616	–	1 452	NP	NP	NP	NP	3 387	NP	NP	NP	NP	2 283	545	?	2 497	2 343	2 359
Pc (*Th.*)	298	284	0	130					286					>72	153		>43	287	>18.4
Pi	2 251	900	1 063	1 582	NP	NP	NP	NP	3 673	NP	NP	NP	NP	NP	698	2 347	NP	2 630	NP
Pi (*Th.*)	253	>50	9	238					>44						137	>199		>181	
Pg	2 504	NP	1 072	1 820	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	835	NP	NP	NP	NP
Pg (*Th.*)	38		87	40											58				
Ph	2 542	NP	1 159	1 860	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	893	NP	NP	NP	NP
Ph (*Th.*)	32		38	112											312				
Pn	–	NP	–	–	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	1 205	NP	NP	NP	NP
Pn (*Th.*)	0		0	0											>481				
p∈	2 574	NP	1 197	1 972	NP	20	NP		NP	NP	NP	NP	NP	NP	NP	NP	NP	(f)2 719	NP
TD	2 600	950	1 201	1 981	2 903	27	3 643	4 115	3 717	4 854	486	4 065	2 248	2 355	1 686	2 546	2 540	2 811	2 377

Note: Formation tops are relative to KB. In some cases where a formation is faulted or not fully penetrated, the thickness given is based on seismic data
Jy = Yarragadee Formation; Jd = Cadda Formation; Jc = Cattamarra Coal Measures; Je = Eneabba Formation; Ʀl = Lesueur Sandstone; Ʀw = Woodada Formation; Ʀk = Kockatea Shale; Ʀkb = Bookara Sandstone Member; Pou = 'upper sandstone member' of the Dongara Sandstone; Po = Dongara Sandstone; Pw = Wagina Sandstone; Pb = Beekeeper Formation; Pc = Carynginia Formation; Pi = Irwin River Coal Measures; Pg = High Cliff Sandstone; Ph = Holmwood Shale; Pn = Nangetty Formation; p∈ = Precambrian basement;
NP = not penetrated; (*Th.*) = thickness of unit; (f) = faulted contact

Appendix 6

Two-way times to top Cattamarra, Permian, and basement in petroleum exploration wells in the onshore northern Perth Basin

Well name	*Eastings*	*Northings*	*Depth below sea level datum (m)*			*Two-way times below datum (sec)*		
			Top Jc	*Top P*	*Basement*	*Top Jc*	*Top P*	*Basement*
Allanooka 1	306709	6774447	414	833	–	0.334	0.613	–
Allanooka 2	304876	6779136	343	707	915	0.279	0.536	0.655
Arramall 1	315574	6725010	556	(f)2 184	2188	0.410	(f)1.325	1.330
Arrowsmith 1	317502	6722749	573	2 651	3 364	0.473	1.674	2.040
Beekeeper 1	324471	6711454	988	2 693	–	0.702	1.638	–
Beharra 1	307500	6736379	618	(f)1 724	2014	0.460	(f)1.104	1.240
Beharra 2	308363	6733160	591	1 409	–	0.444	0.942	–
Beharra Springs 1	319610	6739001	1 334	3 234	–	0.875	1.835	–
Beharra Springs 2	320000	6737470	1 329	3 245	–	0.875	1.857	–
BMR 10A	304333	6698689	–	986	1 453	–	0.704	0.966
Bonnifield 1	297043	6771198	371	887	988	0.300	0.638	0.697
Bookara 1	282899	6791650	39	–	242		–	–
Bookara 2	296739	6771638	425	–	–	0.340	–	–
Bookara 3	294568	6778128	100	–	442	0.095	–	0.378
Cadda 1	328252	6642452	–	1 952	2 663		1.036	1.380
Conder 1	297743	6785206	-5	–	200	-0.007	–	0.184
Connolly 1	300542	6786087	118	–	338	0.092	–	0.258
Coomallo 1	347594	6652578	2 944	–	–	1.655	–	–
Denison 1	301200	6765280	758	1 738	–	0.560	1.150	–
Depot Hill 1	337002	6779581	(f) 386	692	–	(f)0.299	0.550	–
Dongara 1	304603	6762259	808	1 622	–	0.422	1.061	–
Dongara 2	303380	6762670	765	1 655	–	0.526	1.064	–
Dongara 3	305774	6761664	754	1 574	–	0.520	1.034	–
Dongara 4	303884	6764772	754	1 627	–	0.520	1.067	–
Dongara 5	303939	6769423	615	1 499	–	0.436	0.997	–
Dongara 6	299658	6768548	653	1 423	1 515	0.496	0.972	1.025
Dongara 7	308516	6756013	815	2 047	–	0.566	1.276	–
Dongara 8	307841	6762407	731	1 655	–	0.514	1.081	–
Dongara 9	305818	6765391	759	1 591	–	0.524	1.043	–
Dongara 10	306039	6763762	749	1 659	–	0.517	1.084	–
Dongara 11	306547	6760691	677	1 623	–	0.476	1.063	–
Dongara 12	307708	6763883	824	1 596	–	0.572	1.045	–
Dongara 13	305230	6766643	751	1 708	–	0.518	1.110	–
Dongara 14	307304	6765380	770	(f)1 663	–	0.533	(f)1.086	–
Dongara 15	307371	6759843	666	1 566	–	0.470	1.030	–
Dongara 16	304989	6760352	815	1 623	–	0.566	1.063	–
Dongara 17	308390	6758690	761	1 668	–	0.526	1.089	–
Dongara 18	308964	6759843	726	1 633	–	0.510	1.069	–
Dongara 19	310093	6760294	1 136	1 659	–	0.790	1.083	–
Dongara 20	307788	6760743	687	1 628	–	0.488	1.064	–
Dongara 21	306458	6764293	710	1 651	–	0.500	1.079	–
Dongara 22	303569	6762700	728	1 665	–	0.498	1.074	–
Dongara 23	306217	6761304	694	1 562	–	0.494	1.028	–
Dongara 24	307268	6764093	715	1 604	–	0.506	1.051	–
Dongara 25	308037	6763452	820	1 617	–	0.569	1.059	–
Dongara 26	302806	6762908	802	1 663	–	0.556	1.086	–
Dongara 27	307688	6768036	671	1 444	–	0.476	0.931	–
Donkey Creek 1	334674	6721380	1 648	–	–	1.004	–	–
East Heaton 1	329697	6778058	1 160	1 782	–	0.800	1.135	–
East Lake Logue 1	321582	6698148	354	2 226	–	0.320	1.380	–
Ejarno 1	313144	6755558	1 201	2 647	–	0.784	1.645	–
Eleven Mile 1	293884	6781565	40	–	258	0.050	–	0.217
Eneabba 1	338446	6727627	1 427	–	–	0.886	–	–
Erregulla 1	344475	6749142	1 847	3 668	–	1.181	2.055	–
Erregulla 2	344472	6749358	1 842	–	–	1.185	–	–
Eurangoa 1	318825	6776475	859	1 442	–	0.620	0.962	–
Gairdner 1	321273	6671849	–	1 558	–	–	0.855	–
Georgina 1	312601	6774447	952	1 587	–	0.653	1.023	–
Heaton 1	326086	6777203	1 121	1 940	–	0.776	1.217	–
Hill River 1	337671	6650325	39	–	–	0.032	–	–
Horner West 1	309604	6775285	741	(f)1 155	–	0.540	(f)0.790	–

Appendix 6 (*continued*)

Well name	*Eastings*	*Northings*	*Depth below sea level datum (m)*			*Two-way times below datum (sec)*		
			Top Jc	*Top P*	*Basement*	*Top Jc*	*Top P*	*Basement*
Hunt Gully 1	320163	6779698	1 088	(f)1 694	–	0.756	(f)1.046	–
Indoon 1	321465	6692662	–	2 114	–	–	1.308	–
Jurien 1	312022	6663466	–	262	964	–	0.185	0.558
Mondarra 1	317080	6757112	1 264	2 602	–	0.820	1.511	–
Mondarra 2	316688	6758026	1 191	2 695	–	0.779	1.539	–
Mondarra 3	316688	6758026	1 192	2 780	–	0.780	1.577	–
Mondarra 4	315630	6755022	1 174	2 752	–	0.770	1.558	–
Mount Adams 1	322121	6745518	1 372	3 437	–	0.892	1.965	–
Mount Hill 1	303740	6782662	197	–	–	0.158	–	–
Mount Horner 1	313693	6776146	917	1 377	–	0.633	0.905	–
Mount Horner 2	313022	6774322	974	1 576	–	0.666	1.018	–
Mount Horner 3	313693	6776117	907	1 354	–	0.628	0.891	–
Mount Horner 4	314181	6776059	867	1 574	–	0.605	1.016	–
Mount Horner 4a	314219	6776126	869	–	–	0.606	–	–
Mount Horner 5	313990	6776455	873	1 586	–	0.609	1.023	–
Mount Horner 5a	314068	6776434	869	–	–	0.606	–	–
Mount Horner 6	314220	6775310	878	–	–	0.611	–	–
Mount Horner 7	314307	6776715	883	1 570	–	0.620	1.009	–
Mount Horner 8	314349	6775696	874	–	–	0.609	–	–
Mount Horner 9	314474	6776308	878	–	–	0.611	–	–
Mount Horner 10	314807	6775858	876	–	–	0.610	–	–
Mount Horner 11	316050	6774216	881	–	–	0.613	–	–
Mullering 1	339559	6603467	513	–	–	0.398	–	–
Narkarino 1	295655	6777083	226	–	–	0.197	–	–
Narlingue 1	315317	6782700	794	1 393	–	0.564	0.911	–
North Erregulla 1	337337	6763636	1 710	3 054	–	1.118	1.801	–
North Yardanogo 1	315885	6738699	1 100	–	–	0.753	–	–
North Yardarino 1	309430	6769368	955	(f)1 822	2 136	0.740	(f)1.15	–
Ocean Hill 1	345227	6687116	3 028	–	–	1.658	–	–
Peron 1	322368	6685060	–	1 840	2 515	–	1.040	1.386
Point Louise 1	313807	6675166	–	440	–	–	0.300	–
Rakrani 1	295749	6771183	405	1 048	1 182	0.334	0.768	0.840
Robb 1	309788	6729839	240	1 384	1 940	0.232	0.989	1.28
South Yardango 1	316116	6735198	1 098	–	–	0.760	–	–
Strawberry Hill 1	317428	6762320	1 333	2 672	–	0.871	1.576	–
Wakeford 1	295411	6788491	–	–	4	–	–	–
Walyering 1	353044	6600873	2 766	–	–	1.536	–	–
Walyering 2	353850	6602270	2 760	–	–	1.582	–	–
Walyering 3	355839	6598817	2 855	–	–	1.669	–	–
Warradong 1	322389	6757211	1 683	3 075	–	1.088	1.779	–
Warro 2	378110	6661902	4 173	–	–	2.430	–	–
Wattle Grove 1	296206	6774216	221	681	762	0.187	0.519	0.570
West Erregulla 1	335959	6743499	1 764	3 743	–	1.104	2.060	–
West White Point 1	309689	6752060	954	2 098	–	0.644	1.308	–
West White Point 2	309940	6748307	851	2 195	–	0.581	1.367	–
Woodada 1	320147	6702378	426	2 165	–	0.371	1.392	–
Woodada 2	321389	6702476	435	2 208	–	0.390	1.384	–
Woodada 3	321674	6706972	368	2 360	–	0.324	1.486	–
Woodada 4	320549	6698033	–	2 087	–	–	1.335	–
Woodada 5	320153	6704936	133	2 286	–	0.200	1.514	–
Woodada 6	320296	6700600	–	2 158	–	–	1.388	–
Woodada 8	320854	6694933	–	2 097	–	–	1.298	–
Woodada 9	322314	6692646	–	2 175	–	–	1.343	–
Woodada 10	319218	6700046	–	2 165	–	–	1.381	–
Woodada 11	320498	6698626	–	2 081	–	–	1.333	–
Woolmulla 1	325725	6677119	–	2 172	2 599	–	1.855	1.408
Yardarino 1	310993	6765846	1 058	2 241	–	0.770	1.319	1.710
Yardarino 2	311455	6767610	1 078	2 276	–	0.760	1.330	1.710
Yardarino 3	310950	6765446	–	2 277	–	0.780	1.320	1.720
Yardarino 4	309882	6766321	1 086	2 316	–	0.770	1.330	1.710

Note: (f) = faulted contact

Appendix 7

Velocity functions and coefficients for selected wells in the onshore northern Perth Basin

Well name	*Equation*	A_0	A_1	A_2
Arramall 1	Power	1 188.4	0.2497	
Arrowsmith 1	Exponential	1 185.8	0.1487	
Beekeeper 1	Exponential	1 275.37	0.1585	
Behara Springs 1	Exponential	1 333.04	0.1558	
Behara Springs 2	Exponential	1 280.26	0.1746	
Bonniefield 1	Hyperbolic	–3 672.49	–12 148.51	–3.2934
Barberton 1	Exponential	1 042.62	0.2033	
Cadda 1	Hyperbolic	–29 176.26	–450 355.9	–15.51744
Conder 1	Exponential	817.8	1.7237	
Connolly 1	Hyperbolic	–2 796.09	–6 823.5	–2.4361
Coomalloo 1	Power	1 613.74	1.1734	
Cypress Hill 1	Hyperbolic	–5 761.06	–34 263.93	–5.9185
Denison 1	Hyperbolic	–7 214.27	–43 021.39	–5.9569
Depot Hill 1	Exponential	1 230.47	0.1976	
Dongara 2	Hyperbolic	–17 933.28	–219 609.4	–12.2763
Dongara 26	Exponential	1 319.74	0.1295	
Dongara 27	Hyperbolic	–6 024.18	–29 231.65	–4.8458
East Heaton 1	Exponential	1 177.63	0.2459	
East Lake Logue 1	Hyperbolic	–13 634.63	–126 832.3	–9.3728
Ejarno 1	Hyperbolic	–10 970.57	–83 376.07	–7.6398
Eleven Mile 1	Power	1 163.46	0.95733	
Eneabba 1	Power	1 632.85	1.16157	
Erregulla 1	Power	1 505.58	1.2380	
Erregulla 2	Power	1 492.05	1.2269	
Gairdner 1	Hyperbolic	–59 819.03	–1 967 702	–32.90892
Horner West 1	Exponential	1 151.82	0.31527	
Indoon 1	Hyperbolic	–13093.49	–116 312.1	–8.90472
Jurien 1	Power	1 914.96	1.1745	
Mondarra 1	Power	1 576.89	1.3386	top half only
	Hyperbolic	–14 472.09	–129 551.3	–9.06247
Mount Adams 1	Power	1 545.44	1.1885	top half only
	Hyperbolic	–36 449.65	–783 821.5	–21.61945
Mount Horner 2	Exponential	1 290.10	0.18041	
Mount Horner 7	Power	1 534.59	1.13095	top half only
	Hyperbolic	–8 227.68	–50 827.12	–6.196224
Mullering 1	Hyperbolic	–4 244.34	–15 620.85	–3.6798
Narkarino 1	Exponential	1 010.76	0.4227	
North Erregulla 1	Hyperbolic	–9 980.547	–74 538.33	–7.510252
North Yardarino 1	Hyperbolic	–8 545.15	–55 997.61	–6.65719
Ocean Hill 1	Exponential	1 265.47	0.2212	
Peron 1	Power	1 747.26	1.11909	
Point Louise 1	Power	1 676.30	1.0855	
Rakrani 1	Hyperbolic	–4 986.39	–21 922.1	–4.40136
Robb 1	Exponential	973.075	0.35675	
South Yardanogo 1	Hyperbolic	–8 595.53	–57 521.7	–6.70045
Walyering 1	Power	1 687.57	1.1425	
Walyering 3	Hyperbolic	–11 409.1	–93 575.9	–8.242613
Warradong 1	Power	1 522.67	1.22272	
Warro 1	Exponential	1 064.87	0.19609	
Warro 2	Exponential	1 139.64	0.16234	
West Erregulla 1	Hyperbolic	–13 348.1	–122 596.2	–9.22739
Woodada 1	Hyperbolic	–6 805.65	–37 813.91	–5.5995
Woodada 2	Hyperbolic	–6 859.53	–38 276.41	–5.6035
Woodada 5	Power	1 310.38	1.34754	
Woodada 9	Hyperbolic	–9 484.90	–66 678.45	–7.05055
Woodada 10	Hyperbolic	–6 395.22	–33 867.4	–5.3267
Woolmulla 1	Exponential	1 635.045	0.090337	
West White Point 1	Power	1 567.41	1.10682	
Yallallie 1	Hyperbolic	–6 739.43	–40 133	–6.0106

