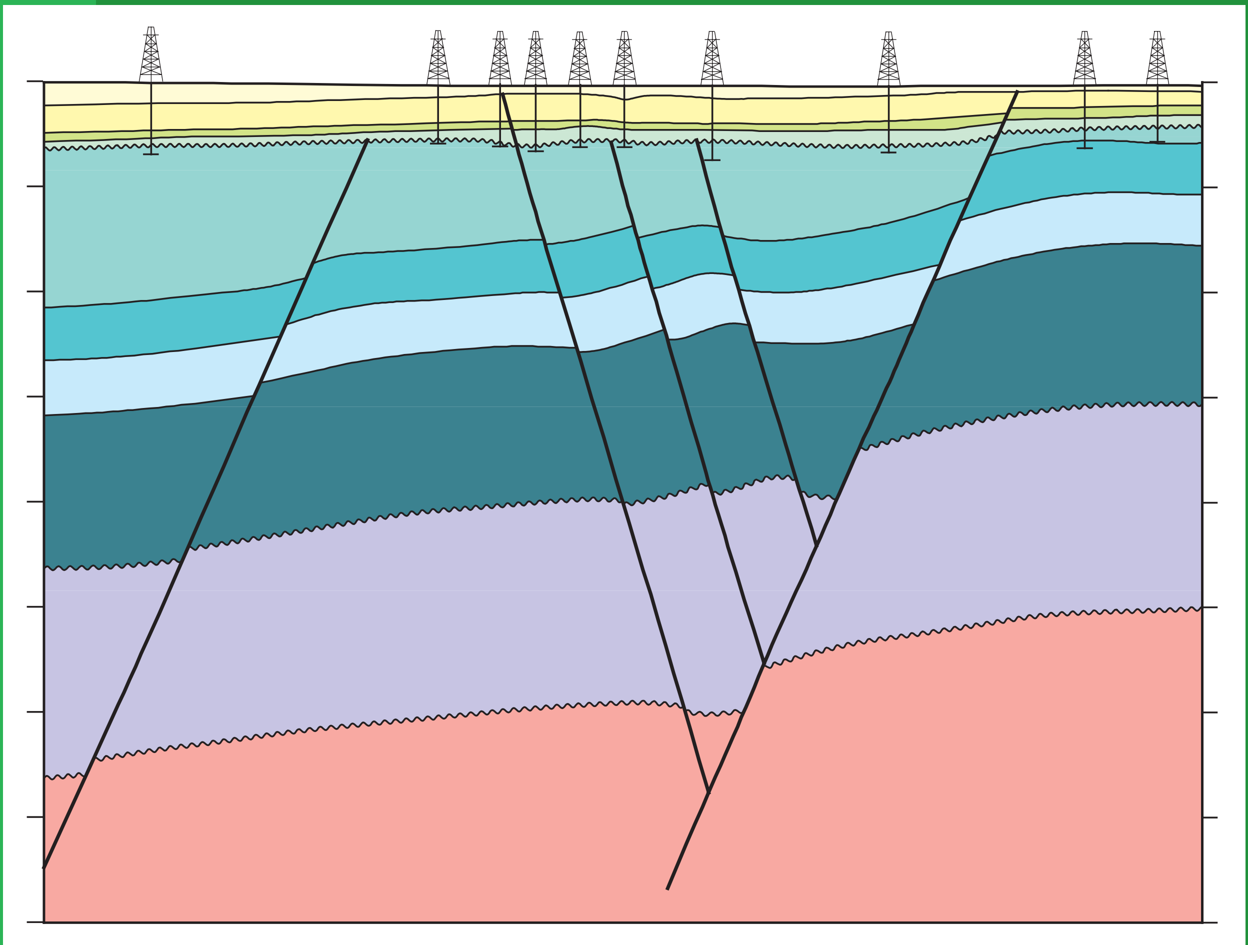
REPORT 73

GOVERNMENT OF WESTERN AUSTRALIA

PETROLEUM GEOLOGY OF THE PEEDAMULLAH SHELF AND ONSLOW TERRACE NORTHERN CARNARVON BASIN WESTERN AUSTRALIA

by A. Crostella, R. P. Iasky, K. A. Blundell, A. R. Yasin and K. A. R. Ghori



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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Perth 2000

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Copy editor: C. D'Ercole

REFERENCE
The recommended reference for this publication is:
CROSTELLA, A., IASKY, R. P., BLUNDELL, K. A., YASIN, A. R., and GHORI, K. A. R., 2000, Petroleum geology of the Peedamullah Shelf and Onslow Terrace, Northern Carnarvon Basin, Western Australia: Western Australia Geological Survey, Report 73, 119p.

National Library of Australia
Cataloguing-in-publication entry

Petroleum geology of the Peedamullah Shelf and Onslow Terrace, northern Carnarvon Basin, Western Australia

Bibliography.

ISBN 0 7307 5648 3

1. Petroleum — Geology — Western Australia — Carnarvon.
I. Crostella, A. (Angelo), 1929–. (Series: Report (Geological Survey of Western Australia); 73).

553.28099413

ISSN 0508–4741

Grid references in this publication refer to the Australian Geodetic Datum 1984 (AGD84)

Printed by Lamb Print Pty Ltd, Perth, Western Australia

Copies available from:
Information Centre
Department of Minerals and Energy
100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
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Petroleum geology of the Peedamullah Shelf and Onslow Terrace, Northern Carnarvon Basin, Western Australia

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Abstract

The Peedamullah Shelf and the adjacent Onslow Terrace in the Northern Carnarvon Basin are established petroleum provinces with potential for both oil and gas accumulations. Their geology and petroleum potential were investigated by carrying out post-mortems of wells in the area, seismic interpretation of three pre-breakup and two post-breakup horizons, and geochemical analysis of samples from selected wells.

The Peedamullah Shelf and Onslow Terrace formed during Carboniferous to Jurassic rifting episodes. The shelf remained an elevated area during the Jurassic, whereas a thick Jurassic succession was deposited in a deep-water rift to the northwest. During Late Jurassic to earliest Cretaceous rifting, the Barrow Group delta prograded to the northwest into the Barrow Sub-basin, and onlapped older formations on the Onslow Terrace and the shallower water parts of the Peedamullah Shelf. After the early Neocomian breakup of Gondwana, the marine transgressive units of the Winning Group were deposited over the Barrow Group with no detectable angularity. The relationship between the two units implies only minor tectonism at breakup in the Barrow Sub-basin. Middle Miocene transpressional tectonism reactivated major faults, which resulted in folds that produced many economically attractive petroleum traps in the Barrow Sub-basin and Onslow Terrace. However, southeast of the Flinders Fault System on the Peedamullah Shelf, the result of this tectonism is only minor.

On the Peedamullah Shelf and Onslow Terrace, the oil was sourced from the pre-Jurassic section whereas the gas, which is of biogenic origin, was from the Cretaceous section. Biogenic gas could also be present in other areas, such as the eastern part of the Exmouth Sub-basin where dry mature gas is present in basal Cretaceous reservoirs and also within Upper Cretaceous levels. Hydrocarbons on the Peedamullah Shelf and Onslow Terrace did not migrate into the area from the Barrow Sub-basin, as previously believed, because the oil from this latter area was sourced from Upper Jurassic rocks.

Hydrocarbon accumulations may be present in pre-main unconformity fault traps of latest Jurassic or older age. Truncation traps sealed by the Muderong Shale may exist. These plays have not been properly tested on the Peedamullah Shelf. Middle Miocene anticlines may also be present, largely within the Onslow Terrace, although it is also possible that oil displaced from the Onslow Terrace moved towards the margins of the Peedamullah Shelf and became trapped in other Middle Miocene anticlines.

KEYWORDS: stratigraphy, stratigraphic correlation, structure, time structure maps, geophysics, seismic surveys, gravity, aeromagnetic data, petroleum potential, petroleum geochemistry, petroleum reservoirs, traps, Peedamullah Shelf, Western Australia

Introduction

The Peedamullah Shelf is the southeastern subdivision of the Northern Carnarvon Basin, and extends northeast approximately 200 km from the Exmouth Gulf to Mardie Station, between latitudes 21°00' and 22°15'S and longitudes 114°30' and 115°50'E. The sub-basin averages 80 km in width over an area of approximately 16 000 km^2, three-quarters of which is located onshore (Fig. 1).

?Ordovician to Pleistocene rocks are present across the Peedamullah Shelf, although almost half of the onshore part of this sub-basin consists of a thin Cretaceous succession unconformably overlying basement rocks (Fig. 2). The down-to-the-basin Flinders Fault System and its southwestern extension, the Weelawarren Fault, represent the northwestern boundary with the Barrow Sub-basin. The southeastern boundary is the southern extent of Cretaceous sedimentary rocks overlying Precambrian

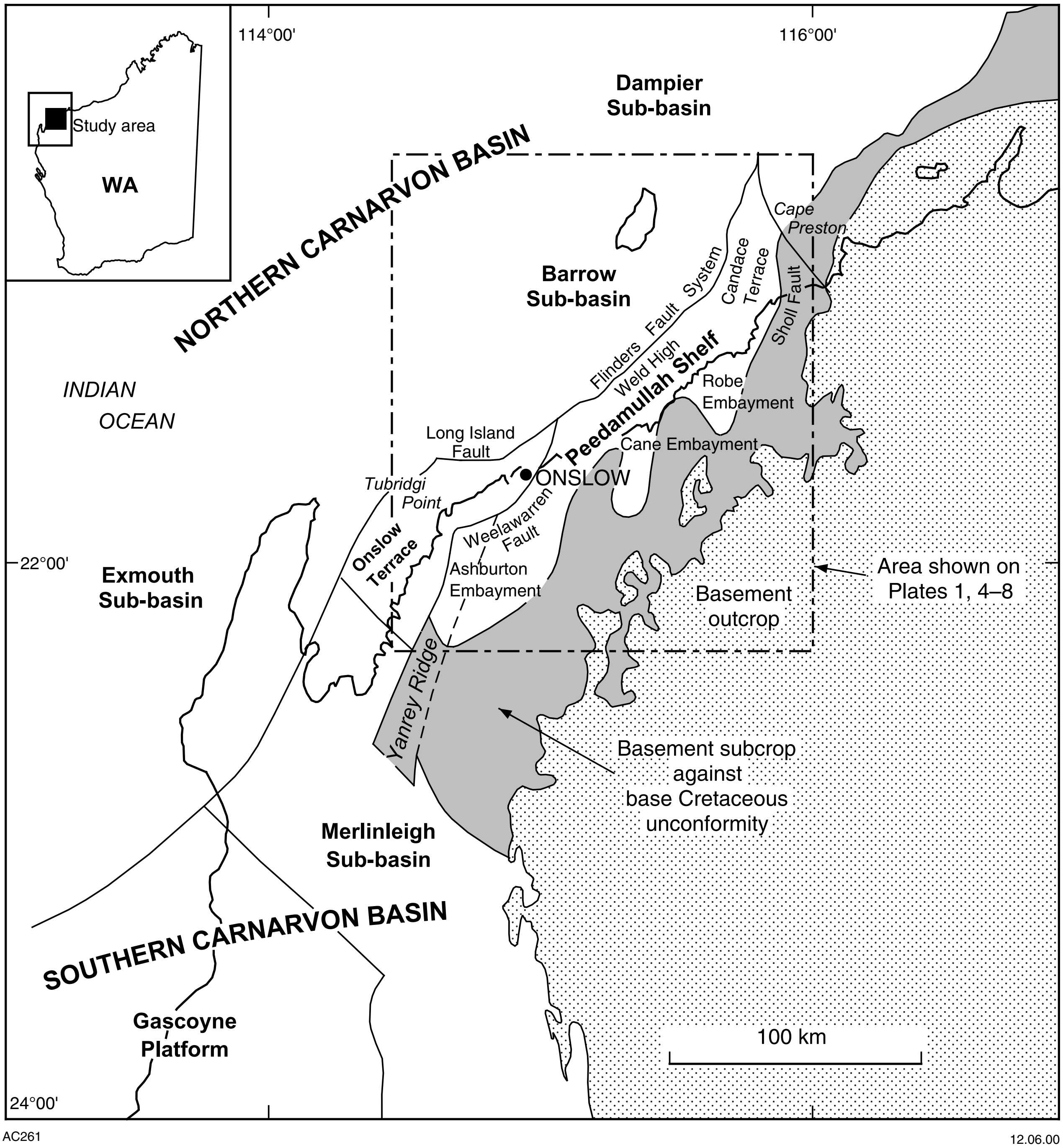


Figure 1. Location of the Peedamullah Shelf and Onslow Terrace showing the regional tectonic framework

metamorphic and igneous rocks of the Hamersley Basin. The Onslow Terrace, which lies between the Weelawarren and Long Island Faults in the Barrow Sub-basin (Fig. 2), is included in the study area because it has features that are common to both the Peedamullah Shelf and the main Barrow Sub-basin.

Geological maps covering the Peedamullah Shelf include the YANREY* (SF 50-9), ONSLOW (SF 50-5), and YARRALOOLA (SF 50-6) 1:250 000 map sheets. Although pre-Cretaceous strata do not outcrop in any of the map sheets, the distribution of pre-Cretaceous units (Fig. 2) has been interpreted from well and seismic data.

The oldest documented sedimentary rocks within the Peedamullah Shelf probably belong to the Ordovician Tumblagooda Sandstone in Echo Bluff 1 on the Robe Embayment (Fig. 3). In the Robe Embayment, this unit is overlain by Devonian clastic and carbonate rocks (Echo Bluff 1, Mardie 1, Murnda 1, Sharon 1, and Windoo 1). In contrast, the oldest rocks encountered in the Ashburton Embayment, Weld High, and Candace Terrace are Lower

* Capitalized names in this Report refer to standard map sheets.

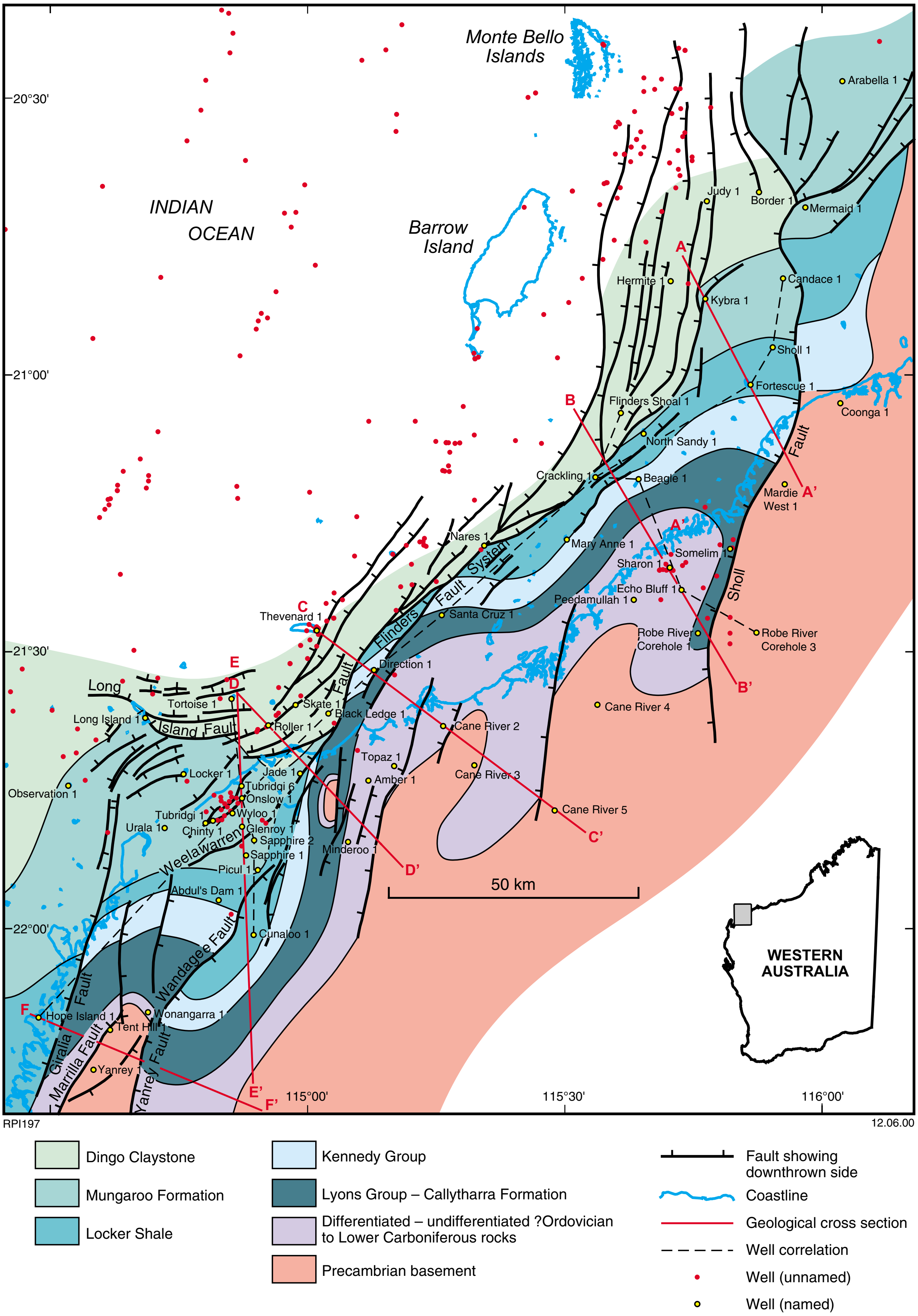


Figure 2. Pre-Cretaceous geology of the Peedamullah Shelf and Onslow Terrace with the location of geological cross sections and well-log correlations. All well locations are shown, but only those with a yellow symbol are named

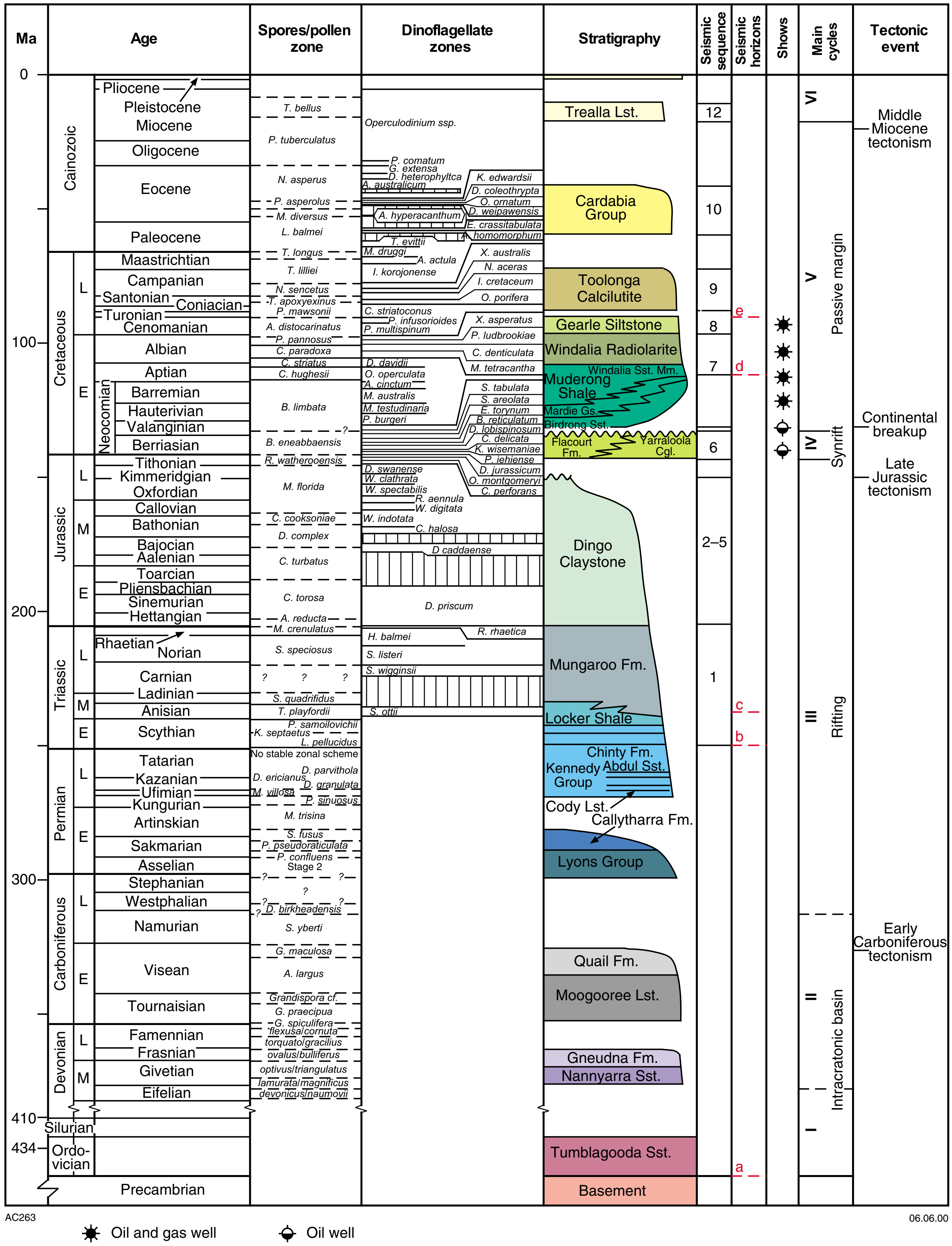


Figure 3. Stratigraphy of the Peedamullah Shelf and Onslow Terrace modified after Hocking et al. (1987). Seismic sequences are from Westphal and Aigner (1997), interpreted seismic horizons (Figs 17–21, Plates 4–8) are: a = basement, b = top Kennedy Group, c = top Locker Shale, d = top Muderong Shale, and e = top Gearle Siltstone

Carboniferous (Wonangarra 1, Topaz 1, and Kybra 1 respectively), compared to Lower Permian – Upper Carboniferous rocks on the Onslow Terrace (Onslow 1). In addition to the major unconformity due to the separation of Australia from Greater India in the Early Cretaceous (breakup unconformity), other major periods of nondeposition are documented between the Lower and Upper Carboniferous (Bentley, 1988), Lower and Upper Permian (Mory and Backhouse, 1997), and Jurassic and Cretaceous (Parry and Smith, 1988) successions. The Lower Cretaceous succession has been the primary target for petroleum exploration on the Peedamullah Shelf and Onslow Terrace. This succession is represented by the deltaic Flacourt Formation, its lateral equivalent the fluvial Yarraloola Conglomerate, and an overlying marine section consisting of the Birdrong Sandstone, Muderong Shale, and Windalia Radiolarite (in ascending order). The overlying Gearle Siltstone and Toolonga Calcilutite were deposited in the Late Cretaceous, and are disconformably overlain by the Eocene Cardabia Group and Miocene Trealla Limestone (Fig. 3).

The Peedamullah Shelf contains northwesterly dipping, pre-Cretaceous strata that are transgressive on basement and become progressively younger and thicker seawards to the northwest. Palaeozoic rocks are much shallower than in the Barrow Sub-basin, which is downfaulted along the Flinders Fault System. Extensional normal faults appear to characterize the pre-Cretaceous section, although the presence of large folds in the Candace Terrace, and locally in the Ashburton Embayment, indicates that some compressional forces were active at breakup. The Onslow Terrace and the adjacent belt along the Weelawarren Fault within the Ashburton Embayment are characterized by mid-Miocene compressional structures. The seawards-prograding Cainozoic succession oversteps both older sedimentary rocks and Precambrian basement (Figs 1, 4, and 5).

The lithostratigraphy of the region is based on petroleum exploration wells and described within the regional framework of Hocking et al. (1987). The stratigraphic information from petroleum companies has been revised utilizing palynological studies by the Geological Survey of Western Australia (GSWA), in part published by Mory and Backhouse (1997). Plates 2 and 3 and Figures 4, 5, and 6 show strike and dip well-log correlations within the shelf. The analyses of fault trends and the tectonic history of the study area are based on subsurface structure maps of basement, top Kennedy Group, top Locker Shale, top Muderong Shale, and top Gearle Siltstone horizons (Plates 4–8). The regional structure is based largely on seismic and well data, but has also been supplemented by gravity (Fig. 7) and aeromagnetic (Fig. 8) data.

At the end of 1997, 86 wells had been drilled in the area for hydrocarbon exploration and development (Appendix 1) and many had shows of biodegraded oil and dry gas. The gas is demonstrated to be of biogenic origin and genetically unrelated to the oil. The only field of economic relevance is the Tubridgi Gasfield, which contains predominantly methane. In the study area, 165 geophysical surveys have been carried out (Appendix 2), although many extend into the Barrow Sub-basin. These surveys include 136 two-dimensional reflection seismic, 11 three-dimensional reflection seismic, 4 refraction seismic, 10 aeromagnetic or magnetic, and 4 gravity surveys. Selected lines from the two-dimensional reflection seismic surveys and the available gravity and magnetic data were used to provide a regional structural interpretation of the study area (Plates 4–8; Figs 7 and 8).

The aim of the study was to provide a consistent lithostratigraphy and regional structural framework for future petroleum exploration of the area. In this Report, inconsistencies in stratigraphic interpretations between various petroleum companies have been rationalized. The Tubridgi Gasfield, the only producing field in the study area, has been fully re-evaluated by analysing the reservoir characteristics of the three productive units (Birdrong Sandstone, Flacourt Formation, and Mungaroo Formation) and reinterpreting the seismic data in the gasfield (top lower Gearle Siltstone horizon; Fig. 9). Within the post-mortems of the relevant wells, formation tops are revised where necessary, the reason for drilling, results, and the reason for failure or discovery of hydrocarbon are critically discussed. In each post-mortem, the pre-drill prospect evaluation is based on company interpretations (in figures showing prospect details), although structural styles revised by the authors are indicated where appropriate (in figures of seismic sections and geological cross sections). Additionally, a regional structural interpretation has been carried out including mapping major horizons in the pre- and post-Cretaceous succession (Plates 4–8) and key seismic sections are displayed in the text. Similarities between the Peedamullah Shelf and Barrow Sub-basin are discussed, and recommendations for future petroleum exploration in the region are made.

History of petroleum exploration

Petroleum exploration activities on the Peedamullah Shelf began in 1947 when AMPOL obtained onshore leases. However, little activity followed until CALTEX joined AMPOL and, subsequently, when the West Australian Petroleum (WAPET) was formed. In 1949, the Bureau of Mineral Resources (BMR), now the Australian Geological Survey Organisation (AGSO), began geological mapping on the Northwest Cape, west of the Peedamullah Shelf area (Condon, 1954, 1965). In 1950, the BMR conducted the first reconnaissance gravity survey on the Peedamullah Shelf (Thyer, 1951; Robertson et al., 1978). In 1953, the BMR carried out a regional gravity traverse between Onslow and Derby (Dooley, 1963), in the same year that WAPET struck oil at Rough Range 1 in the Exmouth Sub-basin, west of the Peedamullah Shelf. The well flowed 550 barrels of oil per day (BOPD) from the Lower Cretaceous Birdrong Sandstone. This discovery enormously increased the interest of oil companies in the region.

In 1954, WAPET made a regional reconnaissance geological survey in the Northern Carnarvon Basin and in 1955–56, conducted a semidetailed gravity survey across the eastern flank of the Yanrey Ridge and Onslow Terrace in areas around Onslow not covered by the 1950

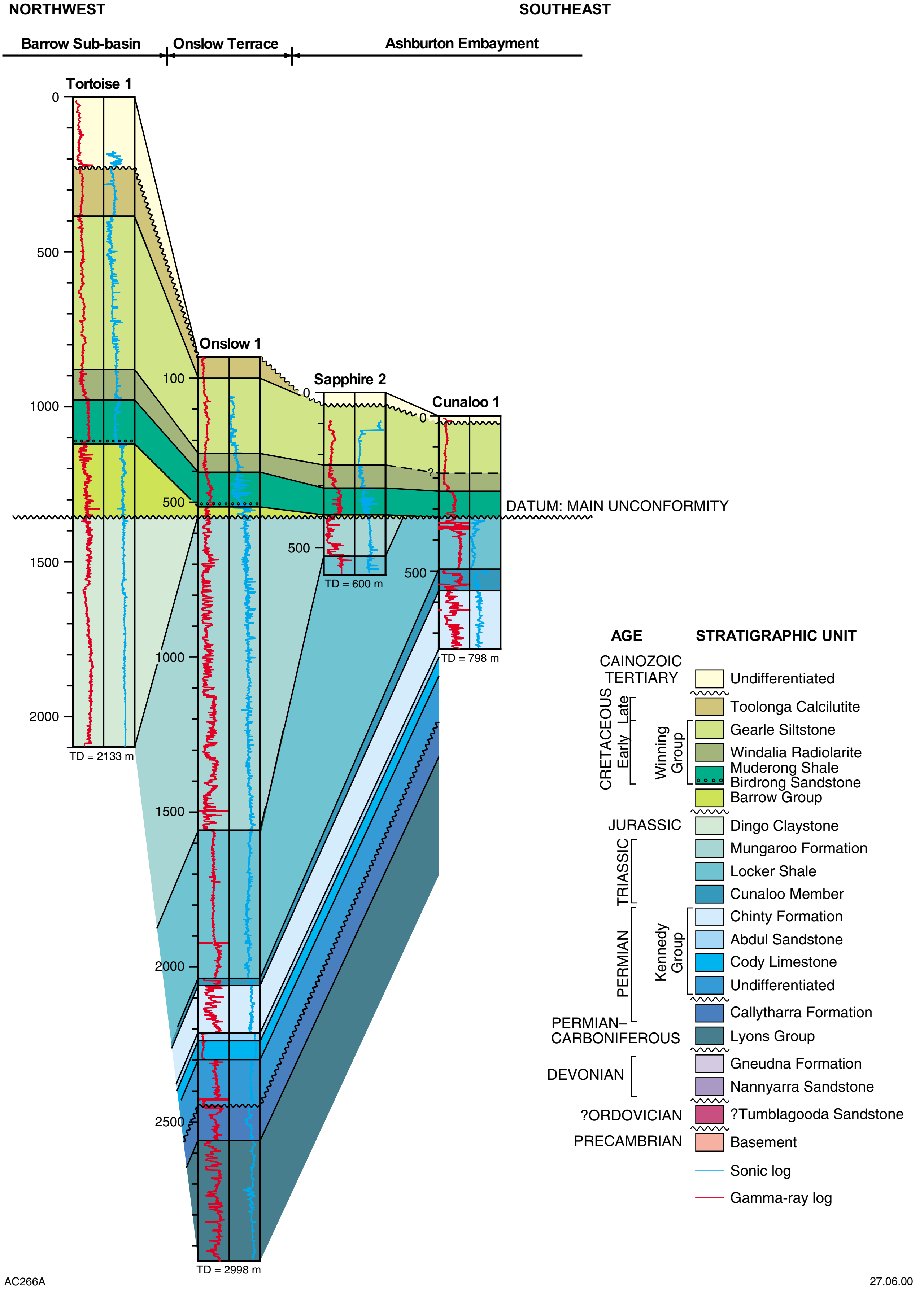


Figure 4. Well-log correlation — Tortoise 1 to Cunaloo 1. The location of this line of wells is shown in Plate 1 and Figure 2

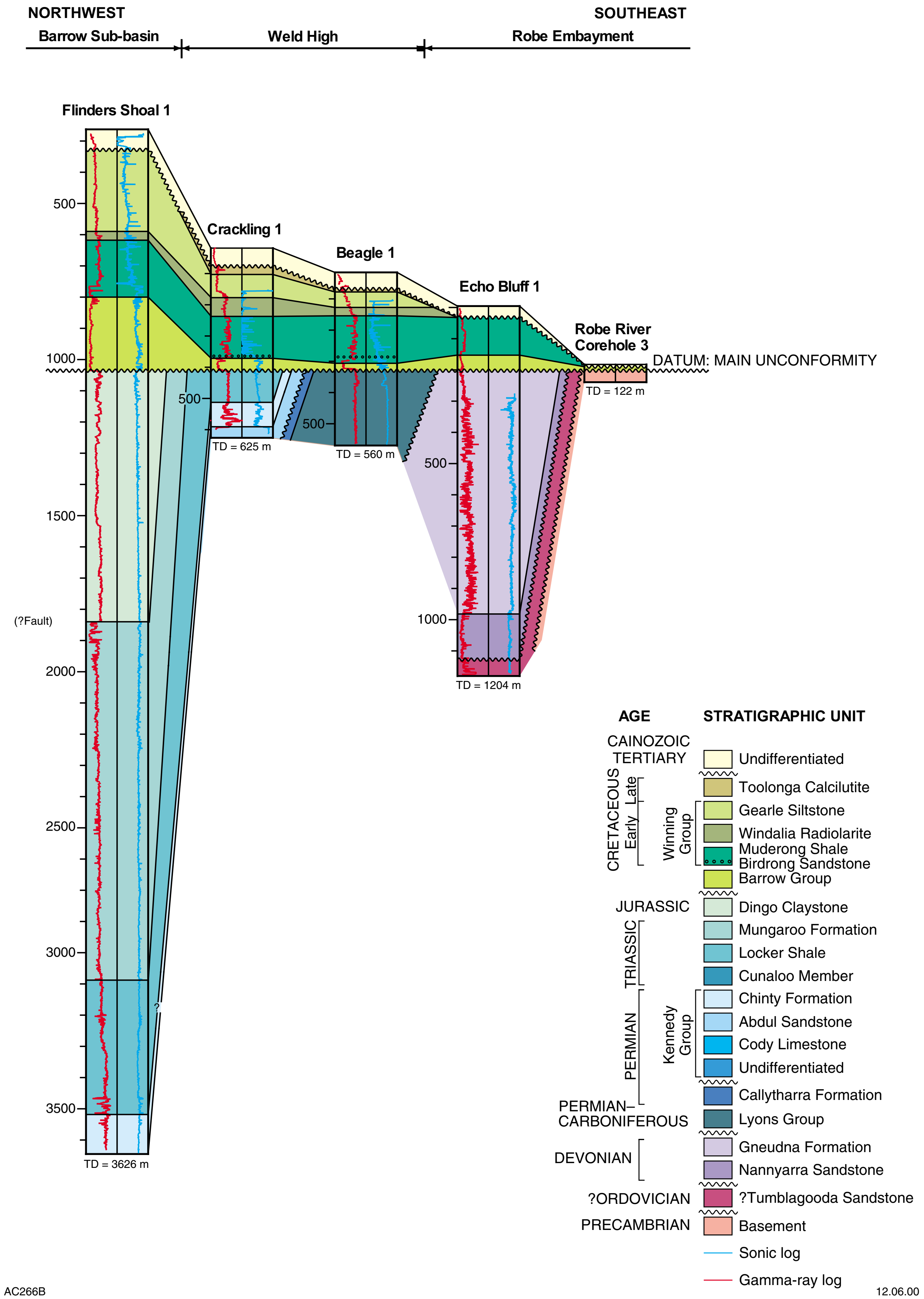


Figure 5. Well-log correlation — Flinders Shoal 1 to Robe River Corehole 3. The location of this line of wells is shown in Plate 1 and Figure 2

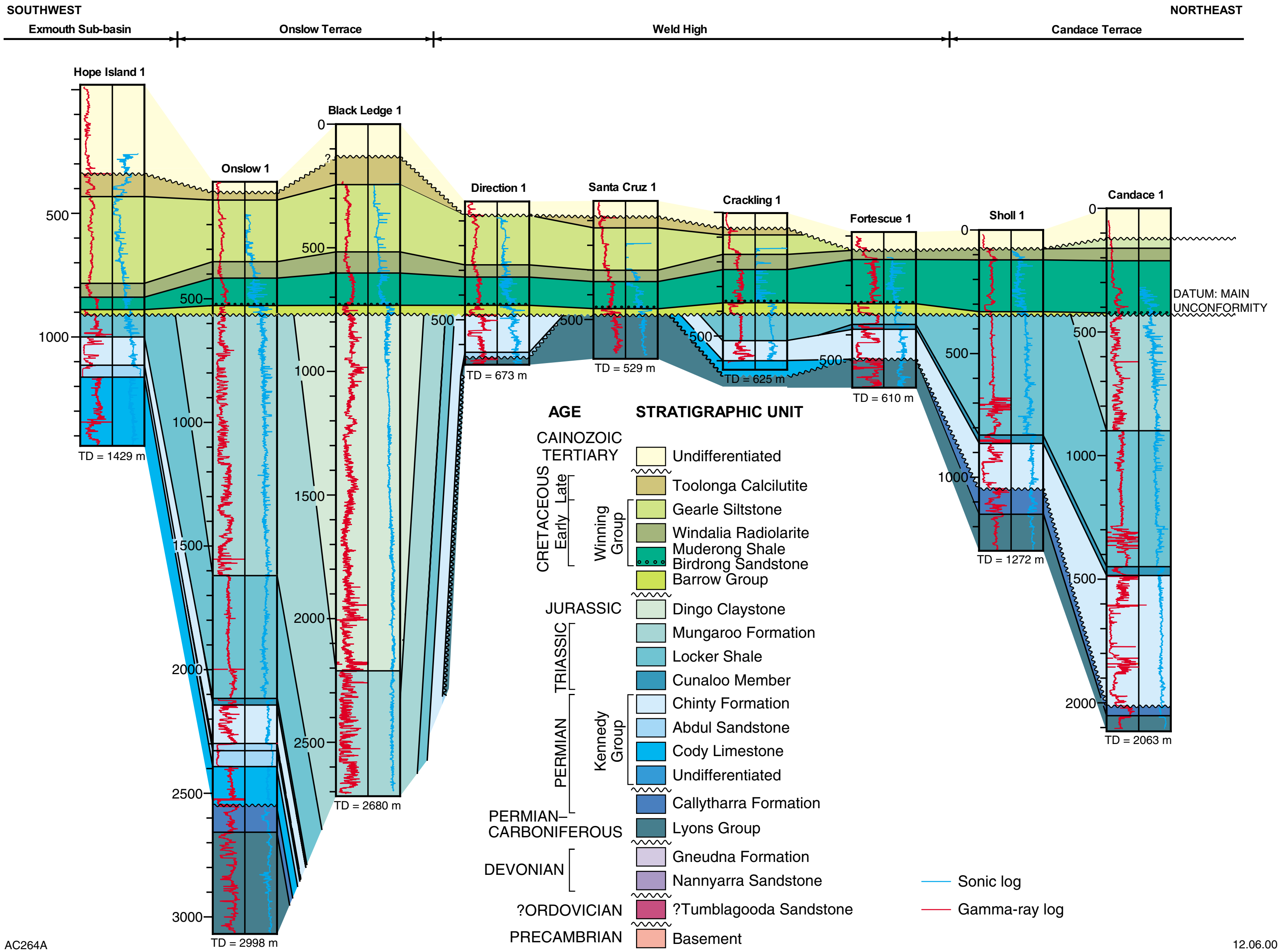


Figure 6. Well-log correlation — Hope Island 1 to Candace 1 — showing erosion of the Cretaceous succession towards the northeast. The location of this line of wells is shown in Plate 1 and Figure 2

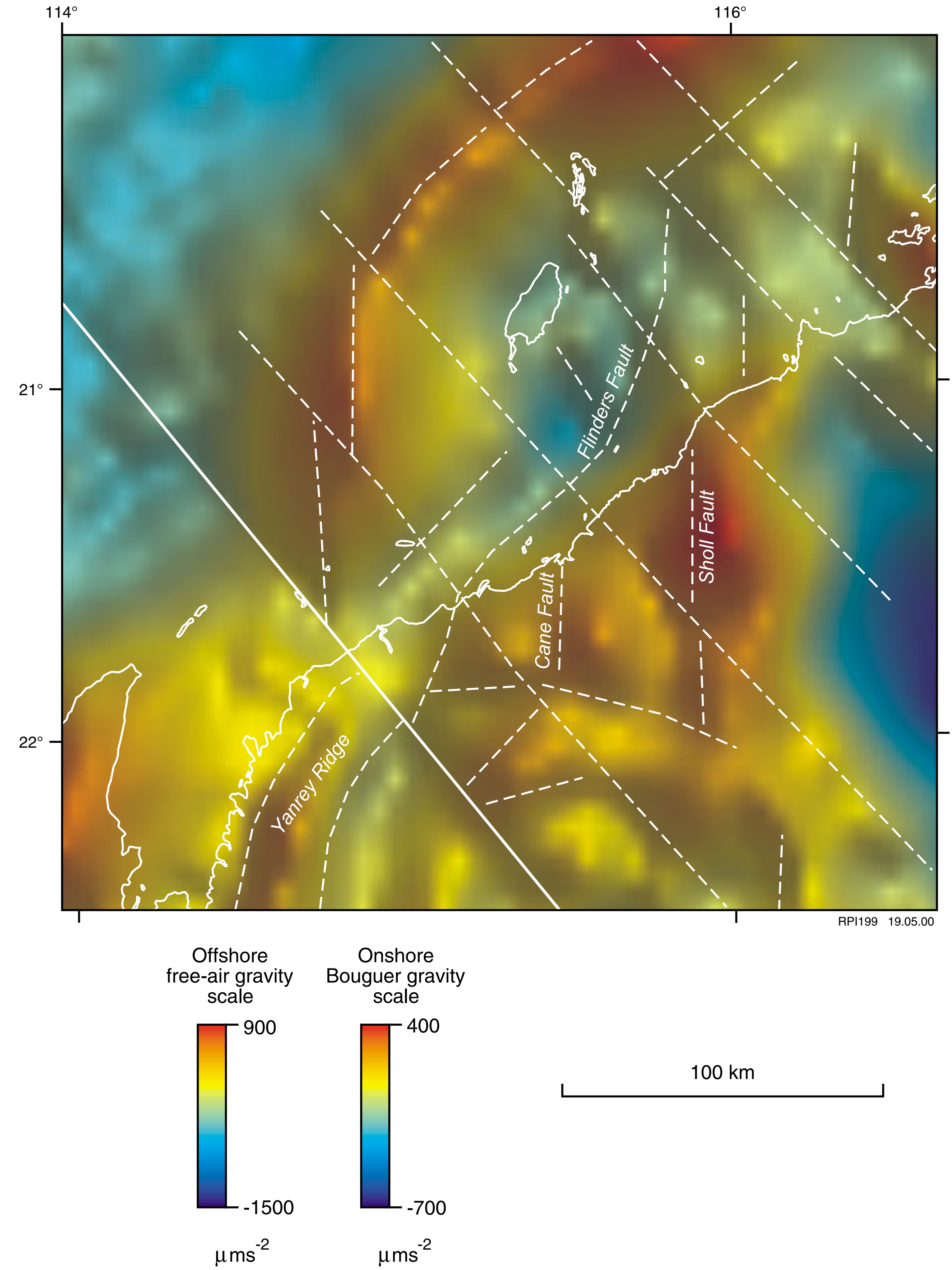


Figure 7. Bouguer gravity image of the Peedamullah Shelf with interpreted lineaments. The coastline is shown in white

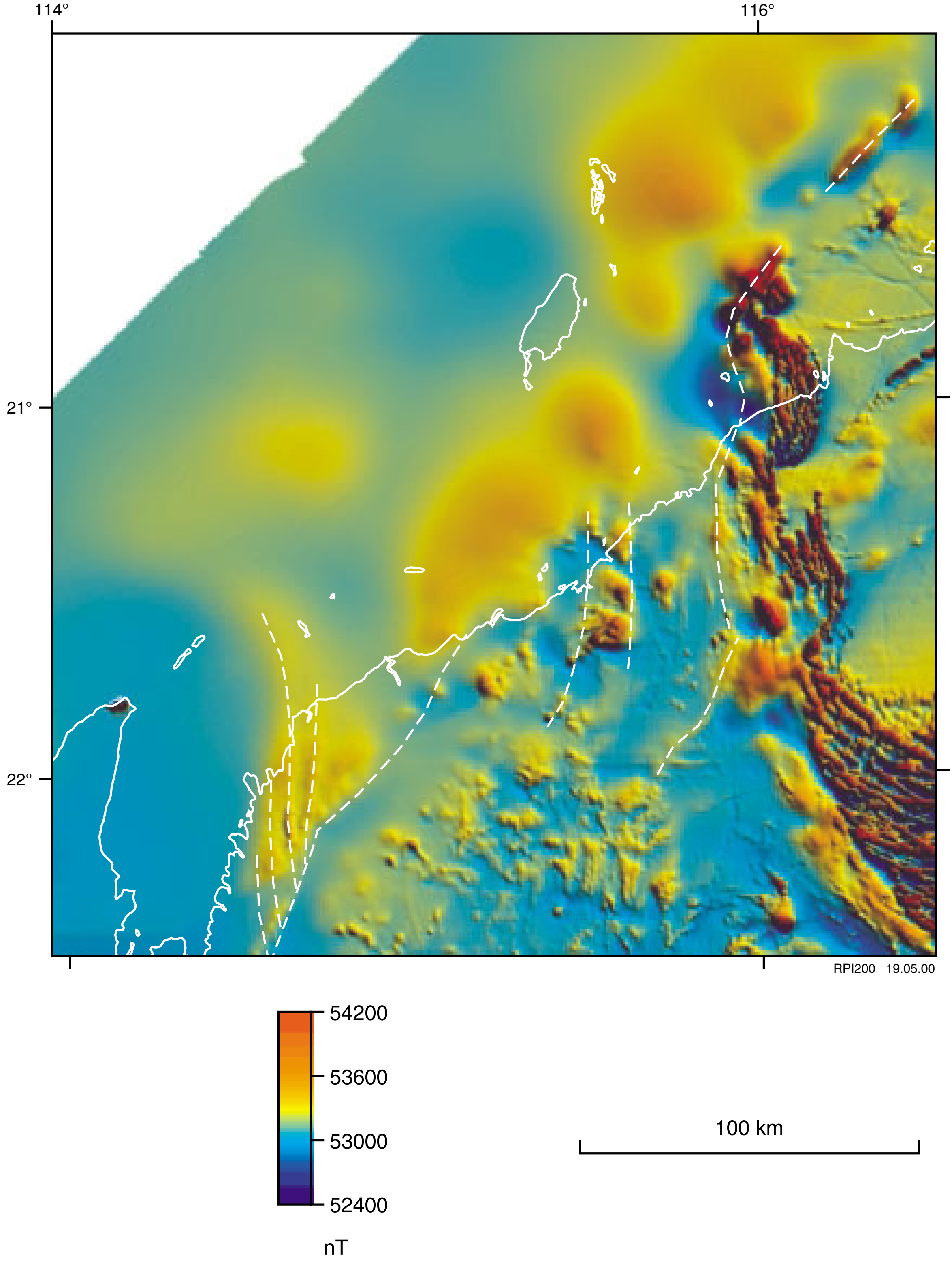


Figure 8. Total magnetic intensity image of the Peedamullah Shelf with interpreted lineaments. The coastline is shown in white

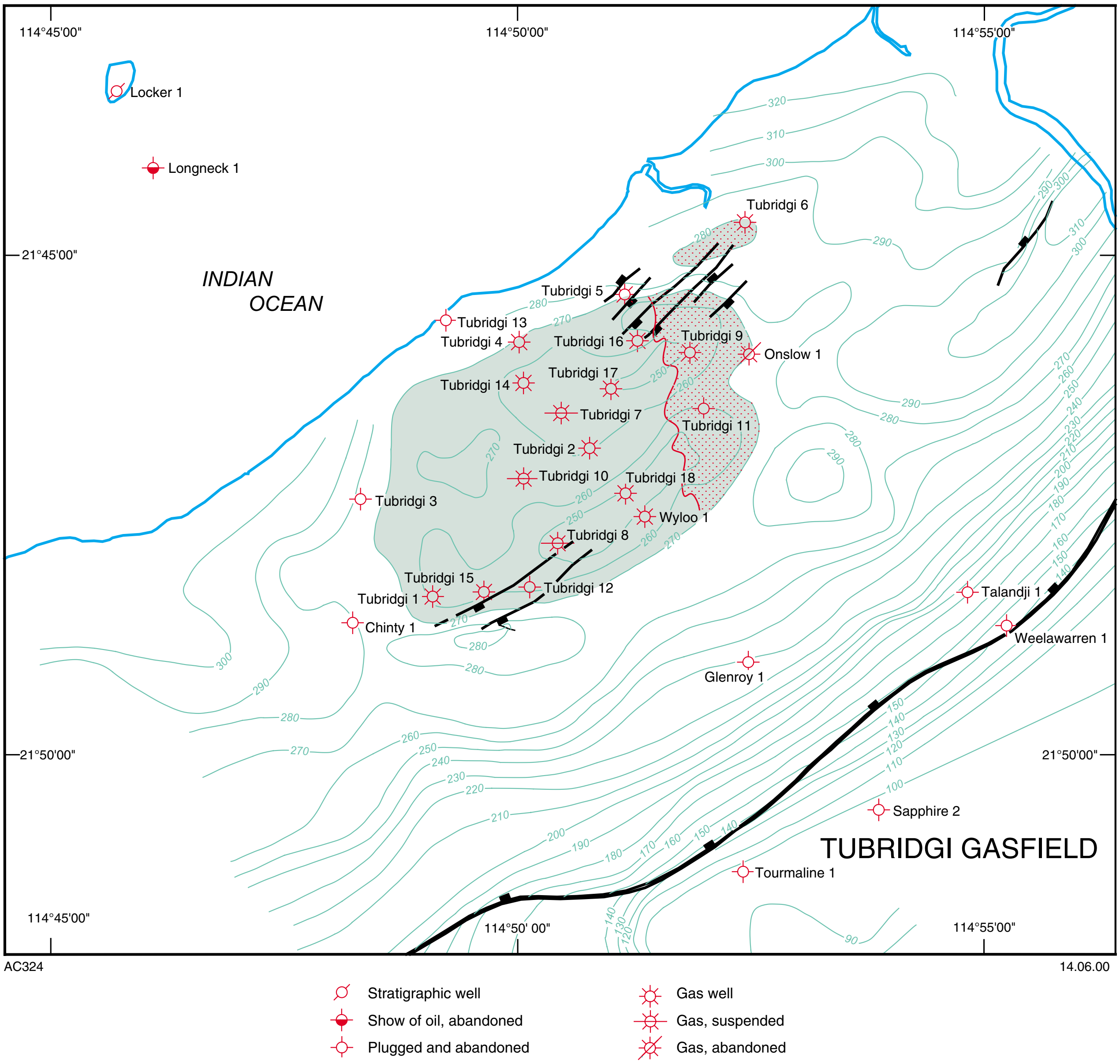


Figure 9. Two-way time contours of the top lower Gearle Siltstone horizon for the Tubridgi Gasfield. The reservoir area is shaded and the area with poor reservoir development is hatched. The coastline is shown in blue

BMR survey. In 1957, WAPET mapped the surface geology of the Onslow area including a reconnaissance survey of the nearby islands (Hoelscher and McKellar, 1957). The company also conducted a refraction and reflection seismic survey over the Yanrey Ridge and then drilled Yanrey 1. In 1961, the BMR conducted an aeromagnetic survey in the Northern Carnarvon Basin, which also covered the Peedamullah Shelf. The results from this survey demonstrated the seaward extension of the Yanrey Ridge through the Long Island area (Spence, 1961). In 1963, WAPET drilled Minderoo 1 in the Onslow area to investigate pre-Cretaceous rocks in a trough interpreted from gravity and magnetic data (Thyer, 1951; Forsyth, 1960; Spence, 1961, 1962) between the Yanrey Ridge and Precambrian margin of the basin.

The major hydrocarbon discovery of the Barrow Island Field in 1964 established the largely offshore Northern Carnarvon Basin as an important hydrocarbon province and created further interest in exploration. In 1966, a reconnaissance seismic survey confirmed a deep sedimentary embayment in the Onslow Terrace (Smith, 1966). WAPET drilled Onslow 1 on a seismically interpreted closed anticline, and encountered fluorescence and gas shows in the Lower Cretaceous Birdrong Sandstone. Two drill stem tests (DST) in this formation recovered formation water with minor gas, interpreted as solution gas. Onslow 1 was further deepened to investigate deeper targets and drilling was terminated within the Lower Permian rocks at a total depth (TD) of 2998 m. To date, this is the deepest well in the study area.

In 1966, WAPET estimated a sediment thickness of at least 1000 m in the Robe Embayment using aeromagnetic data, and consequently carried out a refraction and reflection seismic survey. During this survey, about 20 litres of heavy brown crude, followed by a strong artesian water flow with solution gas, were recovered at a depth of 77 m from seismic shot hole 1374.5 (21°27'50"S, 115°47'45"E) on seismic line Mardie-Line-A.

In 1967, WAPET conducted a gravity survey along seismic lines (Byerly, 1967; Wongela Geophysical Pty Ltd, 1967), which confirmed the presence of a deep sedimentary trough in the Robe Embayment. In the same year, five shallow coreholes (Robe River Corehole 1 to 5) were drilled in the vicinity of the oil show. Robe River Corehole 1, 2, 4, and 5 had oil and gas shows in the Mardie Greensand or the Yarraloola Conglomerate, with small amounts of oil flowing to the surface. In 1967–68, four more coreholes were drilled in the same embayment to test the Palaeozoic succession below the basal Cretaceous unconformity. The first of these coreholes, Mardie 1, was located on a small, seismically interpreted closure and reached the Lower Cretaceous Yarraloola Conglomerate. The other three wells, namely Yarraloola 1, Peedamullah 1, and Mulyery 1, were stratigraphic, and all except Peedamullah 1 demonstrated good hydrocarbon shows in the Mardie Greensand or Yarraloola Conglomerate.

In 1966–69, WAPET drilled ten stratigraphic wells without seismic control (Sholl 1, Fortescue 1, North Sandy 1, Beagle 1, Mangrove 1, Mary Anne 1, Thevenard 1, Tortoise 1, Long Island 1, and Observation 1) on islands in the shallow, offshore part of the Peedamullah Shelf and Onslow Terrace.

Mardie 2 was drilled in 1969 between Mardie 1 (oil shows) and Mulyery 1 (gas shows) within the Robe embayment, but only good oil shows were present.

Following a farmout agreement with WAPET, Hematite Petroleum drilled five stratigraphic coreholes named Cane River 1 to 5, from November 1971 to January 1972, aiming to find an embayment similar to the Robe Embayment, but there were no significant shows. Although the Upper Permian Kennedy Group was intersected below the Birdrong Sandstone in Cane River 1 and 2, the presence of an embayment was not confirmed because Lower Cretaceous rocks directly overlie Precambrian basement in Cane River 3, 4, and 5.

In late 1972, Hematite Petroleum drilled five more stratigraphic holes in the Robe Embayment, namely Woorawa 1, Windoo 1, Surprise 1, Coonga 1, and Mardie West 1. Hydrocarbon shows were found in the first three wells. In the 1970s, additional DSTs were run in four promising wells, namely Mardie 1, Mulyery 1, Woorawa 1, and Surprise 1, but production could not be sustained. In 1974, WAPET drilled Mardie 1A and Windoo 1A but pumping tests yielded only a minor flow of gas.

A new permit covering the Robe Embayment was awarded to J. O. Clough and Avon Engineering in July 1979 and, from 1981 to 1984, Avon Engineering drilled 7 wells: Thringa 1, Carnie 1, Saddleback 1, Multhuwarra 1, Myanore 1, Murnda 1, and Echo Bluff 1. The results of the previous seismic survey could not be used to define structural traps at the shallow Mardie Greensand and Yarraloola Conglomerate levels. Therefore, the Robe Seismic Survey was shot in October 1982 to obtain information on the shallow horizons. Although the quality of the data from the survey was fair to poor, with only marginal improvement over the previous survey, several anticlinal features were interpreted at the Mardie Greensand level. The most prominent feature was tested by Myanore 1, but no trap was found. Even though drilling plans were carefully made to avoid damaging the formation at the objective Mardie Greensand, no discovery of economic significance was made. Echo Bluff 1, the deepest well in the Robe Embayment (1204 m TD), was located with the support of the 1983 Yarraloola Seismic Survey but was unsuccessful.

In June 1981, additional seismic control helped Pan Pacific Petroleum NL to discover the Tubridgi Gasfield within the onshore part of the Onslow Terrace. Tubridgi 1 intersected gas-saturated Birdrong Sandstone and Flacourt Formation: a DST produced a stabilized flow of 59.5 km^3/day of mainly methane through a 12.7 mm choke. Subsequently, six appraisal wells (Wyloo 1 and Tubridgi 2 to 6) were drilled; gas was encountered in Tubridgi 4 and 5 and the producing reservoirs included the Mungaroo Formation, directly below the Flacourt Formation. Additionally, a secondary gas accumulation was found in the Upper Cretaceous Gearle Siltstone. Subsequent activities in the area revealed that Onslow 1 had been drilled in the field, but near the edge of the gas–water contact. During the mid-1980s, the Dampier–Bunbury natural gas pipeline was constructed, and the government policy changed to facilitate competition in the domestic gas market. In 1990, the development of the Tubridgi Gasfield proceeded with the drilling of Tubridgi 7 and 8. Production and storage facilities were installed, and a gas pipeline was constructed to the Dampier–Bunbury pipeline. In September 1991, gas production started from six wells, namely Tubridgi 2, 4, 5, 7, 8, and Wyloo 1. More wells followed: Tubridgi 9 in 1993, Tubridgi 10 in 1994, Tubridgi 11 to 15 in 1997, and Tubridgi 16 to 18 in 1999. In 1994, gas gathering and storage facilities at the Tubridgi Gasfield were increased and the delivery of gas from the Thevenard Island production complex commenced in September. In November, gas from the Thevenard Island and Griffin Fields also began to be stored within the Tubridgi Gasfield reservoirs.

In 1981, an exploration permit over the Candace area in the northeastern Peedamullah Shelf was awarded to a group led by Australian Occidental. The company collected 7642 km of seismic data over a wide area, including the Barrow Sub-basin and northern Peedamullah Shelf, before drilling Candace 1 in 1982 to test the Triassic and Permian section in an anticlinal structure adjacent to the Sholl Fault. The well was dry and drilling was terminated in the Upper Carboniferous – Lower Permian Lyons Group at 2063 m. In 1987, Bond Corporation drilled Kybra 1 to a total depth of 2562 m, reaching the Lower Carboniferous Moogooree Limestone.

In 1983, Pan Pacific Petroleum NL drilled Weelawarren 1 in the Ashburton Embayment, just south of the Weelawarren Fault. In the early 1980s, Esso Exploration and Production Australia started exploring on the Onslow Terrace and Ashburton Embayment. Two seismic surveys were carried out in 1984–85 and in 1985, Chinty 1 was drilled to the south of the Tubridgi Gasfield, aiming at pre-basal Cretaceous unconformity objectives. The well was unsuccessful.

The discovery of several oilfields in the Barrow Sub-basin (South Pepper in 1982, North Herald in 1983, Chervil in 1983, Saladin in 1985, Yammaderry in 1988, Cowle in 1990, Roller in 1990, and Skate in 1991) revived exploration activities on the Peedamullah Shelf. Subsequently, seismic surveys were carried out (Appendix 2) and many more wells have been drilled in the region since the late 1980s. Minora Resources NL drilled Tent Hill 1 in 1989 on the Yanrey Ridge. Pan Pacific Petroleum NL drilled Talandji 1 in 1987–88, Abdul's Dam 1 in 1991, Picul 1 in 1992, Jade 1 in 1993, Amber 1 in 1994, and Ruby in 1996 within the Ashburton Embayment, and Jasper 1 in 1994, Topaz 1 in 1995, and Topaz 2 in 1996 within the Weld High. On the Onslow Terrace, WAPET drilled Black Ledge 1 in 1992 and Curler 1 in 1997. Carnarvon Petroleum NL drilled Sapphire 1 in 1993, Sapphire 2 in 1993, and Tourmaline 1 in 1997 within the Ashburton Embayment, and Command Petroleum Holdings NL drilled Crackling 1 in 1993 and Santa Cruz 1 in 1993 within the Weld High. All these wells were plugged and abandoned as dry holes.

Current exploration is directed towards shallow targets within the Cretaceous and Palaeozoic successions, although structures formed by the mid-Miocene tectonism are difficult to define due to the poor resolution of the shallow seismic data in the region.

Regional framework

In this Report the Peedamullah Shelf has been subdivided into six structural units: the Yanrey Ridge, Ashburton Embayment, Cane Embayment, Weld High, Robe Embayment, and Candace Terrace. Four of these were used by Hocking et al. (1987) and by oil companies operating in the region and two new ones are proposed here (Cane Embayment and Weld High). The entire onshore Northern Carnarvon Basin is covered in this study with the inclusion of the Onslow Terrace north of the Ashburton Embayment (Fig. 1).

Yanrey Ridge

Although Hocking (1994) considered the Yanrey Ridge to be a northerly extension of the Wandagee Ridge in the Southern Carnarvon Basin, the two ridges are separated by a gravity low and represent discrete structures. The Yanrey Ridge is taken to constitute the westernmost subdivision of the Peedamullah Shelf, in agreement with oil industry usage. It is a basement high bounded to the west by the Marrilla Fault and to the east by the Yanrey Fault (Fig. 2). The basement consists of quartz–mica schist and is covered at its structurally highest point by a veneer of Cainozoic rocks (Yanrey 1 and Tent Hill 1). The Yanrey Ridge plunges northwards, as indicated by the presence of Carboniferous (Wanangarra 1) and Triassic (Urala 1) sedimentary rocks beneath the basal Cretaceous unconformity. Gravity data (Fig. 7) show that the ridge does not extend past the coastline, where it is truncated by a northwesterly gravity lineament interpreted as a transfer fault at basement level. However, seismic data immediately offshore indicate the presence of a narrow horst extending north near Long Island (Plates 4–6).

Ashburton Embayment

The Ashburton Embayment has been loosely referred to by the petroleum industry as a discrete Palaeozoic sub-basin (Thomas and Smith, 1976). However, the Mesozoic sub-basin cannot be separated easily from the Palaeozoic sub-basin as there is little or no evidence of an unconformity between the Upper Permian Kennedy Group and the Lower–Middle Triassic Locker Shale. The latter unit, in turn, passes gradually upwards to the Middle–Upper Triassic Mungaroo Formation (Parry and Smith, 1988). Here it is preferred to formalize the term 'Ashburton Embayment' (already recognized by Hocking, 1994) as a sedimentary trough filled with Palaeozoic to Triassic rocks. The embayment is bounded to the west by the Giralia Fault and to the east by a basement high that is covered only by Cainozoic rocks (Fig. 2). The Yanrey Ridge extends into the southern part of the Ashburton Embayment. Basement has not been reached by any well in the embayment, and it is possible that strata older than Carboniferous are present as they are in the Merlinleigh Sub-basin to the southwest and the Robe Embayment and Candace Terrace to the northeast. To the northwest, the Ashburton Embayment is separated from the Onslow Terrace by the Weelawarren Fault and to the northeast it passes gradually into the Weld High. In the Ashburton Embayment, deformation of the pre-breakup section is commonly limited to extensional normal faults that created a horst and graben structural framework, although locally there are indications of compressional features (Fig. 10). Closer to the Onslow Terrace, Middle Miocene compressional anticlines are common.

Cane Embayment

The Cane Embayment was introduced by Yasin and Iasky (1998) as the Cane River Terrace, but is here redefined as a small trough between two basement highs. The trough can be identified from a gravity image of the area (Fig. 7) and is verified from seismic section PP88A-013 (Fig. 11), which indicates a southeastwardly thickening sedimentary section beneath the Cretaceous. Thickening of the sedimentary succession to the southeast and northerly oriented gravity lineaments (Fig. 7) suggest that the trough is controlled by a northerly trending fault, en echelon to the Sholl Fault. The stratigraphy of the sedimentary succession is unknown and the limit of the trough is poorly defined, as there has been no drilling and geophysical coverage of the area is extremely limited.

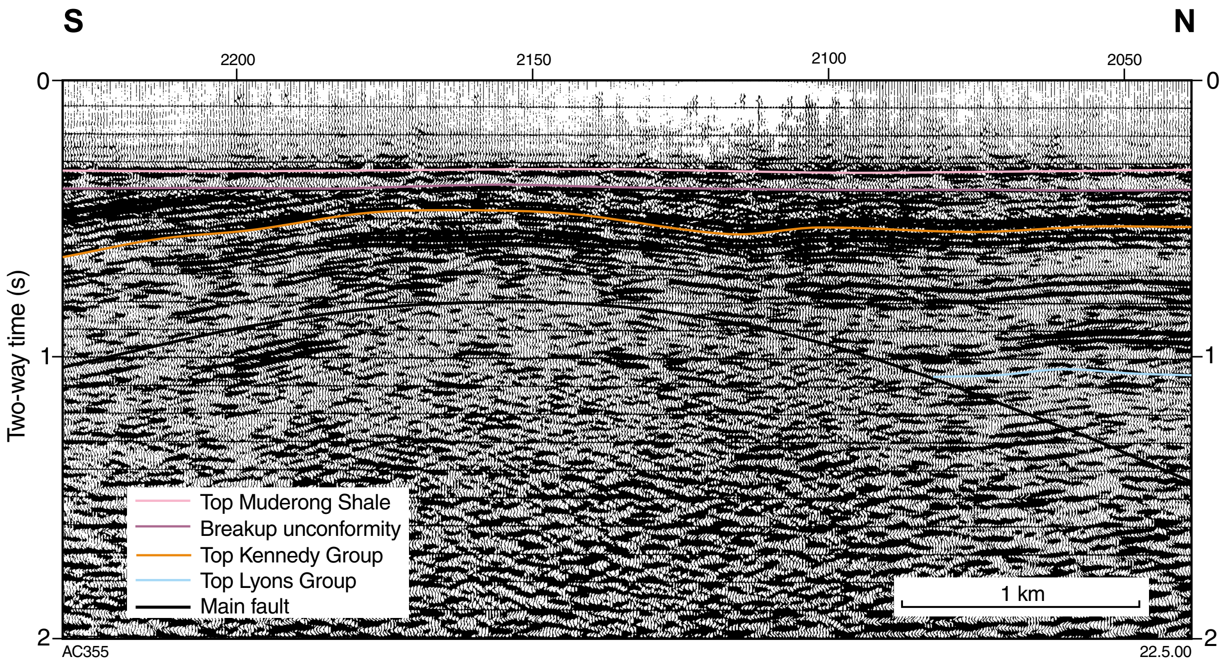


Figure 10. Seismic section J85A-163 showing folds below the main unconformity in the Ashburton Embayment. The location of the section is shown in Plate 1

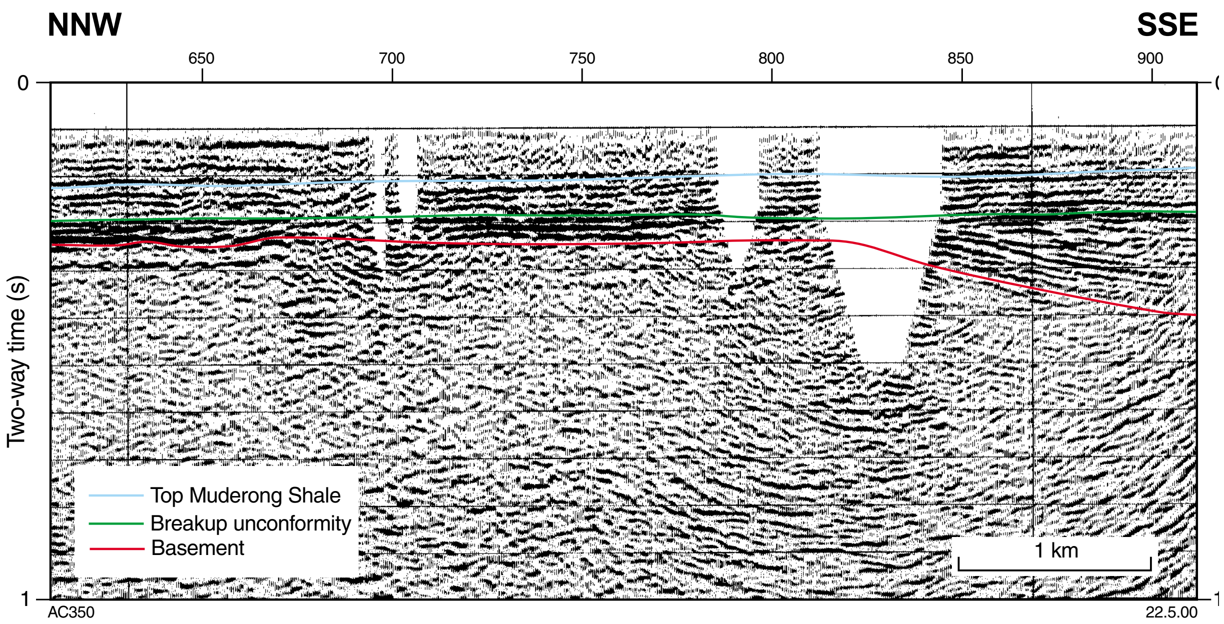


Figure 11. Seismic section PP88A-013 showing the thickening sedimentary succession in the Cane Embayment. The location of the section Is shown in Plate 1

Robe Embayment

The Robe Embayment was recognized by Hocking (1994) as the main outcrop area of the Yarraloola Conglomerate. The term has been extensively utilized by the petroleum industry, and intense drilling and testing has taken place. The Robe Embayment is here defined as a Palaeozoic sedimentary trough between a basement high to the west and the Pilbara Craton to the east, which locally has a veneer of post-breakup rocks. At Palaeozoic level, the trough is wedge-shaped with a deeper, fault-bound eastern part (Fig. 2). To the south, it thins towards the basement, whereas to the north it plunges gradually into the Weld High and Candace Terrace. The boundary between the Robe Embayment and Candace Terrace is placed somewhat arbitrarily as the boundary between the Lyons Group – Callytharra Formation and Ordovician – Lower Carboniferous sections as shown on the subcrop map (Fig. 2). Devonian carbonate and clastic rocks have been penetrated in several wells within the Robe Embayment, but possibly the oldest sedimentary section penetrated is the interval 1145–1204 m (TD) in Echo Bluff 1, which is tentatively referred to as the Ordovician Tumblagooda Sandstone. The structure in the embayment consists predominantly of extensional pre-breakup normal faults.

Weld High

The Weld High is proposed here as a new subdivision of the Peedamullah Shelf to define the basement high separating the Onslow Terrace – Ashburton Embayment region to the southwest and the Candace Terrace to the northeast (Plate 2, Figs 2 and 6). The name is derived from Weld Island, near the mouth of the Cane River. To the northwest, the Weld High is separated from the down-thrown Barrow Sub-basin by the Flinders Fault System. Southeast of the fault system only Palaeozoic rocks are present below the breakup unconformity and the high gradually rises to the southeast to an area where basement is covered only by Cainozoic sediments. Onshore, the Weld High extends to the southwest into the Topaz area (10 km southeast of Onslow; Plate 1) and is bounded to the east by the Cane Embayment. As only Palaeozoic rocks underlie the Cretaceous succession within the main part of the Robe Embayment, and offshore well control is sparse in the northeast, the extension of the Weld High near Mary Anne 1 (Plate 1) is only tentatively proposed.

Candace Terrace

The offshore Candace Terrace (Bentley, 1988; Hocking, 1994) has the thickest sedimentary section in the Peedamullah Shelf, and is bounded on the east by the Sholl Fault and on the west by the Flinders Fault System (Fig. 2). To the south and southwest the terrace grades into the onshore Robe Embayment and offshore Weld High, whereas to the north the western and eastern bounding faults converge.

Cainozoic, Cretaceous, Triassic, Permian, and Carboniferous rocks have been penetrated within the terrace. As interpreted by Bentley (1988), Jurassic sediments may also have been deposited in the sub-basin and subsequently largely eroded to be preserved only in the northernmost part. The oldest formation penetrated is the Lower Carboniferous Moogooree Limestone (in Kybra 1), but seismic data indicate the presence of a thick, older succession probably equivalent to the Palaeozoic in the Robe Embayment (Fig. 2). Structurally, the Candace Terrace is characterized by large breakup folds (Candace and Kybra anticlines; Fig. 12) controlled by reverse movement along the Sholl Fault. Oblique compressional forces during breakup caused both strike-slip and reverse movements along parts of the fault. In the Kybra area, the Lower Carboniferous Quail Formation is eroded below the Carboniferous–Permian Lyons Group at the crest of the structure, implying Early Carboniferous structural movement (Fig. 12).

Onslow Terrace

The Onslow Terrace straddles the coastline and corresponds to the area defined as the 'Locker Terrace' by Hocking (1994); however, the former name has been widely used by the petroleum industry and is therefore retained. The Onslow Terrace is the southwestern-most extension of the Barrow Sub-basin (Thompson, 1992) and includes the Tubridgi Gasfield. However, Jurassic sedimentary rocks, which are widespread in the Barrow Sub-basin, are not present over the Tubridgi Gasfield. The Weelawarren Fault represents the southwestern extension of the Flinders Fault System, and is taken as the eastern boundary of the Peedamullah Shelf (Hocking, 1994) against the Barrow Sub-basin.

The Onslow Terrace is bounded by the Long Island Fault System to the north and the Weelawarren Fault to the southeast, and the offshore extension of the Giralia Fault separates the Onslow Terrace from the main Ashburton Embayment. The Long Island and Weelawarren Faults converge northeastwards. Cainozoic to Cretaceous sedimentary rocks gently folded by mid-Miocene transpressional movements and unconformably overlying Jurassic–Permian rocks have been block faulted by extensional faults and largely eroded on the structurally highest areas. Onslow 1, the deepest well in the Onslow Terrace, was terminated in the Carboniferous–Permian Lyons Group, but it is likely that older Palaeozoic rocks are also present as they are in the Peedamullah Shelf.

Stratigraphy

The lithostratigraphic units referred to in this Report (Fig. 3) are those utilized by the petroleum industry and represent a simplified version of the units discussed by Hocking et al. (1987; Appendix 3). Cainozoic to Triassic units can be correlated with the seismic stratigraphic analysis of Westphal and Aigner (1997), whereas the Permian stratigraphic succession is based on Mory and Backhouse (1997), with the introduction of the Abdul Sandstone within the Kennedy Group. The associated palynological zonation for the entire succession is shown in Figure 3. Four tectonic events separate the

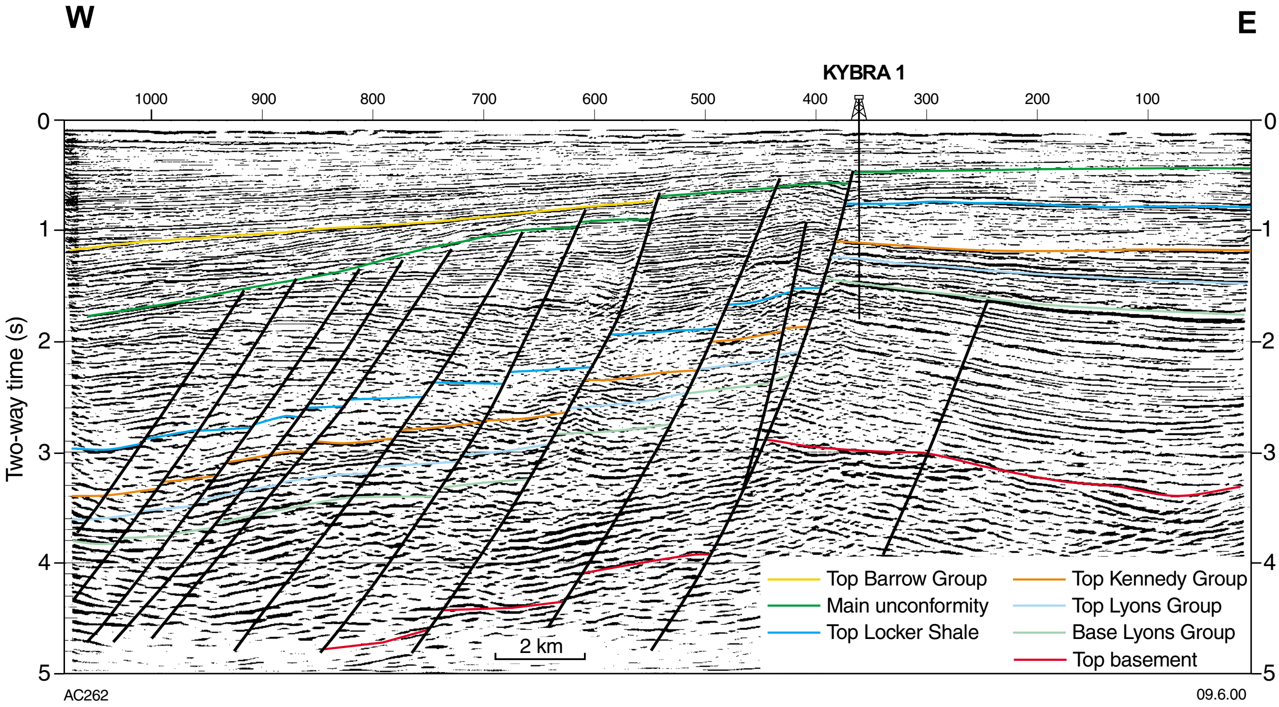


Figure 12. Seismic section 82A-333D showing a dip section across the Kybra 1 structure. The location of the section is shown in Plate 1

five main stratigraphic cycles of the Peedamullah Shelf and Onslow Terrace.