Notes: The functions used are:

Power $D = A_0*(T**A_1)$

Exponential $D = A_0*T*exp(A_1*T)$

Hyperbolic $D = A_0+(A_1/(A_2+T))$

where: A_0, A_1, A_2 are coefficients
D is depth to horizon in metres
T is two-way time to horizon in seconds

Appendix 8

Vitrinite reflectance data (R_o mean) in the onshore northern Perth Basin

Well name	*Depth (m)*	*Ro*
ALLANOOKA 1	197.0	0.35
(Cook, 1979b)	279.0	0.30
	398.0	0.36
	489.0	0.34
	580.0	0.43
	608.0	0.39
	700.0	0.43
	766.0	0.46
	809.0	0.41
	913.0	0.43
	977.0	0.43
ARROWSMITH 1	2 268.0	0.44
(BARRACK, 1989a)	2 679.0	0.58
BEHARRA 2	1 112.5	0.23
(Cook, 1979b)	1 204.0	0.29
	1 249.7	0.29
	1 341.1	0.37
	1 373.0	0.50
	1 396.0	0.51
	1 414.3	0.40
	1 432.6	0.43
	1 450.8	0.95
	1 508.8	0.56
	1 797.0	0.76
	1 830.0	0.83
	1 871.0	0.81
	1 923.0	0.85
BMR 10A	1 223.0	0.55
(Cook, 1979a)	1 224.5	0.52
	1 265.7	0.65
	1 304.5	0.64
	1 338.8	0.65
	1 397.5	0.60
	1 414.3	0.65
BONNIEFIELD 1	570.0	0.39
(Kenway and Sutherland, 1985)	625.0	0.40
	745.0	0.36
	795.0	0.38
	995.0	0.40
BOOKARA 2	180.0	0.34
(Cook, 1979b)	271.0	0.31
	394.0	0.28
	431.0	0.41
	521.0	0.36
	742.0	0.39
	748.0	0.39
CADDA 1	1 698.0	0.39
(BARRACK, 1989b)	1 701.0	0.64
CASUARINAS 1	342.5	0.40
(Gorter et al., 1982)	375.0	0.41
	402.5	0.39
	437.5	0.41
	437.5	0.48
	475.0	0.39
	525.0	0.40
	545.0	0.40
	572.5	0.41
	572.5	0.49
	675.0	0.49
	722.5	0.42
	722.5	0.45
	767.5	0.45
	782.5	0.54
CASUARINAS 1 (cont.)	877.5	0.39
	877.5	0.54
	962.5	0.39
	962.5	0.84
	962.5	1.03
	997.5	0.39
	1 047.5	0.77
	1 087.5	0.40
	1 087.5	0.54
	1 087.5	0.74
	1 135.0	0.40
	1 135.0	0.53
	1 135.0	0.73
	1 135.0	0.85
	1 187.5	0.41
	1 187.5	0.85
	1 225.0	0.40
	1 225.0	0.80
	1 225.0	1.18
	1 275.0	0.39
	1 275.0	0.85
	1 275.0	1.02
	1 275.0	0.56
	1 325.0	0.40
	1 365.0	0.50
	1 365.0	0.80
	1 455.0	0.41
	1 455.0	0.76
	1 455.0	1.04
	1 455.0	1.27
CONDER 1	86.05	0.34
(Thompson, 1988a)	123.23	0.41
	173.90	0.55
	190.64	0.46
	193.47	0.40
	196.26	0.44
	200.01	0.59
CONNOLLY 1	203.0	0.39
(Thompson, 1988b)	213.5	0.41
	273.0	0.39
	385.0	0.41
	390.0	0.47
	398.0	0.43
COOMALLO 1	687.5	0.49
(Kantsler, 1978)	785.0	0.49
	875.0	0.45
	932.5	0.51
	1 242.5	0.51
	2 002.5	0.52
	2 192.5	0.52
	2 272.5	0.55
	2 285.0	0.60
	2 430.0	0.57
	2 997.5	0.61
	3 212.5	0.61
	3 260.0	0.75
DEPOT HILL 1	926.5	0.52
(MESA, 1983)	1 272.0	0.59
	1 452.0	0.57
	1 674.0	0.41
	1 940.0	0.46
	2 130.0	0.55
	2 277.5	0.50
	2 442.0	0.55

Appendix 8 (*continued*)

Well name	*Depth (m)*	*Ro*
DONKEY CREEK 1	413.0	0.43
(Cook, 1979b)	1 091.0	0.48
	1 335.0	0.49
	1 801.0	0.49
	1 830.0	0.54
	1 864.0	0.63
	1 985.0	0.65
	1 985.0	0.50
	1 985.0	0.57
	2 319.0	0.60
	3 204.0	0.60
	3 740.0	0.82
	3 740.0	0.88
	3 832.0	0.68
	3 832.0	0.81
EAST HEATON 1	1 092.0	0.30
(WMC, 1985)	1 377.0	0.40
	1 545.0	0.35
	2 010.0	0.39
	2 039.0	0.50
	2 100.0	0.48
	2 271.0	0.50
	2 351.0	0.58
	2 445.0	0.59
	2 513.0	0.63
ELEVEN MILE 1	199.5	0.31
(Mitchell, 1988)	202.5	0.30
	205.5	0.31
	208.5	0.29
	211.5	0.29
	214.5	0.31
	217.5	0.33
	220.5	0.33
	223.5	0.33
	226.5	0.36
	229.5	0.36
	232.5	0.33
	235.5	0.33
	238.5	0.34
	241.5	0.35
	244.5	0.37
	247.5	0.37
	250.5	0.35
	253.5	0.37
	256.5	0.37
	259.5	0.37
	268.5	0.37
	289.5	0.38
	295.5	0.40
ENEABBA 1	251.0	0.48
(Cook, 1979a)	645.0	0.51
	666.0	0.49
	779.0	0.39
	940.0	0.39
	940.0	0.64
	1 041.0	0.42
	1 270.0	0.75
	1 880.0	0.67
	1 888.0	0.68
	1 947.0	0.64
	1 965.0	0.68
	2 072.0	0.66
	2 331.0	0.66
	2 370.0	0.67
	2 421.0	0.67
	2 596.0	0.65
	2 864.0	0.60
	3 346.0	1.35
	3 421.0	1.14
	3 430.0	1.09
	3 540.0	1.16
	3 961.0	1.21

Well name	*Depth (m)*	*Ro*
ERREGULLA 1	1 233.0	0.35
(Cook, 1979b)	1 434.0	0.43
	1 617.0	0.42
	1 663.0	0.41
	1 891.0	0.54
	1 891.0	0.42
	1 891.0	0.32
	2 028.0	0.54
	2 307.0	0.64
	2 343.0	0.62
	2 379.0	0.74
	2 379.0	0.59
	2 379.0	0.68
	2 500.0	0.68
	2 729.0	0.70
	2 729.0	0.75
	3 406.0	0.66
	3 510.0	0.64
	4 223.0	0.90
GEELVINK 1A	490.0	0.43
(Cook, 1979b)	500.0	0.33
	600.0	0.37
	685.0	0.44
	700.0	0.38
	795.0	0.38
	800.0	0.38
	900.0	0.38
	1 000.0	0.45
	1 020.0	0.48
	1 100.0	0.45
	1 200.0	0.49
	1 300.0	0.45
	1 310.0	0.47
	1 360.0	0.52
	1 400.0	0.50
	1 500.0	0.47
	1 600.0	0.50
	1 600.0	0.58
	1 630.0	0.53
	1 700.0	0.49
	1 900.0	0.55
	2 000.0	0.61
	2 100.0	0.63
	2 165.0	0.61
	2 200.0	0.61
	2 300.0	0.65
	2 305.0	0.76
	2 400.0	0.63
	2 700.0	0.65
	2 720.0	0.67
	2 800.0	0.65
	2 800.0	0.67
	2 900.0	0.69
	2 940.0	0.90
	2 940.0	0.96
	2 970.0	1.04
	3 000.0	1.31
	3 053.0	1.42
INDOON 1	1 176.0	0.62
(Lane and Eisenbarth, 1983)	1 190.0	0.64
	1 263.0	0.62
	1 296.0	0.64
	1 331.0	0.60
	1 420.0	0.64
	1 450.0	0.60
	1 510.0	0.65
	1 540.0	0.58
	1 600.0	0.60
	1 660.0	0.58
	1 690.0	0.57
	1 700.0	0.62
	1 720.0	0.57
	1 740.0	0.58
	1 750.0	0.58

Appendix 8 (*continued*)

Well name	Depth (m)	Ro
INDOON 1 (cont.)	1 780.0	0.60
	1 810.0	0.58
	1 820.0	0.61
	1 840.0	0.60
	1 870.0	0.54
	1 900.0	0.59
	1 910.0	0.58
	1 930.0	0.58
	1 945.0	0.60
	1 960.0	0.61
	1 975.0	0.64
	2 020.0	0.65
	2 050.0	0.65
	2 090.0	0.62
	2 103.0	0.67
	2 113.0	0.66
	2 121.0	0.66
	2 128.0	0.69
	2 135.0	0.71
	2 143.0	0.69
	2 150.0	0.71
	2 162.0	0.73
	2 165.0	0.72
	2 168.0	0.73
	2 221.0	0.73
	2 223.0	0.70
	2 225.0	0.73
JURIEN 1	94.0	0.56
(BARRACK, 1989b)	267.0	0.63
MONDARRA 1	2 504.0	0.73
(WMC, 1986)	2 624.0	0.57
MOUNT HORNER 1	1 038.0	0.46
(Cook, 1979b)	1 065.0	0.55
	1 321.0	0.48
	1 525.0	0.72
	1 644.0	0.76
	1 775.0	0.63
	1 801.0	0.57
	2 141.0	0.96
	2 233.0	0.53
PERON 1	825.0	0.70
(Lane et al., 1983)	1 050.0	0.82
	1 375.0	0.81
	1 480.0	0.85
	1 515.0	0.86
	1 730.0	0.95
	1 900.0	1.37
	1 961.0	1.48
	2 351.0	2.05
	2 416.0	2.13
RAKRANI 1	1 180.0	0.38
(Mitchell, 1990)		
ROBB 1	852.0	0.45
(Lane and Watson, 1985)	924.0	0.46
	1 366.0	0.54
	1 380.0	0.54
	1 393.0	0.59
	1 398.0	0.51
	1 409.0	0.56
	1 499.0	0.56
	1 572.0	0.58
ROBB 1 (cont.)	1 637.0	0.67
	1 900.0	0.72
	1 913.0	0.77
WALYERING 1	532.0	0.40
(Cook, 1979b)	1 145.0	0.51
	1 791.0	0.55
	2 337.0	0.31
	2 337.0	0.46
	2 572.0	0.55
	2 907.0	0.68
	2 992.0	0.66
	3 172.0	0.64
	3 395.0	0.62
	3 507.0	0.70
	3 593.0	0.82
	3 593.0	1.10
WATTLE GROVE 1	524.0	0.34
(BALMORAL, 1985)	560.0	0.40
	650.7	0.38
	688.7	0.47
	790.0	0.45
WEST WHITE POINT 2	172.0	0.30
(Cook, 1979b)	474.0	0.39
	594.0	0.38
	733.0	0.41
	855.0	0.42
	879.0	0.42
	1 224.0	0.30
	2 074.0	1.20
	2 250.0	1.06
	2 278.0	0.65
WOOLMULLA 1	1 313.0	0.57
(BARRACK, 1989; Cook, 1979a)	1 699.0	0.98
	1 700.0	1.08
	1 997.0	2.06
	2 358.0	2.70
	2 684.0	4.64
	2 711.0	4.43
YARDARINO 1	157.0	0.49
(Cook, 1979a; WMC, 1986)	258.0	0.46
	314.0	0.30
	314.0	0.42
	314.0	0.49
	431.0	0.45
	605.0	0.50
	1 029.0	0.56
	1 184.0	0.32
	1 184.0	0.47
	1 282.0	0.50
	1 345.0	0.52
	1 364.0	0.61
	1 379.0	0.49
	1 410.0	0.53
	1 580.0	0.51
	1 635.0	0.56
	1 702.0	0.60
	2 309.0	0.70
	2 339.0	0.75
	2 368.0	1.31
	2 368.0	1.56
	2 368.0	1.40
	2 370.0	1.09

Appendix 9

Calculated temperature gradients for selected wells and water bores in the onshore northern Perth Basin

Well name	Eastings	Northings	Depth (m)	Corrected temperature (°C)	Surface temperature (°C)	Gradient (°C/100 m)
Petroleum exploration wells						
Allanooka 1	306709	6774447	1 186	69	25	3.7
Arramall 1	315574	6725010	2 246	103	25	3.5
Arranoo 1	312965	6774970	1 737	79	24	3.1
Arrowsmith 1	317502	6722749	3 445	132	22	3.2
Barberton 1	401692	6589966	3 406	83	22	1.8
Batavia 1	232811	6800024	2 550	125	22	3.2
Beekeeper 1	324471	6711454	3 013	127	25	3.4
Beharra Springs 1	319610	6739001	3 416	135	22	3.3
Beharra Springs 2	320000	6737470	3 491	144	25	3.4
Beharra 1	307500	6736379	2 056	90	22	3.3
Bonniefield 1	297043	6771198	1 012	60	22	3.8
Bookara 1	282899	6791650	279	52	20	6.6
Bookara 2	296739	6771638	760	60	22	5.0
Bookara 3	294568	6778128	537	57	22	6.6
Cadda 1	328252	6642452	2 788	111	22	3.2
Cataby 1	340248	6603818	2 290	81	22	2.6
Conder 1	297743	6785206	252	32	20	4.8
Connolly 1	300542	6786087	476	43	20	5.0
Coomallo 1	347594	6652578	3 496	102	25	2.2
Cypress Hill 1	385926	6629163	989	56	20	3.7
Denison 1	301200	6765280	2 303	114	22	4.0
Depot Hill 1	337002	6779581	2 468	121	20	4.1
Diamond Soak 1	331050	6800062	1 722	101	22	4.6
Dongara 21	306458	6764293	1 887	80	22	3.1
Dongara 22	303569	6762700	1 798	80	22	3.2
Dongara 23	306217	6761304	1 758	95	25	4.0
Dongara 24	307268	6764093	1 767	80	22	3.3
Dongara 25	308037	6763452	1 817	81	20	3.4
Dongara 26	302806	6762908	1 829	86	22	3.5
Donkey Creek 1	334474	6721380	3 845	122	22	2.6
East Heaton 1	329697	6778058	2 518	100	25	3.0
East Lake Logue 1	321582	6698148	2 430	109	22	3.6
Ejarno 1	313144	6755558	2 869	113	22	3.2
Eleven Mile 1	293884	6781565	319	39	20	6.1
Erregulla 1	344475	6749142	4 245	143	25	2.8
Erregulla 2	344472	6749358	3 265	106	22	2.6
Eurangoa 1	318825	6776475	2 277	86	20	2.9
Geelvink 1A	237023	6778307	3 047	108	20	2.9
Gairdner 1	321273	6671849	2 170	110	22	4.1
Greenough 1	271242	6805900	442	40	25	3.5
Heaton 1	326086	6777203	2 433	94	22	3.0
Horner West 1	309604	6775285	1 442	69	20	3.4
Houtman 1	165906	6824303	3 846	148	22	3.0
Hunt Gully 1	320163	6779698	1 980	81	22	3.0
Indoon 1	321465	6692663	2 255	119	25	4.2
Jay 1	310818	6781691	1 295	60	22	2.9
Jurien 1	312022	6663466	1 025	77	20	5.6
Leander Reef 1	280407	6741151	3 235	157	25	4.1
Mondarra 1	317080	6757112	3 066	132	25	3.5
Mooratara 1	296716	6766473	1 630	75	25	3.1
Mount Adams 1	322121	6745518	3 791	158	22	3.6
Mount Bridge 1	316166	6723872	3 416	150	22	3.7
Mount Hill 1	303740	6782662	565	52	22	5.4
Mount Horner 1	313693	6776146	2 254	89	24	2.9
Mount Horner 3	313693	6776117	1 559	66	22	2.8
Mount Horner 4	314181	6776059	1 815	72	22	2.8
Mount Horner 4A	314209	6776126	1 252	58	22	2.9

Appendix 9 (continued)

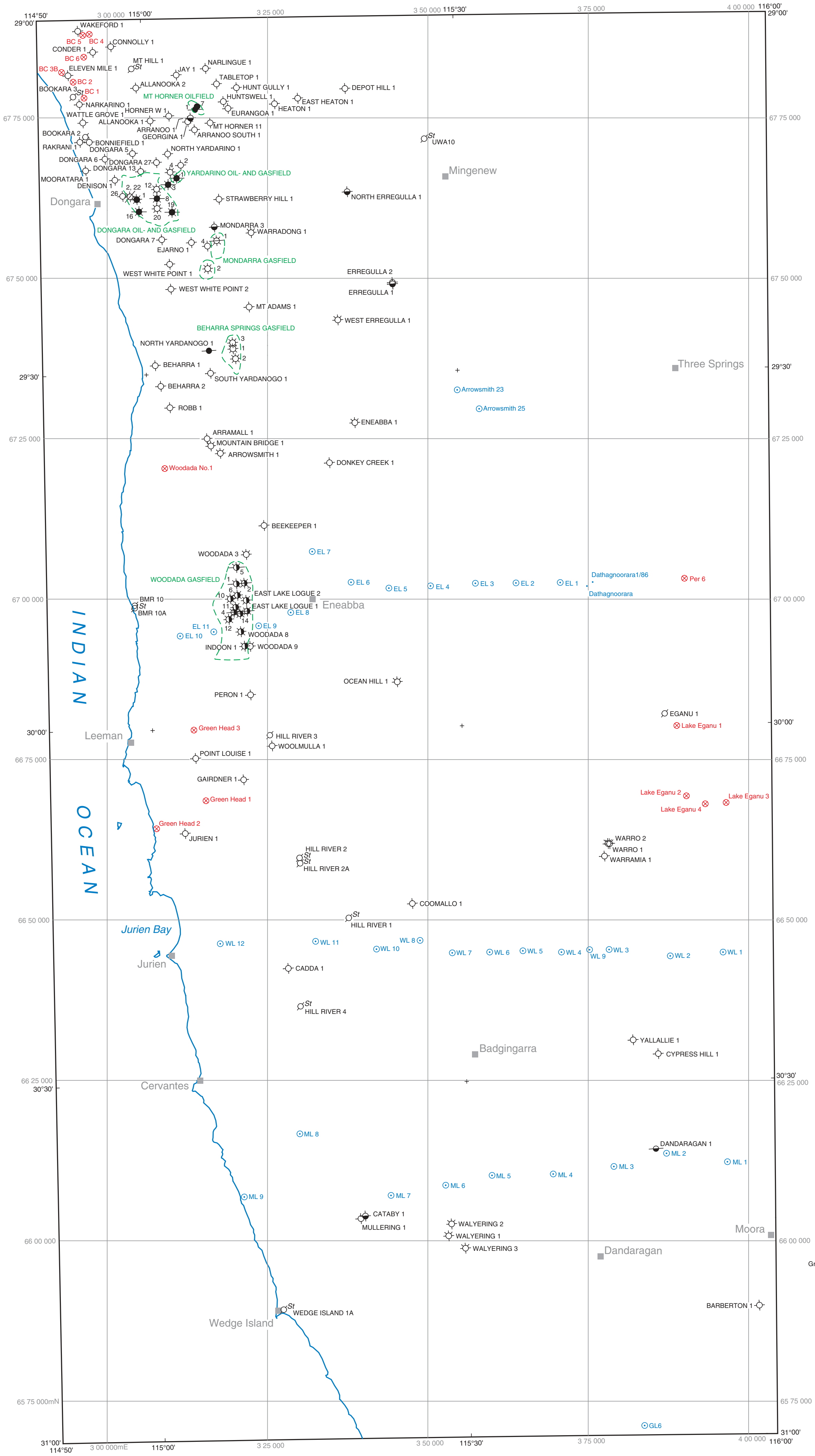
Well name	*Eastings*	*Northings*	*Depth* (*m*)	*Corrected temperature* (*°C*)	*Surface temperature* (*°C*)	*Gradient* (*°C/100 m*)
Mount Horner 5	313990	6776455	1 814	75	22	2.9
Mount Horner 6	314219	6775350	1 847	76	22	2.9
Mount Horner 7	314307	6776715	1 846	77	22	3.0
Mount Horner 8	314349	6775696	1 300	62	22	3.1
Mount Horner 10	314807	6775858	1 441	69	22	3.3
Mount Horner 11	316050	6774216	1 370	62	22	2.9
Mungarra 2	313135	6800525	605	45	25	3.4
Mungarra 3	313236	6794306	625	43	22	3.5
Mungarra 4	330897	6801260	635	42	20	3.5
Mungarra 5	318312	6802116	615	42	20	3.6
Narlingue 1	315318	6782700	2 128	88	22	3.1
North Erregulla 1	337337	6763636	3 449	118	22	2.8
North Yardanogo 1	315895	6738699	2 380	101	25	3.2
North Yardarino 1	309430	6769368	2 202	86	20	3.0
Ocean Hill 1	345227	6687116	3 837	137	22	3.0
Peron 1	322368	6685060	2 600	126	22	4.0
Point Louise 1	313807	6675166	948	64	22	4.4
Rakrani 1	295749	6771183	1 200	65	22	3.6
Robb 1	309788	6729840	1 981	89	22	3.4
South Turtle Dove1	272299	6664501	1 330	86	20	5.0
South Yardanogo 1	316114	6735198	2 341	100	25	3.2
Strawberry Hill 1	317428	6762321	2 901	130	20	3.8
Walyering 3	355839	6598817	4 184	118	22	2.3
Warradong 1	322386	6757211	3 715	147	25	3.3
Warramia 1	377536	6659948	1 498	64	22	2.8
Warro 1	378328	6661876	4 389	131	22	2.5
Wattle Grove 1	296206	6774222	805	50	22	3.5
West Erregulla 1	335959	6743499	4 064	150	20	3.2
West White Pt 1	309689	6752060	2 242	101	25	3.4
West White Pt 2	309940	6748307	2 355	105	25	3.4
Woodada 1	320147	6702378	2 540	111	20	3.6
Woodada 2	321389	6702476	2 453	120	20	4.1
Woodada 3	321674	6706972	2 522	100	25	3.0
Woodada 4	320549	6698032	2 269	103	22	3.6
Woodada 5	320153	6704936	2 808	134	25	3.9
Woodada 6	320296	6700600	2 707	127	22	3.9
Woodada 8	320854	6694932	2 272	117	22	4.2
Woodada 9	322314	6692646	2 354	116	25	3.9
Woodada 10	319218	6700046	2 339	106	22	3.6
Woolmulla 1	325725	6677119	2 813	129	25	3.7
Yallallie 1	381894	6642386	3 145	94	22	2.3
Yardarino 1	310943	6765846	2 290	107	20	3.8

Water bores

Eneabba Line 1	370600	6702600	751	31	20	1.5
Eneabba Line 2	363900	6702500	762	36	20	1.8
Eneabba Line 3	357400	6702500	762	39	20	2.5
Eneabba Line 4	350500	6702100	627	34	20	2.2
Eneabba Line 5	353700	6701900	718	36	20	2.2
Eneabba Line 6	338100	6702700	763	37	20	2.3
Eneabba Line 7	332000	6707400	765	38	20	2.4
Eneabba Line 8	328900	6698000	730	38	20	2.5
Eneabba Line 9	323700	6696100	797	46	20	2.9
Eneabba Line 11	316500	6694500	102	24	20	4.2
Gillingarra Line 1	348000	6564250	1 002	48	20	2.8
Gillingarra Line 2	350300	6566300	1 004	52	20	3.2
Gillingarra Line 3	358700	6567800	1 007	51	20	3.1
Gillingarra Line 4	368150	6566600	1 200	50	20	2.5
Gillingarra Line 5	376750	6569250	1 200	49	20	2.4
Gillingarra Line 6	383700	6571200	974	55	20	3.6
Gillingarra Line 7	394350	6568600	1 201	52	20	2.7
Gillingarra Line 8	405000	6566000	1 169	54	20	2.9
Moora Line 1	396720	6612250	756	40	20	2.7
Moora Line 2	387150	6613540	464	36	20	3.5

Appendix 9 (continued)

Well name	*Eastings*	*Northings*	*Depth (m)*	*Corrected temperature (°C)*	*Surface temperature (°C)*	*Gradient (°C/100 m)*
Moora Line 3	379000	6611510	762	47	20	3.5
Moora Line 4	369500	6610380	731	29	20	1.3
Moora Line 5	360030	6610260	772	31	20	1.4
Moora Line 6	352620	6608530	772	33	20	1.7
Moora Line 7	344150	6606940	801	35	20	1.9
Moora Line 8	329960	6596590	770	35	20	2.0
Watheroo Line 5	365290	6645220	765	36	20	2.2
Watheroo Line 6	359740	6644990	762	36	20	2.1
Watheroo Line 7	353810	6644950	758	37	20	2.2
Watheroo Line 8	348730	6646760	755	37	20	2.3
Watheroo Line 9	342020	6645520	765	36	20	2.2
Watheroo Line 11	332460	6646610	762	50	20	4.0
Watheroo Line 12	317660	6646160	762	37	20	2.3



SYMBOLS

- Mineral exploration drillhole
- GSWA exploratory water bore
- Water Authority water bore

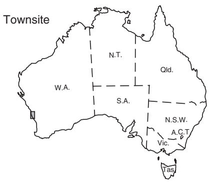
PETROLEUM EXPLORATION WELLS

- Dry, plugged and abandoned
- Show of gas, plugged and abandoned
- Show of oil, plugged and abandoned
- Show of oil, plugged and abandoned
- Show of oil and gas, plugged and abandoned

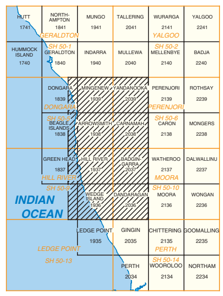
PETROLEUM PRODUCTION WELLS

- Oil
- Gas
- Oil and gas
- Gas and condensate
- Oil, suspended
- Gas, suspended
- Oil and gas, suspended
- Gas and condensate, suspended
- Oil, abandoned
- Gas, abandoned

- St Stratigraphic well
- Oil- and gasfield outlines
- Coastline
- Townsite



INDEX MAP



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PIETRO GUJ, DIRECTOR

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 46 PLATE 1

PETROLEUM WELLS, DEEP BORES AND DRILLHOLES

ONSHORE NORTHERN PERTH BASIN

Status of wells current at 31.12.94

SCALE 1: 500 000

5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Compilation of well data by A.J. Mory

Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and L. Cosgrove

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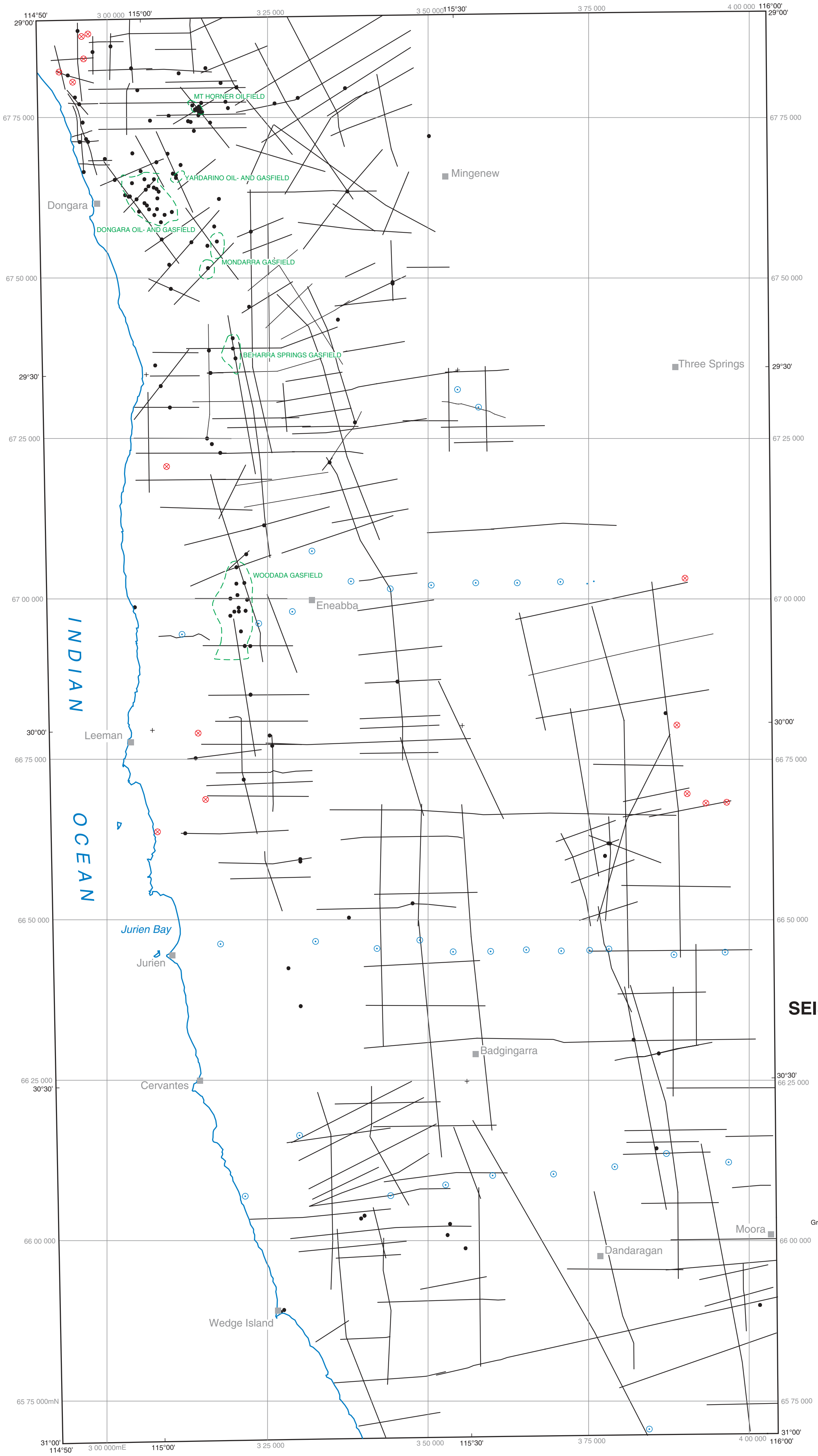
This map is also available in digital form