Three stratigraphic correlations have been produced on the basis of biostratigraphic control (Appendix 4), gamma-ray and sonic signature, regional marker horizons, lithology from composite logs, and some reference to the cutting description. One correlation has been made along the shelf, from Hope Island 1 to Candace 1 (Plate 2; Fig. 6), and two across the shelf, from Tortoise 1 to Cunaloo 1 and Flinders Shoal 1 to Robe River Corehole 1 (Plate 3; Figs 4 and 5). The review of units utilized by petroleum companies exploring in the area revealed several inconsistencies, which are discussed in detail within the section dealing with individual wells. The revised formation tops are listed in Appendix 5. The following discussion of the stratigraphy is based on the review of wells drilled in the region. The Mesozoic–Tertiary succession in the study area is believed to be representative, albeit thinner, of most of the Northern Carnarvon Basin, whereas the Palaeozoic is poorly known further north.

Pre-Upper Carboniferous

Devonian rocks have been penetrated only in a few wells within the Robe Embayment, but Lower Carboniferous sedimentary rocks are widespread across the entire Peedamullah Shelf. On the Candace Terrace there is a marked angular unconformity at the base of the Devonian succession (Fig. 13), which indicates tectonic movement in the terrace, and possibly elsewhere on the shelf, prior to deposition of Middle Devonian sediments. The tectonism is probably Middle Devonian in age and possibly corresponds to the hiatus between the Devonian Sweeney Mia and Nannyarra Formations in the Gascoyne Platform (Iasky and Mory, 1999). Devonian deposition commenced in the Middle Devonian with transgressive sands (Nannyarra Sandstone) followed by mud and carbonate (Gneudna Formation). Following a hiatus in the Early Carboniferous, carbonate (Moogooree Limestone) was deposited followed by clastic sediments (Quail Formation).

The Ordovician Tumblagooda Sandstone may be present in Echo Bluff 1 over the interval 1145–1204 m (TD), and consists of a poorly sorted, coarse-grained, and locally conglomeratic reddish hematitic sandstone.

Upper Carboniferous – Permian

After the deposition of the Lower Carboniferous Quail Formation, deposition recommenced in the Late Carboniferous with fine-grained marine deposits (Lyons Group). These deposits have been intersected in several wells on the Peedamullah Shelf and in places, such as the Yanrey Ridge, where they directly overlie basement. During the Early Permian, marine sedimentation including glacial erratics continued (Lyons Group) until the Sakmarian when carbonate and mud (Callytharra Formation) were deposited. Deposition in the region ceased until the Ufimian when marine carbonate and deltaic sand (Kennedy Group) accumulated over the two older Permian units.

In Onslow 1, a unit (Unit ‘A’) consisting of an upper sandstone and lower limestone interval (2258 – 2343.6 m), was incorrectly correlated with the Lower Permian

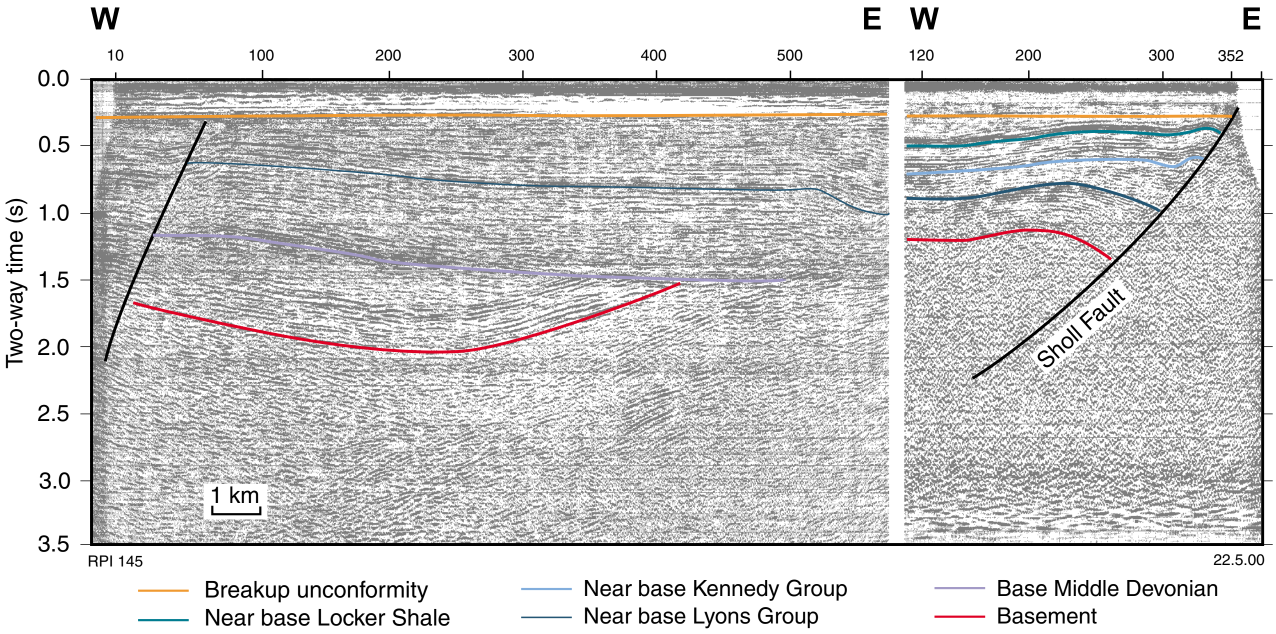


Figure 13. Seismic section 82-176 showing an angular unconformity below the interpreted Middle Devonian succession and seismic section 82-168 showing roll-over along the Sholl Fault. The sections are 18 km apart. The location of the sections is shown in Plate 1

Wandagee Formation (Byro Group; Jones, 1967). Palynological analysis, however, places the sandstone unit in the Late Permian at the base of the Chinty Formation and the limestone unit at the top of the undifferentiated Kennedy Group (Mory and Backhouse, 1997). The two units also have been penetrated within the Ashburton Embayment in Abdul's Dam 1 and Ruby 1. In Abdul's Dam 1, Pan Pacific Petroleum NL (1991) did not name the shallower sandstone unit, but identified the lower limestone unit as Wandagee Limestone of the Lower Permian Byro Group. In Ruby 1, Mills (1997a) referred the two units to the Nalbia Sandstone and Wandagee Formation (Byro Group) respectively. However, in the palynological appendix attached to Mills (1997a), it is stated that *Didecitriletes ericianus* is present in both these units, indicating that they are Late Permian in age, consistent with Mory and Backhouse (1997). The sandstone unit is therefore formally defined as the Abdul Sandstone (Table 1). The limestone unit has been referred to as the Cody Formation by Gorter and Davies (1999). The Cody Limestone is preferred here to Cody Formation, as the unit is entirely represented by limestone.

The thickness of the potential reservoir section within the Kennedy Group increases from southwest to northeast (Plate 2; Fig. 6), consistent with the increase in thickness of the entire group.

Triassic

In the seismic sequence scheme of Westphal and Aigner (1997), seismic sequence 1 corresponds to the Locker Shale – Mungaroo Formation. Their sequence boundary (SB) 1 at the base of the Triassic is characterized by a marked truncation of older rocks. In the Arabella 1 well completion report, Australian Occidental Pty Ltd (1983) considered the older succession to be Permian, and that the Devonian microflora from the basal interval (1888–2209 m) was reworked, even though there is no palaeontological evidence for this interpretation. The unconformity in Arabella 1 (Fig. 14) is more likely to be of the same age as that in Kybra 1 between the Lower Carboniferous succession and the overlying Upper Carboniferous – Lower Permian Lyons Group (Fig. 12). In contrast, 20 km to the south of Arabella 1, the Permian–Triassic boundary is conformable in Mermaid 1 (Young and Wright, 1978). Therefore, following an episode of

Table 1. Definition of the Abdul Sandstone

ABDUL SANDSTONE	
Type section:	Abdul's Dam 1 (707 – 747.5 m) latitude: 21°57'2.2"S longitude: 114°49'43.6"E thickness: 40.5 m
Lithology:	Clear, translucent and milky white, fine- to medium-grained sandstone; rarely coarse grained, well-sorted, minor microcrystalline limestone
Stratigraphic position:	Conformable with the overlying Chinty Formation and underlying Cody Limestone
Palynozone:	*D. ericianus*
Age:	Ufimian
Identified in:	Onslow 1, Abdul's Dam 1, Ruby 1

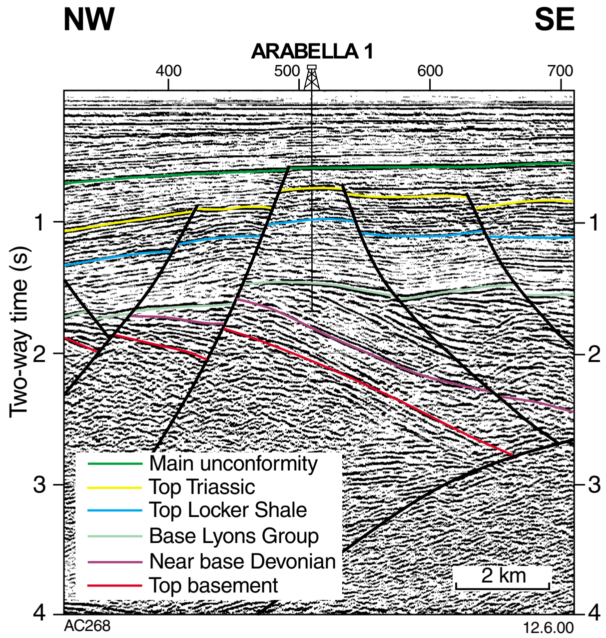


Figure 14. Seismic section 082-20 (migrated) showing a dip section across the Arabella 1 structure. The location of the section is shown in Plate 1

tectonism in the Early Carboniferous, the Triassic transgressed across older strata on the Peedamullah Shelf.

The Cunaloo Member of the Locker Shale is represented in the study area by a widespread limestone overlying a prominent radioactive shale, which in turn overlies the Upper Permian Chinty Formation (Yasin, 1997). Higher in the section, another prominent radioactive shale marker is present in the Locker Shale. The presence of several shelf-wide important marker horizons within the Triassic sequence, possibly representing maximum flooding surfaces, should allow further subdivision of sequence 1.

The Locker Shale ranges in age from Scythian (*Protohaploxypinus samoilovichii* Zone) to Anisian (*Triplexisporites playfordii* Zone). The Mungaroo Formation ranges from Ladinian (*Staurosaccites quadrifidus* Zone) to Rhaetian (*Minutosaccus crenulatus* Zone), except in the Candace Terrace, where deposition of the coarser clastics of the Mungaroo Formation commenced earlier. The thickness of the Locker Shale greatly increases towards the depocentre of the Barrow Sub-basin, where clastic rocks are more fine grained than at the southern margin of the Peedamullah Shelf (Fig. 15).

Jurassic

In the study area, the Jurassic has been penetrated only by Black Ledge 1 and Curler 1 on the Onslow Terrace. In Black Ledge 1, 1405.5 m of the Hettangian to Oxfordian (Lower to Upper Jurassic) Dingo Claystone was penetrated below the basal Cretaceous transgression. This unit conformably overlies the Mungaroo Formation. Age dating indicates that deposition took place throughout the Jurassic in at least part of the Onslow Terrace. The lack of Jurassic rocks in other wells in the area is probably the result of widespread erosion following Late Jurassic uplift. The Jurassic lithofacies in Black Ledge 1 and Curler 1 is predominantly sandy, so the two wells cannot be easily correlated with the sequence stratigraphic units of Westphal and Aigner (1997) or the detailed subdivisions proposed by Jablonski (1997) in more basinal locations.

Cretaceous

Pre-Cretaceous units are unconformably overlain by the Barrow Group, which in the study area is represented by the Flacourt and Nannutarra Formations, and the Yarraloola Conglomerate. In the study area, the Flacourt Formation has been identified only on the Onslow Terrace and Ashburton Embayment. Westphal and Aigner (1997) assigned this unit to their seismic sequence 6, which is separated from the overlying seismic sequence 7 by SB7, marking the intra-Valanginian breakup of Gondwana. On the Onslow Terrace, the boundary does not have a pronounced seismic signature, because of its marginal position within the basin and the relatively thin overlying and underlying units. The fluviatile to deltaic Flacourt Formation is composed of medium- to coarse-grained sandstone supplied by the ancestral Robe and Ashburton rivers. The sandstone locally fines up in the upper part, is light grey to milky white, commonly unconsolidated, and in places has a permeability of more than five darcies (D). The lack of dinoflagellates does not allow a distinct palynozonation and the age of the Flacourt Formation is based only on spore and pollen (Fig. 3; *Biretisporites eneabbaensis* palynozone). The base of the unit corresponds to SB6, here correlated with eustatic sea-level falls following Late Jurassic (?Tithonian) rifting. The subcrop map of the pre-Cretaceous units against the basal Cretaceous unconformity (Fig. 2) and the regional stratigraphic correlations (Figs 4, 5, and 6; Plates 2 and 3) indicate that significant erosion followed Jurassic tectonism.

The Yarraloola Conglomerate was deposited in a fluviatile floodplain and is restricted to the palaeo-Robe River drainage area and minor buried channels between the Ashburton and Cane rivers. The unit has been identified only in petroleum wells within the Robe Embayment and in shallow wells drilled for Uranium exploration (Valsardieu et al., 1981). The Nannutarra Formation (continental to shallow marine), which outcrops at the margins of the Peedamullah Shelf, has not been recognized in the subsurface. This formation and the Yarraloola Conglomerate are likely to be time equivalent to the Flacourt Formation (Yasin and Iasky, 1998).

The Birdrong Sandstone, Mardie Greensand, Muderong Shale, Windalia Sandstone Member, Windalia Radiolarite, and Gearle Siltstone (Hauterivian to Turonian Winning Group) represent a marine clastic sedimentary section, commencing with the transgression that followed the breakup of Gondwana (SB7). The interval corresponds to the seismic sequences 7 and 8 of Westphal and Aigner (1997). In the Barrow–Dampier Sub-basins, the break between sequences 6 and 7 is minor and not represented

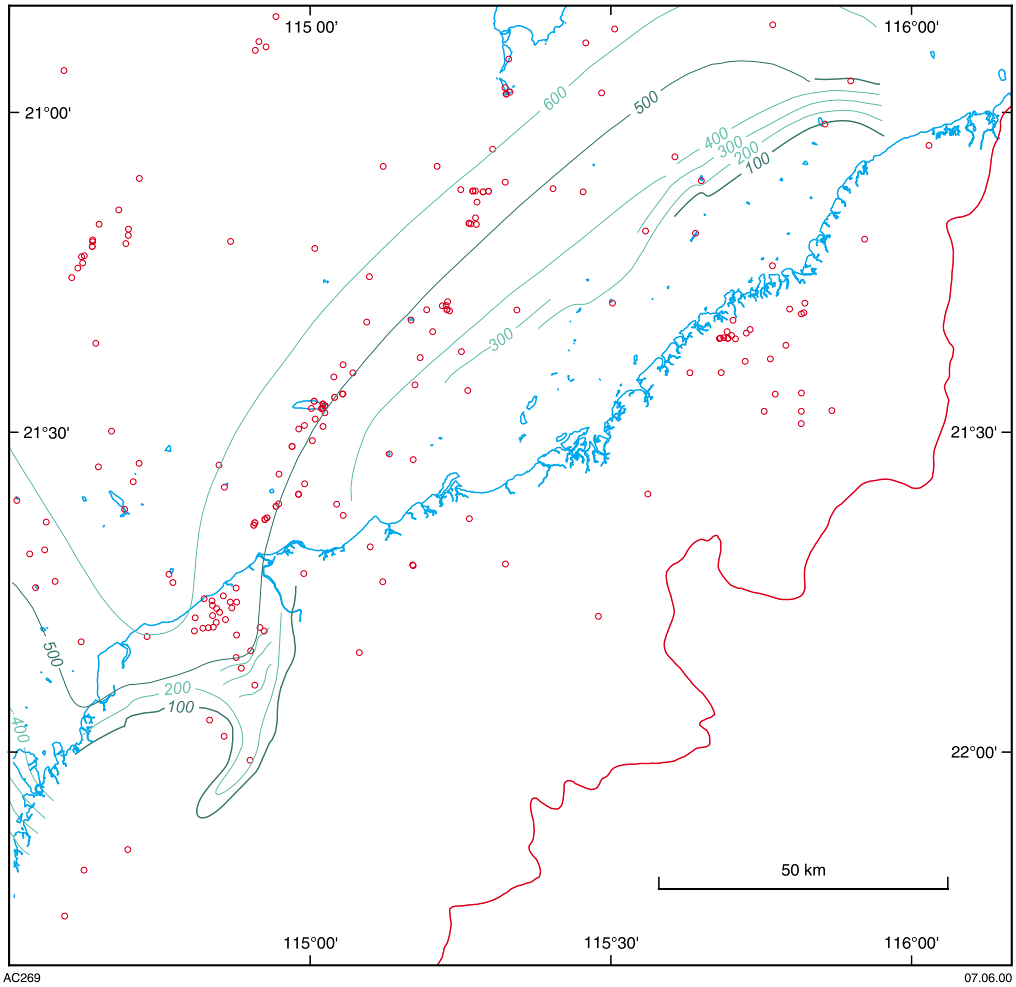


Figure 15. Isopach contours of the Locker Shale. The unit thickens towards the Barrow Sub-basin. The coastline is shown in blue, red circles are wells, and basement outcrop is shown in red

as an angular unconformity (Barber, 1982). Within the Tubridgi Gasfield, SB7 corresponds to the Flacourt Formation – Birdrong Sandstone contact. The former unit is described as a medium- to coarse-grained, clean, unconsolidated sandstone without glauconite, whereas the latter is a fine- to medium-grained, well-sorted, highly glauconitic sandstone (Doral Resource NL, 1995), and is believed to be representative of the region. The presence of glauconite within the Birdrong Sandstone, at the base of the Winning Group, is consistent with a regional post-breakup marine transgression. The base of the Birdrong Sandstone is clearly recognizable on wireline logs by a distinct decrease in gamma values.

The Windalia Sandstone Member is now recognized as belonging to the upper part of the Muderong Shale (Hocking et al., 1987). There is a poorly constrained depositional hiatus between the regressive fine-grained sands of the Windalia Sandstone Member and the transgressive glauconitic silts of the Windalia Radiolarite, which marks a significant change in the marine environment. Although both these units have been included within seismic sequence 7 (Westphal and Aigner, 1997), the boundary between them is clearly marked by increases in resistivity, density, and gamma ray (due to glauconite). Another poorly constrained hiatus is evident at the conformable contact between the glauconitic siltstone of the Windalia Radiolarite and the shale at the base of the Gearle Siltstone, corresponding to SB8. These two depositional breaks have also been identified in GSWA Barrabiddy 1, within the Gascoyne Platform, where they are palynologically well constrained (Mory and Yasin, 1999). Shelf carbonate of the Coniacian to Campanian Toolonga Calcilutite comprises seismic sequence 9 (Westphal and Aigner, 1997).

In the northern part of the Peedamullah Shelf, the Gearle Siltstone and Toolonga Calcilutite gradually thin and pinchout, whereas the Muderong Shale thickens, as it commonly does basinwards (Fig. 16). These variations in thickness are depositional, as the stratigraphic succession is relatively uniform south of the Barrow–Dampier Sub-basins.

Glauconite is present at the base of the Muderong Shale, widespread in the Mardie Greensand, and also characteristic of the Birdrong Sandstone, with only a very few exceptions in the innermost part of the basin. The

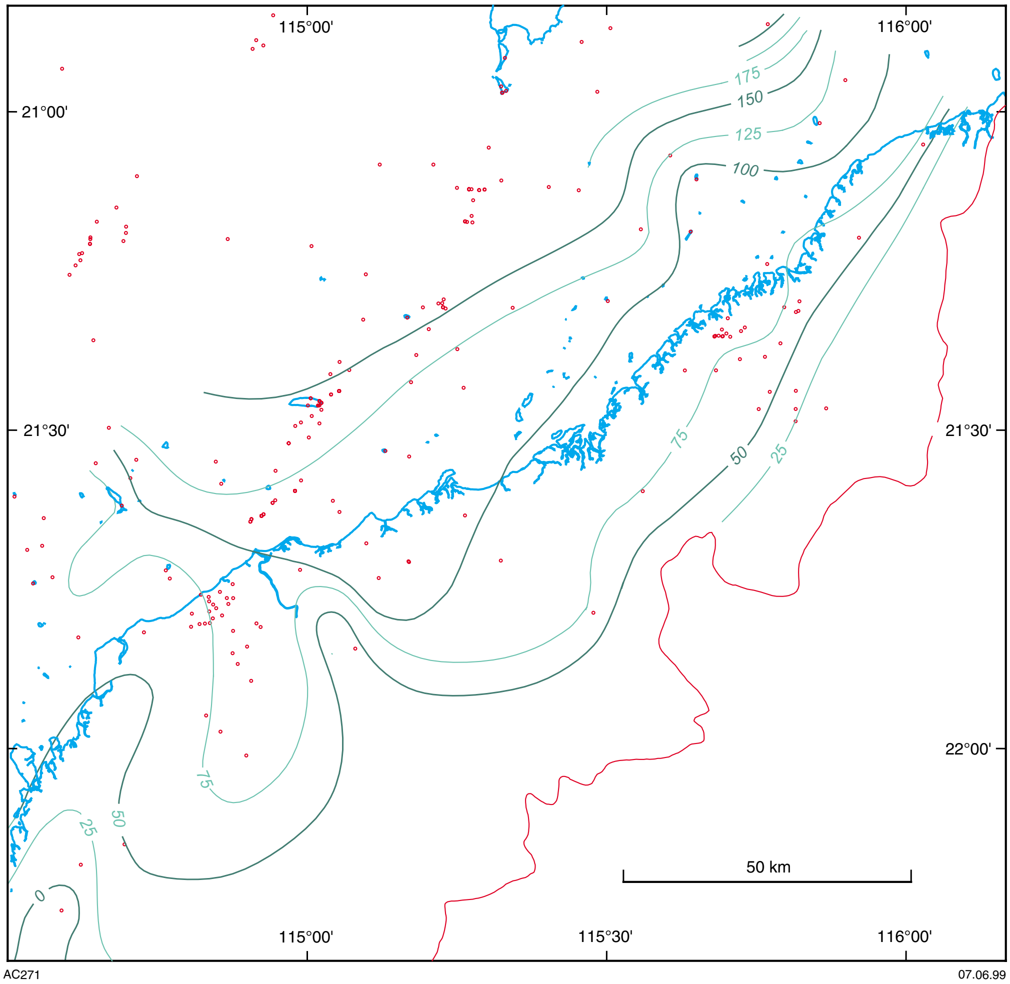


Figure 16. Isopach contours of the Muderong Shale. The unit thickens towards the Barrow Sub-basin. The coastline is shown in blue, red circles are wells, and basement outcrop is shown in red

Birdrong Sandstone is a fine- to medium-grained, well-sorted sandstone with an average permeability of several hundred millidarcies (mD). Dinoflagellates allow a detailed palynological zonation (Fig. 3), and the base of the unit displays a strong seismic reflection. The gradual transition to the overlying Mardie Greenstone makes the boundary between the two units fairly subjective. On seismic sections, petroleum companies have identified the contact between the two units on the basis of the better reservoir quality of the Birdrong Sandstone. Both units are time transgressive (Fig. 3).

Tertiary

The calcareous Cardabia Group disconformably overlies the Toolonga Calcilutite and represents seismic sequence 10 of Westphal and Aigner (1997).

The Giralia Calcarenite (seismic sequence 11) has not been identified in the study area. It is either present but not sampled, or eroded following mid-Miocene tectonism (Fig. 3). Westphal and Aigner (1997) commented that the base of seismic sequence 12 (SB12), represented by the Trealla Limestone, cuts deeply into the Giralia Calcarenite in the main basinal area. Within the Onslow Terrace and Peedamullah Shelf, the Trealla Limestone transgresses across units that are older in the northeast than in the southwest (Plate 2).

Structure

The structural framework of the study area is depicted in five structural maps for the region, namely the seismic time maps of basement (Fig. 17; Plate 4), the top Kennedy Group (Fig. 18; Plate 5), top Locker Shale (Fig. 19; Plate 6), top Muderong Shale (Fig. 20; Plate 7), and top to the intra-Gearle Siltstone horizons (Fig. 21; Plate 8). The stratigraphic position of these horizons is shown in Figure 3. The maps are supplemented by six cross sections (Fig. 22). Figure 23 shows the available seismic coverage.

Structure maps

The seismic interpretation was extended offshore to the northwestern boundary of the Peedamullah Shelf, along the Flinders Fault System in the central and northern part

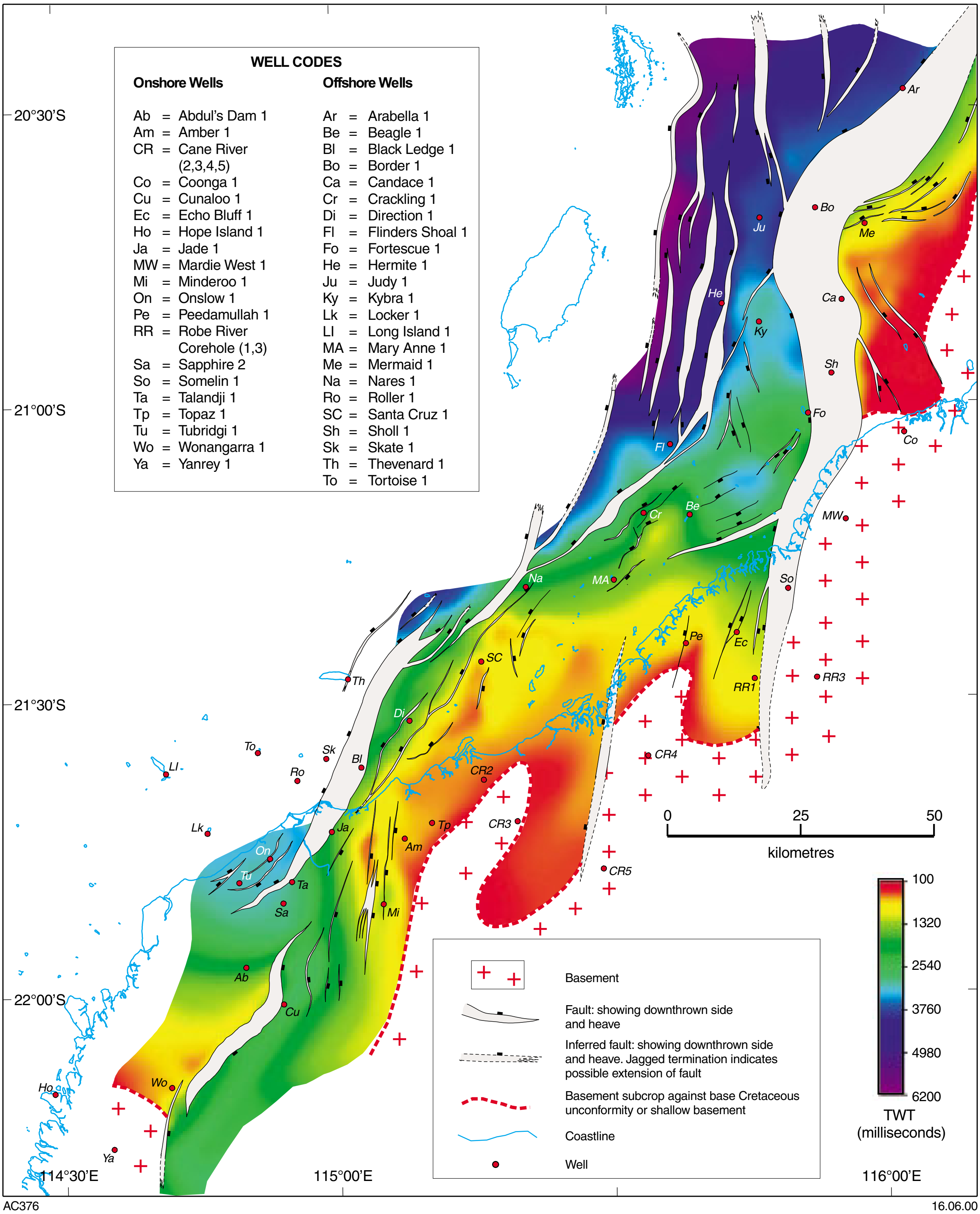


Figure 17. Simplified image of two-way time to basement. Wells shown are those used for well-log correlations or those providing key stratigraphic information

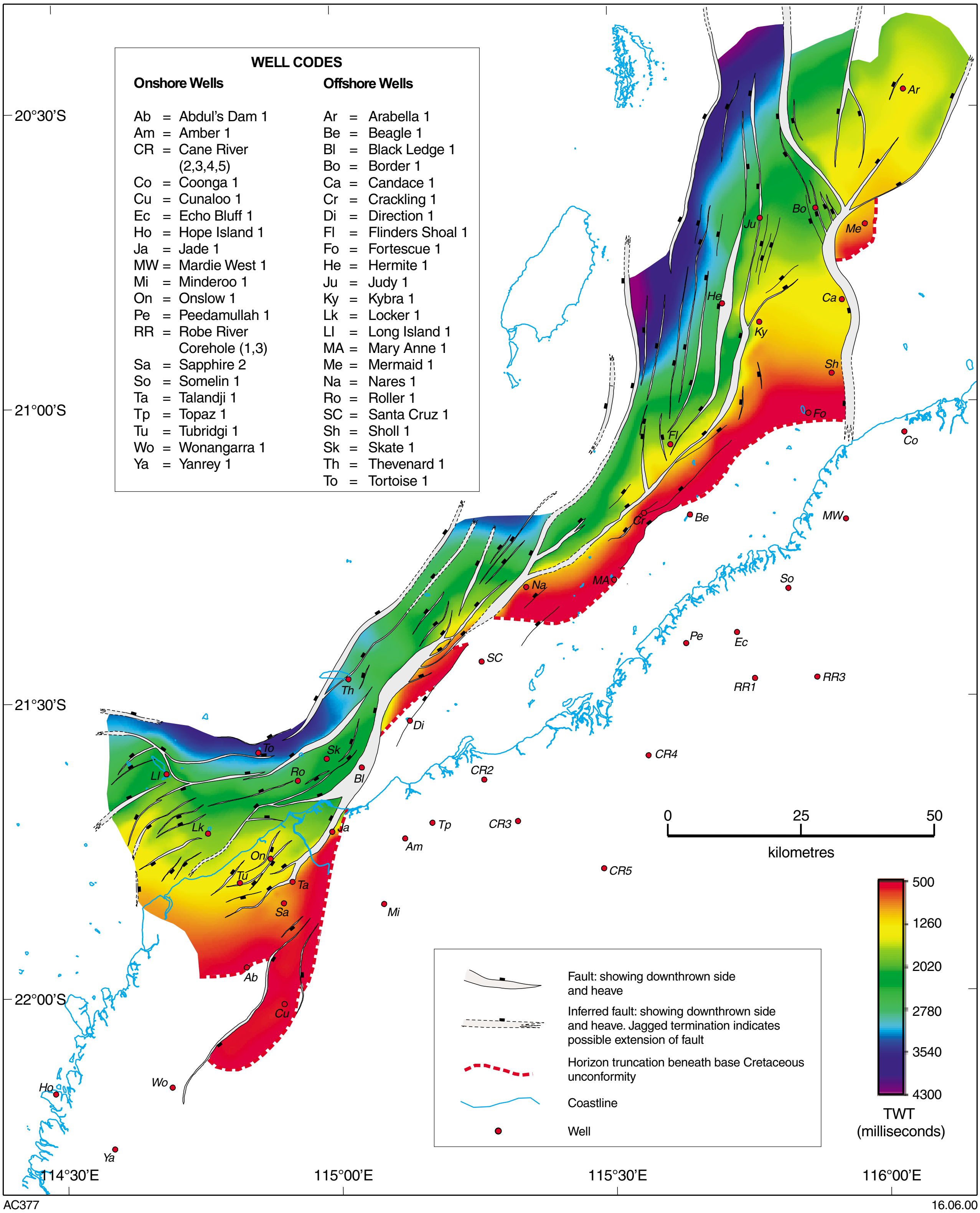


Figure 18. Image of two-way time to the top Kennedy Formation simplified from Plate 5. Wells shown are those used for well-log correlations or those providing key stratigraphic information

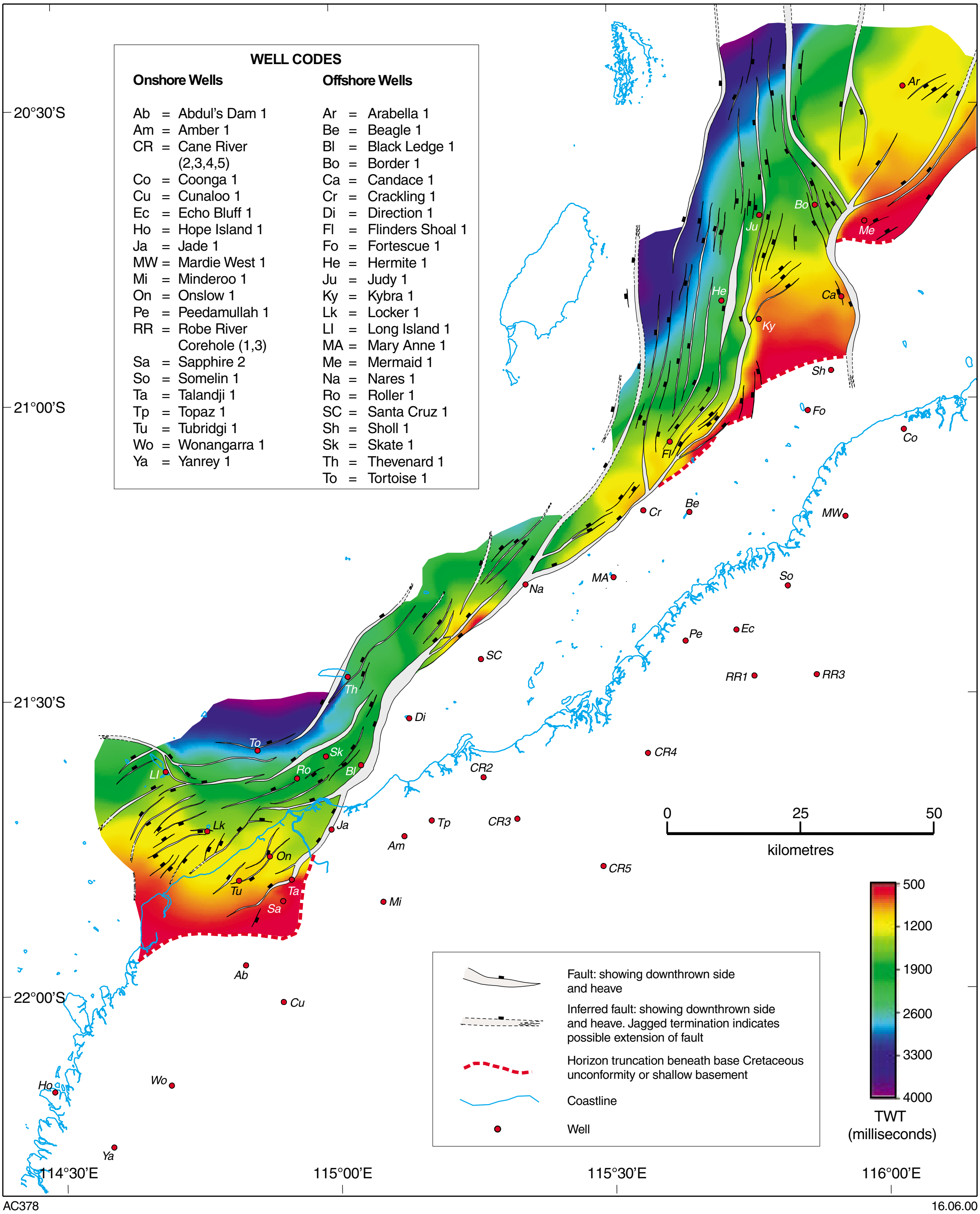


Figure 19. Image of two-way time to the top Locker Shale simplified from Plate 6. Wells shown are those used for well-log correlations or those providing key stratigraphic information

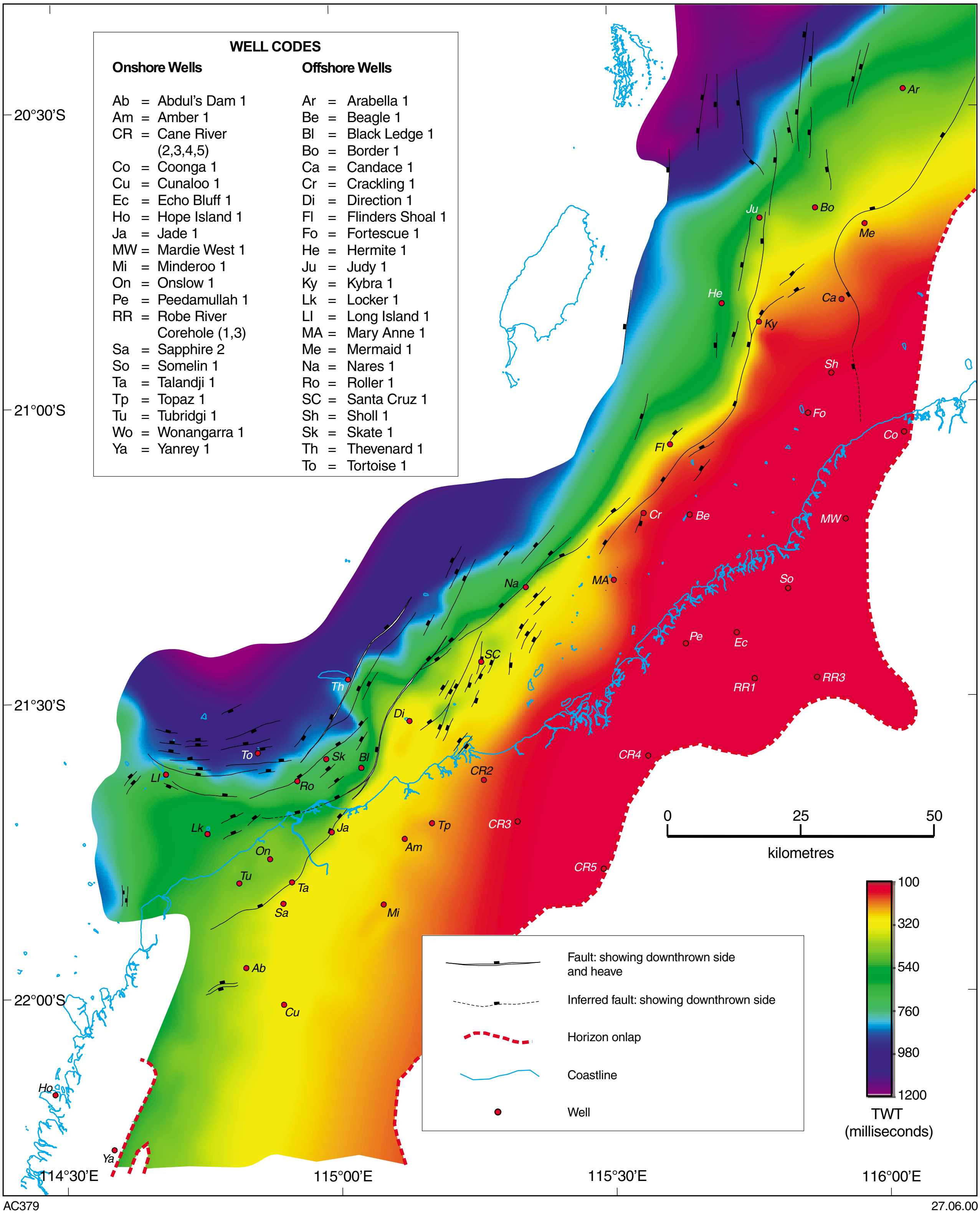


Figure 20. Image of two-way time to the top Muderong Shale simplified from Plate 7. Wells shown are those used for well-log correlations or those providing key stratigraphic information. The horizon onlap is interpreted from seismic data in the northeastern and southwestern parts of the image. Well and basement outcrop data were used to interpolate this boundary elsewhere

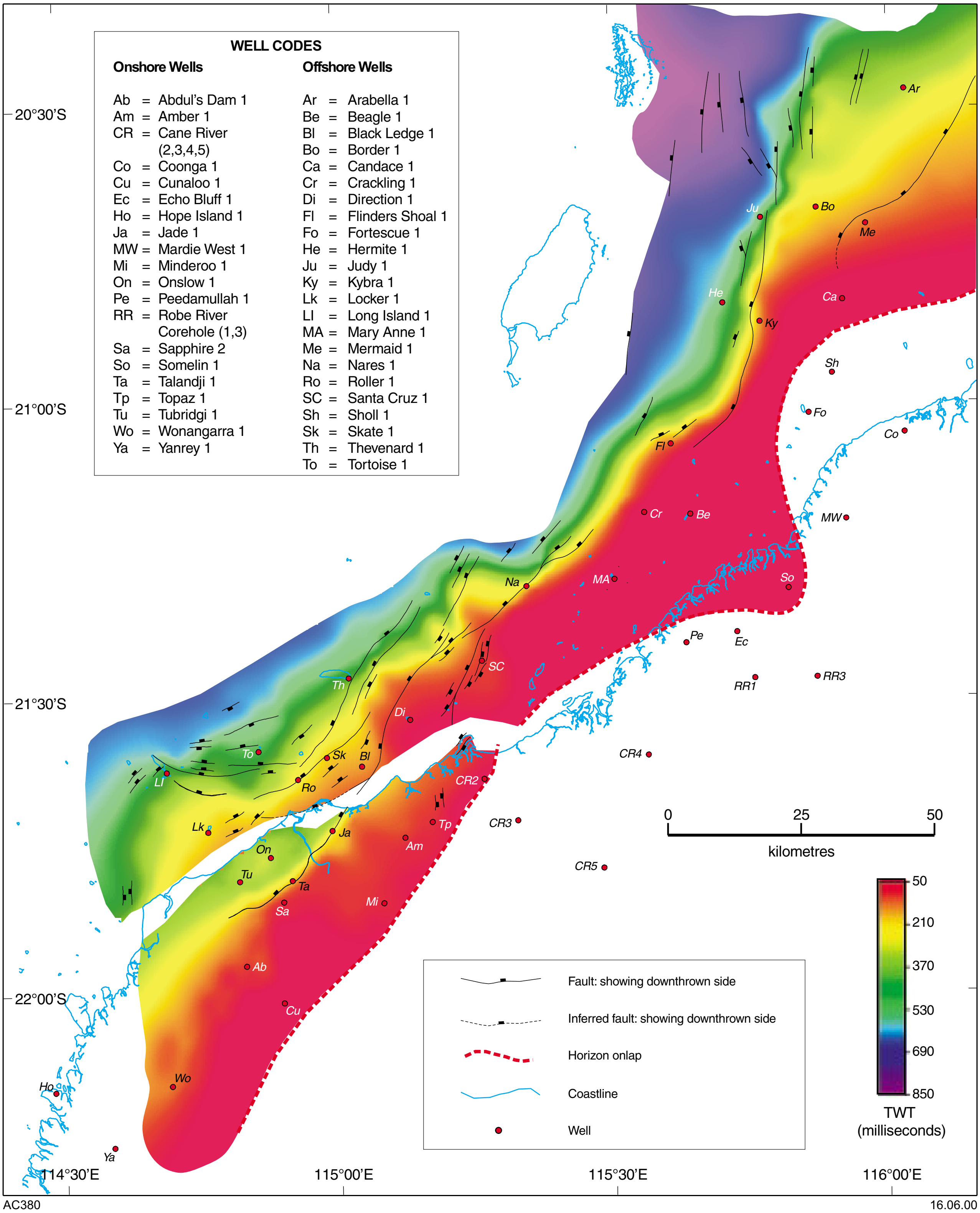


Figure 21. Image of two-way time to the top Gearle Siltstone (offshore) and top lower Gearle Siltstone (onshore) simplified from Plate 8. Wells shown are those used for well-log correlations or those providing key stratigraphic information. The horizon onlap is interpolated from well data

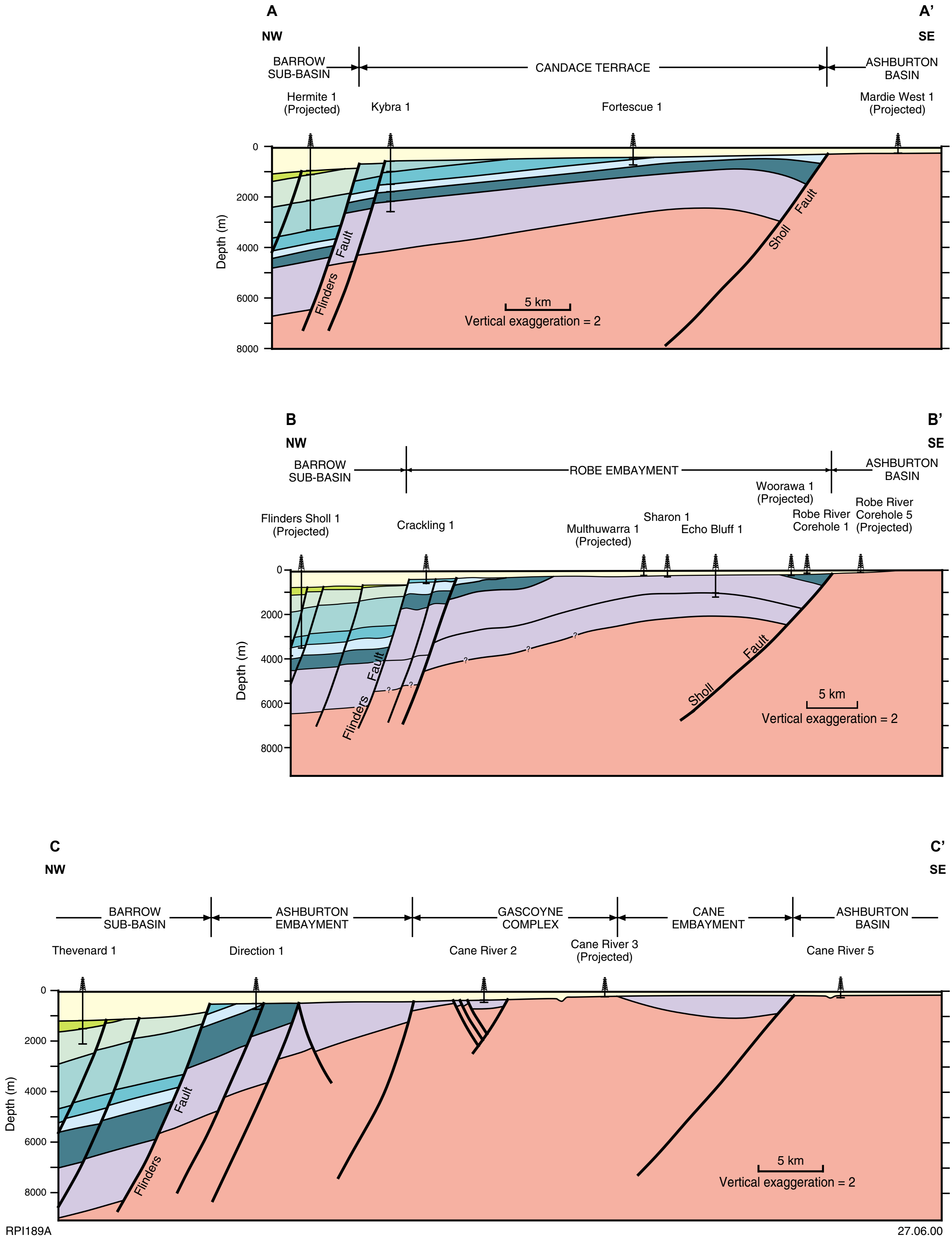
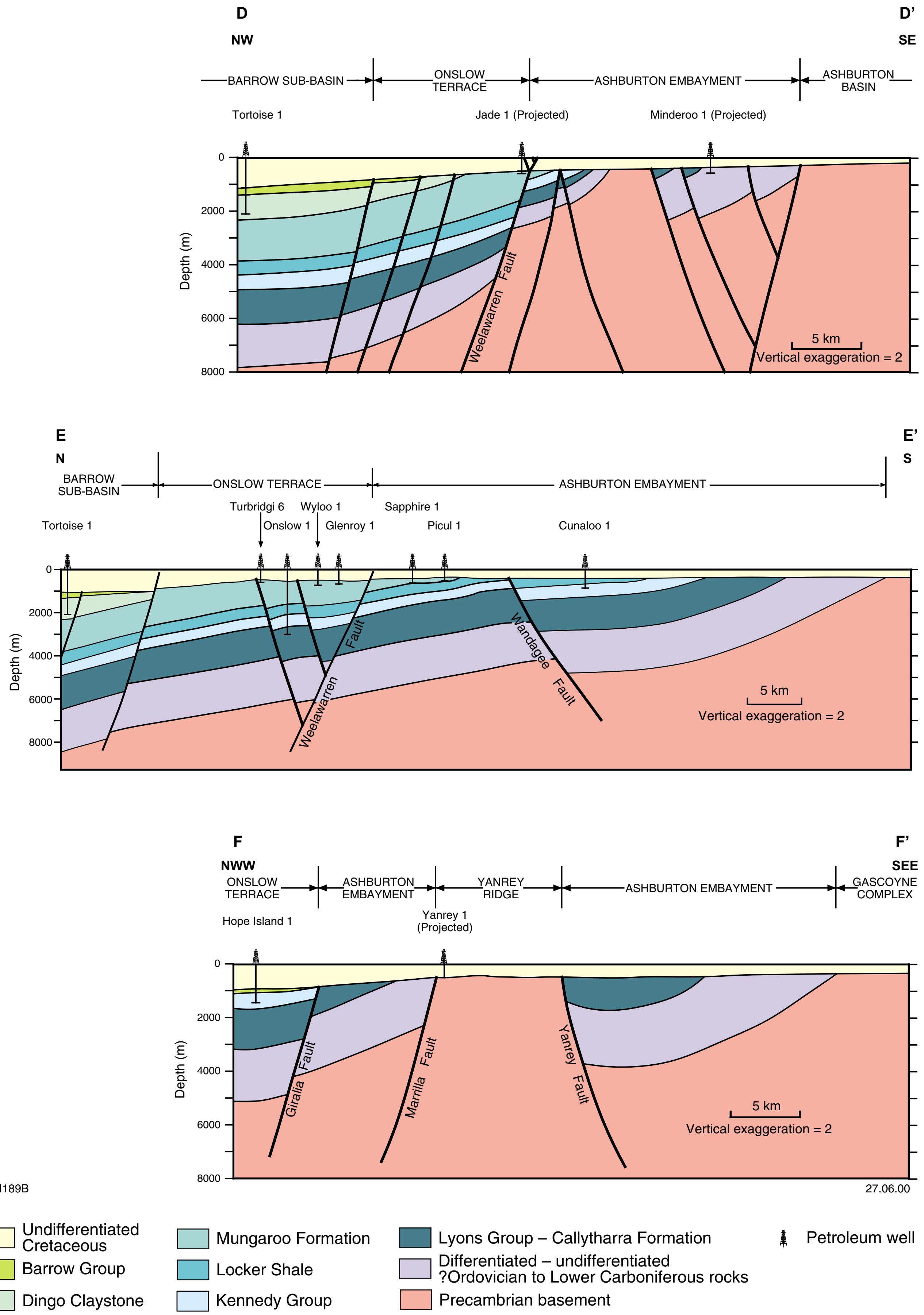


Figure 22. Regional structural cross sections across the Peedamullah Shelf. The locations of the sections are shown in Figure 2 and Plate 1



D
D’
NW
SE
BARROW SUB-BASIN
ONSLOW TERRACE
ASHBURTON EMBAYMENT
ASHBURTON BASIN
Tortoise 1
Jade 1 (Projected)
Minderoo 1 (Projected)
Depth (m)
0
2000
4000
6000
8000
Weelawarren Fault
5 km
Vertical exaggeration = 2
E
E’
N
S
BARROW SUB-BASIN
ONSLOW TERRACE
ASHBURTON EMBAYMENT
Turbridgi 6
Wyloo 1
Sapphire 1
Tortoise 1
Onslow 1
Glenroy 1
Picul 1
Cunaloo 1
Depth (m)
0
2000
4000
6000
8000
Weelawarren Fault
Wandagee Fault
5 km
Vertical exaggeration = 2
F
F’
NWW
SEE
ONSLOW TERRACE
ASHBURTON EMBAYMENT
YANREY RIDGE
ASHBURTON EMBAYMENT
GASCOYNE COMPLEX
Hope Island 1
Yanrey 1 (Projected)
Depth (m)
0
2000
4000
6000
8000
Giralia Fault
Marrilla Fault
Yanrey Fault
5 km
Vertical exaggeration = 2
RPI189B
27.06.00
Undifferentiated Cretaceous
Barrow Group
Dingo Claystone
Mungaroo Formation
Locker Shale
Kennedy Group
Lyons Group – Callytharra Formation
Differentiated – undifferentiated ?Ordovician to Lower Carboniferous rocks
Precambrian basement
Petroleum well

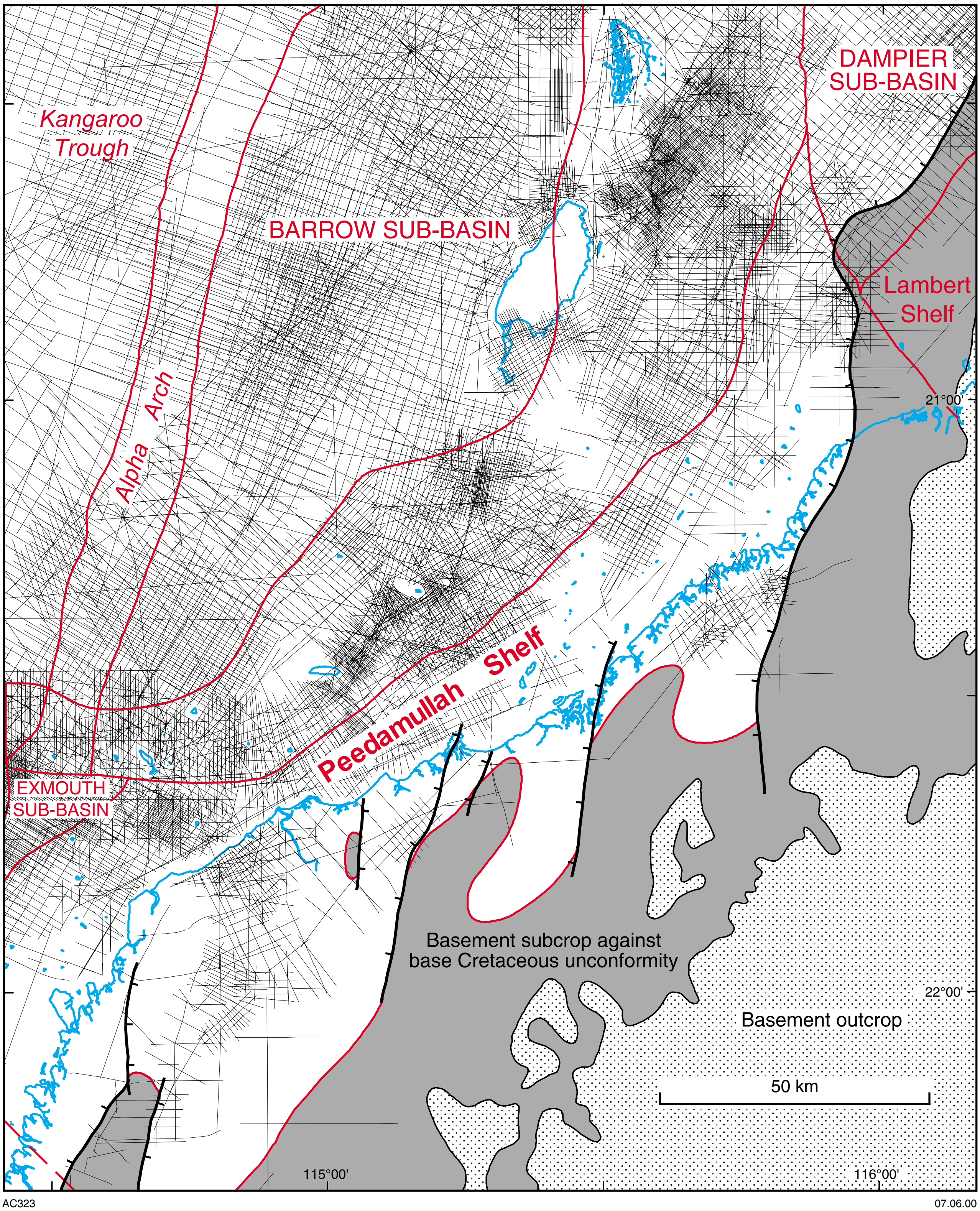


Figure 23. Seismic coverage on the Peedamullah Shelf and Onslow Terrace

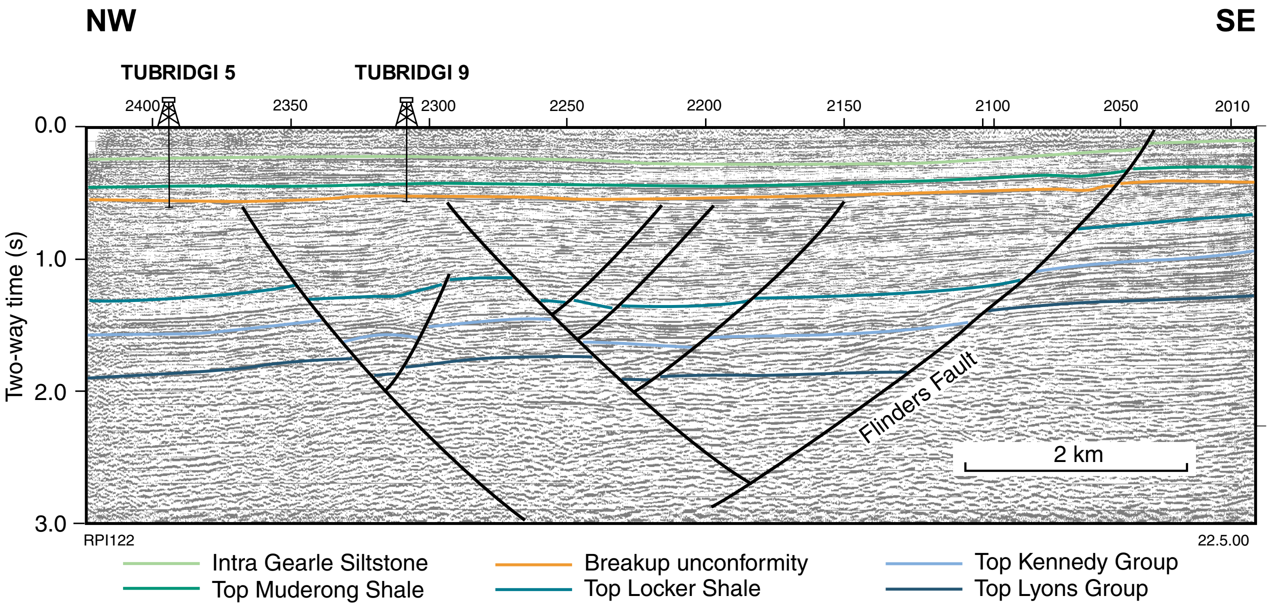


Figure 24. Seismic section J84A-023 showing pre-breakup unconformity deformation in the Tubridgi area. The location of the section is shown in Plate 1

of the study area, and along the Long Island Fault in the southern part (Plate 1).

The interpretation was carried out on selected lines (as shown on Plates 4–8) to map the structure pre- (Figs 17–19; Plates 4–6) and post- (Figs 20 and 21; Plates 7 and 8) basal Cretaceous unconformity as both successions are prospective for hydrocarbons. Onshore, the breakup unconformity and main unconformity are too close to be separated in seismic sections and are identified as one horizon (Fig. 24). Offshore, the thickness of the Barrow Group increases towards the Barrow Sub-basin's depocentre, and the two unconformities can be distinguished (Fig. 12). These unconformities were not mapped in this Report because they have been previously mapped by petroleum companies and locally, do not properly represent the deformation caused by the mid-Miocene tectonism due to velocity pull-down caused by gas migrating from the Cretaceous sandstone reservoirs (Fig. 25).

The basement horizon (Fig. 17; Plate 4) was mapped to provide an indication of the Phanerozoic sedimentary thickness in the study area. This horizon was mapped with a low level of confidence especially west of the Flinders Fault System (including the Weelawarren Fault) where the horizon deepens dramatically. Where basement is shallow, it can be identified more confidently as a zone of chaotic reflections beneath a set of high-amplitude, low-frequency reflectors (Fig. 26). The extension and position of the Sholl Fault, and the fault defining the eastern boundary of the Cane Embayment, were interpreted from gravity and magnetic images (Figs 7 and 8). The top Kennedy Group (Fig. 18; Plate 5) and top Locker Shale (Fig. 19; Plate 6) horizons may be regarded as objective horizons and have not been previously mapped throughout the study area. These horizons have been mapped at a reasonably high level of confidence as the units have a characteristic seismic character (Fig. 26) in most of the study area. The top of the Kennedy Group can be identified by a strong, continuous reflector representing a limestone unit underlying the sandstone of the Chinty Formation (Fig. 26). The top of the Chinty Formation is also a strong, but commonly discontinuous, reflector due to localized coal beds. The top of the Locker Shale does not have a distinctive reflector, but is easily identified by the non-reflective interval between the higher amplitude reflectors of the overlying Mungaroo Formation and underlying Kennedy Group (Fig. 26). The Muderong Shale (Fig. 20; Plate 7) and Gearle Siltstone (Fig. 21; Plate 8) were mapped to define the gentle deformation caused by the mid-Miocene tectonism. Onshore, the top of the Muderong Shale is characterized by a dominant

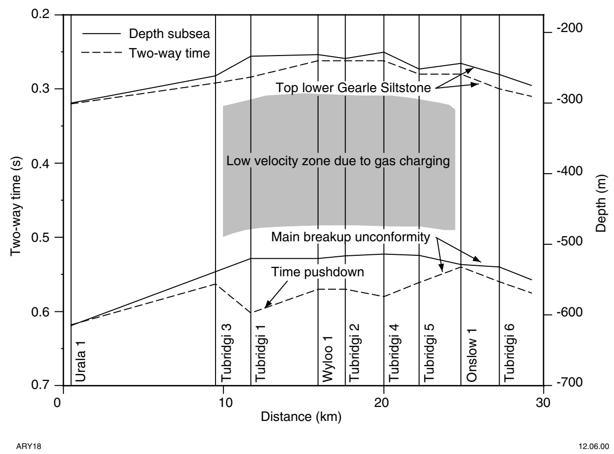
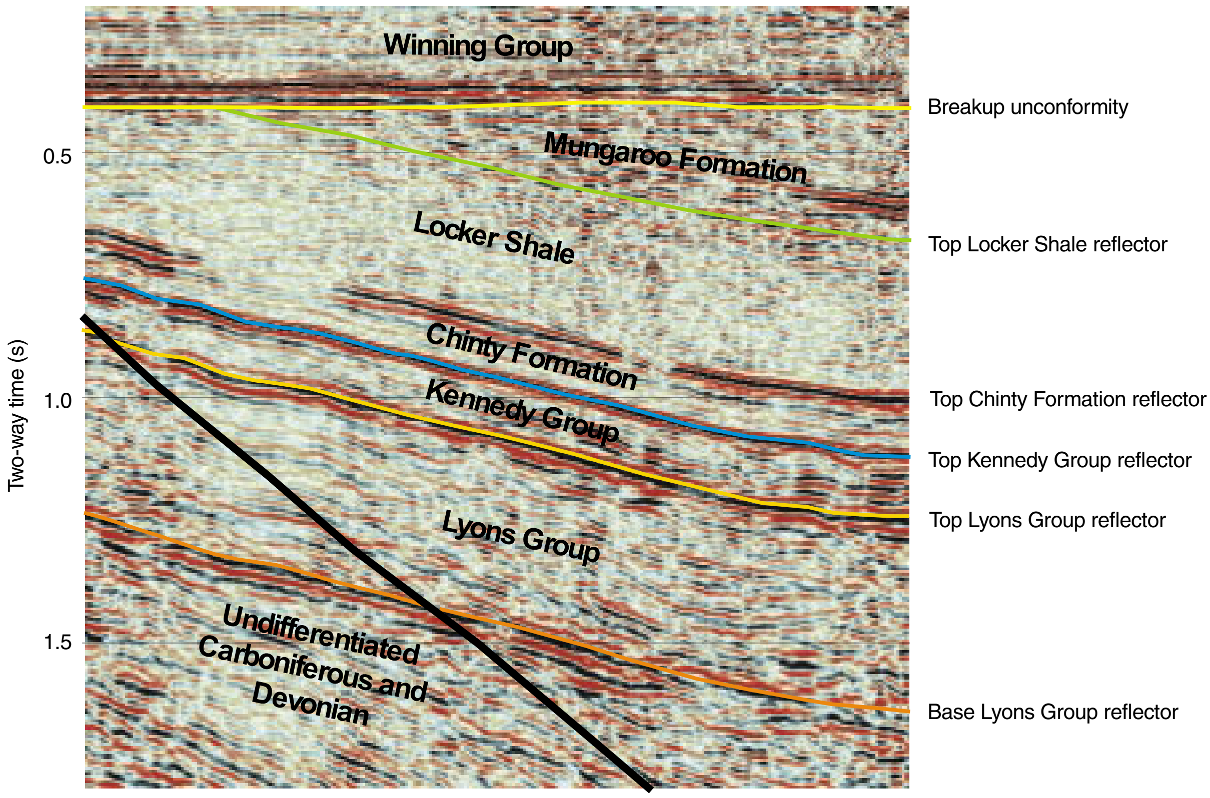


Figure 25. Effect of gas on the two-way times to the prospective horizons in the Tubridgi Gasfield (after Firth, 1983). The two-way times do not correspond to the depths

a) Line 93BA-05 (Shot points 1500 –1750)



b) Line 93BA-04 (Shot points 3010 –3460)

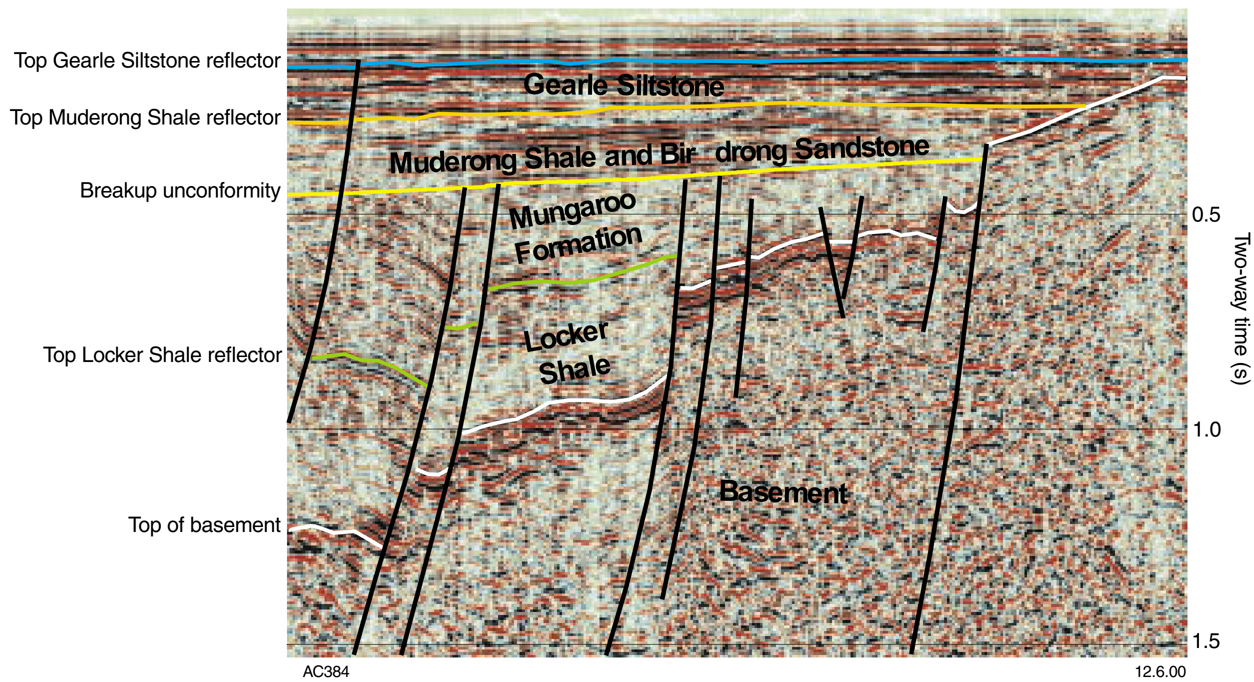


Figure 26. Seismic character from example sections: a) part of seismic line 93BA-05 showing the Locker Shale, Kennedy Group, and Chinty Formation; b) part of seismic line 93BA-04 showing basement and the Winning Group — also evident in a)

continuous reflector and was mapped with a high level of confidence (Fig. 24), whereas offshore the reflector is not as distinct (Fig. 26) and well data are needed to adequately map the horizon. The top of the Gearle Siltstone horizon was mapped with less confidence as it is shallow over a large part of the study area and commonly does not display a characteristic reflection (Fig. 26). Furthermore, onshore in the Onslow Terrace and Ashburton Embayment, part of the Gearle Siltstone has been eroded and the top lower Gearle Siltstone horizon was mapped instead. The Winning Group onlaps basement in the northern part of the study area, so that progressively younger units, such as the Gearle Siltstone, extend further east than older units, such as the Muderong Shale (Fig. 26b). The horizons were mapped in seismic time only, although six depth-converted geological cross sections (Fig. 22) were drawn based on seismic and well data.

Onshore, the top Kennedy Group and Locker Shale horizons are present only on the Onslow Terrace and part of the Ashburton Embayment (Figs 18 and 19; Plates 5 and 6). In the remainder of the onshore Peedamullah Shelf (Cane and Robe Embayments, and Weld High), the pre-Cretaceous structure is only illustrated by the basement horizon (Fig. 17; Plate 4) as other Palaeozoic horizons do not extend over the whole area and are difficult to identify because of the lack of well control. Onshore, the Muderong Shale and top lower Gearle Siltstone horizons (Figs 20 and 21; Plates 7 and 8) could only be mapped from seismic data on the Onslow Terrace and part of the Ashburton Embayment. The Winning Group extends over the remaining part of the onshore Peedamullah Shelf, but thins significantly towards the southeast margins where there are insufficient seismic data. However, the approximate extent of the top lower Gearle Siltstone (Fig. 21) and Muderong Shale (Fig. 20) horizons can be interpreted from well and outcrop information.

The quality of the seismic data is reasonable in the majority of the study area, except in areas where basement is high, such as the Yanrey Ridge and Weld High (Plate 1; Fig. 1). The Barrow Basin Spec (1992) marine seismic survey carried out by Australian Seismic Brokers (line prefix is 93BA; Appendix 2) is a very good quality regional survey, which covers most of the Candace Terrace and was used in its entirety. Most of the other seismic surveys (Appendix 2) were processed to enhance the first two seconds of recording and the resolution of the deeper reflections is low.

Discussion

The study area is controlled by easterly trending faults along the Long Island Fault System on the offshore Onslow Terrace, to a north-northeasterly trending fault system along the central part of the Peedamullah Shelf, to a northerly trending system on the Candace Terrace (Figs 17–21; Plates 4–8). Mapping seismic data shows that the Flinders Fault comprises a series of en echelon faults and is more appropriately referred to as a fault system. The Sholl Fault, however, is a single fault up to its northern extremity, where the Candace Terrace is adjacent to the Dampier Sub-basin (Figs 17–21; Plates 4–8). In this area, the structural trend changes direction from northerly to northeasterly. This change in direction is also reflected where displacement on the Flinders Fault System in the Peedamullah Shelf – Barrow Sub-basin is relayed across to the Sholl Fault in the Dampier Sub-basin (Fig. 27). The Flinders Fault System controlled the development of the sub-basin and its trend commonly follows the coastline. Mapping also shows that the main deformational event was during the Late Jurassic – Early Cretaceous rifting (Figs 17–19), and that the Flinders Fault System and Sholl Fault were re-activated after breakup with minor vertical displacement (Figs 20–21). The main faults are downthrown to the northwest towards the Barrow Sub-basin and the regional dip of the sedimentary succession is approximately 5° to the northwest (Fig. 22, section EE').