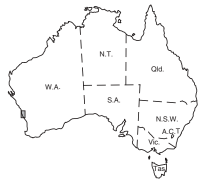
Printed by Allwest Print, Western Australia

The recommended reference for this map is: MORY, A.J., and IASKY, R.P., 1996, Petroleum wells, deep bores and drillholes, onshore northern Perth Basin: Western Australia Geological Survey, Report 46, Plate 1

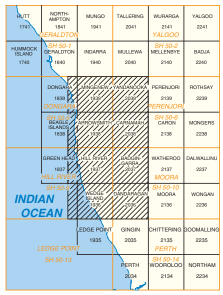


SYMBOLS

- Seismic line
- Petroleum well
- Mineral exploration drillhole
- GSWA exploratory water bore
- Water Authority water bore
- Coastline
- Townsite
- Oil- and gasfield outlines



INDEX MAP



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REPORT 46 PLATE 2

SEISMIC LINE LOCATION MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000

5000 0 5 10 15 20

Metres Kilometres

TRANSVERSE MERCATOR PROJECTION

Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Compilation of seismic lines and selected wells by R.P. Iasky, and A.J. Mory

Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and L. Cosgrove

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Printed by Allwest Print, Western Australia

The recommended reference for this map is:
MORY, A.J., and IASKY, R.P., 1996, Seismic line location map, northern onshore Perth Basin:
Western Australia Geological Survey, Report 46, Plate 2

SYMBOLS

Seismic line showing shotpoints

Coastline

Townsite

PETROLEUM EXPLORATION WELLS

Dry, plugged and abandoned

Show of gas, plugged and abandoned

Show of oil, suspended

Show of oil, plugged and abandoned

Show of oil and gas, plugged and abandoned

PETROLEUM PRODUCTION WELLS

Oil

Gas

Oil and gas

Gas and condensate

Oil, suspended

Gas, suspended

Oil and gas, suspended

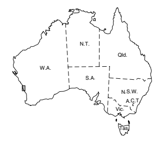
Gas and condensate, suspended

Oil, abandoned

Gas, abandoned

Stratigraphic well

Oil- and gasfield outlines



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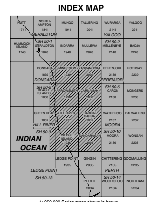

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REPORT 46 PLATE 3

SEISMIC SHOTPOINT LOCATION MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 250 000

4000 0 10 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Compilation of seismic shotpoint location by R.P. Iasky

Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and L. Cosgrove

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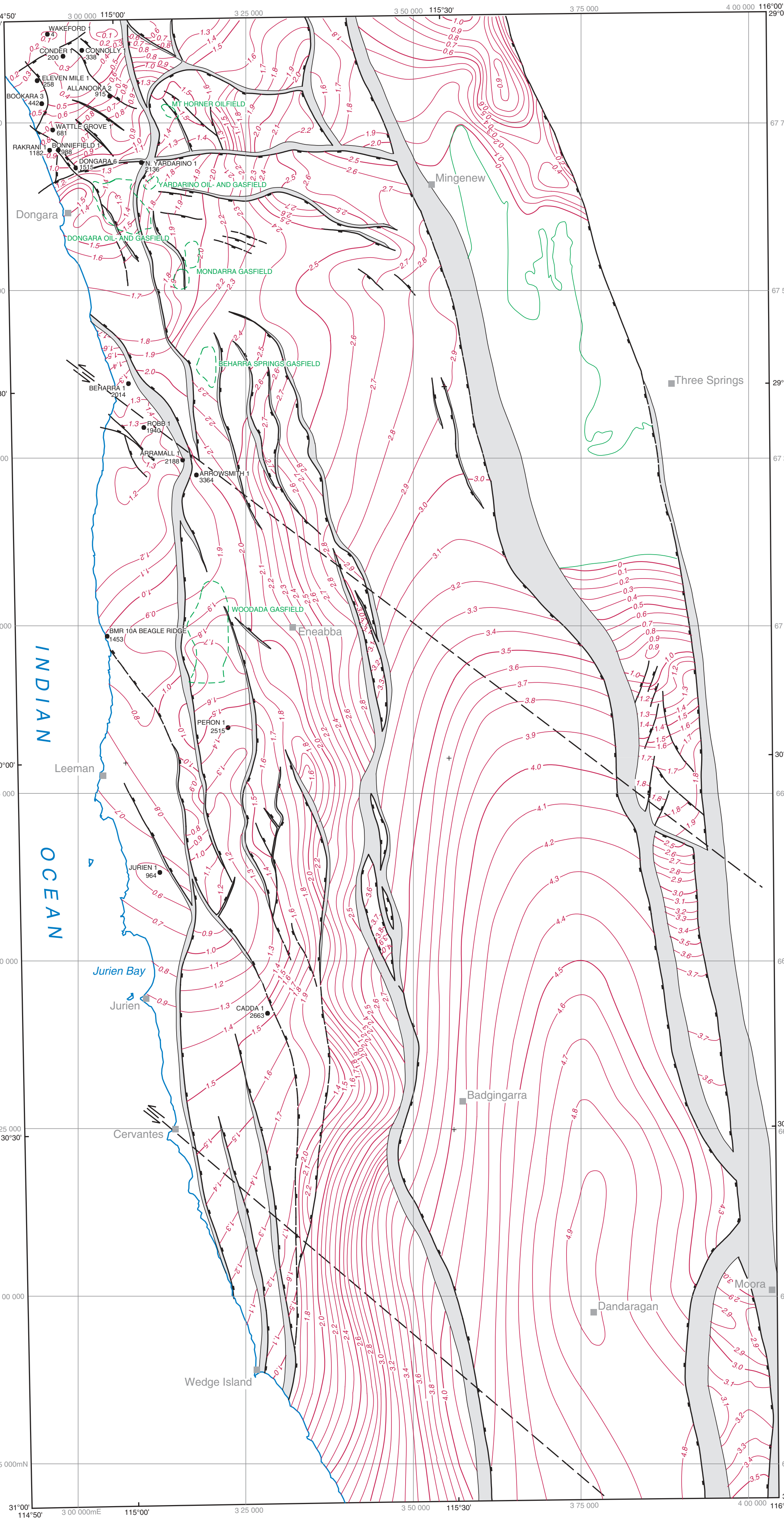
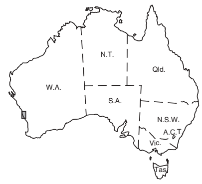
The recommended reference for this map is: MORY, A.J., and IASKY, R.P., 1996, Seismic Shotpoint location map, onshore northern Perth Basin: Western Australia Geological Survey, Report 46, Plate 3

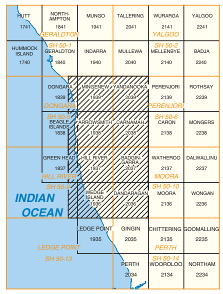


SYMBOLS

- Two-way time contours, in seconds, contour interval 100 milliseconds
- Fault; showing downthrown side and heave, inferred. Tick on downthrown side
- Transfer fault
- Pre-Quaternary "surface" intersection Top basement
- Petroleum well location; showing depth to basement in metres subsea
- Coastline
- Townsite
- Oil- and gasfield outlines



INDEX MAP



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REPORT 46 PLATE 4

TOP BASEMENT TWO-WAY TIME STRUCTURE MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000

5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Seismic and gravity interpretation by R.P. Iasky
Geology by A.J. Mory
Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and L. Cosgrove
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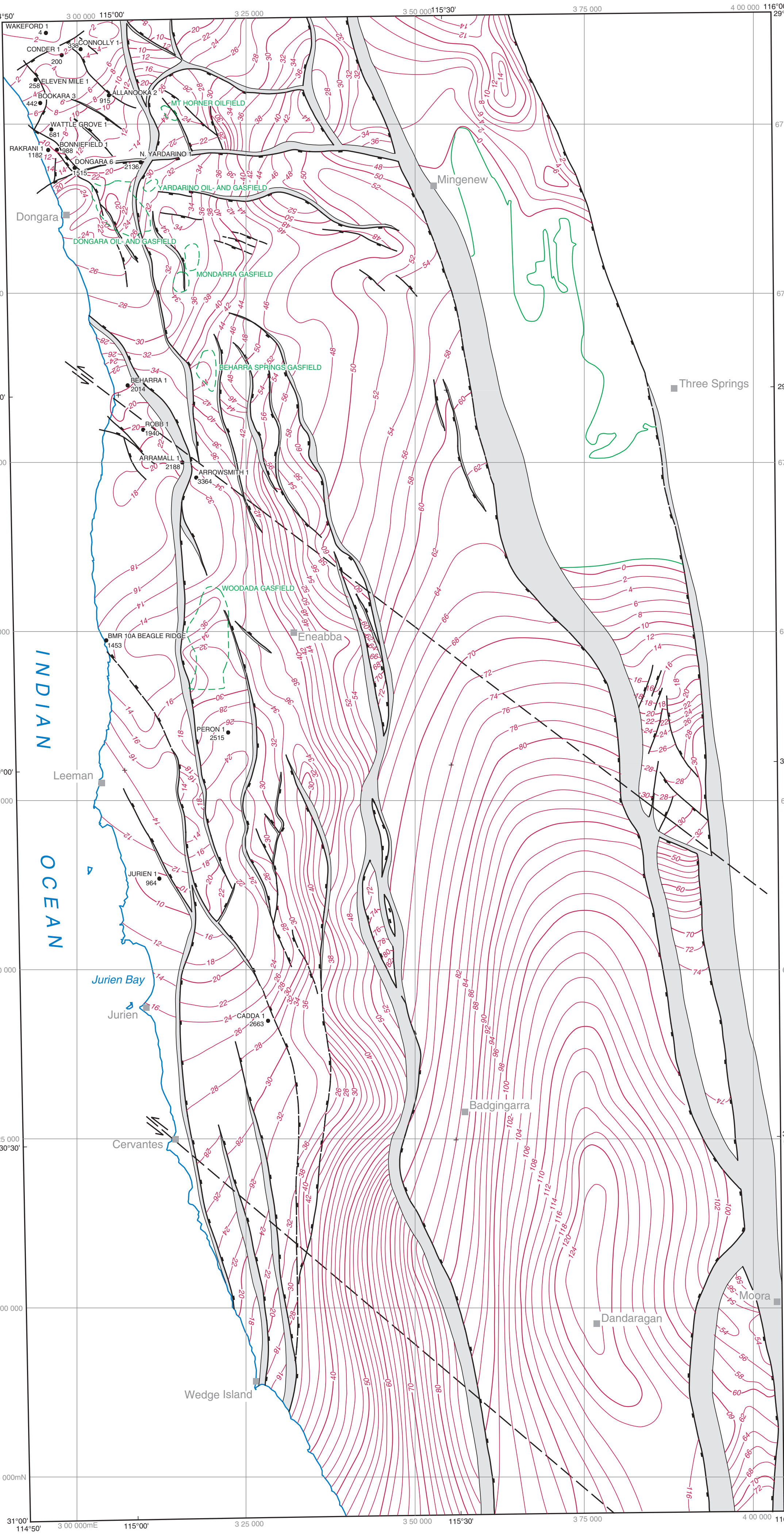
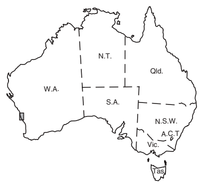


SYMBOLS

- Depth contours, in hundred metres subsea, contour interval 200 metres
- Fault; showing downthrown side and heave, inferred. Tick on downthrown side
- Transfer fault
- Pre-Quaternary "surface" intersection Top basement
- Petroleum well; showing depth to basement in metres subsea
- Coastline
- Townsite
- Oil- and gasfield outlines



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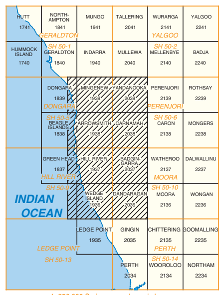

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REPORT 46 PLATE 5

TOP BASEMENT DEPTH STRUCTURE MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000

5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Seismic and gravity interpretation by R.P. Iasky
Geology by A.J. Mory

Edited by S. Willis, D. Ferdinando and G. Loan
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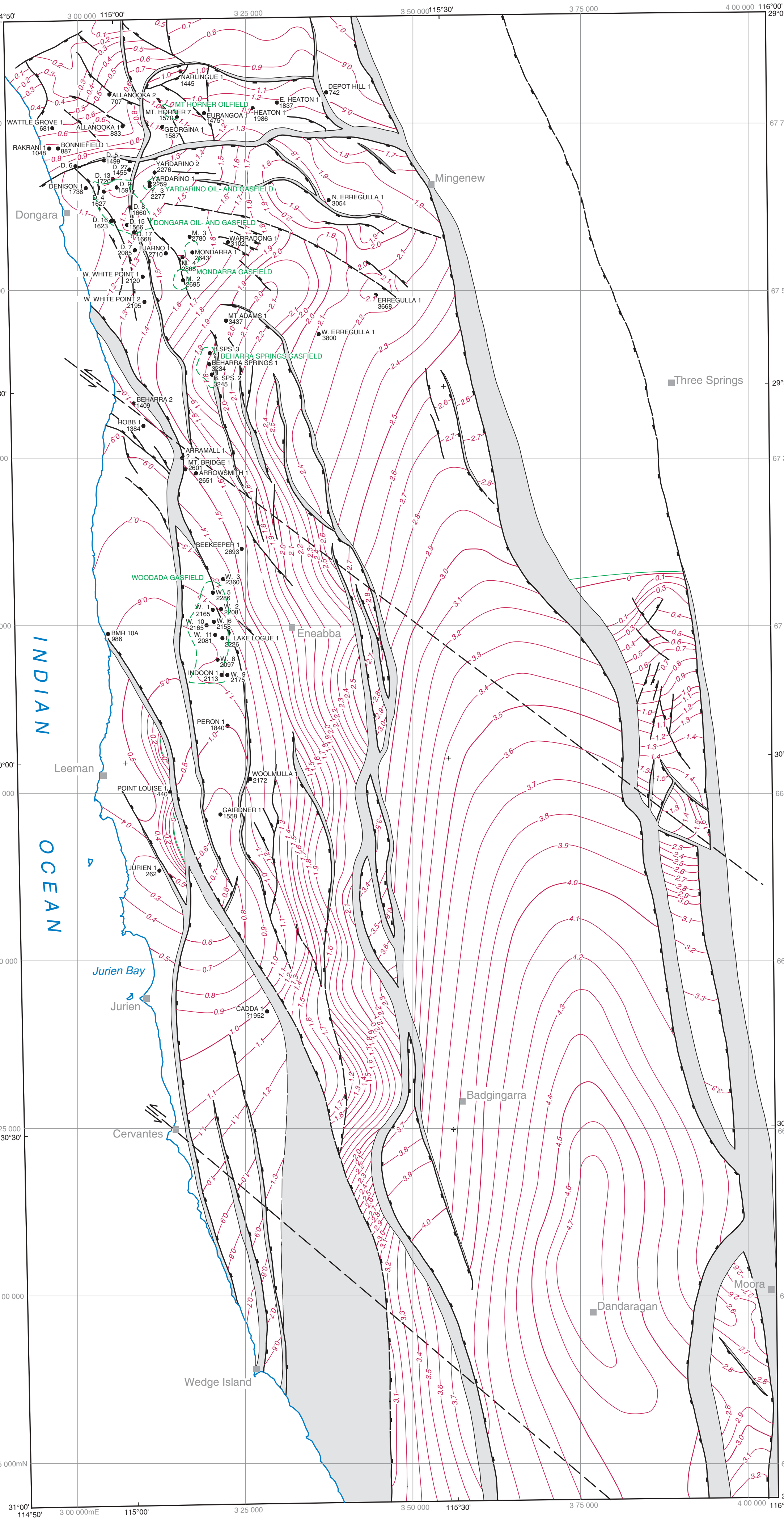
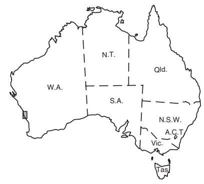


SYMBOLS

- 2.8 — Two way time contours, in seconds, contour interval 100 milliseconds
- Fault; showing downthrown side and heave, inferred. Tick on downthrown side
- Transfer fault
- Pre-Quaternary "surface" intersection Top Permian
- Petroleum well; showing depth to Top Permian in metres subsea
- D. 17 — Dongara Field wells
- W. 2 — Woodada Field wells
- Coastline
- Townsite
- Oil- and gasfield outlines



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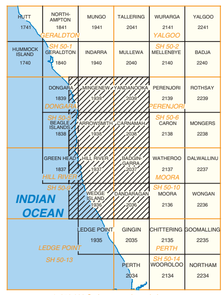

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REPORT 46 PLATE 6

TOP PERMIAN TWO-WAY TIME STRUCTURE MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000

5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Seismic and gravity interpretation by R.P. Iasky
Geology by A.J. Mory

Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and L. Cosgrove

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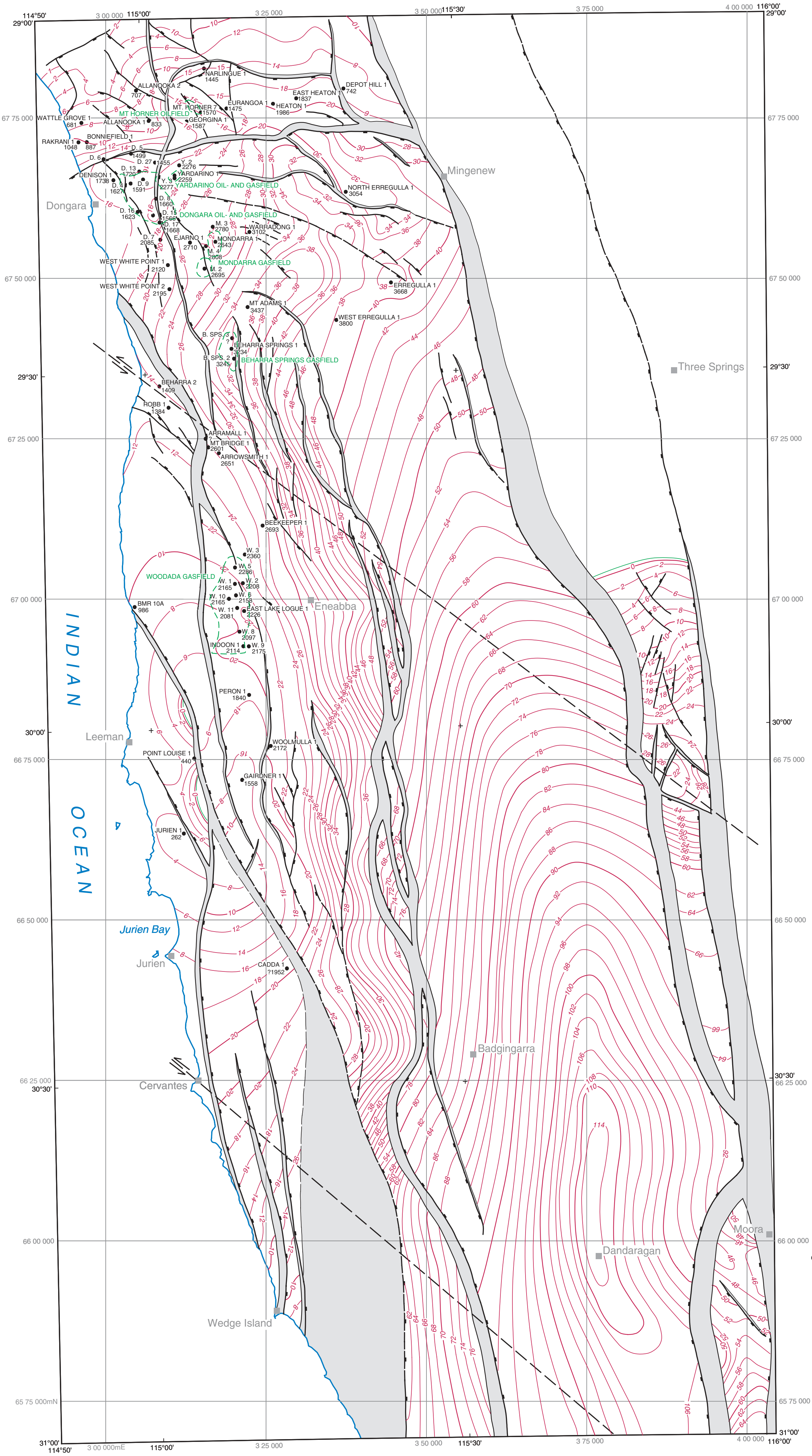
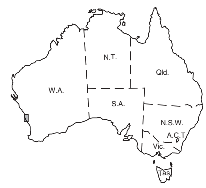
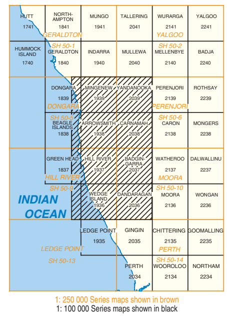


SYMBOLS

94	Depth contours, in hundred metres subsea, contour interval 200 metres
	Fault; showing downthrown side and heave, inferred. Tick on downthrown side
	Transfer fault
	Pre-Quaternary "surface" intersection Top Permian
•	Petroleum well; showing depth to top Permian in metres subsea
D. 17	Dongara Field wells
W. 17	Woodada Field wells
	Coastline
	Townsite
	Oil- and gasfield outlines



INDEX MAP



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REPORT 46 PLATE 7

TOP PERMIAN DEPTH STRUCTURE MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000

5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Seismic and gravity interpretation by R.P. Iasky
Geology by A.J. Mory

Edited by S. Willis, D. Ferdinando and G. Loan
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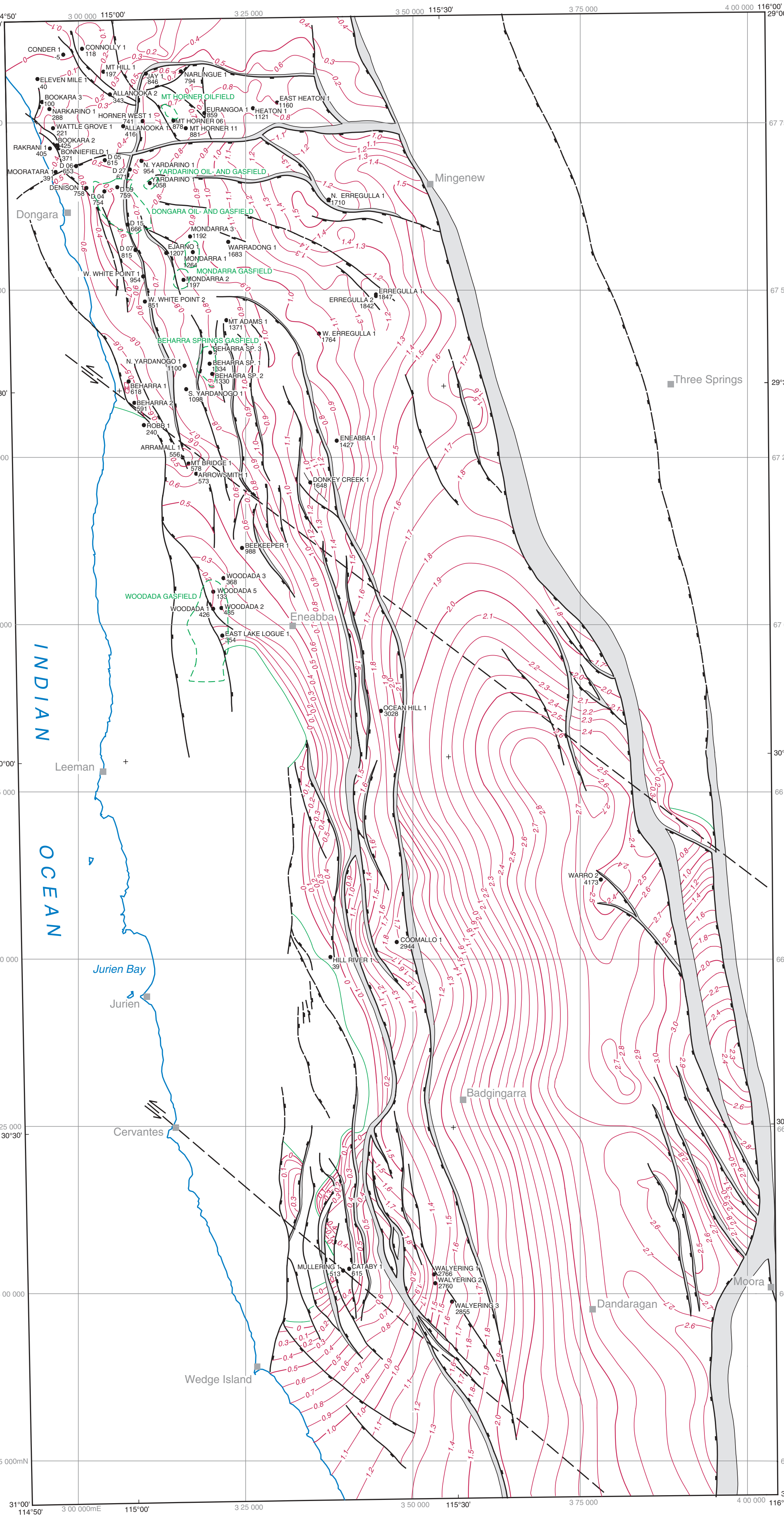
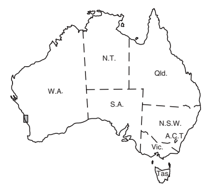


SYMBOLS

- Two-way time contours, in seconds, contour interval 100 milliseconds
- Fault; showing downthrown side and heave, inferred. Tick on downthrown side
- Transfer fault
- Pre-Quaternary "surface" intersection Top Cattamarra Coal Measures
- Petroleum well; showing depth to Top Cattamarra Coal Measures in metres subsea
- Coastline
- Townsite
- D 17 Dongara Field wells
- Oil- and gasfield outlines



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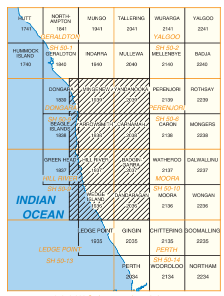

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REPORT 46 PLATE 8

TOP CATTAMARRA COAL MEASURES TWO-WAY TIME STRUCTURE MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000
5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Seismic and gravity interpretation by R.P. Iasky
Geology by A.J. Mory

Edited by S. Willis, D. Ferdinando and G. Loan
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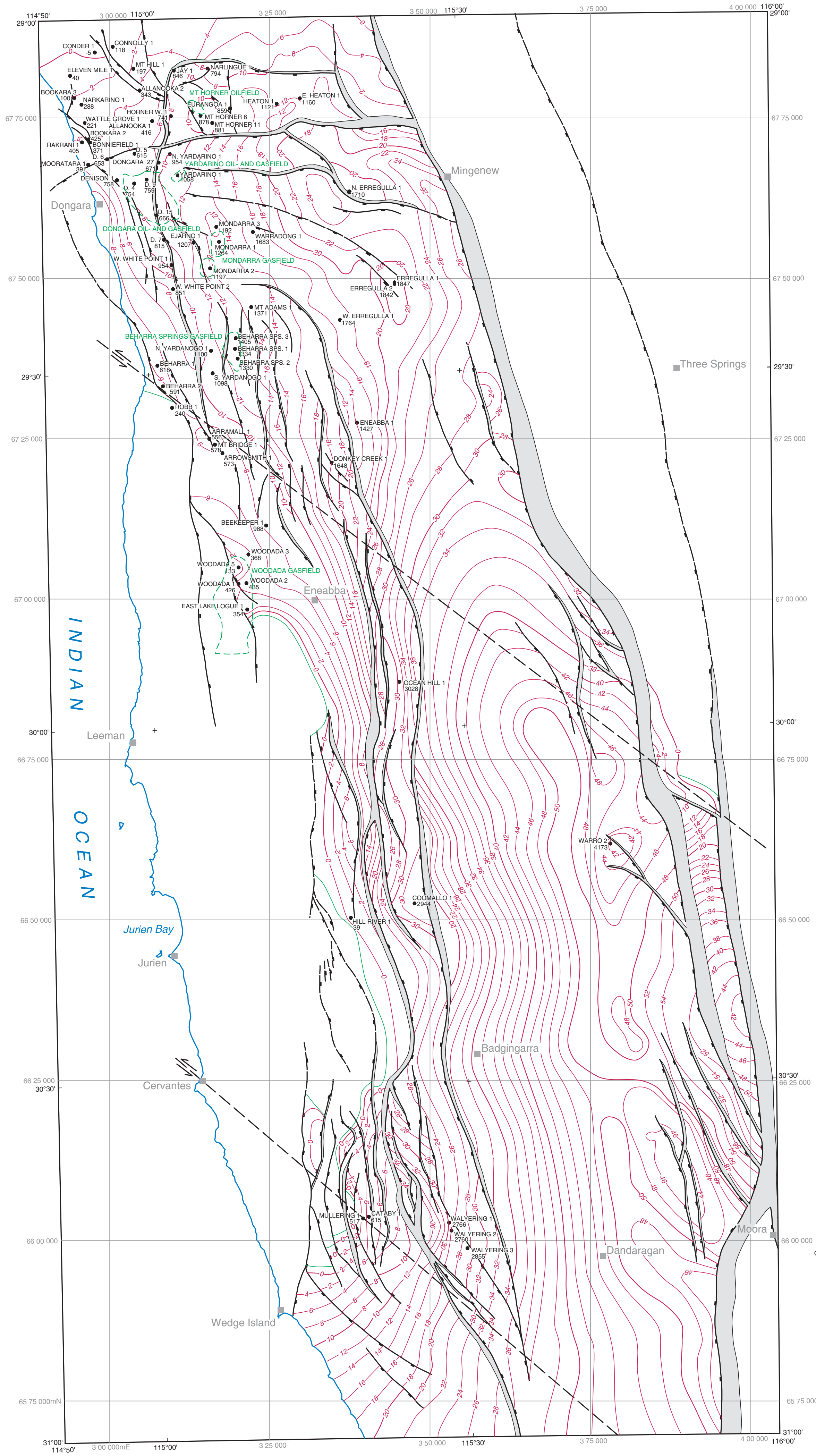
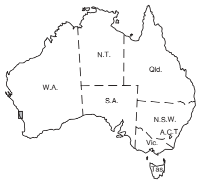
The recommended reference for this map is: MORY, A.J., and IASKY, R.P., 1996, Top Cattamarra Coal Measures, two-way time structure map, onshore northern Perth Basin: Western Australia Geological Survey, Report 46, Plate 8