In the Candace Terrace, the angular unconformity between the ?Ordovician – Lower Devonian and Middle Devonian successions to the west of the Sholl Fault (Fig. 13) indicates uplift and erosion in the terrace during the Early to Middle Devonian. Rollover of the Middle to Upper Devonian – Lower Carboniferous rocks into the Sholl Fault, as seen in the Robe Embayment, implies a renewed phase of growth during deposition of this succession (Fig. 28). Delfos and Dedman (1988) have also recognized a Devonian marine transgression in this area. The pre-breakup strata in the Cane Embayment thicken towards the postulated Cane River Fault (Yasin and Iasky, 1998). The northerly gravity lineament, upon which the

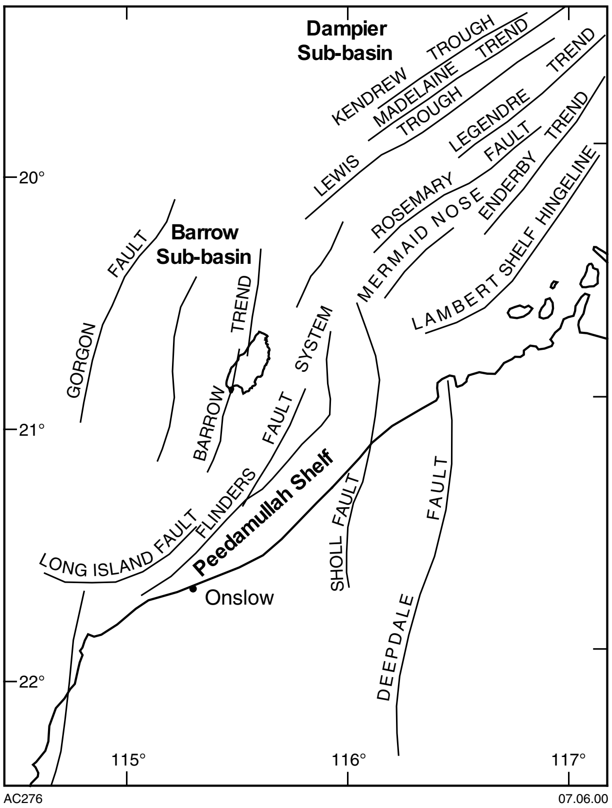


Figure 27. Contrasting tectonic lineaments between the Barrow and Dampier Sub-basins

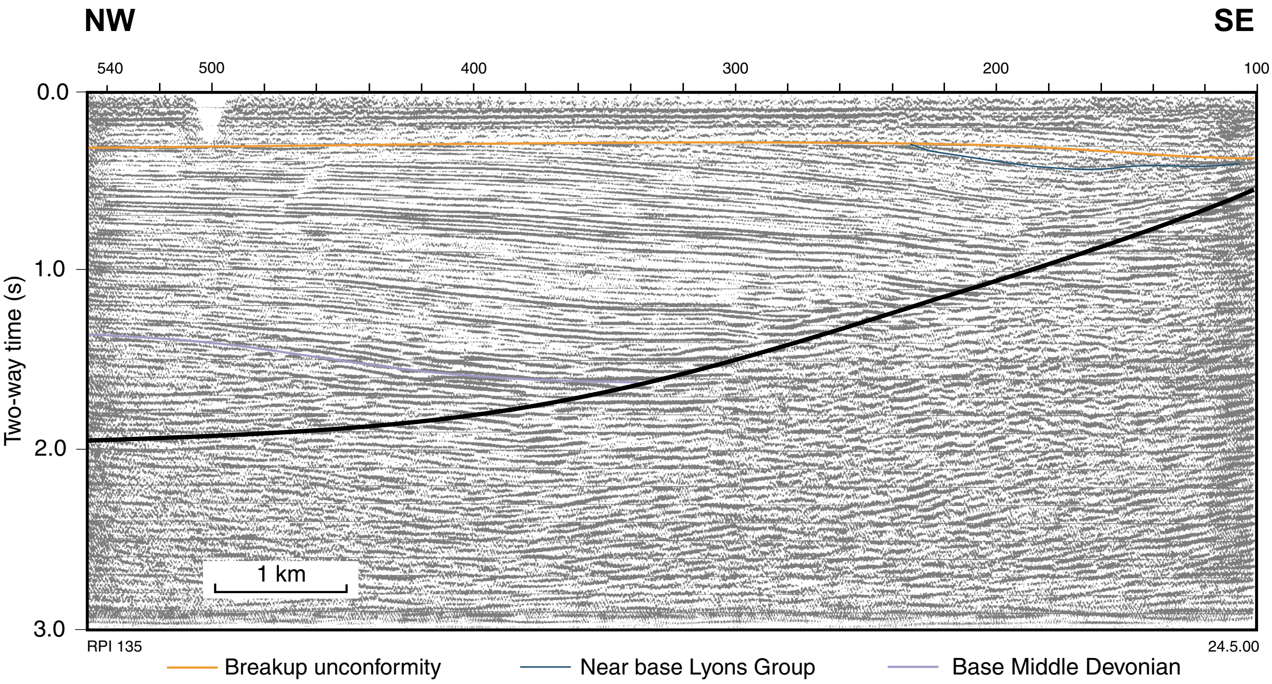


Figure 28. Seismic section T85-026 showing the Middle–Upper Devonian succession truncated by the Sholl Fault in the Robe Embayment. The location of the section is shown in Plate 1. The section is oblique to the Sholl Fault

presence of this fault is inferred (Fig. 7), indicates that it may be en echelon with the onshore part of the Sholl Fault.

An Early to Middle Carboniferous tectonic event can also be recognized in the Candace Terrace where the base of the Carboniferous–Permian Lyons Group is transgressive over the eroded crest of the Kybra structure (Fig. 12). The stratigraphic succession in Kybra 1 consists of the Lyons Group unconformably overlying the Lower Carboniferous Quail Formation, indicating that the moderately folded Kybra structure was formed in the Early to Middle Carboniferous. The tectonism can be tentatively correlated with the Early Carboniferous Meda Transpression movement in the Canning Basin (Apak and Backhouse, 1998). This Early Carboniferous tectonic event is widespread throughout the Southern Carnarvon Basin and Peedamullah Shelf although a distinct angular unconformity is not evident (Fig. 22, sections AA'–FF'). However, this event is noticeable in the adjacent Mermaid Nose (Dampier Sub-basin; Fig. 27), where the inner flank of an enhanced fold was penetrated in Arabella 1 (Fig. 14). In this well, the Locker Shale unconformably overlies sedimentary rocks interpreted to be Devonian based on the palynological report in the well completion report (Australian Occidental Pty Ltd, 1983). The similarity of the unconformity in Kybra 1 and Arabella 1 suggests that the Candace Terrace and Mermaid Nose shared a similar geological history, at least up to the Middle Carboniferous.

There is no evidence for other major tectonic events in the Peedamullah Shelf until the Late Jurassic. A time-break within the Permian (Mory and Backhouse, 1997) is not evident from seismic data and may be related to a change in sea level or a period of quiescence in this region. During the Late Permian, Triassic, and Jurassic, sedimentation appears to have been continuous and hence, conformable until at least the Oxfordian, as indicated by the succession in Onslow 1 and Black Ledge 1 (Plate 2).

Synrifting transgressive episodes are identified during the Jurassic from near basal Pliensbachian, near basal Callovian, and near top Tithonian horizons within the offshore Northern Carnarvon Basin (Jablonski, 1997). These events mark the beginning of the rift that culminated in the breakup of Gondwana, and eventually took place during the Valanginian (early Neocomian). Breakup was marked by the deposition of a shelf-wide marine succession (Winning Group) over deltaic sediments (Barrow Group). The Flinders Fault System and its southwestern extension, the Weelawarren Fault, developed during the Jurassic (Fig. 24), although the main fault and several splay faults appear to be basement controlled (Plate 4; Fig. 17). In the Peedamullah Shelf, only one rifting episode, constrained in age between the Oxfordian and Neocomian, can be identified, as indicated by Black Ledge 1. As the first transgression that followed this rifting episode was the deposition of the basal Barrow Group in the earliest Neocomian, the unconformity present in Black Ledge 1 must be older and therefore, is here tentatively referred to the late Tithonian. A number of normal faults, which resulted from the rifting and large-scale block faulting with associated uplift, become widespread in the area (Figs 17–19; Plates 4–6). Uplift, tilting, and erosion of the Jurassic and older strata at this time produced a noticeable angular unconformity (Fig. 22, sections AA'–FF', and Fig. 29). In places, these movements cannot be recognized but tectonism with a compressional component, where Jurassic folds are superimposed on earlier structures, is evident throughout the Peedamullah

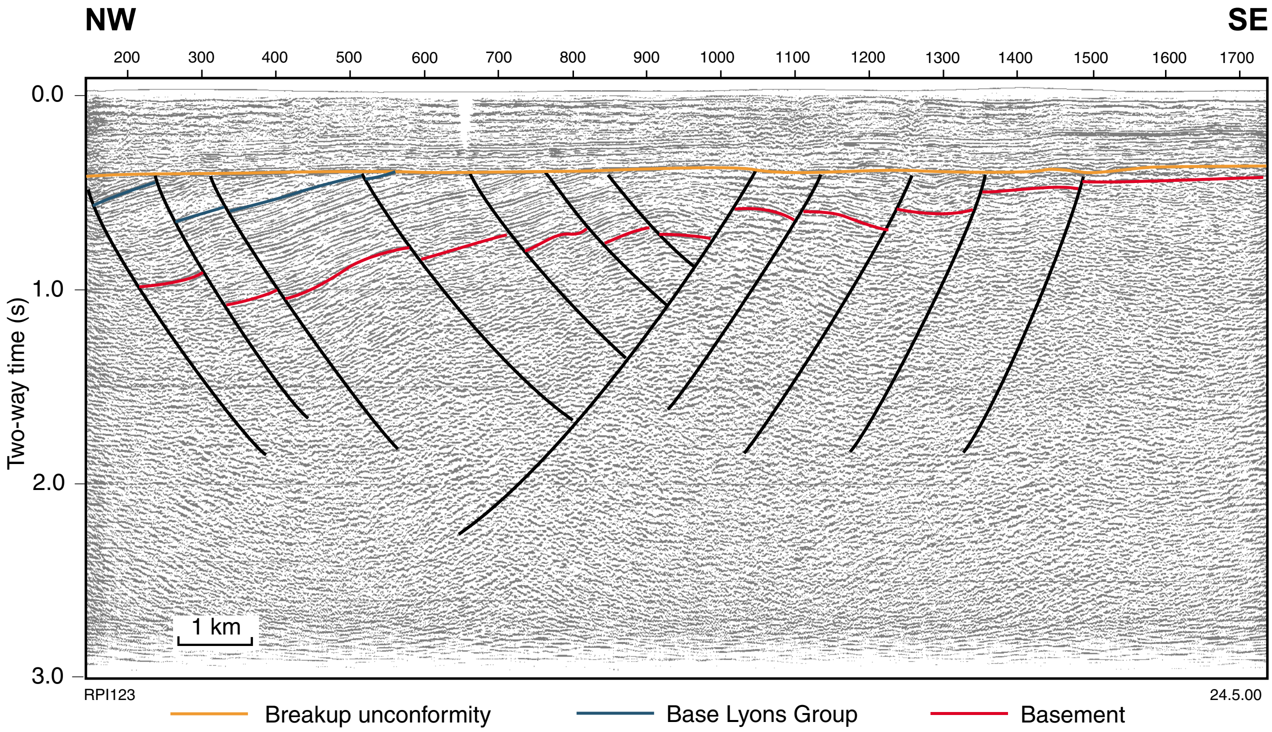


Figure 29. Seismic section PP92-D showing block faulting below the breakup unconformity in the Ashburton Embayment. The location of the section is shown in Plate 1

Shelf, most noticeably in the Candace Terrace (Figs 12 and 13), but less so in the Onslow Terrace (Fig. 24).

Structural deformation related to rifting is evident along major faults (Figs 12, 13, and 30) with greater deformation on the Candace Terrace than in other parts of the Peedamullah Shelf (Figs 17–19; Plates 4–6). Cretaceous and Tertiary deposition continued undisturbed until the Middle Miocene when a transpressional movement overprinted the previous structural movements and anticlines developed preferentially over older positive features (Fig. 31). During the Middle Miocene, major normal faults were reactivated (Figs 20 and 21; Plates 7 and 8) with a strike-slip component producing small, normal and reverse throws and, more importantly, anticlines prior to the deposition of the flat-lying Trealla Limestone (Fig. 32). These folds are commonly low amplitude and not always controlled by faults, nor can they always be resolved by the available seismic data. The mid-Miocene movement affected the entire Barrow Sub-basin, including the Onslow Terrace along the Weelawarren Fault. Anticlinal structures developed preferentially over older positive features (Fig. 31) at an angle less than 45° to the Flinders Fault System (e.g. Tubridgi, Roller, and Skate fields; Plate 1). To the east and the southeast of the Flinders Fault System, the Cainozoic section appears to be undisturbed, as in the Candace Terrace and Dampier Sub-basin.

Basin evolution

Six main depositional cycles characterize the evolution of the Peedamullah Shelf and Onslow Terrace. These cycles are outlined, together with the intervening tectonic episodes, in Figure 3. The older cycle, namely the Ordovician to Silurian, may exist, but the presence of the Ordovician Tumblagooda Sandstone, here tentatively suggested in Echo Bluff 1, is not proven. However, seismic data in the Candace Terrace indicate a Palaeozoic succession may be present (Fig. 2) similar to that of the Gascoyne Platform. Bentley (1988) suggested the presence of such a succession, to which she assigned a Silurian age. Although this lower Palaeozoic succession has been penetrated by one well, seismic data indicate that it may be present across the entire Peedamullah Shelf.

Ordovician to Early Devonian cycle (I)

The presence of the Ordovician to Early Devonian cycle is suggested from seismic data in the Candace Terrace and from the lowermost section (1145–1294 m) penetrated by Echo Bluff 1 within the Robe Embayment. Additionally, the seismic section across Echo Bluff 1 shows a strong reflection and at least an additional 1000 m of sedimentary succession underlying the well, estimated from stack velocities (Fig. 33), are possibly indicative of a thick section of Tumblagooda Sandstone. On the Candace Terrace (Fig. 13), an angular unconformity near the Sholl Fault separates a Middle Devonian section from older rocks. This is corroborated by other seismic data on the Candace Terrace that show a pre-Middle Devonian succession, about 3500 m thick, underlying the Lyons Group (Fig. 30). It is unclear what part of the Ordovician to Early Devonian cycle is present to the east of the Sholl

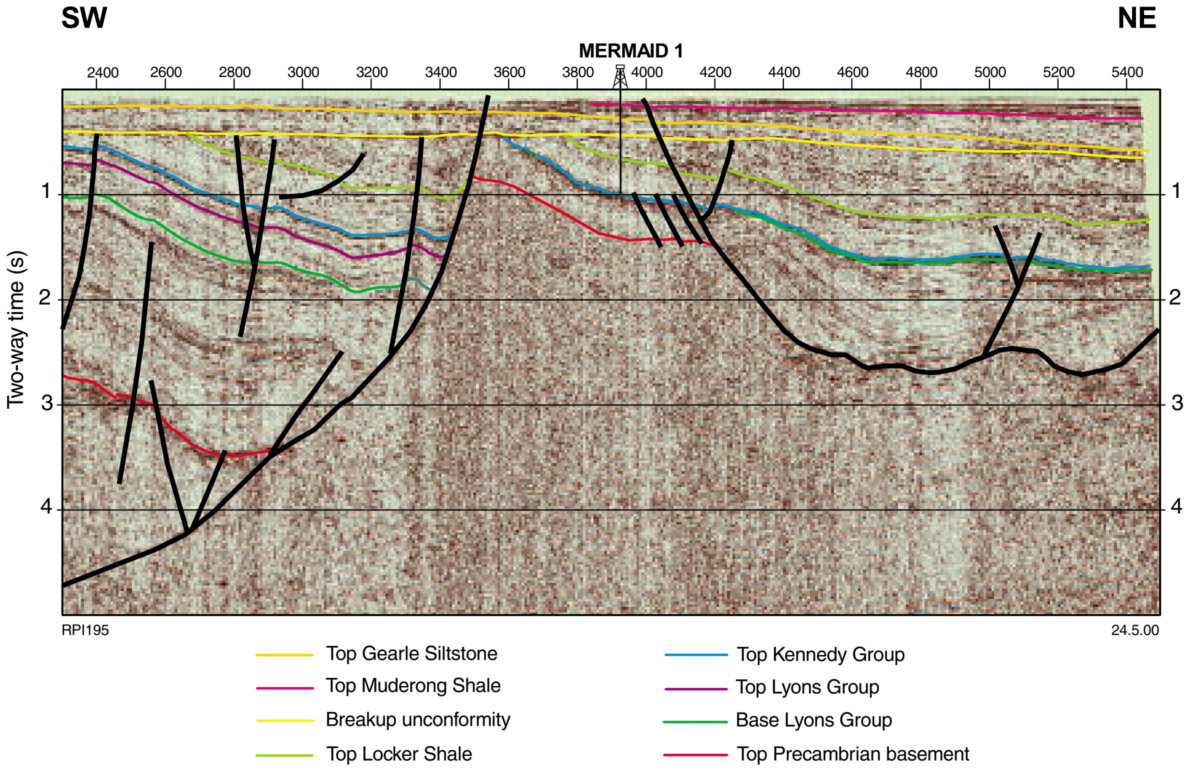


Figure 30. Seismic section 93BA-01 showing a thick sedimentary section underlying the base Lyons Group unconformity in the Candace Terrace, and the transition from the Candace Terrace to the Dampier Sub-basin. The location of the section is shown in Plate 1

Fault into the Dampier Sub-basin. Mermaid 1, drilled east of the Sholl Fault, penetrated the Permian Kennedy Group at 1230 m, which directly overlies basement at 1259 m (Fig. 30). Although the pre-Permian is absent at Mermaid 1, further to the northeast the pre-Permian section is thicker (Fig. 30).

Middle Devonian to Late Carboniferous cycle (II)

On the Peedamullah Shelf, the Middle Devonian to Early Carboniferous cycle was deposited either directly on basement or on Ordovician – Lower Devonian rocks. The limited number of wells that reached basement in the region prevents a firmer conclusion. Devonian to Carboniferous carbonates and clastics have been penetrated in the Candace Terrace (Kybra 1), Robe Embayment (Echo Bluff 1, Mardie 1, Murnda 1, Peedamullah 1, Sharon 1, Windoo 1, and Yarraloola 1), Weld High (Amber 1, Minderoo 1), and Ashburton Embayment (Amber 1, Topaz 1; Plate 1). In this Report, the succession is interpreted to be the product of deposition during a sag phase within a large and stable intracratonic basin that covers both the Southern and Northern Carnarvon Basin, and also extends further north into the Canning Basin. Within the Peedamullah Shelf the cycle is represented by the conformable succession of the transgressive basal Nannyarra Sandstone, shelf carbonates of the Gueudna Formation and Moogooree Limestone, and clastic deposits of the Quail Formation — in ascending order. Other units present in the Southern Carnarvon Basin (Hocking et al., 1987) have not been recognized.

Late Carboniferous to Late Jurassic cycle (III)

Early Carboniferous sedimentation was interrupted by a tectonic uplift phase that is well represented in the Candace Terrace (Fig. 14), is probably coeval with the Meda Transpressional event in the Canning Basin (Apak and Backhouse, 1998), and is, therefore, believed to be of Visean age. In other parts of the basin, the tectonic movements are characterized primarily by block faulting (Fig. 22, sections AA'–FF'), as in the Merlinleigh Sub-basin and further to the south in the Perth Basin where the structural grain is predominantly northerly. On the Peedamullah Shelf, the marine transgression (Lyons Group) over older strata marks the commencement of a rift stage that opened up a basin up to 500 km wide (Gartrell, 2000). Deposition of the Lyons Group is interpreted to be related to a climatic change that caused melting of glaciers in polar regions and resulted in a rise in sea level. Erratic dropstones in these sediments are a byproduct of melted icebergs. The accumulation of the predominantly clastic Lyons Group was followed by deposition of calcareous, shallower marine sediments (Callytharra Formation) in the Early Permian.

On the Peedamullah Shelf, Mory and Backhouse (1997) identified a period of nondeposition separating the Lower Permian Lyons Group or Callytharra Formation

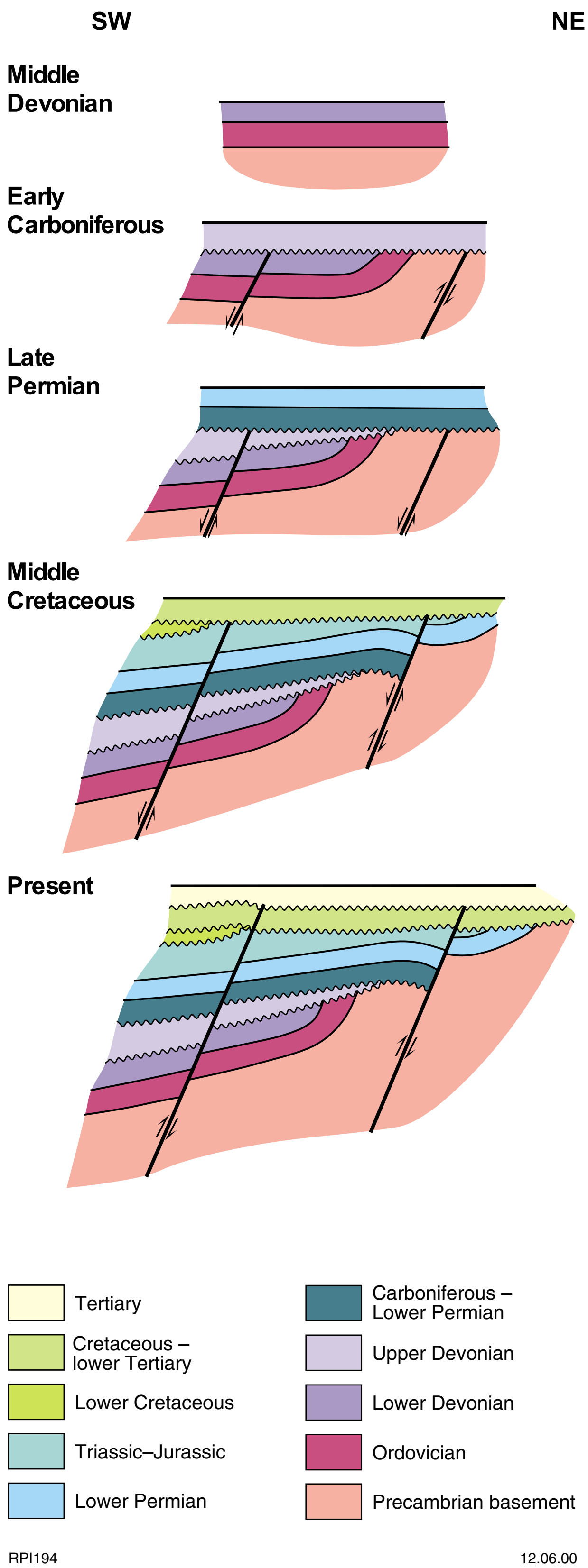


Figure 31. Southwest to northeast schematic structural evolution of the Peedamullah Shelf, from the Ashburton Embayment and Onslow Terrace in the southwest, to the Candace Terrace in the northeast

from the Upper Permian Kennedy Group. The depositional environment of the lower, carbonate-bearing part of the Kennedy Group is much the same as that for the Callytharra Formation, and the hiatus between the two units may be due to a change in sea level or a period of quiescence, as the relevant seismic horizons are subparallel. The basin, which had originally opened up during Early Carboniferous tectonism, was then filled by younger sediments (Kennedy Group) for which Hocking et al. (1987) proposed a sandy, marine-shelf depositional environment. Deposition in the rift valley continued during the Triassic and Jurassic with a few possible brief breaks, implying only minor changes in sea level. Transgressive shallow-marine deposition in the Early to Middle Triassic (Locker Shale) was followed by a regressive fluviodeltaic complex of Middle to Late Triassic age (Mungaroo Formation) and then by Jurassic basinal marine shale (Dingo Claystone). A great thickness of Permian–Jurassic rocks filled the rift basin. Tectonism has not been identified during cycle III within the Peedamullah Shelf, although two breakup events were identified in other parts of the Northern Carnarvon Basin, such as in the Dampier Sub-basin (Gartrell, 2000). In the study area, the Jurassic is present only in the northeastern corner of the Onslow Terrace, and comprises fine-grained clastic rocks interbedded with minor coarse, sandy intervals. Deposition during the Late Carboniferous to Late Jurassic was interrupted by an extensional rifting episode in the Tithonian.

Earliest Cretaceous cycle (IV)

Although Tithonian extension in the Peedamullah Shelf created a rift in the Barrow Sub-basin and adjacent areas, the Pilbara Craton was emergent. During the early Neocomian, a deltaic complex (Barrow Group) sourced from the emergent land filled the active rift valley. The greatest thickness of these sediments was deposited in the most basinal parts of the region, whereas the marginal area of the Peedamullah Shelf was covered only by thinner and younger deposits (Flacourt Formation). To the northeast, within the Dampier Sub-basin, a condensed claystone interval represents time-equivalent deposition (Muderong Shale). The extent of the Barrow Group can be gauged from petroleum wells in the area, and indicates that it was also deposited southeast of the Flinders Fault System (Fig. 34). The Yarraloola Conglomerate and Nannutarra Formation, which have only been identified in outcrop, represent continental facies within the group.

Cretaceous to Early Miocene cycle (V)

Following the breakup of Gondwana, the deltaic sediments (Barrow Group) were overlain unconformably by a marine clastic succession (Winning Group) consisting of conformable units (Birdrong Sandstone, Mardie Greensand, Muderong Shale, Windalia Sandstone Member, and Windalia Radiolarite) interrupted only by minor hiatuses. The Gearle Siltstone is, at least locally, disconformable on older Cretaceous rocks (Westphal and Aigner, 1997), and the Toolonga Calcilutite is the

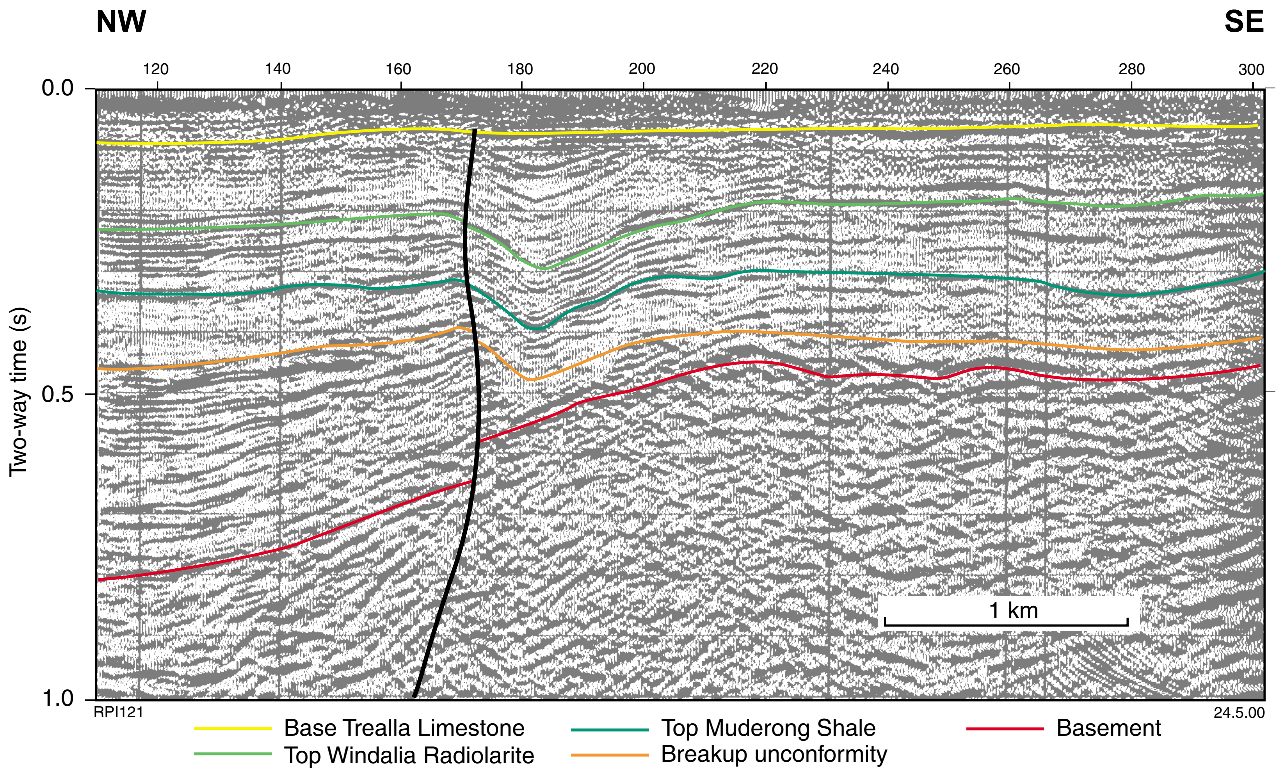


Figure 32. Seismic section C93-010 showing the folded Cretaceous – lower Tertiary succession overlain by subhorizontal Middle Miocene Trealla Limestone. The location of the section is shown in Plate 1

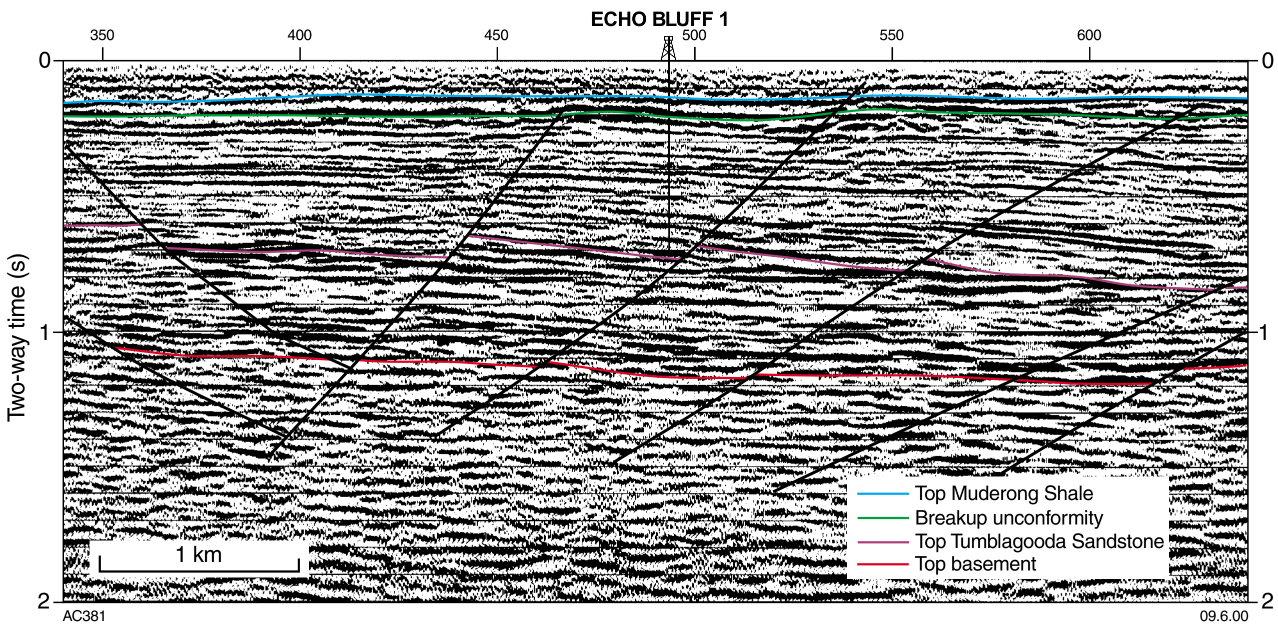


Figure 33. Seismic section T85-31 showing the structure at Echo Bluff 1. The location of the section is shown in Plate 1

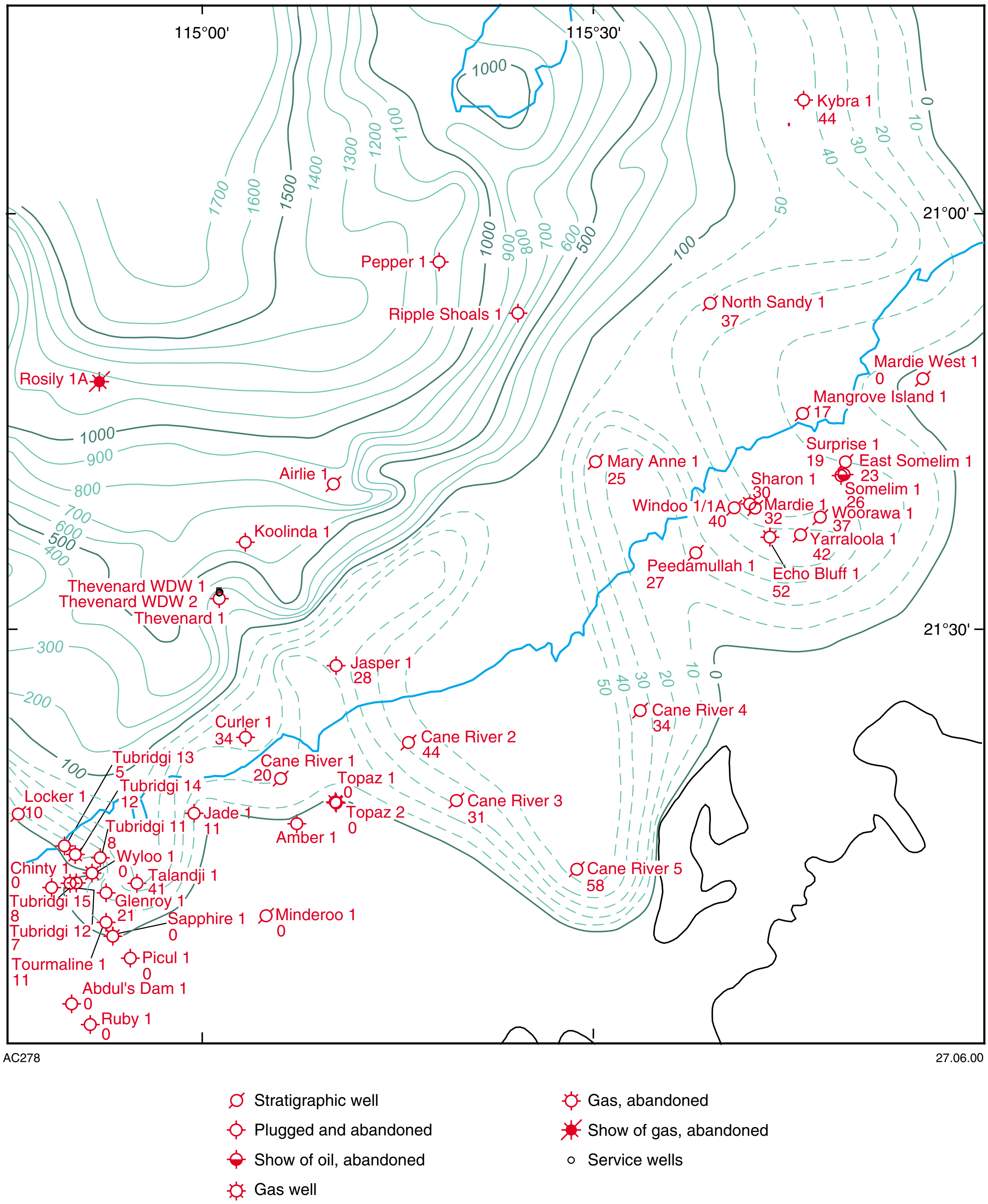


Figure 34. Gross isopach contours of the Barrow Group extended to the Peedamullah Shelf (after Eriyagama et al., 1988)

uppermost unit in the Cretaceous succession. The evolution of the passive continental margin continued with the deposition of Lower Cainozoic calcareous sediments (Cardabia Group) after a hiatus interpreted to be a change in sea level.

Late Miocene to Pliocene cycle (VI)

Deposition within the passive margin of the Australian continent was interrupted to the north and near the Flinders Fault System by a Middle Miocene compressional event. Deposition resumed with shallow-marine carbonates (Trealla Limestone) unconformably overlying the Cardabia Group where the tectonism was most active. In the inner parts of the Peedamullah Shelf, the disconformable relationship between the two units indicates only mild tectonism, possibly similar to the soft-linked, downward-propagating faults in the Timor Sea areas (de Ruig et al., 1999).

The latest phase in the evolution in the study area was the deposition of a veneer of Quaternary continental sediments.

Tubridgi Gasfield

The Tubridgi Gasfield is the only hydrocarbon accumulation of economic value presently known in the study area (Plate 1), and as such, the factors controlling the field have regional significance. Gas production commenced in 1991, and in 1994 the Tubridgi Project was expanded to include gathering and storage of gas from the Thevenard Island and Griffin Fields, in the offshore Barrow Subbasin. Basic information on the Tubridgi Gasfield is provided by Furr (1981), Rushworth (1982a–e), Doral Resources NL (1991a,b, 1994, 1995), and Mitchell (1998a–e). The gasfield was discovered when Pan Pacific Petroleum NL drilled Tubridgi 1 in 1981. The Tubridgi structure, however, had been identified much earlier by WAPET, who drilled Onslow 1 (Jones, 1967) near the northeastern margin of the field (Fig. 9). A total of 20 wells have been drilled in the area to September 1999, including Onslow 1 and Wyloo 1, which is a step-out from Tubridgi 1. Five wells (Tubridgi 3, 6, 12, 13, and Onslow 1) were drilled outside or very close to the gas–water contact and are not productive, whereas Tubridgi 11 was water bearing, although it was drilled within the field boundary. The other fourteen wells are (or were) productive or capable of production. The presence of gas above the reservoir causes inaccurate conversion of seismic time to depth of the base of the sealing formation, the Muderong Shale (Fig. 25), and therefore obscures the boundary of the Tubridgi Gasfield.

Structure

The Tubridgi gas is trapped in a large, low-relief, northeasterly trending, asymmetric mid-Miocene anticline, in which the inner southern flank is the steepest. The structure is superimposed on a pre-breakup high (Fig. 35). The orientation of the anticline is consistent with the Flinders and Long Island Faults, which bound the Onslow Terrace. The crest of the field is at the top of the Flacourt Formation at a depth of 504 m, and the lowest closing contour of this horizon is at 520 m (Thompson, 1992). Thompson (1992) suggested that the structure was formed by drape and differential compaction of the Cretaceous section over a pre-existing high, with faults reactivated during the mid-Miocene tectonic episode. However, seismic and well data over the Tubridgi anticline show that the Cretaceous and younger sections are parallel and maintain a constant thickness across the structure, indicating deformation due to tectonism rather than by compaction. This is consistent with the limited thickness of Cretaceous–Tertiary rocks overlying a Triassic structural high composed of similar density rocks. Furthermore, seismic data (Fig. 24) indicate a mid-Miocene anticline, without any suggestion of previous growth. The modest vertical relief (slightly greater than 20 m) is present at all Cretaceous and pre-Trealla Cainozoic levels and the structure, with the inner steepest flank, appears similar to offshore structures to the north.

Reservoir

Three superimposed reservoirs contain the main Tubridgi gas accumulation, namely the Birdrong Sandstone, Flacourt Formation, and the unconformably underlying Mungaroo Formation (in descending order). The porosity of the three formations is similar, averaging 28%, whereas the permeability varies from approximately 500 mD in the Birdrong Sandstone to 5 D in the Flacourt Formation and 2 D in the Mungaroo Formation. The Mungaroo and Flacourt Formations are highly cemented in the northeastern section of the field (Fig. 9). A further small accumulation is present within the Mardie Greensand and gas levels have been encountered also within the Gearle Siltstone and Windalia Radiolarite, indicating widespread gas throughout the Cretaceous section of the field. The Muderong Shale seals the gasfield.

Type of hydrocarbon

The Tubridgi gas is predominantly methane (as is the gas associated with the Roller and Skate Fields, 20–25 km to the northeast), but includes approximately 5.6% nitrogen and 0.5% carbon dioxide that is not derived from biodegradation of hydrocarbons (Pan Pacific Petroleum NL, 1996, appendix G), and a negligible percentage of higher hydrocarbons. Carbon isotope analyses, by the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Petroleum Resources in Sydney, of a gas sample taken from Tubridgi 7 (Pan Pacific Petroleum NL, 1996, appendix G) shows that the composition of methane is –50 $\delta^{13}C$‰, PDB standard (from the belemnite Peedee Formation of South Carolina). This carbon composition is similar to the results from CSIRO of the gas from Topaz 1, DST 2 (-46.2 $\delta^{13}C$‰, PDB). When the level of organic metamorphism and thermal alteration index is plotted against the isotopic separation between the methane and ethane, it confirms

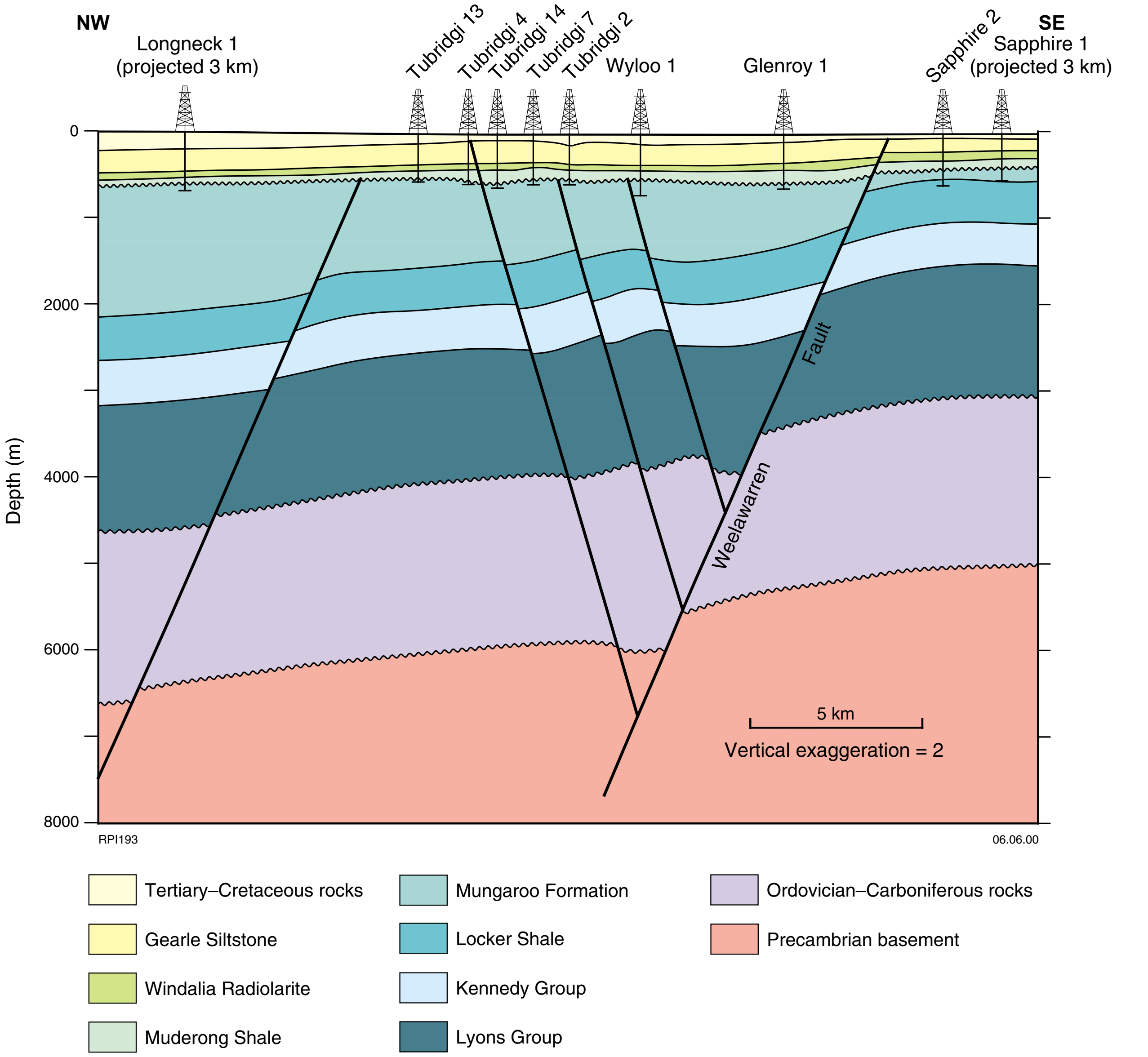


Figure 35. Structural cross section along the Tubridgi structure based on well data along the section and interpreted structure from seismic data (Plates 4–8). The location of the section is shown in Plate 1

that the gas has been generated at a very low level of maturity (Pan Pacific Petroleum NL, 1996, appendix G) and suggests a biogenic origin. The characteristics of the Tubridgi gas are consistent with the typical characteristics of biogenic gas, as C_1/C_{1-5} is higher than 99%, sulfates are not present, and CO_2 is present (Rice and Claypool, 1981; Crostella and Boreham, in prep.).

Biodegraded residual 29.5° API (American Petroleum Institute specific gravity scale) oil is present in poor quality reservoir sands within and below the gas accumulation, and is consistent with the presence of biogenic gas as the same bacteria could have degraded the oils. The oil is heavier than the average Barrow Sub-basin oils, but similar to that of the closer Roller and Skate Fields (Beacher et al., 1994). In Tubridgi 9, high frequency oil inclusions at 511.7 m within the Flacourt Formation, similar in composition to oil from producing fields, are consistent with an oil column that has migrated out (Doral Resources NL, 1994, appendix H). However, the residual oil is contained in low permeability reservoirs and therefore, the presence of a structural trap was not critical, implying there may not have been an oil accumulation in the area.

Discussion

When the Tubridgi structure (Fig. 9) was first filled with hydrocarbons, what is now a tight reservoir sandstone was probably outside structural closure. This allowed formation waters to cement the sandstone with calcite. The gas was subsequently displaced when the northeastern part of the Tubridgi anticline was structurally elevated. This tilting allowed the migration and accumulation of gas in that part of the field, which was previously water bearing. Similarly, the Barrow Oilfield was formed by Middle Miocene arching, which was later modified by a second movement (Crank, 1973). The later movement consisted of tilting to the north, which is noticeable on the post Middle Miocene Trealla Limestone outcropping on Barrow Island. This tilting was followed by the migration of a small amount of gas evident as a perched gas cap at the crest of the surface anticline, but considerably downdip from the oil accumulation (Fig. 36). Similarly, the main Middle Miocene compression possibly controlled the once-oil-filled Tubridgi structure. This movement was followed by an intra-Trealla Limestone tilting to the northeast that controlled the present geometry of the gasfield. Bottom-water drive is commonly considered to be the main factor for the field production, assuming the pressure support of an infinite aquifer, but also an expansion factor is present, as is demonstrated by the lower gas pressure (Jursa, 1993).

The original gas reserves of the field, considered to have been filled to spill point, have been calculated at 3 069 544 × 10^3 m^3 (Department of Minerals and Energy, 1998).

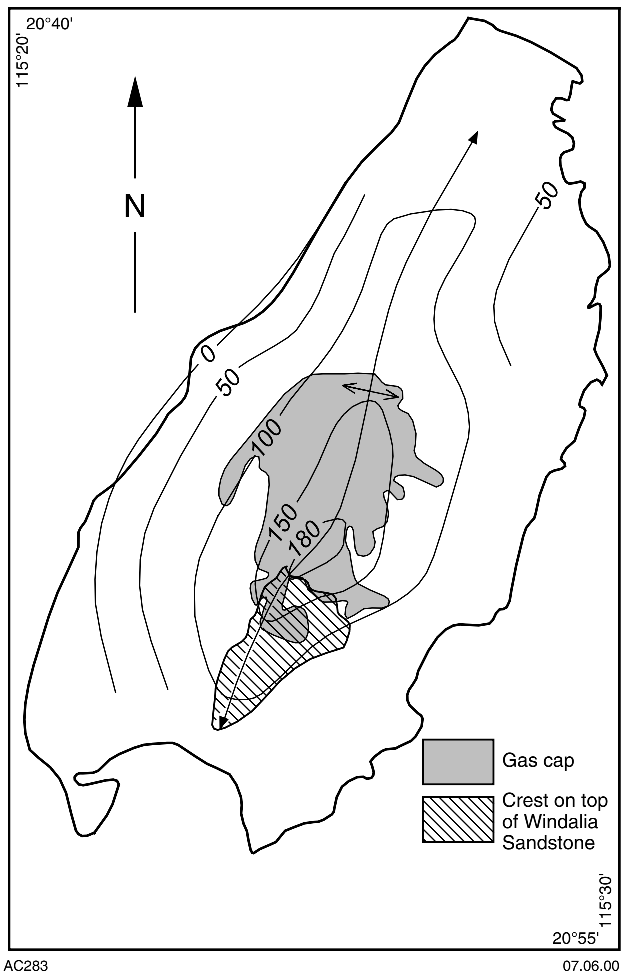


Figure 36. Surface structure of Barrow Island represented by depth contours to a near-basal Trealla Limestone horizon. Superimposed is the crest of the structure on the top of the Windalia Sandstone Member, which contains 98% of the Barrow Island oil (after Crank, 1973)

Tubridgi 11 and 12, drilled in October 1997, intersected poor-quality reservoirs in the Birdrong Sandstone and Flacourt Formation that were water bearing and calcite cemented. In 1997–1998, other wells (e.g. Tubridgi 2 and 7) produced a high percentage of water, whereas the percentage of water in Tubridgi 1 and 8 increased. In 1995, Wyloo 1 had to be recompleted and economic production, although at reduced rate, was possible only by isolating the Flacourt Formation. The level of water observed in the wells does not fit with their expected performance and is not consistent across the field. Tubridgi 4, for example, had an inferred gas–water contact 10 m higher than the field average (Thompson, 1992). These anomalies have been explained by the presence of faults compartmentalizing the field (Thompson, 1992). Alternatively, the very high permeability of the Flacourt Formation (and also of the Mungaroo Formation) may have allowed this aquifer to draw-in water from a wide area. Therefore, structurally higher areas where only the Birdrong Sandstone and the uppermost Flacourt Formation are above the gas–water level are most likely to produce water. The low reservoir pressure of the shallow gasfield could allow further encroachment of water into previously gas-bearing reservoirs. However, the variable sandstone quality and tight streaks could result in pressure isolation during production of the less permeable Birdrong Sandstone (especially the uppermost section) and Mardie Greensand, thereby allowing production to be extended, whereas the Flacourt Formation may be depleted independently.

Post-mortems of dry petroleum wells

To the end of 1997, 86 mostly shallow wells had been drilled within the Peedamullah Shelf, Onslow Terrace, and Candace Terrace. Of these, 17 were drilled for the Tubridgi Gasfield (including Onslow 1 and Wyloo 1, but excluding Tubridgi 16, 17, and 18, which were drilled in 1999). The results of the remaining 69 wells are reviewed and discussed on the basis of reports on the stratigraphy, palynology, seismic data, geochemistry, petroleum engineering, and petrophysics produced by the petroleum exploration companies. Palynological reviews of selected wells are included in Appendix 4 and formation tops, as revised herein, are in Appendix 5.

Only 23 of the 69 wells located outside of the Tubridgi Gasfield are classified as exploration wells, the remainder were either stratigraphic (19) or appraisals of the Robe Embayment oil shows (27). The wells are reviewed separately, with the exception of the closely spaced shallow wells drilled within the central part of the Robe Embayment with no, or poor, seismic control. Of the 19 stratigraphic wells drilled by WAPET during 1967–69, 8 were on islands between Tubridgi Point and Cape Preston. WAPET's primary objective was to investigate the thickness, reservoir potential, and fluid parameters in sandstones within the Muderong Shale and Birdrong Sandstone. A secondary aim was to determine the age and lithology of the pre-Cretaceous section.

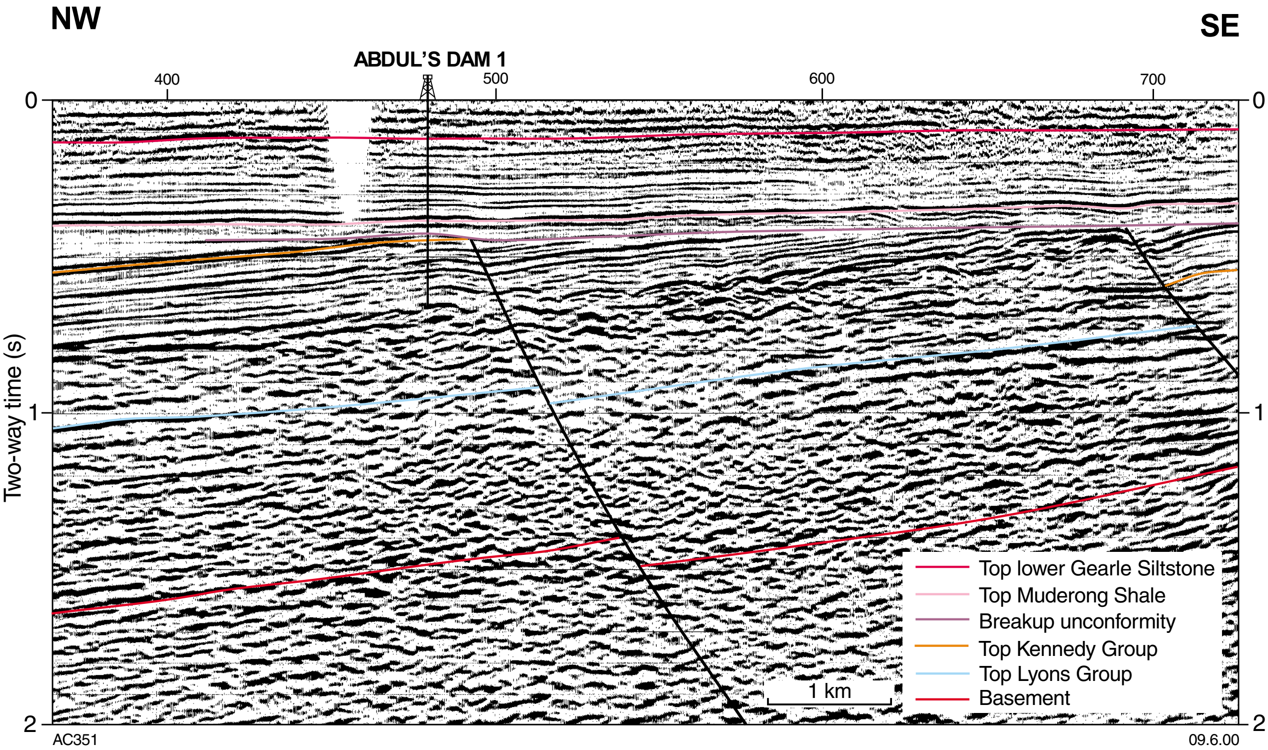


Figure 37. Seismic section PP90A-201, showing the structure at the Abdul's Dam 1 prospect. The location of the section is shown in Plate 1

Abdul's Dam 1

Abdul's Dam 1 well was drilled within the Onslow Terrace (Plate 1) by Pan Pacific Petroleum NL in 1991 to test the hydrocarbon potential of all levels from the Lower Cretaceous Birdrong Sandstone to a postulated Lower Permian karst limestone (Fig. 37). The pre-drill seismic time map shows an areal closure of approximately 4 km^2 at the intra-Neocomian unconformity level and 0.6 km^2 at the top of the Lower Permian limestone.

The Tertiary–Cretaceous regional stratigraphic succession is present down to the Muderong Shale. Below the intra-Neocomian unconformity (at 422 m), the Lower–Middle Triassic Locker Shale was penetrated above the Upper Permian (*Dulhuntyispora parvithola* palynozone) Chinty Formation, Abdul Sandstone, and Cody Limestone (Kennedy Group), to the total depth of 770 m. Pan Pacific Petroleum NL (1991) erroneously interpreted the Cody Limestone as a Lower Permian Byro Group limestone, equivalent to the Wandagee Formation.

Remapping after drilling indicates that the Abdul's Dam 1 feature lacks structural closure (Mills, 1997a). The only significant hydrocarbon indication was a total gas peak of 4.8% at 709 m at the top of the Abdul Sandstone. This sandstone was tested, but only gas-cut saline water flowed to the surface. The flow rate of 500 barrels per day indicates very good permeability.

Abdul's Dam 1 failed to discover hydrocarbons because the Birdrong Sandstone is not present at this location and deeper units, including the main objective (Cody Limestone), depends critically on an unpredictable fault seal (Fig. 38). An unfaulted anticline would represent a more reliable trap than the faulted structure tested by this well.

Amber 1, Topaz 1, and Topaz 2

Amber 1, Topaz 1, and Topaz 2 were drilled in 1994, 1995, and 1996 respectively, by Pan Pacific Petroleum NL within the onshore westernmost part of the Weld High. The wells were located in the same general area to test similar fault plays to, but about 30 km from, the Tubridgi Gasfield (Plate 1). The main objective of the drilling campaign was the Birdrong Sandstone, sealed by the Muderong Shale, although Topaz 2 was also programmed to test the hydrocarbon potential of the Quail Formation, which had not been properly evaluated in Topaz 1 due to lost circulation problems. The Mardie Greensand was expected to either have poor reservoir quality or to be tight. All the objectives were expected to be within horst blocks. Amber 1 and Topaz 1 were located on faulted structures that prior to drilling were estimated to have approximately 3 km^2 of areal closure and 20 m of vertical relief, and 7 km^2 of areal closure and 30 m of vertical relief respectively (at the base of the Muderong Shale). High seismic amplitude anomalies at the top of the Muderong Shale and Birdrong Sandstone characterize the Topaz 1 location.

In Amber 1, the fine-grained, glauconitic, well-sorted, pyritic sandstone of the Mardie Greensand was reached at 365.5 m and the underlying sandy unit, referred to as

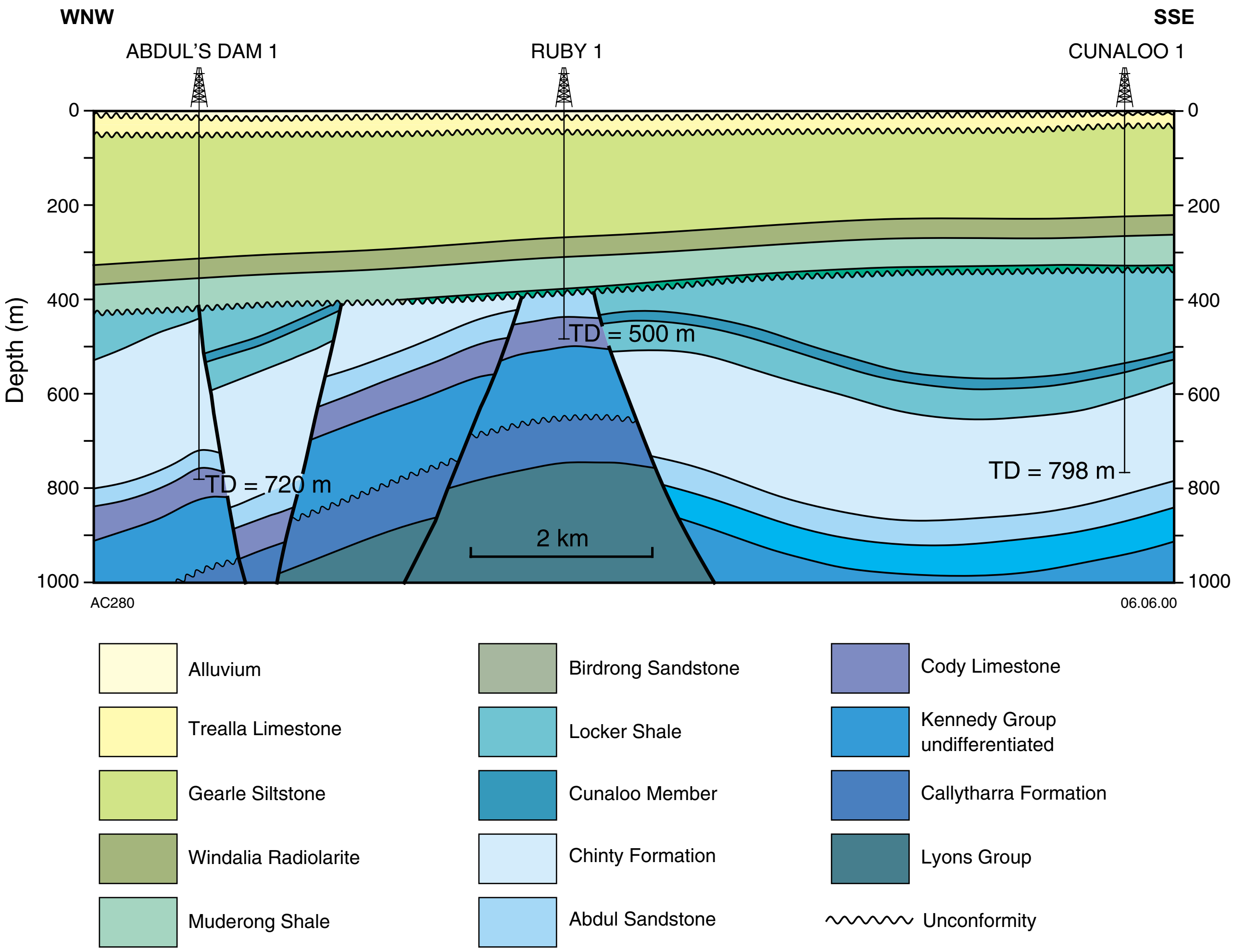


Figure 38. Schematic structural cross section Abdul's Dam 1 – Ruby 1 – Cunaloo 1, showing that the structure at Abdul's Dam is dependent on a fault seal

the Birdrong Sandstone, at 372 m (Pan Pacific Petroleum NL, 1995a). Below the basal Cretaceous unconformity at 389 m, the Lower Carboniferous Quail Formation and Moogooree Limestone were present to a total depth of 682.7 m. In Topaz 1, the Mardie Greensand was reached at 335.5 m and the underlying sandy unit, referred to as the Birdrong Sandstone, at 337 m (Pan Pacific Petroleum NL, 1996). Below the basal Cretaceous unconformity, the Quail Formation was present from 352.5 to 378 m and then the Moogooree Limestone to the total depth of 423 m. Because Topaz 2 was drilled 160 m to the south-east and slightly downdip of Topaz 1 (Pan Pacific Petroleum NL, 1996), all stratigraphic units in the well were slightly lower than in Topaz 1. Total depth was reached at 446 m in the Moogooree Limestone.

In Amber 1, minor oil was extracted from a sidewall core in the Mardie Greensand, but a subsequent DST proved the interval to be water bearing. In Topaz 1, oil was extracted from core 3 (350 – 354.5 m). The portion of the core recovered is cemented by calcite and may represent either the base of the Cretaceous or the top of the Carboniferous. The oil in both wells is biodegraded and can be correlated with the oil of Tubridgi 7 and Jasper 1. Geochemical analyses indicate that the organic source is moderately mature and of mixed marine and terrestrial origin, and from beds deposited under suboxic to anoxic conditions (Pan Pacific Petroleum NL, 1996, appendix C). Biodegraded oil, with vitrinite reflectance equivalent of 0.8 – 0.85%, similar to oils in Amber 1 and Topaz 1 (Mills, 1997b), was recovered from Topaz 2 as scum covering water (DST 1, 342–349 m). In this well, the Palaeozoic section did not yield any hydrocarbons.

Gas indications were recorded at several levels in Topaz 1: the average percentage of gas by volume was 0.3 in the Gearle Siltstone, 0.25 in the Windalia Radiolarite, 0.08 in the Muderong Shale, 1.3 in the Mardie Greensand and Birdrong Sandstone, and 0.1 in the Carboniferous units. Following a gas peak of 3.7%, a DST was carried out in the open hole across the base of the Muderong Shale, the Mardie Greensand, and the top of the Birdrong Sandstone over the 332–341 m interval. The gas reached surface at a stabilized rate of about 20 000 m^3/day (700 000 ft^3/day). The large isotopic separation between the methane and ethane in the Topaz 1 gas (Pan Pacific Petroleum NL, 1996, appendix G) indicates that it was generated at a very low level of maturity (vitrinite reflectance equivalent of 0.3%), and that it is of biogenic origin or biodegraded. The hydrocarbons in this well are almost entirely methane (only 0.02% of ethane is present in sample 1 and none in sample 2) and are accompanied by nitrogen (5.46 – 5.43%) and carbon dioxide (0.86 – 0.87%). The Topaz 1 carbon isotopic composition is -46.2‰, in contrast to the commonly accepted isotopic composition for biogenic gas of -55 to -90 (Rice and Claypool, 1981) — Crostella and Boreham (in prep.) discussed this discrepancy. In Amber 1, Topaz 1, and Topaz 2, the unit referred to as the Birdrong Sandstone by Pan Pacific Petroleum NL (1995a, 1996) and Mills (1997b) is typical of the Flacourt Formation as described in the Tubridgi Gasfield (Doral Resources NL, 1995). In these three wells, the top of the unit is marked by a decrease in gamma count and lower density values, and the unit is medium to very coarse grained, with no visible cement and little, if any, glauconite. The very high permeability, excellent reservoir quality, and lack of glauconite of the unit are consistent with it being the Flacourt Formation. The units referred to as Birdrong Sandstone and Mardie Greensand by Pan Pacific Petroleum NL are here reinterpreted as representing only the Birdrong Sandstone.

The presence of the Flacourt Formation below the Winning Group implies that the basal Cretaceous unconformity mapped by Buchan (1994a) represents the palaeotopographic surface at the base of the Flacourt Formation. This interpretation is consistent with the large number of low relief structural highs shown by his map (Fig. 39), but not at higher levels (Figs 40 and 41). The top Birdrong Sandstone horizon of Buchan (1994a; Fig. 40) is here interpreted as a level near the base of the Muderong Shale. The top Muderong Shale horizon (Fig. 41) is stratigraphically better defined, because the thinness of the Flacourt Formation and Birdrong Sandstone makes their seismic resolution difficult.

As hydrocarbons, potential reservoirs, and seals are all present in the three wells, their failure to discover commercial hydrocarbons is attributed to the poor definition of the Tertiary anticlines and Early Cretaceous palaeotopographic highs. A very gentle, unfaulted anticlinal structure, with the steepest flank to the southeast, is present in the Topaz area (Fig. 42). This structure is similar in style to the Middle Miocene Tubridgi structure. A reinterpretation of the area may lead to the definition of better locations where the basal Cretaceous objectives are not only within closure, but are also structurally higher.

Beagle 1

Beagle 1 was drilled in 1969 by WAPET on Beagle Island within the Weld High (Plate 1), as one of the series of stratigraphic wells located on islands.

In Beagle 1, the regional Cretaceous stratigraphic succession was intersected down to 320 m. The interval referred by Moyes (1969a) to the Yarraloola Conglomerate is represented by fine-grained to pebble-sized, poorly sorted, and only partially cemented sandstone that is here assigned to the Flacourt Formation. The Birdrong Sandstone, as recognized herein, was included by Moyes (1969a) within the lower part of the glauconitic Muderong Shale. Beneath the Cretaceous the Carboniferous–Permian Lyons Group is present to the total depth of 560 m.

Shows of methane, with no indications of heavier hydrocarbons, were encountered within the Cretaceous. Gas peaks were noted in siltstone stringers intercalated within the Muderong Shale, Birdrong Sandstone, and Flacourt Formation. Low background gas was present throughout the pre-Cretaceous section.

Black Ledge 1 and Curler 1

Black Ledge 1 was drilled offshore by WAPET in 1992 within the northeastern part of the Onslow Terrace (Plate 1), primarily to test the hydrocarbon potential of sandstone within the Mungaroo Formation sealed by the overlying Dingo Claystone. Sandstone in the Cretaceous Barrow Group represented a secondary objective. Below the regional Tertiary–Cretaceous post-breakup stratigraphic succession, the Barrow Group was penetrated at a depth of 737.5 m. Below the Barrow Group, the well penetrated a sandy Dingo Claystone at 772.5 m and the objective Mungaroo Formation at 2178 m. The apparently continuous Hettangian to Oxfordian section suggests that the main uplift in the Onslow Terrace was during the Late Jurassic (?Tithonian). Reworked Permian and Triassic palynomorphs in the Mungaroo Formation imply the emergence of a section of this age during the Jurassic. Total depth was reached at 2680 m in the Mungaroo Formation (Copley, 1993).

Black Ledge 1 was drilled in a northerly trending fault block, downthrown from the Flinders Fault (named the Paroo Fault by Copley, 1993), which was expected to provide the critical lateral seal to the south and east (Fig. 43). Seismic data indicated the presence of dip closure to the west and to the north, but no significant hydrocarbons were found in the well.

In 1997, Curler 1 was drilled by WAPET updip from Black Ledge 1 within the same, although slightly reinterpreted, Onslow Terrace fault block but in a near crestal location (Fig. 44). WAPET aimed to test the hydrocarbon potential of the Barrow Group and overlying Mardie Greensand, sealed by the Muderong Shale (Strautins and Hatton, 1997). The top of the main objective of Curler 1, namely the topset sandstone of the Barrow Group, was intersected below the post-breakup succession at 615 m. Total depth was reached at 759 m within the Dingo Claystone. There were no shows of hydrocarbons.

The most likely reason for the failure of Black Ledge 1 and Curler 1 is the lack of seal along the Flinders Fault. Hydrocarbons may have leaked from the downthrown sandstone in either the Barrow Group or Mungaroo Formation, into juxtaposed Permian sandstone or limestone, or along the fault plane.

Candace 1

Australian Occidental drilled Candace 1 in 1982 (Plate 1) to test the hydrocarbon potential of the Permian–Triassic succession within the offshore Candace Terrace.

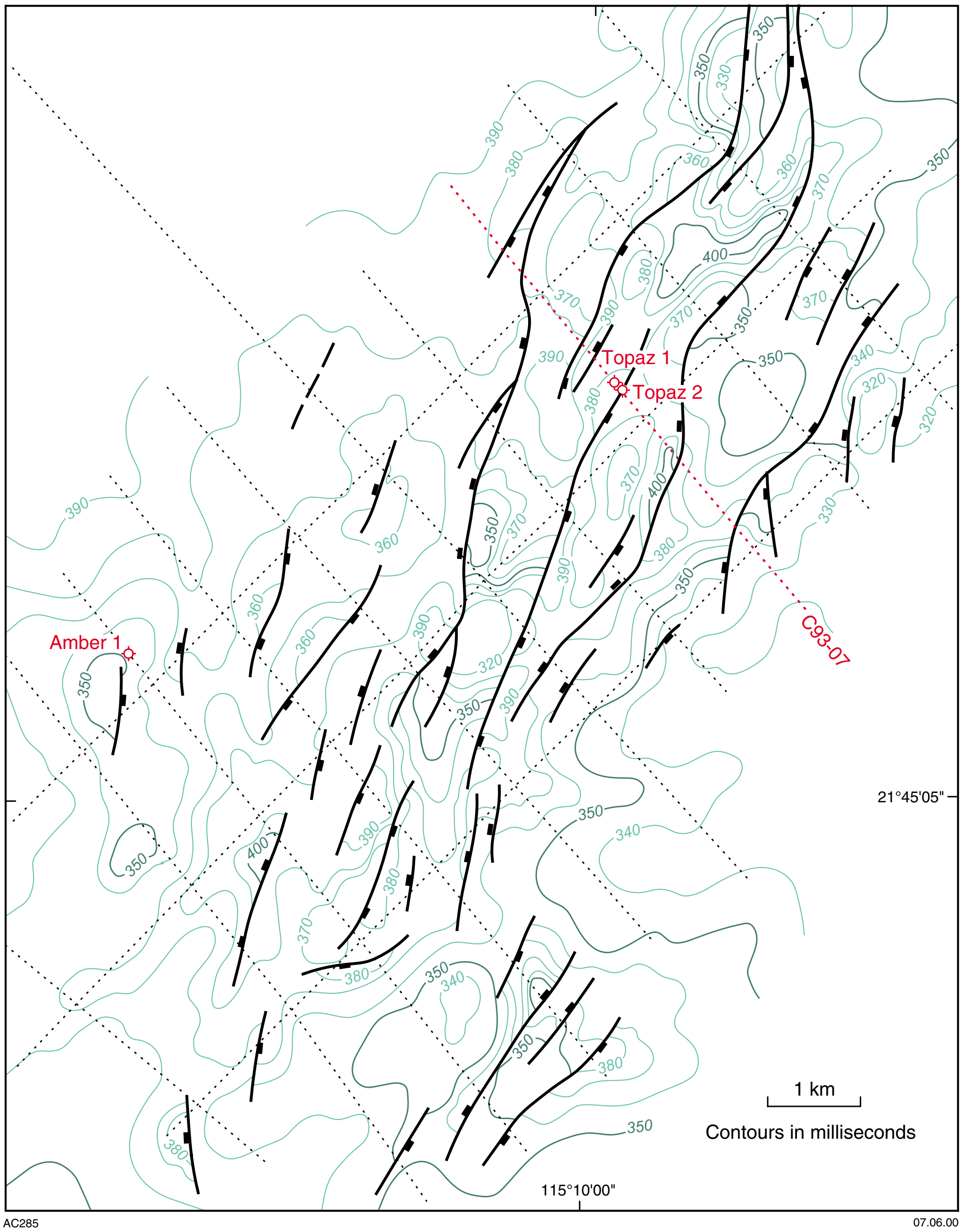


Figure 39. Two-way time contours to the basal Cretaceous unconformity in the Amber–Topaz area (after Buchan, 1994a). The dotted lines represent seismic lines

Below the flat-lying Tertiary–Cretaceous succession, the Middle–Upper Triassic Mungaroo Formation and the underlying Lower–Middle Triassic Locker Shale were penetrated at 415 m and 880 m respectively (Australian Occidental Pty Ltd, 1982). The Upper Permian Kennedy Group was reached at 1458 m and it disconformably overlies the Lower Permian ?Callytharra Formation at 1970 m. The Lyons Group was reached at 2007 m (Mory and Backhouse, 1997) within which the well was terminated at 2063 m. The interval 2017.5 – 2063 m was interpreted by Australian Occidental Pty Ltd (1982) as ‘pyroclastic breccia’, but the rocks are more likely to be glacigene, a characteristic of the Lyons Group.

Structurally Candace 1 was located on a seismically defined breakup anticlinal structure, on the downthrown side of the northerly trending Sholl Fault. A reinterpretation of the seismic in the Candace area is presented in Figure 45. The upward movement of the footwall along the Sholl Fault juxtaposed younger rocks of the hanging wall against older rocks of the footwall. No significant hydrocarbon shows were recorded in the well, and only methane, which is regionally widespread, was recorded on the chromatograph.

The lack of hydrocarbons within the Mungaroo Formation can be explained by the lack of structural closure at the base of the Cretaceous sealing horizon. The

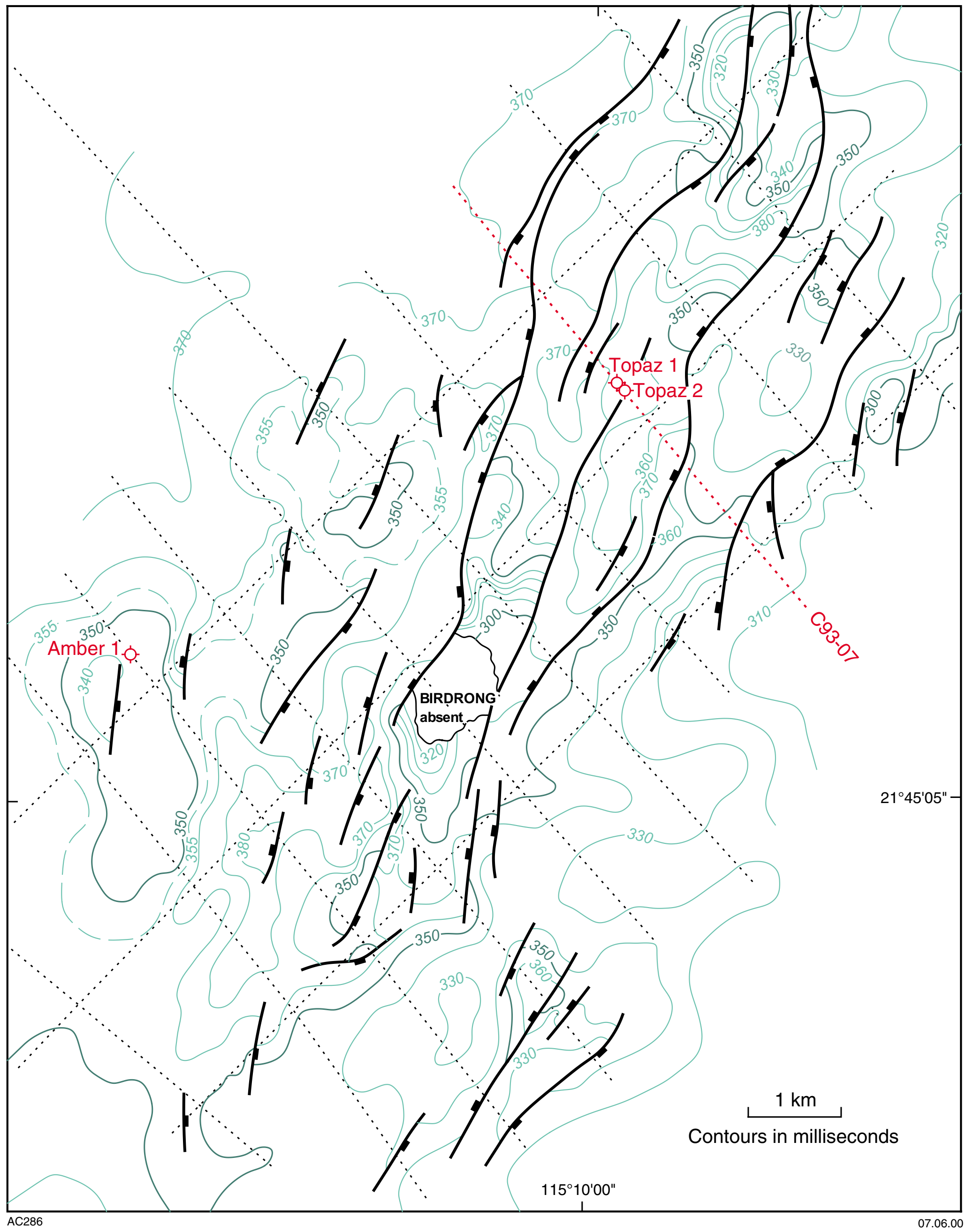


Figure 40. Two-way time contours to the top Birdrong Sandstone in the Amber–Topaz area (after Buchan, 1994a)

reason for the lack of hydrocarbons within the Upper Permian rocks is probably because the anticlinal feature tested by Candace 1 is critically dependant on fault sealing at the top Kennedy Group horizon (Fig. 45).