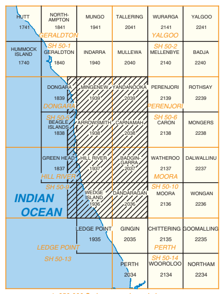


SYMBOLS

- Depth contours, in hundred metres subsea, contour interval 200 metres
- Fault; showing downthrown side and heave, inferred. Tick on downthrown side
- Transfer fault
- Pre-Quaternary "surface" intersection Top Cattamarra Coal Measures
- Petroleum well; showing depth to Top Cattamarra Coal Measures in metres subsea
- Coastline
- Townsite
- D 17 Dongara Field wells
- Oil- and gasfield outlines



INDEX MAP



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REPORT 46 PLATE 9

TOP CATTAMARRA COAL MEASURES DEPTH STRUCTURE MAP

ONSHORE NORTHERN PERTH BASIN

SCALE 1: 500 000

5000 0 Metres — 5 10 15 20 Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Seismic and gravity interpretation by R.P. Iasky
Geology by A.J. Mory
Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and L. Cosgrove
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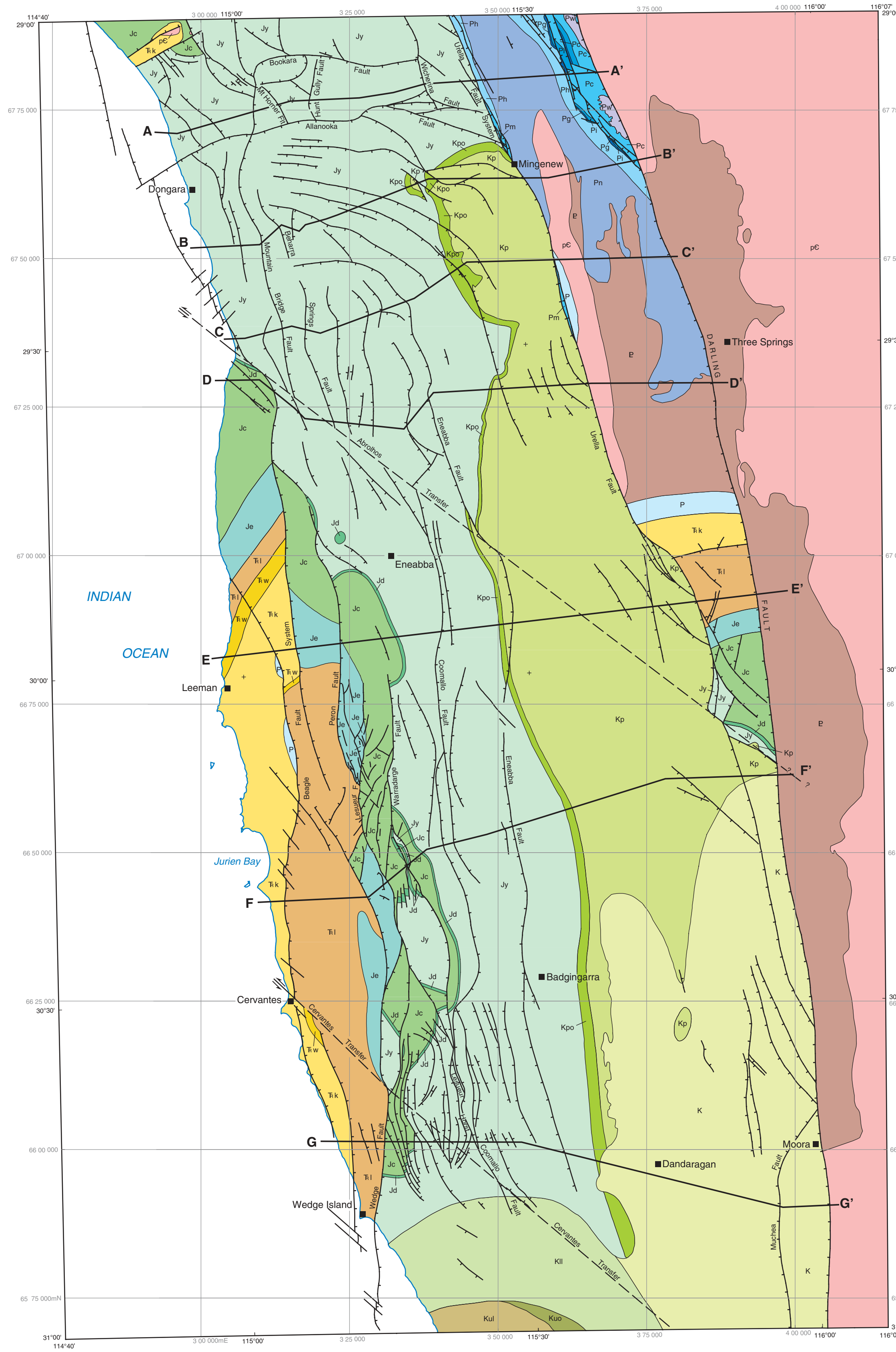


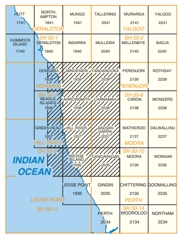
REFERENCE

CRETACEOUS	K	Undifferentiated Cretaceous
	Kul	Lancelin Formation
	Kuo	Osborne Formation
	Kll	Leederville Formation
	Kp / Kpo	Parmelia Formation, Otorowiri Member
JURASSIC	Jy	Yarragadee Formation
	Jd	Cadda Formation
	Jc	Cattamarra Coal Measures
	Je	Eneabba Formation
TRIASSIC	Ŧl	Lesueur Sandstone
	Ŧw	Woodada Formation
	Ŧk	Kockatea Shale
PERMIAN	P	Undifferentiated Permian
	Pw	Wagina Sandstone
	Pm / Pc	Mingenew and Carynginia Formations
	Pi	Irwin River Coal Measures
	Pg	High Cliff Sandstone
	Ph	Holmwood Shale
	Pn	Nangetty Formation
PRECAMBRIAN	Ɇ	Moora and Yandanooka Groups
	p€	Undifferentiated basement rocks

SYMBOLS

- Geological boundary
- Fault, showing downthrown side
- Transfer fault
- Coastline
- Townsite
- Line of sections A A'
  (Sections are shown on Plate 11)

INDEX MAP



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

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REPORT 46 PLATE 10

PRE-CAINOZOIC GEOLOGY

ONSHORE NORTHERN PERTH BASIN

5000 0 5 10 15 20
Metres Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 50

Geology by A.J. Mory

Seismic and gravity interpretation by R.P. Iasky

Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by T. Lenane and S. Dowsett

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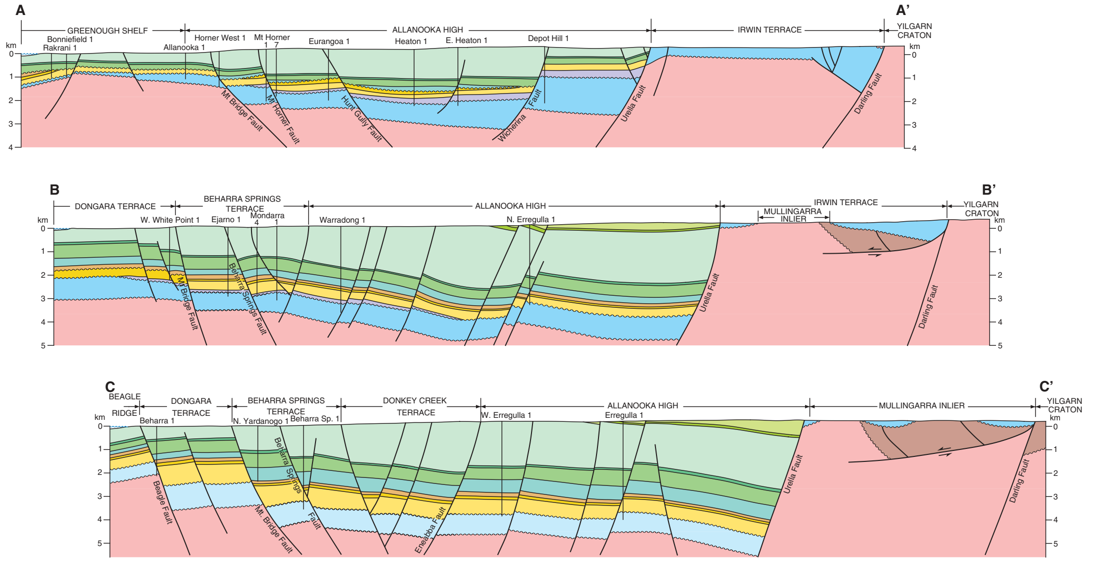
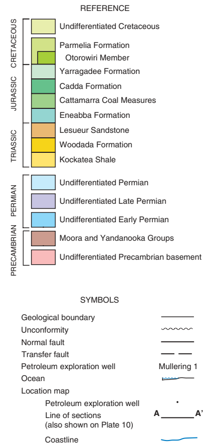
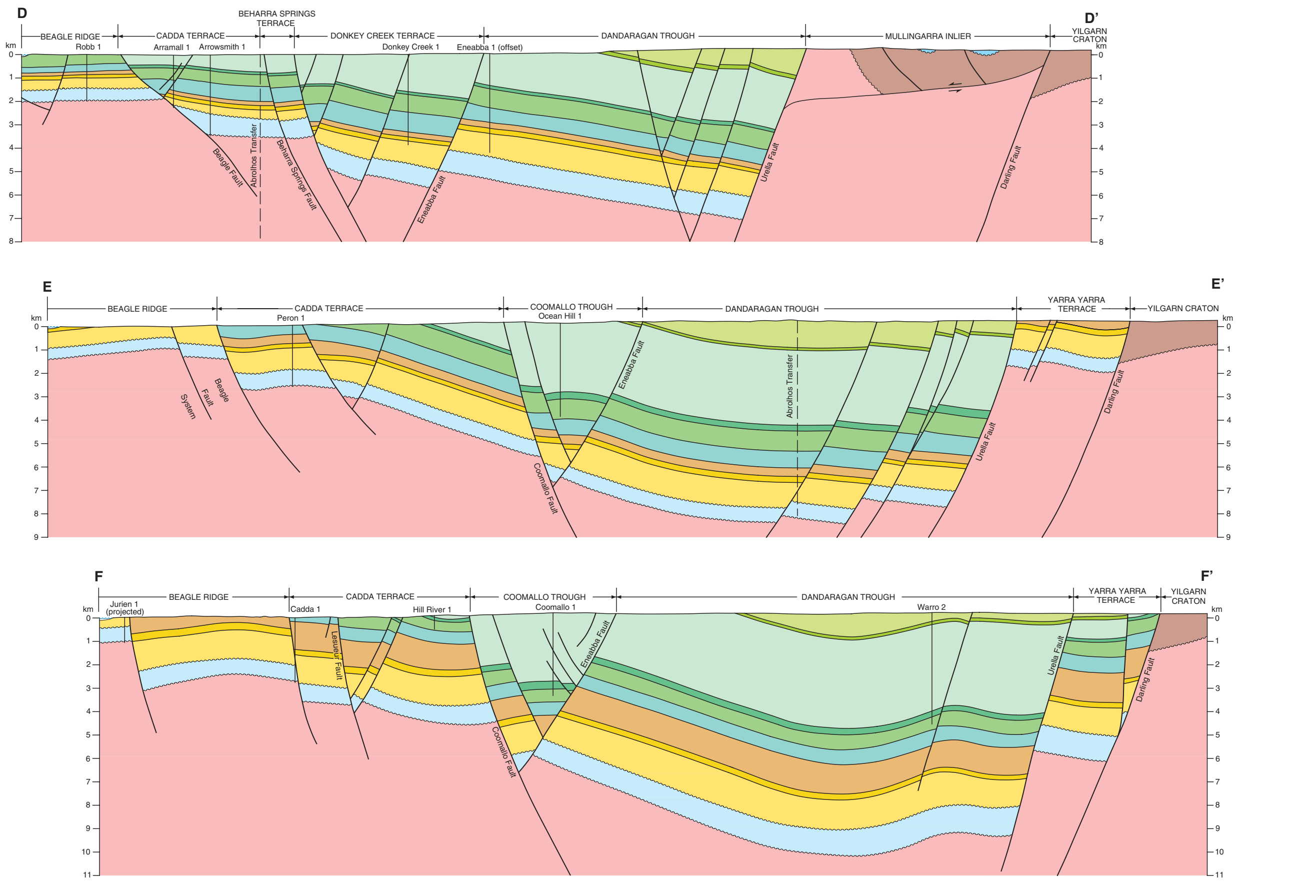
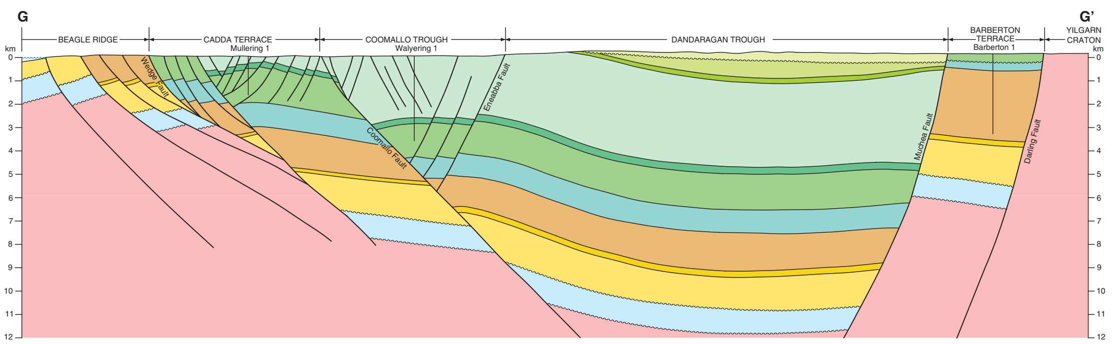
The recommended reference for this map is:
MORY, A.J., and IASKY, R.P., 1996, Pre-Cainozoic geology, onshore northern Perth Basin: Western Australia Geological Survey, Report 46, Plate 10

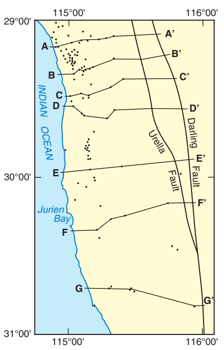








LOCATION MAP



SCALE 1: 250 000

5000 0 5 10

Metres Kilometres

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REPORT 46 PLATE 11

EAST-WEST GEOLOGICAL SECTIONS

ONSHORE NORTHERN PERTH BASIN

$\frac{V}{H} = 2$ Depth shown below mean sea level

Geology by A.J. Mory

Seismic and gravity interpretation by R.P. Iasky

Edited by S. Willis, D. Ferdinando and G. Loan
Cartography by S. Dowsett

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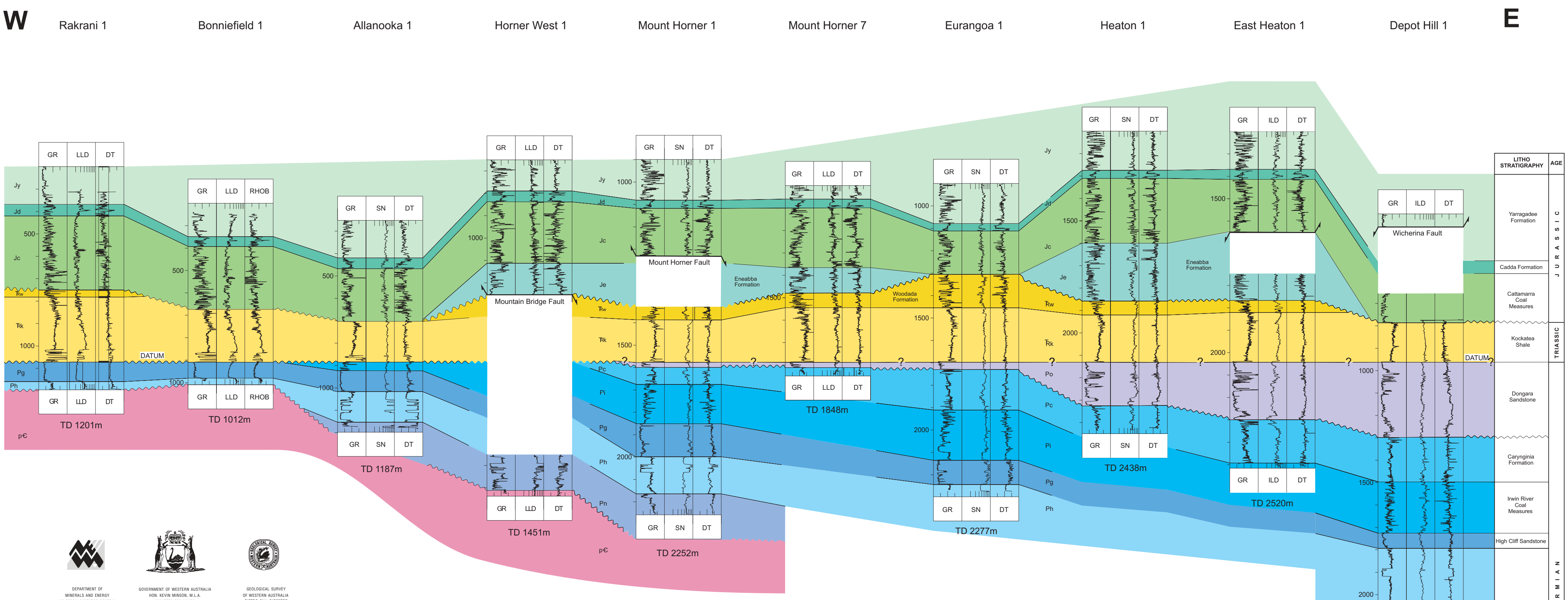
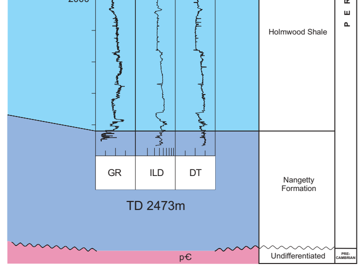
Western Australia Geological Survey, Report 46, Plate 11





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REPORT 46 PLATE 12

EAST-WEST LOG CORRELATION RAKRANI 1 TO DEPOT HILL 1

Datum : top Permian
Log depths in metres relative to KB

Compiled by A. J. Mory

Edited by S. Willis and G. Loan
Computer Assisted Drafting by E. Jones

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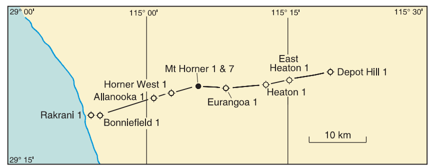
The recommended reference for this Map is: MORY, A. J., 1996
East-west log correlation: Rakrani 1 to Depot Hill 1: Western
Australia Geological Survey Report 46, Plate 12

Log Scales

GR	LLD ILD SN	DT	RHOB
API 0 — 250	ohm-m 0.2 — 50	s/f 140 — 40	g/c³ 1.95 — 2.95

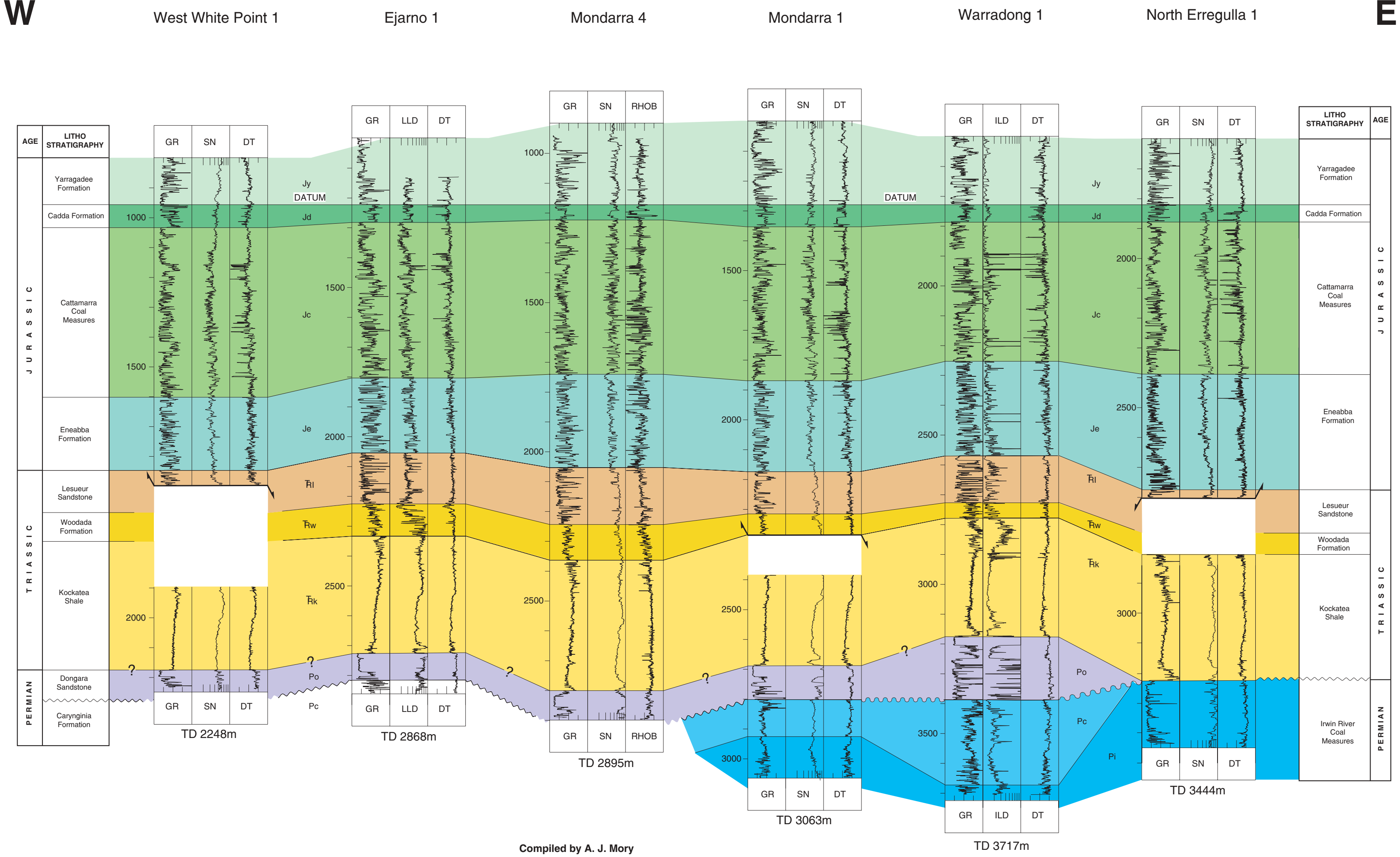
Normal Fault - break in log indicates missing section

Location Map



MORY12.CDR

19/08/96



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REPORT 46 PLATE 13

EAST-WEST LOG CORRELATION
WEST WHITE POINT 1 TO NORTH ERREGULLA 1

Datum : top Cadda Formation
Log depths in metres relative to KB

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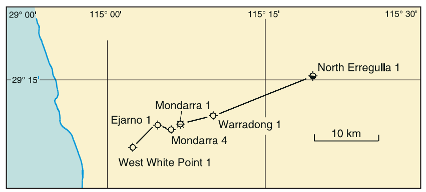
The recommended reference for this Plate is:
MORY, A. J., 1996 East-west log correlation:West White Point 1 to North Erregulla 1, Western Australia Geological Survey Report 46, Plate 13

Log Scales

GR	SN LLD	DT	RHOB
API	ohm-m	s/f	g/c³
0 — 250	0.2 — 50	140 — 40	1.95 — 2.95

Normal Fault - break in log indicates missing section

Location Map



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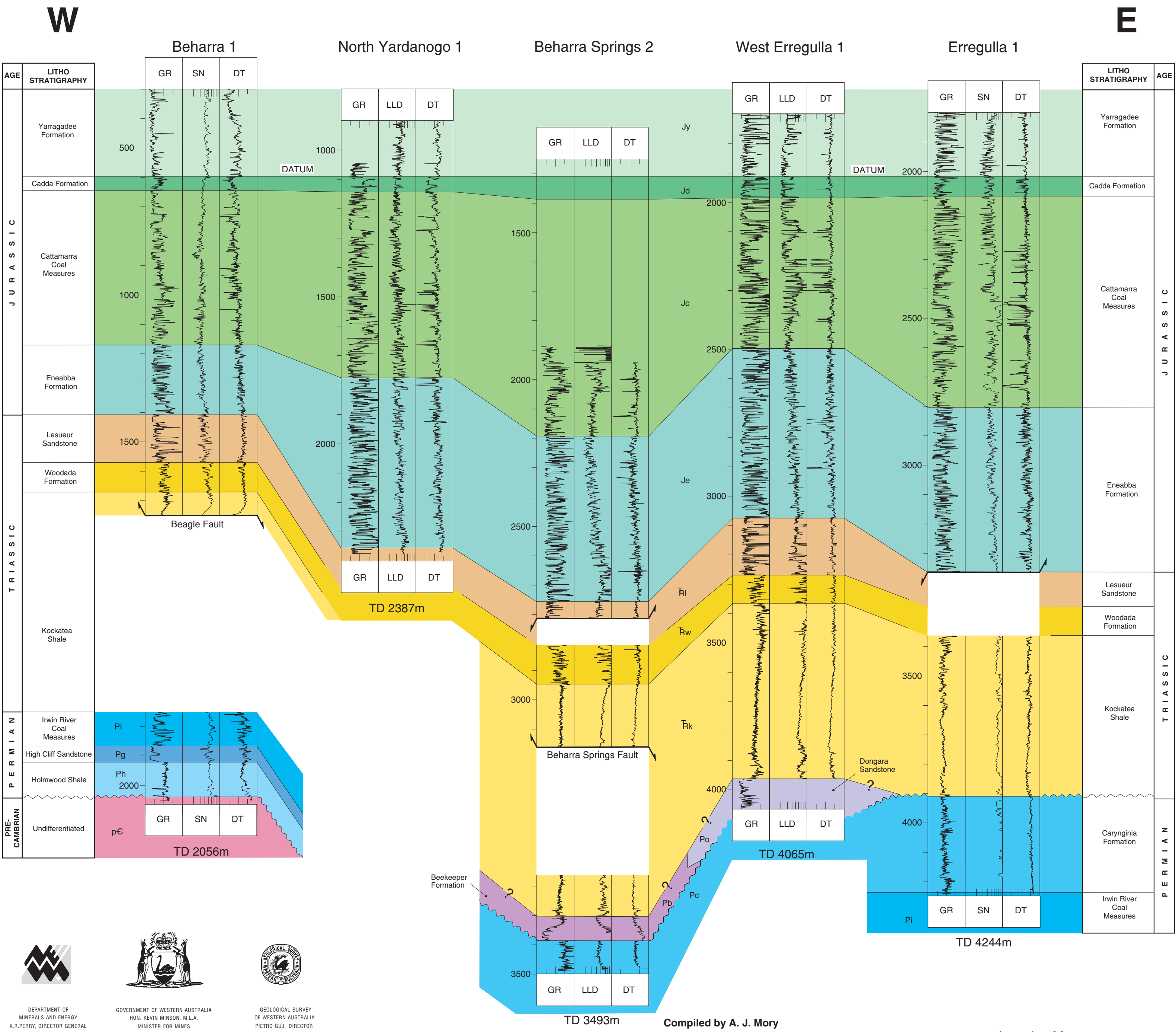
19/08/96



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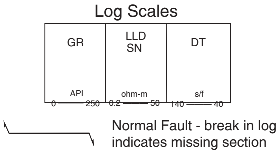
REPORT 46 PLATE 14

EAST-WEST LOG CORRELATION BEHARRA 1 TO ERREGULLA 1

Datum : top Cadda Formation
Log depths in metres relative to KB

Log Scales



Normal Fault - break in log indicates missing section

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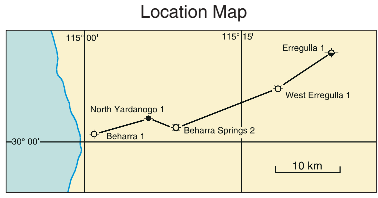
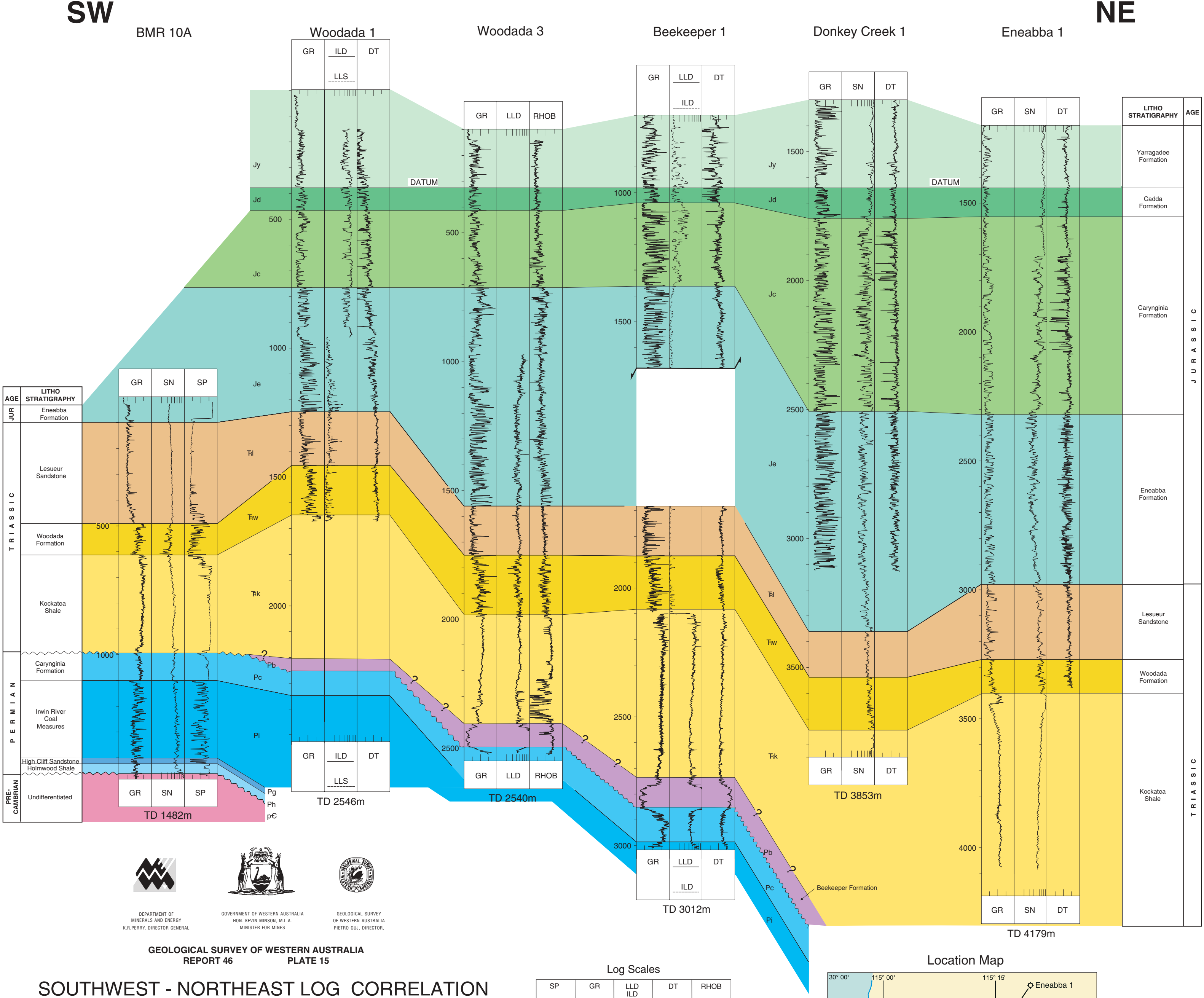
The recommended reference for this Plate is:
MORY, A. J., 1996 East-west log correlation: Beharra 1 to Erregulla 1, Western Australia Geological Survey Report 46, Plate 14