Cane River 1–5

The Cane River 1–5 stratigraphic wells were drilled 10–25 km from each other, in 1971–1972, by Hematite Petroleum within the Ashburton and Cane Embayments (Plate 1). The wells were designed to investigate the Cretaceous and underlying rocks in a setting southwest of the previously tested Robe Embayment, which was considered favourable for the stratigraphic entrapment of hydrocarbons.

The typical Cainozoic to Cretaceous regional stratigraphic units were found down to the basal Cretaceous unit assigned to the Yarraloola Conglomerate by Hematite Petroleum Pty Ltd (1972a). In these wells, this unit is described as a sandstone containing clasts that are fine grained to pebble size, clear and milky white, unconsolidated, with local stringers of lignite. These characteristics suggest that the unit may be better referred to as the deltaic Flacourt Formation. If this is the case, the hard glauconitic and pyritic sandstone present at the base of the unit from 347.5 – 393 m referred to

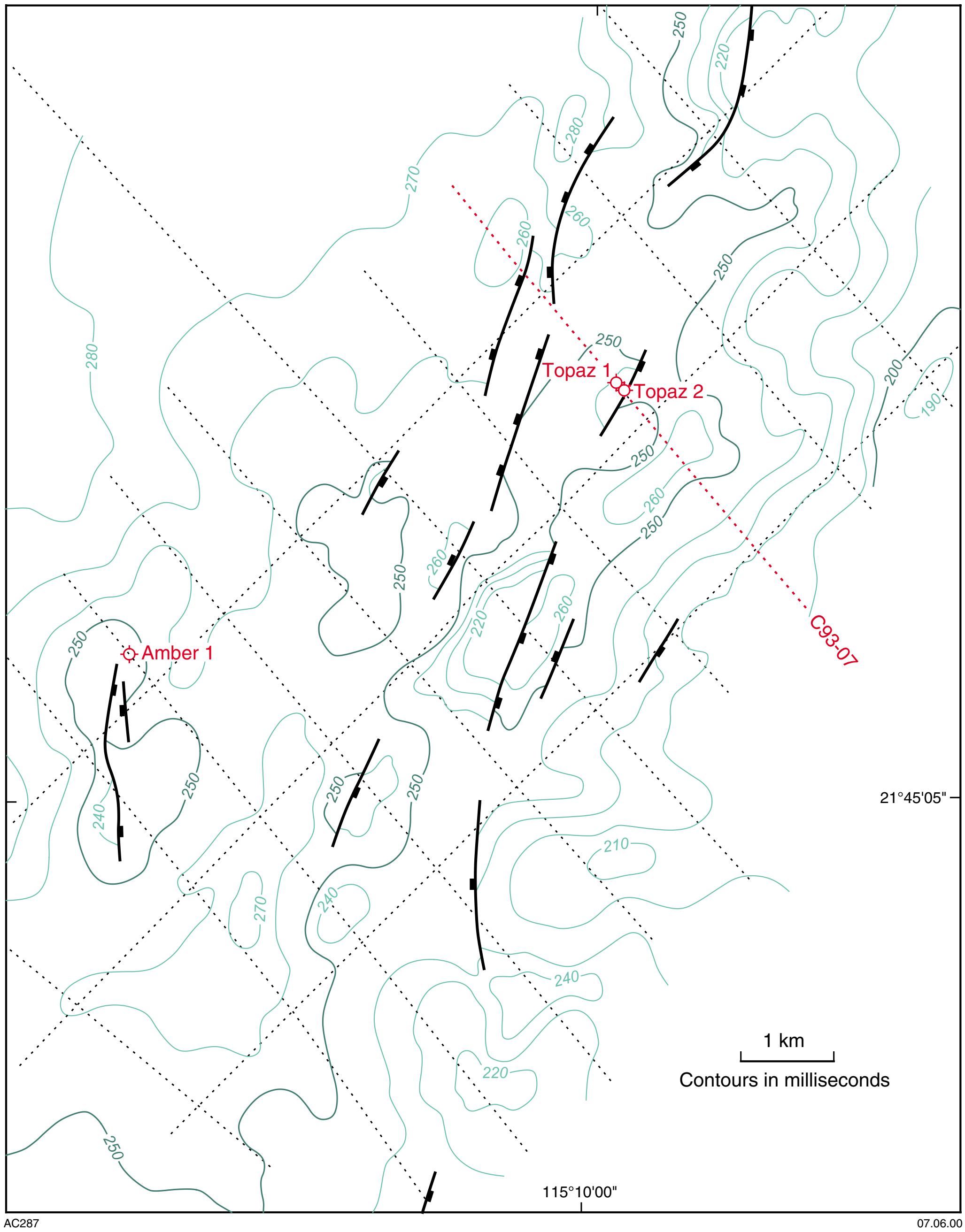


Figure 41. Two-way time contours to the top Muderong Shale in the Amber–Topaz area (after Buchan, 1994a)

as Muderong Shale in Cane River 1 by the company, indicates a marine transgression, and is here assigned to the Birdrong Sandstone. Cemented and glauconitic rocks in other Cane River wells were referred to as the top of the Yarraloola Conglomerate by Hematite Petroleum Pty Ltd (1972b), but are here assigned to the base of the Birdrong Sandstone. Beneath the basal Cretaceous unconformity, Lower Carboniferous (*Grandispora maculosa* palynozone) clastic rocks, here assigned to the Quail Formation, are present in Cane River 1, Devonian carbonates in Cane River 2, and pre-Palaeozoic metamorphic rocks in Cane River 3, 4, and 5 (Appendix 5).

Structurally, the drilling results confirm the presence of a weakly deformed Cretaceous section, gently and uniformly dipping to the northeast, superimposed on block-faulted Palaeozoic strata. In addition, the drilling indicates that progressively thicker and younger Cretaceous rocks were deposited to the northeast.

No significant shows of hydrocarbons were detected, but in Cane River 3 local globules of light-brown oil are present in water from the Yarraloola Conglomerate, in which the level of background methane gas also increased (Hematite Petroleum Pty Ltd, 1972b).

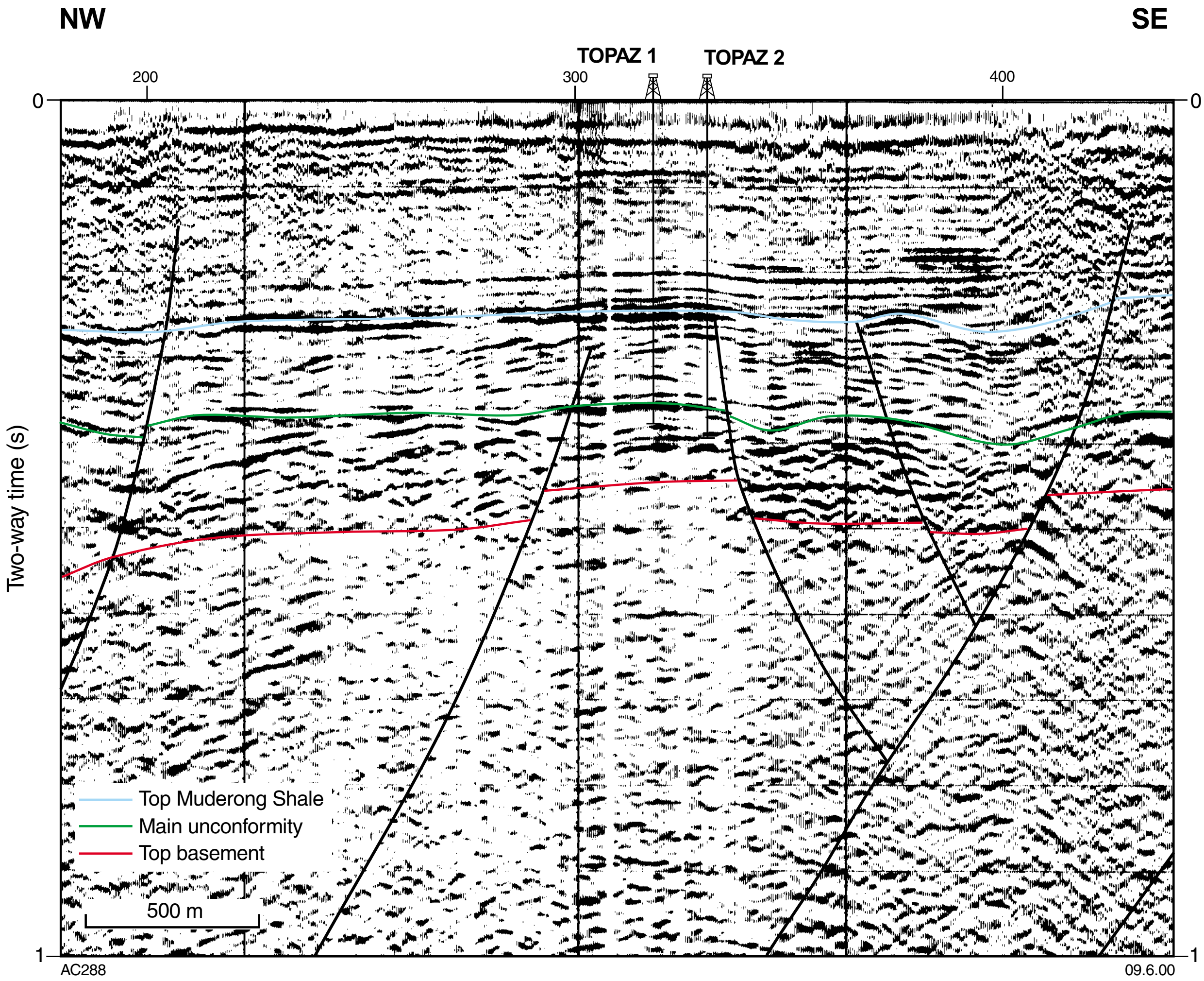


Figure 42. Seismic section C93-007 showing the structure at the Topaz 1 and Topaz 2 prospects. The location of the section is shown in Plate 1 and Figure 39

Chinty 1

Esso Exploration and Production Australia drilled Chinty 1 in 1985 within the Onslow Terrace (Plate 1). The primary objective was to test sandstone of the Upper Permian Chinty Formation within a horst block (Fell, 1985; Fig. 46).

The regional Tertiary–Cretaceous lithostratigraphic units were penetrated down to 545 m, where the intra-Neocomian unconformity was penetrated. The seismic data show that there is little post-breakup deformation (Fig. 46). The top of the underlying Mungaroo Formation, Locker Shale, and Chinty Formation have been revised (Yasin, 1997). The proposed trap as tested by the well, relied on fault-plane seal due to smearing along the fault plane or a favourable geometry of the two bounding faults juxtaposing porous against impervious strata. The lack of hydrocarbons indicates that either or both these factors are not present.

No significant gas peaks were observed in Chinty 1, indicating that the well was drilled outside the adjacent Tubridgi structure. The log-derived porosity of sandstone within the Mungaroo Formation is up to 18–25%, indicating a good-quality potential reservoir. Within the Locker Shale, intercalated sandstone reaches a maximum porosity of 16%. Sandstone beds within the Chinty Formation have a porosity of 14–20% and therefore, also represent good potential reservoirs.

Chinty 1 did not find an economic hydrocarbon accumulation because it did not test a valid trap.

Coonga 1

Coonga 1 was drilled to a total depth of 176 m in December 1972 by Hematite Petroleum some 50 km to the northeast of the central part of the Robe Embayment (Plate 1). Coonga 1 was the fifth and last of a series of shallow wells designed to investigate the potential for stratigraphically trapped hydrocarbons within the Lower Cretaceous rocks. No shows are mentioned in the poorly documented well completion report (Hematite Petroleum Pty Ltd, 1973).

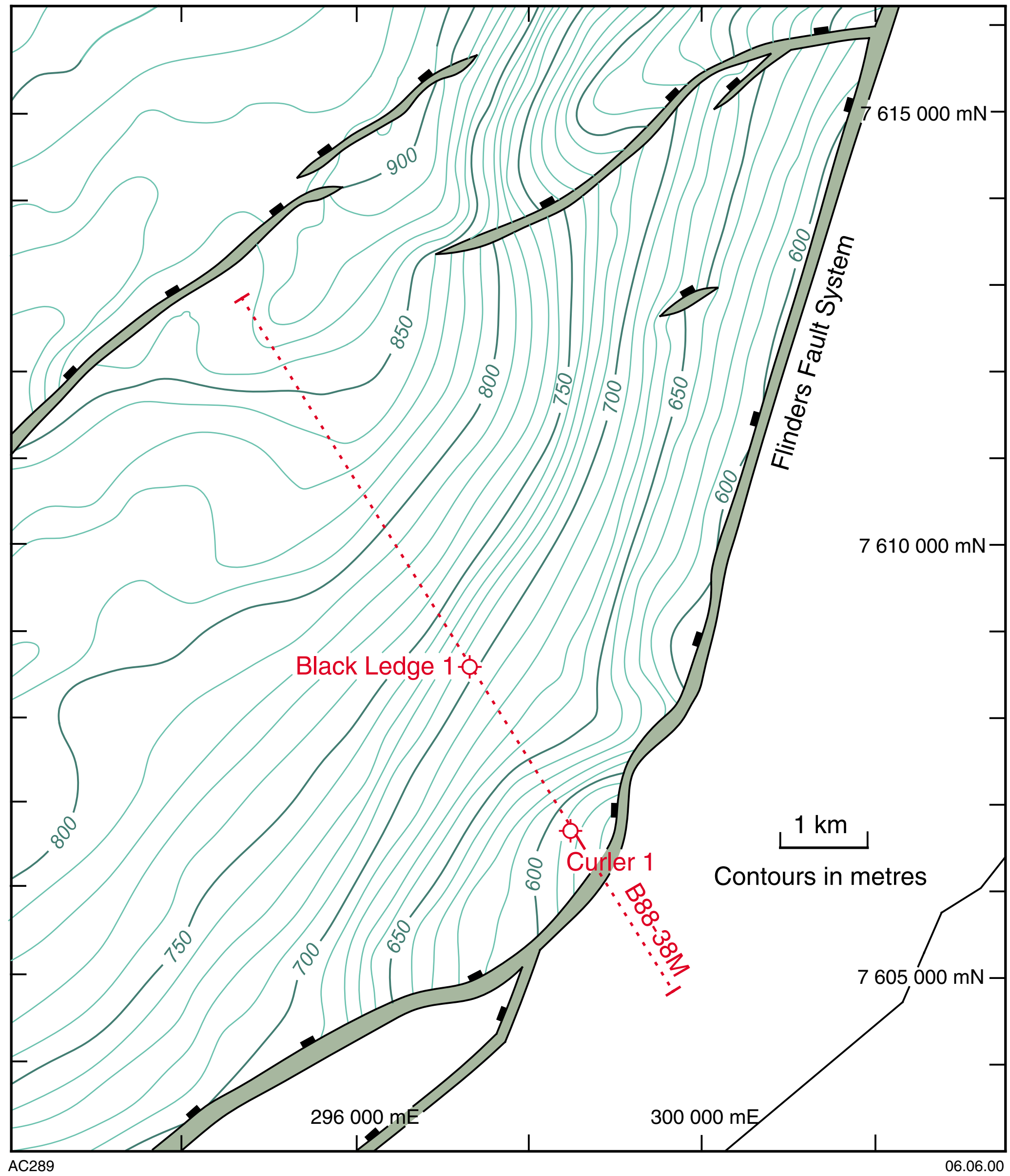


Figure 43. Depth contours to the top of the Barrow Group in the Black Ledge 1 and Curler 1 area (after Strautins and Hatton, 1997)

Crackling 1

Crackling 1 was drilled in 1993 by Command Petroleum Holdings NL on the Weld High, within the offshore part of the Peedamullah Shelf (Plate 1), to test the hydrocarbon potential of the Lower Cretaceous Birdrong Sandstone on an interpreted northerly trending horst block. However, a reinterpretation of the seismic data indicates that Crackling 1 was located on a Tertiary small anticline that is superimposed over a northerly trending, Triassic horst block (Fig. 47). Below the regional Tertiary–Cretaceous section, the primary objective, the Birdrong Sandstone, was reported at 369.2 m (Command Petroleum Holdings NL, 1994a). The unit, however, is medium to coarse grained, conglomeratic in part, loose, quartzose, with only traces of glauconite and up to 8 D permeability (plug from core 3), and with a low average sonic log velocity of 1869 ms^{-1}. These characteristics are indicative of the Flacourt Formation; furthermore, the basal part of the overlying unit, assigned to the Mardie Greensand by the company, has very high porosities averaging 38%, and permeabilities ranging from 900 to 1300 mD. These reservoir characteristics are more indicative of the Birdrong Sandstone than the Mardie Greensand. At 411 m, the basal Cretaceous unit unconformably overlies the Lower–Middle Triassic Locker Shale. At 515 m, Upper Permian shale with interbedded sandstone of the Chinty Formation (Kennedy Group) are present. The Abdul Sandstone is absent and the total depth was reached at 625 m within a tight limestone (594–625 m) assigned to the Cody Limestone of the Kennedy Group.

Biodegraded residual oil of 30° API has been extracted from the tight, lower part of the Muderong Shale and

Mardie Greensand. No shows of hydrocarbons were detected within the highly permeable unit between 369. 2 and 411 m, here assigned to the Flacourt Formation. In this area, a more attractive target would be provided where Flacourt Formation palaeotopographic highs are structurally higher than the onlapping Birdrong Sandstone. However, the contact between the Birdrong Sandstone and Flacourt Formation is difficult to resolve from the existing seismic data, as the combined units may only be 40–50 m thick. The structural map utilized for the well location shows mostly northerly trending faults (Fig. 48) in contrast to the northeasterly regional trend (Fig. 27). With more seismic control, an alternative interpretation of the small Crackling structure should be possible. The water-wet Permian section relies only on an unpredictable lateral seal along a fault plane, which if not present, may invalidate the closure.

Cunaloo 1

Cunaloo 1 was drilled in 1972 by WAPET within the Ashburton Embayment (Plate 1) to test the hydrocarbon potential of the basal Cretaceous sandstone in the seismically defined Cunaloo structure (Fig. 49), and to acquire information on the pre-Cretaceous stratigraphy. At the base of the Cretaceous succession, clear to white, medium to very coarse grained, loose sandstone was intersected over the interval 347–354 m, which was assigned by Meath (1972) to the Birdrong Sandstone with no palaeontological support. The overlying Muderong Shale was dated by Meath (1972, appendix 6.1) as Aptian, suggesting a stratigraphic gap between the two units. The interval 347–354 m is here tentatively assigned to the Locker Shale, as there is no discernible lithological difference between the sandstone within the interval and below it. This interpretation is supported by the stratigraphy in the closest wells, Abdul's Dam 1, in which the Muderong Shale overlies the Locker Shale, and Ruby 1, in which the Muderong Shale overlies 2 m of glauconitic Birdrong Sandstone. In Cunaloo 1, the sandy–shaly Locker Shale was penetrated below the basal Cretaceous unconformity down to 592 m, and is underlain by the Chinty Formation to total depth (798 m). Within the lower part of the Locker Shale, Hocking et al. (1987) proposed the interval 534 – 548.6 m as the type section of the Cunaloo Member. A cross section between Abdul's Dam 1, Ruby 1, and Cunaloo 1 is shown in Figure 38.

No evidence of significant hydrocarbons was seen in the section penetrated. The poor and limited seismic sections available to define the Cunaloo structure cast some doubt on its closure.

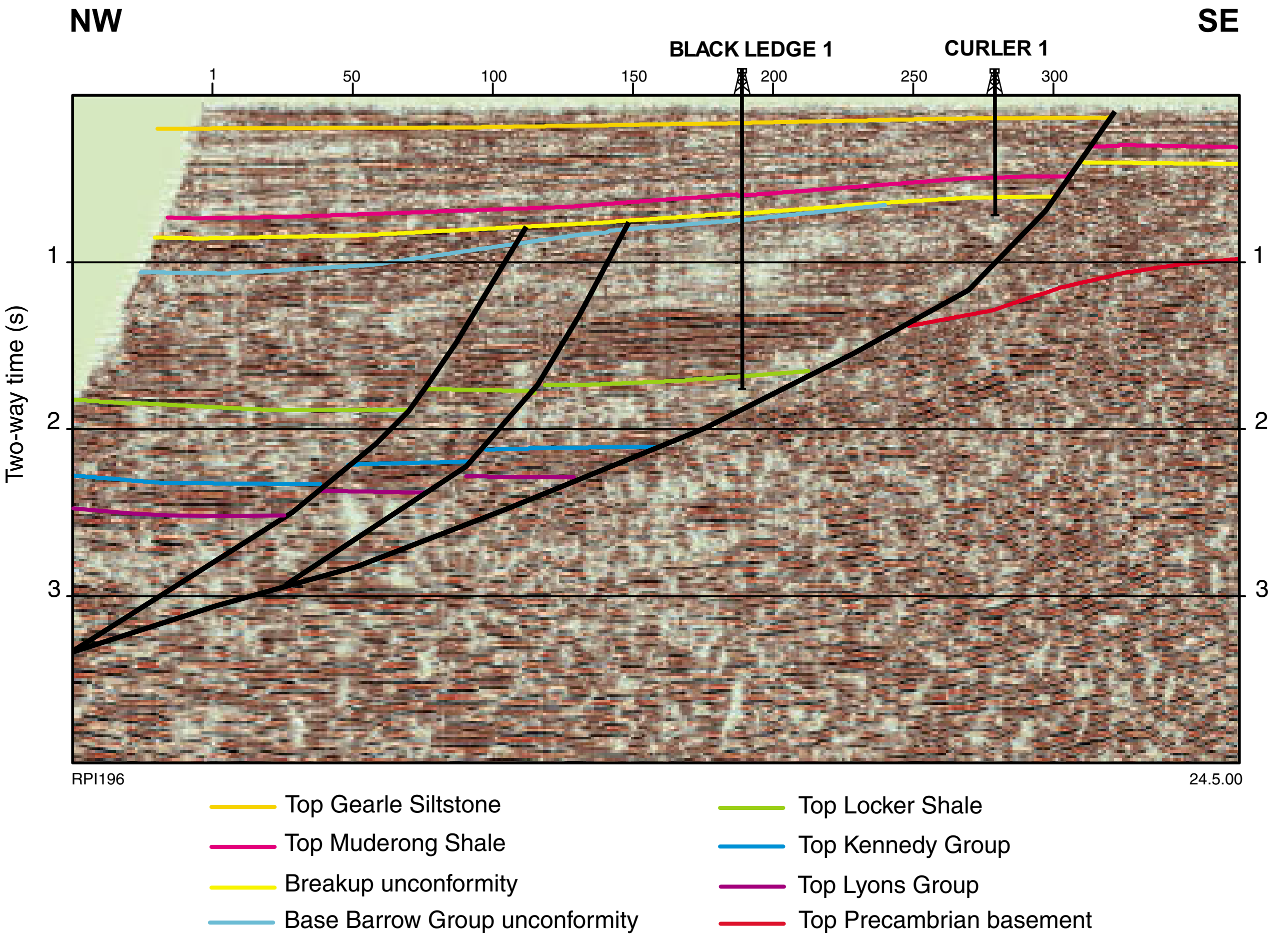


Figure 44. Seismic section B88-38M showing the structure at the Curler 1 prospect. The location of the section is shown in Plate 1

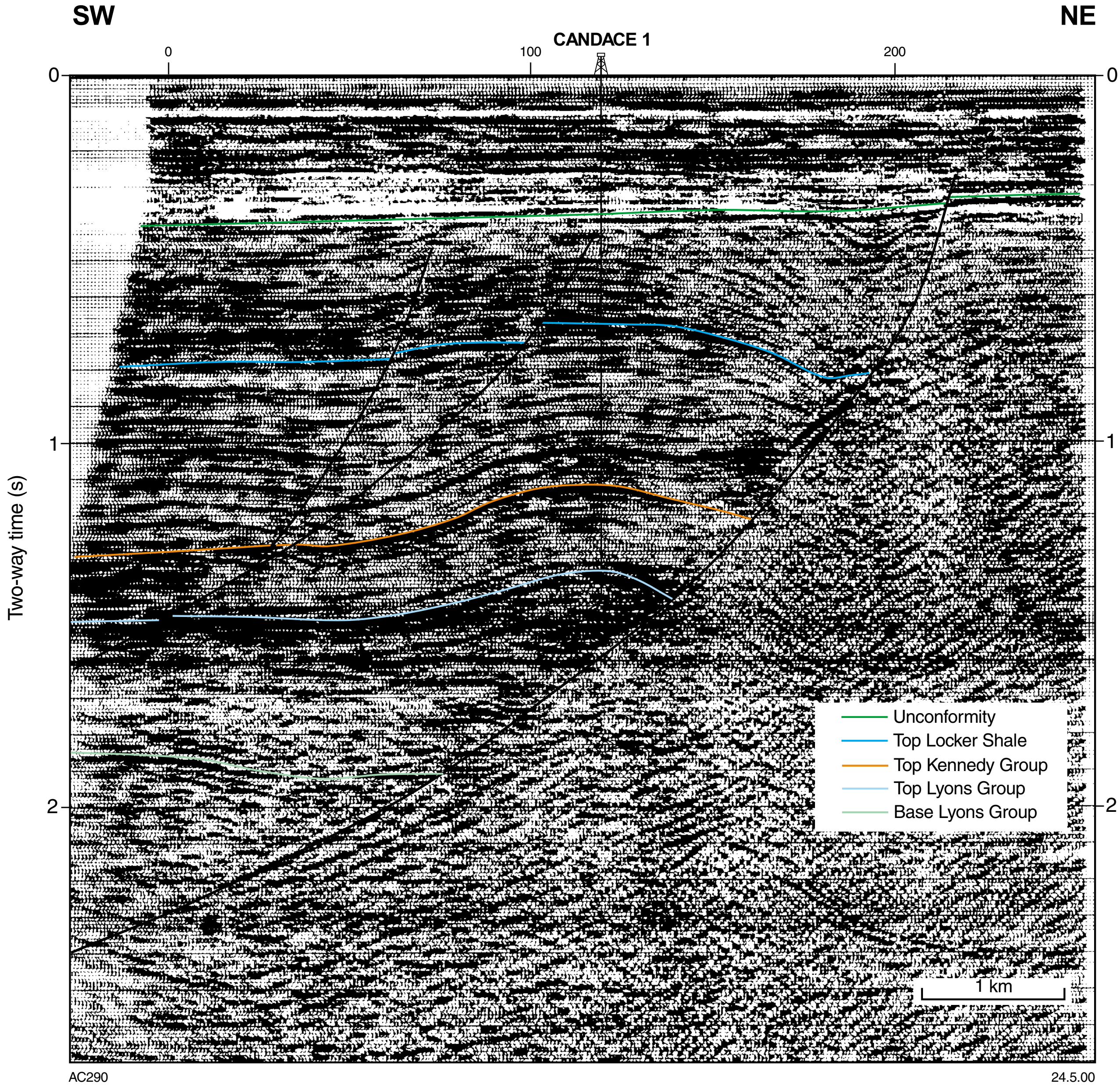


Figure 45. Seismic section 82-255 showing the structure at the Candace 1 prospect. The location of the section is shown in Plate 1

Direction 1

Direction 1 was drilled in 1968 as a stratigraphic test by WAPET on Direction Island within the Weld High (Plate 1).

At the base of the Cretaceous section, clean, colourless, fine-grained to pebbly sandstone, assigned by Reid (1968a) to the Birdrong Sandstone, was intersected between 458 and 478 m. The upper 7.6 m of this section is cemented by calcite, but the lower part is uncemented and friable, and shows good reservoir potential. The presence of plant remains and lack of glauconite suggest that the unit may be better assigned to the Flacourt Formation. If so, the breakup unconformity is at 458 m, and the overlying very fine to fine grained glauconitic sandstone between 442 and 458 m is the Birdrong Sandstone. The Flacourt Formation unconformably overlies the Chinty Formation of the Kennedy Group at 478 m, and a normal fault was intersected at 564 m where the Chinty Formation overlies undifferentiated Kennedy Group. The Kennedy Group unconformably overlies the Lyons Group at 630 m (Mory and Backhouse, 1997), in which the well was terminated at 673 m.

Reid (1968a) states that no significant hydrocarbon shows were found, although the gas log shows high background readings of methane over the entire Cretaceous section. A DST at the top of the Flacourt Formation, as interpreted here, yielded saltwater with a small flow of methane.

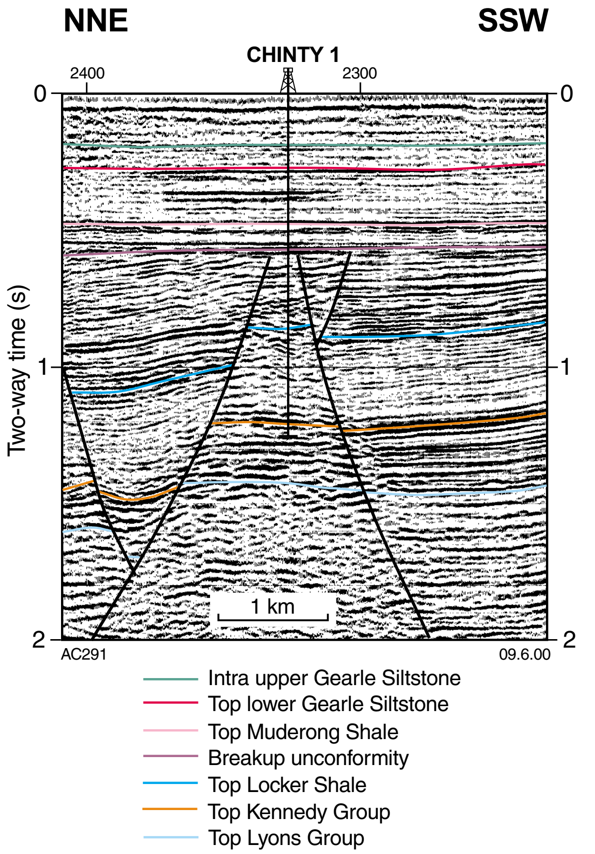


Figure 46. Seismic section J84A-011 showing the structure at the Chinty 1 prospect. The location of the section is shown in Plate 1

Fortescue 1

Fortescue 1 was drilled in June 1969 by WAPET on Long Island within the Candace Terrace, as part of their islands stratigraphic drilling program (Plate 1). The well was also intended to test sandstone of the Kennedy Group in a possible fault trap, updip from Sholl 1, and was thought to be located on the same fault block. The drilling showed that there is no trap at the Cretaceous level.

Below the Tertiary section, the Winning Group is represented by the partially eroded Windalia Radiolarite overlying the Windalia Sandstone Member, Muderong Shale, and a unit assigned by Reid (1969a) to the Mardie Greensand but here interpreted as the Birdrong Sandstone. The uncemented, clean, coarse quartz sandstone unconformably below the Winning Group was assigned to the Yarraloola Conglomerate by Reid (1969a), but it is here assigned to the Flacourt Formation. Beneath the Cretaceous section, the top of the Locker Shale was penetrated at 327 m, above the Chinty Formation (381 m), undifferentiated Kennedy Group (415 m), and the Lyons Group (498 m), in which the well was terminated at 610 m (Mory and Backhouse, 1997).

While drilling the Winning Group, very high methane gas readings were detected. The gas indications decreased gradually in the Flacourt Formation and then stayed low to total depth. It is believed that hydrocarbons are absent within the Upper Permian section because there is no trap (Reid, 1969a).

Glenroy 1

Following the good hydrocarbon shows seen in Onslow 1, Glenroy 1 was drilled in October 1966 by WAPET within the Onslow Terrace (Plate 1) to evaluate the hydrocarbon potential of the basal Cretaceous sandstone, updip from the former well. Glenroy 1 was located on a seismically defined, broad northerly plunging structural nose truncated by a fault downthrown to the north (Morris and Kempin, 1966).

Below 46 m of younger rocks, the Cretaceous succession was penetrated to the total depth of 648 m. The marine Winning Group — represented by the Gearle Siltstone, Windalia Radiolarite, Muderong Shale, and Birdrong Sandstone — overlies the continental Flacourt Formation of the Barrow Group. New subsurface data acquired over the area since the well was drilled indicate that the Flacourt Formation was penetrated at 543 m, and at 564 m it unconformably overlies the Mungaroo Formation (Appendix 5).

A DST in the Birdrong Sandstone yielded a large flow of water containing methane in solution, but no trace of oil. The water has a different salinity than that contained in the Flacourt Formation. Glenroy 1 failed to find

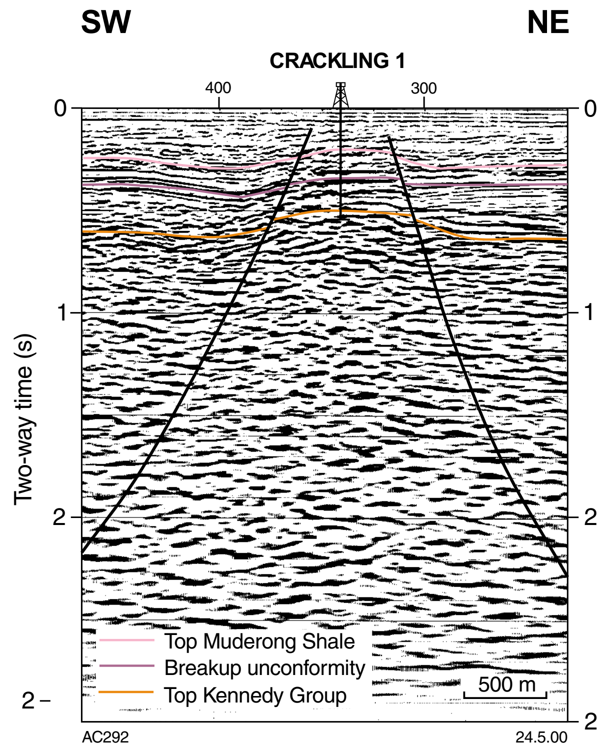


Figure 47. Seismic section C92-107 showing the structure, along strike, at the Crackling 1 prospect. The location of the section is shown in Plate 1

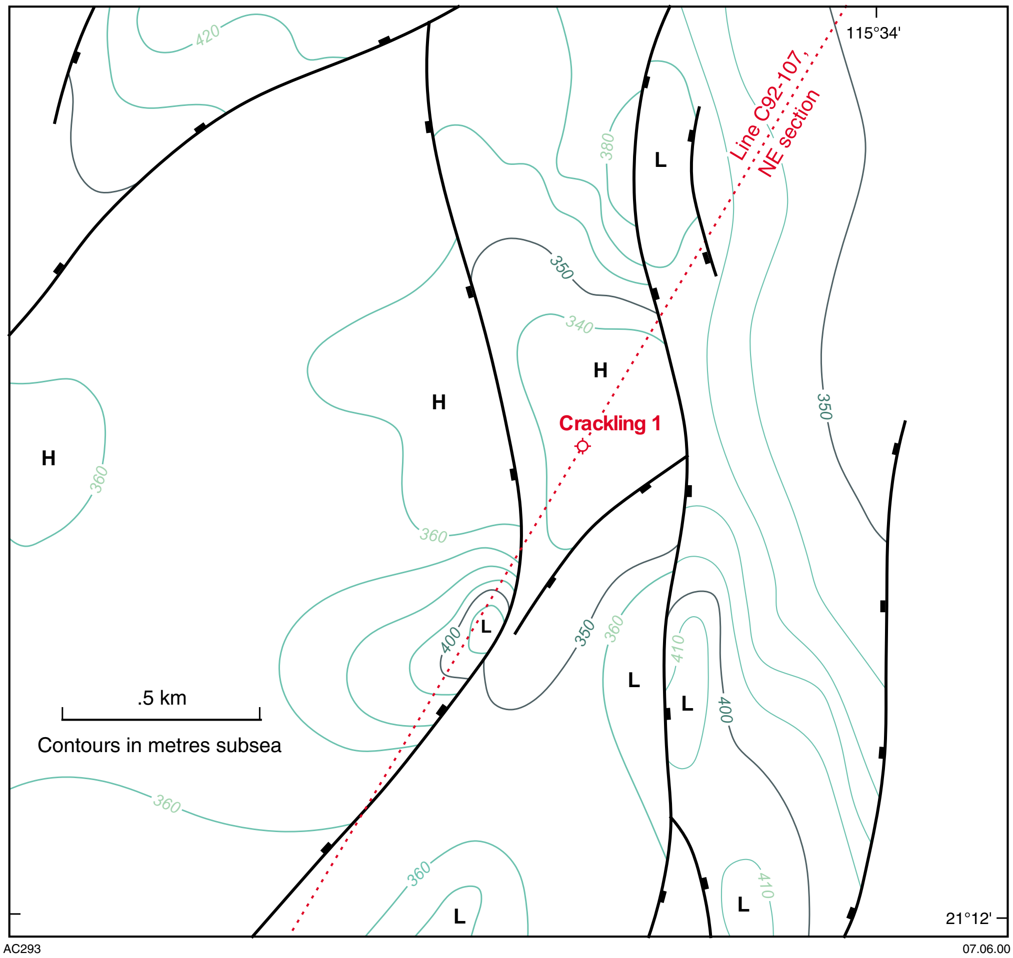


Figure 48. Pre-drill depth contours to the top Birdrong Sandstone of the Crackling structure (from Command Petroleum Holdings NL, 1994a)

an accumulation of hydrocarbons because the fault bounding to the north of the Glenroy nose does not provide a seal for hydrocarbon entrapment (Morris and Kempin, 1966).

Jade 1

Jade 1 was drilled in 1993 by Pan Pacific Petroleum NL on the southeastern part of the Onslow Terrace to test the hydrocarbon potential of the Birdrong Sandstone. The trap was expected to be a northeasterly trending, fault-dependent closure on the downthrown side of the Weelawarren Fault, the southwestern extension of the Flinders Fault (Plate 1). Dip closure is present in three directions, but the southeastern closure was critically dependent on the effec]tiveness of the Weelawarren Fault as a seal (Figs 50 and 51).

Pan Pacific Petroleum NL (1993a) reported the objective Birdrong Sandstone close to prediction between 490 and 501.5 m, and with good reservoir characteristics (average porosity 25%) but entirely water bearing. However, the lithological characteristics of the unit given by the company closely correspond to those of the Flacourt Formation, as present in the Tubridgi Gasfield (Thompson, 1992), 10–20 km to the southwest. Pan Pacific Petroleum NL (1993a) probably included the Birdrong Sandstone within the Mardie Greensand (476.5 – 490 m), which contains sandstone with good inferred porosity, but is otherwise tight due to the high clay content.

The Flacourt Formation unconformably overlies the Mungaroo Formation, which is present down to the total depth of 604 m. Sandstone in the Mungaroo Formation is also extremely porous and water bearing. No significant hydrocarbon shows were observed in the well, indicating that the Weelawarren Fault does not seal the Jade structure. A high level of background gas, almost entirely methane, is present throughout the Gearle Siltstone and Windalia Radiolarite, as is common in the region.

Jasper 1

Jasper 1 was drilled in October 1994 by Pan Pacific Petroleum NL within the Ashburton Embayment (Plate 1) to test the hydrocarbon potential of the Lower Cretaceous Birdrong Sandstone in an interpreted four-way dip closure covering 22 km^2.

Tertiary to Middle Carboniferous sedimentary rocks were penetrated to a total depth of 549.7 m. Beneath the Muderong Shale, Pan Pacific Petroleum NL (1995b) assigned the intervals 417.6 – 429.8 m and 429.8 – 457.7 m to the Mardie Greensand and Birdrong Sandstone respectively. The latter unconformably overlies the Carboniferous Quail Formation, in which the well was terminated. However, the cemented, marine greensand of the 417.6 – 429.8 m unit is assigned here to the Birdrong Sandstone, and the underlying, cement-free, continental subarkose and shale in the upper part (429.8 – 435.3 m), to the Flacourt Formation (429.8 – 458 m). The glauconitic Birdrong Sandstone has a sedimentary provenance whereas the Flacourt Formation has a granitic source (Pan Pacific Petroleum NL, 1995b). A gradual transition is indicated from the Birdrong Sandstone to the overlying Muderong Shale, the lower part of which is glauconitic. Typically, the unconformably underlying Flacourt Formation has a permeability of up to 6 D.

Low levels of methane were recorded throughout the Cretaceous section. Only minor shows of biodegraded oil without economic significance were present within the Birdrong Sandstone. The Carboniferous strata in the Jasper prospect are controlled by wrench faults, whereas the overlying Cretaceous and pre-Trealla Cainozoic beds are gently folded. In seismic section D93-01 (Fig. 52), the anticline has only ten milliseconds of vertical relief, but it is clearly recognizable at the top of the Muderong Shale. The structural setting of the lowermost Cretaceous horizons, however, gradually becomes less clearly defined, probably because of the localized presence of gas within the section. The seismic time-structure maps, and especially their conversion to depth, therefore become increasingly less reliable with depth, as is clearly shown by the inconsistencies between the various structural maps in Buchan (1994b). As the post-breakup structures are regionally related to the mid-Tertiary tectonic phase, the closures of each pre-Trealla stratigraphic horizon should be superimposed. The most reliable maps are the intra-Gearle Siltstone and top Muderong Shale (Fig. 53) time-structure maps, which indicate the presence of a small anticline of some 3–4 km^2 areal closure not tested by Jasper 1. The lack of hydrocarbons in Jasper 1 is probably due to the lack of structural closure at the top of the potential reservoir.

Kybra 1

Bond Corporation drilled Kybra 1 in 1987 on the western edge of the Candace Terrace, adjacent to the Flinders Fault System (Plate 1), to test the hydrocarbon potential of sandstone within both the Kennedy Group and the unknown ‘pre-Late Palaeozoic unconformity’ succession. A faulted trap, controlled to the south by a submarine ‘canyon’, was envisaged for the Kennedy Group and a fault-controlled fold for the ‘pre-Late Palaeozoic unconformity’ succession (Bond Corporation Petroleum Division, 1988).

The stratigraphic unit assigned by Bond Corporation Petroleum Division (1988) to the Birdrong Sandstone is here believed to be the Flacourt Formation, because it lacks glauconite, is slightly friable, and has good porosity.

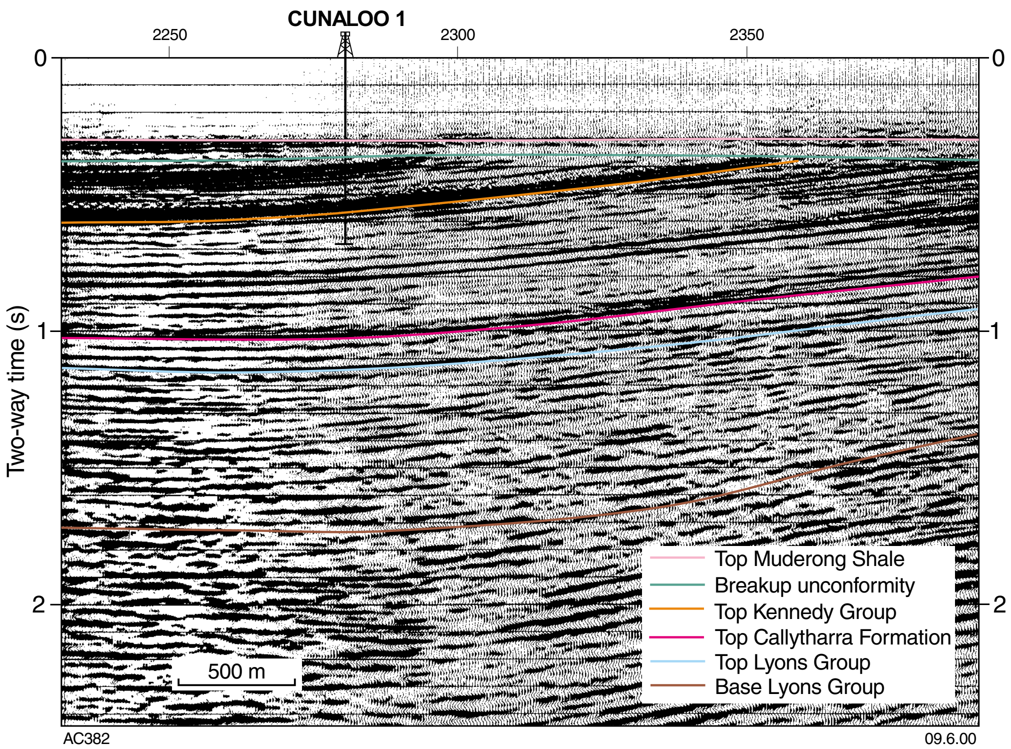


Figure 49. Seismic section J85A-159 showing the structure at the Cunaloo 1 prospect. The location of the section is shown in Plate 1

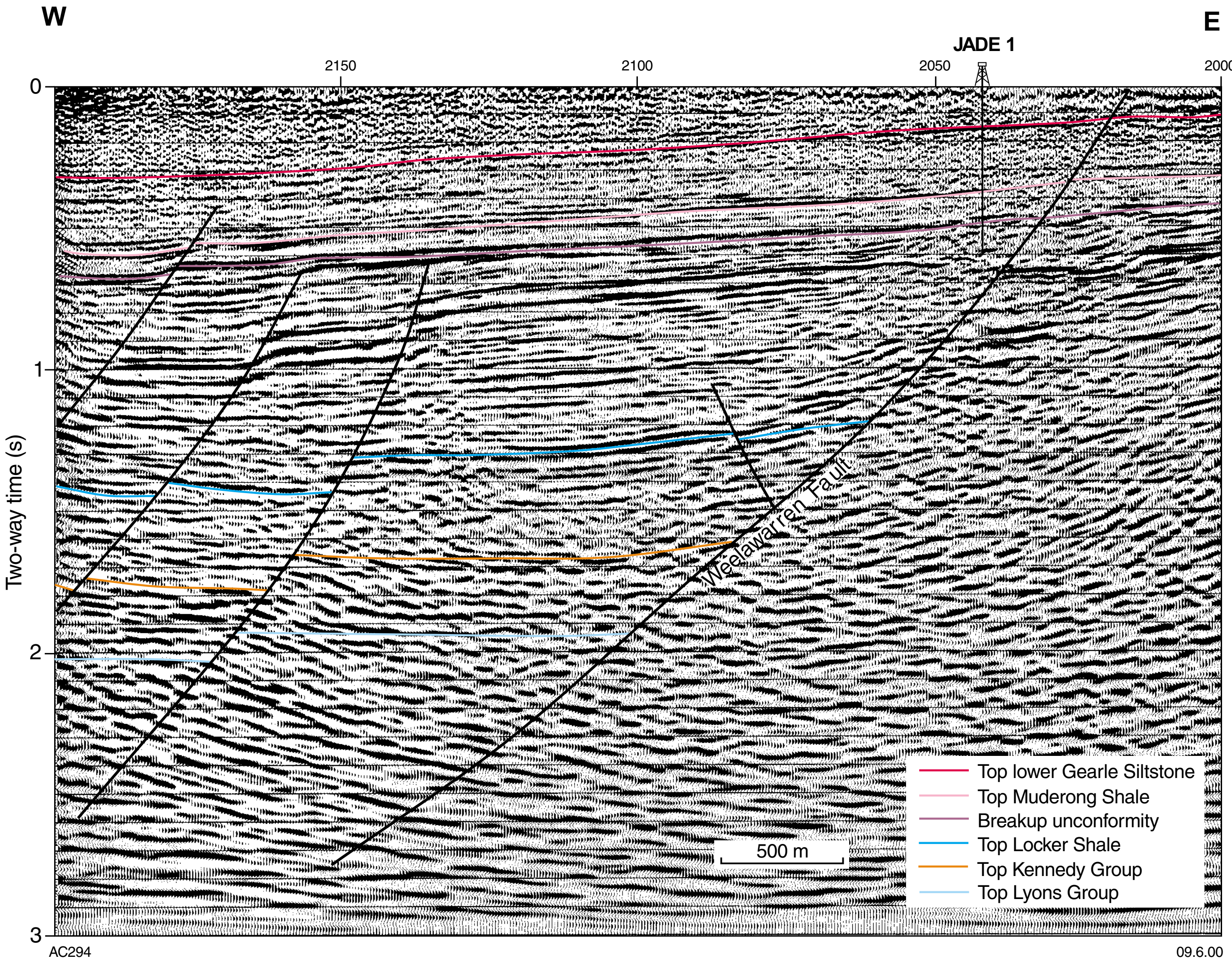


Figure 50. Seismic section J84A-039 showing the structure at the Jade 1 prospect. The location of the section is shown in Plate 1

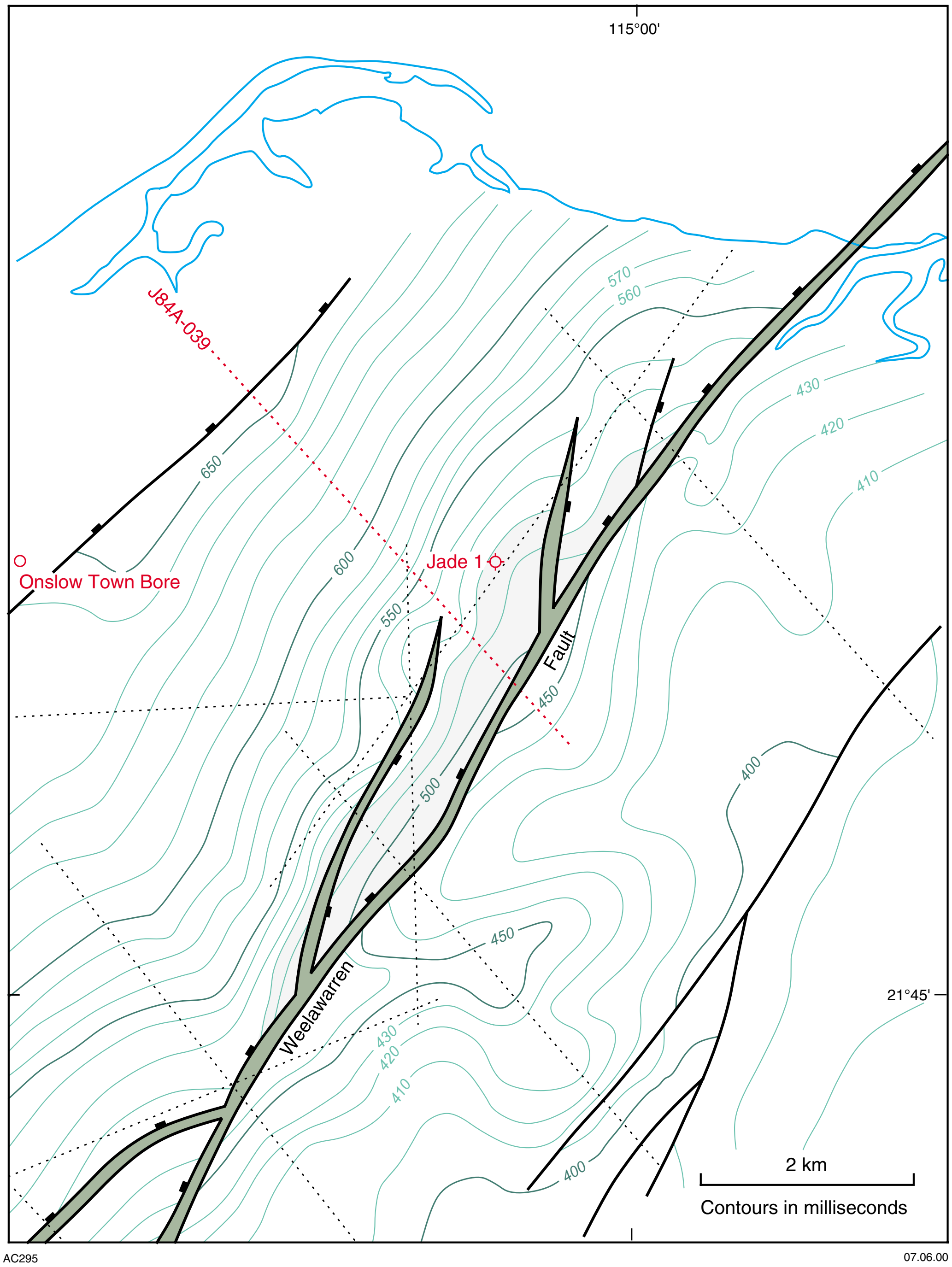


Figure 51. Two-way time contours of the basal Cretaceous unconformity in the Jade area (from Pan Pacific Petroleum NL, 1993a). The coastline is shown in blue

Below the Cretaceous section, the following units were penetrated in descending order: Mungaroo Formation (mainly sandy), Locker Shale, Kennedy Group (mostly sandy), and Lyons Group (mostly shaly) unconformably overlying the Lower Carboniferous Quail Formation and Moogooree Limestone. The succession assigned to the Byro Group is here interpreted as part of the Kennedy Group, which disconformably overlies the Lyons Group as in Candace 1 (Mory and Backhouse, 1997). Total depth was reached at 2562 m in the Moogooree Limestone.

No significant hydrocarbon shows were found in the well. The Quail Formation was intersected at the crest of a large fold in which the western flank has been downthrown to the west by the Jurassic Flinders Fault System (Fig. 12). The seismic interpretation of a 'canyon' is not supported by the drilling results. It is possible that hydrocarbons trapped within the pre-Late Carboniferous fold escaped because of Jurassic tectonism. The postulated objectives in the Kennedy Group would have relied on the sealing potential of the Flinders Fault System to the west,

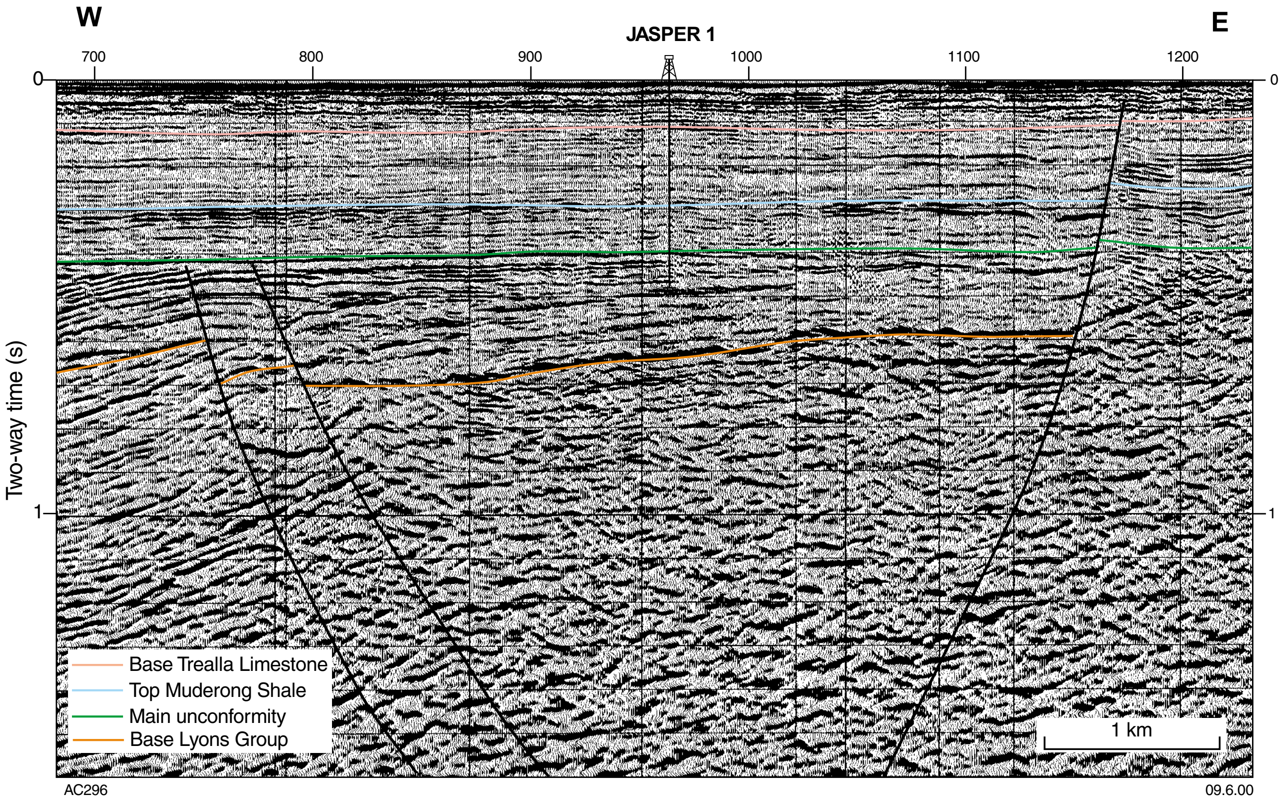


Figure 52. Seismic section D93-01 showing the post-breakup deformation at Jasper 1. The location of the section is shown in Plate 1

and to the south on the presence of a sealing 'canyon', but neither feature was verified by the well results. The main fault of the Flinders Fault System was locally rejuvenated in the Miocene and displaces the lowermost Cretaceous strata.

Locker 1

Locker 1 was drilled during June–July 1967 by WAPET on Locker Island within the Onslow Terrace as one of a series of stratigraphic wells (Plate 1). Structurally, the well was located on the northern plunge of the Yanrey Ridge where seismic data suggested a possible small anticlinal closure at the basal Cretaceous unconformity. The Mungaroo Formation was expected to have been eroded by Late Jurassic tectonism.

Beneath a thin Tertiary section, the Upper Cretaceous Toolonga Calcilutite and Winning Group were penetrated down to 624 m. The interval 606–634 m was assigned by Hosemann and Parry (1967) to an undifferentiated 'base Cretaceous sand'. The glauconitic sandstone of the upper interval (606–624 m) is here assigned to the Birdrong Sandstone, and the highly permeable conglomeratic sandstone of the lower interval (624–634 m) to the Flacourt Formation. The latter unit unconformably overlies the Mungaroo Formation, which is present down to the total depth of 766 m.

Shows of gas were detected while drilling the fine-grained sedimentary rocks of the Winning Group. Traces first appeared in the lower portion of the upper Gearle Siltstone, and increased to fair shows as drilling progressed into the Muderong Shale. The shows then decreased to background levels within the Mungaroo Formation. Some fluorescence was noted in the Windalia Radiolarite (core 1: 494–499 m) and Flacourt Formation (core 2: 627–633 m). A DST within the latter (627–633 m) yielded gas-cut saltwater — the flow pressure reached static formation pressure during the initial six minute flow period, confirming the regional optimal reservoir potential of the unit.

Structurally, the core from the Flacourt Formation shows subhorizontal strata, whereas the Mungaroo Formation contains dips of 5°.

Mangrove 1

Mangrove 1 was drilled in 1968 by WAPET within the Weld High (Plate 1), as one of the series of stratigraphic holes located on islands.

At the base of the intra-Neocomian post-breakup succession, a sandy unit named 'Muderong Greensand' by Andrejewskis (1968) was penetrated between 165.5 and 191 m. The unit, here believed to be equivalent to the Birdrong Sandstone, contains claystone between 177 and 183 m. Gas from this formation blew out of the well, but DST 1 and four re-runs over the interval failed, as no packer seat was obtained. The marine Birdrong Sandstone

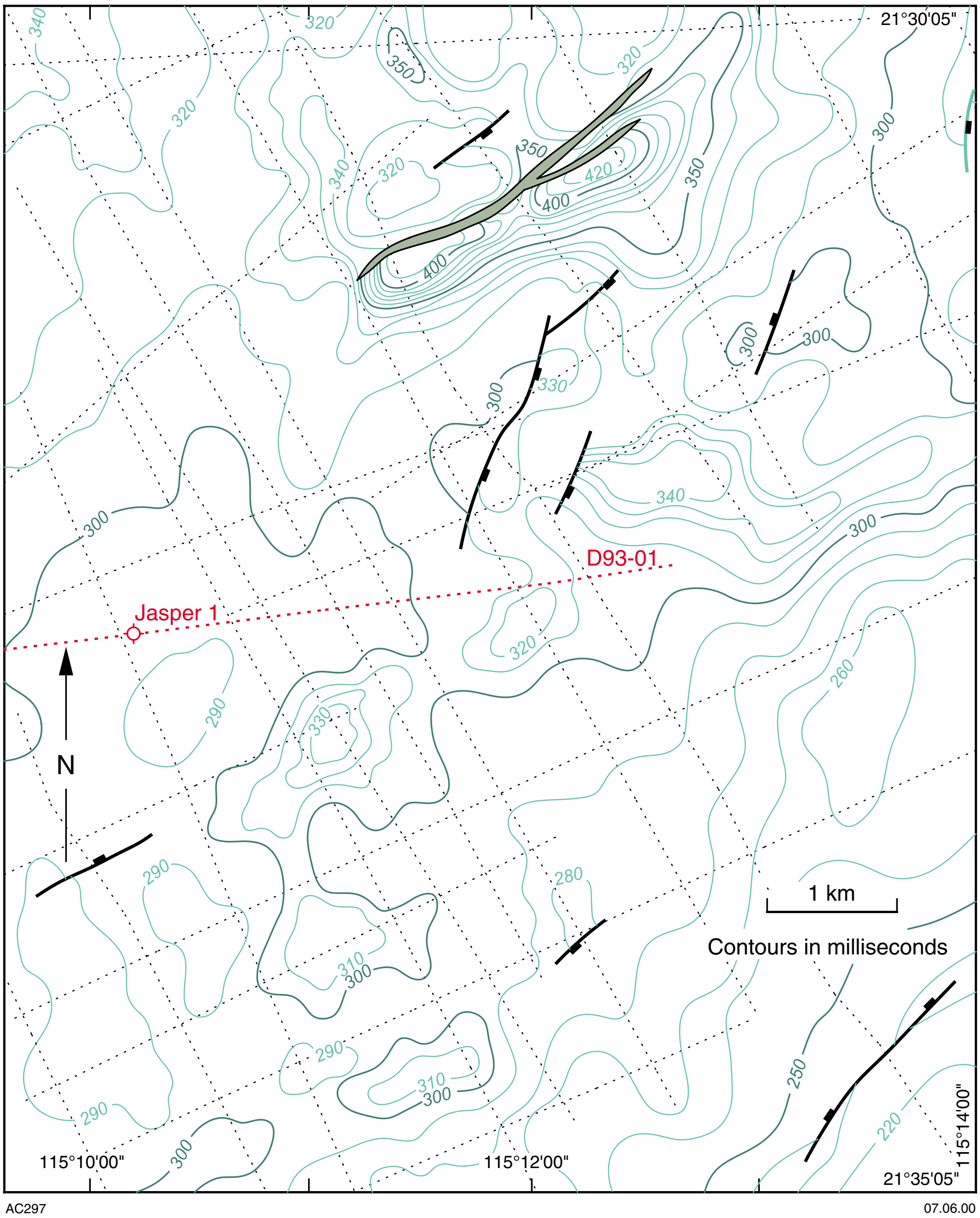


Figure 53. Two-way time contours of the top Muderong Shale in the Jasper area (after Buchan, 1994b). The dotted lines represent seismic lines

unconformably overlies the deltaic basal Cretaceous Barrow Group (191–208 m), which consists of sandstone in the top 3 m and conglomerate in the lower part of the section. DST 2, carried out over the interval 198–204 m, recovered a small amount of methane and 2.2 barrels of saline formation water. The Barrow Group unconformably overlies the Carboniferous–Permian Lyons Group, penetrated to 286 m (TD).

No information is available on the structural setting of Mangrove Island. If a trap is present, a gas accumulation is possible, but the tendency of the well to blow out implies a small reservoir with pressure greater than the hydrostatic pressure.

Mardie West 1

Mardie West 1 was drilled in December 1972 by Hematite Petroleum within the Robe Embayment, some 30 km to the northeast of the central part of the embayment where five other Mardie wells were drilled (Plate 1). Mardie West 1 was the fourth of a series of five shallow stratigraphic wells designed to investigate the potential for stratigraphically trapped hydrocarbons within the Lower Cretaceous rocks. No shows are mentioned in the poorly documented completion report (Hematite Petroleum Pty Ltd, 1973). The well was drilled to a total depth of 135 m.

Mary Anne 1

Mary Anne 1 was drilled in May 1968 by WAPET on the southern end of Large Island in the Mary Anne group of islands (Plate 1), as one of a series of shallow stratigraphic wells.

In Mary Anne 1, the Upper Cretaceous Toolonga Calcilutite and Winning Group are present below Quaternary and Tertiary carbonates. The lower Neocomian Flacourt Formation was first intersected at 326 m and unconformably overlies siltstone, shale, and sandstone of the Lower–Middle Triassic Locker Shale (351–533 m, TD). Lyons (1968) assigned the interval 326–351 m to the Birdrong Sandstone, but the fine to very coarse grained, unconsolidated sandstone grading downwards to conglomerate he described fits better with the regional description of the Flacourt Formation. The glauconitic sandstone from the interval 301–326 m contains common shell fragments, crinoid stems, and foraminifera, and was assigned to be the Muderong Shale by Lyons (1968), but is here considered to be the Birdrong Sandstone. Dipmeter data indicate that bedding within the Locker Shale is horizontal. High gas readings, up to five times the average background gas, were recorded whilst drilling the Windalia Radiolarite and Muderong Shale.

A gas peak nine times the background was registered within the Flacourt Formation. No fluorescence was observed in any of the 34 sidewall cores. A DST over the interval 324–334 m, in correspondence to the gas peak within the Flacourt Formation, yielded a strong flow of gas-cut saline formation water.

Minderoo 1

Minderoo 1 was drilled as a stratigraphic well by WAPET in April 1963 within the Ashburton Embayment (Plate 1) in order to define the petrophysical characteristics of the Lower Cretaceous and underlying strata.

Minderoo 1 demonstrated the presence of the Birdrong Sandstone, which is composed of 45 m of predominantly medium grained, porous, but non-glauconitic sandstone. The unit was tentatively assigned an Aptian age by Johnston et al. (1963, appendix F). Unconformably below the Cretaceous at 387 m is the Carboniferous–Permian Lyons Group in which the well was terminated at 610 m.

Structurally the Cretaceous strata dip gently to the west-northwest away from nearby Precambrian basement. An angular unconformity is present between the Birdrong Sandstone and underlying Lyons Group, in which dips of approximately 10–15° are evident in cores 7 and 10–12.

North Sandy 1

North Sandy 1 was one of the series of stratigraphic wells drilled by WAPET on near-shore islands. The well was drilled in 1968 on North Sandy Island within that part of the Candace Terrace where the Flinders Fault System is represented by a set of down-to-the-basin, subparallel faults (Plate 2; Fig. 22, section AA').

Beneath the Cainozoic section, the presence of the Toolonga Calcilutite above the Winning Group was not demonstrated, due to a lost circulation zone. No sandstone is present at the top of the Muderong Shale. The interval 311–332 m was included within the Muderong Shale by Reid (1968b), but the presence of glauconitic siltstone and sandstone suggests that it represents the Birdrong Sandstone. Reid (1968b) placed the interval 332–369 m in the Birdrong Sandstone, but here it is assigned to the Flacourt Formation. This unit overlies the Mungaroo Formation, which is present to 512 m, and the Locker Shale to the total depth of the well (609.6 m).

Several indications of dry gas were recorded within the Winning Group. A DST run over the interval 329–338 m (basal Birdrong Sandstone to top of the Flacourt Formation) resulted in a flow of gas-cut formation water, which reached the surface after 10 minutes, confirming the high permeability of the unit. Heavy oil was present within the Windalia Radiolarite (core 1), but core analysis indicated low permeability.

Onslow 1

Onslow 1 was drilled by WAPET in 1966 in the Onslow Terrace (Plate 1) to investigate the then unknown stratigraphy of the area and the hydrocarbon potential of a seismically defined anticline (Jones, 1967). At the base of the Tertiary–Cretaceous, marine regional succession, the well penetrated 32 m of sandstone, assigned to the Flacourt Formation by Thompson (1992). This sandstone unconformably overlies the Triassic Mungaroo Formation, which overlies the Locker Shale. Below the Locker Shale, Jones (1967) interpreted the Kennedy Group (2096–2258 m) to overlie the Byro Group (2258–2644 m) and Wooramel Group (2644–2707 m). However, palynological analysis by Mory and Backhouse (1997) has shown that the Chinty Formation (2096–2258 m) overlies undifferentiated Kennedy Group (2258–2495 m). Furthermore, there is a substantial time break between the Callytharra Formation and the overlying Kennedy Group at 2495 m, which does not correspond to the time of deposition of the Byro and Wooramel Groups.

As is typical of the region, significant gas shows were recorded in the lower part of the Gearle Siltstone, and fluorescence and gas were recorded from the Flacourt Formation. Two DSTs run across the Flacourt Formation, however, yielded only saltwater with heads of gas. With the benefit of additional seismic and well control, Thompson (1992) suggested that Onslow 1 tested the low-relief Tubridgi anticlinal structure at the gas-water contact; therefore, just missing the Tubridgi Gasfield.

Picul 1

Picul 1 was drilled in 1992 on the Onslow Terrace (Plate 1) by Pan Pacific Petroleum NL to test the hydrocarbon potential of the Birdrong Sandstone within a large structural closure, defined at the breakup unconformity level (Fig. 54).

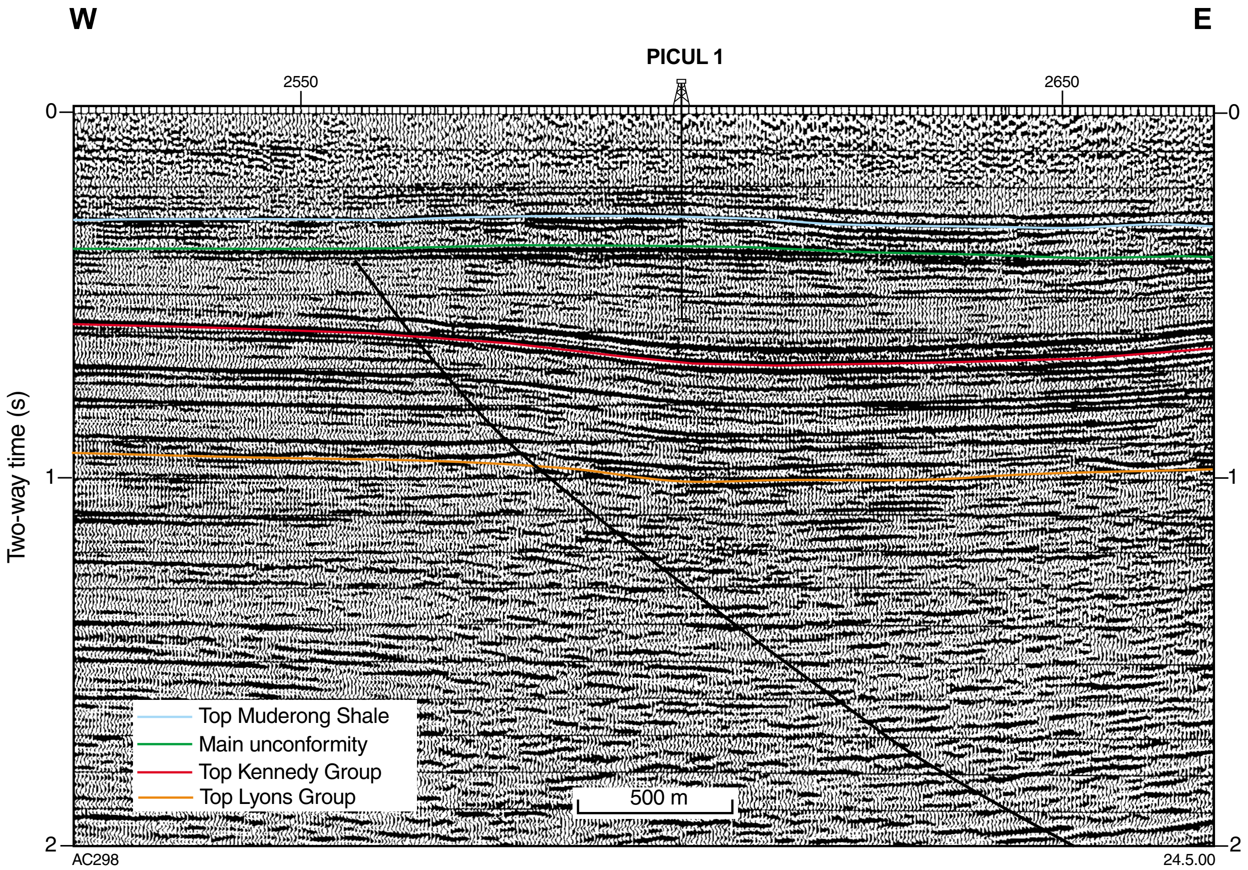


Figure 54. Seismic section J84A-012 showing the structure at the Picul 1 prospect. The location of the section is shown in Plate 1

In Picul 1, the regional Tertiary to Cretaceous stratigraphic succession was penetrated down to the Muderong Shale (377 m), which unconformably overlies a section here assigned to the Mungaroo Formation. The well bottomed in the Mungaroo Formation at a total depth of 500.8 m. The Picul structure was estimated by converting seismic time to depth, to have a closure 20 km^2 in area with a vertical relief of 30 m (Pan Pacific Petroleum NL, 1993b). On the seismic section shown in Figure 54, the structure is clearly evident at the basal Cretaceous unconformity, as well as at the top of the Muderong Shale and Windalia Radiolarite. Shallower horizons cannot be differentiated in the seismic data, but are expected to be conformable up to the Middle Miocene. The Picul structure is interpreted to be a Tertiary anticline, similar to the Tubridgi structure, because all mappable Cretaceous horizons are subparallel.

Minor oil shows were encountered in greensands within the Muderong Shale, but their low permeabilities discouraged any testing. This oil was derived from a terrestrial source rock, but is severely biodegraded (Fig. 55).

The lack of the postulated objective is the obvious reason for the lack of hydrocarbons in Picul 1. It has been suggested that the Birdrong Sandstone may have been deposited as bars and islands in relatively high areas (Pan Pacific Petroleum NL, 1993b). The Birdrong Sandstone,

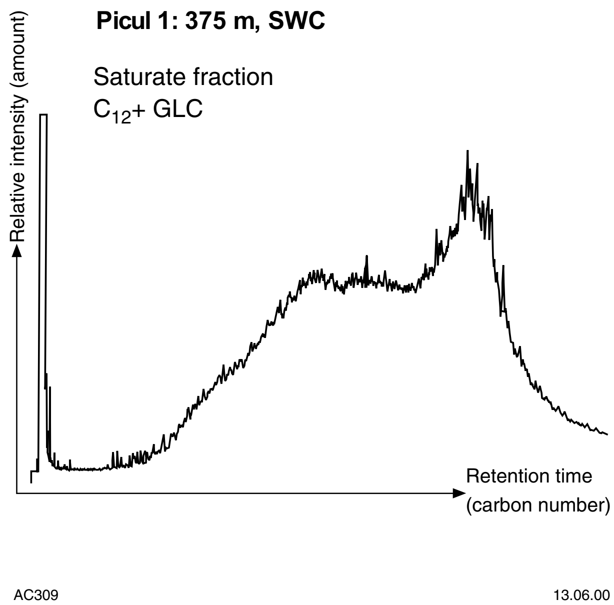


Figure 55. Gas chromatograph of sidewall core at 375 m from Picul 1, showing C_{12}+Gas Liquid Chromatography (GLC) saturate fraction

however, formed as the widespread mid-Neocomian marine transgression advanced, incorporating, or in places totally reworking, sandstone of the uppermost Flacourt Formation or equivalent pre-existing unconsolidated sediments (Hocking et al., 1987). Therefore, it is possible that basal Neocomian, coarse-grained clastic rocks are present in the undrilled northern part of the Picul structure, closer to the Tubridgi Gasfield.