Location Map



19/08/96

MORY14.CDR



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REPORT 46 PLATE 15

SOUTHWEST - NORTHEAST LOG CORRELATION BMR 10A TO ENEABBA 1

Datum : top Cadda Formation
Log depths in metres relative to KB

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Log Scales

SP	GR	LLD ILD SN LLS	DT	RHOB
mv 0 — 80	API 0 — 250	ohm-m 0.2 — 50	s/f 140 — 40	g/c3 1.95 — 2.95

Normal Fault - break in log indicates missing section

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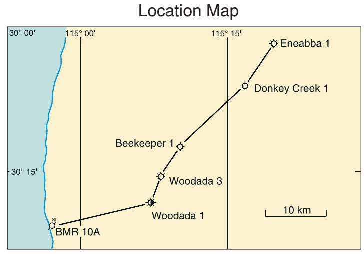
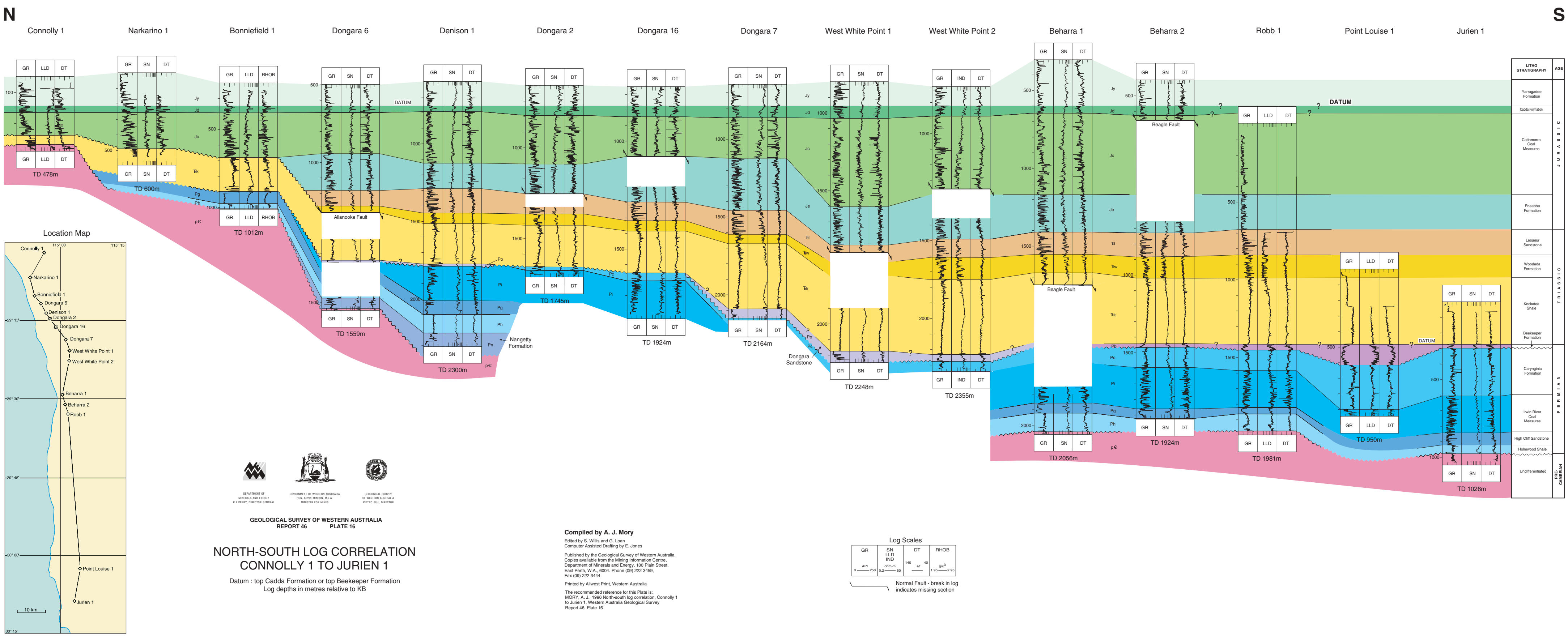
The recommended reference for this Plate is:
MORY, A. J., 1996 Southwest-northeast log correlation: BMR 10A to Eneabba 1, Western Australia Geological Survey Report 46, Plate 15

Location Map





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REPORT 46 PLATE 16

NORTH-SOUTH LOG CORRELATION CONNOLLY 1 TO JURIEN 1

Datum : top Cadda Formation or top Beekeeper Formation
Log depths in metres relative to KB

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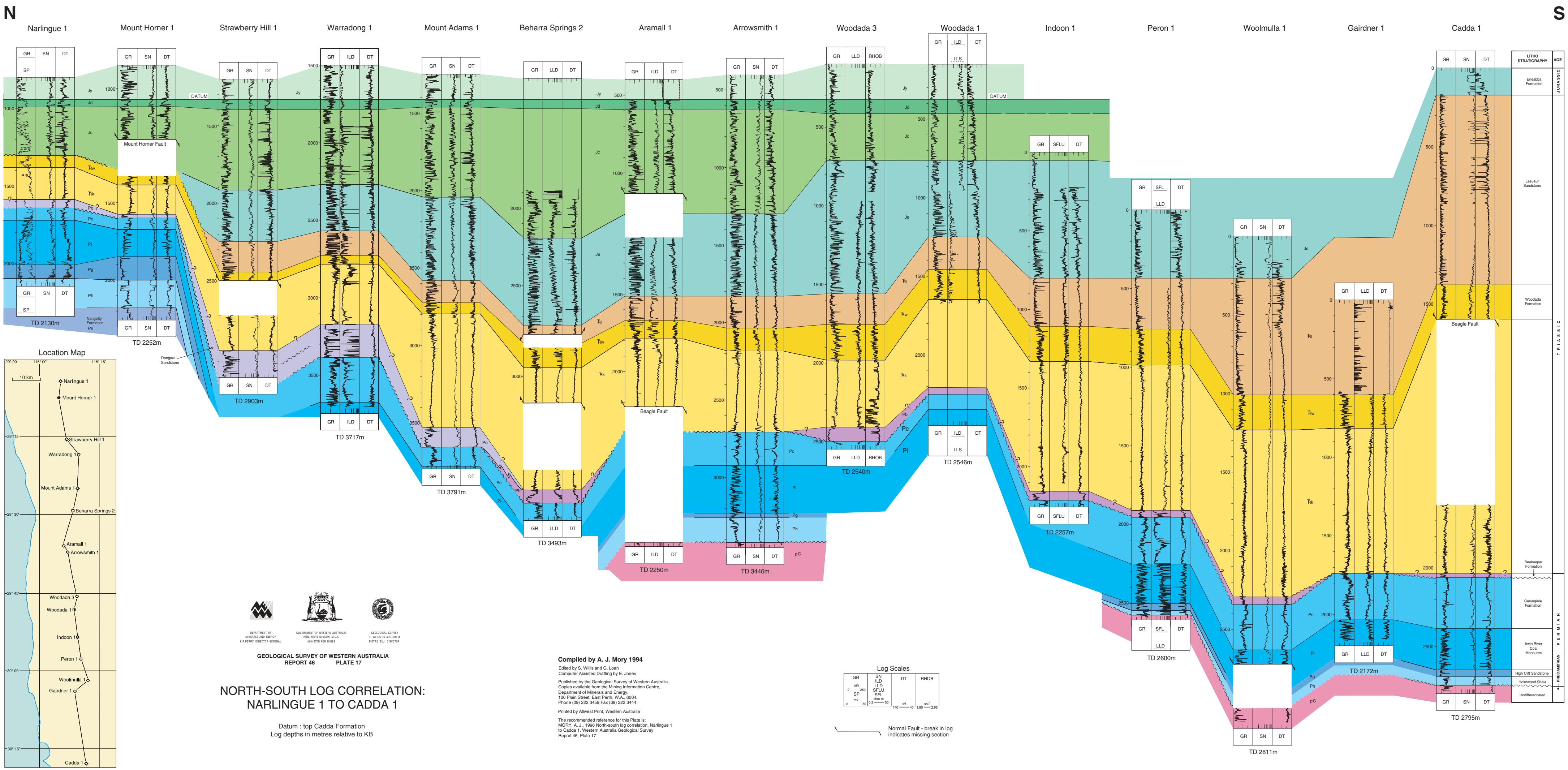
The recommended reference for this Plate is:
MORY, A. J., 1996 North-south log correlation, Connolly 1 to Jurien 1, Western Australia Geological Survey Report 46, Plate 16

Log Scales

GR	SN LLD IND	DT	RHOB
API	ohm-m	140 s/f 40	g/c3
0 — 250	0.2 — 50		1.95 — 2.95

Normal Fault - break in log indicates missing section



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NORTH-SOUTH LOG CORRELATION: NARLINGUE 1 TO CADDA 1

Datum : top Cadda Formation
Log depths in metres relative to KB

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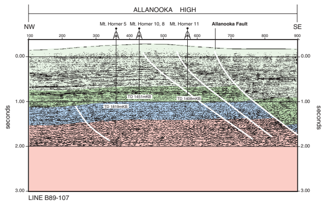
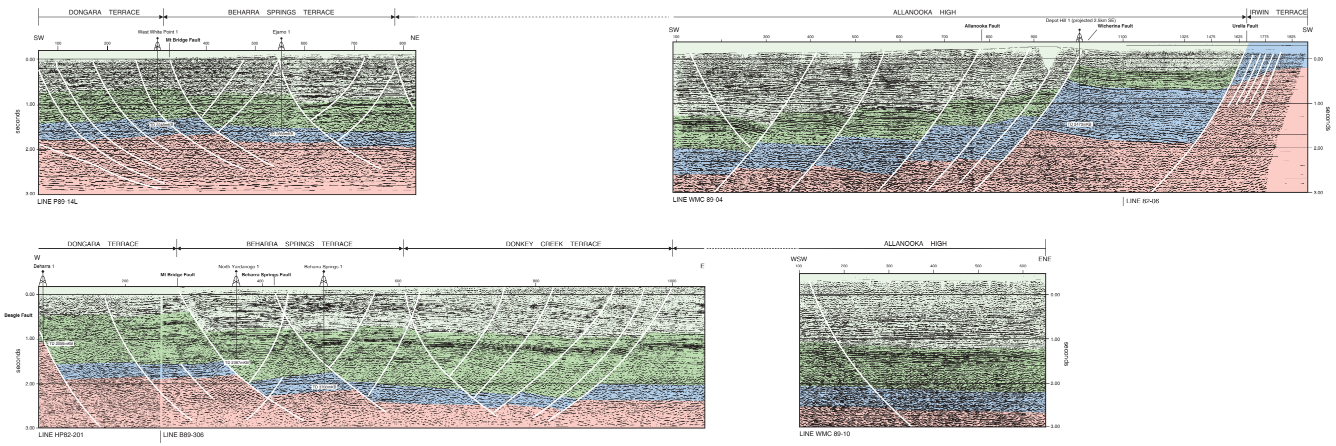
The recommended reference for this Plate is:
MORY, A. J., 1996 North-south log correlation, Narlingue 1 to Cadda 1, Western Australia Geological Survey Report 46, Plate 17

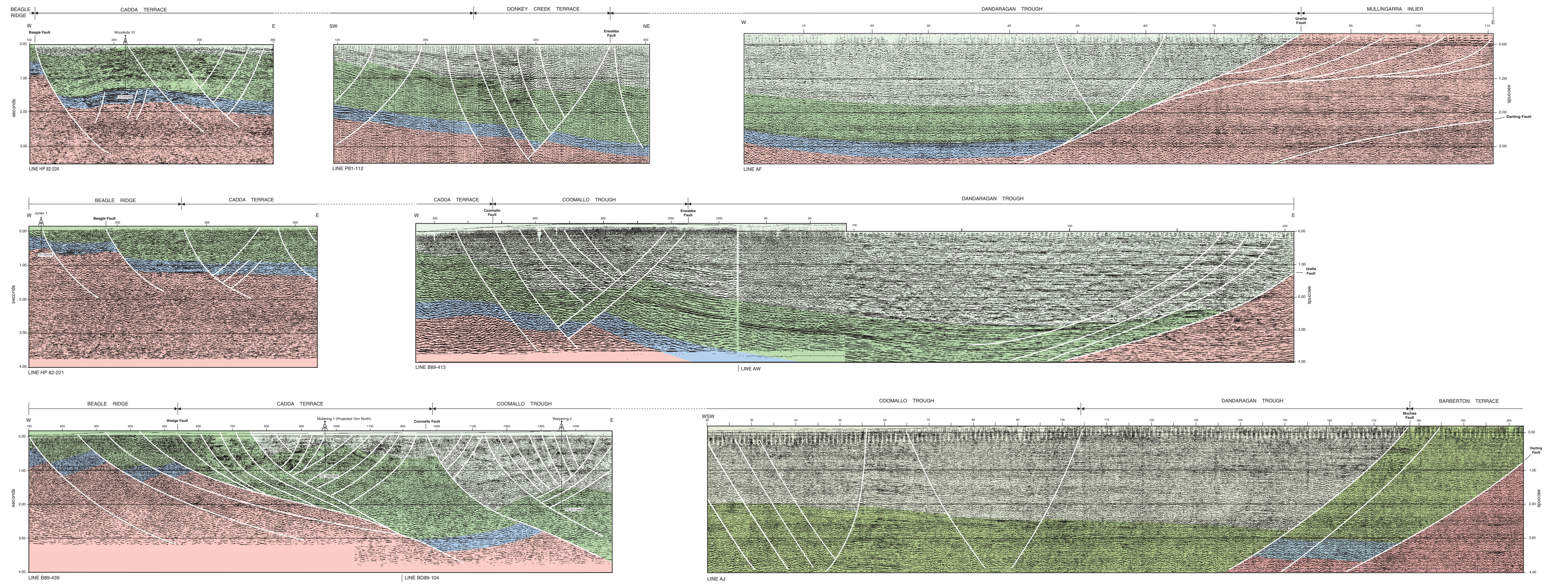
Log Scales

GR	SN ILD LLD SFLU SFL	DT	RHOB
API 0 —— 250 SP mv 0 —— 80	ohm-m 0.2 —— 50	s/f 140 —— 40	g/c³ 1.95 —— 2.95

Normal Fault - break in log indicates missing section







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REPORT 46 PLATE 18

MONTAGE OF SEISMIC SECTIONS

ONSHORE NORTHERN PERTH BASIN

Two-way time in seconds
Scale 1:100 000

1000 0 1 2 3 4 5
Metres Kilometres

Compiled by R. P. IASKY

Edited by S. Willis and G. Loan
Computer Assisted Drafting by M.C. Jones

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The recommended reference to this map is:IASKY, R. P., 1996,
Montage of seismic sections, onshore northern Perth Basin:
Western Australia Geological Survey, Report 46, Plate 18

REFERENCE

Upper Jurassic — Lower Cretaceous

Triassic — Middle Jurassic

Permian

Precambrian

Petroleum well with depth below KB in metres