Robe Embayment wells

From 1967 to 1993 a total of 27 wells were drilled in an area of approximately 400 km^2 within the central part of the Robe River Embayment (Appendix 1; Plate 1) to appraise the hydrocarbon potential of the Cretaceous succession. The potential of the area appeared attractive to several companies, as the Cretaceous objectives are shallow. Some wells, however, were drilled deeper to also test pre-Cretaceous objectives. The interest of oil companies in the central Robe River Embayment was provoked by a blow-out of gas with 20 litres of oil from a 77 m-deep shot-hole, drilled in 1966–1967 by WAPET during the first seismic survey in the area. Numerous hydrocarbon occurrences have been found since then, but no oil- or gasfields have been discovered.

The first exploration drilling activities were carried out by WAPET, who drilled 16 wells from 1967 to 1974. Avon Engineering commenced a new exploration phase in 1979 with an aeromagnetic and three seismic surveys. The first seismic survey was carried out using dynamite as the source of energy and provided poor results. Consequently, two other surveys were later carried out using vibroseis as the energy source. Seven wells followed from 1982 to 1984. Following further acquisition of seismic data, Somelim 1 was drilled by Metana Energy in 1989, and East Somelim 1 and Mardie 1B were drilled by Lennard Oil NL in 1991 (Lennard Oil NL, 1991b). Stirling Resource NL commenced exploration activities in the area in 1992 and conducted a testing program by re-entering Mardie 1B, Murnda 1, Windoo 1A, Thringa 1, and Mardie 2. The company subsequently drilled Mardie 3 in 1993.

The main objectives of the exploration wells were the Mardie Greensand and sandstone within the Muderong Shale, as no significant hydrocarbons were found in the Yarraloola Conglomerate and Lower Carboniferous – Upper Devonian targets. In particular, the strong artesian flow of water from the Yarraloola Conglomerate in several wells was so abundant that drilling programs were implemented to avoid this interval. Special drilling fluids and drilling techniques were used in wells such as Carnie 1 (Furr and Allchurch, 1982) to avoid formation damage, but there is no evidence for significant hydrocarbon-bearing zones having been missed due to such damage (Fig. 56). Gas flows at rates too small to measure associated with water production from essentially undamaged DST intervals in Glenroy 1A, North Sandy 1, and Surprise 1 and are consistent with levels of gas coming out of solution of formation water (Havord, 1999).

Hydrocarbon occurrences in the Mardie Greensand and sandstone within the Muderong Shale have been penetrated in the majority of the wells, of which the most significant are listed in Table 2. The prevalently bio-degraded oil (14–20° API) is interpreted to be residual and

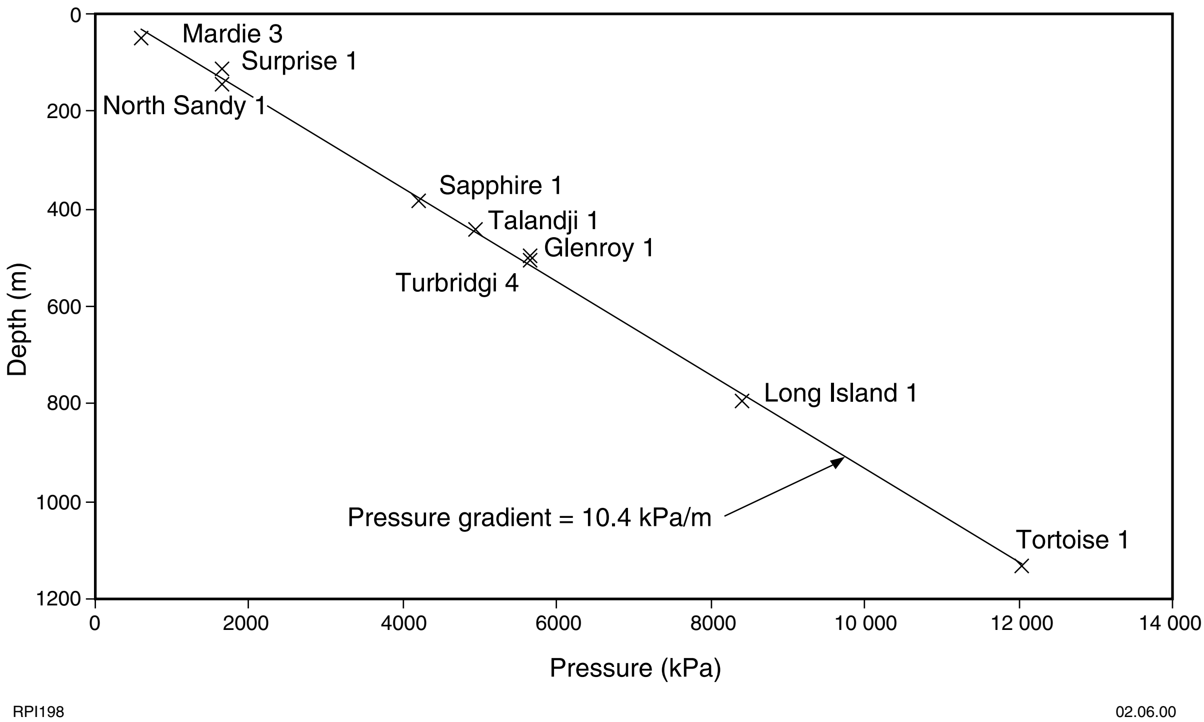


Figure 56. Pressure–depth relationship for extrapolated pressures from DSTs of selected wells on the Peedamullah Shelf (from Havord, 1999)

Table 2. Significant hydrocarbon occurrences in wells drilled within the Robe Embayment

Well	*Hydrocarbons*	*Type of test*	*Depth (m)*	*Stratigraphic unit*	*Reference*
Carnie 1	30 MCFD of dry gas decreasing rapidly	Production test	148.2 – 152.0	Mardie Greensand	Furr and Allchurch (1982)
Mardie 1	10–20 MCFD gas declining to 7 MCFD; 14.5 – 20° API oil from core	Production test	154–158	Mardie Greensand	Bowering and Parry (1968)
Mardie 1A	14.5 – 20° API oil from core; 1–3 BBL oil; low rates of gas	Production test	153.3 – 164.3	Mardie Greensand	Allchurch (1982)
Mardie 1B	98–110 MCFD gas	Production test	86.5 – 92.5	Intra-Muderong Sandstone	Stirling Resources NL (1993)
Mardie 2	Unstabilized 15 BOPD (38.5° API); only a few litres recovered; 40 MCF of gas	Production test	61.2 – 63.45	Intra-Muderong Sandstone	Stirling Resources NL (1993)
Mardie 2	0.25 barrels of oil; 200 MCFD of gas; flow rate diminishing with time	Production test	57.6 – 62.4	Intra-Muderong Sandstone	Lipski (1995)
Mulyery 1	40 MCFD of gas	Production test	123–128	Birdrong Sandstone	Jones (1968)
Murnda 1	40 MCFD of gas	Production test	163–169	Mardie Greensand	Stirling Resources NL (1993)
Sharon 1	Unspecified amount of oil and gas	Production test	172.5	Mardie Greensand	Hartung-Kagi (1987)
Thringa 1	Gas to surface at a rate too small to measure	Production test	92–95	Intra-Muderong Sandstone	Stirling Resources NL (1993)
Thringa 1	Unstabilized gas flow	Production test	162.4 – 16.5	Mardie Greensand	Stirling Resources NL (1993)
Uphole drilled at SP 1374.5 on Mardie-Line-A	20 litres 19.5° API oil	Blow-out	Unknown	Mardie Greensand or Yarraloola Conglomerate	Bowering and Parry (1968)
Windoo 1A	Up to 298 MCFD gas, declining with time	Production test	154.5 – 168.8	Mardie Greensand	Stirling Resources NL (1993)

NOTES: BOPD: barrels of oil per day
MCF: thousand cubic feet
MCFD: thousand cubic feet per day
API: American Petroleum Institute specific gravity scale
BBL: barrels

the gas is almost entirely methane with traces of ethane (Stirling Resources NL, 1993). The majority of these occurrences are low-pressure dry methane (Table 1), which is considered to have migrated into the embayment after the oil, probably causing the biodegration. No economically significant hydrocarbon accumulations were discovered. The high gas background, reaching 8% (methane only), is attributed to solution gas. Mardie 2, however, yielded 15 barrels per day of light oil (38.5° API) during testing.

Within the Cretaceous section, it appears that only the tighter sandstone has reservoired hydrocarbons in small traps, controlled by permeability barriers, without economic potential. Thomas (1978) speculated that the abundance of the oil shows in the Robe Embayment was due to regional migration of oil into a Late Tertiary hydrodynamic trap. Subsequently, the oil was biodegraded and the trap was breached, leaving pockets of oil in low permeability sandstones, mainly in the Mardie Greensand. The mapped structural closures are either incorrect — for example, East Somelim 1 ‘structure’ was found not to exist (Lennard Oil NL, 1991a) — or insufficient to control the hydrodynamic pressure of the underlying Yarraloola Conglomerate aquifer.

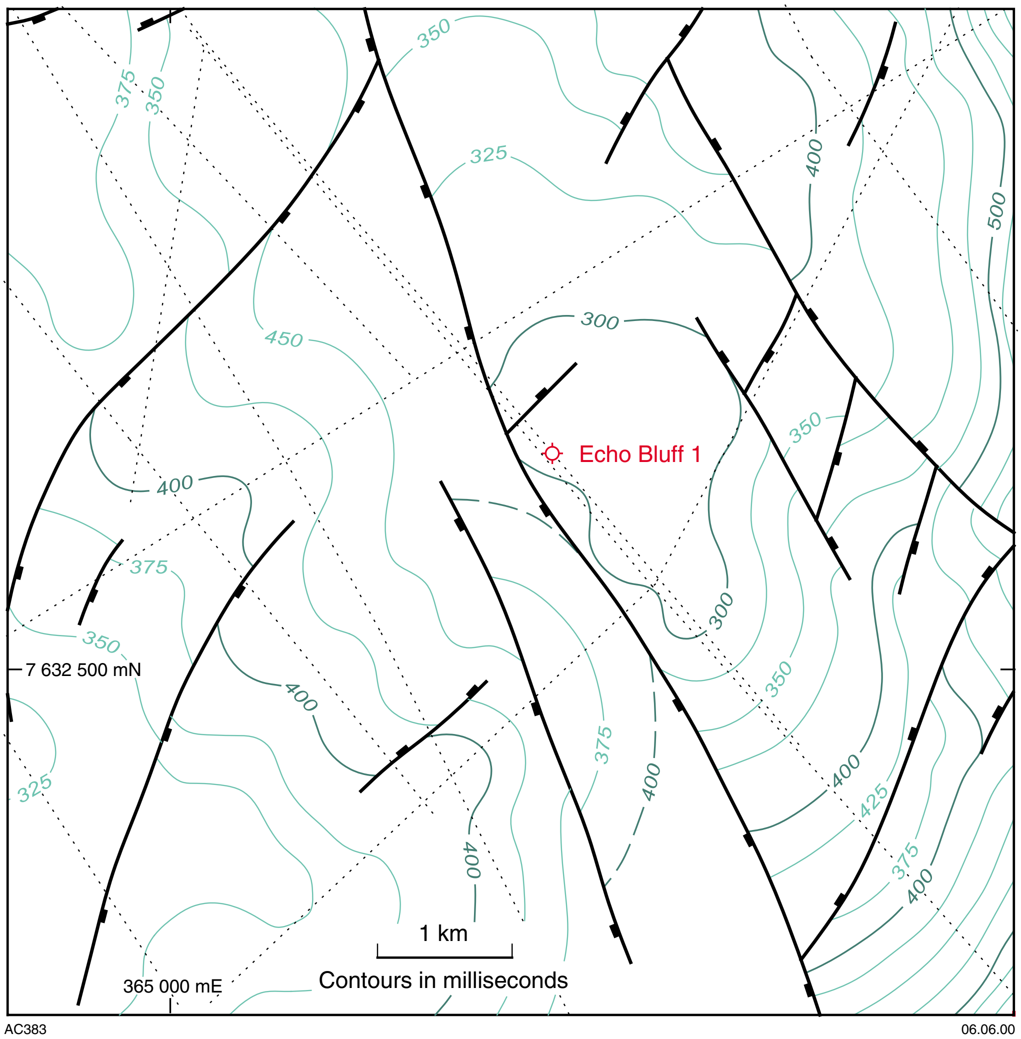


Figure 57. Two-way time contours of the top Yarraloola Conglomerate for the Echo Bluff 1 prospect (from Allchurch, 1984)

Sandstone beds within the Muderong Shale are lenticular, of varying reservoir quality, and very limited in both thickness and areal distribution. The pre-Cretaceous targets exhibit good reservoir potential in Echo Bluff 1, but the presence of an effective trap that depends on fault closure (Figs 57 and 58) was not confirmed. Furthermore, Echo Bluff 1 was structurally poorly located (Allchurch, 1984). The Lower Carboniferous – Middle Devonian objectives may, however, still be valid, although defining suitable traps is difficult.

Ruby 1

Ruby 1 was drilled within the Onslow Terrace by Pan Pacific Petroleum NL in 1996, approximately 4 km south-southeast of Abdul's Dam 1 and 46 km southwest of Onslow (Plate 1). The well was drilled to test the hydrocarbon potential of a porous Permian sandstone (Abdul Sandstone) penetrated in Abdul's Dam 1.

The regional stratigraphy was penetrated from the Trealla Limestone to the intra-Neocomian unconformity at 400 m. Above the unconformity, 2 m of ?Mardie Greensand were reported by Mills (1997a). To be regionally consistent, however, this glauconitic, predominantly coarse grained, unconsolidated sandstone is assigned here to the Birdrong Sandstone.

Below the intra-Neocomian unconformity, two Permian units were penetrated and assigned by Mills (1997a) to the Nalbia Sandstone (400 – 449.5 m) and Wandagee Limestone (449.5 – 500 m, TD) of the Lower Permian Byro Group. Palynological control (Appendix 4), however, indicates that these units are within the Upper Permian Kennedy Group and are assigned here to the Abdul Sandstone and Cody Limestone respectively.

The Ruby 1 trap was interpreted as a large, seismically defined, combined truncation and fault trap, updip of Abdul's Dam 1 (Fig. 59). The interpreted structure has an approximate areal closure of 30 km^2 and vertical relief of 45 m. The eastern and southern margins of the prospect were defined along the Wandagee Fault, whereas the western and northern margins consist of the pre-Cretaceous section subcropping against the intra-

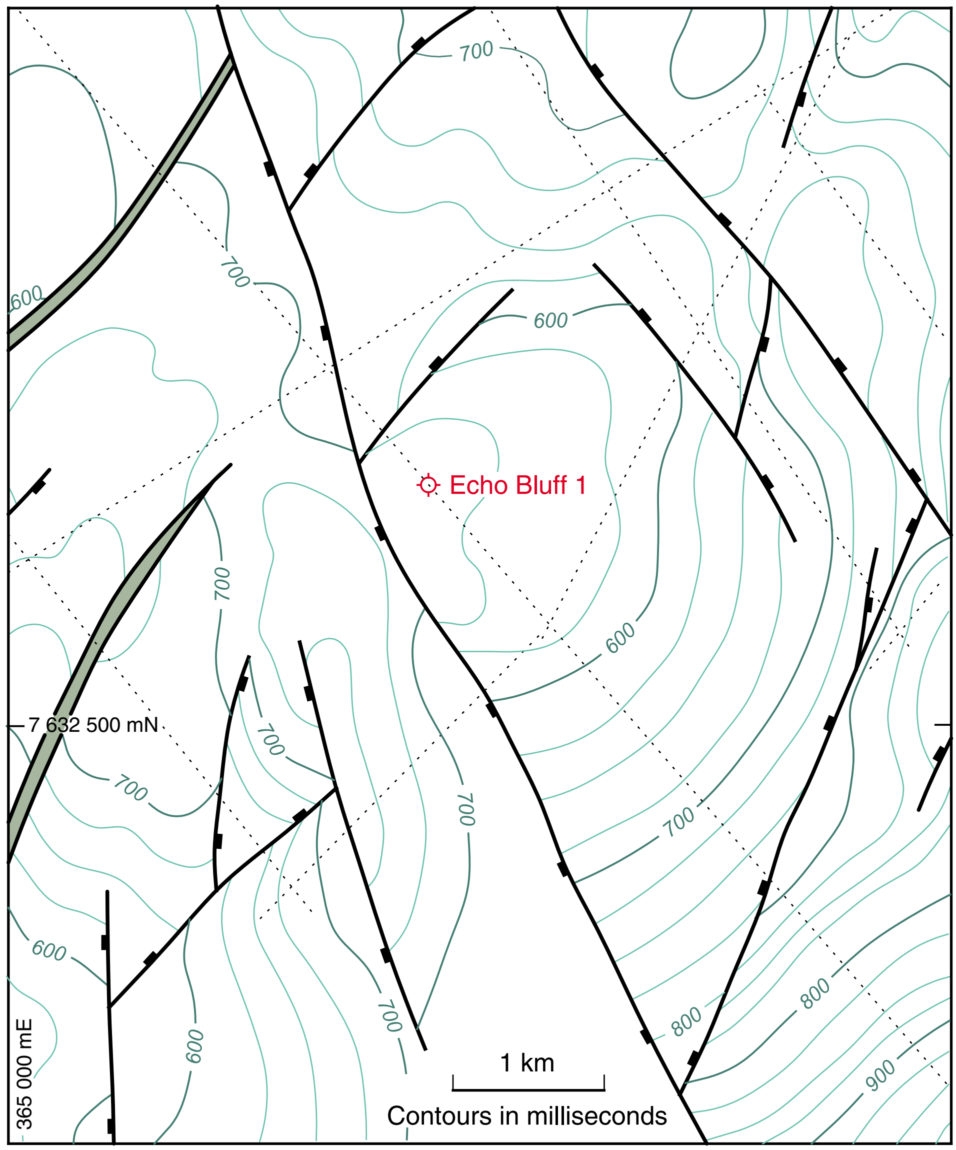


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Figure 58. Two-way time contours of an intra-Devonian horizon for the Echo Bluff 1 prospect (from Allchurch, 1984)

Neocomian unconformity. The postulated trap, therefore, relied on the presence of a regional seal above the unconformity.

No significant hydrocarbon indications were encountered even though the Abdul Sandstone has good reservoir potential, with an average porosity of 25% in this well.

The presence of a 2 m-thick sandstone overlying the intra-Neocomian unconformity (Fig. 38) invalidates the postulated trap because it destroys the seal integrity over the prospect (Mills, 1997a). Lack of trap is thus the reason for failure in Ruby 1.

Santa Cruz 1

Santa Cruz 1 was drilled offshore within the Onslow Terrace (Plate 1) by Command Petroleum Holdings NL in November 1993 to test the hydrocarbon potential of the Lower Cretaceous Birdrong Sandstone and possible pre-breakup objectives. A small, low-relief closure was mapped at depth (Fig. 60). The seismic section indicates flat-lying strata at the level of the Gearle Siltstone and Muderong Shale (Fig. 61).

The Cainozoic section was not sampled and the Cretaceous can be closely correlated with the regional succession, although the Windalia Radiolarite appears to be absent. A poorly permeable section of Mardie Greensand, of nearshore marine origin, was identified at 417.3 m, overlying a unit with poor reservoir quality at 432.3 m assigned to the Birdrong Sandstone by Command Petroleum Holdings NL (1994b). In the interval 432.3 – 456 m, interpreted as fluvial channels, the presence of only minor glauconite and the *B. eneabbaensis* palynozone dominated by spores with pollen and very few long-

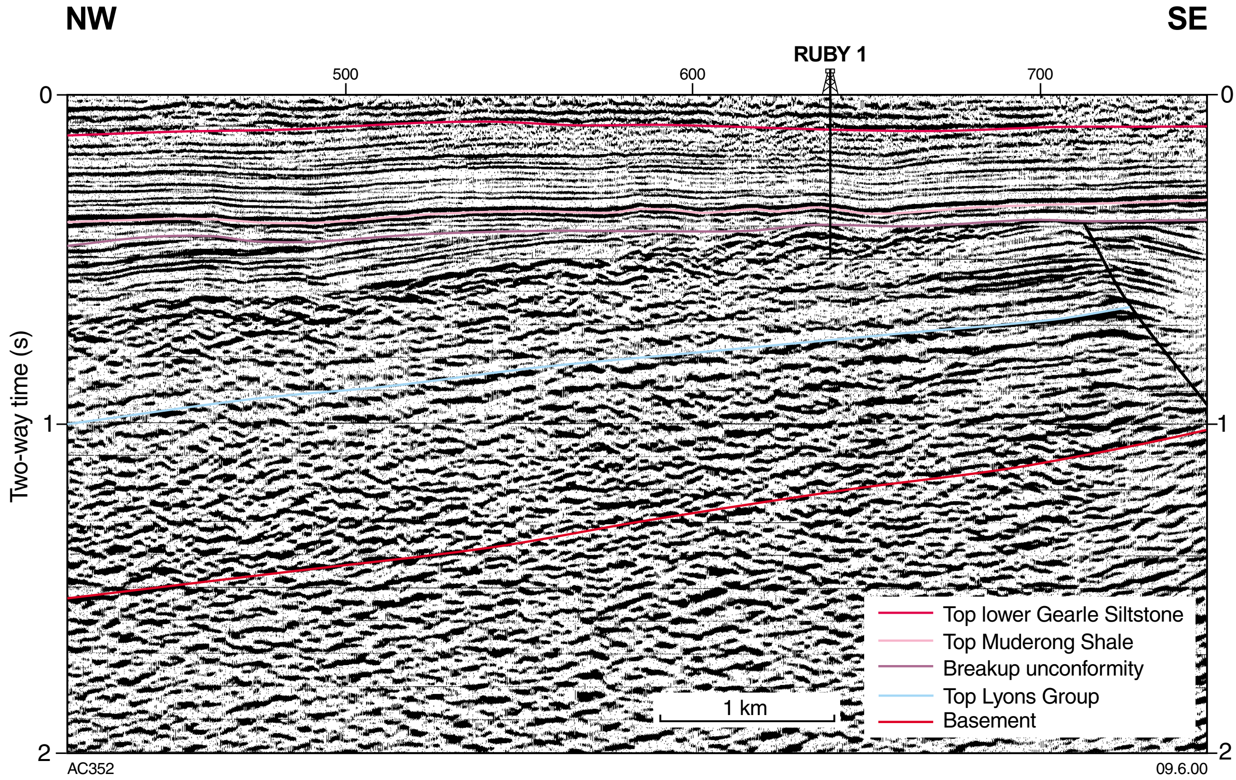

Figure 59. Seismic section PP90A-203 showing the structure at the Ruby 1 prospect. The location of the section is shown in Plate 1

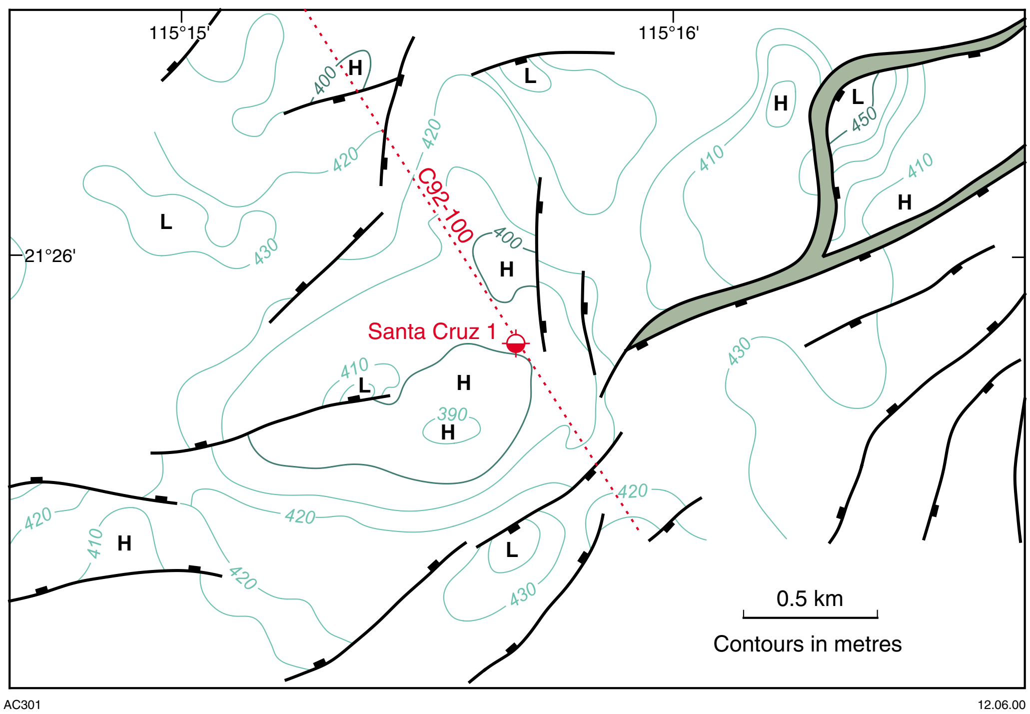

Figure 60. Depth contours to the top Birdrong Sandstone in the Santa Cruz area

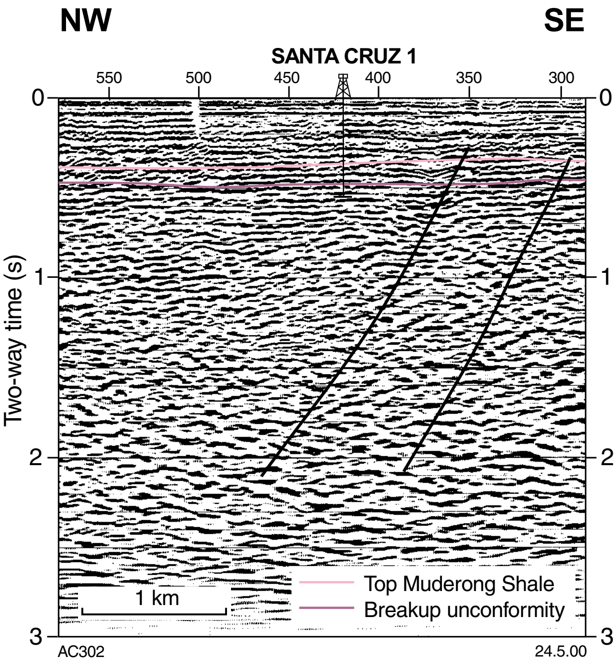

Figure 61. Seismic section C92-100 showing the structure at the Santa Cruz 1 prospect. The location of the section is shown in Plate 1

ranging dinoflagellates (Command Petroleum Holdings NL, 1994b, appendix 5) suggests that it may be assigned to the Flacourt Formation. Between 456 m (intra-Neocomian unconformity) and total depth at 629 m, claystone of the Lyons Group was penetrated.

High levels of background methane (up to 8% total gas) were present throughout the Winning Group. Low saturation, biodegraded, 28–30° API oil was detected in sidewall core 1 and 2 (427 m and 445 m). At 435 m, near the top of the Barrow Group, 21 cubic feet of methane was obtained with a report formation tester (RFT) tool. The well was plugged and abandoned.

The widespread presence of gas in the area makes time-to-depth conversions of the basal Cretaceous level difficult. Problems in the depth conversion are also suggested by the apparent lack of conformity between the lower and higher Cretaceous levels and the irregular widespread presence of small, very gentle highs and lows at the interpreted Birdrong Sandstone level (Smith and Pomilio, 1993). The presence of a Birdrong Sandstone structural high was proven to be incorrect when this unit was penetrated 56.7 m lower than expected (Command Petroleum Holdings NL, 1994b). Therefore, Santa Cruz 1 probably did not test a valid trap.

Sapphire 1 and Sapphire 2

Carnarvon Petroleum NL drilled Sapphire 1 and 2 in 1993 on the Onslow Terrace (Plate 1). Both wells aimed to test the hydrocarbon potential of the Triassic Mungaroo Formation in a truncation trap against post intra-Neocomian unconformity strata. The bottom seal was the Locker Shale, whereas the top seal was expected to be the base of the Winning Group (Figs 62 and 63). Along strike, the structural closure was provided by a syncline predating the intra-Neocomian unconformity (Fig. 64). The Sapphire prospect is located updip of the Tubridgi Gasfield, which was full to spill-point and therefore, all the excess charge should have been available to fill the postulated Sapphire trap.

Stratigraphically, the Tertiary Trealla Limestone, Cretaceous Winning Group, intra-Neocomian unconformity, and then Triassic rocks were penetrated. Below the unconformity, the Triassic is represented by a shaly section within the Mungaroo Formation, down to 558 m. In Sapphire 2, a stratigraphically higher part of the Mungaroo Formation, which exhibits excellent reservoir potential, is present above the shaly section penetrated in Sapphire 1. Locally, 8 m of Flacourt Formation are interpreted to be present between the Mungaroo Formation and Winning Group. The well was terminated at 600 m in the former unit. The stratigraphy described in the well completion reports (Carnarvon Petroleum NL, 1994a,b) is here revised as the presence of the *S. quadrifidus* palynozone and gamma-sonic signatures indicate that the succession below the intra-Neocomian unconformity is within the Mungaroo Formation in both wells. No hydrocarbon indications of significance were found in Sapphire 1, whereas in Sapphire 2 minor oil shows are present within the section assigned by Carnarvon Petroleum NL (1994b) to the Mardie Greensand. That section is assigned here to the Birdrong Sandstone to be consistent with the regional stratigraphy. The severely biodegraded oil extracted from a sidewall core at 401 m appears to be the product of a marginally mature, terrestrial source, similar to the oil extracted from greensand within the Muderong Shale in Picul 1.

Sapphire 1 failed to discover any hydrocarbons because the objective reservoir unit is not present. In the case of Sapphire 2, the seismic interpretation was not disproved by the well results, but the flat-lying Birdrong Sandstone has no sealing capability, indicating the trap is not valid.

Sholl 1

Sholl 1 was drilled during January 1967 on Sholl Island within the Candace Terrace, as one of the series of WAPET stratigraphic wells located on islands (Plate 1).

A unit assigned by Brownhill (1967) to the ‘basal Cretaceous Sand’ is here tentatively divided into the Birdrong Sandstone (285.6 – 319.7 m) of marine (probably near-shore) origin, overlying the continental Flacourt Formation (319.7 – 338 m), containing wood fragments. As detailed by Mory and Backhouse (1997), the pre-Cretaceous section comprises the Lower–Middle Triassic Locker Shale, the Upper Permian Chinty Formation, and an undifferentiated section of the Kennedy Group disconformably overlying the Upper Carboniferous – Lower Permian Lyons Group (Appendix 4).

No significant hydrocarbon shows were found, although the Triassic and Upper Permian section has some

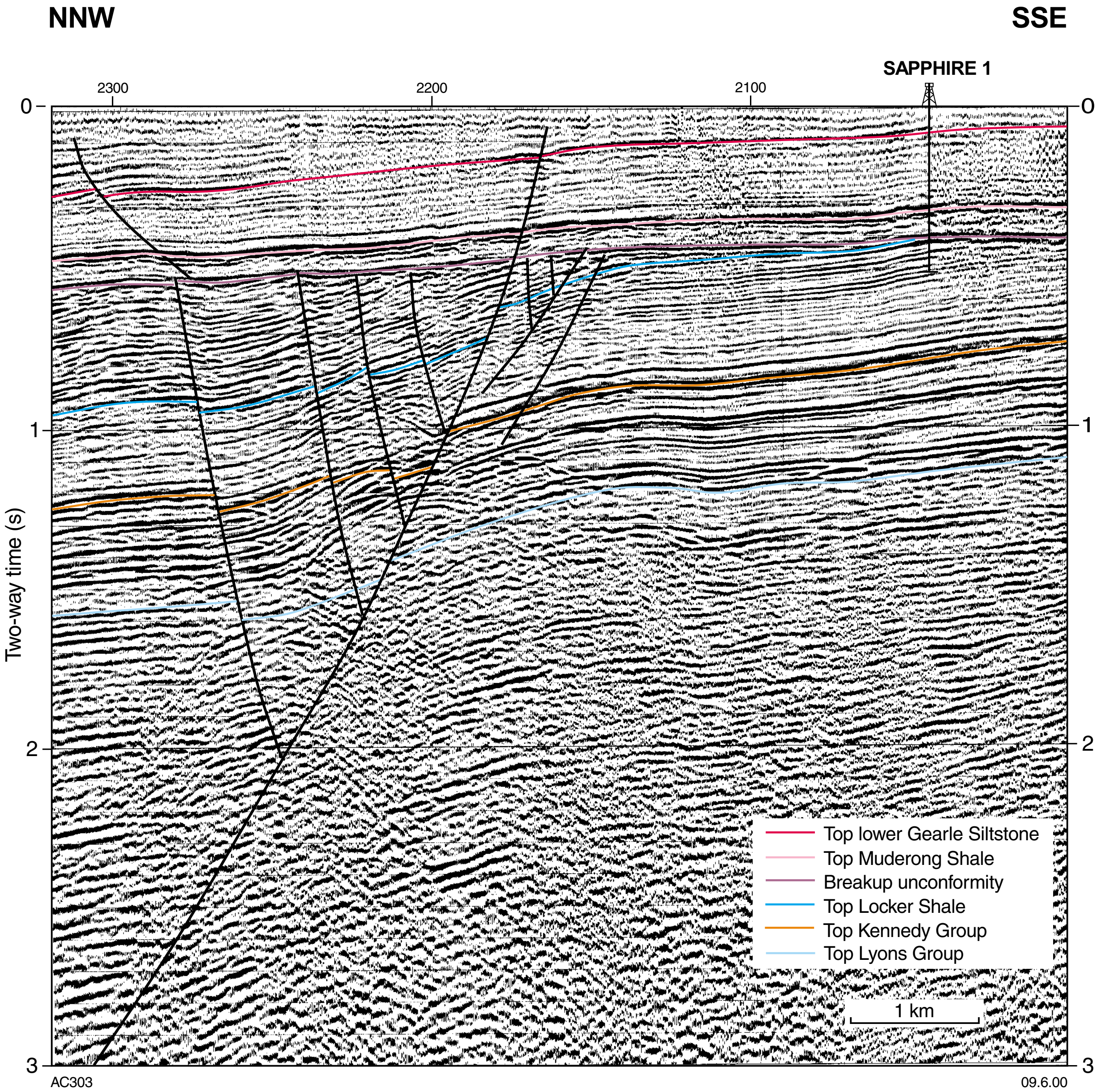

Figure 62. Seismic section J84A-019 showing structure at the Sapphire 1 prospect. The location of the section is shown in Plate 1

potential for sourcing hydrocarbons. Gentle dips, commonly to the southwest, are indicated by the dipmeter.

Talandji 1

Talandji 1 was drilled in 1987–88 by Pan Pacific Petroleum NL on the eastern part of the Onslow Terrace, 1 km to the northeast of Weelawarren 1 (Plate 1). The primary objective was the Birdrong Sandstone and a secondary objective was the Mungaroo Formation on the northwestern downthrown side of the Weelawarren Fault (Figs 65 and 66). A seismically defined closure was mapped, critically depending on the Weelawarren Fault acting as a seal. A Cainozoic to Cretaceous section was penetrated, unconformably overlying the Middle–Upper Triassic Mungaroo Formation and the Lower–Middle Triassic Locker Shale, in which the well was terminated at 1488 m.

In our reinterpretation of the basal Cretaceous section penetrated by Talandji 1 (Table 3), the Mardie Greenstone is absent, but both the Birdrong Sandstone (a marine interval containing glauconite and microplankton) and Flacourt Formation (a sandstone with loose grains of clear, white, fine to very coarse quartz) are present. A very high drilling rate, averaging 1 minute per metre, was achieved within the Flacourt Formation whereas the top hundred metres of the Triassic Mungaroo Formation, with a similar lithology, was penetrated at an average rate of 7 minutes per metre.

Both the Flacourt and Mungaroo Formations have good reservoir potential and high background methane,

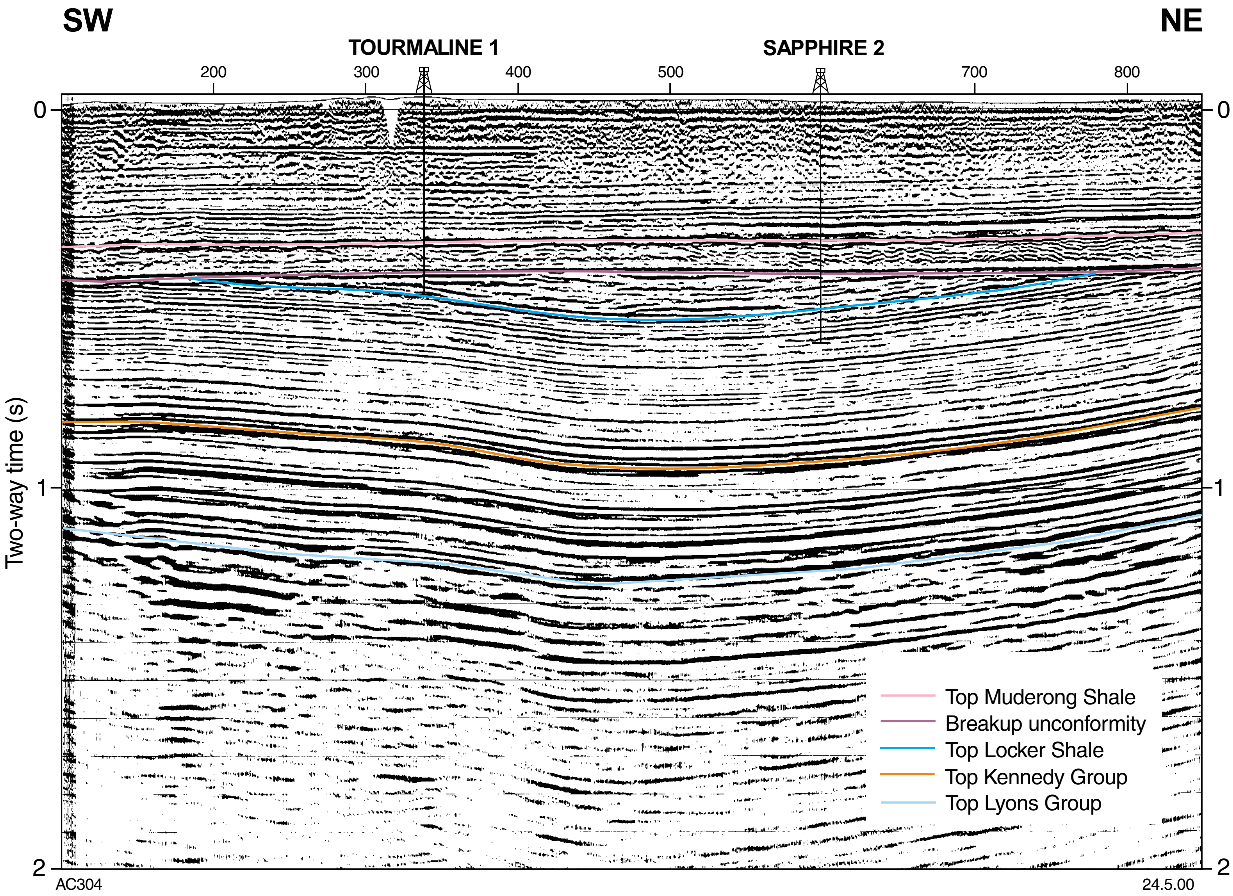

Figure 63. Seismic section CP96-007L showing structure at the Sapphire 2 and Tourmaline 1 prospects. The location of the section is shown in Plate 1

averaging 2% by volume, was detected throughout the Windalia Radiolarite, Muderong Shale, Birdrong Sandstone, and Flacourt Formation. A 4% methane peak (Pan Pacific Petroleum NL, 1988) corresponds to a silty interval within the Muderong Shale, and another peak of 5% to the base of the Flacourt Formation. An open hole DST (451.7 – 344.7 m) across the Birdrong Sandstone recovered only formation water. Minor methane peaks were also present within the Mungaroo Formation originating from thin beds of coal.

It is believed that Talandji 1 did not intersect hydrocarbons of economic value because the Weelawarren Fault does not provide an effective seal. A comparison with Weelawarren 1 indicates that the main development of the Weelawarren Fault resulted from Late Jurassic tectonism, with a vertical displacement of approximately 700 m at the base of the Mungaroo Formation. The Weelawarren Fault was rejuvenated during the Cretaceous, with 60 m of vertical throw at the base of the Muderong Shale and possibly 27 m of throw at the intra-Gearle Siltstone level (Pan Pacific Petroleum NL, 1988).

Tent Hill 1

Tent Hill 1 was drilled in December 1989 by Minora Resources NL on the Yanrey Ridge to test the hydrocarbon potential of the Lower Cretaceous Birdrong Sandstone in a postulated pinchout trap against basement, 8.5 km north of Yanrey 1 (Plate 1). The trap was seismically defined within an embayment, flanked by basement on the western side of the Yanrey Ridge.

The regional stratigraphy was penetrated down to the Birdrong Sandstone objective (532–572 m), which was interpreted by Minora Resources NL (1990) to be directly above Precambrian basement in which the well was terminated at 580 m. Unusually high vitrinite reflectance values (Ro = 1.0 – 1.2%) were recorded in the interval 550–572 m. These high values suggests that this unfossiliferous interval is considerably older, and that it may have been deeply buried prior to the Cretaceous (Minora Resources NL, 1990, appendix K). In Tent Hill 1, the Birdrong Sandstone has excellent reservoir quality, both in the lower fluvial to marginal marine interval and in the upper marine interval, separated by a 3 m-thick, shaly section (550–553 m). No hydrocarbon shows were intersected (Minora Resources NL, 1990).

The seismic control available does not prove the stratigraphic closure of the Birdrong Sandstone pinchout, because the intra-Muderong Shale marker is the deepest seismic horizon that can be confidently mapped in the area. Therefore, Tent Hill 1 was drilled either outside a stratigraphic closure or, less likely, too far downdip from the pinchout edge.

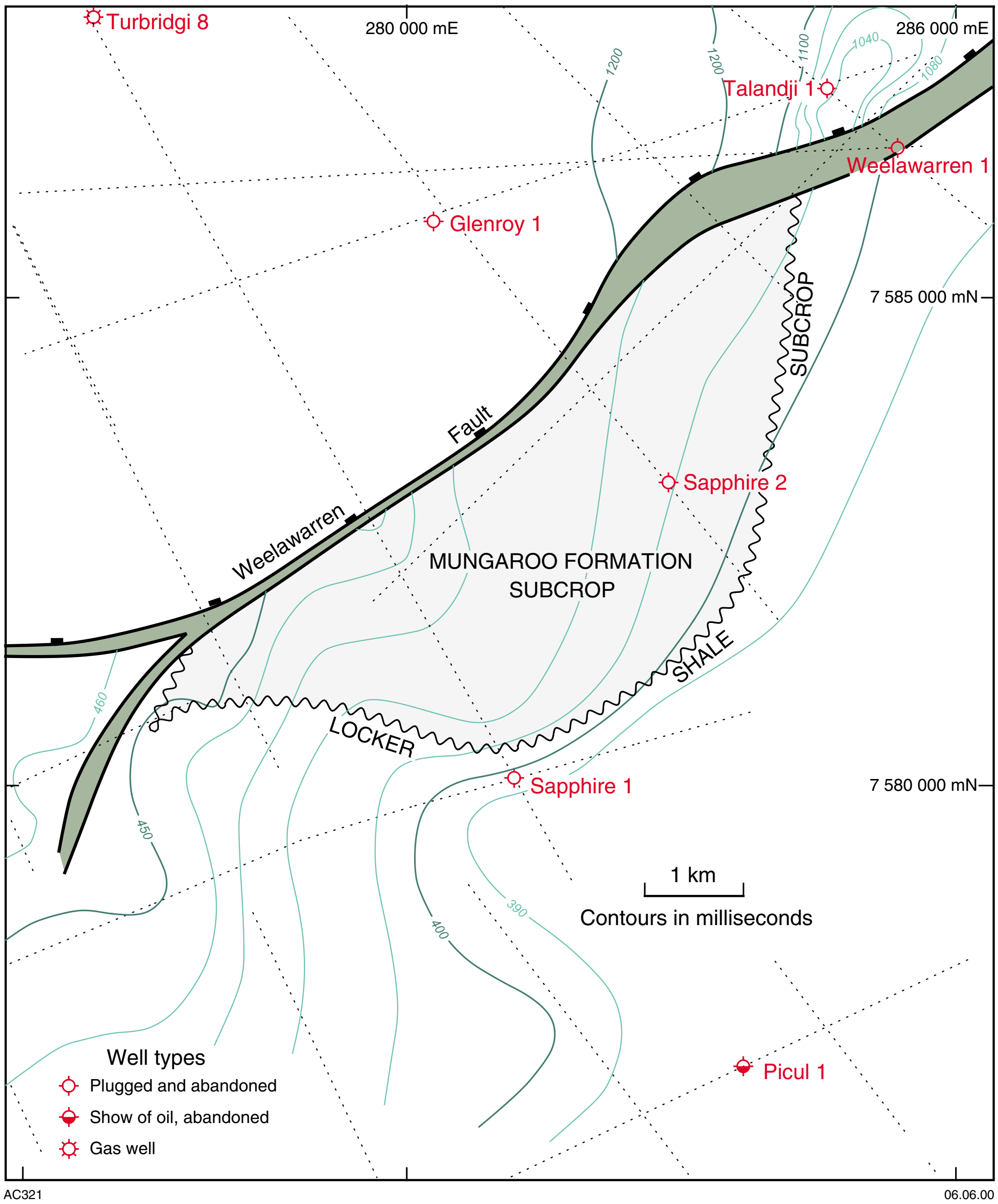

Figure 64. Depth contours to the basal Cretaceous unconformity for the Sapphire truncation trap prospect

Tourmaline 1

Tourmaline 1 was drilled within the Ashburton Embayment (Plate 1) by Carnarvon Petroleum NL in 1997 to test the hydrocarbon potential of the Birdrong Sandstone and Mungaroo Formation. The Tourmaline prospect lies 1 km south of the Weelawarren Fault, and is a small structural closure at the top of the interpreted Birdrong Sandstone. A seismic amplitude anomaly coinciding with the closure gave the company some confidence as to the validity of the interpretation (Fig. 63). In the event that a competent seal overlies the basal Cretaceous unconformity, they also expected a postulated Mungaroo Formation truncation to be controlled by subcrop of Locker Shale.

The regional stratigraphic succession was penetrated down to the base of the Cretaceous, at 420.5 m, which overlies the Middle–Upper Triassic Mungaroo Formation to total depth at 472.6 m. The interval 409 – 420.5 m beneath the basal Cretaceous unconformity is here assigned to the Flacourt Formation, because it is composed of poorly consolidated, coarse-grained, pale-grey to milky white sandstone. The post-breakup marine Mardie Greensand – Muderong Shale section transgresses over the Flacourt Formation, which in turn unconformably overlies the Mungaroo Formation with a major time break. The only gas peaks recorded are 100% methane, and correspond to thin sandstone intervals within the Gearle Siltstone. Minor indications of residual oil were encountered within the Flacourt and Mungaroo Formations. Bunt (1998) concluded that the failure of Tourmaline 1 to discover an economic accumulation of hydrocarbons was the lack of structural closure. This is consistent with the only proven traps in the region having

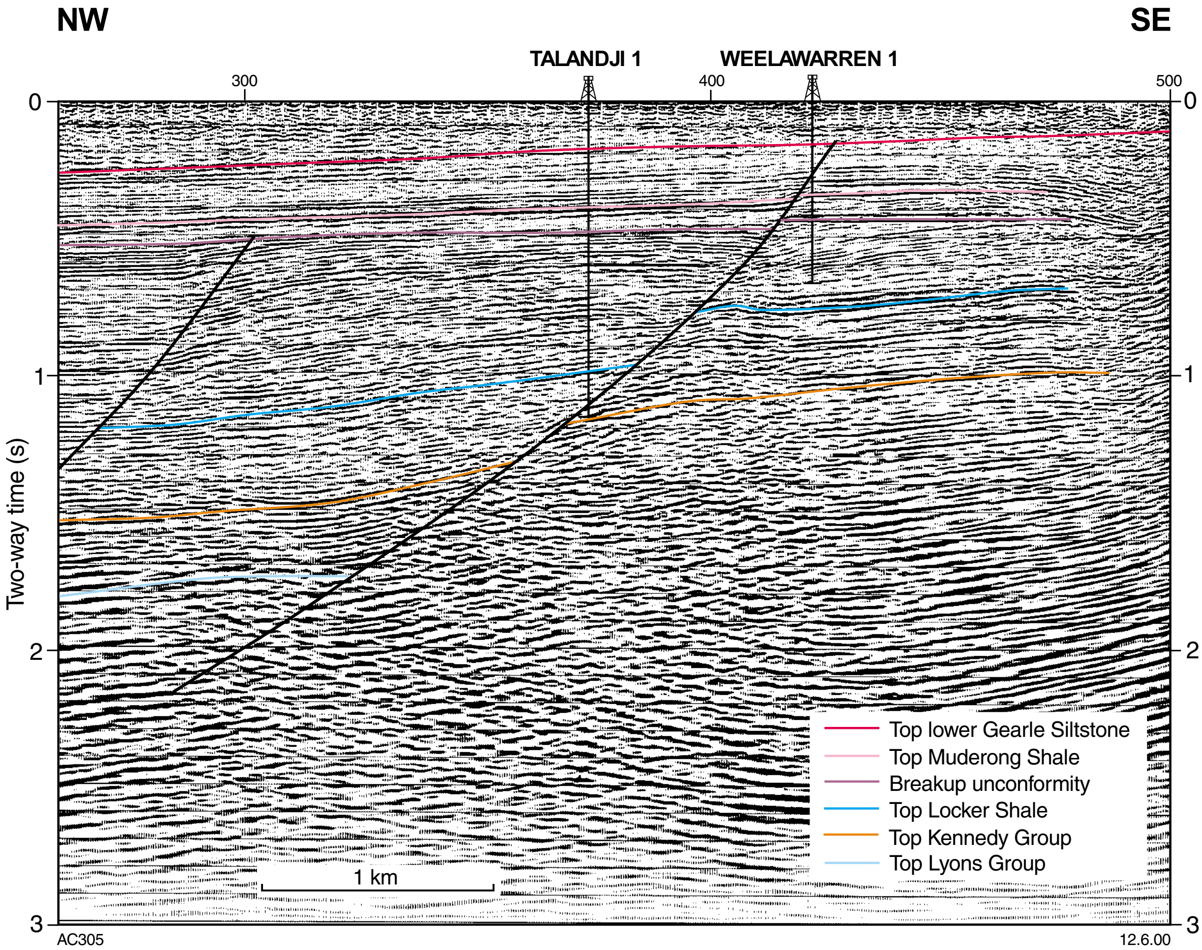

Figure 65. Seismic section A82-006 showing the structure at the Talandji 1 and Weelawarren 1 prospects and the seismic anomaly interpreted to be a direct hydrocarbon indicator at Weelawarren 1. The location of the section is shown in Plate 1

formed during the mid-Miocene, and the only other effective closures are palaeotopographic highs or stratigraphic pinchouts within the basal Cretaceous objectives, when sealed by unstructured younger Cretaceous strata.

Urala 1

Urala 1 was drilled in 1968 by WAPET as a stratigraphic well to determine the thickness, lithology, and fluid content of the Birdrong Sandstone on the northern plunge of the Yanrey Ridge (Reid, 1969b). The well location is approximately 45 km west-southwest of the town of Onslow (Plate 1).

The Birdrong Sandstone was intersected between 604 and 618 m. At this location the unit is dominated by siltstone, and only the basal 3.6 m consists of clean sandstone with a sonic-derived porosity of 24%. The Birdrong Sandstone, therefore, is not a particularly attractive objective in this area. A DST carried out between 613 and 618 m recovered methane-cut saline formation water (32 900 ppm). The Middle–Upper Triassic Mungaroo Formation is present between 618 m and total depth at 762 m. Gas indications in the water-saturated formations decreased from 38 units in the Birdrong Sandstone to 10 units in the Mungaroo Formation. The porosities of the prevailing sandstone intervals in the latter unit are high, reaching 30.7%.

Apart from the methane dissolved in water, there were no other shows of hydrocarbons.

Weelawarren 1

Weelawarren 1 was drilled in 1983 by Pan Pacific Petroleum NL in the northeastern part of the Ashburton Embayment (Plate 1), 1 km southwest of Talandji 1. The well was designed to test the basal Cretaceous sandstone in a northeast trending horst (Fig. 66) with an interpreted area of closure of 10 km^2 and a vertical relief of 30 m. A subhorizontal, high-amplitude seismic event was interpreted as a direct hydrocarbon indicator (Fig. 65). The horst was formed during the Late Jurassic, although movements on the bounding fault continued into the Cretaceous (Laing, 1983).

The section drilled in Weelawarren 1 comprises 391 m of Tertiary calcareous and Cretaceous clastic strata

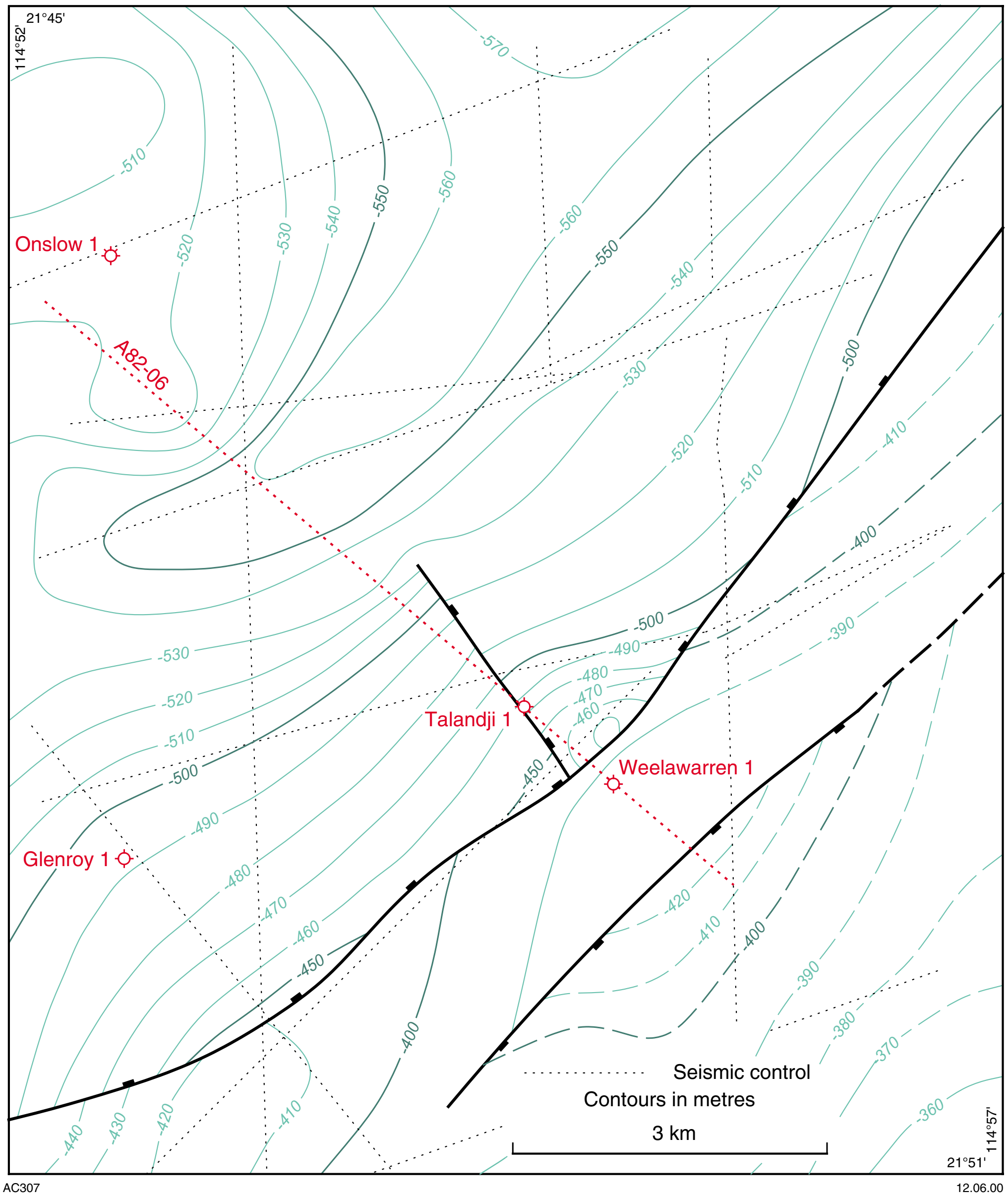

Figure 66. Depth contours to the basal Cretaceous unconformity showing the Talandji 1 and Weelawarren 1 locations

unconformably overlying Triassic clastic rocks of the Mungaroo Formation. The shale in the interval 545 – 552.7 m (TD) was referred to as the Locker Shale (Laing, 1983). The basal Cretaceous section is represented by the Muderong Shale, which is slightly glauconitic towards the base, and rests directly on the Mungaroo Formation, thereby indicating that the area was a local high during the Early Cretaceous transgression. Gas shows encountered in the lower Gearle Siltstone at 135 and 240 m correspond to the most porous intervals.

The failure of Weelawarren 1 to find economic hydrocarbons is due to the lack of the basal Cretaceous sandstone. It is also possible that the well was not drilled within closure, as the seismic control of the Weelawarren structure is poor (Laing, 1983). However, seismic section A82-006 (Fig. 65) indicates the presence of a low-relief anticline above the Mesozoic horst, probably related to the Middle Miocene tectonism that also formed the Tubridgi structure of similar low relief. The crest of the drilled structure is approximately 15 milliseconds higher 1 km southeast of Weelawarren 1 (Fig. 65). A well in this structurally higher location could test either the Triassic Mungaroo Formation sealed by the Muderong Shale, or possibly the Birdrong Sandstone and Flacourt Formation, if there was a minor, undetected, post-unconformity normal fault that cut out the base of the Cretaceous in Weelawarren 1.

Wonangarra 1

Wonangarra 1 was drilled during April 1969 by WAPET as a stratigraphic test on the eastern side of the Yanrey

Table 3. Basal Cretaceous section in Talandji 1

	Dipmeter drift	*Borehole deviation*	*Environment*	*Palynology (Pan Pacific Petroleum NL, 1988, app. 4)*	*Pan Pacific Petroleum NL (1988)*	*This Report*
MUDERONG SHALE				*M. australis* (405–433 m)	365–438 m	365–438 m
MARDIE GREENSTONE	Dips ranging from north to southwest	NE	Marine	Not identified	450 – 461.6 m	Not identified
BIRDRONG SANDSTONE				*M. testudinaria* (448–464 m)	461.6 – 475.1 m	438–464 m
BREAKUP UNCONFORMITY					475.1 m	464 m
FLACOURT FORMATION			Continental	No sidewall cores	Not identified	464–505 m
BASAL CRETACEOUS UNCONFORMITY					475.1 m	505 m
MUNGAROO FORMATION	Well-defined dips to SW	NW	Deltaic to marginal marine			

NOTES: Basal Cretaceous section in Talandji 1. The intra-Valanginian breakup unconformity is present between the Birdrong Sandstone and Flacourt Formation. The basal Cretaceous unconformity, related to the Late Jurassic tectonism, is present between the Flacourt and Mungaroo Formation

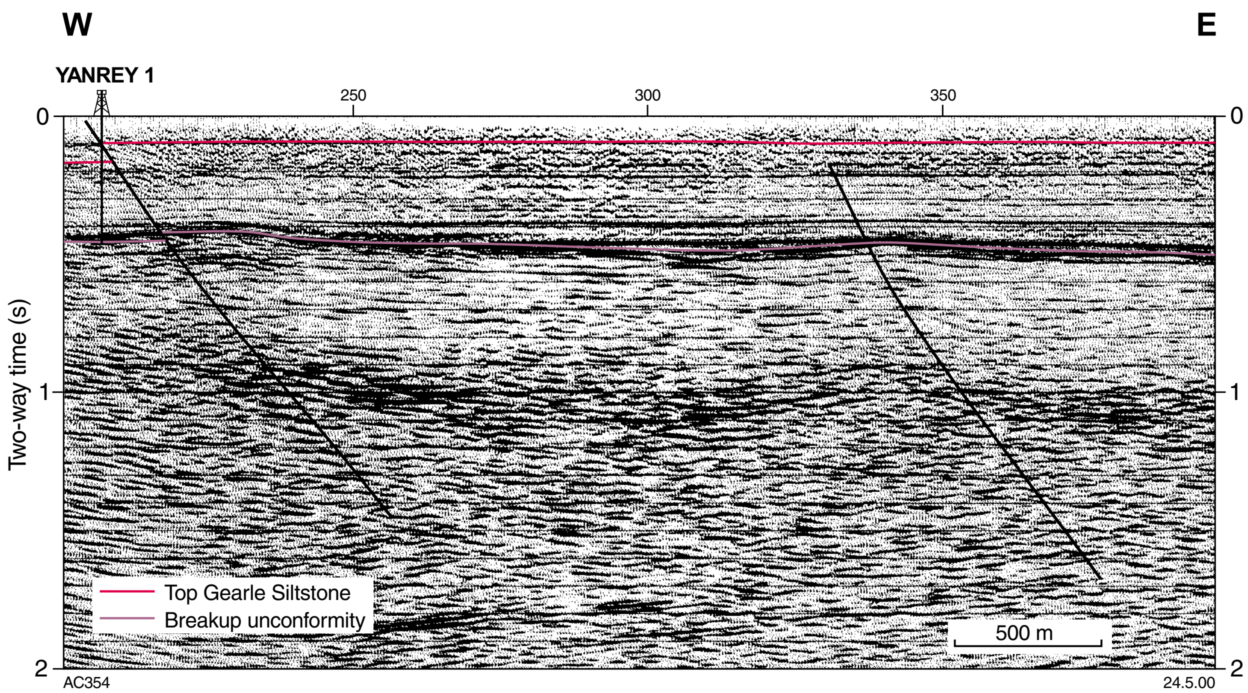

Figure 67. Seismic section PP88A-012 showing the structure at the Yanrey 1 prospect. The location of the section is shown in Plate 1

Ridge, 16 km to the northwest of Yanrey 1 (Plate 1). The well was planned to investigate a postulated Birdrong Sandstone pinchout trap onto basement of the Yanrey Ridge. Possible sandstone beds within the Lower Cretaceous shale section represented secondary objectives.

A section of Tertiary carbonates, Toolonga Calcilutite, Gearle Siltstone, Windalia Radiolarite, Muderong Shale, and glauconitic, silty Birdrong Sandstone was penetrated between 514 and 533 m. Beneath the breakup unconformity (533 m) to the total depth of 575 m, a sandstone–limestone unit assigned to the Kennedy Group by Moyes (1969b) is present. A sample from core 3 at 574 m, however, contains a palynological assemblage of Early Carboniferous age (Appendix 4), which confirms that Wanangarra 1 was drilled on an uplifted block near the Yanrey Ridge.

There were no shows of hydrocarbons.

Yanrey 1

Yanrey 1 was drilled in 1957 by WAPET on the Yanrey Ridge (Plate 1) to test the hydrocarbon potential of the Birdrong Sandstone in an interpreted anticlinal closure estimated to cover 10 km^2, with 37 m of vertical closure (Pudovskis, 1957).

The regional Tertiary to Cretaceous succession was penetrated down to 421.5 m where the Windalia Radiolarite (or the Muderong Shale) overlies Precambrian quartz–mica schists. A review of the foraminifera from the Cretaceous section (Haig, D., 2000, pers. comm.) indicates that the Korojon Calcarenite – Gearle Siltstone is repeated over the intervals 32–97 m and 97–405 m. A reinterpretation of the poor-quality seismic data confirms the presence of a reverse fault at 97 m (Fig. 67). The well was terminated at 431 m in basement rocks. No indications of hydrocarbons were seen.

Although seismic reflection, refraction, and gravity data supported the structural closure, the anticline at Yanrey 1 was drilled on the downthrown side of a reverse fault. Therefore, the well is substantially downdip from the crest of the anticline, which was probably formed in the Middle Miocene.

Geochemistry

Both liquid and gaseous hydrocarbons are present on the Peedamullah Shelf and Onslow Terrace, as discussed in the **Post-mortems of dry exploration wells**. The first hydrocarbon discovery (albeit uncommercial) was 20 litres of oil associated with gas that blew out from a seismic shot hole within the Robe Embayment in 1982 (Table 2). This discovery was followed by many more, which can be categorized in three discrete groups:

- Heavy (14–20° API) biodegraded oil either tested from several Robe Embayment wells (Table 2) or extracted from wells scattered throughout the entire region;
- Light oil (38.5° API), recovered only from Mardie 2 in the Robe Embayment; and
- Dry gas trapped in the Tubridgi Gasfield and widespread within the Cretaceous section in the entire study area.

Soil hydrocarbon geochemistry indicates that in some regions, such as near Abdul's Dam 1, anomalous surface levels of light (C_1) and heavier (C_4) hydrocarbons are present, with an anomalously low ratio of heavier to light hydrocarbons (Mills, 1997a), thereby indicating that the dry gas is unrelated to the oil.

Oil occurrences

The majority of the oil present within the basal Cretaceous of the Peedamullah Shelf and Onslow Terrace is highly biodegraded and immobile. The most encouraging indication of crude oil was about 20 litres recovered from a depth of 77 m in a seismic shot hole at shot point 1374.5 on the Mardie-Line-A (Plate 1), but geochemical data on the recovered oil are not available. An unspecified amount of crude oil was recovered from Sharon 1 and the Muderong Shale in Mardie 2 yielded a few barrels of 38.5° API crude oil (Table 2). Furthermore, 0.114 barrels of oil were recovered from the Birdrong Sandstone during a deliverability test of Tubridgi 2 (T. Fekete and Associates Consultants Ltd, 1981).

Characterization of the crude oils being produced in the Northern Carnarvon Basin by gas chromatography (GC) and gas chromatography – mass spectrometry (GC–MS) biomarkers indicate that most of these oils were sourced from an open-marine environment source rock of Late Jurassic age (Scott and Hartung-Kagi, 1998). The source of oils recovered and extracted from wells within the Peedamullah Shelf and Onslow Terrace is uncertain, because they are highly biodegraded and locally contaminated during drilling. The geochemical database for the characterization and correlation of such oils is limited to data from the wells listed in Table 4.

Analyses of oil samples from Sharon 1, on the Onslow Terrace, taken from production tests and extracts from Cretaceous and Devonian cuttings and core samples indicate contamination during drilling. However, the extracted original crude oils are biodegraded, mature, and sourced from organic matter of a mixed terrestrial and marine origin that was deposited in a reducing depositional environment. The biomarker distributions of the Sharon 1 oil and extracts from Devonian samples taken from Quobba 1 on the Gascoyne Platform (Blake et al., 1984) are similar, indicating that they may be genetically related (Hartung-Kagi, 1987).

The geochemical characterization of the crude oil recovered from the Windalia Sandstone in Mardie 2, within the Robe Embayment, indicates that it is mature and predominantly sourced from marine organic matter that was deposited in an anoxic environment. Contamination is suspected because the GC and GC–MS biomarkers are different from oils derived from Upper Jurassic sources, and very similar to the diesel from Middle East oils that have been used in Australia (Geotechnical Services Pty Ltd, 1992). However, it is possible that the Sharon 1 and Mardie 2 oils were

Table 4. GC and GC–MS geochemical data from wells on the Peedamullah Shelf and Onslow Terrace

Well	*Depth (m)*	*Sample type*	*GC*	*GC–MS*	*Structural unit*	*Stratigraphic unit*
Amber 1	368.0	swc 26	–	Yes	Weld High	Mardie Greensand
Echo Bluff 1	249.0 – 252.0	cuttings	Yes	–	Robe Embayment	Gneudna Formation
Echo Bluff 1	348.0 – 354.0	cuttings	Yes	–	Robe Embayment	Gneudna Formation
Fortescue 1	330.0 – 360.0	cuttings	Yes	–	Candace Terrace	Locker Shale
Jasper 1	427.7	swc 25	–	Yes	Ashburton Embayment	Birdrong Sandstone
Mardie 1	167.0 – 172.0	core 17	Yes	–	Robe Embayment	Mardie Greensand
Mardie 1	213.0 – 225.5	cuttings	Yes	–	Robe Embayment	Gneudna Formation
Mardie 2	61.2 – 63.5	oil	Yes	Yes	Robe Embayment	Windalia Sandstone
Peedamullah 1	213.4 – 231.7	cuttings	Yes	Yes	Peedamullah Shelf	Gneudna Formation
Peedamullah 1	322.5 – 328.9	cuttings	Yes	Yes	Peedamullah Shelf	Gneudna Formation
Picul 1	373.0	swc 9	–	Yes	Onslow Terrace	Muderong Shale
Sapphire 2	401.0	swc 13	–	Yes	Onslow Terrace	Birdrong Sandstone
Sharon 1	161.0 – 167.0	core 3	Yes	Yes	Robe Embayment	Mardie Greensand
Sharon 1	167.7	core 4	Yes	Yes	Robe Embayment	Mardie Greensand
Sharon 1	168.3	core 4	Yes	Yes	Robe Embayment	Mardie Greensand
Sharon 1	172.5	production test 3	Yes	Yes	Robe Embayment	Mardie Greensand
Sharon 1	172.5	production test 4	Yes	Yes	Robe Embayment	Mardie Greensand
Sharon 1	201.0 – 204.0	cuttings	Yes	Yes	Robe Embayment	Yarraloola Conglomerate
Sharon 1	207.0 – 231.0	cuttings	Yes	Yes	Robe Embayment	Gneudna Formation
Sharon 1	228.0 – 231.0	cuttings	Yes	Yes	Robe Embayment	Gneudna Formation
Topaz 1	345.7	core 2	–	Yes	Weld High	Birdrong Sandstone
Tubridgi 2	–	crude oil	–	Yes	Onslow Terrace	Birdrong Sandstone
Tubridgi 4	–	crude oil	–	Yes	Onslow Terrace	Birdrong Sandstone
Tubridgi 7	521.0 – 523.0	oil	–	Yes	Onslow Terrace	Birdrong Sandstone

NOTES: GC: gas chromatography
MS: mass spectrometry
SWC: sidewall core

sourced from nearby Devonian rocks, rather than Upper Jurassic rocks.

The geochemical characterization of crude oils from Tubridgi 2, 4, and 7 indicates the presence of eudalene, a higher plant aromatic biomarker from a very specific higher plant group not found in oils derived from Upper Jurassic source facies (Geotechnical Services Pty Ltd, 1996a). The Tubridgi oil, therefore, was probably sourced from post-Devonian to pre-Upper Jurassic rocks.

The geochemical characterization of oils extracted from sidewall cores in Amber 1, Jasper 1 (Geotechnical Services Pty Ltd, 1994a), and Topaz 1 (Geotechnical Services Pty Ltd, 1996b) in the Ashburton Embayment, indicate that they are so severely biodegraded that all n-alkanes have been removed. Similarly aromatic biomarkers are not available for these samples. However, on the basis of triterpane and sterane biomarkers they can be considered as a single group. These biomarkers indicate that the oil was generated from a mixed terrestrial–marine source rock at a maturity equivalent to a vitrinite reflectance of 0.9% Ro, and are similar to the oils of the Tubridgi Gasfield (Geotechnical Services Pty Ltd, 1996a).

Oil extracted from sidewall cores in Picul 1 within the Ashburton Embayment (Geotechnical Services Pty Ltd, 1993) and Sapphire 2 within the Onslow Terrace (Geotechnical Services Pty Ltd, 1994b) are also severely biodegraded. The diagnostic steranes and triterpanes were not found in the Sapphire 2 extract, but the aromatic biomarkers indicate a similar terrestrial source to the oil from Picul 1. These extracts are moderately mature with vitrinite reflectance equivalent values between 0.8 and 0.9% Ro, and were sourced from predominantly terrestrial source rock.

The available geochemical data preclude a definitive characterization and correlation for any of the oil from the Peedamullah Shelf and Onslow Terrace due to the high degree of biodegradation and contamination. However, the data indicate that the oils from this area differ in their biomarker distributions from the oils sourced by Upper Jurassic source facies. The main differences include:

- Oils from the Robe Embayment are low in pristane to phytane ratios and were sourced from predominantly mixed marine–terrestrial organic facies that accumulated in an anoxic environment (Fig. 68a). The pristane to phytane ratio for oils recovered from the Lower Cretaceous rocks in Mardie 2 and Sharon 1 are lower than 1.2. This ratio is more comparable to the ratio of oils derived from Palaeozoic source rocks (Gneudna Formation and Dirk Hartog Group) than the pristane to phytane ratio for the Upper Jurassic oils, which are commonly greater than 2.5;
- Extracts from Picul 1 (Ashburton Embayment), Sharon 1 (Robe Embayment), and GSWA Woodleigh 2A (Gascoyne Platform) indicate that the source-rock organic matter has a content with a predominant terrestrial component (Fig. 68b), and;
- Oil and extracts from the Onslow Terrace were sourced from mixed marine–terrestrial organic facies characterized by the presence of eudalene, a specific higher plant aromatic biomarker.

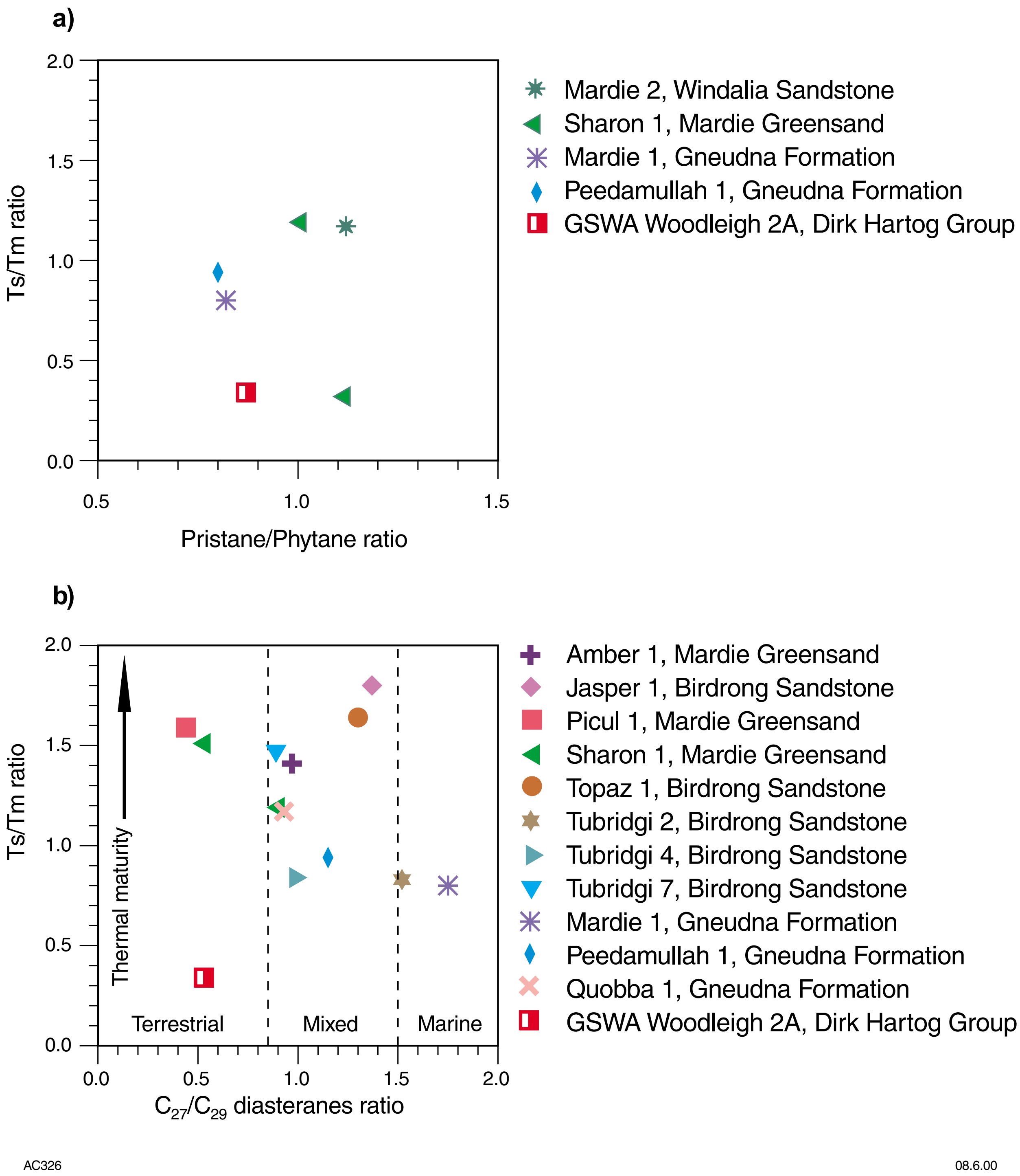

Figure 68. Biomarkers ratio crossplots: a) pristane/phytane ratios versus 18a(H)-hopane/17a (H)-hopane (Ts/Tm) ratios, including recent GC–MS extract data from Silurian rocks in GSWA Woodleigh 2A (Ghori, in prep.); b) C_{27}/C_{29} diasteranes versus 18a(H)-hopane/17a (H)-hopane (Ts/Tm) ratios

Pre-Cretaceous source rocks in the Onslow Terrace and Ashburton Embayment

In spite of abundant indications of hydrocarbons, effective source rocks have yet to be identified in the area.

Suggestions that the hydrocarbons in the Peedamullah Shelf and Onslow Terrace migrated from Jurassic source rocks in the deeper parts of the Barrow Sub-basin (Thomas, 1978), like much of the oil in the Barrow Sub-basin, are contradicted by the oil commonly having been derived from pre-late Lower Jurassic sources.

In Tent Hill 1 on the Yanrey Ridge, Minora Resources NL (1990, appendix I) rated the petroleum-generating potential of the interval 550–572 m, referred to as the Birdrong Sandstone by Minora Resources NL (1990), as poor to fair. This interval, however, is believed to be considerably older than Lower Cretaceous rocks, as the 1.0 – 1.2% Ro values are greater than expected for the postulated age and depth of the Birdrong Sandstone in the region. In Observation 1 on the Exmouth Sub-basin (Plate 2), such values are reached at a depth of approximately 3500 m within the Permian (Harris, 1991).

The Chinty Formation in both Onslow 1 (Fig. 69) and Abdul's Dam 1 (Pan Pacific Petroleum NL, 1991, appendix C) is organically lean. In Amber 1, the Lower Carboniferous Quail Formation has total organic carbon (TOC) values ranging from 0.18 to 0.30%, which are too low to be an effective source (Pan Pacific Petroleum NL, 1995a, appendix D).

In contrast to the Carboniferous and Permian units, the Middle–Upper Triassic Mungaroo Formation in Observation 1 shows very good petroleum-generating potential. The coal measures of the Mungaroo Formation have a potential yield greater than 13.48 mg/g rock and the mixed type kerogen indicates the possible generation of both gas and oil (Fig. 69). The Triassic coal measures may have been the source of the liquid hydrocarbons in the Rankin Trend (Harris, 1991). Onshore, Triassic source rocks became mature in the Late Jurassic and are currently mature to overmature.

Pre-Cretaceous source rocks in the Robe Embayment and Candace Terrace

The source potential of Peedamullah 1 (Robe Embayment), Candace 1, and Kybra 1 (Candace Terrace) has been evaluated by Ghori (1998). In Peedamullah 1, the Gneudna Formation has fair petroleum-generating potential (Fig. 69). Within the Robe Embayment, however, TOC values in the Gneudna Formation show considerable lateral change — 2.6% in Sharon 1, 0.2% in Mardie 1, less than 0.2% in Echo Bluff 1, and 1.3% in Peedamullah 1 (Mitchell, 1992) — and therefore, the

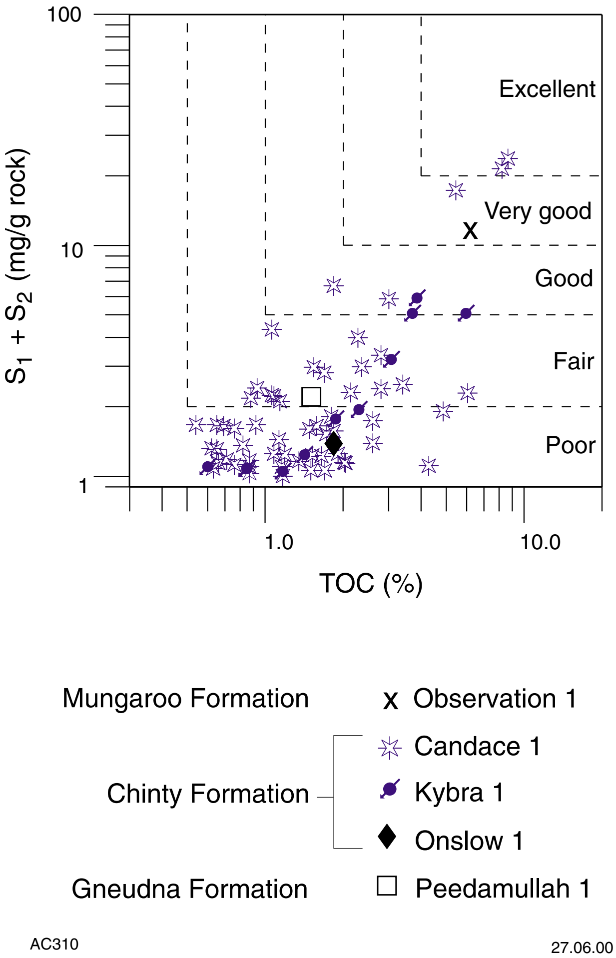

Figure 69. Petroleum-generating potential as TOC versus $S_1 + S_2$ in the Peedamullah Shelf and adjacent area, for Middle–Upper Devonian Gneudna Formation (Ghori, 1998), Upper Permian Chinty Formation, Kennedy Group (Ghori, 1998), and Middle–Upper Triassic Mungaroo Formation (Harris, 1991)

petroleum-generating potential is also expected to vary greatly.

Plots of hydrocarbon index versus T_{max} for the Gneudna Formation in Peedamullah 1 demonstrate the presence of type III, gas-prone hydrocarbons (Fig. 70). Spore colouration within the formation indicates that the unit is mature for oil generation below 982 m in Echo Bluff 1 (Allchurch, 1984).

In Kybra 1 and Candace 1 on the Candace Terrace, the petroleum-generating potential of the Chinty Formation ranges from poor to excellent (Figs 69 and 71). The Chinty Formation source beds in these two wells are within the oil window (Fig. 72), and fall between type II and type III, thereby indicating potential for both gas and oil (Fig. 70).

The presence of oil generated from pre-Jurassic rocks in very shallow Cretaceous reservoirs indicates that considerable vertical migration has taken place in both the Onslow Terrace – Ashburton Embayment and Robe Embayment – Candace Terrace areas.

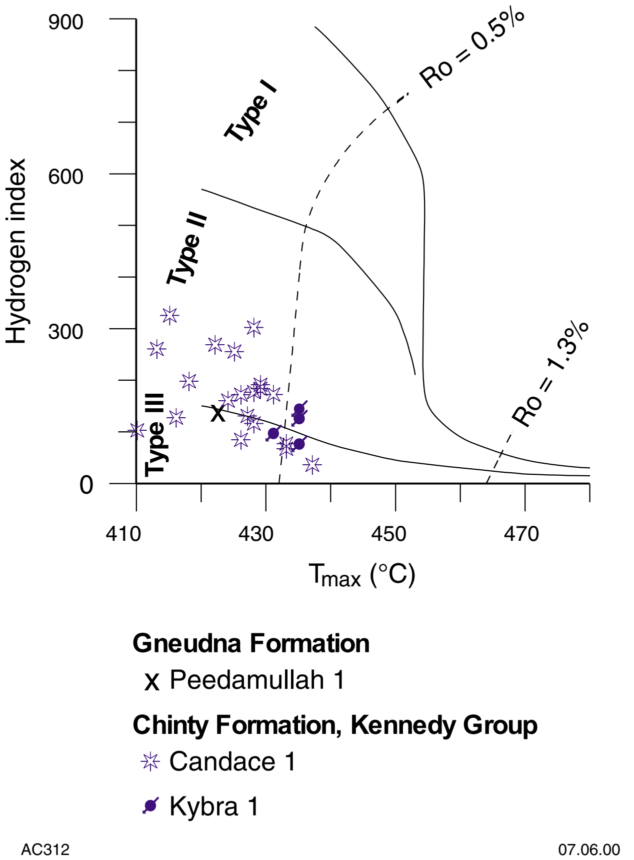

Figure 70. Rock-Eval kerogen typing as hydrogen index versus T_{max} for Middle–Upper Devonian Gneudna Formation and Upper Permian Chinty Formation of the Kennedy Group

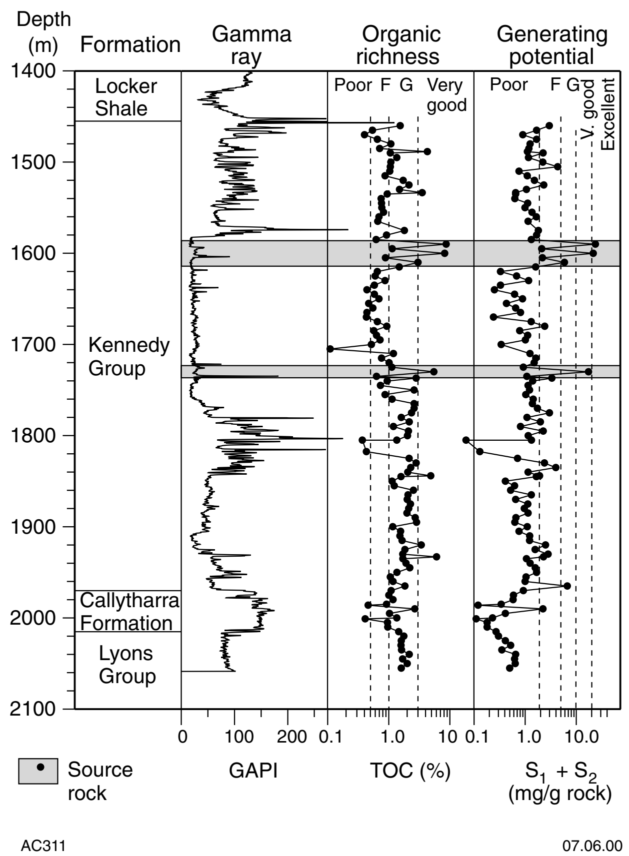

Figure 71. Organic richness and petroleum-generating potential of rocks in Candace 1 (from Ghori, 1998)

Pre-Cretaceous source-rock maturity

The thermal maturation of pre-Cretaceous rocks of the Peedamullah Shelf and Candace Terrace is based on organic petrology and Rock-Eval pyrolysis.

Organic petrology: Organic petrology is available for 100 samples from six wells. Maturity values increase with depth and most of the Triassic samples are immature to marginally mature, whereas most of the Palaeozoic samples are within the oil-generative window, being at depths greater than 1500 m (Fig. 73).

Rock-Eval pyrolysis: T_{max} is a maturation parameter corresponding to the temperature (in °C) at which the pyrolytic yield of hydrocarbons (from a rock sample) peaks. Another maturation parameter is the production index (PI) — the ratio of hydrocarbons in a free or adsorbed state (S_1) to hydrocarbons produced by the pyrolysis of kerogen (S_2). The values, commonly

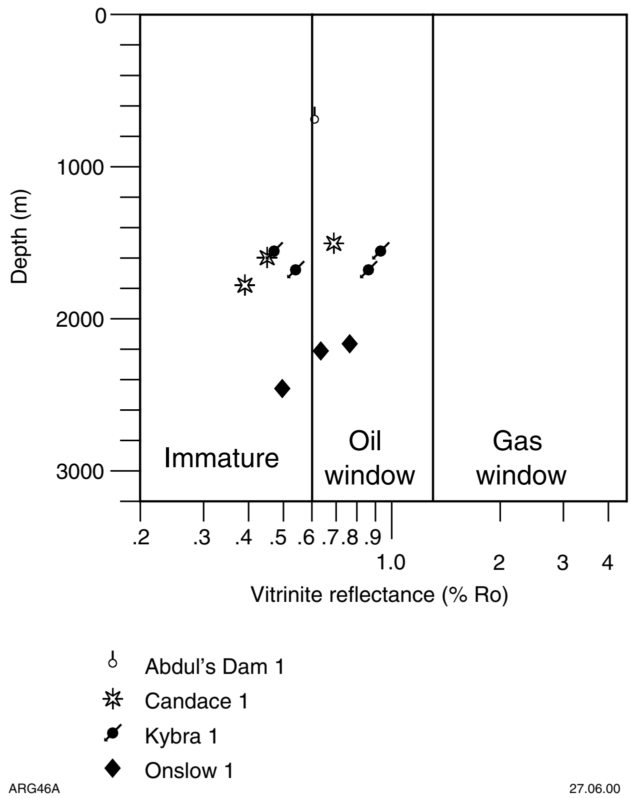

Figure 72. Measured maturity as vitrinite reflectance versus depth in the Peedamullah Shelf and Onslow Terrace for the Upper Permian Chinty Formation

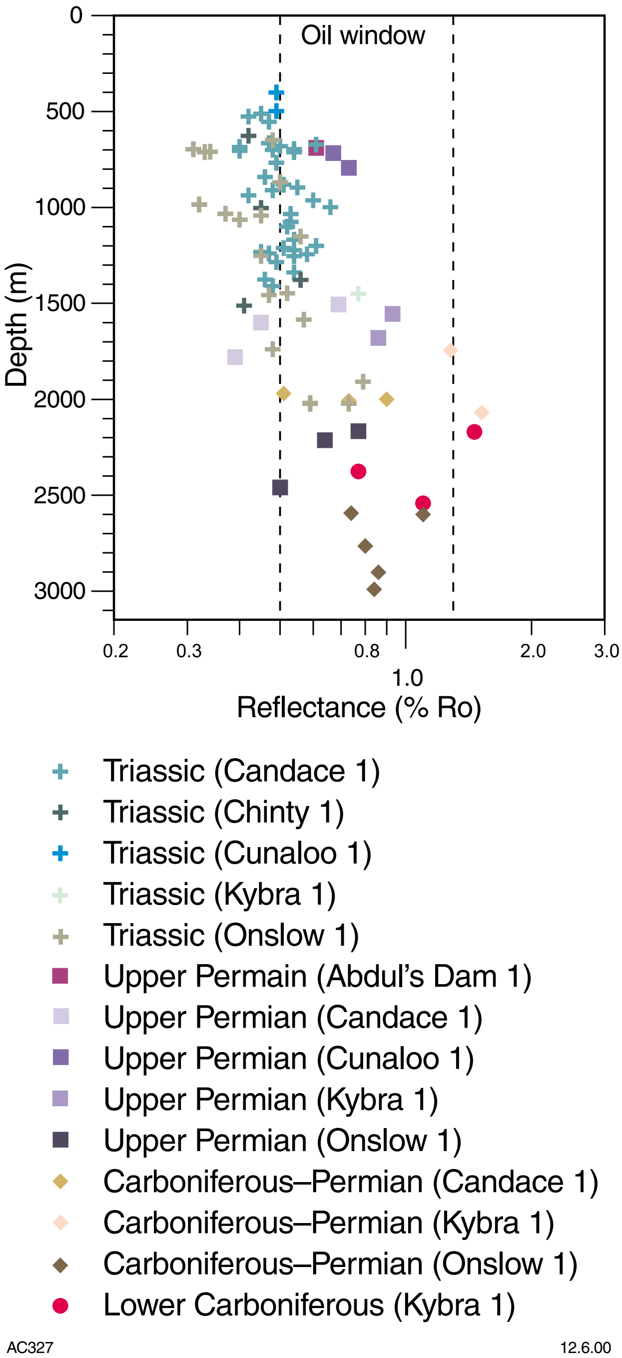

Figure 73. Maturity as a function of vitrinite reflectance versus depth for Carboniferous, Permian, and Triassic rocks

considered to indicate the oil window, for T_{max} are 435–470, PI 0.1 – 0.4, and % Ro 0.5 – 1.3. These values can vary according to different kerogen types and the geothermal history of the area. The T_{max} and PI values for samples considered reliable for maturity evaluations are plotted versus depth in Figure 74. This plot shows that the maturity indicated by T_{max} values are consistently lower than that indicated by the corresponding PI values. Furthermore, both T_{max} and PI values indicate a lower maturity than the corresponding vitrinite reflectance values. These apparent differences in maturity possibly indicate that the values of T_{max} and PI commonly used to define the oil window are not appropriate for the study area.

Rock-Eval maturity parameters suggest that the Upper Permian, Carboniferous–Permian, and Lower Carboniferous samples are mature in Candace 1 and Kybra 1 (Candace Terrace) and in Onslow 1 (Onslow Terrace). However, vitrinite reflectance values from Kybra 1 indicate a predominantly overmature source (Bond Corporation Petroleum Division, 1988, geochemistry appendix).

Source-rock thermal history

In the study area only a few wells are sufficiently deep enough to provide maturity data necessary to constrain the thermal history. For this study, Echo Bluff 1 in the Robe Embayment, Kybra 1 in the Candace Terrace, and Onslow 1 in the Onslow Terrace have been selected for thermal history modelling and to calculate the level and timing of maturation of the region (Table 5). These wells were selected on the basis of available data necessary to constrain the models: maturity, lithology, stratigraphy, total drill depth, and stratigraphic penetration. The numerous shallow wells drilled within the Ashburton Embayment and Weld High do not have sufficient data to produce a model. The models were developed firstly by constructing one-dimensional models of the wells utilizing BasinMod 1-D (version 7.06, Platte River Associates), and then amalgamating the one-dimensional models using BasinMod 2-D (version 4.13, Platte River Associates) to produce a two-dimensional, cross sectional model (Fig. 75).

One-dimensional burial histories were reconstructed from the stratigraphic sections and lithologies penetrated in the selected wells using estimated erosional histories, and adjusting thermal conductivities and transient heat flow to constrain maturity models versus measured data. Corrected bottomhole temperatures (BHTs), % Ro, and T_{max} were used to constrain present-day and palaeotemperatures. The time–stratigraphy relationships utilized in developing the models are summarized in Table 5.

Finally, two-dimensional modelling of a cross section from Onslow 1 (in the southwest) to Kybra 1 (in the northeast) was developed (Fig. 75), to estimate and illustrate the maturation levels across the region and to determine the timing of maturation. The model was constrained against measured present-day temperatures and maturity (Fig. 75a), using present and palaeotemperatures. The estimated maturation stages reached at different stratigraphic levels for the three locations are shown in Figure 75b, whereas maturity across the region is illustrated in Figure 75c. The maturity modelling of Onslow 1 and Kybra 1 are better constrained than for Echo Bluff 1, because reliable maturity data from organic petrology (% Ro) and Rock-Eval pyrolysis (T_{max} and PI) are available from the former wells. The available reliable maturity data from Echo Bluff 1 is limited to only one thermal alteration index (TAI) measurement (approximately 1.0% Ro).

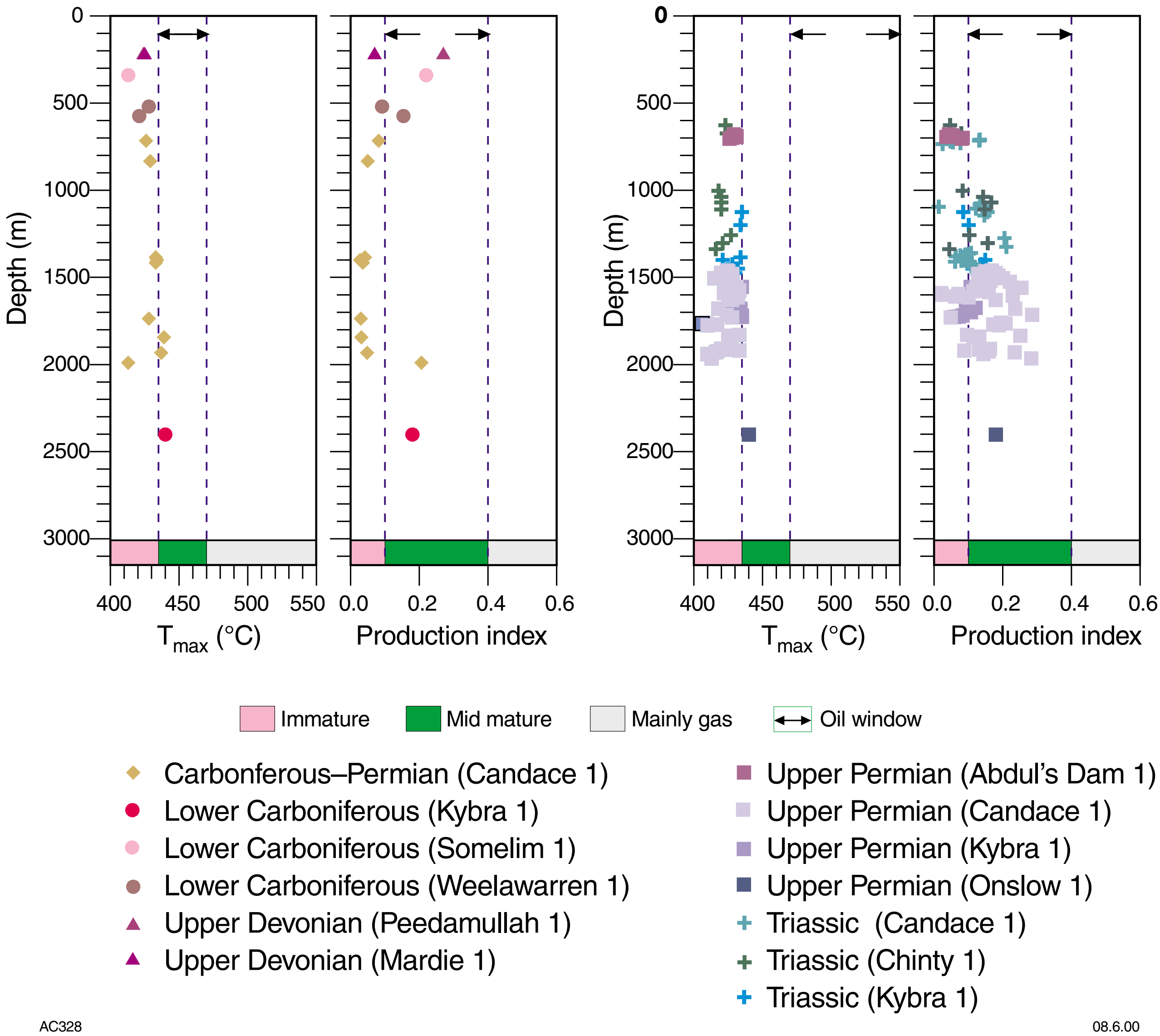

Figure 74. Maturity as a function of Rock-Eval parameters, T_{max} and production indexes (PI) versus depth for Devonian, Carboniferous, Permian, and Triassic rocks

In the study area, the stratigraphic units most likely to contain source beds for hydrocarbon generation are the Middle–Upper Devonian Gneudna Formation, Lower Carboniferous Moogooree Limestone, Upper Permian Kennedy Group, and Lower–Middle Triassic Locker Shale.

Echo Bluff 1 intersected the oldest potential source rock of the modelled wells (Gneudna Formation). Modelling suggests that the formation is mid- to late mature, and that up to 2100 m of section may have been be eroded prior to the Cretaceous. The highest maturity was reached in Kybra 1 (Candace Terrace) in which the Locker Shale and Kennedy Group are mid-mature and the Moogooree Limestone is late to over mature. In this well, up to 2500 m of section may have been eroded prior to the Cretaceous. In Onslow 1, the deepest well in the study area, the Lyons Group, Callytharra Formation, and Kennedy Group are mid-mature and the Locker Shale is early mature. At this location up to 200 m of section may have been eroded prior to the Cretaceous. Within the pre-Cretaceous source rocks, maturation levels are sufficient to generate hydrocarbons, and peak generation was probably reached during the Triassic–Jurassic.

Gas occurrences

Dry gas, predominantly methane, is widespread within the Cretaceous section across the entire Peedamullah Shelf. Most wells in the area encountered high background values of methane throughout the Winning and Barrow Groups, with discrete peaks at horizons with good reservoir characteristics. The Tubridgi Gasfield originally had reserves exceeding 3×10^9 m^3 of dry methane within the Cretaceous Birdrong Sandstone, Flacourt Formation, and the unconformably underlying Triassic Mungaroo Formation (Department of Minerals and Energy, 1998), and is still being exploited. Dry gas in water solution was recovered from several DSTs, indicating that the gas is

Table 5. Time–stratigraphy for the thermal maturation models on the Peedamullah Shelf and Onslow Terrace

Formation or event name	*Starting age (m.y.)*	*Formation tops (from ground level in m)* Echo Bluff 1	Kybra 1	Onslow 1
Recent	2	0	–	0
Unconformity	11	–	–	–
Tertiary	16	3.13	17.6	29
Unconformity	73	–	–	–
Cretaceous	89	21.13	108	54
Unconformity	146	–	–	–
Dingo Claystone	159	–	–	–
Mungaroo Formation	235	–	518	551
Locker Shale	251	–	930	1 582
Kennedy Group	274	–	1 459	2 095
Unconformity	286	–	–	–
Callytharra Formation	292	–	1 703	2 491
Lyons Group	305	–	1 724	2 601
Unconformity	325	–	–	–
Quail Formation	330	–	2 112	np
Moogooree Limestone	354	–	2 133	np
Gneudna Formation	375	195.13	np	np
Nannyarra Sandstone	378	989.13	np	np
TD		**1 198.13**	**2 527**	**2 993**

NOTES: m.y.: million years
TD: total depth
np: not penetrated

retained in interstitial pore spaces. In many instances, seismic sections show horizons with direct hydrocarbon indications, but when drilled, proved to contain only gas-cut water. On the upthrown part of the Sholl Fault there is a mound spring with a gas seep at Mount Salt (7.5 m ASL), near Coonga 1 (Plate 1; Thomas, 1978).

The analysed gas has a C_1/C_{1-5} ratio of 0.99, which is indicative of a primary biogenic origin. The presence of such gas in the Cretaceous section of the Peedamullah Shelf is consistent with generation within immature, marine Cretaceous sediments at shallow depth and low temperatures (lower than 75°C), and a sulfate-deficient environment. Alternatively, the biogenic gas may have a secondary origin (Scott et al., 1994), that is, the gas may have been thermogenically generated, then migrated via faults into shallow reservoirs, and subsequently biodegraded by the metabolic activity of bacteria introduced by meteoric waters. This process requires burial below the oil window, and uplift and erosion of the basin margin to expose the carrier beds, a succession of events that is also evident in the Peedamullah Shelf. The carbon dioxide present is not derived from biodegradation (Pan Pacific Petroleum NL, 1996, appendix G). A primary origin for the methane requires shallow depths, since bacterial activity ceases at advanced stages of dewatering and compaction. Such gas, therefore, commonly cannot be generated at depths exceeding 2000 m. These conditions are also present in the study area. In predominantly methane gases, heavier hydrocarbons commonly represent less then 1% by volume but in biogenic gas can reach up to 2%. The association of the biogenic gas with biodegraded heavier hydrocarbons may support a secondary biogenic origin. However, a vitrinite reflectance value of 0.3% Ro has been calculated for the gas (Pan Pacific Petroleum NL, 1996, appendix C), indicating a low maturity. Conversely, as discussed above, oils in the Peedamullah Shelf and Candace Terrace have vitrinite reflectance equivalent values close to 1.0% Ro. As gas is much more prevalent than oil within the Peedamullah Shelf, the present distribution of fluids implies that any oil in place was replaced by the later migration of gas, from either a different source or the same source.

Accumulations of methane on the Peedamullah Shelf are not associated with pre-Jurassic heavier hydrocarbons. However, in the Barrow Sub-basin oil and gas coexist in the same field. Geochemical analyses of methane alone, however, do not prove either interpretation. Carbon isotopic analyses of the gas (-50 and -46.25 $\delta^{13}C$‰ PDB in Tubridgi 7 and Topaz 1 respectively, as discussed in **Tubridgi Gasfield**) are also not definitive (Scott et al., 1994, fig. 9). It is suggested here that the biogenic gas of the Peedamullah Shelf is a mixture of both primary and secondary origin. On geological grounds, the percentage of secondary biogenic gases increases northwestwards where oil fields are moderately biodegraded and associated with methane gas caps. Southeastwards, primary biogenic gas probably dominates. Further analyses should allow a more quantitative interpretation. Similar occurrences of methane are widespread across the Peedamullah Shelf. The gas-generating bacteria probably also biodegraded residual oil present in the region, as well as further basinwards in the Roller and Skate Fields. Biodegradation commonly decreases northwestwards, away from areas of shallow basement where the Cretaceous is thin (Kopsen and McGann, 1985).

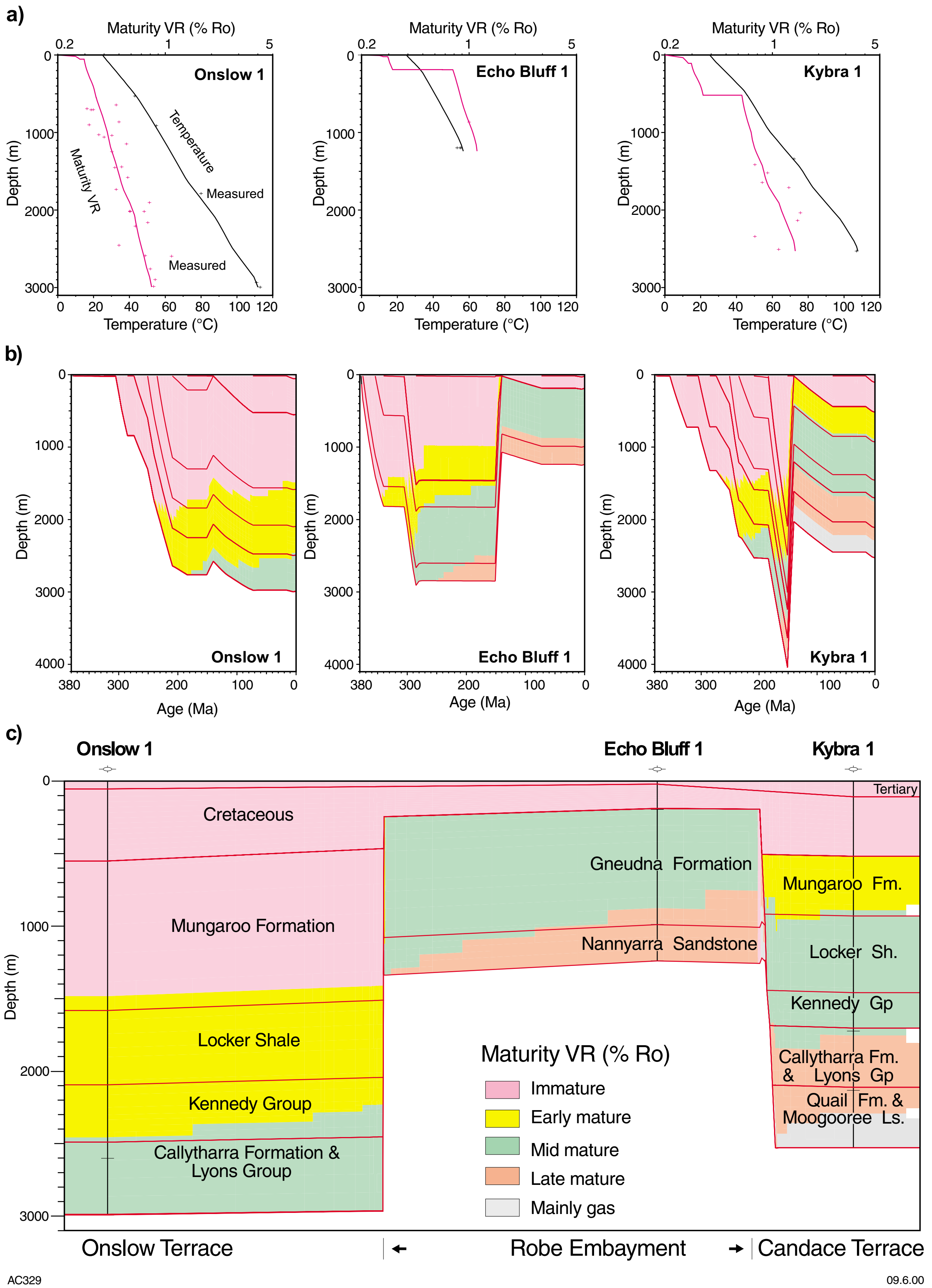

Figure 75. Maturity across the Onslow Terrace, Robe Embayment, and Candace Terrace from Onslow 1 in the southwest to Kybra 1 in the northeast: a) calibration of calculated versus measured maturity; b) burial and thermal histories; c) calculated maturity cross section. The maturity is based on two-dimensional modelling. Well locations are shown in Plate 1

Cretaceous potential source rocks

Data on the potential source rocks in the Cretaceous are scarce because their lower thermal maturity discouraged researchers from carrying out such analyses. However, the available geochemical data reported by Robertson Research (1986), Burns (1989), and Viaggi et al. (1993) indicate the presence of organic-rich intervals of good hydrocarbon-generating potential within the Cretaceous (Table 6; Fig. 76). Many of the samples analysed from Gorgon 1, Spar 1, Anchor 1, and Griffin 1 can be classified as good potential source rocks, with TOC values of 1–4%, potential yield up to 8.90 mg/g rock, and HI values up to 414. These organic-rich intervals are reported from the Barrow Group, Muderong Shale, Windalia Radiolarite, and Gearle Siltstone. However, the best potential source rocks are reported from the Muderong Shale and Windalia Radiolarite (Table 6).

The GSWA has drilled several fully cored, stratigraphic holes in the Gascoyne Platform (Mory and Yasin, 1999; Yasin and Mory, 1999), and carried out geochemical analyses on selected Cretaceous samples. Although these wells are within the Southern Carnarvon Basin, remote from the Peedamullah Shelf, they are relevant as the depositional environment and geological setting of the Cretaceous succession in the Gascoyne Platform and Peedamullah Shelf are similar. The analyses indicate that the petroleum-generating potential of the Cretaceous in the Southern Carnarvon Basin ranges from fair to good (Fig. 77).

Petroleum potential

Reservoir potential

Pre-main unconformity and basal Cretaceous sandstones have good to excellent reservoir potential within the Peedamullah Shelf, and are obvious objectives for petroleum exploration.

Within the pre-main unconformity objectives the Middle Devonian Nannyarra Sandstone, Upper Permian Abdul Sandstone, and sandstones in the Upper Permian Chinty Formation and the Middle–Upper Triassic Mungaroo Formation provide the best reservoir potential. In Echo Bluff 1 on the Robe Embayment, the Nannyarra Sandstone is 150 m thick and has a maximum porosity of 30.7% with an average of 20%. The Abdul Sandstone, which is up to 50 m thick in several wells within the Ashburton Embayment, has a porosity of 23–38%. Sandstones in the Chinty Formation on the Peedamullah Shelf range in thickness from 19 to 40.5 m and have an average porosity of 25%. These sandstones show bimodal porosity distribution with peaks at 5 and 25% and

Table 6. TOC and Rock-Eval data for the Cretaceous succession

Unit	*TOC (%)*	*S_1+S_2 (mg/g rock)*	*HI*
Gorgon 1			
Muderong Shale		[(a)]3.83	[(a)]163
Flacourt Formation		[(a)]2.98	[(a)]151
Spar 1			
Windalia Radiolarite		[(a)]5.44	[(a)]230
Muderong Shale		[(a)]3.44	[(a)]184
Barrow Group		[(a)]2.0	<150
Anchor 1			
Muderong Shale	[(b)]1.7		
Griffin 1			
Gearle Siltstone	1.0 – 2.0	0.91 – 3.27	76–168
Windalia Radiolarite	1.15 – 1.45	1.97 – 4.36	142–252
Muderong Shale	>1.0	2.40 – 8.90	172–414
Barrow Group	>1.0	5.36 – 6.08	367–398
Barrow Island			
Upper Cretaceous	2.0 – 3.0 (high gas background)		
Lower Cretaceous	1.0 – 3.0		
Flag 1			
Toolonga Calcilutite	(high gas background)		

NOTES: (a) denotes a maximum value
(b) denotes an average value
TOC: total organic carbon
S_1+S_2: potential yield
HI: hydrogen index

SOURCE: Robertston Research (1986); Burns (1989); Viaggi et al. (1993)

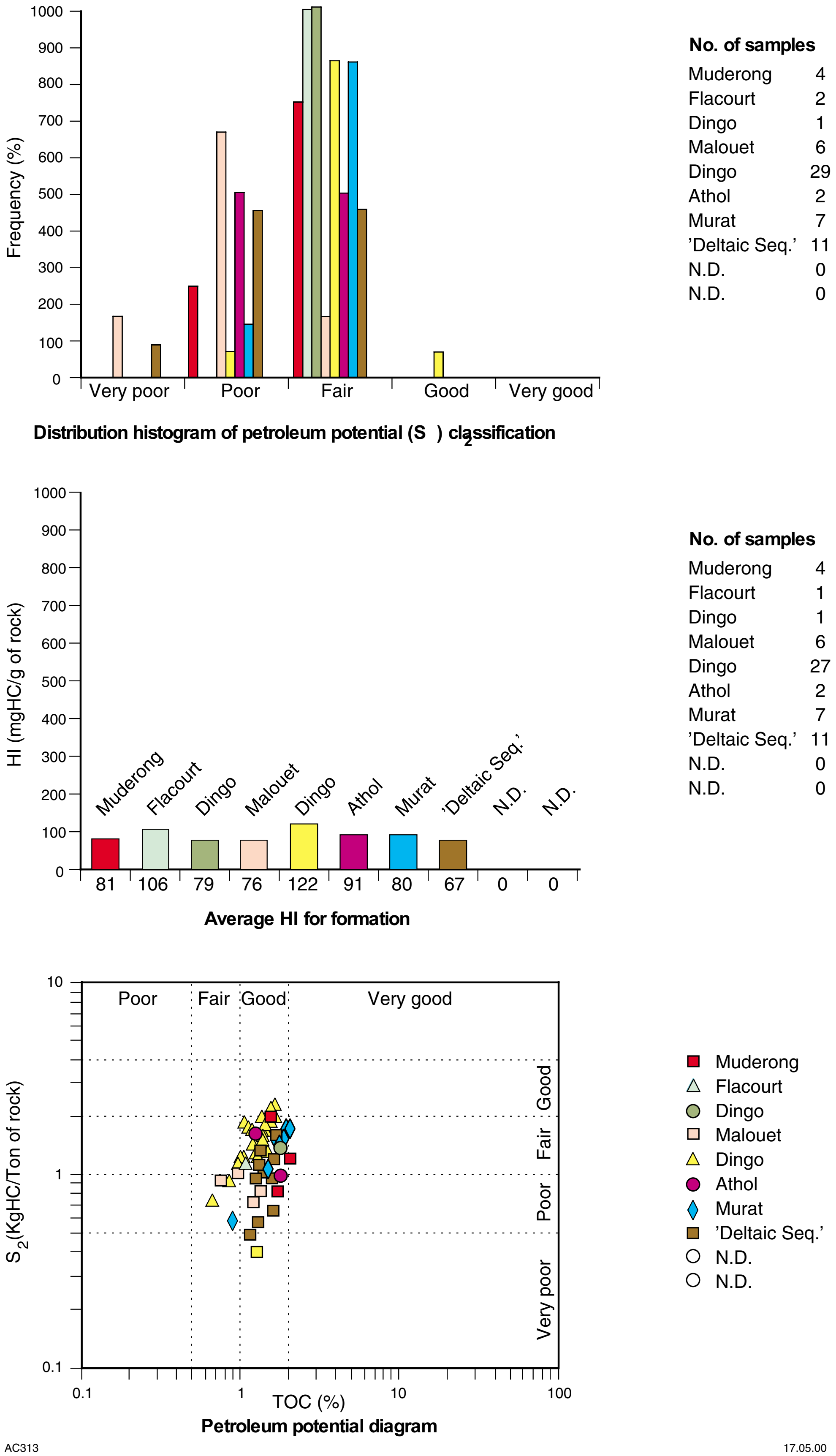

Figure 76. Petroleum potential diagram; average HI for formation and distribution histogram of petroleum potential (S_2) classification from Anchor 1, Northern Carnarvon Basin (from Viaggi et al., 1993)

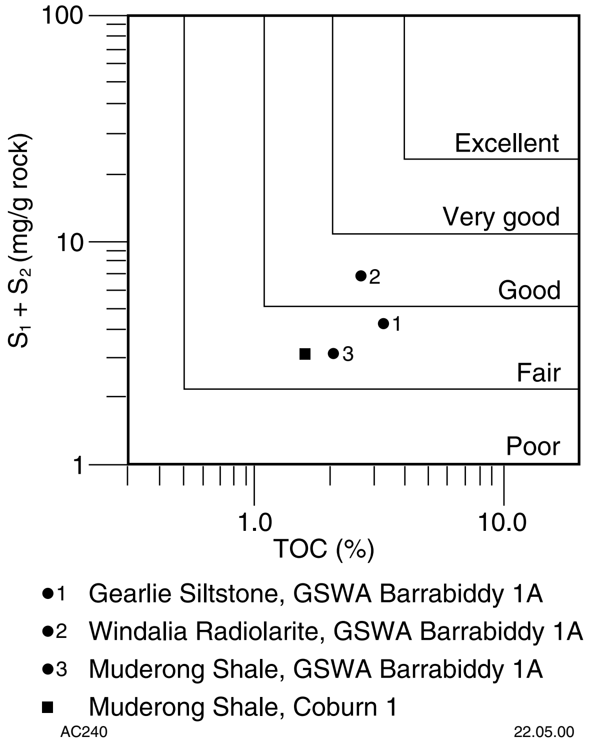

Figure 77. Petroleum-generating potential as TOC versus $S_1 + S_2$ for Cretaceous core samples taken from Barrabiddy 1A and Coburn 1 (after Mory and Yasin, 1999, and Yasin and Mory, 1999).

corresponding permeabilities of 0.5 – 30 mD and 100–1000 mD respectively (Fig. 78). Sandstone intervals in the Mungaroo Formation are known to be reservoirs for the large gas accumulations on the Rankin Platform and also show good reservoir potential in the Peedamullah Shelf, where porosity reaches 30% and permeability exceeds 1000 mD (Fig. 78). In the Tubridgi Gasfield, the Mungaroo Formation, which consists of medium-grained, moderately sorted quartzose sandstone to conglomerate, contains 11% of the reserves (the remaining reserves are within the overlying Flacourt Formation and Birdrong Sandstone). In this field, the Mungaroo Formation has an average porosity of 24% and an average permeability of 2 D based on core analyses.

Clastic secondary objectives within the pre-main unconformity succession include sandstone interbeds within the largely impervious Gneudna Formation (porosity up to 28.5%; Allchurch, 1984), sandstone of the Lower Carboniferous Quail Formation (log-porosity of 10–25% at shallow depth; Johnston et al., 1963; McTavish, 1968; Pan Pacific Petroleum NL, 1995a), and sandstone with moderate reservoir potential near the base of the Locker Shale (Fig. 78). Furthermore, limestone of the Devonian Gneudna Formation, if fractured, could have reservoir potential, as could the Lower Permian Cody Limestone if fractured or karstified (Gorter and Davies, 1999). Sandstone beds in the Carboniferous–Permian Lyons Group, however, have too low a porosity to represent attractive targets (Fig. 78).

The reservoir potential of basal Cretaceous sandstone is clearly demonstrated in the Tubridgi Gasfield. In this field the Flacourt Formation and Birdrong Sandstone contain 89% of the total reserves (65 and 24% respectively). The deltaic Flacourt Formation contains massive, poorly consolidated, well-sorted sandstone horizons up to 10 m thick, for which excellent porosity values of 29–35% and permeability values of over 7 D have been measured from core. These data do not apply within the northeastern portion of the field, as the reservoirs there have been affected by post-depositional calcite cementation. Marine, fine- to coarse-grained glauconitic quartz sandstone (Fig. 79) in the 4–7 m-thick Birdrong Sandstone has an average porosity of 33% and a permeability of several hundred millidarcies, although pyritic and sideritic cementation locally reduce the reservoir quality of the unit. The reservoir characteristics of the highly glauconitic (Fig. 79) Mardie Greensand are not fully understood, but the porosity of the unit within the Tubridgi Gasfield is up to 27%. However, the porosity effectively contributing to the production is much lower, as permeability appears to be very low, barely reaching 20 mD. A recent study within the Thevenard Island area by Seeburger et al. (1998) documented the performance of Mardie Greensand reservoirs with low water saturation and interconnected intragranular porosity, in which a pore throat radius less than 0.5 μm produces water-free hydrocarbons. These reservoirs are associated with intervals of glauconitic intrapelloidal porosity with high, but immobile, water saturation. The analytical approach to glauconitic reservoirs in this and other (Delfos, 1994) studies may help to quantify the reservoir potential of the Mardie Greensand. In the Tubridgi Gasfield, and in other areas, gas shows have also been found within the Muderong Shale, Windalia Sandstone, Windalia Radiolarite, and Gearle Siltstone, but from thin beds of limited extent, which therefore do not appear to represent viable targets. However, the biggest oilfield in the Barrow Sub-basin on Barrow Island is reservoired in the Windalia Sandstone Member, which could also be economically significant on the Peedamullah Shelf. In the Robe Embayment, the Yarraloola Conglomerate has excellent porosity and permeability (Thomas, 1978), but is artesian.

Well sonic logs indicate good porosity (up to 25%) in both the Windalia Sandstone Member and Windalia Radiolarite, but log-interpreted values may be optimistically high due to the presence of shaly intervals. Permeability reaches 3 mD in the Windalia Sandstone Member, but is less than 1 mD in the overlying Windalia Radiolarite.

Seals

Shales within the conformably overlying Gneudna Formation effectively seal the Devonian Nannyarra Sandstone. Within the region, the entire Gneudna Formation is expected to have sealing characteristics, as the interbedded carbonates are probably fractured only locally. The Permian Abdul Sandstone is conformably overlain by shale beds of the Chinty Formation, which are interbedded with sandstones (Figs 4, 5, and 6). Consequently, the Chinty Formation can provide only a

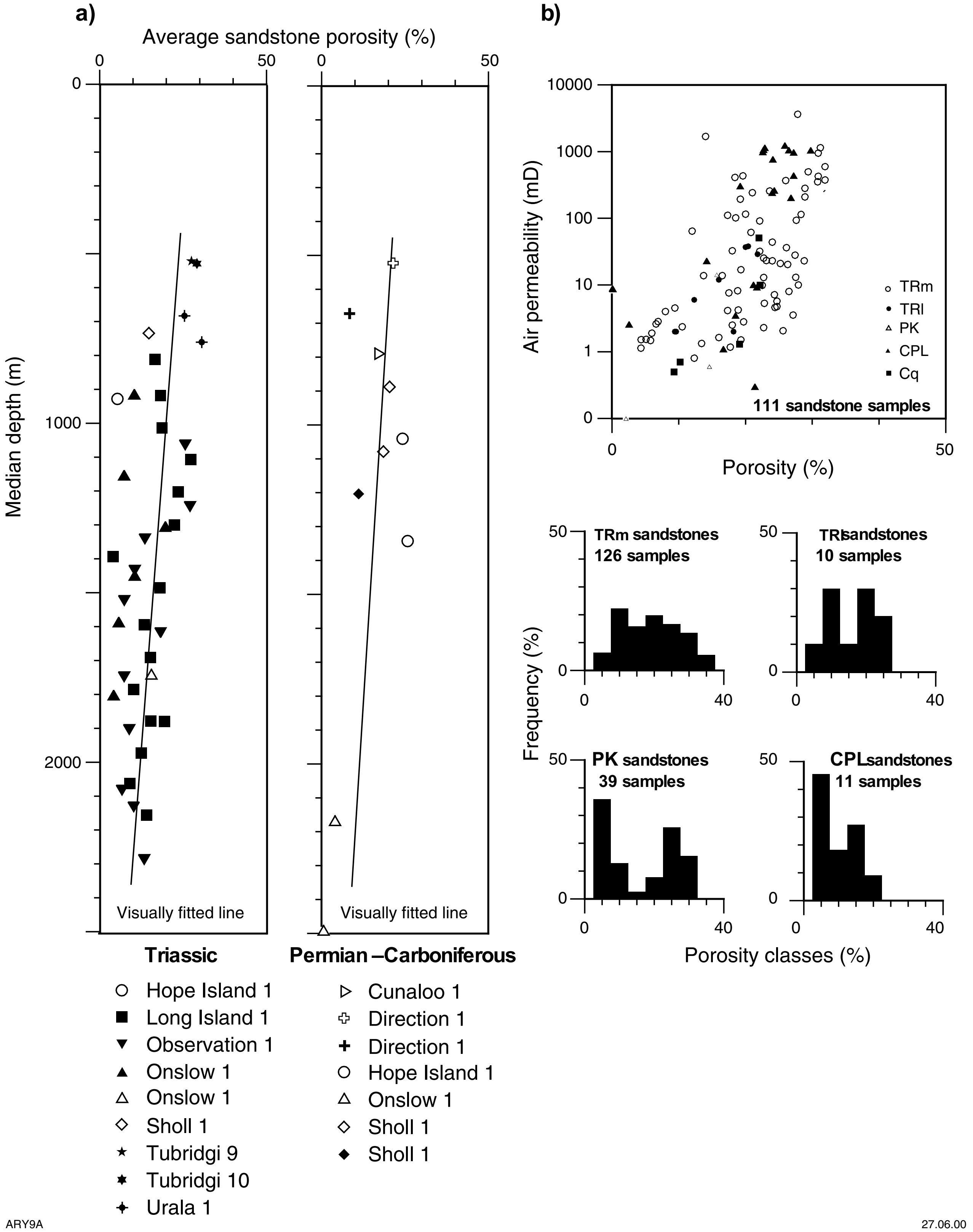

Figure 78. a) Porosity versus depth of the Triassic and Permian–Carboniferous sandstone on the Peedamullah Shelf and Onslow Terrace. Triassic: solid symbols = Mungaroo Formation, empty symbols = Locker Shale. Permian–Carboniferous: solid symbols = Lyons Group, empty symbols = Chinty Formation, Kennedy Group; b) porosity versus permeability trends of the Triassic and Permian–Carboniferous sandstone on the Peedamullah Shelf and Onslow Terrace. TRm = Mungaroo Formation, TRl= Locker Shale, PK = Kennedy Group, CPL = Lyons Group, Cq = Quail Formation

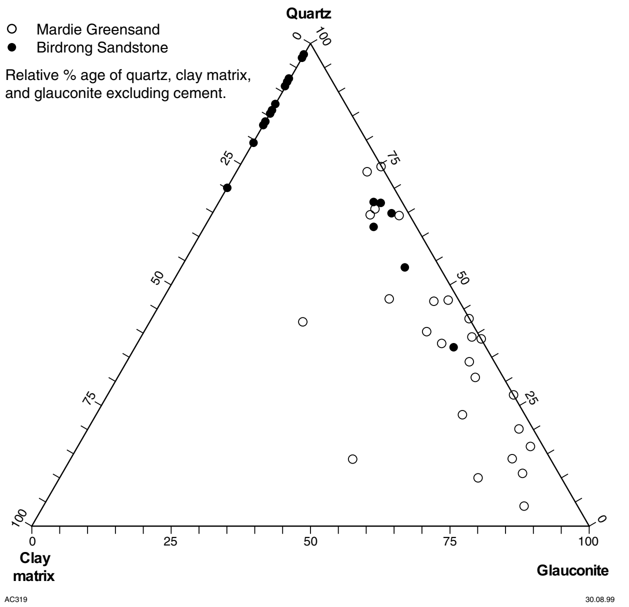

Figure 79. Relative percentage of quartz, glauconite, and clay matrix in the Birdrong Sandstone and Mardie Greensand within the Peedamullah Shelf and Onslow Terrace

limited potential for sealing both the underlying Abdul Sandstone and the interbedded intraformational sandstone beds. However, the conformably overlying Triassic Locker Shale may provide a regional seal for reservoirs in the uppermost Chinty Formation and the base of the Triassic.

Although there are intraformational seals in the Triassic Mungaroo Sandstone, the primary hydrocarbon accumulations within the formation are sealed regionally by the flat-lying Muderong Shale in truncation traps (e.g. Rankin Platform). In the Tubridgi Gasfield, sandstone of the Mungaroo Formation together with the overlying Flacourt Formation and Birdrong Sandstone forms a single reservoir, which is sealed by the Muderong Shale. The presence of this sealing unit is the critical factor, controlling all basal Cretaceous accumulations on the Peedamullah Shelf and Barrow Sub-basin.

Amongst the secondary objectives, carbonate in the Gneudna Formation depends on an intraformational seal, sandstone of the Lower Carboniferous Quail Formation may be regionally covered by shale in the Carboniferous–Permian Lyons Group, and karst traps in the Cody Limestone should subcrop beneath the Muderong Shale to be effectively sealed.

Traps

Typically, pre- and post-main unconformity trapping mechanisms are present within the Peedamullah Shelf and Onslow Terrace. Pre-main unconformity Devonian, Carboniferous, and Permian potential reservoirs may be in fault traps, created by Late Jurassic extensional rifting and resultant block faulting. Such traps may be effective, as they are in the Northern Carnarvon Basin, where intraformational seals are present. Examples include Gorgon 1 within the Barrow Sub-basin (Menzel et al., 1982), the Goodwyn South Field within the Rankin Platform (Vincent and Tilbury, 1988), Leatherback 1 within the Exmouth Sub-basin (Bauer et al., 1994), Vinck 1 in the Investigator Sub-basin (Esso Exploration and Production Australia Incorporated, 1981), and the Lambert Shelf (Kingsley et al., 1998). Therefore, block faulting has been demonstrated to form effective traps in the region, although this type of trapping mechanism is less common in fields sealed by post-main unconformity units.

Anticlines formed at the end of the Jurassic are also present (Fig. 10). In the Barrow Sub-basin, however, the post-main unconformity basal Cretaceous reservoirs are commonly evident in anticlinal traps that formed in the mid-Miocene. Downfaulted structures require four-way dip closures, as in the Tubridgi (Fig. 9) and Reindeer (Ballesteros, 1988) Gasfields. Three-way dip closures can be effective traps when controlled by a fault downthrowing the objective section in the fourth direction, as in the Saladin, Yammaderry, Griffin, and Harriet Oilfields (Howell, 1988; Tait et al., 1989; Beacher et al., 1994; Berean et al., 1994) and in the Legendre–Jaubert Oilfield, and Alkimos and Wonnich gas- and oilfields (Ballesteros, 1988). In these fields, the juxtaposition of Barrow Group reservoirs against the impervious rocks of the Winning Group provide the required lateral seal. In the Roller Field, however, a fault appears to provide a partial seal to the downthrown structure (Beacher et al., 1994). Within the Onslow Terrace, the Tubridgi Gasfield lies within a Middle Miocene anticline.

Additional trapping possibilities are offered by truncation traps, namely dipping, pre-main unconformity reservoirs sealed by subhorizontal shales (e.g. North Rankin), Early Carboniferous four-way dip closures (evident in the Candace Terrace), sandstone in the Flacourt Formation within palaeotopographic highs, or basal Cretaceous sandstones that pinchout, both sealed by Muderong Shale. Diagrams illustrating these play concepts, and other less likely play concepts, are shown by Yasin and Iasky (1998, fig. 16).

Prospectivity

A total of 86 wells have been drilled within the Peedamullah Shelf and Onslow Terrace to the end of 1997 (Appendix 1). Of these, 19 were drilled for stratigraphic control, including 8 drilled as part of the ‘islands’ project carried out by WAPET in the late 1960s. Within the Robe Embayment, 27 wells were very closely spaced (Mardie Area insets, Plate 1) to test postulated accumulations of oil, but with limited structural control. In the Tubridgi area, 20 appraisal and development wells have been drilled to the end of 1999 (Plate 1; Figs 9 and 25). Out of the total, only 23 can therefore be considered effective exploration wells, only one of which — Tubridgi 1 — was successful. Of the remaining 22, 16 are considered to be tests of basal Cretaceous sandstone drilled out of closure, whereas 6 were drilled to test pre-Cretaceous objectives and lacked the interpreted fault trap. In three wells, the expected main

Table 7. Categories of wells drilled on the Peedamullah Shelf and Onslow Terrace

Type of well	*No. wells*
Stratigraphic wells	19
Robe Embayment wells	(a)27
Wells lacking closure at the basal Cretaceous level	16
Wells lacking fault controlled trap at pre-Cretaceous levels	6
Wells where the postulated main objective was not present	3
Appraisal and development wells	(b)16
Discovery wells (gas)	1

NOTES: (a) Robe Embayment wells except Echo Bluff 1, as they have been located without or with very poor structural control
(b) including Onslow 1 and Wyloo 1, as they fall within the Tubridgi Gasfield

target was not present. It is acknowledged that this overall assessment of the region (Table 7) is approximate, and in wells with more than one objective, only the most important target was considered.

In spite of the considerable drilling, the Peedamullah Shelf and Onslow Terrace petroleum province still contains opportunities for additional discoveries, as addressed in **Petroleum potential**. The plays expected in each structural unit are reviewed and rated below.

Yanrey Ridge

Virtually all of the few wells in the southern part of the Yanrey Ridge tested stratigraphic plays. The aim was to investigate basal Cretaceous sandstones pinching out against impervious basement, and sourced from deeply buried mature strata. Long-range migration of hydrocarbons was postulated. This play is still conceptually valid (Fig. 80) because the wells were located on limited and poor seismic control. Although a high risk should be attached to this play type, further drilling in the area appears to be justified, but requires additional seismic control.

Within the Yanrey Ridge — as in the entire region — the basement progressively deepens northward. Therefore, the northern part of the ridge could be expected to be as prospective as the Onslow Terrace. Although the reservoir quality of the Birdrong Sandstone is limited to a thin basal interval in Urala 1, the Mungaroo Formation represents an additional attractive objective. Methane, probably biogenically generated from the Cretaceous, is widespread.

Ashburton Embayment

The Ashburton Embayment offers potential for pre-Cretaceous targets in fault blocks. Potential reservoirs and seals are present within the Permian–Triassic succession and possibly in older rocks. The regional presence of both biogenic gas and oil sourced from pre-Jurassic rocks has been discussed in the previous section. Locally, the lowermost Cretaceous unit is the Muderong Shale (e.g. in Abdul's Dam 1, Cunaloo 1, Picul 1, Sapphire 1, and Weelawarren 1) and thus truncation plays are feasible where subhorizontal basal Cretaceous shales seal gently dipping Triassic and Permian sandstone. Progressively younger units are present beneath the main unconformity to the north (Plate 3; Fig. 4) where units with proven reservoir potential, such as the Mungaroo Formation and Abdul Sandstone, have been penetrated, thereby indicating that the hydrocarbon potential is greater in this direction.

Middle Miocene positive features, such as the Picul and Weelawarren anticlines, are developed along a belt parallel to the Weelawarren Fault (Figs 54 and 65; Plate 1). As basal Cretaceous and mid-Triassic sandstone within Tertiary anticlines has been a successful play in the Onslow Terrace (Tubridgi Gasfield), the two prospects (Picul and Weelawarren) deserve further investigation. Within the large Picul structure, basal Cretaceous sandstone may have been deposited locally or a truncation play may be present. Within the Weelawarren prospect, a structurally higher location is feasible, as discussed in **Weelawarren 1**, quite apart from the possibility of redefining the structure with additional seismic control. Tertiary anticlines may also be present, but not identified, due to the poor resolution of shallow horizons. Three-way dip closures on the upthrown part of major faults, such as the Weelawarren Fault, also could be present.

In conclusion, two well-proven and independent plays are valid within the Ashburton Embayment. The pre-

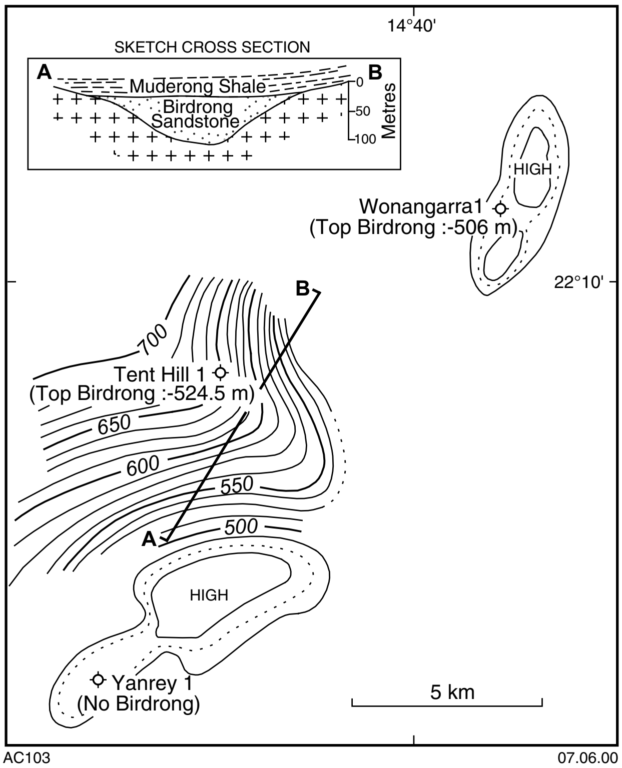

Figure 80. Two-way time to the basal Cretaceous unconformity for the Yanrey Ridge area (simplified after Minora Resources NL, 1990)

Cretaceous Permian–Triassic fault block play is probably oil-prone, although it is more difficult to define, and therefore, more risky. Basal Cretaceous sandstone reservoirs in Middle Miocene anticlines appear most likely to be successful, but are a gas-prone play.

Cane Embayment

The Cane Embayment has been defined only on the basis of geophysical data. Theoretically, it should have a similar potential to the Ashburton and Robe Embayments, but — as no economic discovery has yet been made in the two latter embayments — a success in either of these two areas is critical to evaluating this play type in the Cane Embayment.

Robe Embayment

Oil has been discovered in basal Cretaceous clastic rocks within many of the Robe Embayment wells, and attracted exploration investment from several oil companies. No mid-Miocene structures have been recognized and thus basal Cretaceous sandstone can only be expected to form traps stratigraphically or in palaeotopographic highs. However, source rocks, potential reservoirs, and seals are proven in the pre-Cretaceous section. It is unlikely that all the oil generated in the area has escaped, as there were suitable traps at the time of migration. There also may have been long-range migration from the Barrow Sub-basin into the Robe Embayment. Palaeozoic anticlines and fault traps, albeit difficult to define, offer the best possibility for an oil discovery although additional seismic control, necessary to better define the Cretaceous and Cainozoic horizons, may reveal attractive post-breakup features. A new phase of exploration will benefit from an evenly and closely spaced seismic grid, and an interpretation consistent with the regional geology. The reservoir potential of the Mardie Greensand then may be re-evaluated in the light of the success already achieved offshore.

Weld High

Limited subsurface control is available on the Weld High. Mid-Miocene deformation took place, at least locally, as indicated by the well-defined Tertiary anticline documented in the Amber–Topaz area (Fig. 42). Methane is present in the Cretaceous within virtually all wells, but has been tested only in Topaz 1. Indications of oil, albeit poor, are also widespread.

On present data, a Tertiary trap, if present in the Amber–Topaz area, would offer the best petroleum potential. In such a trap, the Flacourt Formation may provide the main reservoir objective and the Birdrong Sandstone and Mardie Greensand may provide additional objectives, with the Muderong Shale as a seal. Deeper objectives, such as sandstone in the Mungaroo Formation, may be present in fault blocks within the offshore portion of the Weld High, but on present knowledge this play has a high risk.

Candace Terrace

The Candace Terrace offers many plays. Although post-breakup horizons are subhorizontal and, on present knowledge, do not offer viable targets, folding of Early Carboniferous (Fig. 2) and earliest Cretaceous (tested by Candace 1) age has been recognized. Potential reservoirs, seals, and traps are present. The intensely faulted area separating the Candace Terrace from the Barrow Sub-basin may offer attractive prospects, especially along faults closer to the main depositional centre of the latter, as well as within the upthrown blocks. Triassic and Permian sandstone reservoirs, largely sealed intraformationally, may be present in pre-Cretaceous fault traps. Devonian reservoirs regionally sealed by the Gneudna Formation and sandstone in the Lower Carboniferous Quail Formation, unconformably sealed by shale of the Lyons Group, may be present in Early Carboniferous folds.

In the Candace Terrace, dry methane is present within the Cretaceous section and may have migrated into the underlying Mungaroo Formation, wherever a trap is present. Liquid hydrocarbons have yet to be identified, but in the Chinty Formation source rocks are currently within the oil window and have the potential to generate both gas and oil (Figs 69–72). In the Candace Terrace only two structures have been tested, but neither is considered to be valid: there is, therefore, considerable scope for further drilling of valid structures in this large area.

Onslow Terrace

The only proven petroleum system within the area of investigation exists in the Tubridgi Gasfield. The trap is an anticline formed in the mid-Miocene, in which the Muderong Shale seals biogenic gas accumulated in the Mungaroo, Flacourt, Birdrong, and Mardie reservoirs. As the gas is biogenic, it must have been generated from Cretaceous source rocks (Crostella and Boreham, in prep.). Any biogenic gas generated before the mid-Miocene probably did not migrate from the source rock until the Miocene tectonism created suitable migration paths and may still be largely trapped 'in situ', as suggested by the widespread background gas found in most wells in the region.

The significant amount of biodegraded oil present indicates that oil was generated in, and migrated through, the region. As the oil is mainly pre-Jurassic, and all the Barrow Sub-basin fields contain oil generated from Upper Jurassic source rocks (van Aarssen et al., 1997), long-range migration from deeper parts of the Barrow Sub-basin is not proven. However, the presence of light oil in Mardie 2 and intermediate oil in Crackling 1 and Santa Cruz 1 suggest that some oil migrated from the Barrow Sub-basin, at least to the Weld High and Robe Embayment. No chemical data are available to refer the oil to a specific source rock and, consequently, the time of their generation cannot be established. As the Tubridgi gas probably displaced a pre-existing oil accumulation, at least some oil migrated (or re-migrated) after the mid-Miocene. Maturation and migration possibly also took place earlier, and the hydrocarbons — oil or thermogenic gas — could have been lost or trapped in small permeability traps, Late Tithonian fault traps, or anticlines that were not destroyed by later structuring.

The presence of the Tubridgi Gasfield, widespread indications of methane and oil, and highly attractive reservoir objectives such as the Mungaroo and Flacourt Formations and Birdrong Sandstone, combined with the presence of Tertiary anticlines and pre-Cretaceous fault blocks, makes the Onslow Terrace very attractive to petroleum explorers. The first recommended step for further exploration activities should be a detailed examination of the available seismic data for undrilled or poorly tested Tertiary anticlines. By analogy with the Roller Field, which was discovered on the downthrown side of the Long Island Fault, similar structures may be present along the downthrown side of the Weelawarren Fault. Four-way dip closures, however, appear to be necessary to make this a valid trap. On the upthrown side of the Long Island Fault and other regional faults, three-way dip closure should be sufficient to provide an effective trapping mechanism. As long-range migration has not been proven, the possible Tertiary traps are likely to be gas prone, whereas deeper fault blocks may possess potential for both gas and oil.

Conclusions

The Peedamullah Shelf and Onslow Terrace are part of the Northern Carnarvon Basin that formed during Carboniferous to Jurassic rifting episodes, which culminated after the early Neocomian breakup of Gondwana. The Late Palaeozoic to Early Mesozoic rift basin was superimposed over a widespread pre-Upper Carboniferous intracratonic basin. During rifting, fault block movements on the Peedamullah Shelf allowed the Jurassic to remain structurally high, while a thick Jurassic succession was deposited in a deep-water rift to the northwest.

During Late Jurassic to Earliest Cretaceous rifting, the Barrow Group delta (Flacourt Formation) prograded to the northwest into the Barrow Sub-basin, infilling the fluvio-marine basin and onlapping older formations in shallow parts of the sub-basin (Tait, 1985). The observed thinning of the Barrow Group from north to south across the sub-basin is largely depositional, and the distribution of Barrow Group (Fig. 34) is limited when compared to the deposition of post-breakup Cretaceous and Cainozoic units that covered the entire North West Shelf. The source of the delta was probably uplifted basement immediately east of the Candace Terrace, controlled by movement along the Sholl Fault, whereas to the southeast the delta transgressed unconformably over the Robe Embayment. After breakup, the marine transgressive units of the Winning Group were deposited over the Barrow Group with only a small hiatus and virtually no angularity. The relationship between the two units implies only minor tectonism at breakup in the Barrow Sub-basin. It is possible that the stable Pilbara Craton to the east of the Barrow delta may have dampened the breakup tectonism in the general area, in contrast to the larger movements evident along most of the western margin of Australia. The amplitude of Miocene movements within the Barrow Sub-basin and parts of the adjacent Exmouth Sub-basin may be due to the superposition of movements along the northerly and northeasterly structural trends (Fig. 27). The mid-Miocene transpressional tectonism created widespread anticlines in the Barrow Sub-basin and Onslow Terrace, but the effects of this tectonism is only minor southeast of the Flinders Fault System. The mid-Miocene reactivation of major faults produced many folds that may be economically attractive traps for hydrocarbons.

The Peedamullah Shelf and adjacent Onslow Terrace constitute an established petroleum province with potential for both oil and gas accumulations. The oil was sourced from the pre-Jurassic section and biogenic gas was from the Cretaceous. The widely held contention that the hydrocarbons migrated into the area from the main Barrow Sub-basin is unlikely as the oil in the latter area was generated from the Upper Jurassic rocks.

Biogenic gas could also be present in other areas, such as the eastern part of the Exmouth Sub-basin where dry mature gas is present in basal Cretaceous reservoirs and also within Upper Cretaceous levels (Tindale et al., 1998). Locally the gas is clearly not associated with the oil (e.g. Blencathra 1A). In the event that the presence of biogenic gas is confirmed — even if mixed with some non-biogenic gas at an early stage of thermal maturation — the charge history of many Barrow and Exmouth Sub-basins oilfields may be less complex than presently thought.

Oilfields may be present in pre-main unconformity fault traps produced during the latest Tithonian or older tectonism, as is the case in other parts of the Northern Carnarvon Basin. Truncation traps sealed by the Muderong Shale may exist. It is also possible that oil displaced from the Tubridgi anticline, or other traps in similar basinal position, moved towards the margins of the basin and became trapped in mid-Miocene anticlines, where present. However, effective fault traps could be difficult to define, because deep subsurface information is scarce and a high risk factor should be attached to this play.

Gas-, and possibly oilfields, may be present in mid-Miocene anticlines, largely within the Onslow Terrace and adjacent parts of the Ashburton Embayment, as is the case for the Tubridgi Gasfield. More efforts should be made to interpret the structural setting of the shallow Cretaceous–Cainozoic horizons that are, in general, poorly defined because of inappropriate seismic acquisition parameters.

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Appendix 1

Wells drilled for petroleum exploration on the Peedamullah Shelf and Onslow Terrace to 1997, including all wells drilled in the Tubridgi Gasfield to 1999

Well Name	*Onshore/ Offshore*	*S. number*	*Ground or sea bed elevation (m AHD)*	*Latitude (S)*	*Longitude (E)*	*Class type*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Company*	*Well status*	*Gas shows*	*Oil shows*
Abdul's Dam 1	ON	20097	4	21°57'2.2"	114°49'43.6"	NFW	8	770	Upper Permian	1991	Pan Pacific	PA	Nil	Nil
Amber 1	ON	20250	15	21°44'6.6"	115°07'9.6"	NFW	18	682.7	Lower Carboniferous	1994	Pan Pacific	PA	Poor	Fair
Beagle 1	ISL	469	5	21°11'26.0"	115°38'29.0"	STR	6	560	Permian	1969	WAPET	PA	Nil	Nil
Black Ledge 1	OFF	20115	-11	21°36'50.1"	115°02'32.2"	NFW	32	2 680	Upper Triassic	1992	WAPET	PA	Nil	Poor
Candace 1	OFF	2202	-22	20°49'37.4"	115°55'7.0"	NFW	32	2 063	Lower Permian	1982	Australian Occidental	PA	Nil	Nil
Cane River 1	ON	670	8	21°40'50.6"	115°05'54.3"	STR	10	694	Permian–Carboniferous	1971	Hematite Petroleum	PA	Nil	Nil
Cane River 2	ON	688	5	21°38'12.9"	115°15'50.7"	STR	7	413	Devonian	1971	Hematite Petroleum	PA	Nil	Nil
Cane River 3	ON	689	15	21°42'28.0"	115°19'28.0"	STR	17	255	Proterozoic	1971	Hematite Petroleum	PA	Poor	Poor
Cane River 4	ON	691	13	21°35'54.0"	115°33'45.0"	STR	16	173	Proterozoic	1972	Hematite Petroleum	PA	Nil	Nil
Cane River 5	ON	692	31	21°47'22.0"	115°28'48.0"	STR	37	201	Proterozoic	1972	Hematite Petroleum	PA	Nil	Nil
Carnie 1	ON	1997	9	21°24'30.0"	115°41'5.0"	NFW	11	163	Lower Cretaceous	1982	Avon	SUSP	Good	Nil
Chinty 1	ON	2827	3	21°48'40.8"	114°48'13.9"	NFW	11	1 673	Upper Permian	1985	ESSO	PA	Nil	Nil
Crackling 1	OFF	20201	-12	21°11'14.0"	115°33'29.1"	NFW	32	625	Upper Permian	1993	Command	PA	Poor	Fair
Cunaloo 1	ON	693	12	22°00'48.6"	114°53'46.8"	STR	15	798	Upper Permian	1972	WAPET	PA	Nil	Nil
Curler 1	OFF	20391	-8	21°37'53.0"	115°03'12.1"	NFW	29	759	Jurassic	1997	WAPET	PA	Poor	Poor
Direction 1	ISL	424	5	21°32'8.0"	115°07'50.0"	STR	6	673	Lower Permian	1968	WAPET	PA	Nil	Nil
East Somelim 1	ON	20105	7	21°18'52.0"	115°49'21.0"	NFW	9	143.6	Permian–Carboniferous	1991	Lennard	SUSP	Poor	Good
Echo Bluff 1	ON	2605	11	21°23'26.0"	115°43'29.0"	NFW	17	1 204	Ordovician	1984	Avon	SUSP	Nil	Poor
Fortescue 1	ISL	467	5	21°01'10.0"	115°51'24.0"	STR	6	610	Lower Permian	1969	WAPET	PA	Nil	Poor
Glenroy 1	ON	328	3	21°49'4.5"	114°52'28.3"	NFW	5	648	Triassic	1966	WAPET	PA	Fair	Nil
Jade 1	ON	20178	6	21°43'20.0"	114°59'13.8"	NFW	11	604	Triassic	1993	Pan Pacific	PA	Nil	Nil
Jasper 1	OFF	20253	-9	21°32'39.9"	115°10'13.5"	NFW	25	549.7	Lower Carboniferous	1994	Pan Pacific	PA	Nil	Nil
Kybra 1	OFF	2514	-18	20°51'51.7"	115°46'9.2"	NFW	35	2 562	Lower Carboniferous	1987	Bond	PA	Nil	Nil
Locker 1	ISL	362	3	21°43'21.4"	114°45'42.3"	STR	5	766	Upper Triassic	1967	WAPET	PA	Poor	Nil
Mangrove 1	ISL	428	5	21°14'27.4"	115°46'11.3"	STR	6	286	Lower Permian	1968	WAPET	PA	Fair	Nil
Mardie 1	ON	349	5	21°21'19.5"	115°42'30.3"	STR	6	225.5	Devonian	1967	WAPET	PA	Good	Fair
Mardie 1A	ON	1079	5	21°21'18.0"	115°41'43.0"	STR	8	164.3	Lower Cretaceous	1974	WAPET	PA	Excellent	Fair
Mardie 1B	ON	20108	6	21°21'16.0"	115°41'46.0"	EXT	9	165.8	Lower Cretaceous	1991	Lennard	SUSP	Fair	Good
Mardie 2	ON	474	6	21°20'47.4"	115°43'25. 3"	STR	8	165	Lower Cretaceous	1969	WAPET	PA	Poor	Fair
Mardie 3	ON	20193	3	21°20'27.0"	115°43'58.0"	NFW	7	165	Lower Cretaceous	1993	Stirling	PA	Poor	Fair
Mardie West 1	ON	763	6	21°11'56.5"	115°55'23.9"	STR	9	135	Precambrian	1972	Hematite Petroleum	PA	Nil	Nil
Mary Anne 1	ON	421	5	21°17'60.0"	115°30'11.3"	STR	6	533	Middle Triassic	1968	WAPET	PA	Poor	Nil
Minderoo 1	ON	70 V2	11	21°50'45.4"	115°04'47.3"	STR	12	610	Upper Carboniferous	1963	WAPET	PA	Nil	Nil
Multhuwarra 1	ON	W2207	4	21°19'35.0"	115°43'15.0"	NFW	6	185	Lower Cretaceous	1982	Avon	PA	Nil	Nil
Mulyery 1	ON	W404	5	21°18'31.4"	115°47'55.3"	STR	5	140	Lower Cretaceous	1968	WAPET	PA	Good	Nil
Murnda 1	ON	W2348	5	21°21'14.0"	115°41'20.0"	STR	7	252	Devonian	1983	Avon	PA	Nil	Nil
Myanore 1	ON	W2350	5	21°20'39.0"	115°41'40.0"	NFW	7	175	Lower Cretaceous	1983	Avon	PA	Good	Nil
North Sandy 1	ISL	W422	5	21°06'30.5"	115°39'3.3"	STR	6	609.6	Lower Triassic	1968	WAPET	PA	Fair	Ni
Onslow 1	ON	W313	0	21°45'59.5"	114°52'28.8"	NFW	5	2 998	Lower Permian	1966	WAPET	PA	Good	Nil

Appendix 1 (continued)

Well Name	*Onshore/ Offshore*	*S. number*	*Ground or sea bed elevation (m AHD)*	*Latitude (S)*	*Longitude (E)*	*Class type*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Company*	*Well status*	*Gas shows*	*Oil shows*
Peedamullah 1	ON	W403	5	21°24'31.0"	115°37'57.0"	STR	7	328	Devonian	1967	WAPET	PA	Nil	Nil
Picul 1	ON	W20148	8	21°53'46.8"	114°54'17.0"	NFW	13	500.8	Triassic	1992	Pan Pacific	PA	Nil	Nil
Robe River Corehole 1	ON	W367V	22	21°28'7.6"	115°45'23.8"	STR	23	103	Lower Cretaceous	1967	WAPET	PA	Poor	Poor
Robe River Corehole 2	ON	W367V	29	21°28'6.6"	115°49'7.0"	STR	30	74	Lower Cretaceous	1967	WAPET	PA	Poor	Poor
Robe River Corehole 3	ON	W367V	32	21°28'2.4"	115°49'7.0"	STR	34	122	Precambrian	1967	WAPET	PA	Nil	Nil
Robe River Corehole 4	ON	W367V	24	21°26'23.5"	115°49'7.5"	STR	26	103	Lower Cretaceous	1967	WAPET	PA	Poor	Good
Robe River Corehole 5	ON	W367V	31	21°29'15.6"	115°49'6.8"	STR	32	67	Lower Cretaceous	1967	WAPET	PA	Poor	Poor
Ruby 1	ON	W20376	12	21°58'33.7"	114°51'10.5"	NFW	16	500	Upper Permian	1996	Pan Pacific	PA	Poor	Poor
Saddleback 1	ON	W1993	22	21°26'30.0"	115°46'30.0"	NFW	24	148	Lower Cretaceous	1982	Avon	PA	Poor	Nil
Santa Cruz 1	OFF	W20196	-14	21°26'11.5"	115°15'42.0"	NFW	29	629	Permian–Carboniferous	1993	Command	PA	Poor	Good
Sapphire 1	ON	W20177	8	21°52'11.3"	114°52'55.8"	NFW	13	558	Upper Triassic	1993	Carnarvon	PA	Good	Poor
Sapphire 2	ON	W20208	5	21°50'33.2"	114°53'52.3"	NFW	9	600	Middle Triassic	1993	Carnarvon	PA	Nil	Fair
Sharon 1	ON	W3131	6	21°01'1.0"	115°42'7.0"	NFW	14	258.9	Upper Devonian	1987	Avon	SUSP	Nil	Fair
Sholl 1	ON	W296	5	20°57'6.0"	115°53'57.0"	STR	9	1 272	Lower Permian	1967	WAPET	PA	Nil	Nil
Somelim 1	ON	W3544	7	21°18'58.5"	115°49'5.9"	NFW	10	413.5	Lower Carboniferous	1989	Metana Energy	PA	Nil	Nil
Spider 1	OFF	W20321	-8	21°49'38.7"	114°36'51.8"	NFW	27	957	Lower Cretaceous	1995	Discovery	PA	Nil	Nil
Surprise 1	ON	W764	10	21°17'57.8"	115°49'26.8"	STR	12	216	Permian–Carboniferous	1972	Hematite Petroleum	PA	Fair	Poor
Talandji 1	ON	W3253	6	21°48'22.5"	114°54'49.3"	NFW	11	1 488	Middle Triassic	1987	Pan Pacific	PA	Poor	Nil
Tent Hill 1	ON	W3702	4	22°11'2.6"	114°37'1.6"	NFW	7	580	Precambrian	1989	Minora	PA	Nil	Nil
Thringa 1	ON	W1995	5	21°21'15.0"	115°41'0.0"	NFW	7	173	Lower Cretaceous	1982	Avon	SUSP	Produce	Good
Topaz 1	ON	W20311	2	21°42'32.5"	115°10'9.0"	NFW	6	423	Lower Carboniferous	1995	Pan Pacific	PA	Good	Good
Topaz 2	ON	W20377	1	21°42'36.5"	115°10'12.6"	NFW	6	446	Lower Carboniferous	1996	Pan Pacific	PA	Good	Good
Tourmaline 1	ON	W20443	5	21°51'10.4"	114°52'25.0"	NFW	9	472.6	Middle Triassic	1997	Carnarvon	PA	Nil	Nil
Tubridgi 01	ON	W1840	4	21°48'25.1"	114°49'5.3"	NFW	7	611	Upper Triassic	1981	Otter	G	Produce	Nil
Tubridgi 02	ON	W1921	0	21°46'56.0"	114°50'46.2"	EXT	2	592.3	Upper Triassic	1981	Otter	G	Produce	Nil
Tubridgi 03	ON	W1923	1	21°47'26.6"	114°48'18.9"	EXT	4	597	Upper Triassic	1981	Otter	PA	Nil	Nil
Tubridgi 04	ON	W1925	0	21°45'52.3"	114°50'1.0"	EXT	3	595	Upper Triassic	1981	Otter	G	Produce	Nil
Tubridgi 05	ON	W1952	-0	21°45'23.6"	114°51'8.8"	EXT	3	593	Upper Triassic	1981	Otter	G	Produce	Nil
Tubridgi 06	ON	W2012	0	21°44'40.3"	114°52'26.2"	EXT	3	594	Upper Triassic	1981	Otter	G	Produce	Nil
Tubridgi 07	ON	W20038	-2	21°46'34.9"	114°50'28.0"	DEV	6	599.7	Upper Triassic	1990	Doral	SUSP	Produce	Good
Tubridgi 08	ON	W20039	-2	21°47'53.1"	114°50'25.7"	DEV	6	598.4	Triassic	1990	Doral	SUSP	Produce	Fair
Tubridgi 09	ON	W20198	1	21°45'58.5"	114°51'50.8"	DEV	5	601	Upper Triassic	1993	Doral	G	Produce	Nil
Tubridgi 10	ON	W20266	2	21°47'14.3"	114°50'3.8"	DEV	8	631.5	Triassic	1994	Doral	SUSP	Excellent	Nil
Tubridgi 11	ON	W20432	2	21°46'32.2"	114°51'59.6"	DEV	6	577.2	Triassic	1997	Boral	PA	Nil	Nil
Tubridgi 12	ON	W20434	2	21°48'19.7"	114°50'7.7"	DEV	6	575.8	Triassic	1997	Boral	PA	Poor	Nil
Tubridgi 13	ON	W20436	2	21°45'39.2"	114°49'13.9"	EXT	6	581	Triassic	1997	Boral	PA	Poor	Nil
Tubridgi 14	ON	W20439	2	21°46'17.0"	114°50'3.7"	DEV	6	644.6	Triassic	1997	Boral	G	Excellent	Nil
Tubridgi 15	ON	W20446	2	21°48'22.5"	114°49'38.1"	DEV	6	575	Triassic	1997	Boral	G	Excellent	Nil
Tubridgi 16	ON	W20585	1	21°45'51.5"	114°51'17.0"	DEV	6	566	Middle Triassic	1999	Boral	G	Produce	Nil
Tubridgi 17	ON	W20582	2	21°46'20.3"	114°51'20.1"	DEV	5	566	Middle Triassic	1999	Boral	G	Produce	Nil
Tubridgi 18	ON	W20581	2	21°47'23.1"	114°51'9.4"	DEV	5	566	Middle Triassic	1999	Boral	G	Produce	Nil
Urala 1	ON	W438	2	21°49'11.4"	114°43'28.9"	STR	4	762	Triassic	1968	WAPET	PA	Poor	Nil
Weelawarren 1	ON	W2357	2	21°48'42.5"	114°55'14.5"	NFW	4	552.7	Middle Triassic	1983	Pan Pacific	PA	Nil	Nil

Appendix 1 (continued)

Well Name	*Onshore/ Offshore*	*S. number*	*Ground or sea bed elevation (m AHD)*	*Latitude (S)*	*Longitude (E)*	*Class type*	*Kelly bushing elevation (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Company*	*Well status*	*Gas shows*	*Oil shows*
Windoo 1	ON	W765	2	21°21'18.0"	115°40'55.0"	STR	4	219	Devonian	1972	Hematite Petroleum	PA	Poor	Fair
Windoo 1A	ON	W1078	2	21°21'18.0"	115°40'55.0"	STR	5	174	Lower Cretaceous	1974	Woodside	PA	Good	Poor
Wonangarra 1	ON	W463	6	22°09'8.7"	114°41'26.7"	STR	8	575	Lower Carboniferous	1969	WAPET	PA	Nil	Nil
Woorawa 1	ON	W766	13	21°21'55.3"	115°47'33.2"	STR	16	202	Permian–Carboniferous	1972	Hematite Petroleum	PA	Poor	Nil
Wyloo 1	ON	W1859	2	21°47'37.1"	114°51'21.8"	NFW	5	732	Upper Triassic	1981	Otter	G	Produce	Ni
Yanrey 1	ON	W51 V3	14	22°15'20.8"	114°35'3.5"	NFW	16	431	Precambrian	1957	WAPET	PA	Nil	Nil
Yarraloola 1	ON	W394	15	21°23'12.2"	115°45'60.0"	STR	17	272	Carboniferous	1967	WAPET	PA	Poor	Poor

NOTES:

ON: onshore well
OFF: offshore well
ISL: island well
EXT: step-out
DEV: development
NFW: new field wildcat

STR: stratigraphic hole
PA: plugged and abandoned
SUSP: suspended
G: gas producer
S. number: Geological Survey of Western Australia S-series number
AHD: Australian Height Datum

Australian Occidental: Australian Occidental Pty Ltd
Avon: Avon Engineering Pty Ltd
Bond: Bond Corporation Pty Ltd
Boral: Boral Energy Resources Ltd
Carnarvon: Carnarvon Petroleum NL
Command: Command Petroleum Holdings NL
Discovery: Discovery Petroleum NL
Doral: Doral Resources NL
ESSO: Esso Exploration and Production Australia Incorporated

Hematite Petroleum: Hematite Petroleum Pty Ltd
Lennard: Lennard Oil NL
Metana Energy: Metana Energy NL
Minora: Minora Resources NL
Otter: Otter Exploration NL
Pan Pacific: Pan Pacific Petroleum NL
Stirling: Stirling Resources NL
WAPET: West Australian Petroleum Pty Ltd
Woodside: Woodside Offshore Petroleum Pty Ltd

Appendix 2

Seismic surveys conducted for petroleum exploration on the Peedamullah Shelf and Onslow Terrace

Survey name	*Company*	*S. number*	*Start date*	*End date*	*Line prefix*	*Survey type*	*Total kilometres*	*Number of lines*
A95H MSS	Apache Northwest Pty Ltd	10026	30-Jul-95	17-Aug-95	A95H	2D Reflection	169.725	11
A95T MSS	Apache Energy Ltd	10245	22-May-95	6-Jun-95	A95T	2D Reflection	150	–
Abdul's Dam SS	Pan Pacific Petroleum NL	3548	23-May-90	6-Jun-90	PP90A	2D Reflection	140.4	20
Airlie 2 (DW) MSS	West Australian Petroleum Pty Ltd	1118	1-Mar-75	1-Mar-75	B75	2D Reflection	43	1
Airlie 3 (SW) MSS	West Australian Petroleum Pty Ltd	1168	17-Dec-75	29-Dec-75	B75	2D Reflection	167	14
Airlie MSS	West Australian Petroleum Pty Ltd	1042	29-Sep-74	2-Oct-74	B74	2D Reflection	318	8
Airlie MSS	West Australian Petroleum Pty Ltd	1042	29-Sep-74	2-Oct-74	B74	Magnetic	318	8
Anita MSS	Western Mining Corporation Ltd	3213	18-Sep-87	7-Oct-87	W87	2D Reflection	323.9	31
Ashburton (SW) MSS	West Australian Petroleum Pty Ltd	1062	14-Nov-74	22-Nov-74	B74	2D Reflection	247	12
Ashburton SS	Otter Exploration NL	2246	24-Oct-82	1-Nov-82	A82	2D Reflection	52	8
Athena MSS	Western Mining Corporation Ltd	10264	25-Mar-96	4-Apr-96	PA96	2D Reflection	95.425	12
B85 MSS	Bond Corporation Pty Ltd	2746	16-Feb-85	6-Mar-85	B85	2D Reflection	1 069.575	97
B85 MSS	Bond Corporation Pty Ltd	2746	16-Feb-85	6-Mar-85	B85	3D Reflection	96.173	97
B85T MSS	Bond Corporation Pty Ltd	2832	18-Nov-85	17-Feb-86	B85T	2D Reflection	210	25
B86 MSS	Bond Corporation Pty Ltd	3074	16-Sep-86	2-Oct-86	B86	2D Reflection	723	67
B87 MSS	Bond Corporation Pty Ltd	3206	9-Sep-87	16-Sep-87	B87	2D Reflection	177	21
B88 MSS	Bond Corporation Pty Ltd	3325	30-Mar-88	6-Apr-88	B88	2D Reflection	64.2	13
B88T MSS	Bond Corporation Pty Ltd	3371	4-Aug-88	16-Nov-88	B88T	2D Reflection	158.2	24
B89 MSS	Bond Energy Resources	3581	16-Jun-89	1-Jul-89	B89	2D Reflection	239.7	24
B89H MSS	Bond Energy Resources	3582	25-Jun-89	5-Jul-89	B89H	3D Reflection	948.9	114
Barrow 11 MSS	West Australian Petroleum Pty Ltd	3198	29-Aug-87	7-Sep-87	B87	2D Reflection	139	20
Barrow 12 MSS	West Australian Petroleum Pty Ltd	3423	21-Nov-88	29-Mar-89	B88	2D Reflection	217.3	19
Barrow 3 (DW) MSS	West Australian Petroleum Pty Ltd	695 V3	31-Dec-71	15-Jan-72	B72	2D Reflection	1 628.6561	30
Barrow Basin Spec (1992) MSS	Australian Seismic Brokers Pty Ltd	10163 V1	25-May-93	10-Aug-93	93BA	2D Reflection	1 358.9	–
Barrow–Dampier–Beagle MC Aeromag. S	Durrant and Associates	10183 V1	23-Aug-93	27-Nov-93	–	Aeromagnetic	130 000	–
Beadon Mary Anne MSS	Mesa Australia Ltd	2468	3-Sep-83	22-Sep-83	BMA83	2D Reflection	1 259	97
Beadon Shallow Water MSS	Carnarvon Petroleum NL	10301	10-May-96	11-May-96	CP96	2D Reflection	33.875	6
Black Ledge MSS	West Australian Petroleum Pty Ltd	964	18-Sep-74	29-Sep-74	B74	2D Reflection	249	10
Black Ledge MSS	West Australian Petroleum Pty Ltd	964	18-Sep-74	29-Sep-74	B74	Magnetic	228	10
C81A MSS	Esso Exploration and Production Australia Inc.	1813	2-Dec-81	8-Feb-82	C81A	2D Reflection	2 326	171
C81B MSS	Esso Exploration and Production Australia Inc.	1814	13-Jun-81	2-Aug-81	C81B	2D Reflection	3 892	184
C83A MSS	Esso Exploration and Production Australia Inc.	2278	29-Dec-82	4-Feb-83	C83A	2D Reflection	647	54
C85A MSS	BHP Petroleum Pty Ltd	2871	16-Aug-85	22-Aug-85	C85A	2D Reflection	582	43
C85B MSS	BHP Petroleum Pty Ltd	2918	8-Dec-85	15-Dec-85	C85B	2D Reflection	334	28
C86A MSS	BHP Petroleum Pty Ltd	3078	3-Oct-86	5-Oct-86	C86A	2D Reflection	156	12
Campbell MSS	West Australian Petroleum Pty Ltd	1401 V1	14-Jun-78	13-Jul-78	B78	2D Reflection	344.61	19
Cane River SS	West Australian Petroleum Pty Ltd	358 V1	8-Aug-67	23-Aug-67	CR67	2D Reflection	56.327	3
Carapace MSS	Lasmo Oil (Australia) Ltd	10112	8-Jun-92	10-Jun-92	LMC92	2D Reflection	79.4	15

Appendix 2 (continued)

Survey name	*Company*	*S. number*	*Start date*	*End date*	*Line prefix*	*Survey type*	*Total kilometres*	*Number of lines*
Cash 3D MSS	Apache Northwest Pty Ltd	10329	9-Apr-97	11-Jun-97	–	3D Reflection	33 019	–
Chelonia MSS	Lasmo Oil (Australia) Ltd	3935	21-Dec-89	26-Mar-90	LC89	2D Reflection	1 573.7	153
Chelonia MSS	Lasmo Oil (Australia) Ltd	3935	21-Dec-89	26-Mar-90	LC89	3D Reflection	689.3	153
Constance MSS	Wesminco Oil Pty Ltd	2748	17-Feb-85	27-Feb-85	C85	2D Reflection	251	22
Coolgra SS	Pan Pacific Petroleum NL	10177	4-Sep-93	6-Dec-93	C93	2D Reflection	154.2	21
Coolgra Island Gravity Survey	Pan Pacific Petroleum NL	10254	24-Jun-95	12-Jul-95	–	Gravity	–	33
Coral MSS	Mesa Australia Ltd	1893	27-Aug-81	21-Sep-81	C81	2D Reflection	284	18
Dampier Archipelago Aeromag. Survey	West Australian Petroleum Pty Ltd	507	14-Aug-67	5-Dec-67	–	Aeromagnetic	10 458.5	–
Deborah MSS	Mesa Australia Ltd	1834	4-Jun-81	17-Jun-81	D81	2D Reflection	1 419	59
Direction (110) MSS	Pan Pacific Petroleum NL	10164 V1	21-Jun-93	23-Jun-93	D93	2D Reflection	45	8
Dupuy MSS	West Australian Petroleum Pty Ltd	574	5-Feb-69	3-Mar-69	D69	2D Reflection	75.6392	8
East Flank MSS	West Australian Petroleum Pty Ltd	612 V1	4-Mar-71	5-Mar-71	EF71	2D Reflection	43.4523	2
Easter MSS	Tap Oil NL	10381	30-May-98	6-Jun-98	TAP98	2D Reflection	541.45	42
Elliot MSS	Phillips Australian Oil Company	10193	1-Dec-93	19-Dec-93	PW93	2D Reflection	1 486.669	64
Emma MSS	Discovery Petroleum NL	10200 V1	11-Dec-93	15-Dec-93	DC93	2D Reflection	299.5	26
Enderby Terrace South (Phase 1) MSS	PGS Nopec Australia Pty Ltd	10175 V1	10-Aug-93	17-Aug-93	ETS93	2D Reflection	771.8	–
Flag 2 (SW) MSS	West Australian Petroleum Pty Ltd	789 V1	30-Oct-71	1-Nov-71	F71	2D Reflection	38.6243	2
Flag 3 MSS	West Australian Petroleum Pty Ltd	963	27-Sep-74	27-Sep-74	B74	2D Reflection	55	4
Flag MSS	West Australian Petroleum Pty Ltd	612 V2	4-Mar-71	4-Mar-71	F71	2D Reflection	69.2018	3
Fraser MSS	West Australian Petroleum Pty Ltd	461	15-Mar-69	2-Apr-69	F69	2D Reflection	416.8201	19
Fraser MSS	West Australian Petroleum Pty Ltd	461	15-Mar-69	2-Apr-69	F69	2D Refraction	3.2187	19
Glennie MSS	West Australian Petroleum Pty Ltd	10063	8-Oct-91	9-Oct-91	B91	2D Reflection	65.4	9
H90 MSS	Phillips Australian Oil Company	10023	8-Aug-90	26-Aug-90	H90	2D Reflection	558	70
H92T MSS	Hadson Australia Development Pty Ltd	10118	20-Oct-92	15-Apr-93	H92T	2D Reflection	151	–
H93E MSS	Hadson Energy Ltd	10204	9-Oct-93	13-Oct-93	SH93E	2D Reflection	22.4	3
H93S Stag 3D MSS	Hadson Energy Ltd	10190	5-Nov-93	30-Nov-93	H93S	2D Reflection	56	62
H93S Stag 3D MSS	Hadson Energy Ltd	10190	5-Nov-93	30-Nov-93	H93S	3D Reflection	5 288.7	62
H94S MSS	Hadson Energy Ltd	10202	28-Dec-93	5-Jan-94	H94S	2D Reflection	477.5	36
HC90B MSS	BHP Petroleum Pty Ltd	10035	29-Dec-90	31-Dec-90	HC90B	2D Reflection	178.406	16
HC93T MSS	BHP Petroleum Pty Ltd	10186	13-Sep-93	19-Apr-94	HC93T	2D Reflection	101.6	41
Hastings MSS	West Australian Petroleum Pty Ltd	10162	24-Jun-93	26-Jun-93	B93	2D Reflection	69.2	9
Hawksbill MSS	Lasmo Oil (Australia) Ltd	10043	21-Dec-90	27-Dec-90	LH90A	2D Reflection	132	15
Helen MSS	Western Mining Corporation Ltd	3288	18-Feb-88	8-Mar-88	WMC88	2D Reflection	564	44
Hermite (DW) 2 MSS	West Australian Petroleum Pty Ltd	1176	4-Apr-76	10-Apr-76	B76	2D Reflection	262	21
Hermite MSS	West Australian Petroleum Pty Ltd	1120	28-Feb-75	1-Mar-75	B75	2D Reflection	157	10
Irene MSS	Mesa Australia Ltd	2113	5-Apr-82	16-Jul-82	I82	2D Reflection	572	32
J84A SS	Esso Exploration and Production Australia Inc.	2670	9-Nov-84	12-Dec-84	J84A	2D Reflection	207	20
J85A SS	Esso Exploration and Production Australia Inc.	2851	12-Oct-85	6-Nov-85	J85A	2D Reflection	295	35
Jacqueline MSS	Western Mining Corporation Ltd	3757	9-Oct-89	24-Oct-89	J89	2D Reflection	1 874.6	37
Jennifer MSS	Western Mining Corporation Ltd	10099	22-May-92	24-May-92	WMC92	2D Reflection	67.3	7
Kathleen MSS	Western Mining Corporation Ltd	10205	13-Feb-94	22-Mar-94	K294; K394	2D Reflection	135.4	–
Kathleen MSS	Western Mining Corporation Ltd	10205	13-Feb-94	22-Mar-94	K294; K394	3D Reflection	3 445.7	–
Kelly MSS	Mobil Exploration and Producing Australia Pty Ltd	10152	12-Mar-93	9-Apr-93	93MK	2D Reflection	173.7	–
Kendrew Terrace Marine Gravity Survey	Woodside Petroleum Development Pty Ltd	1540	29-Jul-79	19-Aug-79	79GR	Gravity	4 824	–

Appendix 2 (continued)

Survey name	*Company*	*S. number*	*Start date*	*End date*	*Line prefix*	*Survey type*	*Total kilometres*	*Number of lines*
Kennedy (EP 325) 1991 MSS	Mobil Exploration and Producing Australia Pty Ltd	10088	18-Oct-91	30-Oct-91	L91	2D Reflection	538.6	35
Kirsten MSS	Western Mining Corporation Ltd	10074	29-Nov-91	15-Dec-91	K91	2D Reflection	1 673.28	37
Koolinda 2 MSS	West Australian Petroleum Pty Ltd	2910	14-Nov-85	7-Dec-85	B85	2D Reflection	526	46
Koolinda 3 MSS	West Australian Petroleum Pty Ltd	3183	27-Jul-87	28-Aug-87	B87	2D Reflection	315.9	48
Koolinda 4 MSS	West Australian Petroleum Pty Ltd	3327	2-Dec-88	8-Dec-88	B88	2D Reflection	168.2	18
Koolinda 5 MSS	West Australian Petroleum Pty Ltd	10033	11-Sep-90	12-Dec-90	B90	2D Reflection	273	29
Koolinda Deep MSS	West Australian Petroleum Pty Ltd	3376	3-Dec-88	5-Dec-88	B88	2D Reflection	311.3	14
Koolinda MSS	West Australian Petroleum Pty Ltd	2549	8-Apr-84	13-Apr-84	B84	2D Reflection	162	13
Leanne MSS	Ampolex (Western Australia) Inc.	10244	18-Apr-95	21-May-95	A95L	2D Reflection	114	10
Libby 1993 MSS	Western Mining Corporation Ltd	10160	29-May-93	30-May-93	93L	2D Reflection	180.7	15
Lightfoot Reef MSS	Command Petroleum Holdings NL	10109	24-May-92	8-Jun-92	C91	2D Reflection	510	46
Lisa 1996 MSS	Mobil Exploration and Producing Australia Pty Ltd	10299	2-Jul-96	10-Jul-96	A96LA	2D Reflection	754.6	40
Locker SS	West Australian Petroleum Pty Ltd	364	1-Jun-67	29-Sep-67	L67	2D Reflection	301	24
Mermaid 2 MSS	West Australian Petroleum Pty Ltd	1040	24-Sep-74	28-Sep-74	B74	2D Reflection	116	7
Mermaid 2 MSS	West Australian Petroleum Pty Ltd	1040	24-Sep-74	28-Sep-74	B74	Magnetic	71	7
Mermaid MSS	West Australian Petroleum Pty Ltd	612 V3	3-Mar-71	4-Mar-71	M71	2D Reflection	80.4672	3
Mia Mia SS	Marathon Petroleum Australia Ltd	392	29-Aug-67	28-Apr-68	MM	2D Reflection	1 430.7068	31
Mia Mia SS	Marathon Petroleum Australia Ltd	392	29-Aug-67	28-Apr-68	MM	2D Refraction	981.6998	31
Midway MSS	Mesa Australia Ltd	1832	6-May-81	9-May-81	M81	2D Reflection	206	11
Minderoo SS	Otter Exploration NL	1777	2-Mar-81	4-Apr-81	M81	2D Reflection	100	12
Moresby Shoals MSS	Western Mining Corporation Ltd	10298	12-Apr-96	13-May-96	PM96	2D Reflection	209.1	–
Muiron MSS	West Australian Petroleum Pty Ltd	612 V7	16-Mar-71	21-Mar-71	M71	2D Reflection	481.1939	11
Nares MSS	West Australian Petroleum Pty Ltd	1166	12-Dec-75	23-Dec-75	B75	2D Reflection	126	14
Norma MSS	Wesminco Oil Pty Ltd	2823	11-Jun-85	18-Jun-85	85N	2D Reflection	799	35
North Saladin 3D MSS	West Australian Petroleum Pty Ltd	10057	7-Sep-91	18-Oct-91	NS91	3D Reflection	2 075.96	–
North Sholl MSS	West Australian Petroleum Pty Ltd	612 V4	5-Mar-71	5-Mar-71	NS71	2D Reflection	33.7962	1
O82 MSS	Australian Occidental Pty Ltd	2027	18-Feb-82	19-Jun-82	O82	2D Reflection	6 126.575	280
O82A MSS	Australian Occidental Pty Ltd	1776	25-Oct-82	8-Nov-82	O82A	2D Reflection	1 516	107
O83 MSS	Australian Occidental Pty Ltd	2359 V1	21-Jan-83	12-May-83	83	2D Reflection	1 269	80
O83A MSS	Australian Occidental Petroleum Inc.	2438	13-Nov-83	23-Nov-83	83A	2D Reflection	191	25
O84H MSS	Australian Occidental Petroleum Inc.	2530	14-Jan-84	17-Jan-84	84H	2D Reflection	189	21
Observation (SW) MSS	West Australian Petroleum Pty Ltd	1106	28-Dec-74	3-Jan-75	B75	2D Reflection	135	8
Onslow (SW) MSS	West Australian Petroleum Pty Ltd	790 V4	23-Mar-72	27-Mar-72	B72	2D Reflection	260.7137	14
Onslow 1966 SS	West Australian Petroleum Pty Ltd	283	14-Mar-66	13-Jun-66	O66G	2D Reflection	157.7157	12
Onslow 1966 SS	West Australian Petroleum Pty Ltd	283	14-Mar-66	13-Jun-66	O66G	2D Refraction	12.8748	12
Onslow Derby Regional Gravity Survey	Bureau of Mineral Resources	3042	30-May-53	30-Jun-53	–	Gravity	0	–
Onslow Offshore Aeromag. Survey	West Australian Petroleum Pty Ltd	351	14-Aug-67	5-Dec-67	–	Aeromagnetic	3 937.22	51
Patricia Extension MSS	Western Mining Corporation Ltd	10038	12-Dec-90	13-Dec-90	PE90	2D Reflection	46.4	7
Patricia MSS	Western Mining Corporation Ltd	10009	24-Mar-90	2-May-90	P90	2D Reflection	293.1	39
Peedamullah SS	Pan Pacific Petroleum NL	10134	3-Nov-92	27-Nov-92	PP92	2D Reflection	134.4	6
Peewar SS	Avon Engineering Pty Ltd	3232	15-Nov-87	2-Dec-87	P87	2D Reflection	99.4	11
Peta Telseis SS	Western Mining Corporation Ltd	3501	30-Jan-89	12-Feb-89	PE89	2D Reflection	50.3	7
Plato MSS	Santos Ltd	10290	27-Feb-96	6-Mar-96	PLATO	2D Reflection	646.313	56
Robe SS	Avon Engineering Pty Ltd	2217	2-Oct-82	22-Oct-82	R82	2D Reflection	101	11

Appendix 2 (continued)

Survey name	*Company*	*S. number*	*Start date*	*End date*	*Line prefix*	*Survey type*	*Total kilometres*	*Number of lines*
Robe River Gravity Survey	West Australian Petroleum Pty Ltd	508	20-May-67	18-Jul-67	–	Gravity	177.0278	8
Rose MSS	Western Mining Corporation Ltd	10082	11-Dec-91	15-Dec-91	R91	2D Reflection	221.3	13
Rosily North MSS	Offshore Oil NL	1744	23-Dec-80	28-Dec-80	80	2D Reflection	529	19
Rosily Shoals MSS	West Australian Petroleum Pty Ltd	3468	10-Dec-88	10-Dec-88	B88	2D Reflection	36.3	3
Roller 3D MSS	West Australian Petroleum Pty Ltd	10030	2-Sep-90	20-Dec-90	R90	3D Reflection	5 523	545
S96 MSS	Victoria Petroleum NL	10289	27-Feb-96	6-Mar-96	S96	2D Reflection	272.612	–
SPA 1/1993-94	Australian Seismic Brokers Pty Ltd	10219	21-Apr-94	23-Apr-94	BA94	2D Reflection	254.5	6
Saladin Detail (Telseis) MSS	West Australian Petroleum Pty Ltd	3515	2-Mar-89	12-Mar-89	B89	2D Reflection	42.5	8
Santa Cruz MSS	Discovery Petroleum NL	10293	12-Apr-96	8-May-96	SC96	2D Reflection	206.6	25
Scientific Investigation 2/1987-88	Geophysical Service Inc.	3287 V2	15-Jan-88	25-Mar-88	SB88	2D Reflection	890.2	86
Scientific Investigation 2SL/1985	Geophysical Service International	2742 V2	23-Jul-85	30-Jul-85	85DBX	2D Reflection	1 081	48
Shoals Aeromag. Survey	Western Mining Corporation Ltd	10228	8-Sep-94	24-Oct-94	–	Aeromagnetic	40 076.9	926
Sholl (West) MSS	West Australian Petroleum Pty Ltd	1041	25-Sep-74	26-Sep-74	B74	2D Reflection	133	5
Sholl (West) MSS	West Australian Petroleum Pty Ltd	1041	25-Sep-74	26-Sep-74	B74	Magnetic	108	5
Simone MSS	Western Mining Corporation Ltd	10086	13-Dec-91	15-Dec-91	S91	2D Reflection	144.6	20
Snark 2 MSS	West Australian Petroleum Pty Ltd	10165	25-Jun-93	26-Jun-93	B93	2D Reflection	90.4	8
Snark 3D MSS	PGS Exploration Pty Ltd	10273	3-Dec-95	17-Mar-96	–	3D Reflection	11 662	–
Snark MSS	West Australian Petroleum Pty Ltd	10062	11-Oct-91	18-Oct-91	B91	2D Reflection	233.1	–
South Pepper MSS	Mesa Australia Ltd	2303	10-Feb-83	20-Feb-83	SP83	2D Reflection	430	36
South West Barrow MSS	Offshore Oil NL	1453	8-Mar-79	14-Mar-79	79	2D Reflection	385.7	19
Swash MSS	West Australian Petroleum Pty Ltd	10161	25-Jun-93	1-Aug-93	B93	2D Reflection	18.9	4
Tanpool SS	Avon Engineering Pty Ltd	2876	20-Sep-85	10-Oct-85	T85	2D Refraction	151	18
Tauton MSS	West Australian Petroleum Pty Ltd	612 V6	29-Mar-71	2-Apr-71	T71	2D Reflection	223.6988	9
Taylor MSS	Phillips Australian Oil Company	10116	14-Jun-92	5-Jul-92	H92, PW92	2D Reflection	1 272	116
Tent Hill Experimental SS	Minora Resources NL	3307	30-May-88	31-May-88	TH88	2D Reflection	1.2	1
Thevenard 3 MSS	West Australian Petroleum Pty Ltd	10172	21-Jul-93	31-Jul-93	B93	2D Reflection	25.3	3
Tracey MSS	Ampolex (Western Australia) Inc.	10246	7-Jun-95	24-Jun-95	A95T	2D Reflection	33	4
Tubridgi SS	Pan Pacific Petroleum NL	3304	17-Apr-88	5-May-88	PP88B	2D Reflection	90	7
Urala 1994 SS	Doral Resources NL	10232	30-Oct-94	12-Nov-94	DR94	2D Reflection	96.54	11
Vermeer MSS	Ampolex Ltd	10142	5-Dec-92	4-Jan-93	A92V	2D Reflection	3 369.5	179
WA-149-P 1985 Aeromag. Survey	Wesminco Oil Pty Ltd	2739	14-Feb-85	18-Feb-85	–	Aeromagnetic	5 143	–
Wadawan SS	Pan Pacific Petroleum NL	3305	6-May-88	29-Aug-88	PP88A	2D Reflection	142.5	14
West Barrow 3D Spec MSS	Halliburton Geophysical Services Inc.	10037	2-Nov-90	11-Nov-90	WB90	3D Reflection	1 131.7	96
West Barrow MC3D MSS	Western Atlas International Inc.	10373	12-Nov-97	26-Apr-98	–	3D Reflection	162 462.7	–
West Barrow Spec 1986 MSS	Geophysical Service International	3071	29-Aug-86	15-Sep-86	WB86	2D Reflection	1 877.16	82
West Flank MSS	West Australian Petroleum Pty Ltd	612 V5	22-Mar-71	31-Mar-71	WF71	2D Reflection	482.8032	8
Windoo SS	Stirling Resources NL	10139	29-Nov-92	2-Dec-92	W-S92	2D Reflection	30	6
Yanrey Ridge 1989 Aeromag. Survey	Minora Resources NL	3616	3-Mar-90	6-Mar-90	–	Aeromagnetic	2 700	–
Yarraloola SS	Avon Engineering Pty Ltd	2509	13-Dec-83	19-Dec-83	AV83	2D Reflection	58	7

NOTES: MSS: Marine seismic survey
SS: Seismic survey
S. number: Geological Survey of Western Australia S-series number

Appendix 3

Subsurface stratigraphy of the Peedamullah Shelf and Onslow Terrace (simplified from Hocking et al., 1987)

Age	*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Type section*	*Fossils and age*	*Depositional settings*	*Remarks*	*References*
QUATERNARY	Undifferentiated	Variable	Limestone, sand, gravel	Unconformable on Trealla Limestone			Fluvial, eolian, intertidal, marine shelf		
MIDDLE–LATE MIOCENE	CAPE RANGE GROUP Trealla Limestone	20–30	Commonly pure calcirudite, calcarenite, calcisiltite	Unconformable on Cardabia Group and older rocks and coral–algal limestone	Mount Lefroy; 23°13'00"S 114°00'20"E	Rich corals, algae, foraminifera, shells; Middle–Late Miocene	Middle to inner shelf, moderate to high energy, minor lagoonal		Hocking et al. (1987)
PALAEOCENE–EOCENE	CARDABIA CALCARENITE	mostly <100	Calcarenite and calcisiltite, commonly marly, basal greensand	Disconformable on Toolonga Calcilutite	Giralia Anticline; 22°49'20"S 114°08'00"E	Rich and varied fauna; Late Palaeocene – ?Middle Eocene	Shallow marine, inner shelf		Condon (1954) Heath and Apthorpe (1984) Hocking et al. (1987)
LATE CRETACEOUS	TOOLONGA CALCILUTITE	Up to 310	Fossiliferous, pale calcilutite and calcisiltite	Disconformable on Gearle Siltstone	Murchison House Station; 27°36'00"S 114°13'40"E	Rich fauna, especially foraminifers; Santonian–Campanian, locally Maastrichtian	Marine shelf, low energy		Hocking et al. (1987) Apthorpe (1979)
CRETACEOUS	WINNING GROUP								
	Gearle Siltstone	Mostly <200, >500 offshore	Clayey siltstone, dark grey–black claystone, radiolarian siltstone	Conformable on and laterally grades into Windalia Radiolarite on the shelf margins	C–Y Creek, Giralia Anticline; 22°44'S 114°09'E	Foraminifers, bivalves, belemnites; Albian–Turonian	Shallow marine, low energy, restricted circulation		Hocking et al. (1987)
EARLY CRETACEOUS	Windalia Radiolarite	Up to 190	Glauconitic varicoloured radiolarian siltstone and calcilutite; minor argillaceous sandstone, chert, and calcareous claystone to marl	Conformably transgressive on Windalia Sandstone (hummocky contact)	Windalia Hill, Winning Station; 23°16'10"S 114°47'10"E	Rich fauna, common radiolarians, ammonities, belemnites, foraminifers; Aptian–Albian; *M. tetrancantha* palynozone	Shallow marine shelf; low energy, low terrigenous input; high dissolved silica; outer shelf in Dampier Sub-basin	Permeability ~1 mD	Hocking et al. (1987)
	Windalia Sandstone Member	Up to 85	Very fine to fine grained sandstone	Conformable on Muderong Shale (smooth contact)	Barrow 1; 644 – 674.5 m	*M. mcwhaei* palynozone	Regressive shallow-marine shelf	Permeability ~3 D	Hocking et al. (1987)

Appendix 3 (continued)

Age	*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Type section*	*Fossils and age*	*Depositional settings*	*Remarks*	*References*
	Muderong Shale	Commonly <200 onshore; max. >300 offshore	Clayey grey silt-stone, lesser shale, fine sandstone, greensand	Conformable on Birdrong sandstone; unconformable on older units	Northwest Kennedy Range; 24°08'10"S 114°45'50"E	Abundant micro-fossils; diachronous base; Valanginian to Aptian, top late Aptian	Low energy marine shelf, local shoals	Includes Windalia Sandstone Member	Hocking et al. (1987); Wiseman (1979)
	Mardie Greensand	Commonly <30, max. 60	Greensand, glauconitic wacke, and conglomerate	Conformable on Birdrong Sandstone, unconformable on other units	Mardie 1; 145–172 m	Abundant micro-fossils; Valanginian to Aptian	Low to moderate energy marine shelf and slope		Hocking et al. (1987)
	Birdrong Sandstone	Commonly <30, max. 60	Poorly indurated quartz sandstone, variably bioturbated and glauconitic	Unconformable on older rocks, grades laterally into Mardie Greensand and Muderong Shale	Western Kennedy Range; 24°14'50"S 114°49'50"E	Diverse but sparse fauna, diachronous deposition spanning early Hauterivian to Aptian	Shallow-marine basal transgressive sand, minor fluvial in channels at base		Hocking et al. (1987); Wiseman (1979)
	YARRALOOLA CONGLOMERATE	Variable, <50	Pebble to cobble conglomerate, poorly sorted sandstone, minor siltstone	Unconformable on older rocks; grades laterally into Flacourt Formation	11 km southeast of Yarraloola Homestead; 21°37'30"S 115°57'10"E	Sparse bivalve fauna, common wood and leaves; Neocomian to Aptian by position	Fluvial to alluvial fan; minor marine incursions		Hocking and van de Graaff (1978); Hocking et al. (1987)
	BARROW GROUP								
	Flacourt Formation	<60 onshore, reaches >600 offshore	Fine to coarse quartz sandstone; lesser sandy siltstone	Unconformable on older units	Barrow 1; 914–1370 m	Sparse microfauna; diachronous, latest Jurassic to Valanginian	Delta topsets and upper foresets (delta plain and delta front)	Commonly shows fore-setting on seismic sections	Tait (1985); Hocking et al. (1987); Williams and Poynton (1985)
JURASSIC	DINGO CLAYSTONE	No complete sections onshore, reaches 1 500+ offshore	Grey clayey siltstone, lesser claystone, and some sandstone	Mostly conformable on Mungaroo Formation	Barrow Deep 1; 2177–3229 m	Hettangian to Tithonian, diachronous	Marine, low energy, basinal, abundant supply, moderate water depth		Barber (1982); Kopsen and McGann (1985)
TRIASSIC	MUNGAROO FORMATION	Up to 1 030 onshore, reaches 3 000+ offshore	Interbedded sandstone, claystone, siltstone with thick sandy intervals, minor coal and conglomerate	Conformable on Locker Shale	Long Island 1; 749–1992 m	Variable fauna and flora, diachronous; Ladinian–Toarcian	Fluviodeltaic complex	Main reservoir on Rankin Platform	Crostella and Barter (1980); Hocking et al. (1987)
	LOCKER SHALE	Up to 596	Dark pyritic shale with local sandstone interbeds and basal limestone (Cunaloo Member)	Conformable on Chinty Formation	Onslow 1; 1587–2096 m	Rich microfauna and microflora, rare macrofossils, diachronous; Scythian–Ladinian	Low energy marine shelf, prodeltaic, commonly restricted circulation		Crostella and Barter (1980); Hocking et al. (1987)

Appendix 3 (continued)

Age	*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Type section*	*Fossils and age*	*Depositional settings*	*Remarks*	*References*
LATE PERMIAN	KENNEDY GROUP undifferentiated	100–600	Sandstone with lesser shale, siltstone, and limestone	Conformable on Byro Group or unconformable on older units		Varied microfauna and microflora; Tatarian	Marine shelf to coastal		Hocking et al. (1987); Mory and Backhouse (1997)
	Chinty Formation	29–359	Silty grey sandstone with lesser siltstone, shale, and limestone, areally variable	Conformable on Adbul Sandstone	Onslow 1; 2 096–2 258 m	*D. parvithola* palynozone	Moderate energy, shallow marine, shelf to coastal	Restricted to Peedamullah Shelf	Hocking et al. (1987); Mory and Backhouse (1997)
	Abdul Sandstone	Up to 50	Clear, fine- to medium-grained sandstone, minor limestone	Conformable on Ruby Limestone	Abdul's Dam 1; 707–747.5 m	*D. ericianus* palynozone	Marine shelf		this Report
	Cody Limestone	Up to 70	Limestone, dense to microcrystalline, locally calcarenite	Conformable on undifferentiated Kennedy Group	Cody 1; 3 000–3 088 m	*D. ericianus* palynozone, fragments of brachiopods and bryozoans	Marine shelf		Gorter and Davies (1999)
	CALLYTHARRA FORMATION	Up to 110	Fossiliferous, grey-green calcareous siltstone with hard fossiliferous calcarenite	Conformable on Lyons Group	Wooramel River, south end Carrandibby Range; 25°53'30"S 115°30'00"E	Diverse, abundant fauna; late Sakmarian – early Artinskian	Marine shelf, shallowing upwards		Hocking et al. (1987)
LATE CARBONIFEROUS – EARLY PERMIAN	LYONS GROUP	Mostly 200–1 000, max. ~3 000	Varied, mostly siliciclastic, sandstone, siltstone, diamictite, conglomerate	Unconformable on older rocks	North side, Wyndham River; 25°02'35"S 115°42'20"E	Varied cold water marine fauna; Sakmarian to Late Carboniferous	Marine shelf to lacustrine with pronounced glacial influence		Hocking et al. (1987)
EARLY CARBONIFEROUS	QUAIL FORMATION	Up to 100	Sandstone (lithic to quartz wacke), grey siltstone, variably calcareous, minor thin limestone interbeds	Probably conformable on Moogooree Limestone or equivalent	Quail 1; 2100–2452 m	Sparse fauna and flora; Early Carboniferous	Marine shelf, low to moderate energy		Hocking et al. (1987)
	MOOGOOREE LIMESTONE	?Up to 400+	Limestone and dolostone ranging from mudstone to boundstone, minor calcareous sandstone	Disconformable on Gneudna Formation	Southeast of Williambury Homestead; 23°54'S 115°10'40"E	Algae, corals, echinoderms, brachiopods restricted to discrete horizons; Tournaisian	Nearshore marine to intertidal, locally evaporitic		Hocking et al. (1987); Lavering (1979)

Appendix 3 (continued)

Age	*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relationships*	*Type section*	*Fossils and age*	*Depositional settings*	*Remarks*	*References*
DEVONIAN	GNEUDNA FORMATION	Up to 794	Limestone, mostly packstone and locally dolomitized, lesser sandstone and siltstone	Conformable on Nannyarra Sandstone	Southeast of Williambury Homestead; 23°58'10"S 115°12'30"E	Diverse rich fauna, some reefal development; Frasnian	Marine shelf to intertidal		Hocking et al. (1987)
	NANNYARRA SANDSTONE	~150	Sandstone (lithic to quartz wacke) and arenite, minor siltstone and claystone	Unconformable on older rocks	6 km south of Gneudna Well, Williambury Homestead; 23°58'10"S 115°12'40"E	Barren in outcrop, Givetian from position	Mainly shoreface, some braided fluvial in palaeovalleys	Base not penetrated in Peedamullah Shelf	Hocking et al. (1987)
ORDOVICIAN	TUMBLAGOODA SANDSTONE	~1 000	Red sandstone and conglomerate, very minor siltstone and mudstone	Unconformable on older rocks	Murchison River, Hardabut Fault to Second Gully; 27°52'40"S 114°33'30"E to 27°37'20"S 114°12'10"E	Ordovician based on the Late Ordovician to Early Silurian age of overlying Ajana Formation in Gascoyne Platform	Braided fluvial or mixed fluvial and eolian sandsheet	Only intersection in Peedamullah Shelf is in Echo Bluff 1	Hocking et al. (1987)

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Appendix 4

Biostratigraphic data

Well	Depth m From	Depth m To	Basis type	Sample	Zone	Stage	Epoch/Period	Source
Abdul's Dam 1	430	–	D	DC	*D. davidii*	Aptian	Early Cretaceous	Ingram and Purcell (1991)
	545	?705	SP	DC	–	Kazanian–Tartarian	Late Permian	–
	545	?705	SP	–	*D. parvithola*	Kazanian	Late Permian	Backhouse (1996)
Amber 1	390	–	SP	SWC	*G. maculosa*	late Visean – Namurian	Middle Carboniferous	Purcell (1995)
	400	–	SP	SWC	*G. maculosa*	late Visean – Namurian	Middle Carboniferous	–
	500	510	SP	DC	*G. maculosa*	late Visean – Namurian	Middle Carboniferous	–
	600	605	SP	DC	*G. maculosa*	late Visean – Namurian	Middle Carboniferous	–
	665	670	SP	DC	*G. maculosa*	late Visean – Namurian	Middle Carboniferous	–
Beagle 1	113.1	125.6	D	–	*C. operculata*	Aptian	Early Cretaceous	Morgan and Ingram (1990)
	139	265	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	139	265	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	278	–	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	374.3	534.6	SP	–	*?P. confluens*	Sakmarian	Early Permian	Backhouse (1996)
	556.6	–	SP	–	Stage 2	Asselian	Early Permian	Backhouse (1996)
Black Ledge 1	275	301	D	SWC	*D. multispinum*	Cenomanian	Late Cretaceous	Ingram (1992)
	345	385	D	SWC	*E. ludbrookiae*	late Albian	Early Cretaceous	–
	416	–	D	SWC	*C. denticulata*	mid-Albian	Early Cretaceous	–
	462	487.5	D	SWC	*M. tetracantha*	early Albian	Early Cretaceous	–
	532.5	567	D	SWC	*D. davidii*	late Aptian	Early Cretaceous	–
	603	–	D	SWC	*O. operculata*	early Aptian	Early Cretaceous	–
	645	730.5	D	SWC	*M. australis*	late Hauterivian – Barremian	Early Cretaceous	–
	734	736.5	D	SWC	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	773	922.5	D	SWC	*W. spectabilis*	Oxfordian	Late Jurassic	–
	945	1 233.7	D	SWC	*R. aemula*	Oxfordian–Callovian	Middle–Late Jurassic	–
	1 275.5	?1 472	D	SWC	*W. digitata*	Callovian	Middle Jurassic	–
	1 628.3	1 922.6	–	SWC	undifferentiated	Middle Jurassic	Middle Jurassic	–
	1 950.5	2 000.75	SP	SWC	*C. turbatus*	Bajocian–Toarcian	Early–Middle Jurassic	–
	2 000.9	2 177	SP	SWC/C	*C. torosa*	Toarcian–Hettangian	Early Jurassic	–
	2 229.1	2 325.8	SP	SWC	indeterminate	Jurassic–Triassic	Jurassic–Triassic	–
	2 379.2	2 550.3	SP	SWC	indeterminate	possibly Triassic	?Triassic	–
	2 517.8	2 657.5	SP	SWC	*S. quadrifidus*	Ladinian–Anisian	Middle Triassic	–
	?1 501	1 597.5	D	SWC	*W. indotata*	Callovian–Bathonian	Middle Jurassic	–
Candace 1	125	135	F	DC	–	middle Cenomanian	Late Cretaceous	Paltech Pty Ltd (1982)
	140	155	F	DC	–	middle Cenomanian	Late Cretaceous	–
	160	240	F	DC	–	?middle Albian	Early Cretaceous	–
	318	343	–	–	Middle *D. cerviculum*	Barremian	Early Cretaceous	Ingram (1982d)
	318	343	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	Morgan and Ingram (1990)
	389	393	–	–	Lower *D. cerviculum*	Barremian/Hauterivian	Early Cretaceous	Ingram (1982d)
	389	–	D	–	*S. tabulata*	Valanginian	Early Cretaceous	Morgan and Ingram (1990)
	393	–	D	–	*S. areolata*	Valanginian	Early Cretaceous	–
	418	629	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	–
	418.5	629	SP	SWC	*S. quadrifidus*	Ladinian	Middle Triassic	Ingram (1982d), Morgan and Ingram (1990)
	665	1 320	SP	–	*T. playfordii*	Anisian	Middle Triassic	–
	696	–	SP	SWC	*T. playfordii*	Anisian	Middle Triassic	Ingram (1982d)
	705	–	SP	SWC	*T. playfordii*	Anisian	Middle Triassic	–
	1 244	1 253.9	SP	–	*K. saeptatus*	Scythian	Early Triassic	–

Appendix 4 (continued)

Well	*Depth m* *From*	*To*	*Basis type*	*Sample*	*Zone*	*Stage*	*Epoch/Period*	*Source*
	1 404.9	–	SP	SWC	*K. saeptatus*	Scythian	Early Triassic	–
	1 404.9	1 457.5	SP	–	*K. saeptatus*	Scythian	Early Triassic	Morgan and Ingram (1990)
	1 506	1 829	SP	SWC	–	–	Late Permian	Ingram (1982d)
	1 506	1 879.5	SP	–	Stage 5	–	Late Permian	Morgan and Ingram (1990)
	1 506	1 836	SP	–	*D. parvithola*	Kazanian	Late Permian	Backhouse (1996)
	1 994	–	SP	–	*D. ericianus*	Ufimian	Late Permian	Backhouse (1996)
	1 994	2 015.5	SP	–	Stage 2–3	–	Late Carboniferous	Morgan and Ingram (1990)
	2 008	–	SP	SWC	–	–	Early Permian – Late Carboniferous	Ingram (1982d)
	2 008	2 015.5	SP	–	Stage 2/*P. confluens*	Asselian–Sakmarian	Early Permian	Backhouse (1996)
	<124	–	F	DC	–	–	Eocene or Miocene	Paltech Pty Ltd (1982)
Cane River 1	442	–	SP	SWC	–	–	late Early Carboniferous	Balme (1973)
	518.2	–	SP	SWC	–	–	late Early Carboniferous	–
	630.9	634	SP	C	–	–	Carboniferous	Backhouse (1996)
	630.9	634	SP	–	–	–	Early Carboniferous	Ingram (1991)
	631	634	SP	SWC	*G. maculosa*	late Visean – Namurian	Middle Carboniferous	Hannah (1985)
	640.1	643.1	SP	DC	–	–	Carboniferous	Balme (1972)
	630.9/634		SP	–	–	–	Early Carboniferous	Morgan and Ingram (1990)
Cane River 2	118.2	192	D	–	*D. davidii*	late Aptian	Early Cretaceous	Ingram (1991)
	259.1	344.4	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	362.7	344.4	SP	–	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
	119/134	183/192	D	–	*D. davidii*	late Aptian	Early Cretaceous	Morgan and Ingram (1990)
	259/274	335/344	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	362.7/371.9	–	SP	–	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
Crackling 1	160	–	D	DC	*D. davidii*	late Aptian	Early Cretaceous	Morgan et al. (1994)
	200	–	D	DC	*D. davidii – O. operculata*	Aptian	Early Cretaceous	–
	250	–	D	DC	*?M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	345.15	–	D	C	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	349.25	–	SP	C	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
	363	–	D	C	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	369.2	–	SP	C	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
	444	502	SP	DC	*T. playfordii*	Anisian	Middle Triassic	–
	555	580	SP	DC	Upper Stage 5b–c	Tatarian	Late Permian	–
	612	618	SP	DC	Upper Stage 5a	Kazanian	Late Permian	–
Cunaloo 1	265.2	–	–	SWC	–	Albian	Early Cretaceous	Dolby and Wiseman (1972)
	341.4	–	–	SWC	–	Aptian	Early Cretaceous	–
	356.5	429.8	SP	–	*T. playfordii*	Anisian	Middle Triassic	Dolby and Balme (1976)
	356.6	460.2	SP	SWC/C	–	–	late Early or early Middle Triassic	Dolby and Wiseman (1972)
	400.8	410	SP	C	–	–	late Early or early Middle Triassic	–
	400.8	410	C	C	*N. timorensis*	uppermost Scythian – early Anisian	Early–Middle Triassic	McTavish (1972)
	515.1	518.2	C	DC	*N. jubata* (1 specimen)	late Scythian	Early Triassic	–
	530.4	–	SP	SWC	–	–	Early Triassic	Dolby and Wiseman (1972)
	530.4	584.6	SP	–	*K. saeptatus*	Scythian	Early Triassic	Dolby and Balme (1976)
	530.4	533.4	C	DC	–	near Smithian/Spathian boundary	Early Triassic (Scythian)	McTavish (1972)
	545.6	548.6	C	DC	–	near Smithian/Spathian boundary	Early Triassic (Scythian)	–
	600.5	795.5	SP	SWC/C	*D. parvithola*	Kazanian	Late Permian	Backhouse (1996)
	600.9	795.5	SP	SWC/C	–	–	Late Permian	Dolby and Wiseman (1972)
	789.4	795.5	SP	C	–	–	Late Permian	–
Direction 1	105.5	–	D	–	*D. multispinum*	Cenomanian	Late Cretaceous	Morgan and Ingram (1990)
	127.4	–	D	–	*P. ludbrookiae*	late Albian	Early Cretaceous	–
	164	210.3	D	–	*C. denticulata*	middle Albian	Early Cretaceous	–

Appendix 4 (continued)

Well	Depth m From	Depth m To	Basis type	Sample	Zone	Stage	Epoch/Period	Source
	225.6	–	D	–	*M. tetracantha*	Albian	Early Cretaceous	–
	239.6	305.4	D	–	*D. davidii*	late Aptian	Early Cretaceous	–
	321.3	–	D	–	*C. operculata*	Aptian	Early Cretaceous	–
	343.2	440.1	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	456.9	458.1	D	–	*S. areolata*	Valanginian	Early Cretaceous	–
	516.3	–	SP	SWC	*D. parvithola* or higher	Kazanian or younger	Late Permian	Backhouse (1996)
	516.3	655.3	SP	–	Stage 5	–	Late Permian	Morgan and Ingram (1990)
	520.9	–	SP	–	*D. parvithola* or higher	Kazanian or younger	Late Permian	Backhouse (1996)
	522.4	–	SP	C	–	–	Late Permian	McTavish (1972)
	539.5	–	SP	–	*D. parvithola* or higher	Kazanian or younger	Late Permian	Backhouse (1996)
	549.8	–	SP	SWC	*D. parvithola* or higher	Kazanian or younger	Late Permian	–
	581.9	–	SP	–	*D. ericianus/P. rugatus*	Ufimian	Late Permian	–
	596.2	–	SP	–	*D. ericianus/P. rugatus*	Ufimian	Late Permian	–
	606.9	–	SP	–	*D. ericianus* or *D. granulata*	Kungurian–Ufimian	Permian	–
	626.1	–	SP	SWC	*D. ericianus* or *D. granulata*	Kungurian–Ufimian	Permian	–
	640.4	–	SP	SWC	*D. ericianus* or *D. granulata*	Kungurian–Ufimian	Permian	–
	655.3	–	SP	–	*D. granulata*	Kungurian–Ufimian	Permian	–
	670	–	SP	C	*P. confluens*	Sakmarian	Early Permian	–
	672.7	–	SP	C	–	late Sakmarian	Early Permian	McTavish (1972)
	?756.9	?458.1	D	–	*S. areolata*	Valanginian	Early Cretaceous	Morgan and Ingram (1990)
Echo Bluff 1	511.5	660.5	SP	SWC	–	middle Frasnian	Late Devonian	Purcell (1984)
	681.6	712	SP	SWC	–	middle Frasnian	Late Devonian	–
	782	870.2	SP	SWC	–	early Frasnian	Late Devonian	–
Flinders Shoal 1	396.2	–	D	–	*D. davidii*	late Aptian	Early Cretaceous	Morgan and Ingram (1990)
	426.7	–	D	–	*C. cinctum*	Barremian–Aptian	Early Cretaceous	–
	518.2	682.8	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	707.1	777.8	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	1 099.7	1 567.6	D	–	*D. jurassicum*	Tithonian	Late Jurassic	–
	1 588	1 807.4	D	–	*W. clathrata*	Oxfordian–Kimmeridgian	Late Jurassic	–
	1 873.6	–	D	–	*W. spectabilis*	Oxfordian	Late Jurassic	–
	1 892.8	1 908.6	SP	–	*?S. speciosus*	Carnian–Norian	Late Triassic	–
	1 921.15	2 004	SP	–	*?S. quadrifidus*	Ladinian	Middle Triassic	–
	3 507	–	SP	–	–	–	Permian	–
	?	3 226	SP	–	*?T. playfordii*	Anisian	Middle Triassic	–
Fortescue 1	138.1	243.8	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	251.5	272.5	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	298.7	321.3	D	–	*S. areolata*	Valanginian	Early Cretaceous	–
	345.6	–	SP	–	*K. saeptatus*	Scythian	Early Triassic	–
	380.4	570.6	SP	–	Upper Stage 5	–	Permian	–
	433	536	SP	–	*D. parvithola*	Kazanian	Late Permian	Backhouse (1996)
	558.4	604.1	SP	–	*?D. ericianus*	Ufimian	Late Permian	–
	590.1	604.1	SP	–	Stage 5	–	Late Permian	Morgan and Ingram (1990)
Glenroy 1	493.5	–	–	C	–	not older than Albian	younger than late Early Cretaceous	Balme (1966a)
	645.6	–	–	C	–	?Albian	Early Cretaceous	–
	646.5	–	–	C	–	Albian	Early Cretaceous	–
Hope Island 1	280	–	F	DC	?T–10	–	Early Eocene	Apthorpe (1989)
	305	363	F	–	T8	–	Early Eocene	–
	366	–	F	–	–	early Maastrichtian – Campanian	Late Cretaceous	–
	375	–	F	–	–	Santonian – early Maastrichtian	Late Cretaceous	–
	378	–	F	–	–	?Campanian	Late Cretaceous	–

Appendix 4 (continued)

Well	Depth m From	To	Basis type	Sample	Zone	Stage	Epoch/Period	Source
	381	–	F	–	–	late Campanian	Late Cretaceous	–
	402	–	F	–	–	?Campanian	Late Cretaceous	–
	421	–	F	–	C9 or ??C8	early Campanian or ?Santonian	Late Cretaceous	–
	445	–	F	–	–	not older than Campanian–Santonian	Late Cretaceous	–
	472	–	F	–	C5–6	Coniacian – late Turonian	Late Cretaceous	–
	497	–	F	–	–	–	Late Cretaceous	–
	521	–	F	–	–	–	Cretaceous	–
	883.9	–	SP	SWC	–	Neocomian or early Aptian	Early Cretaceous	Balme (1968a)
	897.9	898.2	SP	C	–	Neocomian	Early Cretaceous	–
	914.4	975.3	SP	–	*T. playfordii*	Anisian	Middle Triassic	Dolby and Balme (1976)
	925.7	928.7	SP	C	–	–	late Early Triassic	Balme (1968a)
	975.3	990.6	SP	–	*K. saeptatus*	Scythian	Early Triassic	Dolby and Balme (1976)
	1 039.7	1 044.5	SP	C	–	–	Permian or Early Triassic	Balme (1968a)
	1 082	1 280.2	SP	–	*D. ericianus*	Ufimian	Late Permian	Backhouse (1996)
	1 082.3	1 311	SP	SWC	Lower Stage 5c	Kazanian	Late Permian	Purcell (1994)
	1 153.4	1 154	SP	C	–	very likely Artinskian	Early Permian	Coleman (1968)
	1 249.7	1 252.7	SP	C	–	–	Late or late Early Permian	Balme (1968a)
	1 326.2	1 372	SP	SWC	Lower Stage 5a–b	Kungurian–Kazanian	Permian	Purcell (1994)
	1 341.1	1 344.2	SP	C	–	–	Late or late Early Permian	Balme (1968a)
	1 356.4	1 420.4	SP	–	*D. granulata*	Kungurian–Ufimian	Permian	Backhouse (1996)
Locker 1	495.9	496.2	D	–	*D. davidii*	late Aptian	Early Cretaceous	Morgan and Ingram (1990)
	600.5	603.5	D	–	*C. cinctum*	Barremian–Aptian	Early Cretaceous	–
	627.3	637	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	677.5	743.7	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	–
	677.6	680.9	SP	C	–	–	Middle to Late Triassic	Kaska (1967)
Long Island 1	236.2	362.7	F	SWC	–	–	Eocene	Belford (1966a)
	371.9	–	F	SWC	–	–	latest Paleocene – Early Eocene	–
	387.1	–	F	SWC	–	Campanian	Late Cretaceous	–
	457.2	801.6	F	SWC	–	–	Early Cretaceous	–
	688.8	697.4	M	C	–	–	Cretaceous	Skwarko (1967a)
	688.8	697.4	D	C	–	?Albian	Early Cretaceous	Balme (1966b)
	710.2	–	D	SWC	–	?Aptian	Early Cretaceous	–
	720.9	–	–	SWC	–	Aptian – early Albian	Early Cretaceous	–
	752.9	–	–	SWC	–	?Aptian	Early Cretaceous	–
	783.3	–	–	SWC	–	Neocomian or Aptian	Early Cretaceous	–
	791	–	–	SWC	–	Neocomian or Aptian	Early Cretaceous	–
	795.5	1 487.1	SP	SWC/C	–	–	Late Triassic	–
	795.5	1 270.7	SP	–	*M. crenulatus*	Norian–Rhaetian	Late Triassic	Dolby and Balme (1976)
	1 285.6	1 604.5	SP	–	*S. speciosus B*	Carnian–Norian	Late Triassic	–
	1 637.7	1 803.5	SP	–	*S. speciosus A*	Carnian–Norian	Late Triassic	–
	1 689.5	2 158	SP	C	–	–	Middle–Late Triassic	Balme (1966b)
	1 858.7	1 877	SP	–	*S. quadrifidus B*	Ladinian	Middle Triassic	Dolby and Balme (1976)
	1 886.1	2 157.9	SP	–	*S. quadrifidus A*	Ladinian	Middle Triassic	–
Mangrove 1	208.5	–	SP	–	Stage 2/*P. confluens*	Asselian–Sakmarian	Early Permian	Backhouse (1996)
Mardie 1	91.4	157/163	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	Morgan and Ingram (1990)
	91.4	162.5	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	182	192.2	SP	–	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
	182/188.8	192.2	SP	–	*B. eneabbaensis*	Neocomian	Early Cretaceous	Morgan and Ingram (1990)
Mary Anne 1	103.3	134.1	D	–	*D. davidii*	late Aptian	Early Cretaceous	–
	135.9	170.7	D	–	*C. operculata*	Aptian	Early Cretaceous	–

Appendix 4 (continued)

Well	Depth m From	Depth m To	Basis type	Sample	Zone	Stage	Epoch/Period	Source
	197.5	340.5	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	359.1	532.8	SP	–	*T. playfordii*	Anisian	Middle Triassic	Balme (1968b); Morgan and Ingram (1990)
	465	–	SP	C	–	–	late Early or Middle Triassic	Balme (1968b)
	532.9	–	SP	C	–	–	late Early or early Middle Triassic	–
Mermaid 1	243	–	D	–	*M. tetracantha*	Albian	Early Cretaceous	Morgan and Ingram (1990)
	250	290	D	–	*D. davidii*	late Aptian	Early Cretaceous	–
	325	400	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	411	416	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	422	446.2	D	–	*S. tabulata*	Valanginian	Early Cretaceous	–
	467	488	SP	–	*S. speciosus*	Carnian–Norian	Late Triassic	–
	515	694	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	–
	713	1 186	SP	–	*T. playfordii*	Anisian	Middle Triassic	–
	1 189.5	1 229	SP	–	*K. saeptatus*	Scythian	Early Triassic	–
	1 231.5	1 251.5	SP	–	Upper Stage 5	–	Permian	–
Minderoo 1	88.4	91.4	SP/F	C	–	Cenomanian–Turonian	Late Cretaceous	Edgell (1963)
	181.4	184.4	SP/F	C	–	Cenomanian – early Turonian	Late Cretaceous	–
	272.8	275.8	SP/F	C	–	Albian – early Cenomanian	Late Cretaceous	–
	350.5	351.4	SP/F	C	–	Aptian ?	Early Cretaceous	–
	384	387.1	SP	DC	–	Namurian–Stephanian	Late Carboniferous	–
	410	540.4	SP	C	–	Namurian–Stephanian	Late Carboniferous	–
North Sandy 1	103.6	121.6	D	–	*D. davidii*	late Aptian	Early Cretaceous	Morgan and Ingram (1990)
	135	181.7	D	–	*C. operculata*	Aptian	Early Cretaceous	–
	147.5	317.6	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	197.5	317.6	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	329.2	–	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	375.5	592.5	SP	–	*T. playfordii*	Anisian	Middle Triassic	Dolby and Balme (1976)
	375.5	609.3	SP	–	*T. playfordii*	Anisian	Middle Triassic	Morgan and Ingram (1990)
Observation 1	356.6	–	F	SWC	–	–	Early Miocene	Belford (1968)
	390.1	438.9	F	SWC	–	–	Eocene	–
	491.9	–	F	SWC	–	–	Paleocene	–
	521.2	–	F	SWC	–	Campanian	Late Cretaceous	–
	619	749.8	D	–	*P. ludbrookiae*	late Albian	Early Cretaceous	Morgan and Ingram (1990)
	762	836.7	D	–	*D. davidii*	late Aptian	Early Cretaceous	–
	894.2	917.4	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	899.2	917.4	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	1 015	1 177.7	SP	–	*M. crenulatus*	Norian–Rhaetian	Late Triassic	Dolby and Balme (1976)
	1 015	1 234.4	SP	–	*M. crenulatus*	Norian–Rhaetian	Late Triassic	Morgan and Ingram (1990)
	1 061.9	1 435.6	SP	C	–	–	?Late Triassic	Balme (1968c)
	1 199.4	1 453.9	SP	–	*S. speciosus B*	Carnian–Norian	Late Triassic	Dolby and Balme (1976)
	1 260.7	1 766.6	SP	–	*S. speciosus*	Carnian–Norian	Late Triassic	Morgan and Ingram (1990)
	1 471.3	1 766.6	SP	–	*S. speciosus A*	Carnian–Norian	Late Triassic	Dolby and Balme (1976)
	1 747.7	1 944	SP	SWC/C	–	–	Middle–Late Triassic	Balme (1968c)
	1 781.8	2 289	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	Morgan and Ingram (1990)
	1 781.9	2 041.2	SP	–	*S. quadrifidus B*	Ladinian	Middle Triassic	Dolby and Balme (1976)
	1 781.9	2 289	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	Morgan and Ingram (1990)
	2 040.9	2 051.3	SP	SWC/C	–	–	Middle Triassic	Balme (1968c)
	2 051.3	2 289.1	SP	–	*S. quadrifidus A*	Ladinian	Middle Triassic	Dolby and Balme (1976)
	2 082.4	2 104.6	SP	SWC/C	–	–	?Middle Triassic	Balme (1968c)
	2 287.5	–	SP	C	–	–	not older than late Early Triassic	–
Onslow 1	695.6	716.9	SP	–	*S. speciosus B*	Carnian–Norian	Late Triassic	Dolby and Balme (1976)

Appendix 4 (continued)

Well	*Depth m From*	*Depth m To*	*Basis type*	*Sample*	*Zone*	*Stage*	*Epoch/Period*	*Source*
	697.7	–	SP	SWC	–	–	Triassic	–
	737.9	994.3	SP	–	*S. speciosus* A	Carnian–Norian	Late Triassic	–
	835.5	912.6	SP	SWC/C	–	–	Late Triassic	–
	1 005.8	1 563.6	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	–
	1 151.1	1 586.5	SP	C	–	–	Middle/Late Triassic	–
	1 600.2	2 023.6	SP	–	*T. playfordii*	Anisian	Middle Triassic	–
	1 905	1 905.6	SP	C	–	–	Middle Triassic	–
	2 020.5	2 023.6	SP	C	–	–	Late Early Triassic	–
	2 051.3	2 090.7	SP	–	*K. saeptatus*	Scythian	Early Triassic	–
	2 089.4	–	SP	SWC	–	–	Early Triassic	–
	2 098.5	2 166.5	SP	SWC/C	*D. parvithola*	Kazanian	Late Permian	Backhouse (1996)
	2 165.9	2 187.5	SP	C	–	Kungurian	Early Permian	–
	2 166.5	–	SP	C	Upper Stage 5b–c	Tatarian	Late Permian	Purcell (1994)
	2 224.4	2 432.3	SP	SWC	*D. ericianus – P. rugatus*	Ufimian	Late Permian	Backhouse (1996)
	2 304.3	–	M	C	–	Artinskian	Early Permian	Coleman (1967)
	2 444.5	–	SP	SWC	?*D. granulata*	Kungurian–Ufimian	Permian	Backhouse (1996)
	2 490.2	2 492.3	SP	C	*M. villosa*	Kungurian	Early Permian	–
	2 490.2	2 492.3	SP	C	–	late Artinskian	Early Permian	–
	2 510	2 567	SP	SWC	*M. trisina*	Artinskian	Early Permian	–
	2 592.6	2 595.7	SP	C	*S. fusus*	Artinskian	Early Permian	–
	2 593.8	–	M	C	–	–	Permian	Coleman (1967)
	2 594.3	–	M	C	–	Artinskian	Early Permian	–
	2 595	–	SP	SWC	Lower Stage 4	–	Early Permian	Purcell (1994)
	2 665.5	2 891	SP	SWC/C	*P. confluens*	Sakmarian	Early Permian	Backhouse (1996)
	2 890.1	–	SP	C	–	Sakmarian	Early Permian	–
	2 943.1	–	SP	DC	–	Sakmarian	Early Permian	–
	2 994.1	2 997.7	SP	C	–	–	Early Permian	–
Peedamullah 1	174.3	189.6	SP	–	–	–	Early Cretaceous	Kemp (1968)
	222.5	253.9	SP	–	–	Frasnian	Late Devonian	–
	292.3	306	SP	C	*O. triangulatus*	Givetian–Frasnian	Middle–Late Devonian	Backhouse (1996)
Picul 1	369	371.1	D	–	Upper *M. australis*	Barremian	Early Cretaceous	Ingram (1993a)
	374	375	D	–	Middle *M. australis*	Barremian	Early Cretaceous	–
	380	385	SP	–	*S. quadrifidus*	late Anisian – Ladinian	Middle Triassic	–
Santa Cruz 1	150	300	D	DC	*D. davidii*	late Aptian	Early Cretaceous	Morgan et al. (1993)
	350	–	D	DC	*M. australis*	Hauterivian–Barremian	Early Cretaceous	
	430	–	D	C	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	442.8	448	SP	C	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
	458	606	SP	DC	*D. birkheadensis* – ?Stage 2	Stephanian	Middle–Late Carboniferous	–
Sapphire 1	367	–	D	SWC	*M. australis*	Hauterivian–Barremian	Early Cretaceous	Ingram (1993b)
	377	535	SP	SWC	*S. quadrifidus*	Ladinian	Middle Triassic	–
Sapphire 2	362	396	D	SWC	Upper *M. australia*	Barremian	Early Cretaceous	Ingram (1994)
	396	406	D	SWC	Middle *M. australia*	Barremian	Early Cretaceous	–
	503.5	575	SP	SWC	*S. quadrifidus*	Ladinian	Middle Triassic	–
Sholl 1	87.2	145.1	–	SWC	–	?Aptian	Early Cretaceous	Balme (1967)
	87.2	–	D	–	*C. operculata*	Aptian	Early Cretaceous	Morgan and Ingram (1990)
	183.8	246.9	–	SWC	–	late Neocomian or Aptian	Early Cretaceous	Balme (1967)
	271.3	292.6	–	SWC	–	?Neocomian	Early Cretaceous	–
	336.8	–	–	SWC	–	–	latest Jurassic or Early Cretaceous	Balme (1967)
	336.8	776.3	SP	–	*T. playfordii*	Anisian	Middle Triassic	Dolby and Balme (1976)
	341.4	776.3	SP	–	*T. playfordii*	Anisian	Middle Triassic	Morgan and Ingram (1990)

Appendix 4 (continued)

Well	*Depth m From*	*Depth m To*	*Basis type*	*Sample*	*Zone*	*Stage*	*Epoch/Period*	*Source*
	393.5	574.5	SP	SWC/C	–	–	Middle Triassic	Balme (1967)
	640.1	–	SP	SWC	–	–	late Early or Middle Triassic	–
	702	776.3	SP	SWC/C	–	–	late Early Triassic	Dolby and Balme (1976)
	792.8	837.3	SP	–	*K. saeptatus*	Scythian	Early Triassic	Morgan and Ingram (1990)
	792.8	837.3	SP	–	*K. saeptatus*	Scythian	Early Triassic	–
	804.7	?817.5	SP	SWC	–	–	Early Triassic	Dolby and Balme (1976)
	854	1 119.2	SP	–	Stage 5	–	Late Permian	Morgan and Ingram (1990)
	854.05	1 119.2	SP	–	Stage 5	–	Late Permian	–
	885.7	1 083.3	SP	SWC/C	–	–	Late or late Early Permian	Balme (1967)
	1 130.2	1 204	SP	–	Stage 2	–	Late Carboniferous	Morgan and Ingram (1990)
Surprise 1	198.1	–	SP	SWC	–	–	Late Carboniferous (?pre-glacial)	Balme (1973)
Tent Hill 1	420	520	D	SWC	*D. davidii*	Aptian	Early Cretaceous	Ingram (1990)
	525	530	D	SWC	*O. operculina*	Aptian	Early Cretaceous	–
	532	–	D	SWC	*A. cinctum*	Barremian–Aptian	Early Cretaceous	–
	538	560	D	SWC	Upper *M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	560	570	D	SWC	?Upper *M. australis*	Hauterivian–Barremian	Early Cretaceous	–
Tortoise 1	204.2	–	F	SWC	–	–	Middle–Late Eocene	Belford (1966b)
	222.5	–	F	SWC	–	–	Eocene	–
	304.8	344.4	F	SWC	–	?Santonian	Late Cretaceous	–
	381	490.7	SP/F	SWC	–	–	late Early – early Late Cretaceous	Balme (1966c)
	545.6	640.1	–	SWC	–	?Albian	Early Cretaceous	–
	640.1	769.6	D	–	*P. ludbrookiae*	late Albian	Early Cretaceous	Morgan and Ingram (1990)
	640.1	759.6	D	–	*P. ludbrookiae*	late Albian	Early Cretaceous	–
	685.8	769.6	D	SWC	–	Albian	Early Cretaceous	Balme (1966c)
	858	–	D	–	*C. denticulata*	Middle Albian	Early Cretaceous	Morgan and Ingram (1990)
	871.4	–	D	–	*M. tetracantha*	Albian	Early Cretaceous	–
	883.6	962.9	D	–	*D. davidii*	late Aptian	Early Cretaceous	–
	975.4	987.2	D	–	*C. operculata*	Aptian	Early Cretaceous	–
	998.5	1 141.2	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	1 152.1	–	D	–	*M. testudinaria*	Hauterivian	Early Cretaceous	–
	1 164.9	1 177.7	D	–	*S. areolata*	Valanginian	Early Cretaceous	–
	1 206.4	1 307.6	D	–	*D. lobispinosum*	Berriasian	Early Cretaceous	–
	1 319.8	1 330.8	D	–	*C. delicata*	Berriasian	Early Cretaceous	–
	1 382.6	1 390.8	D	–	*K. wisemaniae*	Berriasian	Early Cretaceous	–
	1 403.3	1 584	D	–	*D. jurassicum*	Tithonian	Late Jurassic	–
	1 496.9	1 649	D	C	–	–	Late Jurassic	Balme (1966c)
	1 597.2	1 607.8	D	–	*O. montgomeryi*	Tithonian	Late Jurassic	Morgan and Ingram (1990)
	1 621.5	–	D	–	*C. perforans*	Tithonian	Late Jurassic	–
	1 634.6	1 795.3	D	–	*D. swanense*	Kimmeridgian	Late Jurassic	–
	1 645.9	1 649	M	C	–	–	Early or Middle Jurassic	Skwarko (1967b)
	1 819	1 980.6	D	–	*W. clathrata*	Oxfordian–Kimmeridgian	Late Jurassic	Morgan and Ingram (1990)
	1 981.2	2 131	D	–	*W. spectabilis*	Oxfordian	Late Jurassic	–
Tubridgi 01	177	185	D	SWC	*E. ludbrookiae* (SZ-a)	late Albian	late Early Cretaceous	Ingram (1981a)
	244.5	?314	–	–	*E. turneri* (SZ-c)	middle Albian	late Early Cretaceous	Ingram (1981a)
	314	–	D	–	*M. tetracantha*	Albian	Early Cretaceous	Morgan and Ingram (1990)
	335	395	D	–	*D. davidii*	late Aptian	Early Cretaceous	–
	355	–	–	–	*E. turneri* (SZ-b)	early Albian	Early Cretaceous	Ingram (1981a)
	367	377	–	–	*E. turneri* (SZ-a)	late Aptian	Early Cretaceous	–
	386.5	395	D	–	*O. operculata* (SZ-c)	Aptian	Early Cretaceous	–
	433	–	D	–	*O. operculata* (SZ-b)	Aptian	Early Cretaceous	–

Appendix 4 (continued)

Well	*Depth m From*	*Depth m To*	*Basis type*	*Sample*	*Zone*	*Stage*	*Epoch/Period*	*Source*
	433	–	D	–	*C. operculata*	Aptian	Early Cretaceous	Morgan and Ingram (1990)
	441	551.5	D	–	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	505	515.5	–	–	*?D. cerviculum*	Barremian	Early Cretaceous	Ingram (1981a)
	527.5	?560	SP	–	*S. quadrifidus* (SZ-b)	Ladinian	Middle Triassic	–
	527.5	547	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	Morgan and Ingram (1990)
Tubridgi 02	240.5	–	D	SWC	*E. ludbrookiae*	late Albian	late Early Cretaceous	Ingram (1982a)
	245.5	295.5	–	SWC	*E. turneri*	middle–early Albian	Early Cretaceous	–
	430	?497.5	D	SWC	*O. operculata*	Aptian	Early Cretaceous	–
	?502	518.5	–	SWC	Upper *D. cerviculum*	Barremian	Early Cretaceous	–
	520	580	SP	SWC	*S. speciosus* (SZ-b)	Carnian	Late Triassic	–
Tubridgi 04	246.5	–	–	SWC	*E. turneri*	middle Albian	Early Cretaceous	Ingram (1982b)
	365.8	501	D	SWC	*O. operculata*	Aptian	Early Cretaceous	–
	508.5	512.5	–	SWC	?Upper *D. cerviculum*	Barremian	Early Cretaceous	–
	517.5	581	SP	SWC	*S. speciosus* (SZ-b)	Carnian–Norian	Late Triassic	–
Tubridgi 05	203.5	235	D	SWC	*E. ludbrookiae* (SZ-b)	late Albian	late Early Cretaceous	Ingram (1982c)
	237	247	–	–	*E. turneri* (SZ-c)	middle Albian	Early Cretaceous	–
	255	302.5	–	–	*E. turneri* (SZ-b)	early Albian	Early Cretaceous	–
	308	365	–	–	*E. turneri* (SZ-a)	late Aptian	Early Cretaceous	–
	382.5	385	D	–	*O. operculata* (SZ-c)	Aptian	Early Cretaceous	–
	406.5	480	D	–	*O. operculata* (SZ-a–b)	Aptian	Early Cretaceous	–
	500	510	–	–	*D. cerviculum*	Barremian	Early Cretaceous	–
	521.5	574	SP	–	*S. speciosus* (SZ-b)	Carnian–Norian	Late Triassic	–
Tubridgi 08	350	424	D	SWC	*D. davidii*	Aptian	Early Cretaceous	–
	480	–	D	C	*M. australis*	Hauterivian–Barremian	Early Cretaceous	–
	509.8	?513.2	SP	C	*B. eneabbaensis*	Neocomian	Early Cretaceous	–
	546.5	–	SP	–	*S. quadrifidus*	Ladinian	Middle Triassic	–
Urala 1	683.1	759.6	SP	C	–	–	Middle–Late Triassic	Balme (1969)
	683.1	759.6	SP	C	*S. quadrifidus*	Ladinian	Middle Triassic	Dolby and Balme (1976)
Weelawarren 1	150	155	D	DC	*E. ludbrookiae* (SZ-a)	late Albian	late Early Cretaceous	Ingram and Morgan (1983)
	245	310	–	DC	*E. turneri* (SZ-a)	late Aptian	Early Cretaceous	–
	315	330	D	DC	Upper *O. operculata* (SZ-a)	Aptian	Early Cretaceous	–
	335	410	D	DC	Lower *O. operculata*	Aptian	Early Cretaceous	–
	410	450	SP	DC	*S. quadrifidus*	Anisian	Middle Triassic	–
	485	550	SP	DC	*T. playfordii*	Anisian	Middle Triassic	–
	550	552	SP	C	*T. playfordii*	Anisian	Middle Triassic	–
Wonangarra 1	573.9	–	SP	C	–	–	?Early Carboniferous	Backhouse (1996)
Woorawa 1	196.6	198.1	SP	SWC	–	–	Late Carboniferous	Balme (1972)
Wyloo 1	310	323	–	SWC	*E. turneri* (SZ-b)	early Albian	Early Cretaceous	Ingram (1981b)
	376.4	–	–	SWC	*E. turneri* (SZ-a)	late Aptian	Early Cretaceous	–
	381.4	431	D	SWC	*O. operculata*	Aptian	Early Cretaceous	–
	523.7	713	SP	SWC	*S. speciosus*	Carnian–Norian	Late Triassic	–
	?437.5	?519	–	SWC	Upper *D. cerviculum*	Barremian	Early Cretaceous	–
Yanrey 1	124.4	–	F	C	–	Maastrichtian	Late Cretaceous	Belford (1957)
	146.3	152.4	F	C	–	Campanian	Late Cretaceous	–
	189.3	195.4	F	C	–	early Turonian	Late Cretaceous	–
	249.9	397.8	F	C	–	Aptian–Albian	Early Cretaceous	

NOTES: **Basis**
D: dinoflagellates
SP: spores and pollen
F: foraminifera
M: macrofauna
C: conodont

Sample type
C: core
DC: ditch cutting
SWC: sidewall core

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Appendix 5

Formation tops of wells drilled for petroleum exploration on the Peedamullah Shelf and Onslow Terrace

Well name	*GL or SB (m AHD)*	*KB (m AHD)*	*Tt*	*Tc*	*Kt*	*KWg*	*KWw*	*Kcm*	*KWmm*	*KWb*	*KBf*	*Ky*	*Jd*	*TRm*
Abdul's Dam 1	4.4	7.7	24	61	–	75	314	330	–	–	–	–	–	–
Amber 1	15	18.4	36	–	–	70	203	264	–	365.5	372	–	–	–
Beagle 1	5	6	33	–	50	59	110	144	–	244	293	–	–	–
Black Ledge 1	-11	31.9	–	–	–	260	532	611	–	722.5	737.5	–	772.5	2178
Candace 1	-21	32	54	–	–	125	160	210	336	396	–	–	–	415
Cane River 1	8	10	34	–	–	64	213	290	–	347.5	393	–	–	–
Cane River 2	5	7	20	–	–	34	91	192	–	290	305	–	–	–
Cane River 3	15	17	4	–	–	–	55	128	–	205	210	–	–	–
Cane River 4	13	16	3	–	–	–	–	43	–	–	123	–	–	–
Cane River 5	34	37	3	–	–	–	–	52	–	–	128	–	–	–
Carnie 1	8.6	10.6	6	–	–	–	–	28	154	np	np	np	np	np
Chinty 1	3.4	10.6	40	–	90	125	365	430	534	538	–	–	–	545
Crackling 1	-12	44	–	–	70	96	173	233.5	357.5	–	369	–	–	–
Coonga 1	6	8	2	–	–	–	–	35	124	–	–	–	–	–
Cunaloo 1	12	16	22	–	–	24	–	265	–	–	–	–	–	–
Curler 1	-8	28.9	–	–	104	159	415	495	–	–	615	–	649	np
Direction 1	5	6	2	–	–	86	274	329	–	442	458	–	–	–
East Somelim 1	6.8	9.1	5	–	–	23	–	47	110	–	–	116	–	–
Echo Bluff 1	11.4	17.3	9	–	–	–	–	27	146	–	–	149	–	–
Fortescue 1	5	6	32	–	–	–	73	105	–	270	280	–	–	–
Glenroy 1	3	5	14	37	46	94	348	411	–	494	543	–	–	?564
Jade 1	6.4	10.9	25	–	–	87	317	382	–	476.5	490	–	–	501.5
Jasper 1	-9.2	25.1	55	–	–	102	255	313	–	417.6	429.8	–	–	–
Kybra 1	-17.6	35	52.6	–	–	143	–	155	–	483	509	–	–	553
Locker 1	3	4	65	–	149	224	475	533	–	606	624	–	–	634
Mangrove 1	15	20	15	–	–	–	–	40	–	165	191	–	–	–
Mardie 1	5	6	12	–	–	–	–	27	150	–	–	173	–	–
Mardie 1A	5	8	8	–	–	–	–	26	159	np	np	np	np	np
Mardie 1B	6.4	8.7	10	–	–	27.5	–	80	161.5	np	np	np	np	np
Mardie 2	6	8	17	–	–	–	–	29	146	–	–	165	np	np
Mardie 3	2.5	7.4	–	–	–	–	–	21	153	–	–	162	np	np
Mardie West 1	6	9	3	–	–	–	–	50	117	–	–	–	–	–
Mary Anne 1	5	6.1	34	–	49	72	157	192	–	301	326	–	–	–
Minderoo 1	11	12	30	–	–	38	234	308	–	342	–	–	–	–
Multhuwarra 1	4.3	6.3	18	–	–	22	–	90	175	–	–	182.6	np	np
Mulyery 1	5	6	12	–	–	–	–	41	117	123	–	130	np	np
Murnda 1	4.8	6.8	12	–	–	27	–	66	164.6	–	–	177	–	–
Myanore 1	4.7	6.7	11	–	–	33	–	72	163	np	np	np	np	np
North Sandy 1	50	6.1	50	–	–	67	135	201	–	311	332	–	–	369
Onslow 1	0	5	34	–	59	100	346	412	–	519	524	–	–	556
Peedamullah 1	5	7	14	–	–	–	44	70	174	–	–	186	–	–
Picul 1	8.2	12.6	12	–	–	45	210	250	369	–	–	–	–	377
Robe River Corehole 1	22	23	16	–	–	–	–	26	97	–	–	101	np	np
Robe River Corehole 2	29	30	24	–	–	–	–	35	64	–	–	68	np	np
Robe River Corehole 3	32	34	18	–	–	–	–	29	36	–	–	40	–	–
Robe River Corehole 4	24	26	21	–	–	–	–	30	76	–	–	81	np	np
Robe River Corehole 5	31	32	16	–	–	–	–	29	59	–	–	64	np	np
Ruby 1	11.67	16.07	30	–	–	59.5	295	330	–	398	–	–	–	–
Saddleback 1	21.7	23.7	–	–	–	–	–	9	92	–	–	96	np	np
Santa Cruz 1	-14	42.5	–	–	66	112	280	325	417	–	432.3	–	–	–
Sapphire 1	8	12.5	5	–	–	54	226	290	–	390	–	–	–	393
Sapphire 2	4.5	9	14	–	–	40	228.5	309	–	396	400.5	–	–	408
Sharon 1	6	13.6	12	–	–	33	–	60	161.4	_	_	177	–	–
Sholl 1	5	9	21	–	–	–	67	110	253	285.6	319.7	–	–	–
Somelim 1	7	10	15	–	–	25	–	45.5	97	–	–	115	–	–
Surprise 1	10	12	2	–	–	–	–	24	104	–	–	123	–	–
Talandji 1	6.4	10.8	18	–	–	54	294	365	–	438	464	–	–	505
Tent Hill 1	4.5	7.5	3	–	112	198	474	520	–	532	–	–	–	–
Thringa 1	5	7	10	–	–	–	–	28	164	np	np	np	np	np
Topaz 1	2	6.4	22	–	–	49	175	242	–	335.5	337	–	–	–
Topaz 2	1.4	5.85	20	–	–	49	173.8	237	–	339.7	340.5	–	–	–
Tourmaline 1	4.81	9.31	17	–	–	47	253	322	–	–	409	–	–	420.5
Tubridgi 01	3.6	6.6	30	74	90	125	382	437	510	517	–	–	–	527.5
Tubridgi 02	-0.4	2.35	20	57	70	120	373.8	428.6	508	516	–	–	–	520
Tubridgi 03	1.1	4.08	47	122	–	145	398.5	452.6	526	539	–	–	–	543
Tubridgi 04	-0.2	2.8	40	70	78	115	360.6	421.5	498.5	511	–	–	–	513.4
Tubridgi 05	-0.5	2.5	23	98	–	118.5	373	425	505	515.6	–	–	–	520.5
Tubridgi 06	0.1	2.8	20	–	–	106.5	384.5	441.5	526	531.5	–	–	–	537
Tubridgi 07	1.9	5.8	40	66	–	102	352	423	498	510	–	–	–	525
Tubridgi 08	1.6	5.5	30	63	–	112	353	426	500	509	–	–	–	527.5

TRl	*TRlc*	*Pky*	*PKa*	*Pko*	*PKu*	*Pc*	*CPL*	*Cq*	*Cm*	*Dg*	*Dn*	*Ot*	*pC*	*TD (m)*
422	–	446	707	747.5	np	np	np	np	np	np	np	np	np	770
–	–	–	–	–	–	–	_	389	np	np	np	np	np	682.7
–	–	–	–	–	–	–	320	np	np	np	np	np	np	560
np	np	np	np	np	np	np	np	np	np	np	np	np	np	2 680
880	1 420–1 444	1 458	–	–	–	1 970	2 007	np	np	np	np	np	np	2 063
–	–	413	–	–	–	–	622	np	np	np	np	np	np	694
–	–	–	–	–	–	–	–	–	–	349	np	np	np	413
–	–	–	–	–	–	–	–	–	–	–	–	–	241	255
–	–	–	–	–	–	–	–	–	–	–	–	–	157	173
–	–	–	–	–	–	–	–	–	–	–	–	–	186	201
np	np	np	np	np	np	np	np	np	np	np	np	np	np	163
1 001	1 421	1 596	np	np	np	np	np	np	np	np	np	np	np	1 673
411	–	515	–	594	np	np	np	np	np	np	np	np	np	625
–	–	–	–	–	–	–	–	–	–	–	–	–	128	176
347	534–548.6	592	np	np	np	np	np	np	np	np	np	np	np	798
np	np	np	np	np	np	np	np	np	np	np	np	np	np	759
–	–	478	–	–	564	–	630	np	np	np	np	np	np	673
–	–	–	–	–	–	–	139	np	np	np	np	np	np	143.6
–	–	–	–	–	–	–	–	–	–	201	995	?1 145	np	1 204
327	362–380	381	–	–	415	–	498	np	np	np	np	np	np	610
np	np	np	np	np	np	np	np	np	np	np	np	np	np	648
np	np	np	np	np	np	np	np	np	np	np	np	np	np	604
–	–	–	–	–	–	–	–	458	np	np	np	np	np	549.7
965	_	1 493.5	_	_	_	1 738	1 759	2 146.5	2 168	np	np	np	np	2 562
np	np	np	np	np	np	np	np	np	np	np	np	np	np	766
–	–	–	–	–	–	–	208	np	np	np	np	np	np	286
–	–	–	–	–	–	–	–	–	–	–	–	–	124	135
–	–	–	–	–	–	–	–	–	–	205	np	np	222	225.5
np	np	np	np	np	np	np	np	np	np	np	np	np	np	164.3
np	np	np	np	np	np	np	np	np	np	np	np	np	np	165.8
np	np	np	np	np	np	np	np	np	np	np	np	np	np	165
np	np	np	np	np	np	np	np	np	np	np	np	np	np	165
351	np	np	np	np	np	np	np	np	np	np	np	np	np	533
–	–	–	–	–	–	–	387	–	np	np	np	np	np	610
np	np	np	np	np	np	np	np	np	np	np	np	np	np	185
np	np	np	np	np	np	np	np	np	np	np	np	np	np	140
–	–	–	–	–	–	–	–	–	–	?247	np	np	np	252
np	np	np	np	np	np	np	np	np	np	np	np	np	np	175
512	np	np	np	np	np	np	np	np	np	np	np	np	np	609.6
1 587	2 076–2 083	2 096	2 258	2 280	2 344	2 495	2 610	np	np	np	np	np	np	2 998
–	–	–	–	–	–	–	–	–	–	213	np	np	np	328
np	np	np	np	np	np	np	np	np	np	np	np	np	np	500.8
np	np	np	np	np	np	np	np	np	np	np	np	np	np	103
np	np	np	np	np	np	np	np	np	np	np	np	np	np	74
–	–	–	–	–	–	–	–	–	–	–	–	–	50	122
np	np	np	np	np	np	np	np	np	np	np	np	np	np	103
np	np	np	np	np	np	np	np	np	np	np	np	np	np	67
–	–	–	400	449.5	np	np	np	np	np	np	np	np	np	500
np	np	np	np	np	np	np	np	np	np	np	np	np	np	148
–	–	–	–	–	–	–	456	np	np	np	np	np	np	629
np	np	np	np	np	np	np	np	np	np	np	np	np	np	558
532.5	np	np	np	np	np	np	np	np	np	np	np	np	np	600
–	–	–	–	–	–	–	–	–	–	207	np	np	np	258.9
338	807–825	840	–	–	–	1 022	1 120	np	np	np	np	np	np	1 272
–	–	–	–	–	–	–	141	–	250	np	np	np	np	413.5
–	–	–	–	–	–	–	142	np	np	np	np	np	np	216
1 246	np	np	np	np	np	np	np	np	np	np	np	np	np	1 488
–	–	–	–	–	–	–	–	–	–	–	–	–	572	580
np	np	np	np	np	np	np	np	np	np	np	np	np	np	173
–	–	–	–	–	–	–	–	352.5	378	np	np	np	np	423
–	–	–	–	–	–	–	–	360	369	np	np	np	np	446
np	np	np	np	np	np	np	np	np	np	np	np	np	np	472.6
np	np	np	np	np	np	np	np	np	np	np	np	np	np	611
np	np	np	np	np	np	np	np	np	np	np	np	np	np	592.3
np	np	np	np	np	np	np	np	np	np	np	np	np	np	597
np	np	np	np	np	np	np	np	np	np	np	np	np	np	595
np	np	np	np	np	np	np	np	np	np	np	np	np	np	593
np	np	np	np	np	np	np	np	np	np	np	np	np	np	594
np	np	np	np	np	np	np	np	np	np	np	np	np	np	599.7
np	np	np	np	np	np	np	np	np	np	np	np	np	np	598.4

Appendix 5 (continued)

Well name	*GL or SB (m AHD)*	*KB (m AHD)*	*Tt*	*Tc*	*Kt*	*KWg*	*KWw*	*Kcm*	*KWmm*	*KWb*	*KBf*	*Ky*	*Jd*	*TRm*
Tubridgi 09	0.8	5.2	24	–	–	102	330	416	496.5	501.4	–	–	–	515
Tubridgi 10	2.4	7.9	36	75	–	121.5	359	435.5	509.5	517.6	–	–	–	525.8
Tubridgi 11	1.1	5.4	23	59	–	103	372	426	506	513	520	–	–	528
Tubridgi 12	1.87	6.17	30	61	–	129	384	436.5	508	513.2	518	–	–	525
Tubridgi 13	4.3	6.3	45	83	–	120	370	436.5	517	524	531	–	–	536
Tubridgi 14	4.3	5.4	37.5	71	–	99	365	446	560	570.5	579	–	–	591
Tubridgi 15	4.3	6.1	33	68	–	128	374	428	501	506	511	–	–	519
Urala 1	2	4	76	133	148	242	465	531	–	604	–	–	–	618
Weelawarren 1	1.7	3.7	21	43	–	60	264	314	NP	NP	NP	NP	NP	395
Windoo 1	2	4	2	–	–	–	–	27	165	–	–	177	–	–
Windoo 1A	2	5	6	–	–	–	–	27	165	NP	NP	NP	NP	NP
Wonangarra 1	6	8	–	–	106	144	411	469	–	514	–	–	–	–
Woorawa 1	13	16	3	–	–	–	–	27	–	–	–	113	–	–
Wyloo 1	2.2	5.2	30	75	85	120	378	439	510	514	–	–	–	519.5
Yanrey 1	14	16	–	–	50/154	70/175	405	–	–	–	–	–	–	–
Yarraloola 1	15	17	20	–	–	–	–	46	85	–	–	110	–	–

NOTES:

Cm:	Moogooree Limestone
CPL:	Lyons Group
Cq:	Quail Formation
Dg:	Gneudna Formation
Dn:	Nannyarra Sandstone
Jd:	Dingo Claystone
KBf:	Flacourt Formation
Kt:	Toolonga Calcilutite
KWb:	Birdrong Sanstone
KWg:	Gearle Siltstone
KWm:	Munderong Shale
KWmm:	Mardie Greensand
KWmw:	Windalia Sandstone Member
KWw:	Windalia Radiolarite
Ky:	Yarraloola Conglomerate
Ot:	Tumblagooda Sandstone
Pc:	Callytharra Formation
pC:	Precambrian rocks

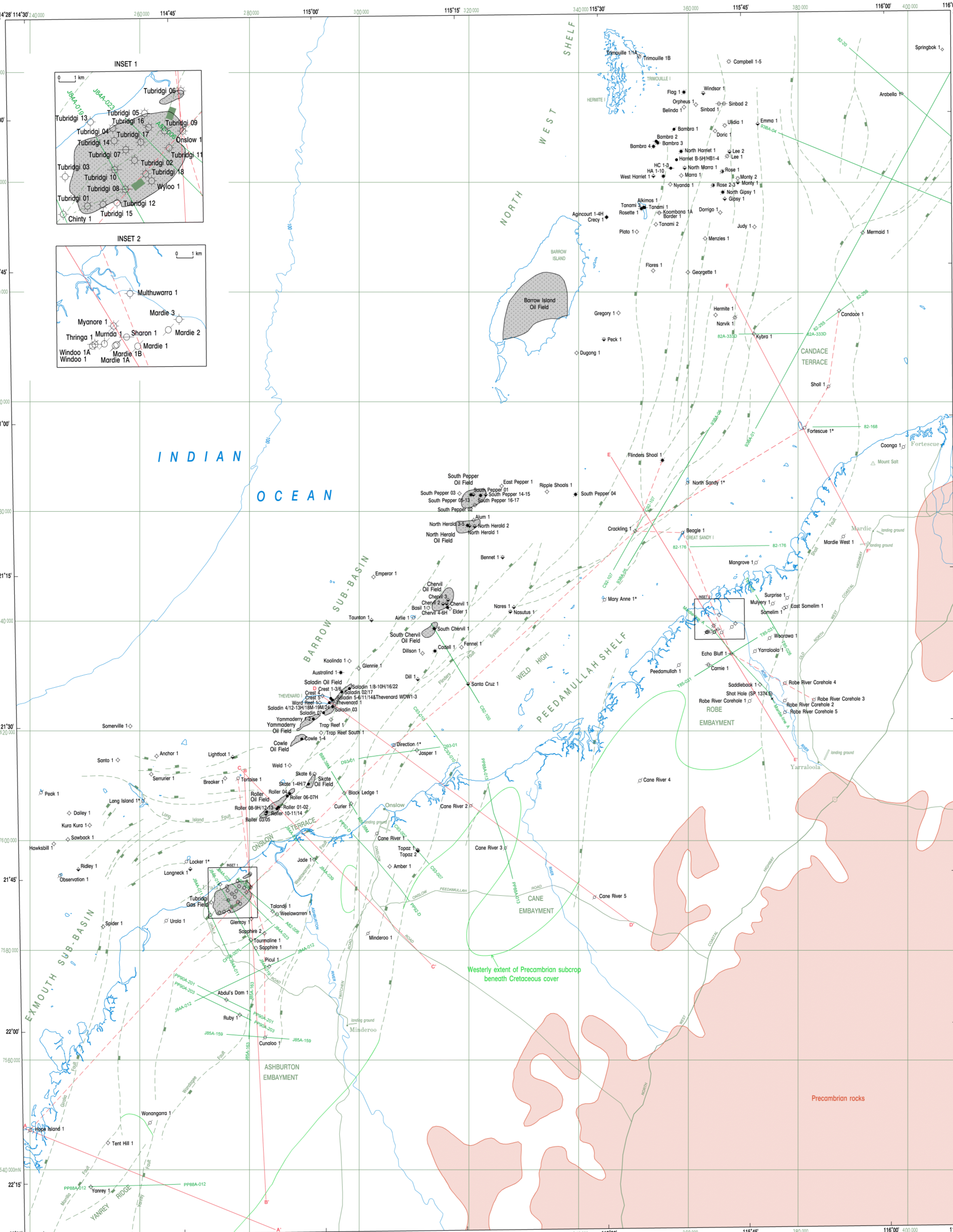
For the Windalia Sandstone Member (KWmw) and Cunaloo Member (TRlc), the formation bottom is also used

TRl	*TRlc*	*Pky*	*PKa*	*Pko*	*PKu*	*Pc*	*CPL*	*Cq*	*Cm*	*Dg*	*Dn*	*Ot*	*pC*	*TD m*
np	np	np	np	np	np	np	np	np	np	np	np	np	np	601
np	np	np	np	np	np	np	np	np	np	np	np	np	np	631.5
np	np	np	np	np	np	np	np	np	np	np	np	np	np	577.2
np	np	np	np	np	np	np	np	np	np	np	np	np	np	575.8
np	np	np	np	np	np	np	np	np	np	np	np	np	np	581
np	np	np	np	np	np	np	np	np	np	np	np	np	np	644.6
np	np	np	np	np	np	np	np	np	np	np	np	np	np	575
np	np	np	np	np	np	np	np	np	np	np	np	np	np	762
545	np	np	np	np	np	np	np	np	np	np	np	np	np	552.7
–	–	–	–	–	–	–	–	–	–	217	np	np	np	219
np	np	np	np	np	np	np	np	np	np	np	np	np	np	174
–	–	–	–	–	–	–	–	–	533	np	np	np	np	575
–	–	–	–	–	–	–	150	np	np	np	np	np	np	202
np	np	np	np	np	np	np	np	np	np	np	np	np	np	732
–	–	–	–	–	–	–	–	–	–	–	–	–	422	431
–	–	–	–	–	–	–	–	152	–	np	np	np	np	272

NOTES:
PKa: Abdul Sandstone
PKo: Cody Limestone
PKu: Kennedy Group undifferentiated
PKy: Chinty Formation
Tc: Cardabia Calcarenite
TRI: Locker Shale
TRIc: Cunaloo Member
TRm: Mungaroo Formation
Tt: Trealla Limestone

GL: ground level
KB: kelly bushing
TD: total depth
np: not penetrated
–: not present or not identified
AHD: Australian Height Datum
SB sea bed

All depths are from rotary table or kelly bushing



SYMBOLS

- Pre-Cretaceous fault pattern
- Stratigraphic correlations shown in report
- A —— A′ Geological cross-section shown in report
- PP92-D —— PP92-D Seismic line shown in report
- Limit of exposure of Precambrian rocks
- Extent of Precambrian subcrop beneath Cretaceous cover
- Fortescue 1* Asterisk indicates that well was drilled on the nearby island, but coordinates taken from well completion report are only approximate
- × Shot Hole referred to in report
- Hydrocarbon Fields: Tubridgi Field boundary from Figure 9; other boundaries after Crostella (1996) and Tindale et al. (1998)
- Coastline
- 100 Bathymetric contour in metres
- Onslow Townsite
- Mardie Homestead

PETROLEUM EXPLORATION WELLS

- Show of oil, suspended
- Show of oil, abandoned
- Show of gas, suspended
- Show of gas, abandoned
- Show of oil and gas, suspended
- Show of oil and gas, abandoned
- Suspended
- Dry, abandoned
- Stratigraphic

PETROLEUM PRODUCTION WELLS

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

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

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

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

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 73 PLATE 1

LOCATION MAP
PEEDAMULLAH SHELF AND ONSLOW TERRACE

SCALE 1: 500 000

5000 Metres 0 5 10 15 20 Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Map Grid Australia Zone 50

Compiled by R. Iasky and K. Blundell
Edited by D. Ferdinando and G. Loan
Cartography by A. Francois

Published by the Geological Survey of Western Australia, copies available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, WA, 6004. Phone (08) 9222 3459, Fax (08) 9222 3444

This map is also available in digital format

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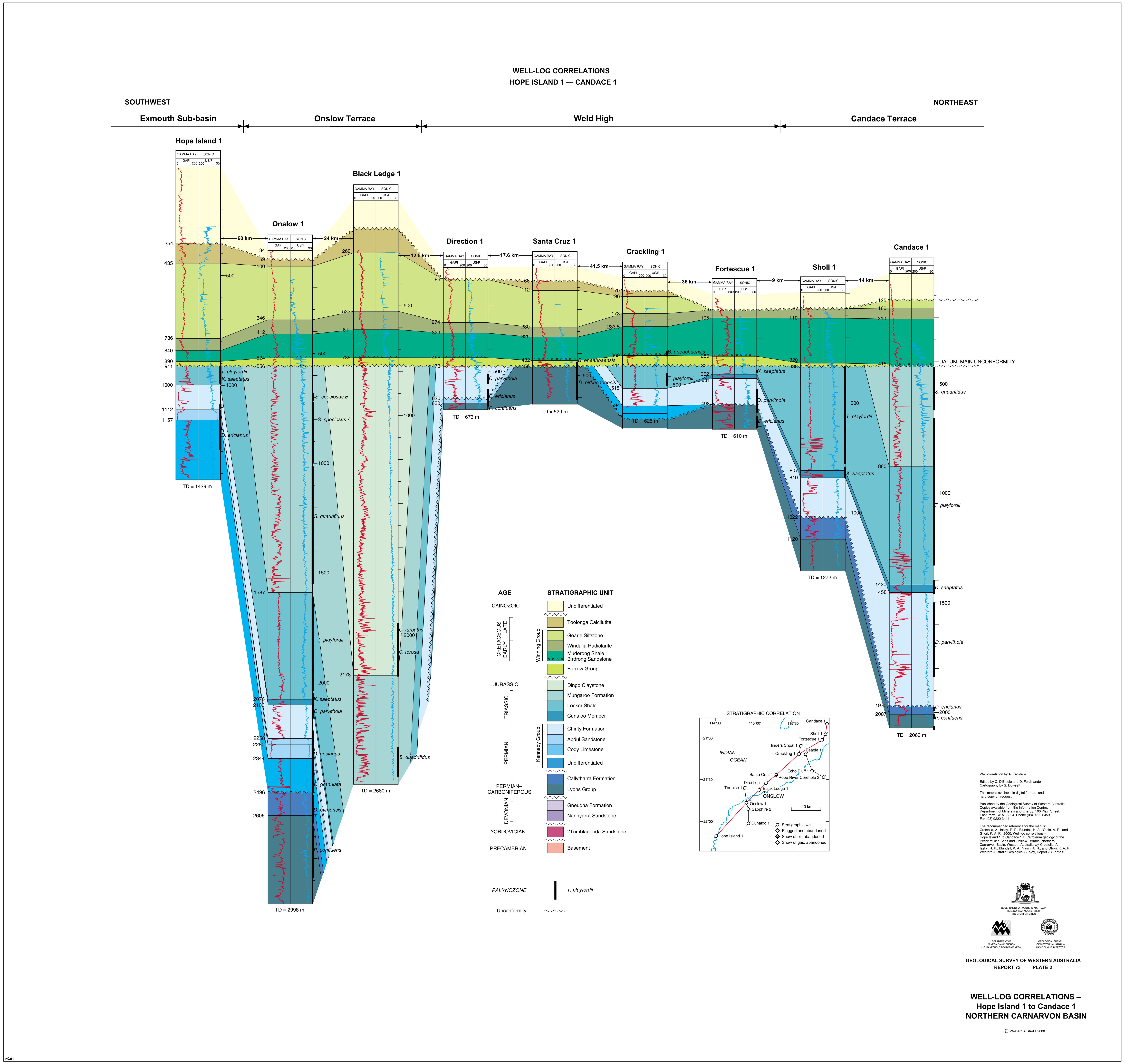
The recommended reference for this map is: Iasky, R.P., and Blundell, K. A., 2000: Location map, Peedamullah Shelf and Onslow Terrace, *in* Crostella, A., Iasky, R. P., Blundell, K. A., Yasin, A. R., and Ghori, K. A. R., 2000: Petroleum geology of the Peedamullah Shelf and the Onslow Terrace, Northern Carnarvon Basin, Western Australia Geological Survey, Report 73, Plate 1



WELL-LOG CORRELATIONS
HOPE ISLAND 1 — CANDACE 1
SOUTHWEST
NORTHEAST
Exmouth Sub-basin
Onslow Terrace
Weld High
Candace Terrace
Hope Island 1
Onslow 1
Black Ledge 1
Direction 1
Santa Cruz 1
Crackling 1
Fortescue 1
Sholl 1
Candace 1
60 km
24 km
12.5 km
17.6 km
41.5 km
36 km
9 km
14 km
GAMMA RAY
SONIC
GAPI
US/F
TD = 1429 m
TD = 2998 m
TD = 2680 m
TD = 673 m
TD = 529 m
TD = 625 m
TD = 610 m
TD = 1272 m
TD = 2063 m
DATUM: MAIN UNCONFORMITY
T. playfordii
K. saeptatus
D. ericianus
S. speciosus B
S. speciosus A
S. quadrifidus
D. parvithola
D. granulata
D. byrnensis
P. confluens
C. turbatus
C. torosa
B. eneabbaensis
D. birkheadensis
AGE
STRATIGRAPHIC UNIT
CAINOZOIC
Undifferentiated
CRETACEOUS
LATE
EARLY
Winning Group
Toolonga Calcilutite
Gearle Siltstone
Windalia Radiolarite
Muderong Shale
Birdrong Sandstone
Barrow Group
JURASSIC
Dingo Claystone
TRIASSIC
Mungaroo Formation
Locker Shale
Cunaloo Member
PERMIAN
Kennedy Group
Chinty Formation
Abdul Sandstone
Cody Limestone
Undifferentiated
PERMIAN–CARBONIFEROUS
Callytharra Formation
Lyons Group
DEVONIAN
Gneudna Formation
Nannyarra Sandstone
?ORDOVICIAN
?Tumblagooda Sandstone
PRECAMBRIAN
Basement
PALYNOZONE
T. playfordii
Unconformity
STRATIGRAPHIC CORRELATION
INDIAN OCEAN
Candace 1
Sholl 1
Fortescue 1
Flinders Shoal 1
Crackling 1
Beagle 1
Santa Cruz 1
Direction 1
Echo Bluff 1
Robe River Corehole 3
Tortoise 1
Black Ledge 1
ONSLOW
Onslow 1
Sapphire 2
Cunaloo 1
Hope Island 1
40 km
Stratigraphic well
Plugged and abandoned
Show of oil, abandoned
Show of gas, abandoned
Well correlation by A. Crostella
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 73 PLATE 2
WELL-LOG CORRELATIONS –
Hope Island 1 to Candace 1
NORTHERN CARNARVON BASIN
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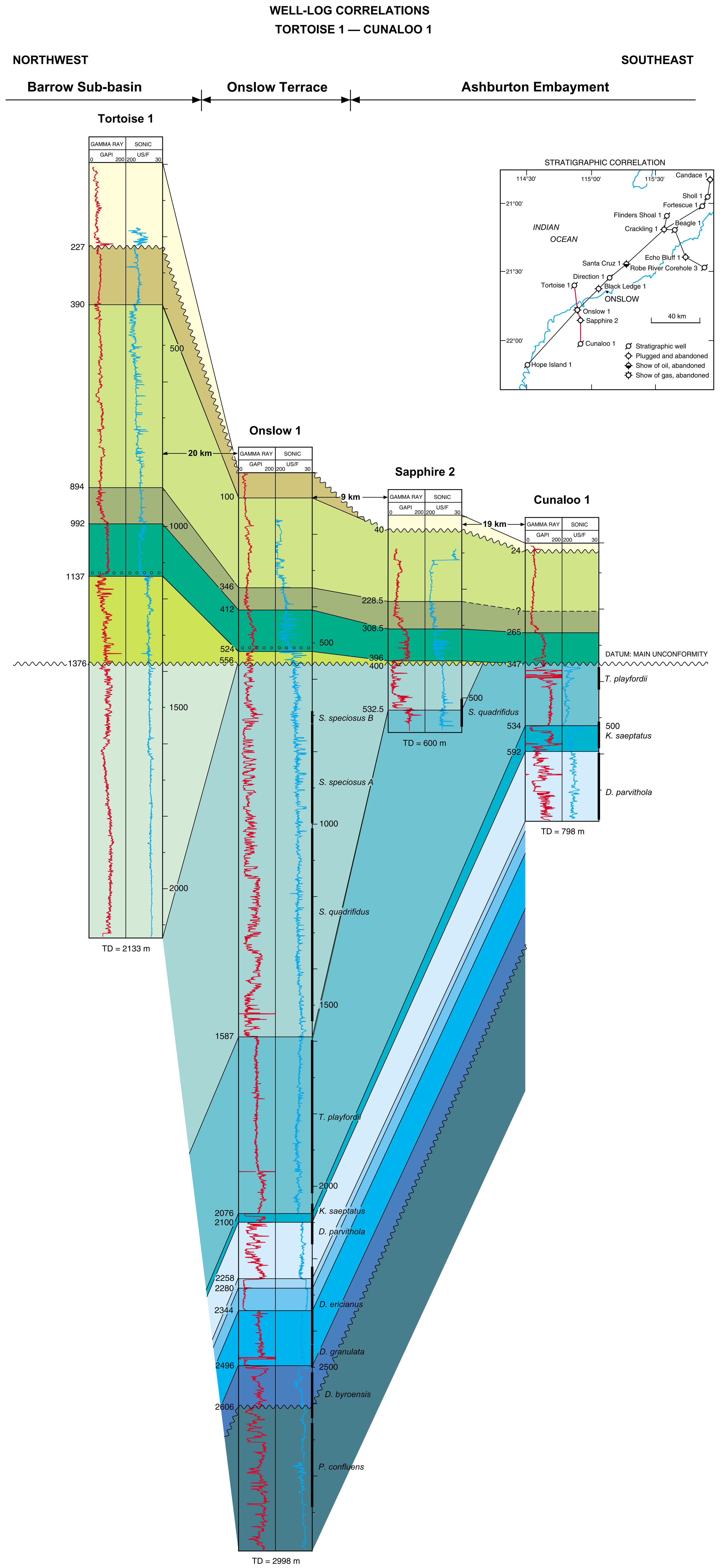

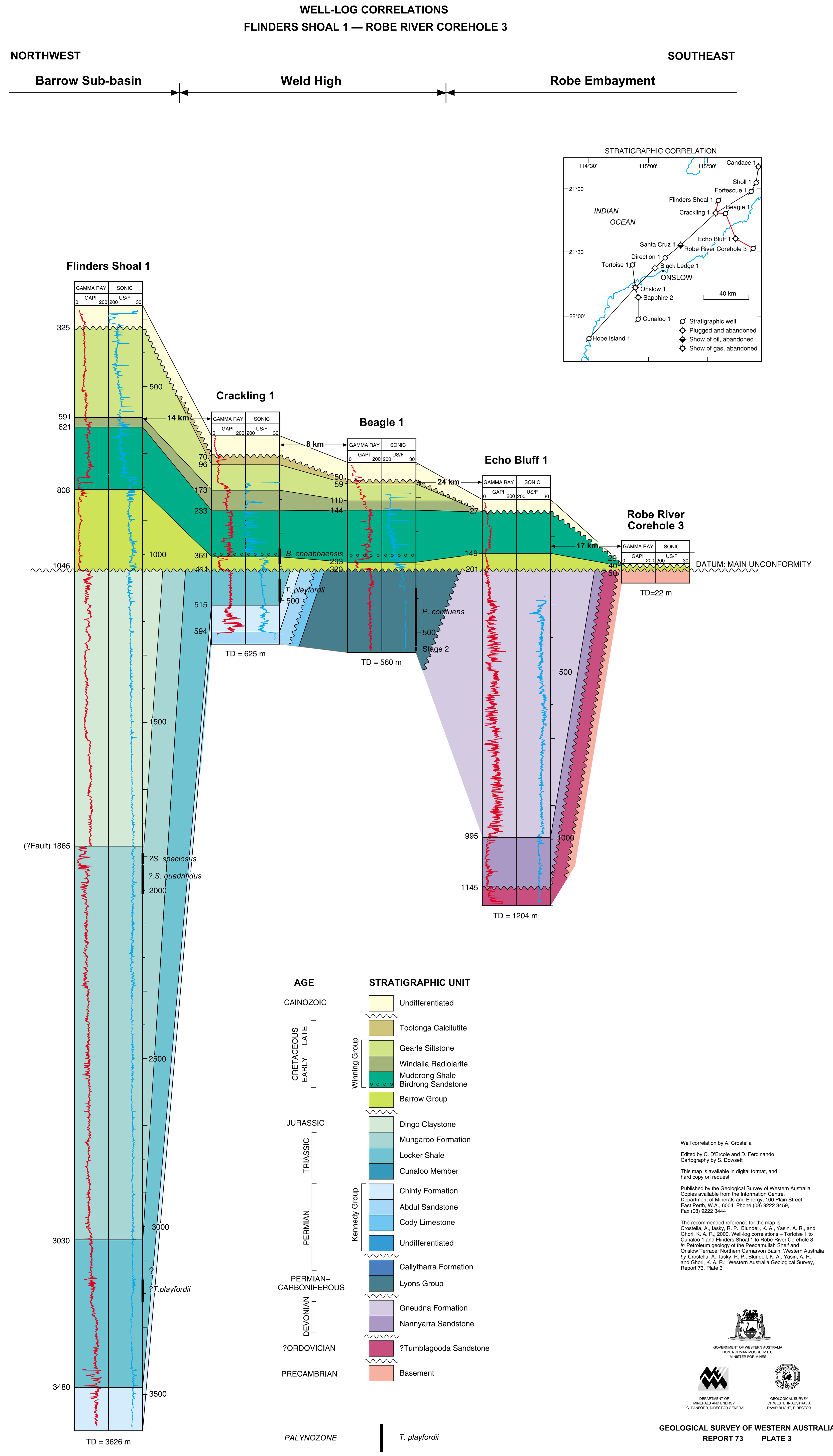

AGE		STRATIGRAPHIC UNIT
CAINOZOIC		Undifferentiated
CRETACEOUS LATE		Toolonga Calcilutite
CRETACEOUS EARLY	Winning Group	Gearle Siltstone
	Winning Group	Windalia Radiolarite
	Winning Group	Muderong Shale Birdrong Sandstone
		Barrow Group
JURASSIC		Dingo Claystone
TRIASSIC		Mungaroo Formation
		Locker Shale
		Cunaloo Member
PERMIAN	Kennedy Group	Chinty Formation
	Kennedy Group	Abdul Sandstone
	Kennedy Group	Cody Limestone
	Kennedy Group	Undifferentiated
		Callytharra Formation
PERMIAN–CARBONIFEROUS		Lyons Group
DEVONIAN		Gneudna Formation
		Nannyarra Sandstone
?ORDOVICIAN		?Tumblagooda Sandstone
PRECAMBRIAN		Basement

PALYNOZONE — *T. playfordii*

Unconformity

Well correlation by A. Crostella

Edited by C. D'Ercole and D. Ferdinando
Cartography by S. Dowsett

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The recommended reference for the map is:
Crostella, A., Iasky, R. P., Blundell, K. A., Yasin, A. R., and Ghori, K. A. R., 2000, Well-log correlations – Tortoise 1 to Cunaloo 1 and Flinders Shoal 1 to Robe River Corehole 3 *in* Petroleum geology of the Peedamullah Shelf and Onslow Terrace, Northern Carnarvon Basin, Western Australia *by* Crostella, A., Iasky, R. P., Blundell, K. A., Yasin, A. R., and Ghori, K. A. R.: Western Australia Geological Survey, Report 73, Plate 3

GOVERNMENT OF WESTERN AUSTRALIA
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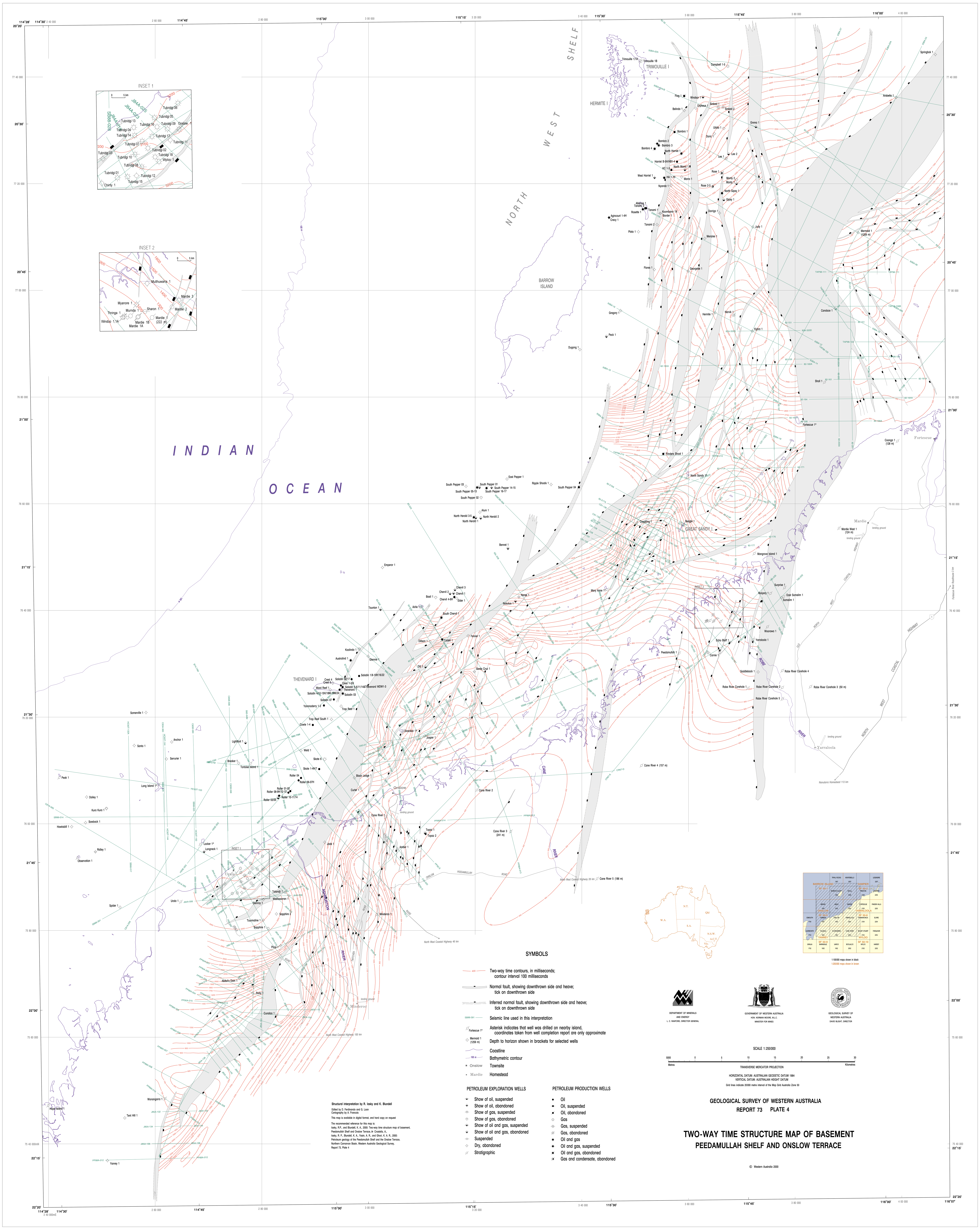
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 73 PLATE 3

WELL-LOG CORRELATIONS – Tortoise 1 to Cunaloo 1 and Flinders Shoal 1 to Robe River Corehole 3 NORTHERN CARNARVON BASIN



INDIAN
OCEAN
NORTH WEST SHELF
BARROW ISLAND
THEVENARD I
GREAT SANDY I
TRIMOUILLE I
HERMITE I
INSET 1
INSET 2
SYMBOLS
Two-way time contours, in milliseconds; contour interval 100 milliseconds
Normal fault, showing downthrown side and heave; tick on downthrown side
Inferred normal fault, showing downthrown side and heave; tick on downthrown side
Seismic line used in this interpretation
Asterisk indicates that well was drilled on nearby island, coordinates taken from well completion report are only approximate
Depth to horizon shown in brackets for selected wells
Coastline
Bathymetric contour
Townsite
Homestead
PETROLEUM EXPLORATION WELLS
Show of oil, suspended
Show of oil, abandoned
Show of gas, suspended
Show of gas, abandoned
Show of oil and gas, suspended
Show of oil and gas, abandoned
Suspended
Dry, abandoned
Stratigraphic
PETROLEUM PRODUCTION WELLS
Oil
Oil, suspended
Oil, abandoned
Gas
Gas, suspended
Gas, abandoned
Oil and gas
Oil and gas, suspended
Oil and gas, abandoned
Gas and condensate, abandoned
Structural interpretation by R. Iasky and K. Blundell
Edited by D. Ferdinando and G. Loan
Cartography by A. Francois
This map is available in digital format, and hard copy on request
The recommended reference for this map is:
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MINISTER FOR MINES
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DAVID BLIGHT, DIRECTOR
SCALE 1:250 000
Metres
Kilometres
TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Map Grid Australia Zone 50
1:100 000 maps shown in black
1:250 000 maps shown in brown
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REPORT 73 PLATE 4
TWO-WAY TIME STRUCTURE MAP OF BASEMENT
PEEDAMULLAH SHELF AND ONSLOW TERRACE
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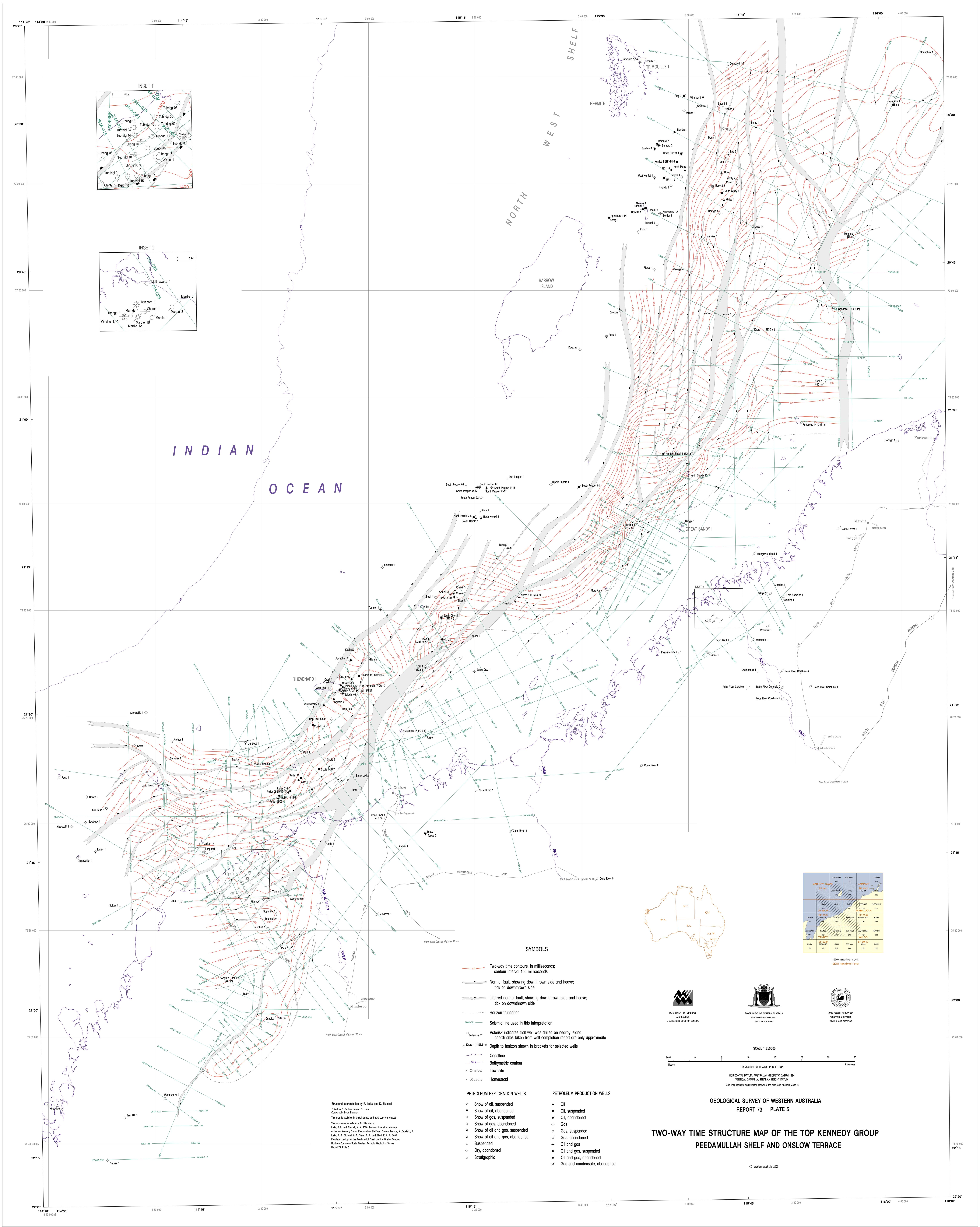

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REPORT 73 PLATE 5
TWO-WAY TIME STRUCTURE MAP OF THE TOP KENNEDY GROUP
PEEDAMULLAH SHELF AND ONSLOW TERRACE
© Western Australia 2000
INDIAN OCEAN
NORTH WEST SHELF
BARROW ISLAND
TRIMOUILLE I
HERMITE I
THEVENARD I
GREAT SANDY I
INSET 1
INSET 2
SYMBOLS
Two-way time contours, in milliseconds; contour interval 100 milliseconds
Normal fault, showing downthrown side and heave; tick on downthrown side
Inferred normal fault, showing downthrown side and heave; tick on downthrown side
Horizon truncation
Seismic line used in this interpretation
Asterisk indicates that well was drilled on nearby island, coordinates taken from well completion report are only approximate
Depth to horizon shown in brackets for selected wells
Coastline
Bathymetric contour
Onslow Townsite
Mardie Homestead
PETROLEUM EXPLORATION WELLS
Show of oil, suspended
Show of oil, abandoned
Show of gas, suspended
Show of gas, abandoned
Show of oil and gas, suspended
Show of oil and gas, abandoned
Suspended
Dry, abandoned
Stratigraphic
PETROLEUM PRODUCTION WELLS
Oil
Oil, suspended
Oil, abandoned
Gas
Gas, suspended
Gas, abandoned
Oil and gas
Oil and gas, suspended
Oil and gas, abandoned
Gas and condensate, abandoned
Structural interpretation by R. Iasky and K. Blundell
Edited by D. Ferdinando and G. Loan
Cartography by A. Francois
This map is available in digital format, and hard copy on request
The recommended reference for this map is:
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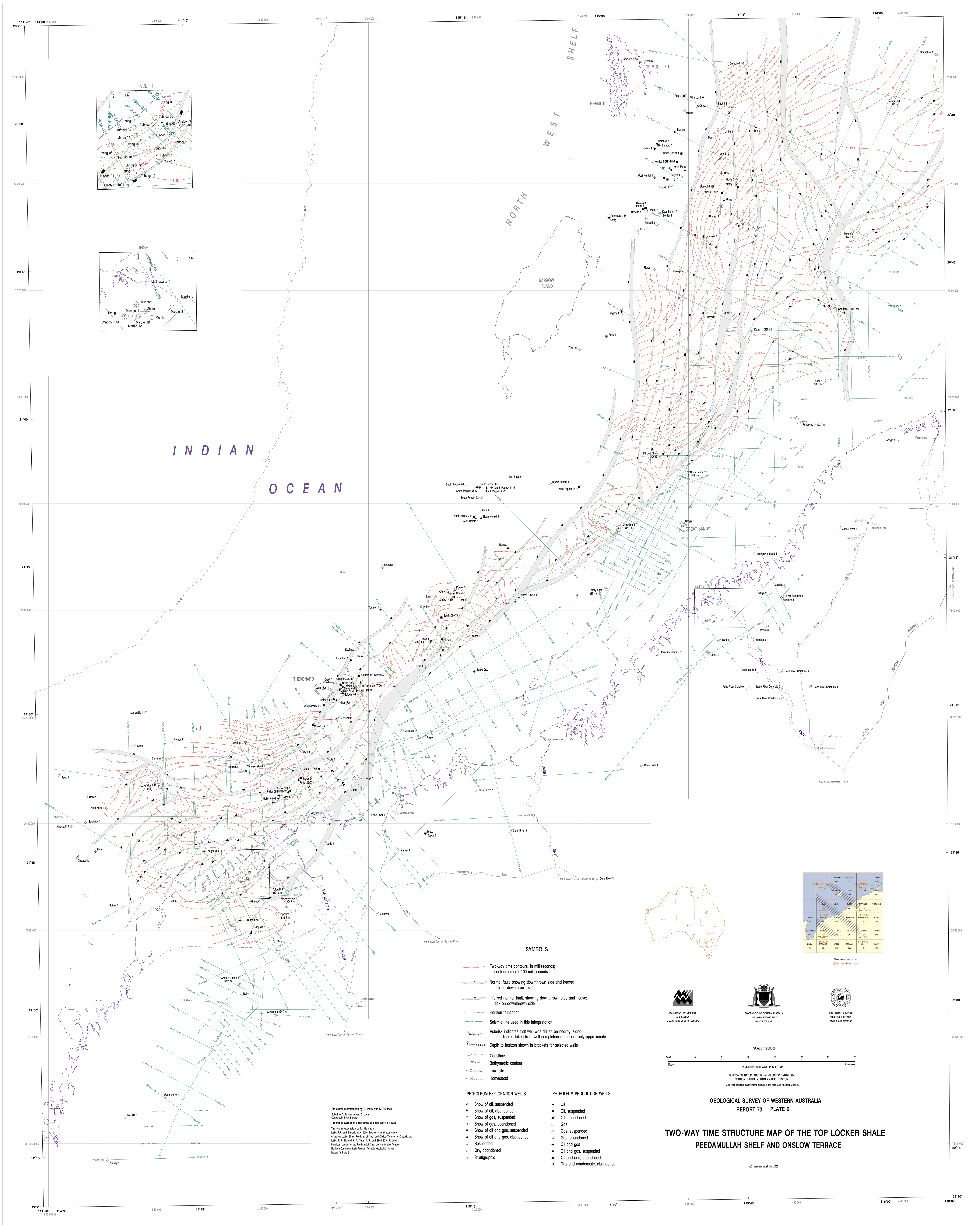
SCALE 1:250 000
TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Map Grid Australia Zone 50
1:100 000 maps shown in black
1:250 000 maps shown in brown


INDIAN OCEAN
NORTH WEST SHELF
BARROW ISLAND
TRIMOUILLE I
HERMITE I
THEVENARD I
GREAT SANDY I
INSET 1
INSET 2
SYMBOLS
Two-way time contours, in milliseconds; contour interval 100 milliseconds
Normal fault, showing downthrown side and heave; tick on downthrown side
Inferred normal fault, showing downthrown side and heave; tick on downthrown side
Horizon truncation
Seismic line used in this interpretation
Asterisk indicates that well was drilled on nearby island, coordinates taken from well completion report are only approximate
Depth to horizon shown in brackets for selected wells
Coastline
Bathymetric contour
Townsite
Homestead
PETROLEUM EXPLORATION WELLS
Show of oil, suspended
Show of oil, abandoned
Show of gas, suspended
Show of gas, abandoned
Show of oil and gas, suspended
Show of oil and gas, abandoned
Suspended
Dry, abandoned
Stratigraphic
PETROLEUM PRODUCTION WELLS
Oil
Oil, suspended
Oil, abandoned
Gas
Gas, suspended
Gas, abandoned
Oil and gas
Oil and gas, suspended
Oil and gas, abandoned
Gas and condensate, abandoned
Structural interpretation by R. Iasky and K. Blundell
Edited by D. Ferdinando and G. Loan
Cartography by A. Francois
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1:100000 maps shown in black
1:250000 maps shown in brown
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SCALE 1:250 000
Metres
Kilometres
TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20000 metre interval of the Map Grid Australia Zone 50
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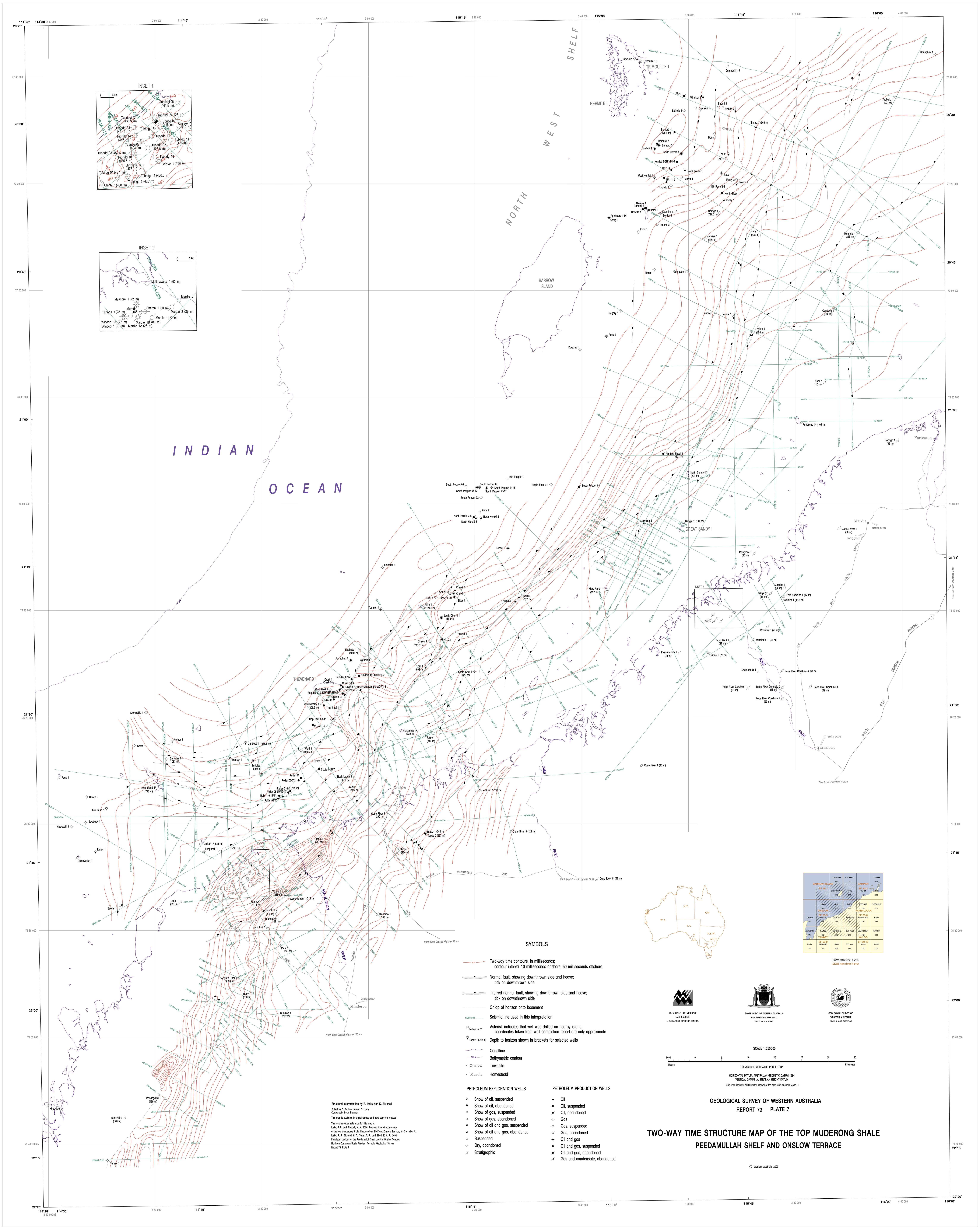
REPORT 73 PLATE 6
TWO-WAY TIME STRUCTURE MAP OF THE TOP LOCKER SHALE
PEEDAMULLAH SHELF AND ONSLOW TERRACE
© Western Australia 2000


INDIAN
OCEAN
NORTH WEST SHELF
BARROW ISLAND
HERMITE I
TRIMOUILLE I
GREAT SANDY I
INSET 1
INSET 2
SYMBOLS
Two-way time contours, in milliseconds; contour interval 10 milliseconds onshore, 50 milliseconds offshore
Normal fault, showing downthrown side and heave; tick on downthrown side
Inferred normal fault, showing downthrown side and heave; tick on downthrown side
Onlap of horizon onto basement
SB88-391
Seismic line used in this interpretation
Fortescue 1*
Asterisk indicates that well was drilled on nearby island, coordinates taken from well completion report are only approximate
Topaz 1 (242 m)
Depth to horizon shown in brackets for selected wells
Coastline
100 m
Bathymetric contour
Onslow
Townsite
Mardie
Homestead
PETROLEUM EXPLORATION WELLS
Show of oil, suspended
Show of oil, abandoned
Show of gas, suspended
Show of gas, abandoned
Show of oil and gas, suspended
Show of oil and gas, abandoned
Suspended
Dry, abandoned
Stratigraphic
PETROLEUM PRODUCTION WELLS
Oil
Oil, suspended
Oil, abandoned
Gas
Gas, suspended
Gas, abandoned
Oil and gas
Oil and gas, suspended
Oil and gas, abandoned
Gas and condensate, abandoned
Structural interpretation by R. Iasky and K. Blundell
Edited by D. Ferdinando and G. Loan
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SCALE 1:250 000
Metres
Kilometres
TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
Grid lines indicate 20 000 metre interval of the Map Grid Australia Zone 50
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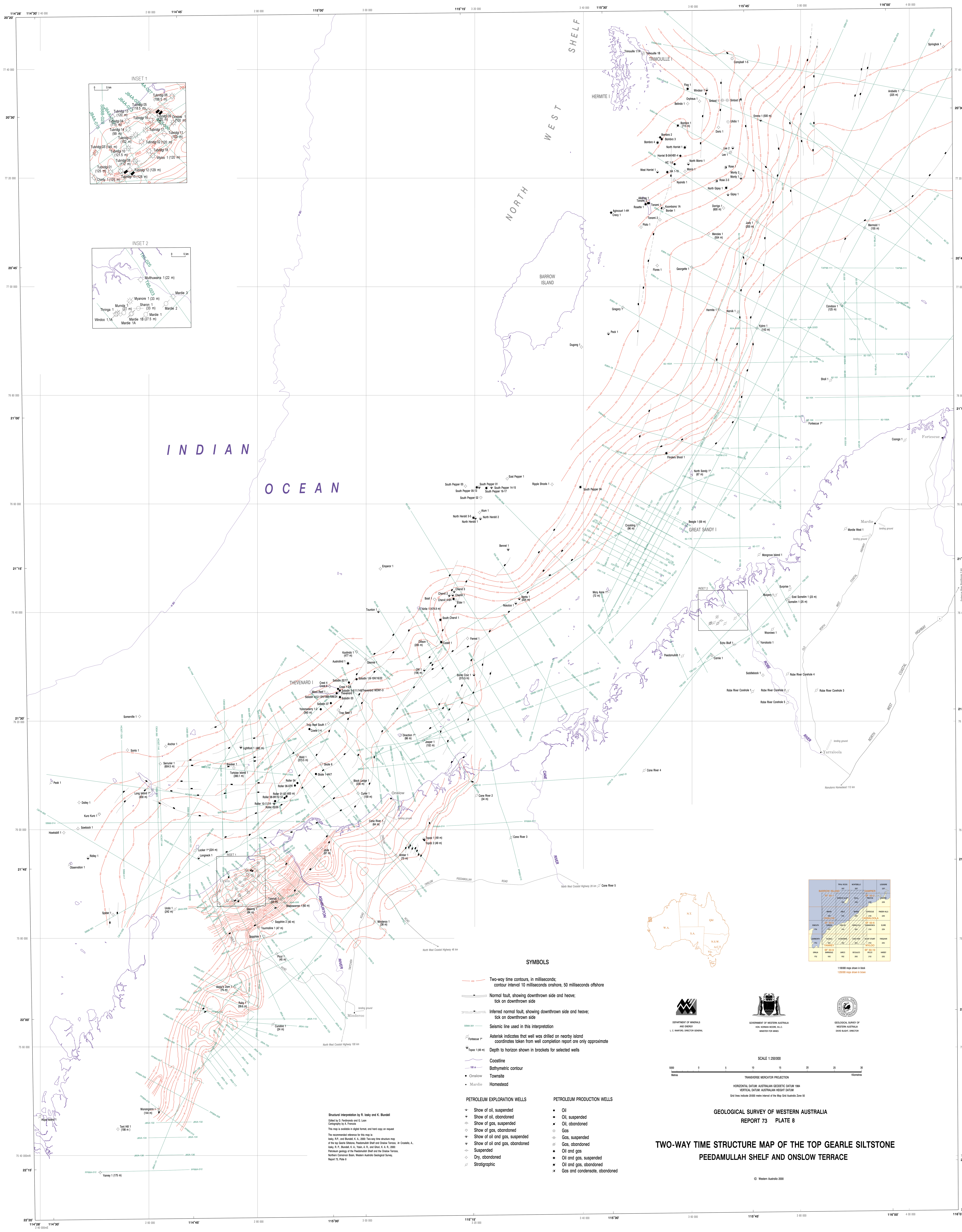
REPORT 73 PLATE 7
TWO-WAY TIME STRUCTURE MAP OF THE TOP MUDERONG SHALE
PEEDAMULLAH SHELF AND ONSLOW TERRACE
© Western Australia 2000



SYMBOLS

- Two-way time contours, in milliseconds; contour interval 10 milliseconds onshore, 50 milliseconds offshore
- Normal fault, showing downthrown side and heave; tick on downthrown side
- Inferred normal fault, showing downthrown side and heave; tick on downthrown side
- SB88-391 — Seismic line used in this interpretation
- Fortescue 1* — Asterisk indicates that well was drilled on nearby island coordinates taken from well completion report are only approximate
- Topaz 1 (49 m) — Depth to horizon shown in brackets for selected wells
- Coastline
- 100 m — Bathymetric contour
- Onslow — Townsite
- Mardie — Homestead

PETROLEUM EXPLORATION WELLS

- Show of oil, suspended
- Show of oil, abandoned
- Show of gas, suspended
- Show of gas, abandoned
- Show of oil and gas, suspended
- Show of oil and gas, abandoned
- Suspended
- Dry, abandoned
- Stratigraphic

PETROLEUM PRODUCTION WELLS

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

Structural interpretation by R. Iasky and K. Blundell

Edited by D. Ferdinando and G. Loan
Cartography by A. Francois

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DAVID BLIGHT, DIRECTOR

SCALE 1:250000

TRANSVERSE MERCATOR PROJECTION

HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 20000 metre interval of the Map Grid Australia Zone 50

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 73 PLATE 8

TWO-WAY TIME STRUCTURE MAP OF THE TOP GEARLE SILTSTONE
PEEDAMULLAH SHELF AND ONSLOW TERRACE